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HIGH-TEMPERATURE EBW DETONATOR

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ABSTRACT

A high-temperature resistant exploding bridgewire detonator is described. The explosive is BTX, which shows no exotherm below the melting point 263°C, and is stable in vacuum stability tests at a temperature exposure of at least 175°C for 90 days. The energy required is higher than is used for PETN detonators. Design studies are being made.

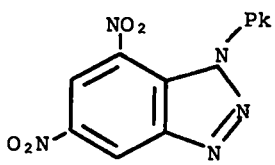
I. INTRODUCTION

Exploding bridgewire (EBW) detonators that contain PETN have a temperature limit of 100°C or less, depending on the length of exposure and other considerations. Improved capability is obtainable with RDX, but the effective gain is small. HMX has a high melting point (∿280°C), but above 100°C phase changes occur with important changes in crystal density. RDX and HMX have very poor vacuum stability at 150°C. HNS of high purity is heat resistant, but the energy required for its initiation by an EBW may be unacceptable for some applications. Thus, a search for a more suitable explosive has continued. This report covers a preliminary study of an explosive, BTX, which appears to make available a truly high-temperature detonator.

II. BTX EXPLOSIVE

The preparation of BTX is described by M. D. Coburn in "Nitro Derivatives of 1-Picrylbenzotriazole," J. Heterocyclic Chem 10, p. 743 (1973).

The structure and properties of BTX are shown below:



BTX

(5,7,-dinitro-1-picrylbenzotriazole)

Melting Point	263°C
DTA	Stable to melting pt.
Vacuum Stability	1.0 m^3/Mg (1.0 mℓ/g) 48 h at 200°C
	1.3 m^3/Mg (1.3 mℓ/g) 91 days at 175°C
Impact Sensitivity	Type 12 - 350 mm Type 12B - 330 mm
Spark Sensitivity	0.48 J, 76-μm foil
Friction Sensitivity	Neg. at all angles
Crystal Density	1.74 Mg/m^3
Detonation Velocity (calc)	7170 m/s
C-J Pressure (calc)	23.4 GPa

The differential thermal analysis (DTA) for BTX used in this work is shown in Fig. 1.

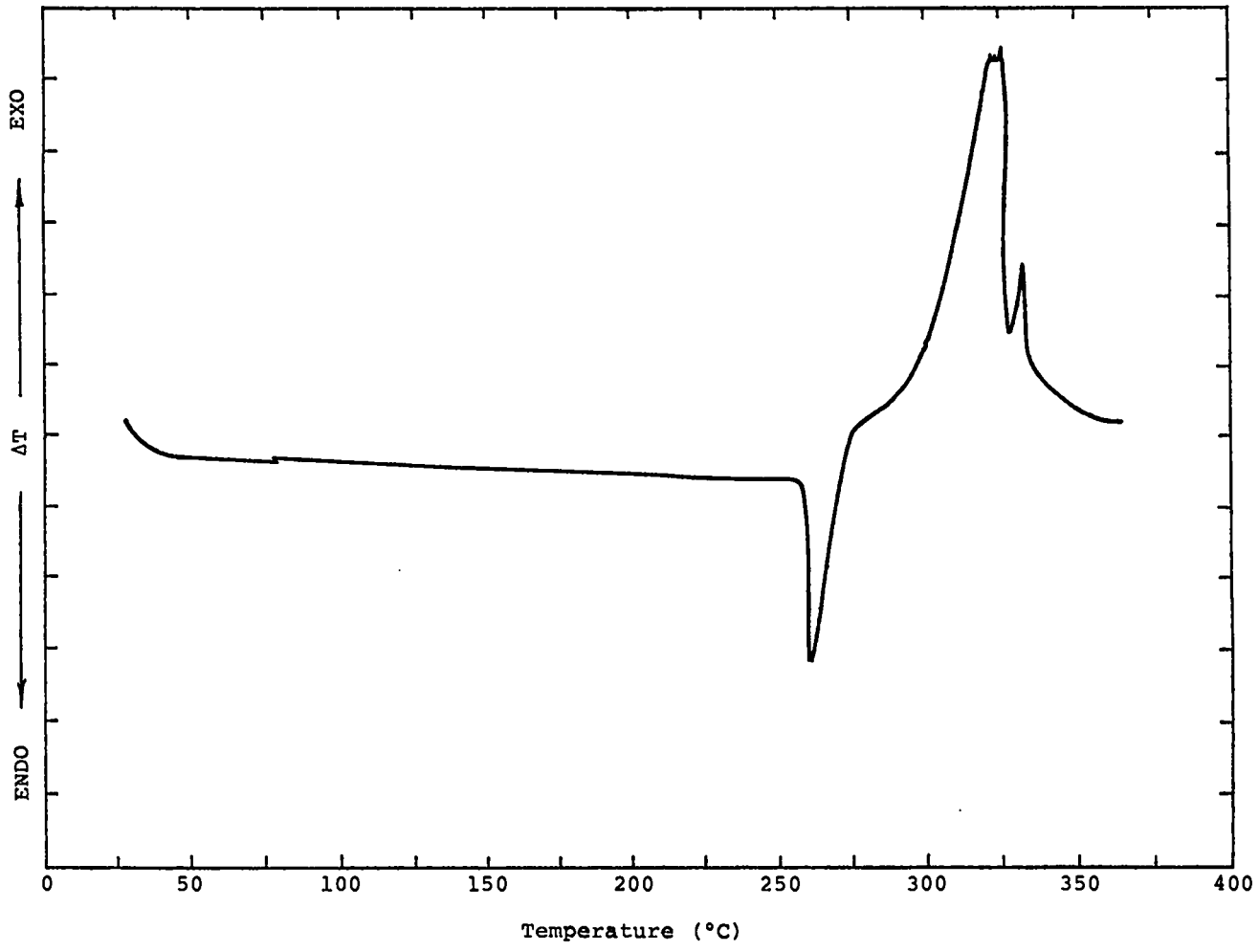


Fig. 1. BTX DTA. 20°C/min heating rate.

Vacuum stability test data at 175°C are given below for BTX and four other explosives.

175°C TEMPERATURE VACUUM STABILITY TESTS[1]

	Time of exposure (days)													
	2	7	14	21	28	35	42	49	56	63	70	77	84	91
Material	Total gas evolved (m^3/Mg at STP. Average of two samples.)													
BTX	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.1	1.2	1.2	1.3
HMX	3.1	31.2												
HNS	0.2	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.1	1.2	1.2	1.2
RDX	4.2	15.1												
TATB	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6

When BTX is prepared originally it is formed in large platelet crystals of less than 100-m^2/kg specific surface. BTX is soluble in acetone, but insoluble in water, and the original BTX was recrystallized by the rapid addition of water to a BTX/acetone solution. Batches of various specific surfaces then were produced for evaluation. BTX scanning electron micrographs are shown in Fig. 2.

III. FIRING CONDITION

The firing unit used a 3-μF capacitor charged to 7 kV to initiate one detonator in the preliminary work. In subsequent tests the voltage was reduced, and two detonators were initiated by the same firing unit.

IV. EXPERIMENTAL DETONATOR

The work was done with SE-1 assemblies which were modified to have larger diameter bridgewires than normal. The configuration is shown in Fig. 3.

V. EBW INITIATION STUDIES

It first was determined that the BTX could be initiated by a bridgewire. An ionization pin was placed over the face of the initial pressing in place of the pellets shown in Fig. 3, and the transit time (t_T) from start of current to closure of the pin was measured.

With an initial pressing density of 0.90 Mg/m^3, the transit time was found to average 2.2 μs when two detonators were fired in parallel at a 7.0-kV firing voltage. For comparison, the time for PETN initial pressings loaded into identical assemblies and fired in the same way was 2.0 μs. From this it was concluded that the BTX was initiated promptly.

Most of the tests were made with a BTX specific surface of approximately 2200 m^2/kg; transit time varied slightly from batch to batch. With a 900-m^2/kg specific surface the detonator performance was poor and indicated a high threshold. With the ∿100-m^2/kg platelet crystals of the originally prepared BTX, using the EBW test condition described above, all detonators failed.

Electrical measurements were made at one test condition. The bridgewire burst current at 7.0 kV was found to be 7 kA and the burst power was 15 MW, using two detonators in parallel and a 130-μm-diam by 1-mm-long gold bridgewire.

A bridgewire length study was made which showed that the voltage threshold with a 0.5-mm-long bridge was 5.0 kV, but with a 1-mm length it was reduced to 3.0 kV. With a 1.5-mm length the initiation delay at the bridge was reduced for the firing voltages below 7.0 kV, although threshold remained at 3.0 kV. At 2.3-mm length no further improvement was seen.

VI. BOOSTER PELLET INITIATION

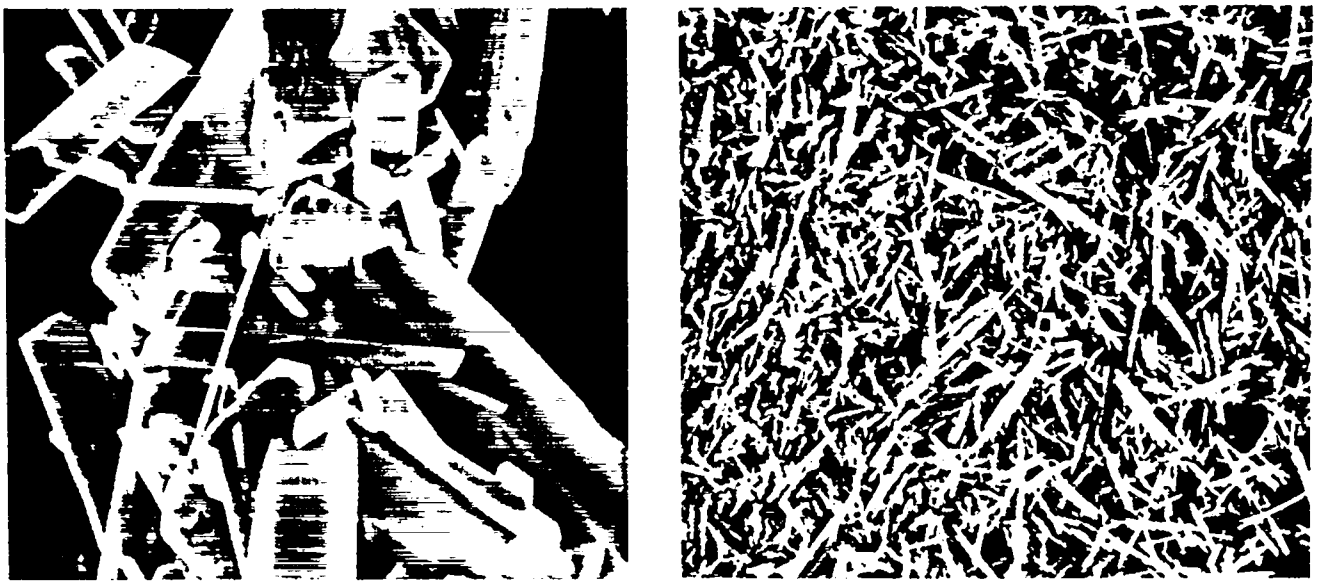
The ability of a BTX initial pressing to initiate a high-density pellet was studied. The initiation of a 1.60-Mg/m^3 density BTX pellet was marginal. The staged pellet density arrangement shown in Fig. 3 was found to perform acceptably in most tests; simpler designs probably can be made. Initiation delay in the 1.2-Mg/m^3 pellet was ∿0.2 μs, but was small in the other pellets.

VII. PLATE DENT

A comparison is shown in Fig. 4 of the plate dent produced in a 6-mm-thick Dural plate by a BTX detonator and a PETN detonator, both built as shown in Fig. 3. The dent from the PETN detonator is a little larger due to its higher detonation pressure (33 GPa) compared to the pressure for BTX (23.4 GPa).

VIII. HIGH-TEMPERATURE EXPOSURE

BTX powder was heated at 175°C for 50 hours, and then was loaded into SE-1 detonators. The test was done in this manner since we wanted to assess the effect on BTX alone and not that in combination with the SE-1 detonator. In addition, we do not have detonator hardware capable of withstanding high temperatures. With PETN the effect of heating is nearly the same whether the powder is heated before or after loading. The test data are shown in the t_T vs voltage curves of Fig. 5. After the heat exposure the specific surface changed to 1700 m^2/kg. Only a small effect was observed on detonator timing and on voltage threshold in comparison with the unheated material.



1000 X

∿100-m^2/kg specific surface

1000 X

2200-m^2/kg specific surface

Fig. 2. Scanning electron micrographs of BTX.

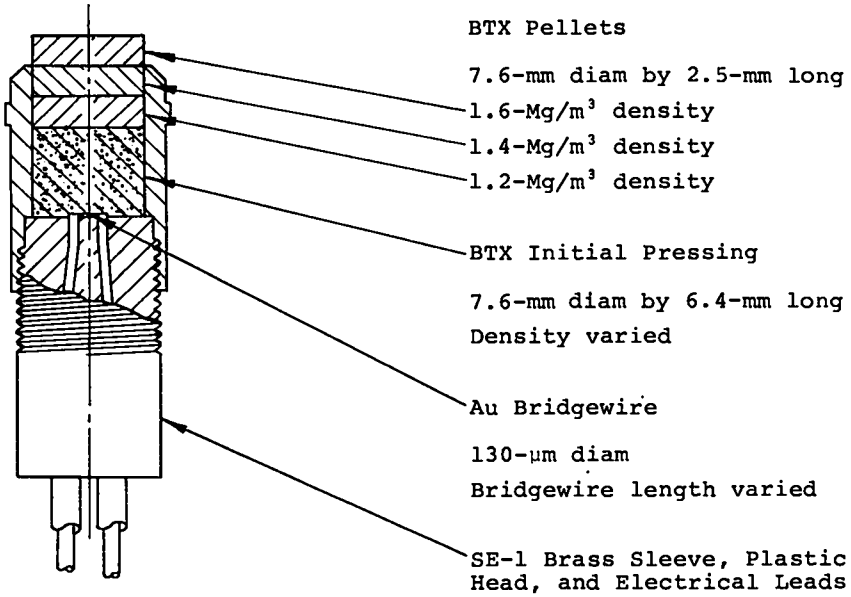
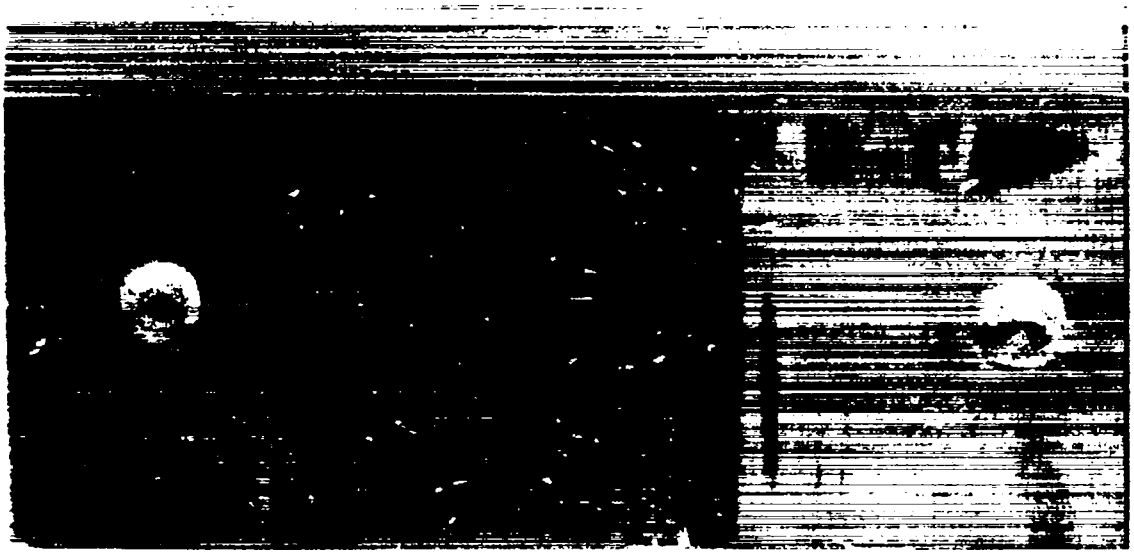


Fig. 3. Modified SE-1 detonator, BTX study.



BTX Detonator PETN Detonator

Fig. 4. Plate dent comparison.

IX. DENSITY THRESHOLD

Using the firing condition that was described previously, the density threshold of BTX was determined for two test conditions: two detonators per test, or one detonator per test, at ambient temperature. The data are shown in the curves of Fig. 6. A higher initial pressing density than 0.90 Mg/m^3 is feasible with BTX, depending on other design requirements.

X. CONCLUSION

It is believed that a practical EBW detonator which contains only BTX can be made for applications that require a high-temperature capability. The BTX detonator probably will require a larger, higher voltage firing unit than is required for PETN EBW detonators. It appears that the BTX detonator itself will need to be somewhat larger than PETN detonators. We are conducting design studies to improve the configuration of detonator components and to reduce the initiation delays. Tests that use the flying plate mode also are being done since it is believed to be more efficient than the EBW mode for the less sensitive explosives.

ACKNOWLEDGMENTS

We are indebted to W. H. Meyers of LASL Group WX-7 for his advice and continuous interest throughout the work, to K. Bostick of Group WX-2 for preparation of the BTX, to R. E. Smith of Group M-1 for scanning electron micrographs, and to J. W. Chenault, L. Rico, and M. S. Mirabal of Group WX-7 for experimental assistance.

REFERENCE

1. J. F. Baytos, "High-Temperature Vacuum Thermal Stability Tests of Explosives," Los Alamos Scientific Laboratory report LA-5829-MS (January 1975).

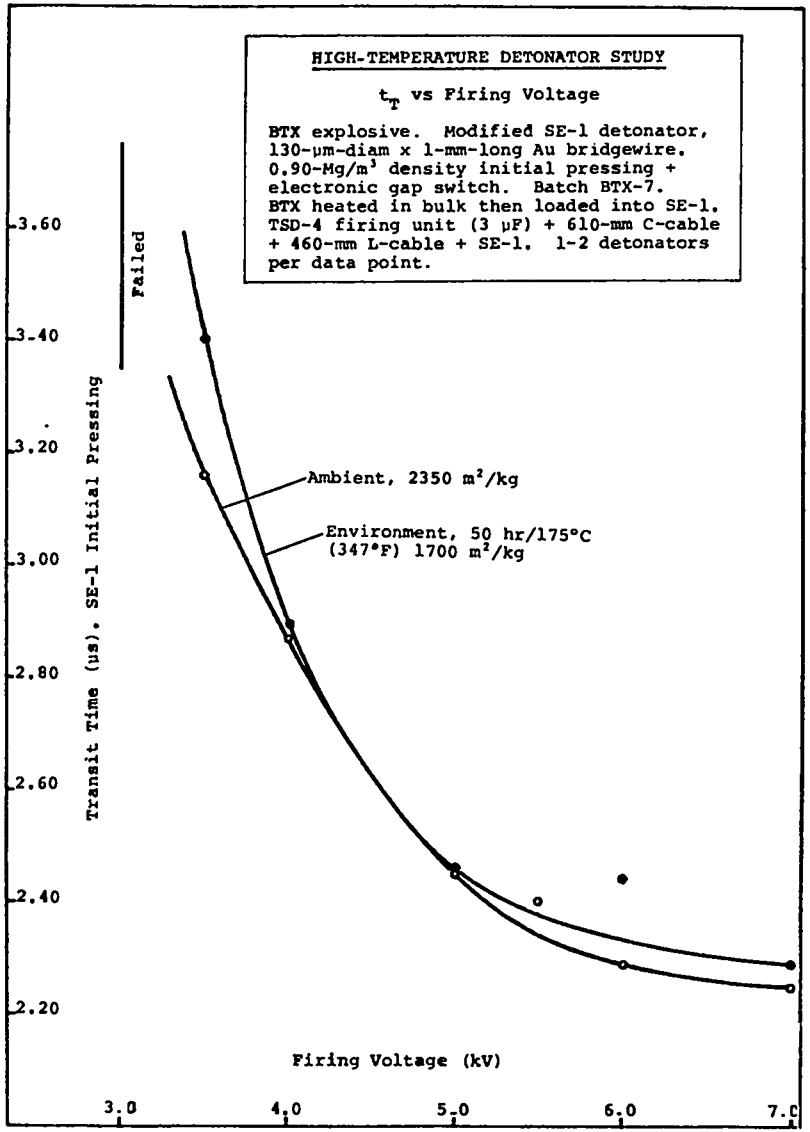

HIGH-TEMPERATURE DETONATOR STUDY
t_T vs Firing Voltage
BTX explosive. Modified SE-1 detonator, 130-μm-diam x 1-mm-long Au bridgewire. 0.90-Mg/m³ density initial pressing + electronic gap switch. Batch BTX-7. BTX heated in bulk then loaded into SE-1. TSD-4 firing unit (3 μF) + 610-mm C-cable + 460-mm L-cable + SE-1. 1-2 detonators per data point.
Failed
Ambient, 2350 m²/kg
Environment, 50 hr/175°C (347°F) 1700 m²/kg
Transit Time (μs), SE-1 Initial Pressing
3.60
3.40
3.20
3.00
2.80
2.60
2.40
2.20
Firing Voltage (kV)
3.0
4.0
5.0
6.0
7.0

Fig. 5.

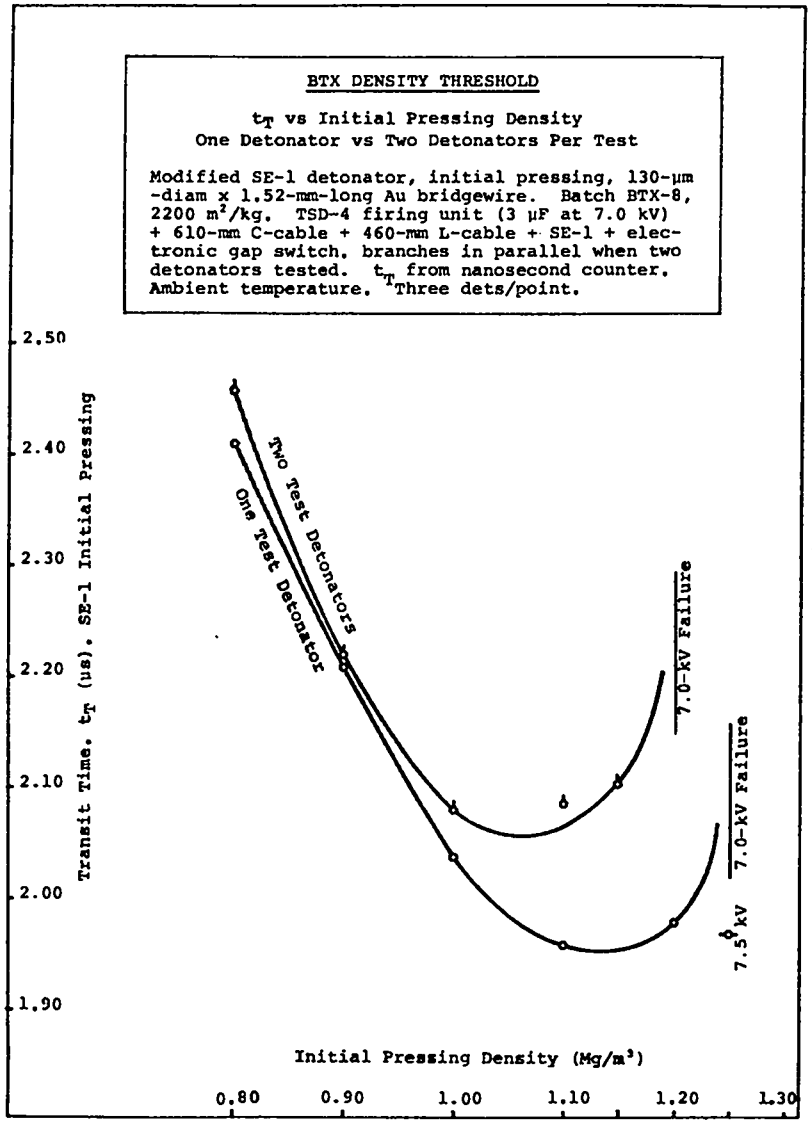

BTX DENSITY THRESHOLD
t_T vs Initial Pressing Density
One Detonator vs Two Detonators Per Test
Modified SE-1 detonator, initial pressing, 130-μm -diam x 1.52-mm-long Au bridgewire. Batch BTX-8, 2200 m²/kg. TSD-4 firing unit (3 μF at 7.0 kV) + 610-mm C-cable + 460-mm L-cable + SE-1 + electronic gap switch, branches in parallel when two detonators tested. t_T from nanosecond counter. Ambient temperature. [a]Three dets/point.
Two Test Detonators
One Test Detonator
7.0-kV Failure
7.0-kV Failure
7.5[a] kV
Transit Time, t_T (μs), SE-1 Initial Pressing
2.50
2.40
2.30
2.20
2.10
2.00
1.90
Initial Pressing Density (Mg/m³)
0.80
0.90
1.00
1.10
1.20
1.30

Fig. 6.