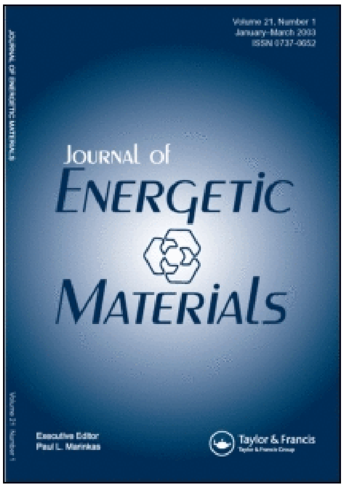
This article was downloaded by:
On: *16 January 2011*
Access details: *Access Details: Free Access*
Publisher *Taylor & Francis*
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Journal of Energetic Materials

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713770432

Analysis methods for explosive materials-I. polynitro compounds

Eleonore G. Kayser[a]
[a] Research and Technology Department, Naval Surface Weapons Center, Silver Spring, Maryland

To cite this Article Kayser, Eleonore G.(1983) 'Analysis methods for explosive materials-I. polynitro compounds', Journal of Energetic Materials, 1: 3, 251 — 273

To link to this Article: DOI: 10.1080/07370658308010621

URL: http://dx.doi.org/10.1080/07370658308010621

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

ANALYSIS METHODS FOR EXPLOSIVE MATERIALS -

I. POLYNITRO COMPOUNDS

Eleonore G. Kayser

Research and Technology Department

Naval Surface Weapons Center

White Oak, Silver Spring, Maryland 20910

ABSTRACT

A high pressure liquid chromatography method has been developed for rapid and quantitative chemical analysis of the following thermally stable explosive materials: DATB, DINA, DIPAM, DNT, DODECA, HNAB, HNBiB, HMX, HNBP, HNS, NONA, ONT, PA, PETN, PYX, RDX, TATB, TETRYL, TNA, TNB, TNN, TNS, TNT, and TPT (see glossary). Additional characterization data was obtained using nuclear magnetic resonance spectroscopy, and thin layer chromatography. Melting point data is also reported.

Journal of Energetic Materials Vol. 1, 251-273

Published in 1983 by Dowden, Brodman & Devine, Inc.

ACKNOWLEDGEMENT

This work is currently being sponsored by the Lyndon B. Johnson Manned Spacecraft Center, Task NASAR12RB, and the Strategic Systems Projects Office, Task B00035B001, R12GC. The identification of vendors and/or products implies neither endorsement nor criticism by the Naval Surface Weapons Center.

INTRODUCTION

The importance of heat resistant and insensitive high explosive compounds is increasing, since new applications, both military and commercial, require materials that can withstand a higher degree of aerodynamic heating and have a lower vulnerability to accidental initiation. A number of these heat resistant materials (e.g. HNS type-I, HNS-type II, DIPAM) are currently used in explosive transfer lines, commonly called shielded mild detonating cord (SMDC), which are designed to transfer a fully contained explosive stimulus and are the most extensively applied components in aircraft crew escape systems. To date, more than a million rigid explosive transfer lines have been manufactured for this application and are currently installed in various types of aircraft.[1,2]

A series of these temperature resistant explosive materials, most of which were synthesized and/or evaluated at the Naval Surface Weapons Center (NSWC), are shown in the glossary. Typical examples include: TATB, PYX, ONT, DATB, HNS, NONA, DODECA, and TPT. Few of the presently used common explosive materials can withstand temperatures above 200°C without melting and/or decomposing, however, the compounds of this investigation are stable and can be used in the temperature range of 230°-350°C. Previously reported assay methods for TATB include spectrophotometric determinations using ethylenediamine (EDA)[3], tetraethylammonium hydroxide (TEAH)[4,5], dimethylsulfoxide (DMSO)[6] and sulfuric acid[7], as well as a liquid chromatography-spectrophotometric method[8]. Spectrophotometric methods of analysis,[3,9] were reported for HNS, DODECA, NONA, ONT, HNBP, TNN, TNB, HNBiB, TPT, PYX, and DNT. HPLC procedures[10-16] have been described for HNS, HNBiB, TNT, TNB, RDX, HMX, PA, TNA, DNT and TATB. This report describes a practical high performance liquid chromatographic (HPLC) analysis method that provides both accuracy and reproducibility within the solubility constraints of these heat-resistant energetic materials. The HPLC method described herein uses the Waters Associates Radial Compression Separation System (RCSS). The RCSS unit consists of two components: a Radial-Pak cartridge containing reverse phase C-18 column packing material and a Model RCM-100 module that compresses the Radial-Pak cartridge. With this system, a quantitative assay (±1%) is achieved for all of the twenty-four compounds investigated (see glossary).

Additional characterization data was obtained using nuclear magnetic resonance spectroscopy (NMR), and thin layer chromatography (TLC). Melting point data is also reported for these materials.

EXPERIMENTAL

Materials and Solutions

Most of the explosive compounds of this investigation are not commercially available and were prepared by the NSWC Synthesis and Formulations Branch. The exceptions were PYX and DIPAM which were obtained from Los Alamos National Laboratory (LANL) and from Northrop Carolina Co., Inc. respectively.

The solvent capacities for TATB, HNS, DODECA, NONA, PYX, TPT, and HMX were determined in methanol, dimethylsulfoxide (DMSO), dimethylformamide, and N-methylpyrrolidone. Although dimethylformamide and N-methylpyrrolidone[17] proved to have the greatest solvent capacity for several of the compounds investigated (e.g. TATB, HMX, and TPT) all the compounds were adequately soluble in DMSO at ambient temperature so that HPLC, NMR, and TLC data could be accurately determined with this solvent. HPLC traces of several neat DMSO samples indicated the presence of two minor impurity peaks with retention times of 3.0-3.2 minutes (methanol:water, 70:30) which could have interfered with the peak height calculations of several of the compounds at the low concentration limits. The DMSO used in this study, therefore, was passed thru a column of activated charcoal which removed 95-98% of these impurities.

Calculations

The concentration of each explosive material was initially determined by peak area as well as peak height. Using the radial compression unit, the percentage accuracy of the area method was found to be equivalent to that of the peak height method. For simplicity reasons, the latter method was used for all data calculation.

HPLC Conditions

A high-performance liquid chromatograph (Waters Associates Model ALC 202) equipped with a 254 nm wavelength detector, a solvent delivery system (Model 6000), and a U6K high pressure loop injector was used with a Model RCM-100 module containing a reverse-phase C-18 Radial-Pak cartridge. Sample solutions were eluted isocratically at ambient temperature. Column flow was 2.0 ml/minute, with a mobile phase consisting of the following mixtures of HPLC grade methanol and distilled water. 20:80 (v/v), 40:60 (v/v), 50:50 (v/v), and 70:30 (v/v). The solvent mixtures were not degassed prior to HPLC analysis and sample injections of 2 to 10 microliters were used.

NMR Conditions

Proton NMR spectra were obtained on a Varian XL-200 NMR spectrometer. The chemical shift values (δ) were determined relative to the reference compound tetramethylsilane (TMS). NMR structure identifications were done in DMSO-d_6 and benzene-d_6.

TLC Conditions

TLC data were obtained with benzene and methanol as the developing solvents. Merck Silica Gel HF-254 was the absorbent coated on glass plates. Spot visualization was achieved with a short wave UV (2537Å) lamp.

Melting Point Conditions

Melting point data were determined on a majority of the compounds with a Thomas Hoover Capillary Melting Point Apparatus using a heating rate of approximately 2°/minute.

RESULTS

Quantitative analysis of the investigated compounds was achieved via reverse-phase HPLC with DMSO as solvent and methanol:water mixtures (70:30, 60:40, 50:50, v/v) as the mobile phase. Separation of a fourteen component mixture can be seen in Figure 1. RDX, TATB, TNB, DATB, TETRYL, TNN, TNT, DNT, HNS, and DIPAM were completely resolved, HMX and PYX were partially resolved,

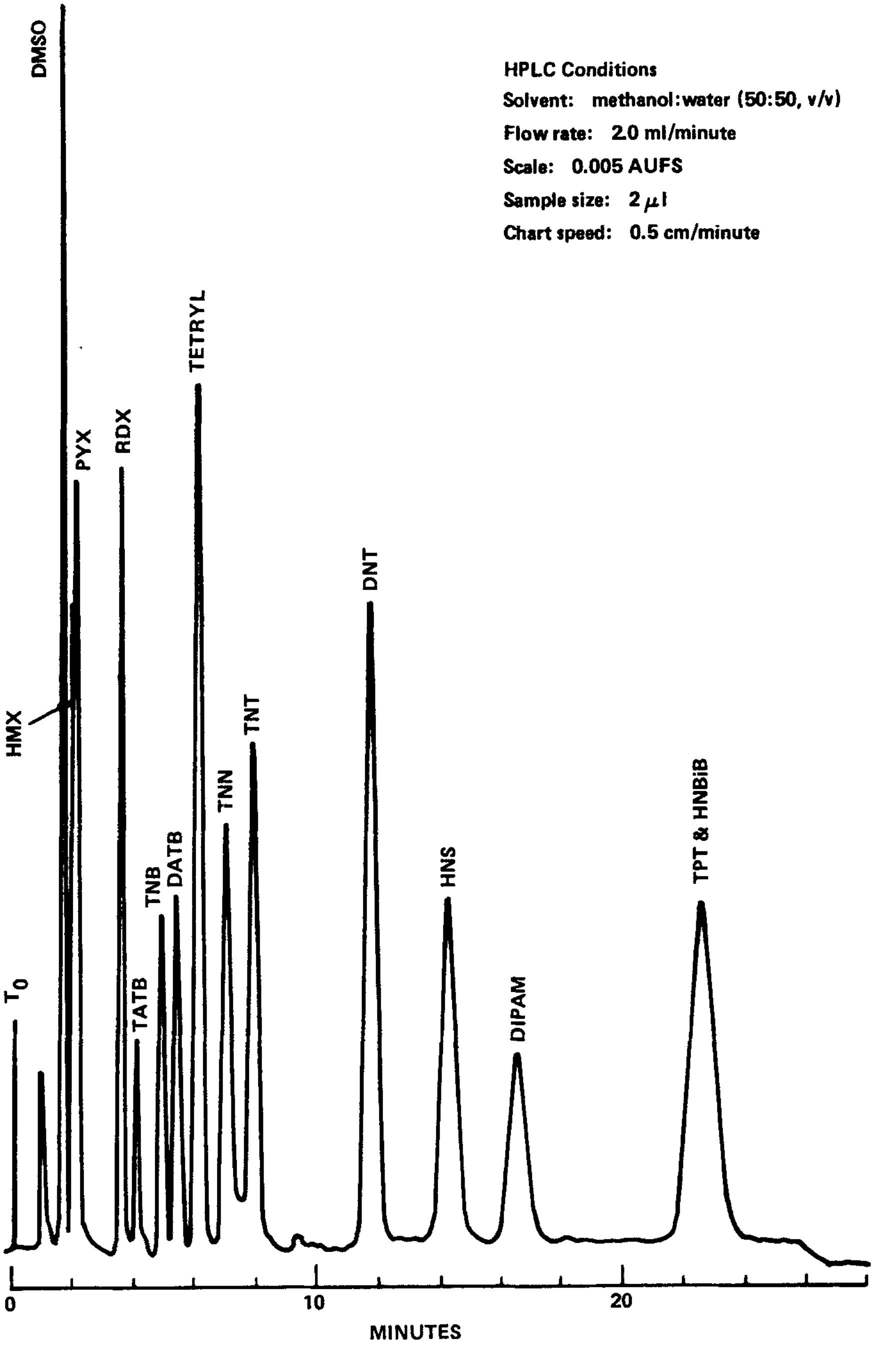


FIGURE 1

HPLC Chromatogram of a Fourteen Component Mixture and TPT and HNBiB remained unresolved. Although HMX, PYX, TPT, and HNBiB were not completely resolvable using the above methanol:water mixtures, these same materials were totally separable with a methanol:water (20:80, v/v) mobile phase. An HPLC chromatogram of a four component mixture containing three impurities (TNB, TNT, HNBiB)[11-13,18] found in production grade HNS-I is shown in Figure 2. The average retention times (minutes), average response factor (mm/mg), solution concentration (Molar), and approximate limits of detection (micrograms/ml) are given in Table 1, 2, and 3. The detection limit for all the materials was determined to be 15 millimeters on 0.005 absorbance units full scale (3×10^{-4}AUFS). This limit was set assuming a signal to noise ratio of 5. PETN displayed the least absorbance at 254nm with an approximate limit of detection of 1000 micrograms/ml (Table 3), however, the nitroaromatics had limits of detection in the 1.3-3.1 micrograms/ml range.

The generated NMR data are reported in Table 4. DMSO was the solvent of choice, however, due to solvent interference with DATB and PA (e.g. DATB peak overlap, and H→D exchange of the OH in PA) structure information with deuterated benzene is also reported.

R_f values were obtained on all the investigated compounds in benzene and methanol with the exception of HMX, TATB, PETN, and TNN which remained at the origin. The TLC data are recorded in Table 5.

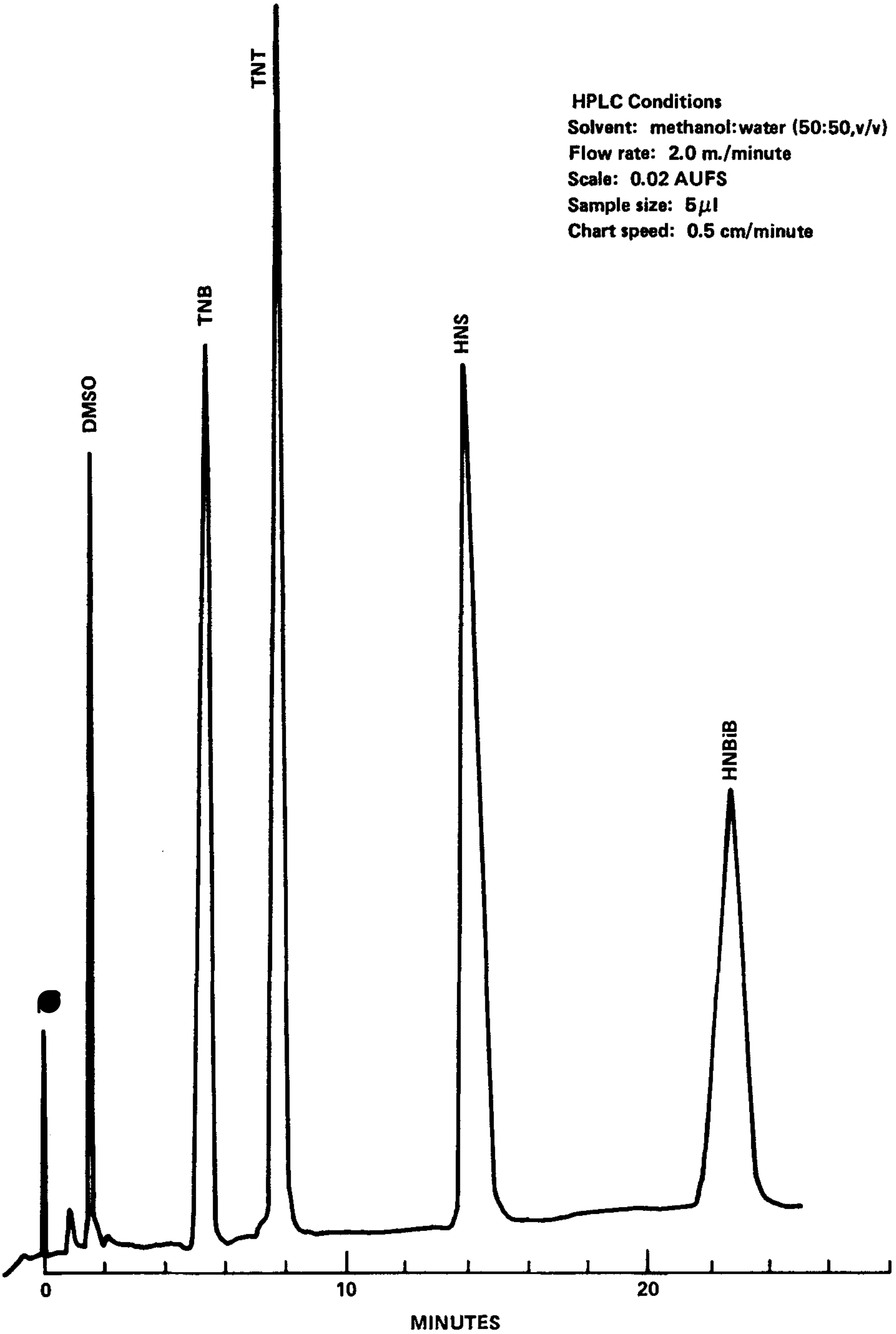


FIGURE 2

HPLC Chromatogram of a Four Component Mixture

TABLE 1 HPLC Data of Explosive Compounds

COMPOUND	AVERAGE RETENTION TIME (minutes)	AVERAGE RESPONSE FACTOR (peak height mm/mg)	DMSO SOLN CONC (moles/liter)	APPROX LIMIT OF DETECTION[a] (micrograms/ml; ppm)
DMSO	1.8	–	–	–
HMX	2.8	–	–	–
PETN	21.2	4.5×10^3	10^{-2} - 10^{-3}	3332
PYX	9.6	1.1×10^6	10^{-4} - 10^{-6}	13.4
RDX	5.8	–	–	–
TATB	7.4	–	–	–
TPT	80.0	1.7×10^5	10^{-4} - 10^{-5}	87.5

CONDITIONS:

Isocratic elution

Detector wavelength, 254 nm

Column: Radial-PAK A with the RCM-100 Radial Compression Module

Flow rate: 2.0 ml/minute

Mobile phase: 40% MeOH/60% H_2O by volume

Chart speed: 0.5 cm/minute

[a] From the peak height responses given, the detection limit for all the explosive compounds was calculated to be 15 mm on scale 0.005 absorbance units full scale (3×10^{-4} AUFS). This limit was set assuming a signal/noise ratio of 5.

TABLE 2 HPLC Data of Explosive Compounds

COMPOUND	AVERAGE RETENTION TIME (minutes)	AVERAGE RESPONSE FACTOR (peak height mm/mg)	DMSO SOLN CONC (moles/liter)	APPROX LIMIT OF DETECTION[a] (micrograms/ml; ppm)
DATB	5.5	$2.77 \pm 0.01 \times 10^{6}$	$10^{-4} - 10^{-5}$	5.4
DINA	4.1	$1.82 \pm 0.04 \times 10^{6}$	$10^{-4} - 10^{-6}$	8.2
DMSO	1.6	–	–	–
DIPAM	16.1	1.55×10^{6}	$10^{-4} - 10^{-6}$	9.7
DNT	11.6	4.37×10^{6}	$10^{-4} - 10^{-6}$	3.4
HNAB	9.2	$9.5 \pm 0.06 \times 10^{5}$	$10^{-4} - 10^{-6}$	~ 15
HNBiB	22.8	2.41×10^{6}	$10^{-4} - 10^{-6}$	9.9
HNS	14.2	2.31×10^{6}	$10^{-4} - 10^{-6}$	6.5
HMX	2.0	4.77×10^{6}	$10^{-4} - 10^{-6}$	3.1
PA	0.8	$8.98 \pm 0.05 \times 10^{7}$	$10^{-4} - 10^{-6}$	0.2
PETN	12.0	$1.31 \pm 0.03 \times 10^{4}$	$10^{-2} - 10^{-3}$	1236
PYX	2.1	$4.04 \pm 0.06 \times 10^{6}$	$10^{-4} - 10^{-5}$	3.7
RDX	3.4	$4.35 \pm 0.04 \times 10^{6}$	$10^{-4} - 10^{-6}$	3.5
TATB	4.0	$3.62 \pm 0.04 \times 10^{6}$	$10^{-5} - 10^{-7}$	4.1
TETRYL	5.8	4.42×10^{6}	$10^{-4} - 10^{-6}$	3.4
TNA	6.8	$2.6 \pm 0.04 \times 10^{5}$	$10^{-4} - 10^{-6}$	5.8
TNB	5.3	4.97×10^{6}	$10^{-4} - 10^{-7}$	3.0
TNN	7.0	$2.12 \pm 0.08 \times 10^{6}$	$10^{-3} - 10^{-5}$	7.3
TNT	7.8	4.74×10^{6}	$10^{-4} - 10^{-6}$	3.1
TPT	22.9	$1.32 \pm 0.01 \times 10^{6}$	$10^{-4} - 10^{-5}$	11.4

CONDITIONS:

Isocratic elution

Detector wavelength, 254 nm

Column: Radial-PAK A with the RCM-100 Radial Compression Module

Flow rate: 2.0 ml/minute

Mobile phase: 50% MeOH/50% H_2O by volume

Chart speed: 0.5 cm/minute

[a] From the peak height responses given, the detection limit for all the explosive compounds was calculated to be 15 mm on scale 0.005 absorbance units full scale (3×10^{-4} AUFS). This limit was set assuming a signal/noise ratio of 5.

TABLE 3 HPLC Data of Explosive Compounds

COMPOUND	AVERAGE RETENTION TIME (minutes)	AVERAGE RESPONSE FACTOR (peak height mm/mg)	DMSO SOLN CONC (moles/liter)	APPROX LIMIT OF DETECTION[a] (micrograms/ml; ppm)
DIPAM	3.3	$7.36 \pm 0.06 \times 10^6$	$10^{-4} - 10^{-6}$	2.0
DMSO	1.5	–	–	–
DNT	3.7	1.19×10^7	$10^{-4} - 10^{-6}$	1.3
DODECA	6.7	$4.81 \pm 0.03 \times 10^6$	$10^{-5} - 10^{-7}$	3.1
HNBiB	3.9	$9.72 \pm 0.03 \times 10^6$	$10^{-4} - 10^{-6}$	1.9
HNBP	3.6	$1.14 \pm 0.02 \times 10^7$	$10^{-4} - 19^{-7}$	1.3
HNS	2.9	$9.71 \pm 0.03 \times 10^6$	$10^{-4} - 10^{-6}$	2.1
NONA	4.7	$8.03 \pm 0.06 \times 10^6$	$10^{-4} - 10^{-6}$	1.9
ONT	5.3	$7.56 \pm 0.04 \times 10^6$	$10^{-4} - 10^{-6}$	2.0
PETN	3.3	5.37×10^4	$10^{-2} - 10^{-3}$	1009
TNN	2.3	$6.32 \pm 0.01 \times 10^6$	$10^{-4} - 10^{-5}$	2.4
TNS	5.2	$5.48 \pm 0.04 \times 10^6$	$10^{-4} - 10^{-6}$	2.7
TNT	2.9	1.07×10^7	$10^{-4} - 10^{-6}$	1.4
TPT	3.1	$7.86 \pm 0.07 \times 10^6$	$10^{-4} - 10^{-7}$	1.9

CONDITIONS:

Isocratic elution

Detector wavelength, 254 nm

Column: Radial-PAK A with the RCM-100 Radial Compression Module

Flow rate: 2.0 ml/minute

Mobile phase: 70% MeOH/30% H_2O by volume

Chart speed: 0.5 cm/minute

[a] From the peak height responses given, the detection limit for all the explosive compounds was calculated to be 15 mm on scale 0.005 absorbance units full scale (3×10^{-4} AUFS). This limit was set assuming a signal/noise ratio of 5.

TABLE 4 H^1 NMR Data of Explosive Compounds

COMPOUND	SOLVENT[a]	NMR SPECTRUM[b] δ
DATB	DMSO-D_6	9.10 (s, Ar-H) 9.10 (s, $2NH_2$)
DATB	BENZENE-D_6	8.91 (s, Ar-H) 8.61 (s, $2NH_2$)
DINA	DMSO-D_6	4.76 (t, $2CH_2$) 4.17 (t, $2CH_2$)
DIPAM	"	9.08 (s, 2Ar-H) 8.68 (s, $2NH_2$)
DNT	"	8.68 (d, Ar-H) 8.42 (q, Ar-H) 7.87 (d, Ar-H) 2.62 (s, CH_3)
DODECA	"	9.39 (s, 2Ar-H) 9.24 (s, 2Ar-H) 9.20 (s, 2Ar-H)
HNAB	"	10.19 (s, 4Ar-H)
HNBiB	"	9.05 (s, 4Ar-H) 3.39 (s, $2CH_2$)
HNBP	"	9.27 (s, 4Ar-H)
HNS	"	9.07 (s, 4Ar-H) 7.11 (s, 2CH)
HMX	"	5.98 (s, 8R-H)
NONA	"	9.26 (s, 5Ar-H)
ONT	"	9.26 (s, 6Ar-H)
PA	"	8.56 (s, 2Ar-H)
PA	BENZENE-D_6	8.07 (s, 2Ar-H) 11.00 (s, OH)
PETN	DMSO-D_6	4.65 (s, $4CH_2$)
PYX	"	8.85 (s, 5Ar-H) 9.10 (s, 2NH)
RDX	"	6.06 (s, 6R-H)
TATB	"	10.00 (s, $3NH_2$)[c]
TETRYL	"	9.28 (s, 2Ar-H) 3.63 (s, CH_3)
TNA	"	9.04 (s, 2Ar-H) 8.98 (s, NH_2)
TNB	"	9.13 (s, 3Ar-H)
TNN	"	8.80 (s, 4R-H)
TNS	"	9.14 (s, 2Ar-H) 8.08 (d, Ar-H) 7.86 (d, 2Ar-H) 7.68 (m, Ar-H) 7.54 (d, CH) 7.09 (d, CH)
TNT	"	8.98 (s, 2Ar-H) 2.52 (s, CH_3)
TPT	"	9.23 (s, 6Ar-H)
DMSO-D_6 (neat)		2.48 (m, $2CH_3$)
BENZENE-D_6 (neat)		7.18 (s, 6Ar-H)

[a] The solvents used were: benzene C_6D_6 - 99.5 atom % D; dimethylsulfoxide DMSO-D_6 - 99.5 atom % D. A water peak δ3.30 (s, 2H) was noted in the DMSO samples.

[b] s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, Ar = aromatic, R = ring protons. Chemical shifts are in δ units downfield from internal TMS with line multiplicity and relative intensity in parentheses. Spectra were determined on a Varian XL-200 Spectrometer. The pulse sequence was repeated 4 times and the signals time-averaged.

[c] The TATB pulse sequence was repeated 5000 times, and the resulting signals time-averaged.

TABLE 5 TLC Data of Explosive Compounds

COMPOUND	R_f[a]	SOLVENT[b]
DATB	0.32	C_6H_6
DINA	0.38	"
DIPAM	0.20	"
DNT	0.78	"
DODECA	0.63[c]	"
HNAB	0.67	"
HNBiB	0.58	"
HNBP	0.76	"
HNS	0.38	"
HMX	0.00	"
HMX	0.00	MeOH
NONA	0.69[c]	C_6H_6
ONT	0.14[c]	"
PA	0.09[c]	"
PA	0.96	MeOH
PETN	0.00	C_6H_6
PETN	0.00	MeOH
PYX	0.00	C_6H_6
PYX	0.96[c]	MeOH
RDX	0.17	C_6H_6
TATB	0.00	"
TATB	0.00	MeOH
TETRYL	0.52	C_6H_6
TNA	0.43	"
TNB	0.75	"
TNN	0.00	"
TNN	0.00	MeOH
TNS	0.62	C_6H_6
TNT	0.86	"
TPT	0.40	"

[a] R_f taken from leading edge of spot. A short wave U V lamp (2537 Å) was used for spot visualization. The adsorbent used was Merck Silica Gel HF-254 coated on glass plates.

[b] The solvents used were: benzene (C_6H_6) and methanol (MeOH).

[c] Streaking or tailing to origin.

TABLE 6 Melting Point Data of Explosive Compounds

COMPOUND	MELTING POINT (°C)
DATB	287[a], 290[20], 286[21]
DINA	52[a]
DIPAM	306 dec[a], 304[21]
DNT	71.5[a], 71[20]
DODECA	> 425[a]
HNAB	220-221[22]
HNBiB	218[a], 218-220[23]
HNBP	239.3-240.8[a]
HNS-I	316 dec[a]
HNS-II	318 dec[a]
HMX	280 dec[a], 273[20]
NONA	440[21]
ONT	> 400[9]
PA	121.8-122.4[a]
PETN	141.3[22]
PYX	360[9]
RDX	204 dec[a], 204[22]
TATB	> 370[a], > 360[20], ~ 450 dec[21]
TETRYL	130 dec[a,20], 129.5[22]
TNA	188[a,22]
TNB	121[a], 121.3[22]
TNN	450[21]
TNS	180-181[a]
TNT	80.7[a], 80.8[22]
TPT	352[7], 352-353[21,24], 349-351[25]

[a] Melting points determined on a Thomas Hoover Capillary Melting Point Apparatus, using a heating rate of approximately 2°/minute. All measured temperatures are corrected.

The melting points of the majority of compounds were determined with a heating rate of approximately 2°/minute. These temperatures were corrected and are listed together with literature data in Table 6.

CONCLUSION

The HPLC data detailed in this report permits rapid and reliable quantitative determinations of several insensitive, heat-resistant energetic materials (e.g. HNS, DIPAM, TATB, and ONT) currently in use. Sensitivity is sufficient for accurate determinations at relatively low concentrations in the 1-3 milligrams/ml range. This method may be applicable for the quantitative analysis of similar materials which because of low solubility can not be accurately determined using other techniques.

REFERENCES

1. L. J. Bement, E. G. Kayser, and M. Schimmel, "Service Life Evaluation of Rigid Explosive Transfer Lines," NASA TP 2143, August 1983.
2. J. M. Bowen and L. J. Bement, Astronautics and Aeronautics, April 1983, p. 76.
3. D. J. Glover and E. G. Kayser, *Anal. Chem.*, Vol 40, 1968, p. 2050.

4. E. Sawicki and T. W. Stanley, Analyt. Chim. Acta, Vol. 23, 1960, p. 551.

5. W. Selig, "Spectrophotometric Determination of Some Nitro and Nitroso Derivatives of Diphenylamine in N,N-Dimethylformamide," Lawrence Livermore Laboratory (ILL) Report, UCRL-6903, May 1963.

6. W. Selig, "Photometric Determination of 1,3,5-Triamino-2,4,6-Trinitrobenzene (TATB) in Dimethylsulfoxide (DMSO)", Lawrence Livermore Laboratory Report, UCID-17542, July 1977.

7. H. E. Ungnade, "1,3,5-Triamino-2,4,6-Trinitrobenzene (TATB) - Preparation and Purification", Los Alamos National Laboratory (LANL) Report, GMX-2-R-64-1, 1963, pp. 10-11.

8. C. S. MacDougall, "A Liquid Chromatographic-Spectrophotometric Assay for TATB in TATB", in Quarterly Progress Report, Mason & Hanger-Silas Mason Co., Inc., Pantex Plant (MHSMP), MHSMP-77-18, Jan-Mar 1977.

9. E. E. Kilmer, "A Characterization Study of Several Heat Resistant Explosives", NOLTR 74-177 Oct 1974.

10. E. G. Kayser and N. E. Burlinson, "Analysis of Water and Soil Samples from Fate of ^{14}C Labelled Explosive Compounds in Soil Study", Final Report from the Naval Surface Weapons Center, White Oak, submitted to the U.S. Army Medical Bioengineering R & D Lab. (USAMBRDL), Fort Detrick, MD., MIPR No. 9952, Jan-Dec 1979.

11. E. G. Kayser, "Analysis of 2,2',4,4',6,6'-Hexanitrostilbene (HNS) by High Performance Liquid Chromatography", NSWC/WOL TR 77-154, 14 March 1978.

12. E. G. Kayser, "An Investigation of the Shipp Hexanitrostilbene (HNS) Process", NSWC TR 80-111, 25 Aug 1980.

13. C. L. Schaffer, "HNS Analysis", Mason & Hanger-Silas Mason Co., Inc., Pantex Plant, MHSMP-75-50, Oct-Dec 1974.

14. T. B. Stanford, Jr., "Determination of Tetryl and 2,3-2,4-, 2,5-,2,6-,3,4-, and 3,5-Dinitrotoluene Using High Performance Liquid Chromatography", Final Report, From Battelle Columbus Laboratories, Columbus, Ohio, submitted to the U.S. Army Research and Development Command, Washington, DC, Contract No. DAMD-17-74-C-4123, 31 Jan 1977.

15. C. L. Schaffer, "Analysis of TATB by HPLC", Mason & Hanger-Silas Mason Co., Inc., Pantex Plant, MHSMP-78-65, 1978.

16. I. S. Krull and M. J. Camp, _American Laboratory_, May 1980, pp. 63-73.

17. M. E. Sitzmann, S. Foti, and C. C. Misener, "Solubilities of High Explosives; Removal of High Explosive Fillers from Munitions by Chemical Dissolution", NOLTR 73-186, 21 Nov 1973.

18. T. W. Stull, "Synthesis of High Purity Hexanitrostilbene", Mason & Hanger-Silas Mason Co., Inc., Pantex Plant, MHSMP-75-37, Sep 1975.

19. J. C. Hoffsommer and J. F. McCullough, _J. Chromatog._, Vol. 38, 1968, p. 508.

20. Headquarters, U.S. Army Materiel Command, _Engineering Design Handbook_, AMCP 706-177.

21. K. G. Shipp, ed., "Properties of Selected Thermally Stable Explosives", NOLTR 70-95, May 1970.

22. Bennett, ed., Chemical & Technical Dictionary, 3rd ed., (New York, New York: Chemical Publishing Co., Inc., 1974).

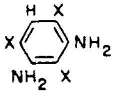
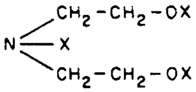
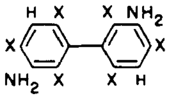
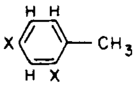
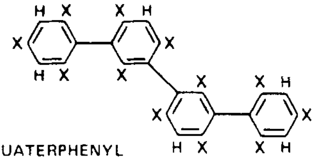
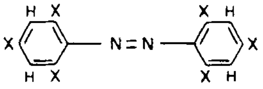
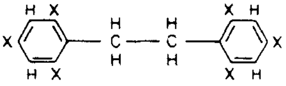
23. K. G. Shipp and L. A. Kaplan, J. Org. Chem., Vol. 31, 1966, p. 857

24. J. C. Dacons and M. E. Sitzmann, J. Heterocyclic Chem., Vol 14, 1977, p. 1151.

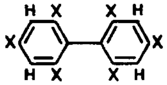
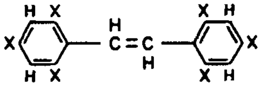
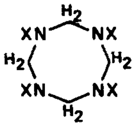
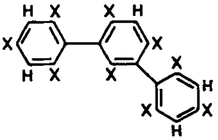
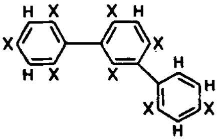
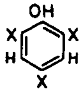
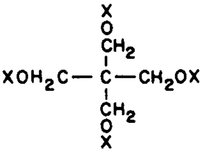
25. J. C. Dacons, "2,4,6-Tripicryl-s-Triazine, TPT; Crystallization and Crystal Density Determination", NSWC/WOL/TR-76-16, Mar 1976.

Glossary

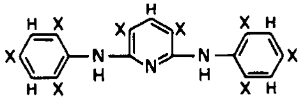
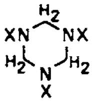
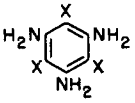
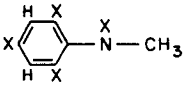
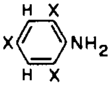
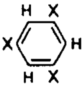
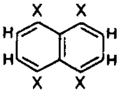
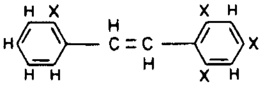
NOTE: $X = NO_2$

COMPOUND	STRUCTURE	CODE
1,3-DIAMINO-2,4,6-TRINITROBENZENE		DATB
DIOXYETHYLNITRAMINE DINITRATE		DINA
DIPICRAMIDE		DIPAM
2,4-DINITROTOLUENE		DNT
2,2′,2″,2‴,4,4′,4″,4‴,6,6′,6″,6‴-DODECANITROQUATERPHENYL		DODECA
2,2′,4,4′,6,6′-HEXANITROAZOBENZENE		HNAB
2,2′,4,4′,6,6′-HEXANITROBIBENZYL, DIPICRYLETHANE		HNBiB

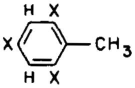
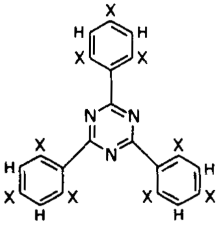
Glossary Continued

COMPOUND	STRUCTURE	CODE
2,2',4,4',6,6'-HEXANITROBIPHENYL		HNBP
2,2',4,4',6,6'-HEXANITROSTILBENE		HNS
1,3,5,7-TETRANITRO-1,3,5,7-TETRA-AZACYCLOOCTANE		HMX
2,2',2'',4,4',4'',6,6',6''-NONANITROTERPHENYL		NONA
2,2',4,4',4'',6,6',6''-OCTANITRO-m-TERPHENYL		ONT
2,4,6-TRINITROPHENOL, PICRIC ACID		PA
PENTAERYTHRITOLTETRANITRATE	 $C(CH_2OX)_4$	PETN

Glossary Continued

COMPOUND	STRUCTURE	CODE
2,6-BIS(PICRYLAMINO)-3,5-DINITROPYRIDINE		PYX
1,3,5-TRINITRO-1,3,5-TRIAZACYCLOHEXANE CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE, CYCLONITE		RDX
1,3,5-TRIAMINO-2,4,6-TRINITROBENZENE		TATB
N,2,4,6-TETRANITRO-N-METHYLANILINE		TETRYL
2,4,6-TRINITROANILINE, PICRAMIDE		TNA
1,3,5-TRINITROBENZENE		TNB
1,4,5,8-TETRANITRONAPHTHALENE		TNN
2,4,6,2′-TETRANITROSTILBENE		TNS

Glossary Continued

COMPOUND	STRUCTURE	CODE
2,4,6-TRINITROTOLUENE		TNT
2,4,6-TRIPICRYL-s-TRIAZINE		TPT