MHSMP-80-28

Dist. Category UC-45

MASTER

Electrostatic Sensitivity of Secondary High Explosives

C. Art Campos

DEVELOPMENT DIVISION

June 1980

Process Development
Endeavor No. 301

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Mason & Hanger-Silas Mason Co., Inc.
Pantex Plant

OPERATED FOR THE
Department of Energy
UNDER
U. S. GOVERNMENT CONTRACT DE-AC04-76DP-00487

P. O. BOX 30020
AMARILLO, TEXAS 79177
806-335-1581

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.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor 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.

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $5.00 ; Microfiche ~~$3.00~~ 3.50

ELECTROSTATIC SENSITIVITY OF SECONDARY HIGH EXPLOSIVES

C. Art Campos

DEVELOPMENT DIVISION
(June 1980)

Process Development
Endeavor No. 301

DISCLAIMER

This book 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.

ABSTRACT

An Electrostatic Sensitivity Test System designed at Pantex was used to evaluate the secondary high explosives PETN, HMX, RDX, HNS I, HNS II and TATB. The purpose of this study was to establish test conditions for a standard electrostatic sensitivity test and measure baseline data of a few secondary explosives. Although secondary explosives are often considered quite insensitive to an electrostatic discharge, PETN, HMX, and RDX were initiated. Several external elements to the high explosive were found to have an influence on sensitivity. Initiation appeared to be dependent on the nature of the discharge current curve.

Those elements recognized as having a significant effect on the results were held constant in this study. These included:

1. Distance between discharge plates.
2. Sample moisture content.
3. Material density.
4. System resistance, capacitance and inductance.

However, no attempt was made in this study to determine the extent to which the high explosive response to electrostatic discharge is affected by these factors since such correlation is not necessary to determine relative sensitivities.

INTRODUCTION

The electrostatic sensitivity of an explosive is difficult to define in absolute terms. The sensitivity of a particular material can be related to that of a well-known explosive. However, absolute data should be restricted to the particular equipment used to obtain the measurements.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Various investigators have used electrostatic sensitivity measurements to resolve different objectives. T. J. Tucker*(1)* compares the electrostatic discharge required for initiation of explosives to that which can be generated by a person. M. S. Kirshenbaun*(2)* used electrostatic sensitivity measurement to distinguish between primary and secondary explosives and compare primary explosives at a fixed energy input of 0.02 J.

The objective of this work is to obtain a relative comparison of electrostatic sensitivity for various secondary explosives. The initial phase of the study reported here involved obtaining baseline sensitivities for conventional explosive powder. Future work will consist of determining sensitivities of new materials in order to evaluate their relative hazard.

An initial concern in this study was the establishment of a sensitivity parameter by which to compare all secondary explosives. Other investigators have shown that current and rise time are influential in defining the spark characteristics necessary for initiation. Using the basic current equation, a sensitivity parameter was defined as:

$$S = I_p q$$

where,

S = indicator of sensitivity

I_p = peak current

q = charge

since,

$$dq/dt = I(t) = I_p e^{-t/\tau}$$

$$q = I_p \int e^{-t/\tau} dt$$

then,

$$S = I_p^2 \int e^{-t/\tau} dt \text{ amp}^2 \text{ sec}$$

t = time

τ = time constant

Note that the expression for sensitivity resembles an energy equation. The variable t needs some explanation. A di/dt probe was used to detect current changes which could be associated with time-to-reaction (TTR), defined as that time for gas ionization state changes to occur due to the reacting explosive. We can let TTR = t. If the TTR is not detected, then the explosive reaction is assumed to be longer than 5 time constants of the discharge system where more than 99% of the capacitance energy has been dissipated. Further testing will be performed to more adequately describe TTR.

The time constant τ is a measured value from the current trace. However, it was found that the time constant changed during the discharge. Instead of attempting to predict the RLC values, it was easier to approximate τ experimentally for each test. This was done using,

$$I(t) = I_p \, e^{-t/\tau}$$

and taking ln I(t)

$$\ln I(t) = \ln I_p - t/\tau$$

where,

$$\ln I_p = \text{intercept}$$

$$-1/\tau = \text{slope}$$

Using measured points along the early part of the current trace and performing linear regression, the slope is determined and τ calculated.

EXPERIMENTAL SAMPLE

The design considerations for the explosive sample holder shown in Fig. 1 included:

1. A short spark gap which reduces the breakdown voltage and increases the energy density.
2. Reproducible sample density.
3. Moisture content of sample.

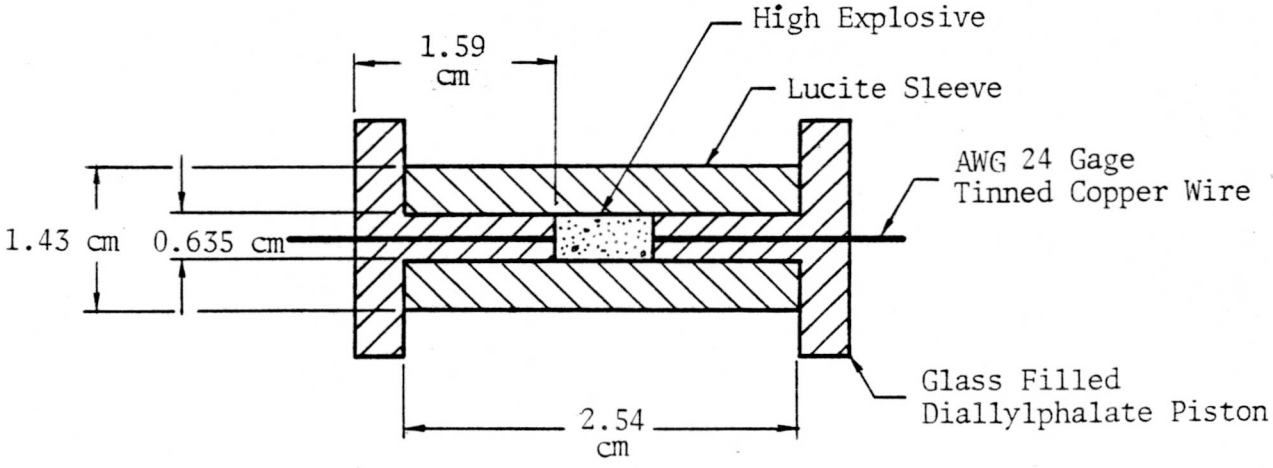


Fig. 1. Typical Sample

Since sensitivity was expected to be a function of compaction of the sample, and each powder has its own characteristic bulk density, standard testing was conducted at 110% of bulk density to improve reproducibility. For example, at bulk density, the sample holders under minor vibrations during handling could result in some uncontrollable compaction of the powder and separation from one of the spark gap conductors causing a variability in test results.

The gap size was determined through a few series of tests. A minimum gap to increase spark energy density was desired. The trade-off was to minimize the gap without sacrificing powder density measurement accuracy. The results showed that a 0.889 mm gap would satisfy both requirements.

Limited testing was performed to show that increased relative humidity decreases the powder sensitivity. In order to test the samples in the most sensitive state, drying was imperative. To accomplish this, the samples were vacuum-dried for no less than 16 hours prior to testing, and testing was limited to days when the relative humidity was less than 20%, since the facility does not have humidity control.

ELECTRICAL SYSTEM

The system designed to meet the objective of testing secondary high explosives is shown in Figs. 2 and 3. It is essentially a portable system capable of containing detonations of up to 0.165 g (as presently proof-tested).

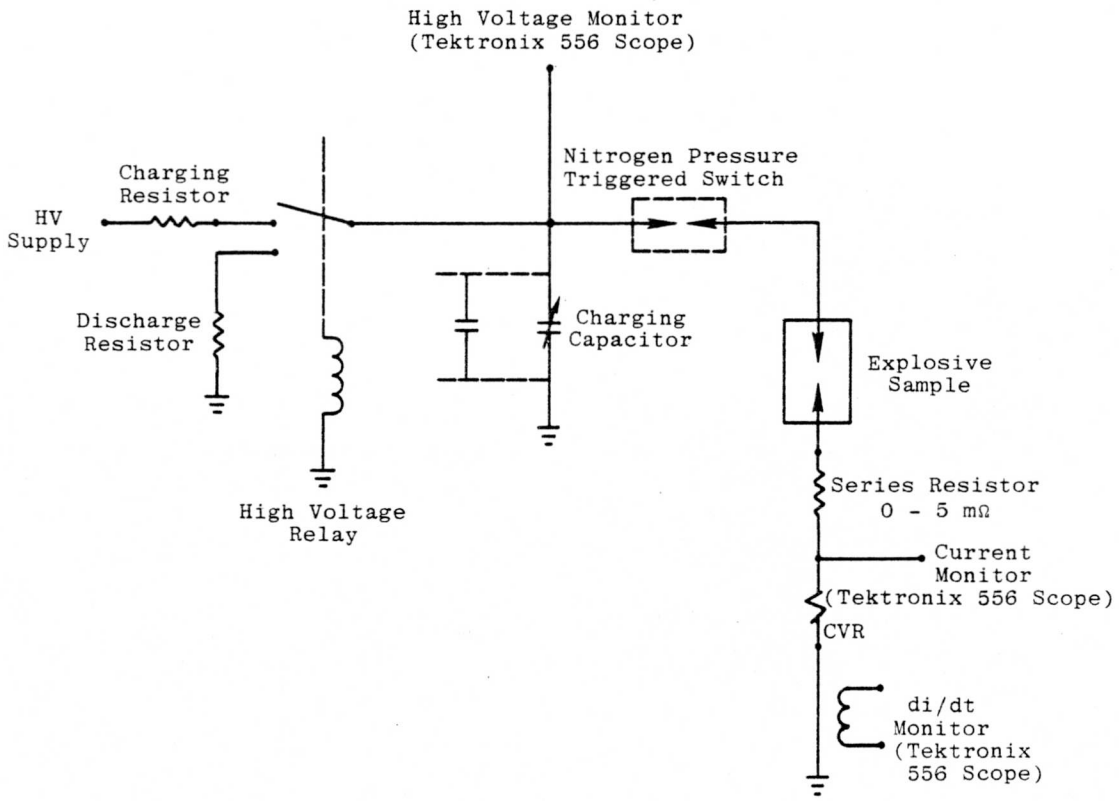
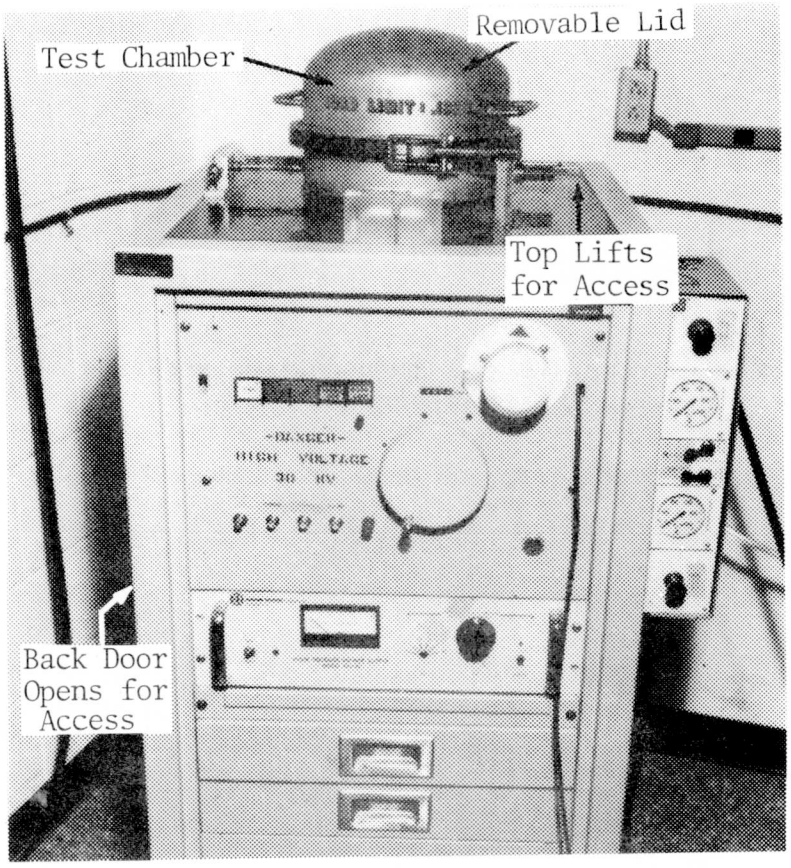
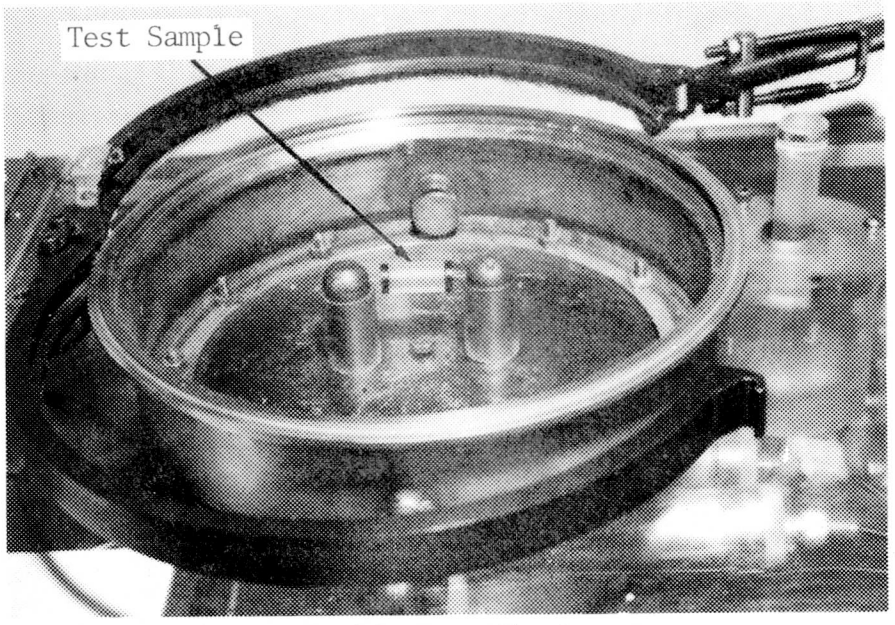


Fig. 2. Electrical System



Control Panel



Inside Test Chamber

Fig. 3. Electrostatic Sensitivity Control Panel and Chamber

Discharge capabilities include:

1. Voltage range from 0 to 27 KV.
2. Wide energy range capability defined by range of capacitors and voltage.
3. Adjustable series resistance up to 5 megaohms.
4. Variable capacitances up to 0.022 μf.
5. Variable discharge gap.
6. Controllable sample size and density.
7. Discharge voltage controlled through a nitrogen pressure sensitive switch.

In the early experiments, energy was varied by changing the capacitance and increasing voltage until sample gap breakdown occurred. It became quickly apparent that more consistent and meaningful testing could be conducted by controlling the charging voltage. A nitrogen pressure activated switch concept acquired from T. J. Tucker was implemented to satisfy this requirement. A few tests were conducted to evaluate varying voltage at constant capacitance.

The following results were obtained using superfine PETN Lot No. 225A at 110% of bulk density (0.70 g/cc), less than 20% RH, 0.889 mm gap and 22 series resistance. These results show that at 7.92 KV a reaction may or may not occur. This voltage was considered the threshold level for reaction and confirmed the effectiveness of controlling voltage.

Charge Voltage (KV)	Reaction Level
7.5	No Reaction
7.75	No Reaction
7.87	No Reaction
7.92	Partial
8.0	Violent Reaction

TIME TO REACTION

If voltage above that required to produce a high order reaction were applied, it would be expected that a decreased time-to-reaction (TTR) should be observed. A di/dt probe was placed in series with a discharge line to measure changes of ionization possibly due to the reacting high explosive. The samples were made from Lot No. 225A PETN at 0.7 g/cc bulk density.

Fig. 4 shows the results from this experiment. Note that the pulse which appears riding on the decaying curve moves down in time as applied voltage increases, and occurs only when reaction is achieved. The 8.5 KV times appear to be inconsistent with times at other voltages, but overall, the di/dt probe did appear useful for measuring TTR. The data are shown in Table I.

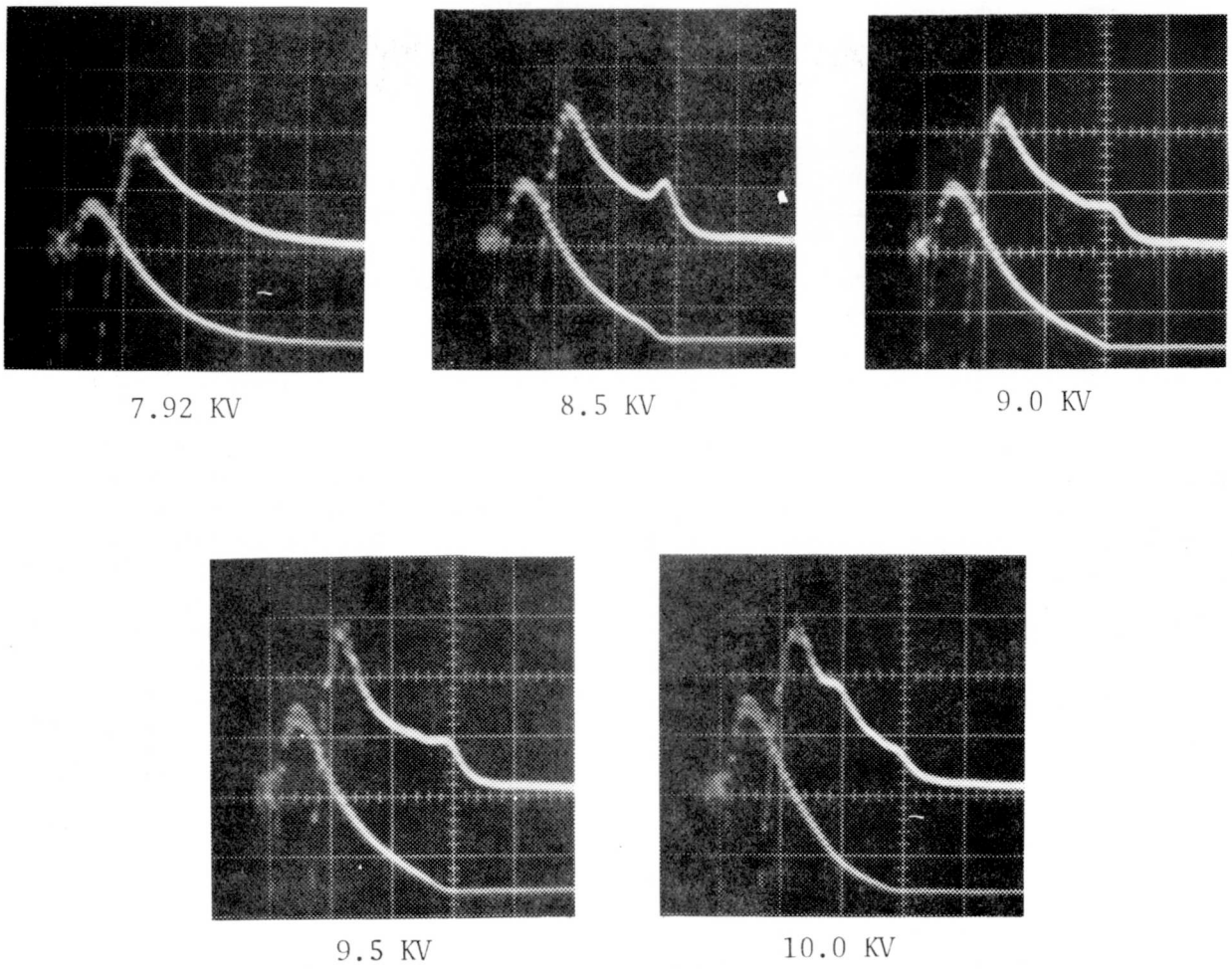


Fig. 4. Scope Traces of the di/dt Probe
(7.92 KV sample was a partial detonation)

Table I. di/dt Probe Results for PETN

Applied Voltage (KV)	Time to Detectable Change (μs)	Reaction Level
7.92	None	Partial
8.50	1.21	Violent
9.0	1.26	Violent
9.5	1.21	Violent
10.00	0.781	Violent

DETONATION THRESHOLD

Certain elements which affect the electrostatic sensitivity of explosives were held constant at the following levels:

1. Capacitance: 0.022 μf.
2. Relative humidity: less than 20%. (Some questions remain to be resolved on the accuracy of the method used.)
3. Sample gap: 0.889 mm.
4. Series resistor: 22 Ω.
5. Powder material compressed to 110% of bulk density.

In choosing explosives for baseline data, an effort was made to use powders which would yield a large spread in sensitivity. Table II shows the results obtained from these tests. As expected, TATB did not show any reaction to voltage discharges at maximum output of the system. Superfine grade PETN was the most sensitive of the powders tested. Voltages at and above the 7.92 KV threshold resulted in reactions. The results from cap grade PETN indicate that the crystalline structure of a powder may have a substantial effect on the sensitivity. There were indications of reaction as low as 12 KV but no violent reactions occurred even up to 23 KV. Scorching was the only response observed from HNS I and HNS II. The scorching was apparent at voltages as low as 11 KV for HNS I. For HNS II, scorching was not observed until voltages of 18 KV and higher were applied.

Fig. 5 illustrates the appearance of a sample following a partial reaction. Normally, it is very simple to determine the difference between samples which show no reaction, those which undergo partial reaction, and those which reach a violent reaction (perhaps approaching high order). A violent reaction will completely break the holder. In this case, the pistons were slightly pushed out.

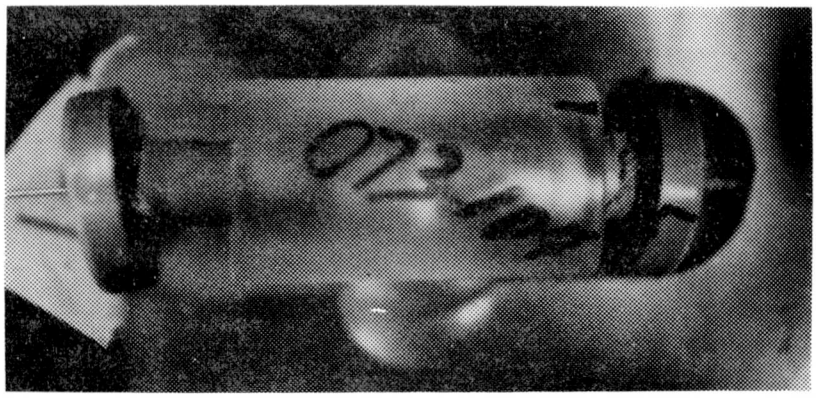


Fig. 5. Typical Results from a Partial Reaction Sample

Table II. Electrostatic Sensitivity of Secondary Explosives
(Values measured at threshold)

Material	Lot No.	Sample Density (g/cc)	Applied Voltage (KV)	I_p[a] (Amp)	Charged Energy (joules)	S x 10^{-2}[b] (Amp^2 sec)	Results
PETN Hercules Superfine	225A	0.702	7.92	224.21	0.69	2.50	Threshold
PETN Cap Grade	2-814	1.206	12.00	452.70	1.58	--	Partials
			23.00	774.20	5.82	--	Partials
RDX	445-8	1.162	10.00	317.41	1.10	4.8	Threshold
HMX	930-4	1.230	14.99	501.56	2.47	16.4	Threshold
HNS-I	8191-07C-001	0.330	11.0	340.0	1.33	--	Scorch[c]
			23.0	787.3	5.82		
HNS-I	9053-FP	0.200	16.0	630.00	2.816	--	Scorch
			23.0	787.3	5.82		
HNS-II	8275-07H-023	0.66	18.0	677.1	3.560	--	Scorch
TATB	7152-135-01 (4F)	0.92	25.0	826.7	6.880	--	No Reaction

[a] I_p -- *peak current.*

[b] S -- *calculatable only at threshold.*

[c] *Scorch -- discoloration observed.*

CONCLUSIONS

Sensitivity was defined in such a manner as to describe the response of the high explosive to electrostatic discharge and yet not be susceptible to changes due to the discharge system parameters. Additional testing will be performed to further evaluate the validity of the equation reported here. In essence, if the sensitivity values are found to change with system variations, then appropriate adjustments will be done at that time. In addition, since the numbers presented in this report are based on limited data, additional samples will be tested to establish an appropriate degree of confidence level and reported at that time. Also, if there is some future requirement to determine the threshold sensitivity of those explosives that did not reach high order detonation, then the system output may require some modification to deliver the necessary current pulse for initiation.

Some instrumentation improvements are necessary. These include a more stable series resistor. Variances were found by measuring the resistance before and after a test. Also, values calculated from measured current and voltage yielded differences in some tests. The first modification will include the use of Allen-Bradley carbon resistors but limited to 3 KV drop across each resistor. This should be an improvement over the present carbon-powder-gel mixture compressed to produce the desired resistance.

The signal-to-noise ratio which appears to stem from ground loops needs to be reduced. Presently, there is an excessive high frequency noise at the beginning of the discharge. There may be several factors involved, but this effort should minimize the noise. Obviously, a more accurate peak current can be measured by improving the signal.

In addition, there remains some degree of uncertainty as to the accuracy of the peak current measured here and will require some effort to measure current with much higher confidence. Any inaccuracies will be rectified and reflected in sensitivity as necessary.

ACKNOWLEDGMENT

The author extends his appreciation to J. W. Srygley and T. J. Tucker for their contribution to the development of the electrostatic sensitivity tests.

REFERENCES

1. T. J. Tucker, Spark Initiation Requirements of a Secondary Explosive, SC-R-68-1759 (October 1968).

2. M. S. Kirschenbaum, An Improved Electrostatic Sensitivity Apparatus and Test Procedure for Characterizing Energetic Materials, Special Publication ARLCD-SP-77004, Proceedings of the Conference on the Standardization of Safety and Performance Tests for Energetic Materials, Vol. I, AVRAM I (September 1977).

DISTRIBUTION

Department of Energy - ALO

Meyer, H. N.
Fredlund, R. R., Jr.

Department of Energy - AAO

Johnson, G. W.

Department of Energy - Washington, D.C.

Caudle, R. E.
  Attn: Clough, R. E.

Lawrence Livermore National Laboratory

Brockett, C. T.
Root, G. S.
  Attn: Van Dyk, A. C. (15)

Los Alamos National Scientific Laboratory

Aragon, J.
Eyster, E. H.
  Attn: Wechsler, J. J.
Rogers, R. N.
Yasuda, S. K.
Report Library

Mason & Hanger - Pantex

Bailey, R. E.
Carr, B. H.
Ihne, R. J.
Johnson, M. S.
Myers, L. C.
Poynor, E. D.
Slape, R. J.
Taylor, R. E.

Circulation Copy:

1. Plant Manager, PX
2. M&H, Lexington, KY

Technical Library
  File (5)
  Technical Information Center (27)

Mound Facility

Braun, R. J.

Sandia National Laboratories - Albuquerque

Arthur, B. E.
Crawford, J. C./Anderson, D. H.
McCampbell, C. B.
Central Technical Files

Sandia National Laboratories - Livermore

Cozine, R. D.

United Kingdom

Long, W. S.
  For: Kirkham, J.