2048
RECEIVED BY DTIC JUL 17 1970

Contract Report

SC-CR-70-6076
May 1970

MASTER

A STUDY OF SOME ASPECTS OF THE BEHAVIOR
OF HEXANITROSTILBENE (HNS) IN SMALL
CHARGES

Prepared by
R. H. Stresau
R. Stresau Laboratory, Inc.
Spooner, Wisconsin

SANDIA LABORATORIES

OPERATED FOR THE UNITED STATES ATOMIC ENERGY COMMISSION BY SANDIA CORPORATION | ALBUQUERQUE, NEW MEXICO, LIVERMORE, CALIFORNIA

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Issued by Sandia Corporation,
a prime contractor to the
United States Atomic Energy Commission

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

SC-CR-70-6076

A STUDY OF SOME ASPECTS OF THE BEHAVIOR OF
HEXANITROSTILBENE (HNS) IN SMALL CHARGES

Prepared by
R. H. Stresau
R. Stresau Laboratory, Inc.
Spooner, Wisconsin

for
Sandia Laboratories
Albuquerque, New Mexico

May 1970

Contract No. 58-6740

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ABSTRACT

Determinations were made of sensitivity to initiation by small sources and detonation velocity in small column diameters as these properties are affected by loading density and of the relationship between loading pressure and loading density of two samples of hexanitrostilbene (one HNS-IA and the other HNS-IIA) which were supplied by the Sandia Laboratories. The HNS-IA was found to load to a lower density at any given pressure and to be more sensitive and have a slightly higher detonation velocity at any given density than the HNS-IIA. These differences can be attributed to the very much smaller particle size of the HNS-I. For the two donor sizes used in the gap tests (0.033-inch diameter and 0.064-inch diameter), the effect of loading density upon gap sensitivity of HNS-IA was rather small. For the smaller (0.033 diameter) donor the HNS-IIA was most sensitive at a density close to 1.6 gms/cc and was significantly less sensitive at both higher and lower densities. For the larger donor (like HNS-I) the effect of density on gap sensitivity was quite small. In the detonation velocity measurements, the smaller (0.052-inch diameter) columns of HNS-IIA had a significantly and systematically lower detonation velocity than in the larger (0.105-inch diameter) column. When these data were extrapolated to the "ideal" detonation velocity, the ideal detonation velocity density relationship was found to be very close to that of HNS-IA.

TABLE OF CONTENTS

I.	INTRODUCTION	Page 1
II.	EXPERIMENTAL ARRANGEMENTS AND PROCEDURES	Page 3
	Miniaturized Gap Tests	Page 3
	Detonation Velocity Measurements	Page 9
	Compaction Pressure-Density Relationships.	Page 16
III.	EXPLOSIVES TESTED.	Page 21
IV.	DISCUSSION AND RESULTS	Page 26
	Loading Pressure Density Data	Page 26
	Miniaturized Gap Tests	Page 31
	Detonation Velocity.	Page 37
V.	CONCLUSIONS AND RECOMMENDATIONS.	Page 39
VI.	REFERENCES	Page 41

LIST OF TABLES

TABLE 1.	LOADING PRESSURE DENSITY DATA.	Page 27
TABLE 2.	MINIATURIZED GAP TEST DATA COMPARING HNS-I OF 2 PARTICLE SIZES PRESSED AT 4 DIFFERENT DEN- SITIES	Page 32

LIST OF ILLUSTRATIONS

Figure 1.	Miniaturized Gap Test Experimental Arrange- ment.	Page 5
Figure 2.	Miniaturized Gap Test Donor	Page 6

LIST OF ILLUSTRATIONS, CONT

Figure 3.	RDX, CE-2 RDX, Class E. Canadian Arsenals Ltd., Batch No. E-40 (X440).	Page 7
Figure 4.	RDX, CE-4 RDX, Class E, Canadian Industries Limited, Batch No. 190	Page 7
Figure 5.	Detonation Velocity Measurement Experimental Arrangement.	Page 10
Figure 6.	Side View, Detonation Velocity Measurement-Experimental Arrangement	Page 11
Figure 7.	End View of Specimen with Probes, Detonation Velocity Measurement-Experimental Arrangement.	Page 11
Figure 8.	Detonation Velocity Measurement Circuit (Schematic).	Page 12
Figure 9.	Typical Detonation Velocity Measurement Oscillogram.	Page 14
Figure 10.	Interpretation of Oscillogram Shown in Figure 9.	Page 14
Figure 11.	Detonation Velocity Specimen with One Probe Applied.	Page 15
Figure 12.	Illustration from Patent of Bore Measuring Device	Page 18
Figure 13.	HNS-IA, Lot #43-39 (X600).	Page 22
Figure 14.	HNS-IA, Lot X498 (X500).	Page 22
Figure 15.	HNS-IIA, Lot 43-13 (X85)	Page 23
Figure 16.	HNS-II, Lot X567 (X85)	Page 23
Figure 17.	Tetryl, Lot X436 (X10)	Page 24
Figure 18.	PETN, Lot T4-1 (X 47.5).	Page 24
Figure 19.	RDX, Lot X-177 (X440).	Page 25
Figure 20.	Loading Pressure vs Loading Density for HNS-IA, Lot 43-39 and HNS-IIA, Lot 43-13, Loaded into Thick Walled Brass Cylinders	Page 28

LIST OF ILLUSTRATIONS, CONT

- Figure 21. Threshold Stimuli (from gap tests) vs Density
for Donors of Various Diameters. Page 35
- Figure 22. Detonation Velocity vs Density of HNS-I and
HNS-II in Small Columns. Page 38

A STUDY OF SOME ASPECTS OF THE BEHAVIOR OF HEXANITROSTILBENE
(HNS) IN SMALL CHARGES

I. INTRODUCTION

In Reference 1 this laboratory proposed a program for the development of design criteria, components, and evaluation techniques for explosive systems with minimum dimensions to the Sandia Corporation. The effort proposed in Reference 1 was subdivided into 15 tasks for each of which a separate cost and time estimate was made to simplify the selection by Sandia Corporation of tasks to be performed and ordering thereof. Reference 2 is a contract for the performance of Task 1 as outlined in Reference 1 and Reference 3 is a report of the work performed in accordance with Reference 2. Based on Task 3 of Reference 1, the statement of work of which is as follows:

Task 1. Conduct a study of the interaction of particle size distribution, charge density, and composition, as it affects the susceptibility of Hexanitrostilbene to initiation by small sources. Standardized techniques developed on Contract 58-6420* are to be employed.

*Reference 2

Reference 5 is an amendment to Reference 4 in which the following is added to the statement of work:

Determine detonation velocity of Hexanitrostilbene as a function of composition, particle size distribution, and density in two small diameters commensurate with the small initiation sources. Also provide compaction pressure versus density of the two types of Hexanitrostilbene.

Samples of two lots of HNS were furnished by Sandia Corporation. One lot was HNS-I and the other was HNS-II. The most significant difference between HNS-I and HNS-II is in their particle size distribution. HNS-I has an average particle size of only a few microns which makes it rather difficult to load and handle. HNS-II is made from HNS-I by a recrystallization process which gives very much larger crystals. As originally envisioned, Task 3 would have included several particle sizes since some of the properties under investigation might very well be non-monotonic functions of particle size. However, the HNS-I is much too fine for separation into particle size groups by means of any procedures for which this laboratory is equipped, and the HNS-II, although large enough in particle size for separation into sieve cuts, has crystals of such large elongation that it would be difficult to say what had been accomplished by such separation. For these reasons it was agreed between representatives of this laboratory and the Sandia Corporation that the effects of particle size distribution would be determined by comparison of results with HNS-I and HNS-II.

The susceptibility to initiation was determined by means of miniaturized gap tests using the test arrangement and procedure described in Reference 3 in which the donor charge diameter is 0.033 inches and the similar test in which the donor charge diameter was 0.065 inches. Acceptor charge diameters

used in these tests were 0.100 inches and 0.125 inches. For the gap tests, the acceptors were loaded at 5,000 10,000 20,000, and 40,000 pounds per square inch. The detonation velocity measurements were made of both varieties of HNS in nominal charge diameters of 0.052 inches and 0.104 inches. Each variety of HNS was loaded at pressures of 250, 1,000, 4,000, 16,000 and 64,000 pounds per square inch. Experiments were performed with both brass and Delrin confinement; but in the smaller diameter with Delrin confinement, only a few measurements were made because of failures in some cases to obtain signals and in other cases of the detonation to propagate.

Density determinations were made for each compaction pressure used in each diameter acceptor used in the gap tests. In the velocity tests the density was determined for each column over which a velocity was measured.

This report includes description of the experimental arrangements, procedures, and results obtained with the two varieties of HNS as well as a few obtained with other explosives for purposes of comparison and assurance that the tests were in control.

II. EXPERIMENTAL ARRANGEMENTS AND PROCEDURES

Miniaturized Gap Tests

The experimental arrangement used in the gap tests was

essentially that described in Reference 3. For these experiments two different sizes of donor were used and the acceptor diameters were adjusted to keep them large compared with the donor charge diameter. Figure 1 shows the experimental arrangement, and Figure 2 shows details of the donor charges.

It may be noted that the donor shown in Figure 2 is somewhat different with respect to explosives and loading pressures from those used in the donors used in the experiments described in Reference 3. The silver azide "flash charge" was eliminated as a simplification on the basis of experiments which indicated that this change had no effect in the present application (which probably resulted in some decrease in electrical sensitivity but the firing circuits used reliably initiated the lead azide in the units shown in Figure 2). The change in the lot and loading pressure of the RDX, Class E, was the result of preliminary experiments aimed at decreasing the variability in donor output which had been noted in the experiments described in Reference 3. Both lots of RDX used were RDX, Class E, purchased from the Canadian facility at Valley Field, Quebec. The material referred to as lot CE-2 was purchased while the facility was still being operated by Canadian Arsenals Limited and that referred to as RDX CE-4 was purchased after the facility had been sold to Canadian Industries Limited. The material referred to as CE-2 has a very much finer particle size (Figure 3) than that referred

Donor Charge Diameter	0.033	0.064
Donor Details (Figure 2)	(A)	(B)
Donor Length (L_t)	0.400	0.600
Acceptor Bore Dia. (B_a)	0.100	0.130

Figure 1. Miniaturized gap test experimental arrangement

Figure 2. Miniaturized gap test donor

Figure 3. RDX, CE-2 RDX, Class E, Canadian Arsenals Ltd.
Batch No. E-40 (X440)

Figure 4. RDX, CE-4 RDX, Class E, Canadian Industries Ltd.
Batch No. 190

to as RDX CE-4 (Figure 4). It was this difference that led to the expectation that the RDX CE-2 should be better for use in charges of very small diameter. However, as noted in Reference 3, the donors had a larger variation in output than is considered desirable for this application and a series of experiments^{was}/performed to determine feasibility of reducing this variation. In this investigation it was found that RDX CE-4 gave more reproducible output than RDX CE-2. One possible explanation for this difference is that the finer material (RDX CE-2) is more variable with respect to the density obtainable at a given pressure. At the same time, it was found that the RDX CE-4, when loaded at the same pressure, gave an appreciably higher output than the RDX CE-2. Since it was believed desirable that the results be as comparable as possible to those reported in Reference 3, the loading pressure for the RDX CE-4 was reduced to 10 kpsi, which gave approximately the same output as measured in steel dent tests (6.3 to 7.2 mils in mild steel block) as the CE-2 had when loaded at 30,000 psi (5 to 7 mils). In the hard (Rockwell C48-51) witness blocks the dent depths with donors loaded in accordance with Figure 2 ranged from 3 mils to 3.31 mils as compared with 2.7 mils to 3.6 mils for the donors used in the experiments reported in Reference 3. These latter dent test results apply to the smaller, 33 mil diameter, donors. For the larger, 64 mil charge diameter.

donors the dent depths in soft witness blocks ranged from 11.2 to 12.3 mils and in the hard blocks they ranged from 4.95 to 5.47 mils.

Detonation Velocity Measurements

The technique used in the measurement of detonation velocities is similar to that described in Reference 6 in which the time interval required for a detonation to transverse the distance between two sets of probes is measured. In the measurements reported herein, the times were measured by means of the cathode ray oscilloscope rather than the vacuum thermocouple timer used in the work described in Reference 6.

The experimental arrangement used for each velocity measurement is shown in Figures 5, 6, and 7. As has been stated in the Introduction, detonation velocities were made with two nominal charge diameters 52 mils and 104 mils. The nominal lengths of the 52 mil diameter charges was 1 centimeter and the nominal length of the 104 mil diameter charges was 1 inch. The circuit used in the detonation velocity measurements is shown, schematically, in Figure 8. The delay lines, which were used to make possible the use of higher sweep rates on the oscilloscope to give better time resolution, were lengths of RG8 cable which had been calibrated at NOL and used in the work reported in Reference 6. Before the cables were used in the present investigation, their pulse transit times were checked using the oscilloscope and found to be in agreement

Figure 5. Detonation velocity measurement experimental arrangement

Figure 6. Side view

Figure 7. End view of specimen
with probes

Detonation velocity measurement - experimental arrangement

Figure 8. Detonation velocity measurement circuit (schematic)

with the nominal sweep rates of the horizontal sweep within the limits of resolution (about 5 nanoseconds). This can be taken to indicate that both the sweep rate of the oscilloscope and the transit time of the delay line are as stated or that each of them has drifted the same amount and same direction in the time since they were calibrated (about 20 years for the delay line and 3 years for the oscilloscope). The coaxial cable was used to delay the "start" signal 1.00 microsecond for the short (1 centimeter long) explosive columns and 2.50 microseconds for the longer (1 inch long) acceptors. The sweep rate of the oscilloscope was established by a combination of a lower sweep rate than that required plus an expansion, a combination which results in a sweep two or more times the width of the oscilloscope screen. The horizontal position control was adjusted so that the delayed start signal fell near the left side of the screen, thus leaving most of the screen for the measurement of the difference between the transit times of the signal and the delay line and the detonation in the explosive column, the resulting typical trace shown in Figure 9. Figure 10 is a diagram illustrating the interpretation of the sweep like that shown in Figure 9. The distance between the start and stop points on each oscillogram was measured by means of a microscope using an eyepiece micrometer. Measurements of each record were made by two independent observers. The measurements of the two independent observers usually agreed within a few nanoseconds. Where disagreement exceeded $1/2$ of 1% of the estimated transit time, a measurement was made by a third observer who almost invariably

Figure 9. Typical detonation velocity measurement oscillogram

$$D = \frac{1.029 \times 25.4}{3.758 \mu s} = 6.975 \text{ mm}/\mu s$$

where D = detonation velocity and
1.029 was the measured distance between probes .

Figure 10. Interpretation of oscillogram shown in Figure 9.

Figure 11. Detonation velocity specimen with
one probe applied
(Not drawn to scale)

agreed with one or another of the first two within a few nanoseconds. The time used was the average of the two closest readings.

For each shot one probe was applied as shown in Figure 11, after which the length was measured by means of a dial indicator height gauge. This length (which upon reflection can be seen to be exactly the distance between the probes) was used in calculating detonation velocities.

Compaction Pressure- Density Relationships

All specimens were loaded by means of hand presses fitted with calibrated spring- dial force gages. For each desired loading pressure and ram diameter, the force and dial reading were calculated and the operators had no difficulty in controlling their applied force to hold the dial reading within a few percent. The density of each specimen was assumed to be the quotient of its weight by the volume of the hole in which it had been loaded. This volume, in turn, was assumed to be that of a right cylinder of the length and diameter of the hole as measured before loading.

This last assumption, with its implication that the expansion of the hole is negligible may require some justification. In a very thick walled cylinder under internal hydrostatic pressure, the "hoop" stress at the bore surface approximates the internal pressure. At a hoop tension of 64,000 psi (the highest loading pressure used in these experiments) the elastic strain of brass would be 0.004 inches per inch, which would increase the area by 0.8 % , which would be not quite negligible. Moreover, since 64,000 psi is appreciably more than the elastic limit of half hard brass, some-

what more than elastic expansion of the hole might be anticipated. This question was considered in the early '50s, when the writer was engaged in studies similar to those described herein at the Naval Ordnance Laboratory (White Oak, Md.), and led to the following experiments: The bores of several brass charge holders, similar to those shown in Figure 5, were measured to the nearest 0.00005 inch by means of a device of the type shown in Figure 12 (and described in Reference 7) after which they were loaded at various pressures up to 100,000 psi with a powdered material (table salt). The salt was soaked out and the bores remeasured. In a recent telephone conversation between Mr. J.N. Ayres of the Naval Ordnance Laboratory and the writer, we agreed in our recollection that there was no evidence of permanent deformation, but neither of us could remember where or whether this experiment had been reported. This lack of permanent deformation at a loading pressure nearly twice the elastic limit of the container may be taken as evidence that the tensile stress in the container must be appreciably less than that calculated assuming hydrostatic internal pressure. Upon reflection, it is clear that the stress patterns must be quite complex and that the resistance of both the powder and the case material to shear tend to reduce the tensile stress and strain. From the foregoing it may be concluded that, even while the ram pressure is being applied, the expansion is appreciably less than that calculated for elastic expansion under internal hydrostatic pressure. After the ram pressure is removed, some residual stress might be anticipated, but it would not conceivably be more than half that under direct loading pressure and is probably usually much less than this. All of which leads to the conclusion that the expansion of the container

due to residual internal pressure increases the area by less (probably much less) than 0.4% for items loaded at the highest pressure used. Since the density scatter is appreciably greater than this, the assumption that the expansion of the hole is negligible is justified for charges loaded in brass. Delrin, of course is much softer and weaker than brass so densities calculated on the basis of this assumption for charges loaded in this material are probably significantly higher than the true densities (at least for charges loaded at the higher pressures)

Procedures used in density determinations differed sufficiently between those for the gap tests and those for detonation velocity measurements that separate descriptions are appropriate. For each determination the container was weighed on an analytical balance by two independent operators. If the weights differed by more than 0.5 milligram, a third operator weighed the container. After loading, the weighing procedure was repeated. The charge weight was taken as the difference between the loaded and empty weights of the container (in each case, the average of two weighings which agreed within 0.5 milligrams).

Since the gap test acceptor charges were loaded into Delrin, the expansion of which, under internal pressure was not known, the loading pressure-density relationship of each type of HNS for each acceptor charge diameter was determined, using brass containers. The charge holders used in the density determinations, except for the material, were as similar as possible to the acceptor charge holders. The holes were drilled, using a number 39 (0.0995 inch) drill for the acceptors to be used with the smaller (0.033 inch charge diameter) donors and a number 30 (0.1285 inch) drill for

the acceptors to be used with the larger (0.064 inch charge diameter) donors. In addition some data were obtained with similar containers drilled with quarter inch (0.250 inch) diameter drills. Hole diameters were measured by means of plug gages with a go,--no-go interval of 0.001 inch. In general, the measuring personnel felt confidence in their estimates to the nearest 0.0005 inch (based on the "feel" of the fit of the plug gage in the hole). For the gap tests, loading pressures of 5,000, 10,000, 20,000, and 40,000 pounds per square inch were used. For each combination of explosive material, charge diameter, and in some cases other variables, three replicate density determinations were usually made.

The density was determined of each detonation velocity specimen. The specimen charges were loaded into thick walled brass and Delrin charge holders (see Figure 5) consisting of lengths of bar stock, centrally drilled and reamed. Two sizes of specimen were used, 0.052 inch diameter by 0.400 inch long and 0.104 inch diameter by 1.000 inch long. The diameters of the holes into which the specimens were to be loaded were measured by means of a device similar to that shown in Figure 12 except that the movement was measured optically rather than mechanically because the small diameter elements necessary were too flexible to overcome the spring tension of a dial indicator. The device had a resolution (and presumed accuracy) of 0.0001 inch. The diameter used in calculating the density of each specimen was the average of diameters determined at two points along the length of the hole. Detonation velocity specimens were loaded at 250,1000, 4000, 16000, and 64000 pounds per square inch. Two specimens, in general, were loaded in

brass containers and one in a Delrin container of each variety of HNS and at each loading pressure.

III. EXPLOSIVES TESTED

The hexanitrosilbene which was the primary subject of this study was furnished by the Sandia Corporation. All other explosives were drawn from stocks on hand at this laboratory. Following are brief descriptions of each of the explosive materials used in the experiments described herein:

HNS-IA, lot # 43-39. Material furnished by Sandia Corporation for this study. Received from Ensign-Bickford Co. in December 1969.

Figure 13 is a photomicrograph of this material.

HNS-IA, HNS, X-498 Received from NOL/White Oak in 1966. Figure 14.

HNS-IIA, lot #43-13. Material Furnished by Sandia Corporation for this study. Figure 15 is a photomicrograph of this material.

HNS-II X-567 Rec'd from NOL/White Oak in January 1969. Figure 16

The Roman numeral and letter designations suffixed to the letters HNS refer to types and grades of hexanitrosilbene as described in Navy Purchase Description WS 5003⁹. Briefly, the distinction between HNS-I and HNS-II is that HNS-II is recrystallized to raise its bulk density to an acceptable minimum of not less than 0.045 minimum. The difference between Type A and Type B is that HNS-IA and HNS-IIA have been certified to conform to all requirements of the Purchase Description, while HNS-IB and HNS-IIB are certified to meet all requirements but the sensitivity and output requirements (the NOL Small Scale Gap Test , Reference 8, and accompanying dent measurements). It is probable that most HNS-IB, and HNS-IIB would meet these requirements but has not been tested.

Figure 13. HNS 1A, Lot #43-39 (X500)

Figure 14. HNS 1A, Lot #X498 (X440)

Figure 15. HNS IIA, Lot #43-13 (X85)

Figure 16. HNS II, Lot #X567 (X85)

Figure 17. Tetryl, Lot #X436 (X10)

Figure 18. PETN, Lot #T4-1 (X47.5)

Figure 19. RDX, Lot #X-177 (X440)

Tetryl , X-336 Supplied by NOL/White Oak. Presumed to be in Compliance with MIL-T-00339A. Figure 17.

PETN, T4-1, PETN, Class 4 (MIL-P-387A) made by Trojan Powder Co. Purchased from Technical Ordnance Inc. 10/22/68. Figure 18.

RDX X-177) furnished by NOL/White Oak. Made by Holston. RDX, Type B, Class E, (MIL-R-00398). Figure 19.

The following explosives were used in loading donors (either in preliminary experiments to reduce output variability or in actual gap tests):

RDX, CE-2, purchased from Canadian Arsenals Limited (their batch E-40) in August 1964. This material is certified to meet requirements of Military Specification MIL-R-00398C (Ord.) for RDX, Class E. Figure 3 is a photomicrograph of RDX, CE-2)

RDX, CE-4, purchased from Canadian Industries Limited (Their batch 190) in November of 1968. Also Certified to MIL-R-00398C as RDX, Class E. Figure 4.

Lead Azide, RD-1333, purchased from DuPont, Batch # 2152.

IV. DISCUSSION AND RESULTS

Loading Pressure Density Data

The loading pressure density data in these tests are given in Table 1 and plotted on semi-log coordinates in Figure 20. It is interesting to note in Figure 20 the near linearity of the relationship of pressure and density in these coordinates over such a large pressure range. For this material the approximation (which has been noted before by other investigators

TABLE 1. LOADING PRESSURE DENSITY DATA

Loading Pressure (psi)	Diameter			Densities g/cm ³					
	Hole	Ram	Length	HNS-IA			HNS-IIA		
				Ave	Max	Min	Ave	Max	Min
1,250	0.105	0.101	1.00	.76	.79	.74	.79	.82	.76
1,000	0.052	0.046	0.400	.96	.99	.92	1.02	1.03	1.01
	0.105	0.101	1.00	0.96	1.01	.92	1.02	1.05	.99
4,000	0.052	0.046	0.400	1.18	1.18	1.17	1.28	1.33	1.23
	0.105	0.101	1.00	1.23	1.23	1.23	1.25	1.28	1.23
4,408	0.105	0.096	1.00	1.26	1.27	1.25	1.335	1.34	1.33
5,000	0.100	0.096	0.250	1.305	1.31	1.30	1.37	1.37	1.37
	0.130	0.128	0.250	1.33	1.34	1.32	1.37	1.38	1.36
	0.250	0.246	0.250	--	--	--	1.395	1.40	1.39
10,000	0.100	0.096	0.250	1.42	1.43	1.41	1.50	1.52	1.47
	0.130	0.125	0.250	--	--	--	1.51	1.55	1.47
	0.130	0.128	0.250	1.43	1.46	1.40	--	--	--
	0.250	0.246	0.250	--	--	--	1.50	1.52	1.48
16,000	0.052	0.046	0.400	1.42	1.48	1.36	1.455	1.46	1.45
	0.105	0.101	1.00	1.43	1.46	1.42	1.46	1.46	1.46
20,000	0.100	0.096	0.250	1.52	1.53	1.51	1.62	1.65	1.60
	0.130	0.125	0.250	--	--	--	1.64	1.66	1.63
	0.130	0.128	0.250	1.51	1.52	1.50	--	--	--
40,000	0.100	0.096	0.250	1.665	1.665	1.665	1.71	1.73	1.69
	0.130	0.128	0.250	1.67	1.68	1.66	1.715	1.72	1.71
64,000	0.052	0.046	0.400	1.65	1.68	1.63	1.70	1.73	1.66
	0.105	0.101	1.00	1.695	1.70	1.69	1.72	1.73	1.70

Samples were loaded into brass

Figure 20. Loading pressure vs loading density for HNS-IA, Lot #43-39 and HNS IIA, Lot #43-13, loaded into thick walled brass cylinders. (See text for ram clearances and other details)

with other explosives) that the density is proportional to the logarithm of the loading pressure seems to be rather good.

The substantial differences between densities obtained at the same pressures with the same explosive loaded in containers and with rams of slightly differing dimensions is of some considerable interest. A large part of this variation is very probably the result of ram clearance differences. As Ayres showed in Reference 8, small variations in ram clearance can result in very large changes in density of the same explosive. He observed a nearly linear change in density of Class A RDX pressed at 10,000 pounds per square inch from 1.6 gms/cc with a ram clearance of 0.3 mils to a minimum density of 1.55 gms/cc at a ram clearance of 1.1 mils after which it increased nearly linearly to over 1.6 gm/cc with a ram clearance of 2.3 mils. HNS is appreciably more difficult to load than RDX Class A because of its very low bulk density and because of its particle size (see Figures 13, 14, 15, and 16) is so small that, even with the smallest practical ram clearance, some particles become wedged between the ram and the bore of the container. In loading the material, the low bulk density makes it necessary to compress the explosive over substantial distances with appreciable wall friction which is greatly increased by the wedging action. With small clearances this wedging action makes the force necessary for ram extraction very nearly equal to the applied loading pressure. In the longer charge holders used in the detonation velocity measurements, this difficulty

was more severe than in the shorter holders used for the gap test acceptors. It was found that this extraction effort became less when the ram clearance was increased to the 5 or 6 mils clearance of the rams used to load the velocity specimens. By extrapolation of Ayres data given above and in Reference 8, this 5 mil clearance would have been expected to have resulted in a substantially higher loading density than obtained with the smaller clearance used in the gap test acceptors. Apparently the relationship for HNS is somewhat more complex because, as Figure 13 shows, the velocity specimens have lower densities for any given pressure than the gap test acceptors. It is possible that other factors such as moisture content of HNS could have contributed to the variations noted in loading density. In experiments at this laboratory with RDX Class E (which has particle size similar to that of HNS) significant differences in loading density were observed with moisture content changes less than 0.1%. Another contributory factor may have been the lesser accuracy with which the diameters of the holes in the gap test acceptor charge holders were measured. This last source of error, however, could not be sufficient to account for the whole difference shown in Figure 13 nor would it account for the larger differences between the two types of container when loaded with HNS-II than loaded with HNS-I.

Loading densities obtained with items loaded in Delrin were very close to those of the similar items loaded in brass

except that at the higher pressures the calculated densities were somewhat higher(probably as the result of expansion of the Delrin).

It would appear that the investigations of loading characteristics of HNS could be a research project of considerable magnitude all by itself.

Miniaturized Gap Tests

Results of the miniaturized gap tests are given in Table 2.

It may be noted that mean threshold stimuli are given in "miniaturized gap decibangs" (DBgm) and "scaled gap decibangs" (SDBg). The "miniaturized gap decibang" is based upon the same transformation function used by Ayres² to define the "gap decibang" (DEg). The "scaled gap decibang" is a new unit of stimulus which is proposed herein for which the transformation function is:

$$X \text{ (SDBg)} = 10 + 10 \log \frac{2R}{g}$$

where $2R$ is the diameter of the donor charge and g is the gap. Although it has not been experimentally demonstrated for this particular system, the "scaled gap decibang" ought to be more directly related to the peak pressure of the transmitted shock for geometrically similar systems of different sizes than the "gap decibang" as proposed by Ayres⁸ since hydrodynamic systems generally tend to follow geometric scaling laws. It may be noted that the sensitivities

Table 2. Miniaturized Gap Test Data Comparing HNS-I of 2 Particle Sizes Pressed at 4 Different Densities

Explosive	Donor Dia (mils)	Acceptor		Threshold Stimulus		
		Loading Pressure (kpsi)	Loading Density (gm/cc)	Mean ($\bar{X}$)		Std Dev
				DBgm	SDBg	DBg
Tetryl,X-436	64	10	1.60	15.375	13.450	0.4125
PETN,T4-1	64	10	1.634	14.625	12.7	0.106
PETN,T4-1	33	10	1.633	18.486	13.61	0.3775
RDX,X-177	64	10	1.46	13.96	12.035	0.4575
RDX,X-177	33	10	1.416	18.00	13.12	0.356
HNS-IA,43-39	64	5	1.326	13.850	11.925	0.375
HNS-IA,43-39	33	5	1.306	19.40	14.52	0.370
HNS-IA,43-39	33	5	1.306	18.446	13.57	1.490
HNS-IA,43-39	64	10	1.431	14.736	12.811	0.470
HNS-IA,43-39	33	10	1.425	17.950	13.07	0.1775
HNS-IA,X-498	64	10	1.43	14.1528	12.228	0.2325
HNS-IA,X-498	33	10	1.375	17.653	12.77	0.406
HNS-IA,43-39	64	20	1.511	14.625	12.700	0.575
HNS-IA,43-39	33	20	1.522	18.53	13.65	0.506
HNS-IA,43-39	64	40	1.6703	14.82	12.895	0.2625
HNS-IA,43-39	33	40	1.665	18.001	13.12	0.469
HNS-IIA,43-13	64	5	1.365	15.1525	13.228	0.23
HNS-IIA,43-13	33	5	1.37	22.15	17.27	0.531
HNS-IIA,43-13	64	10	1.51	15.00	13.075	0.0625
HNS-IIA,43-13	33	10	1.50	20.708	15.83	0.190
HNS-IIA,43-13	64	20	1.643	15.208	13.283	0.094
HNS-IIA,43-13	33	20	1.62	18.675	13.80	0.155
HNS-IIA,43-13	64	40	1.715	15.3125	13.388	0.906
HNS-IIA,43-13	33	40	1.71	19.60	14.72	0.6125

Notes - The material with a lot number beginning with an X was furnished by the U. S. Naval Ordnance Laboratory, White Oak, and the PETN was manufactured by the Trojan Powder Company and purchased by this laboratory. The HNS-IA and HNS-IIA without lot numbers were the materials furnished by Sandia Corporation.

of some of the explosives tested are very nearly the same for both sizes of donor used when measured in scaled decibangs. As noted above, the threshold stimulus in "scaled gap decibangs" (and thus by implication the threshold pressure for firing) is very nearly independent of diameter (within the limited range of these experiments) for some of the explosives tested. For others, on the other hand, the differences are quite substantial. This difference in behavior can be explained in terms of the considerations discussed in Reference 10. As the size of the donor is decreased, the relative rate of energy dissipation from the reaction nucleus increases so that the threshold reaction rate for a propagating reaction must increase; thus, as the source size and hence the reaction nucleus size decrease, it is necessary to increase the rate of the induced reaction of the acceptor in order to result in a propagating reaction. The relationship between shock pressure and the rate of the reaction it induces depends upon a number of factors, including the chemical kinetics of the acceptor explosive, its mean particle size, particle size distribution, configuration of its particles, and its loading density. The explosives whose scaled gap sensitivities are relatively independent of donor size are explosives for which (in the range of threshold conditions for this particular test) the reaction rate varies quite sharply with pressure so

that only a small change in the shock pressure is necessary to double the reaction rate (as is required to compensate for the doubled relative dissipation rate which results from the halving of the donor charge diameter. The materials for which the scaled gap sensitivity shows a large dependence upon donor diameter are those for which reaction rate changes more gradually with pressure. Note in Table 2 and Figure 21 that the differences in sensitivities (in scaled gap decibangs) as measured with the two donor diameters used is generally greater for HNS-II than for HNS-I. This is consistent with the Eyring¹¹ surface burning theory and the large difference in particle size between HNS-I and HNS-II (see Figures 13 and 15). Further support of the foregoing explanation is the observation reported in Reference 3 that the still coarser (Figure 16) HNS-II X567 received from White Oak could not be initiated with the small donor with no barrier (infinite SDBg).

It is of interest to notice the difference in the effect of loading density upon the gap sensitivity of the HNS-II as measured by means of the test with the two sizes of donors. With the larger (64 mil diameter) donor, the sensitivity is apparently nearly independent of loading pressure whereas with the smaller there is quite a sharp dependence. This difference and the trend of which it is part is perhaps more apparent in Figure 21 in which these data are plotted

Figure 21. Threshold stimuli (from gap tests) vs density for donors of various diameters

along with some Small Scale Gap Test data from NOL. From these plots it is apparent that, for any given system, there is an optimum density for maximum susceptibility to initiation of the acceptor and that this optimum is a function of donor size tending to shift from lower densities for larger donors to higher densities for smaller donors. A qualitative explanation of this is more or less as follows. In a low density explosive a relatively weak shock can initiate a reaction at grain surfaces by compressive heating of the interstitial gases, frictional heating at grain surfaces, etc. However, once such a surface burning reaction has been initiated, it is a relatively slow reaction because of the relatively large proportion of voids which militate against the maintenance of high pressures by allowing space for expansion and dissipative flow of the product gases. In contrast, as the loading density increases, higher shock pressures are required to cause significant heating either by compression of the interstitial gases or frictional movement since the higher structural strength of the material must be overcome before such localized heating can occur. However, once a reaction is initiated in the higher density material, its rate may be expected to be higher than that of the lower density material for reasons which are converse to those mentioned above for the low density material. From these considerations, the trend which is apparent for HMS-II in Figure 21 would be expected. It may be noted in Figure 14 that the sensitivity of HMS-II, as measured in the NOL

Small Scale Gap Test and converted into scaled decibangs, is appreciably greater than that as measured by the miniaturized gap tests. A part of this is to be expected on the basis of considerations which have been discussed above. However, the NOL Small Scale Gap Test⁸ should not be compared directly with the miniaturized gap test³ for the following reasons:

1. Both the donor and acceptor of the Small Scale Gap Test (which are each 0.2 inch in diameter) are confined in very thick walled brass tubes (1 inch O.D.). In contrast, the donors of the miniaturized gap test are confined in needle tubing, the wall thickness of which is only a fraction of the radius, and the acceptors are confined only in Delrin which is of negligible value as a confining medium.
2. The donors of the NOL Small Scale Gap Test are loaded at a substantially higher density (1.56 gm/cc) than those of the miniaturized gap test (1.40).
3. The barrier material for the NOL Small Scale Gap Test is acrylic resin while that of the miniaturized gap test is aluminum.

Most, perhaps all, of these differences may be expected to increase the gap and thereby reduce the "stimulus" for threshold initiation as measured in decibang units.

Detonation Velocity

Results obtained in the detonation velocity measurements are plotted in Figure 22. The straight lines are best fits as

Figure 22. Detonation velocity vs density of HNS-I and HNS-II in small columns

determined by an iterative graphical technique. It may be noted that HNS-I exhibits no significant diameter effect but that the diameter effect of HNS-II is significant and nearly constant over the density range investigated.

The approximation (which may be derived from the considerations discussed in Reference 11) that the reduction of the detonation velocity of an explosive column of limited size as compared with the "ideal" "plane wave" detonation velocity is proportional to the reciprocal of the charge diameter was used, graphically, to plot the solid line of Figure 22 for the ideal detonation velocity. It is interesting to note that this line is very close to those for HNS-I, further supporting the view that the reaction zone length of HNS-I is very much shorter than that of HNS-II and, in turn, supporting the Eyring "curved front" theory.¹¹

V. CONCLUSIONS AND RECOMMENDATIONS

The data reported herein indicate that both lots of Hexanitrostilbene, both samples which were received from Sandia Corporation, are from lots which are highly suitable for use in miniaturized explosive systems and small explosive components. However, the data indicate that the suitability of explosives for such application is highly dependent upon particle size. Apparently all HNS-I is of such a fine particle size that, with this material, no difficulties

should be anticipated from lot to lot particle size variation. HNS-II, on the other hand, does show significant diameter effects which have been related to particle size, and it is recommended that the data given herein for HNS-II be considered applicable only to the specific lot tested and, even here, some attention should be given to the question of particle size variation within the lot (and even from the top to the bottom of the column as it rests in a shipping or storage container. It is recommended that study be continued of charge and particle size effects in Hexanitrostilbene.

VI. REFERENCES

1. Proposal 69-4-1, A Proposal "To Develop Design Criteria, Components, and Evaluation Techniques for Explosive Systems of Minimum Dimensions," for Sandia Corporation, Albuquerque, New Mexico, 26 April 1969.
2. Contract No. 586420 from the Sandia Corporation, dated 5/20/69.
3. Stresau, R. H., "A Miniaturized Gap Test," for the Sandia Corporation, Albuquerque, New Mexico, Report No. 69-6-1. (SC-CR-69-3197)
4. Contract No. 58-6740 from the Sandia Corporation, dated 8/13/69.
5. Amendment No. 2 to Sandia Contract No. 58-6740, Amendment dated 1/7/70.
6. Goode, C. W., R. H. Stresau, "The Small Scale Technique for the Measurement of Detonation Velocities," Navord Report 2282, dated 27 December 1951.
7. U. S. Patent No. 3,100,349, Inventor R. H. F. Stresau, "Bore Measuring Device," Filed Feb. 23, 1961, Issued Aug. 13, 1963.
8. Ayres, J. W., "Standardization of the Small Scale Gap Test Used to Measure the Sensitivity of Explosives (U)", NAVWEPS Report 7342, 16 January 1961.
9. Purchase Description for HNS Explosive, WS 5003, by Navy Department, Bureau of Naval Weapons, Naval Ordnance Laboratory, White Oak, Maryland.
10. Stresau, R. H., "Size Factors in Detonation Transfer," (R. Stresau Laboratory, Inc). Paper presented at Fourth Symposium on Detonation, U. S. Naval Ordnance Laboratory, White Oak, October 12-15, 1965.
11. Eyring, H., R. E. Powell, G. H. Duffy, and R. B. Parlin, "The Stability of Detonation," Chem. Rev., Vol. 45, No. 69 (1949).
12. Kilmer, E. E., "Explosive Properties and Handling Characteristics of HNS-I," NOLTR Report 65-111, NOL, White Oak, dated 25 February 1966.

DISTRIBUTION:

NASA Langley Research Center
Langley Station
Hampton, Virginia 23365
Attn: Larry Bement

NASA Manned Spacecraft Center
Houston, Texas 77058
Attn: T. J. Graves

U. S. Naval Ordnance Laboratory
White Oak, Silver Spring,
Maryland 20910
Attn: E. Eugene Kilmer

R. H. Braasch, 1222
M. T. Abegg, 2340
E. A. Kjeldgaard, 2341
J. P. Weber, 2342
J. E. Kennedy, 5133
E. L. Harley, 9225
G. C. McDonald, 3416
Attn: J. G. Wallace (3)
J. L. Gardner, 3421
L. S. Ostrander, 8232
W. K. Cox, 3422-1 (15)