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HNS/TEFLON, A NEW HEAT RESISTANT EXPLOSIVE

Harry Heller, et al

Naval Ordnance Laboratory
White Oak, Maryland

1 July 1973

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BY
Harry Heller
Albert L. Bertram

1 JULY 1973

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NAVAL ORDNANCE LABORATORY, WHITE OAK, SILVER SPRING, MARYLAND

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(U) HNS/Teflon (90/10) is a new pressed explosive developed for use in the APOLLO program. The major advantages of HNS/Teflon are its, (1) excellent thermal stability at elevated temperatures, (2) superior resistance to sublimation at high temperatures and low pressures and (3) ease of molding powder preparation, pressing and machining. The impact sensitivity of HNS/Teflon is between that of Comp B and Comp A-3 while its explosive performance is about the same as TNT Under the severe environmental conditions of the moon's surface, this explosive successfully performed its intended function of generating seismic waves in the APOLLO ALSEP and LSPE experiments.

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Chemical Engineering Division
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NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NOLTR 73-163 1 July 1973

HNS/Teflon, A New Heat-Resistant Explosive

(U) This report describes work conducted for the Lyndon B. Johnson Space Center, Houston under Task NOL-998/NASA. As part of this program a new explosive composition, HNS/Teflon (90/10), was developed for use in the active seismic experiments in both the APOLLO Active Lunar Seismic Experiments Package (ALSEP) and the Lunar Seismic Profiling Experiments (LSPE). This report describes the development, testing, properties and performance of HNS/Teflon charges and should be of interest to engineers and scientists who require explosives that must withstand hostile environments.

(U) HNS is one of a series of heat-resistant explosives synthesized at the Naval Ordnance Laboratory, as part of an active and continuing program with the objective of studying the chemistry of nitro compounds and synthesizing new explosive compounds with improved properties, under Task MAT 03L-000/ZR00-001-010 entitled Explosives Chemistry (Independent Research).

ROBERT WILLIAMSON II
Captain, USN
Commander

Carl Boyars

CARL BOYARS
By direction

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1. Introduction

Explosives perform a number of various functions in military and aerospace systems. For the Apollo program, NASA developed an Apollo Lunar Surface Experiments Package (ALSEP) containing seven experiments, six of which involved passive detection of lunar phenomena. The seventh was an active seismic experiment with the objective of measuring the geophysical properties of the lunar crust by detonating explosive charges on the moon's surface and measuring the velocity of the resulting seismic waves. Later on in the Apollo program a similar experimental package called the Lunar Seismic Profiling Experiment (LSPE) was developed. The Naval Ordnance Laboratory was requested to recommend an explosive which could be expected to survive the unusual environmental requirements of long term storage on the lunar surface.

2. Explosive Requirements

The following explosive properties were considered to be desirable for this application:

a. Safe to handle and use.
b. Ability to survive lunar temperatures from 100 to 400°K but realistically from -60 to 127°C in an insulated package for at least one year.
c. Low volatility under the temperature conditions stated in (b) above and pressures which might range from 13.33×10^{-11} to 13.33×10^{-13} N/m^2 (10^{-12} to 10^{-14} Torr).
d. Capable of being pressed to high density and then machined to fit into the grenade case.
e. Ability to withstand expected shock and vibration during earth launch, lunar landing and emplacement. Launch and flight conditions are relatively mild but accelerations from 98 to 118 m/s^2 might be expected if a poor moon landing was made.
f. Explosive output about the same as TNT.
g. Unaffected by anticipated lunar radiation levels.
h. Capable of reliable initiation with available initiator systems.
i. Material availability within a reasonable time span.

3. Explosive Selection

Over the past 15 years NOL chemists have synthesized a large number of thermally-stable nitroaromatic explosive compounds. Properties of the more promising compounds are listed in reference (1). Based on the requirements shown in 2. above, five nitrocompounds were considered for this application: cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (β-HMX), 1,3-diamino-2,4,6-trinitrobenzene (DATB), 1,3,5-triamino-2,4,6-trinitrobenzene (TATB), and

2,2',4,4',6,6'-hexanitrostilbene (HNS). The properties of these compounds are summarized in Table 1.

The vapor pressures of the five candidate explosives were measured at elevated temperatures in the range of 1.33 x 10^{-3} to 1.33 x 10^{-7} N/m^2. The Langmuir method was used for the determination of vapor pressures from measurements of the rates of sublimation at constant temperature. Vapor pressures were computed from the observed weight loss of the sample heated in a vacuum. The expression used was:

$$P(mN/m^2) = 2.285 \times G \times (T/M)^{1/2}$$

where G is the weight loss in $g/cm^2/sec$, T is the absolute temperature and M is the molecular weight (reference 2).

The vapor pressures of the five explosive compounds at various temperatures are summarized in Table 2. The data in Table 2 clearly demonstrates that HNS is superior in resistance to sublimation at elevated temperatures and low pressures. Fine crystalline material (2 - 10μ) as obtained from the synthesis reaction is called HNS-I. HNS-II is a larger particle size (100 - 200μ) of higher bulk density obtained by recrystallization of HNS-I. The designation, HNS, in this report refers only to form II.

4. Binder Selection

The principal concern in the use of HNS in the ALSEP grenade was its impact sensitivity. HNS had previously been considered to be a booster explosive since its impact sensitivity was in the same range as tetryl. However, on the basis of previous experience with other explosive compounds it was believed that the addition of about 10% of an inert polymer to HNS would provide enough desensitization to raise the impact sensitivity to at least the Comp B level. In addition, the polymer would aid in the pressing and compaction of high density charges and improve the mechanical properties and machinability of the pressed charges.

A program was initiated to find a suitable binder for HNS which would result in a PBX with the following desirable properties:

a. The pressed PBX should be thermally stable and retain a major portion of its physical properties at the maximum temperature encountered.
b. There should be no appreciable chemical interaction between HNS and the binder at elevated temperatures.
c. The PBX should be capable of being pressed to high density (~98% TMD).
d. The binder should possess some degree of flexibility to enable the PBX to withstand volume changes without cracking due to rapid temperature change.

e. The pressed PBX charges should be capable of being machined into various shapes to a tolerance of about ±0.0025 cm. The machined charge should be strong enough to withstand the handling involved in the manufacture and assembly of the grenade package.

In a previous program a number of polymers were evaluated for use as binders for DATB (reference 3). The results obtained in this program provided valuable guidelines for selecting a binder for HNS. In the DATB program a wide variety of commercial thermosetting and thermoplastic resins were evaluated. It was concluded that PBX's made with thermoplastic binders were easier to process on a large scale with conventional equipment

The properties of the three best DATB PBX systems are summarized in Table 3. Of these, Teflon* was chosen as the superior binder. The excellent strength and machining properties obtained with a pressed PBX using powdered Teflon as a binder were unexpected. Normally, Teflon coatings or pressed compacts must be heated to the sintering temperature (360 - 400°C) in order to form dense, strong coatings or shapes. In this instance, the Teflon/explosive molding powder was pressed at ambient temperature since the softening point of Teflon is above the decomposition temperature of the explosive. Equally unexpected was the ability of the Teflon-bonded PBX to withstand severe thermal shock without cracking in the cycling tests. Part of the explanation may lie in the fibrous nature of the Teflon particles. During the pressing operation the individual particles may lock together to form a strong compact.

5. HNS Binder Selection

A number of polymers, including the three found most suitable in the DATB program, were evaluated. These are listed and identified in Table 4. The first step in screening a plastic binder for HNS was to investigate methods for combining binder and explosive to form a molding powder suitable for pressing.

If the binder was insoluble in water but soluble in an organic water-miscible solvent then:

a. The HNS was suspended in water and the plastic solution added to the slurry, where the polymer precipitated. Or:
b. The HNS was suspended in the polymer solution and water was added to precipitate the polymer onto the HNS.

If the polymer solvent was immiscible in water, the HNS was suspended in water and the polymer solution was slowly added while

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*Teflon is a registered tradename of E. I. DuPont DeNemours and Company for polytetrafluoroethylene.

heat was applied to drive off the volatile solvent. The objective was to coat or encapsulate the HNS crystals with plastic binder.

If the polymer was soluble in water the HNS was mixed in an organic solution of the polymer while heat was applied to drive off the solvent. This procedure can be conveniently carried out in a jacketed sigma-blade mixer so that the explosive will be constantly mixed and evenly coated while the solvent is being driven off.

Polymers which are insoluble in organic solvents are most conveniently incorporated in the PBX in finely divided form. Dispersions or fine powders can be combined with the explosive by mixing them in water and then filtering and drying. Dry blending of fine polymer powders with HNS was possible in some cases.

The above procedures were adequate for screening small batches of PBX. For production quantities of PBXs the use of water emulsions or dispersions should be investigated since this would reduce or eliminate the use of organic solvents. The procedure used to make various HNS/polymer molding powders is given in Appendix A.

6. Properties of HNS PBXs

Impact Sensitivity

As stated previously one of the functions of the plastic binder is to desensitize the HNS to a level more consistent with those of standard secondary explosives. The impact machine is perhaps the most simple method of evaluating the impact sensitivity of an explosive composition. In this test, a 2.5 Kg weight is dropped from a preset height onto a 35 mg sample of explosive. A series of drops at different heights is made and a determination made at each height whether or not a positive reaction has occurred. The result of the test is a height in cm at which there is a 50% probability that the test explosive will react (reference 4).

No single or series of sensitivity tests can provide a complete picture of the complex reactions a given explosive can undergo when subjected to various stimuli. But the impact machine test, when carefully done, can provide much useful information on the impact sensitivity of one explosive relative to a well-known, standard explosive. This is especially true when both explosives have similar chemical structures. Table 5 lists NOL (Bruceton, ERL) impact machine data for the HNS PBXs as compared to some standard military explosives. Since the particle size of the "as received" material was similar to the particle size specified in the test, "as received" material was used for the test samples. Table 5 also contains the densities obtained by pressing these PBX molding powders.

Table 5 indicated that 10% of all the plastic binders evaluated, with the possible exception of Viton A, satisfactorily desensitized HNS above the Comp B level.

Thermal Stability and Compatibility

When normally inert materials are added to explosive compounds, the properties of the mixture cannot be inferred from the properties of each component. In the development of explosive mixtures for a specific application, two closely related requirements must be met. First, the explosive system must be thermally stable at the maximum conditions of storage and use. Second, the presence of one material must not interfere with the proper performance of another material in the system.

The vacuum thermal stability test is used to determine whether one or more materials are thermally stable or chemically reactive at some specific temperature/time cycle. Compatibility encompasses something more than a chemical reaction between two or more materials. For example, if a material in contact with a polymer is a good solvent for the curing agent and thus prevents polymer cure at the interface, then the materials are incompatible even though no chemical reaction has occurred and no reaction products are generated. The vacuum stability test measures the amount of gaseous reaction products from the thermal decomposition or chemical reaction of a single compound or mixture of materials. Since some chemical reactions produce solid decomposition products, other stability tests may be used in conjunction with the vacuum stability test.

Table 6 lists the vacuum stability and compatibility data obtained for the HNS PBXs and a number of other materials used or proposed for use in the ALSEP Grenade program (reference 5). The evolution of <2.0 ml gas/gm under the test conditions shown is considered satisfactory. Also shown in Table 6 is the weight percent change at a pressure of 1.3×10^{-5} N/m^2 and a temperature of 136°C.

The thermal stability and volatility of all the compositions with the exception of the Nylon PBX was considered to be quite satisfactory. The thermal stability of neat HNS at 150°C was excellent.

7. HNS/Teflon PBX

Based on its good overall properties, excellent machinability, ease of pressing and the reproducible pressed densities obtained, HNS/Teflon (90/10) was chosen as the PBX fill for the ALSEP grenade. A Teflon 30 water emulsion containing about 60% Teflon solids was blended with the HNS to form the PBX molding powder by the procedure shown in Appendix A. Several lots of molding powder made either at NOL or by a private contractor were analyzed for uniformity and the data is given in Table 7. Lot 11138-25 was reblended into lot 11138-25A to improve its uniformity. A pressed charge of HNS/Teflon (90/10) was sectioned as shown in Table 8 and several sections were analyzed. The uniformity of both the molding powders and the pressed charges was considered to be satisfactory.

Four sizes of explosive charges ranging in weight from 0.045 to 0.454 kg were made for use in the seismic grenade. Their dimensions are given in Table 9. To illustrate the intricate machining required a clear plastic model of the one pound charge is shown in Figure 1. The four machined explosive charges are shown in Figure 2. A detailed description of the procedures involved in the preparation of these explosive charges is given in reference (6). Some miscellaneous properties of HNS/Teflon (90/10) explosive are given in Table 10.

The variation in lunar surface temperature over a 30 day period is shown in Figure 3. In an attempt to determine the effect of these temperature changes on HNS/Teflon charges, two explosive cubes weighing 195 and 319 g were cycled from -73.3 to +150°C at a rate of 3.3°C/hr for two complete cycles (~12 days). Charges were held at the lowest and highest temperature for one hour during each cycle. Each time the test chamber was at ambient temperature, the samples were visually examined for evidence of cracks or deformation. No significant change in either test sample was apparent following the 12 day test. While there were insignificant changes in several dimensions of the two cubes, no weight loss or color change was noted.

8. LSPE Program

For use in the Apollo 17 program, NASA desired a more advanced active seismic experiment as part of the Lunar Seismic Profiling Experiment (LSPE). There were several major differences between the two programs. First, the LSPE explosive charges were to be hand placed a known distance in relation to the geophone array permitting a more accurate velocity measurement of the explosive shock wave. Second, the S & A device was redesigned to improve safety and reliability, (reference 7). Each set of explosive charges for the LSPE program consisted of two 0.057 kg, two 0.114 kg, one 0.227 kg, one 0.454 kg, one 1.362 kg and one 2.724 kg charges (Figure 4). The 2.724 kg charge was in the shape of a cube, all the others were cylinders.

9. HNS/Teflon Molding Powder

Since HNS/Teflon (90/10) pressed explosive charges were found to be satisfactory in the previous ALSEP program, it was decided to use the same explosive in the LSPE program.

A number of HNS/Teflon molding powder samples were made by the same procedure used to prepare molding powder for the previous ALSEP charges using Teflon 30 emulsion coagulated and precipitated with acetone. Both processing problems (severe foaming and flocculent formation upon addition of the acetone) and handling problems (the dried molding powder was not a free-flowing powder but consisted of numerous agglomerates) indicated that the preparation of large quantities of homogeneous and free-flowing HNS/Teflon molding powder utilizing Teflon 30 emulsion would be difficult.

A revised procedure using mechanically blended mixtures of HNS and finely divided Teflon powder was investigated. The procedure was used to prepare four batches of HNS/Teflon molding powder ranging from

50 gm to 5 kg. As noted below:

a. The required quantities of HNS and Teflon were weighed out and placed in a smooth-walled metal cylindrical drum. To insure thorough mixing, the contents should displace a maximum 1/3 of the total volume of the drum. As an example, 540 gm of material can be processes in a 3 liter container.

b. To aid in blending the powdered material 2.54 cm diameter Teflon balls were placed inside the drum. For optimum mixing the sum of the balls diameters should be about 1/2 the drum height. The 5 kg batch (ID 1462) was processed in a drum whose height was 107 cm; 22 2.54 cm diameter balls were used.

c. Mixing was accomplished by rolling the drum on a ball mill. A rotational speed of 120 r.p.m. has been used for laboratory scale preparation with excellent results. The 5 kg batch (ID 1462) was processed at 34 r.p.m. with equally good results. Excellent homogeneity was attained after mixing for eight (8) hours.

d. The molding powder was then removed from the drum and vacuum dried at 50°C for 24 hours. Two 3-gram samples were removed for analyses. The molding powder was stored in dry, airtight containers until pressed into charges.

Preliminary results showed that explosive charges made from the dry blended HNS/Teflon molding powder had a) similar sensitivity properties; b) greater homogeneity; c) better machining characteristics; d) improved mechanical properties and e) were easier to process than similar explosive charges made by the old procedure utilizing Teflon 30 emulsion.

The uniformity is evidenced by two random samples from the 5 kg batch (ID 1462), which were chemically analyzed to determine the amount of Teflon in the molding powder. Results are given in Table 11.

The Teflon powder designated as Teflon 7C gave the best results and was selected for use in the new dry blending process. The blending operations are described in (reference 6).

10. Teflon Analyses

The Teflon content had been previously run on the machinings from the ALSEP project charges. These machinings were blended into one lot (ID 1369) and then reblended to form a second lot (ID 1378). Analyses for Teflon content were run on each of these blends. The results show that a more uniform molding powder can be obtained using Teflon 7C. Results of the analyses are also given in Table 11.

11. Simulant

One of the requirements of the project was to develop compositions and manufacture inert simulator blocks for a NASA contractor to be used in some of their in-plant tests. It was desirable that the properties of the simulant be as similar as possible to HNS/Teflon. A number of simulant compositions were developed and evaluated in an attempt to duplicate the properties of HNS/Teflon as closely as possible. The inert simulant composition selected was:

Melamine (Eastman 1540 or equivalent)	10.0 ± 0.5%
Teflon (Dupont 7C)	24.0 ± 0.5%
Vinylidene fluoride resin (Pennwalt RC 2525)	66.0 ± 0.5%

The background and details of the simulant development and properties are given in reference 8.

12. Impact Sensitivity

Impact sensitivities were run on samples of HNS/Teflon made with Teflon 30 emulsion and Teflon 7C. The impact sensitivities of both compositions were essentially equal.

13. Thermal Properties

Design considerations required that various other thermal properties be run on at least the final explosive. The thermal diffusivity (from which the thermal conductivity was calculated) and specific heats have been obtained for Teflon (as a calibration material), HNS/Teflon 30, HNS/Teflon 7C, and the inert simulant.

The thermal conductivity and specific heat of the selected simulant composition were 5.793×10^{-4} cal/cm/sec-°C and 0.278 cal/cm/°C, respectively. These compare favorably with the values of 5.636×10^{-4} cal/cm/sec-°C and 0.249 cal/cm/°C obtained for HNS/Teflon 7C (ID 1462) made from HNS (X580*) remaining from the ALSEP program. The values for the various materials are given in Table 12.

14. Differential Thermal Analysis

Differential thermal analysis (DTA), described in reference (9). is a method for observing the transitions and reactions that a substance undergoes on heating. The sample and the inert reference are placed symmetrically in a furnace which is heated at a constant rate The difference in temperature between the temperature and the inert reference (ΔT) is observed as a function of furnace temperature. When a reaction occurs, the change in the thermal properties of the sample is indicated by a deflection or peak.

The particular application in the HNS/Teflon work was to ascertain the chemical stability of the material upon thermal heating by observing their phase transition. (either endothermic or exothermic) in the temperature region of interest. A standard DTA setup was used for this work.

Differential thermal analyses were run on HNS (X756), HNS/Teflon 7C (X757 and ID 1462) and Teflon 7C. Heating rates of both 5°C/min and 10°C/min were used on all materials except HNS/Teflon 7C (ID 1462),

---

* NOL magazine identification number.

which was run at only the 5°C/min heating rate.

All of the HNS and HNS/Teflon samples showed a slight exotherm (believed to be due to decomposition) just prior to the endotherm due to melting. The temperature range of the initiation of the melting point endotherm was 311.5°C to 312.5°C for HNS (X756), 311.0°C to 311.8°C for HNS/Teflon 7C (X757), and 325.5°C to 328.6°C for Teflon 7C. Details of the DTA work are shown in Table 13.

15. Thermal Cycling (Design Limit)

For the LSPE program NASA requested the following severe time/temperature environmental tests on the explosive package.

Reduce temperature from ambient to -73.3°C (0-3 hrs)
Raise temperature to -40°C (3 - 6.5 hrs)
Raise temperature to 121°C (6.5 - 11.5 hrs)
Reduce temperature to 88°C (11.5 - 16 hrs)
Reduce temperature to -73.3°C (16 - 18 hrs)
Raise temperature to ambient 23.9°C (18 - 24 hrs)

The explosive packages were x-rayed before and after the thermal shock tests. It was apparent from the radiographs following the tests that cracking occurred in the larger charges. Further investigation revealed that the LSPE charges above the 0.114 kg size showed various degrees of cracking brought about by the thermal cycling. (reference 10).

There is no evidence to suggest that cracks in explosive charges pose any safety or reliability hazards. The measured detonation velocity of cracked and sound explosive charges were the same. Based on a test program comparing cracked and uncracked charges it was concluded that cracked charges did not pose a safety problem and had no effect on the proper functioning of the explosive package.

16. Results

HNS/Teflon - loaded grenade packages were placed on the moon by the Apollo 14 and 16 astronauts. NASA's first tests of its ALSEP moon-grenade launcher left on the moon by Apollo 16 occurred on 23 May 1972 triggered by radio signals from the Spacecraft Center, Houston. Three of the four charges were launched and fired successfully. Following the launching of the third grenade, the mortar package's pitch sensor shifted to offscale high, indicating either that the sensor had failed or that one or more of the four stakes anchoring the mortar to the lunar surface had pulled out of the ground allowing the package to pitch up backward.

The fourth grenade containing the 454g HNS/Teflon charge has not been fired as yet to avoid any possible damage to the rest of the ALSEP package. The Apollo 14 explosive charges have not yet been launched to prevent possible damage to the other still-operating experiments in the ALSEP package.

The eight explosive charges emplaced on the moon by Apollo 17 astronauts for the LSPE program were detonated successfully by radio after the astronauts left the lunar surface.

17. Conclusions

Under the severe environmental conditions imposed by the moon's surface, HNS/Teflon explosive successfully performed its intended function as part of the Apollo ALSEP and LSPE programs.

18. Recommendations

HNS/Teflon should be considered as a prime candidate for future explosive applications involving unusually high temperatures and/or very low pressures.

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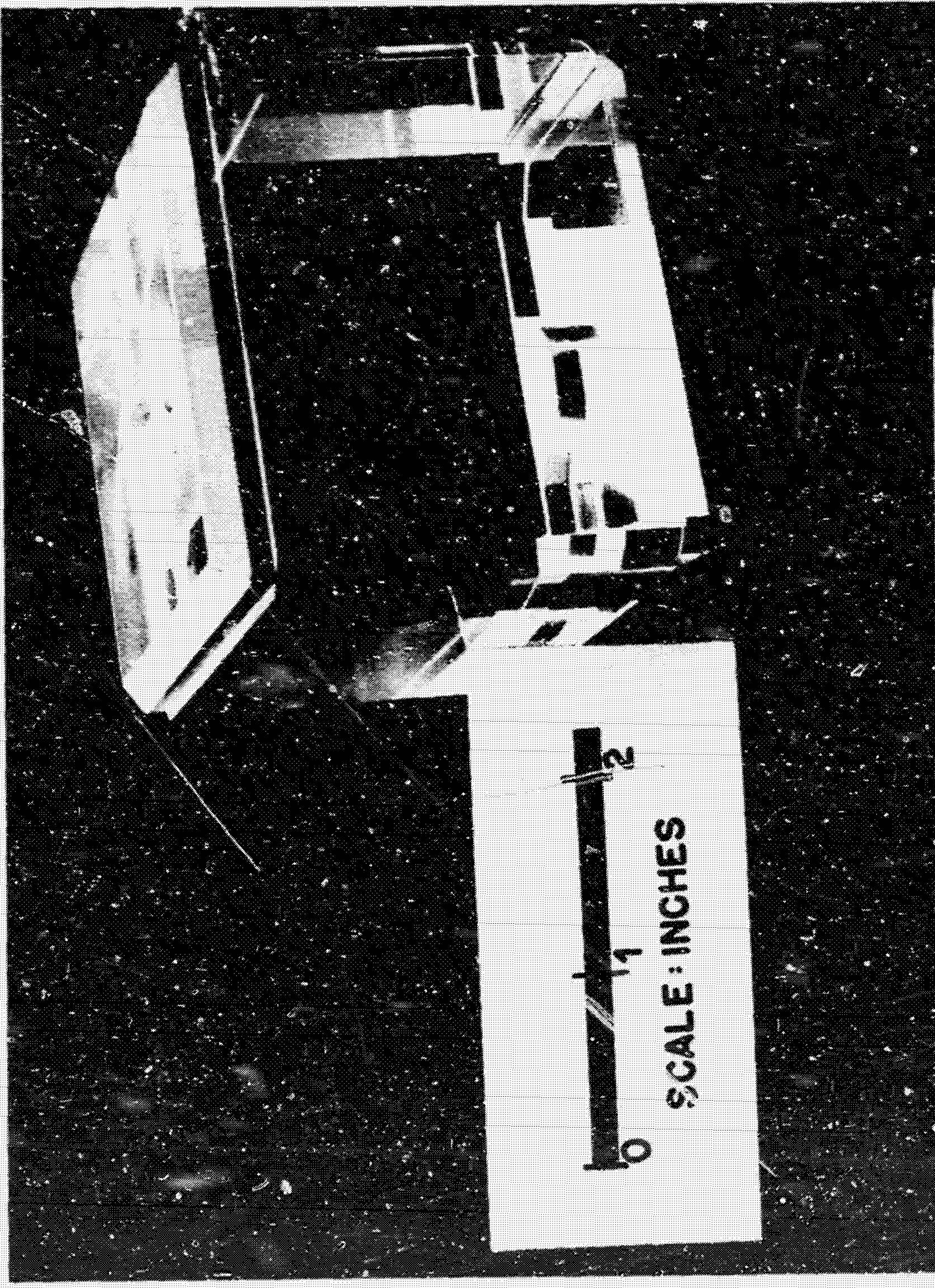


FIG. 1 PLASTIC MODEL OF ONE POUND EXPLOSIVE CHARGE

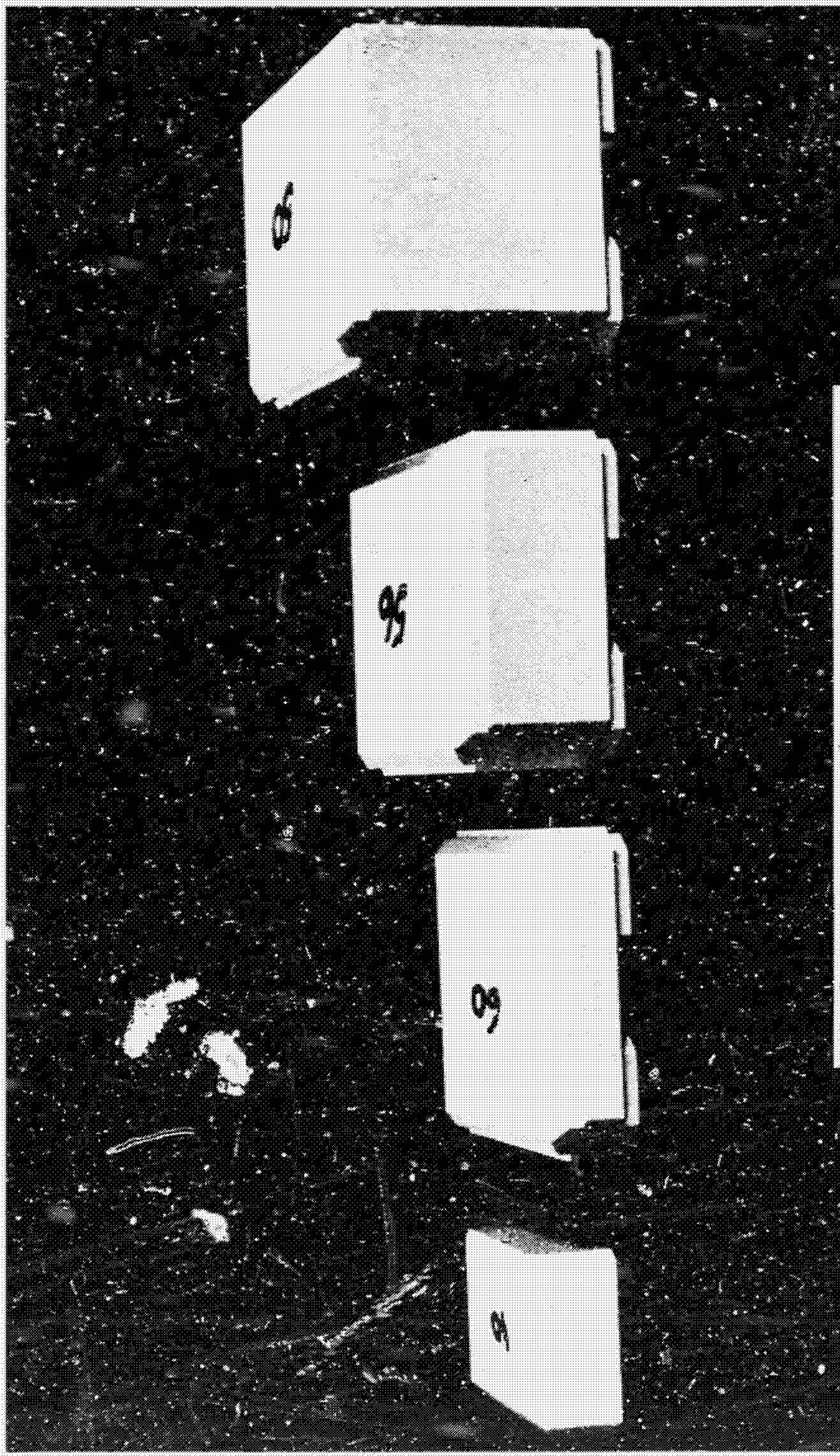


FIG. 2 MACHINED HNS/TEFLON EXPLOSIVE CHARGES

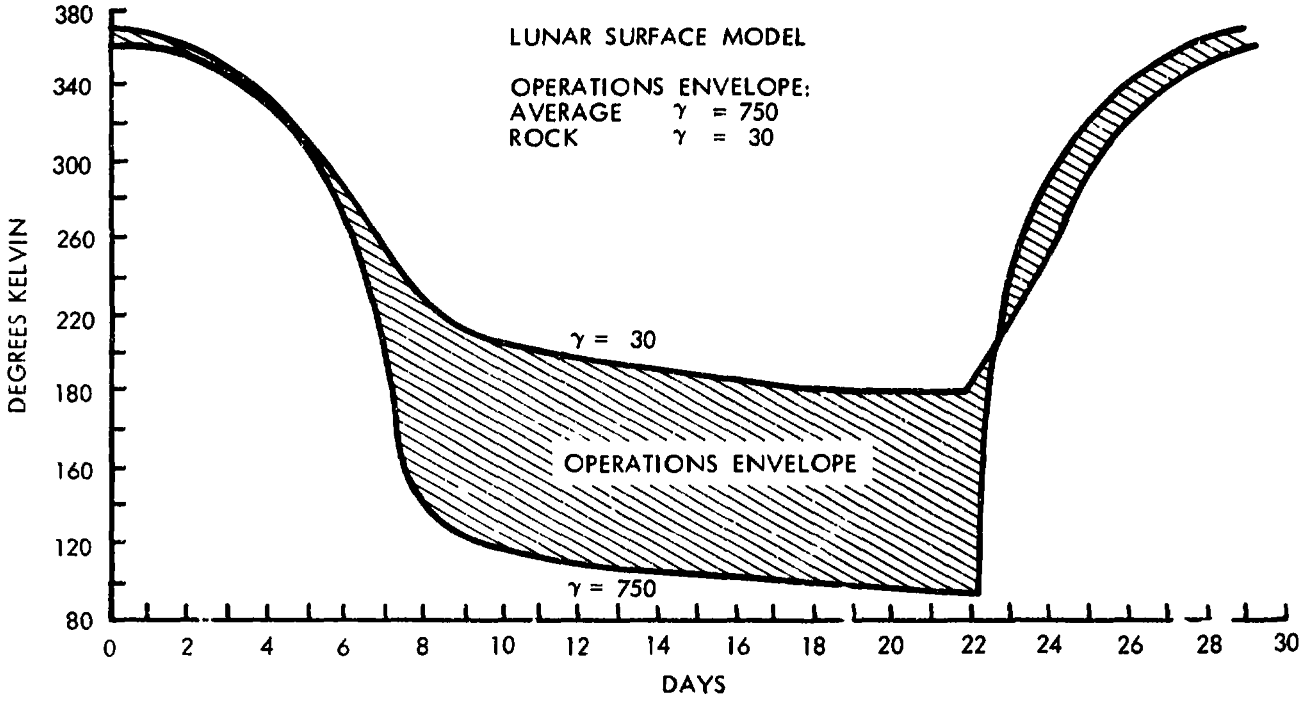


FIG. 3 VARIATION OF LUNAR SURFACE TEMPERATURE DURING A COMPLETE LUNATION

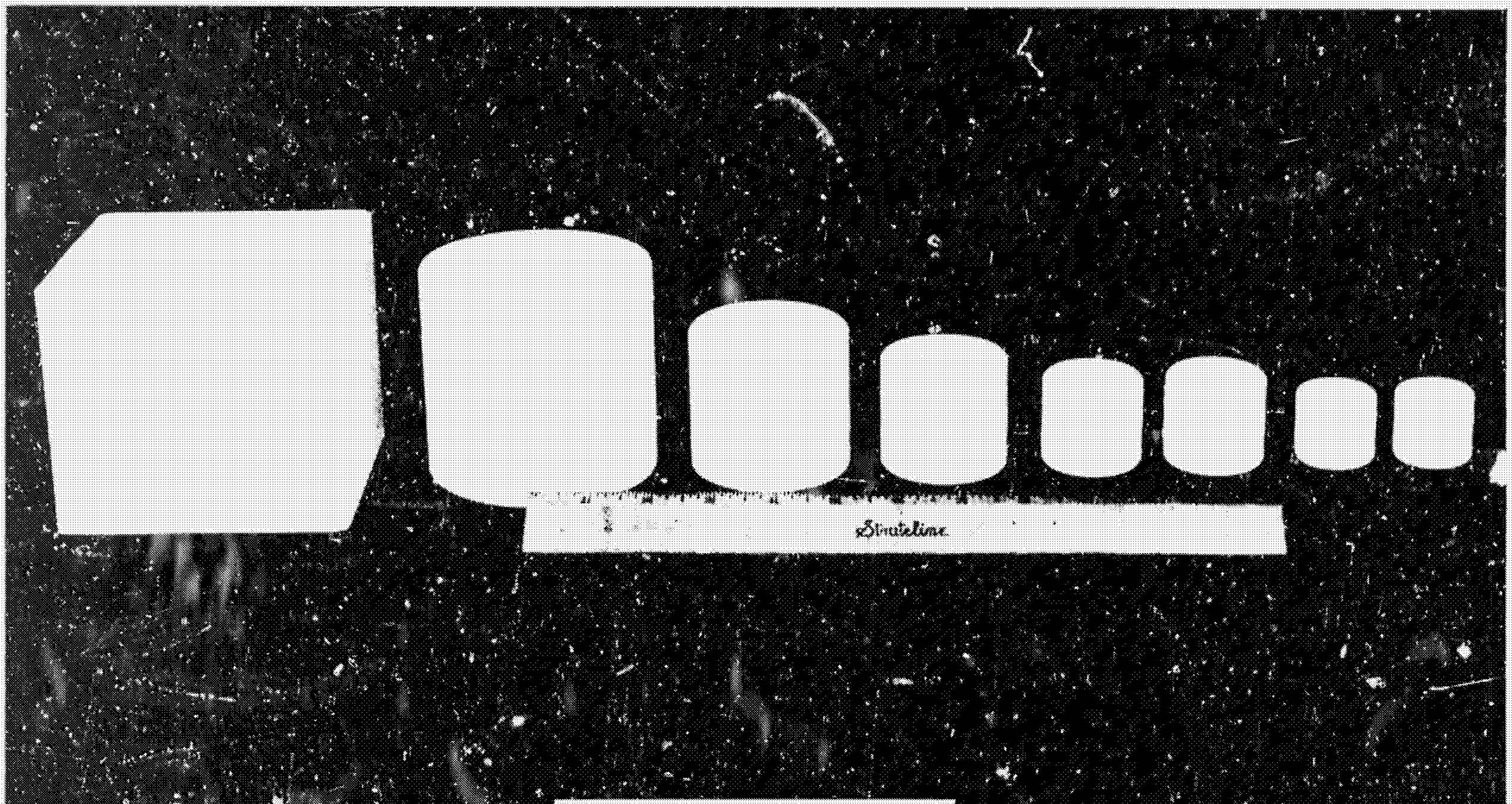


FIG. 4 LSPE EXPLOSIVE CHARGES

Table 1

Properties of Selected Explosive Compounds

	RDX	HMX	DATB	TATB	HNS
Crystal density, g/cm^3	1.82	1.90	1.84	1.94	1.74
Melting point, °C (1)	204	285-287	286	~450	318
Vacuum Stability, ml gas/g/48 hrs (100°C)	0.1	<0.1	<0.1	<0.1	<0.1
, ml gas/g/2 hrs (260°C)	*	*	1.3	0.8	1.1
Detonation velocity, mm/μsec (2)	8.64 (1.77)	9.11 (1.89)	7.6 (1.80)	7.76 (1.88)	7.02 (1.70)
C-J detonation pressure, K bar (2)	338 (1.767)	387 (3) (1.90)	259 (1.78)	291 (3) (1.88)	-
Impact Sensitivity (50% ht,cm)	24	25	>320	>320	53

(1) Decomposition usually occurs at or near melting point
(2) Number in parenthesis is charge density in g/cm^3
(3) Calculated

*Exceeds capacity of apparatus

Table 2

Explosive Vapor Pressures

Compound	T.(°C)	Time (hrs)	Area* (Cm^2)	Wt. Loss (G. x 10^3)	Vapor Pressure (X10^7 mN/m^2)
RDX	78.2	1200	0.791	20.79	10.5
	97.7	402	0.766	55.72	88.9
DATB	97.6	972	6.33	15.9	1.2
	108.1	516	6.33	31.0	4.5
HMX	115.6	7.68	2.31	2.09	0.06
	129.3	2430	2.31	4.83	0.4
TATB	161.4	1440	2.31	29.0	4.3
	177.3	474	2.34	49.16	22.3
HNS	177.3	4800	6.33	22.9	0.3
	206.3	1080	2.53	36.55	5.3

*Surface area of sample

Table 3

Properties of Selected DATB PBX Systems

Properties	DATB-PBX with 5% Teflon	Kynar	Lexan
Melting point of binder (°C)	325(1)	170	268
Pressed density (% TMD)	98	98	98
Machinability	Excellent	Excellent	Good
Compatability of binder with DATB	Excellent	Excellent	Excellent
Thermal cycling resistance (no. of cycles from -54°C to +71°C with no cracking)	5+	3	--(2)
Compressive strength (average) (psi)	7000	9800	10800

(1) Amorphous gel above this temperature.

(2) Not tested.

Table 4

Polymeric Binders Evaluated

Tradename	Composition	Source
Teflon 30	Water emulsion of polytetrafluoroethylene	DuPont
Lexan	Polycarbonate	General Electric Co.
Kynar	Polyvinylidene fluoride	Pennsalt Chem. Co.
Zytel 63	Alcohol soluble nylon	DuPont
Viton A	Copolymer of hexafluoropropylene and vinylidene fluoride	DuPont
Nylon 63	Alcohol soluble polyamide	DuPont
Chemlock 607*	Proprietary Adhesive	Hughson Chemical Co.

*Used in conjunction with Viton A

Table 5

Comparison of Polymeric Binders for HNS

Composition	Impact Sensitivity (Molding Powder) cm	Pressed Density (g/cm^3)	%TMD
HNS (Control)	53	-	-
HNS/Teflon (95/5)	64	-	-
HNS/Teflon (90/10)	77	1.74	97.6
HNS/Lexan (90.10)	99	1.55	92.9
HNS/Viton-A/Chemlock (90/8/2)	94	1.77	98.8
HNS/Kynar (90/10)	84	1.71	98.3
HNS/Viton-A (90/10)	53	1.70	97.1
HNS/Nylon (90/10)	183	1.63	99.4
Tetryl	40	-	-
Comp B	60	-	-
TNT	200	-	-

Table 6

Thermal Stability Tests

Composition	ml gas/gm (150°C)	Time (days)	% Wt. Change at 1.3×10^{-5} N/m^2
HNS/Teflon (90/10)	<0.1 <0.1	2 44	+0.06% in 10 days at 136°C
HNS/Lexan (90/10)	<0.1	30	-
HNS/Kynar (90/10)	0.25	2	-
HNS/Nylon (90/10)	1.1	2	+0.13% in 10 days at 136°C
HNS	0	100	-
ALSEP Propellant (AP/Al/Viton-Teflon)	-	-	-0.15 in 6 days at 177°C
HNS/Teflon/Epoxy Laminate	0.63 0.70	2 7	- -
HNS/Teflon/Silicone Laminate	0.17	3	-
HNS/Teflon/Acrylic Lacquer	0.13	2	-

Table 7

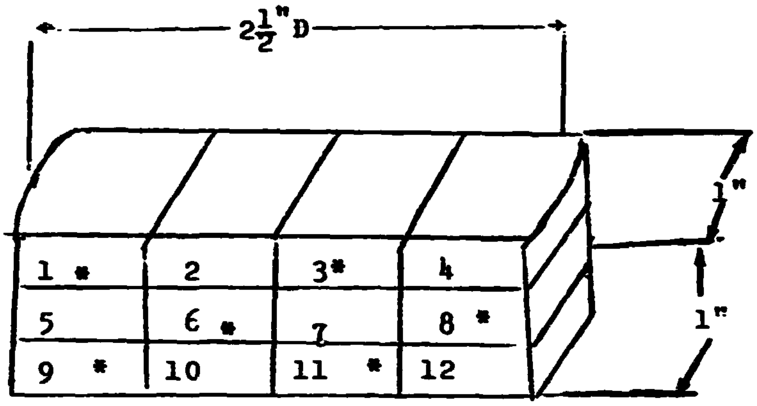
Molding Powder Analysis

HNS/Teflon 90/10

Lot. No.	Sample	% Teflon	Remarks
X 576	--	10.86	5.5 lb Prepared at NOL
X581			
11138-24	A1	9.67	Prepared by contractor
	A2	9.34	36 lb
	A3	10.03	
		9.68 ± 0.23	average
11138-25	B1	10.59	Prepared by contractor
	B2	9.48	73 lb Before blending
	B3	7.91	
	B4	12.42	
		10.10 ± 1.38	average
11138-25	Top	12.64	Prepared by contractor
	Middle	11.12	50 lb After blending
	Bottom	10.16	
		11.31 ± 0.89	average

Table 8

Analysis of Sectioned Charge



Sample No.	% Teflon
1	9.78
3	9.66
6	9.26
9	10.44
11	9.68
Average	9.75 ± 0.24

Table 9

Explosive Charges for Seismic Grenade

Predicted Range (km)	Nominal Weight (kg)	Gross Dimensions (cm)
1.50 km grenade	0.454	6.825 x 6.825 x 6.033
0.915 km grenade	0.272	6.825 x 6.825 x 3.650
0.305 km grenade	0.136	6.825 x 6.825 x 1.905
0.153 km grenade	0.045	3.81 x 3.81 x 1.905

Table 10

Some Properties of HNS/Teflon (90/10) Explosive

Property	
Density, g/cm^3	1.70 - 1.74
Detonation velocity, m/sec (ρ=1.70)	7000
Compressive Strength, g/cm^2	1.1882x10^5
Young's Modulus, g/cm^2	66.9x10^5
Impact Sensitivity, 50% point, cm	77

Table 11

Teflon Analyses

	Percent Teflon			
HNS/Teflon 30 (90/10)				
ID 1368				
Sample #1	14.73	12.81	11.59	13.04
Sample #2	11.26	11.24		11.25
			Average	12.15
ID 1378				
Sample #1	11.16	11.35		11.26
Sample #2	10.61	10.47		10.54
			Average	10.90
HNS/Teflon 7C (90/10)				
ID 1462				
Sample #1	9.75	10.11		9.93
Sample #2	10.05	10.20		10.13
			Average	10.03

Table 12

Thermal Properties

	Thermal Diffusivity cm^2/sec	Density g/cm^3	Specific Heat cal/cm/°C	Thermal Conductivity cal/cm/sec-°C
HNS/Teflon-30 Machinings ID 1368	1.39×10^{-3}	1.676	0.250	5.802×10^{-4}
HNS/Teflon 7C	1.34×10^{-3}	1.689	0.249	5.636×10^{-4}
Teflon Machined Rod	0.94×10^{-3}	2.207	0.259	5.392×10^{-4}
Simulant #20	1.22×10^{-3}	1.708	0.278	5.793×10^{-4}

Table 13

DTA Analyses

Material	Program Rate (°C/min)	Number of Samples	Temperature Range (°C)
HNS (X756*)	5	1	311.5
	10	1	312.5
Teflon 7C	5	2	325.5 - 328.6
	10	1	327.3
HNS/Teflon 7C (X757*)	5	4	311.0 - 311.8
	10	1	311.8
HNS/Teflon 7C (ID 1462)	5	2	311.5 - 312.3

*NOL Magazine identification number

Appendix A

Preparation of PBX Molding Powder

Procedure for HNS/Kynar

HNS	1350 gm	90%
Kynar resin	150 gm	10%
Acetone	7,000 ml	
Distilled water	12,000 ml	

(a) Dissolve the resin in acetone under reflux.

(b) With vigorous stirring, add the HNS to the resin solution and stir for 10 minutes

(c) Add the water and stir for 10 minutes more.

(d) Filter and wash with water.

(e) Dry molding powder at 80°C for 4-6 hours.

Procedure for HNS/Teflon 30

HNS	1350 gm	90%
Teflon 30 (60% solids)	250 gm	10%
Distilled water	4500 ml	
Acetone	3600 ml	

(a) Add HNS to the water and stir vigorously for 5 minutes.

(b) Add Teflon dispersion and stir for 5 minutes.

(c) Add acetone and stir for 10 minutes.

(d) Filter and wash with water.

(e) Dry at 80°C for 4-6 hours in vacuum oven.

<u>Procedure for HNS/Lexan</u>

HNS	450 gm	90%
Lexan	50 gm	10%
Methylene chloride	600 ml	
Distilled water	2400 ml	

(a) The Lexan is dissolved in methylene chloride under reflux.

(b) The HNS is added to the water which has been heated to 50°C and the slurry is stirred vigorously.

(c) The solution of Lexan is added slowly to the stirred slurry and the stirring continued until the solvent has been driven off.

(d) The molding powder is filtered, washed with water and dried for 4-6 hours at 80°C in a vacuum oven.