ARMY RESEARCH LABORATORY

Uniaxial Compression of TNT and Comp-B at Strain Rates of 0.1, 1.0, 10.0, and 100.0 s^{-1}

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Abstract

Two lots of TNT and Comp-B explosives were tested in uniaxial compression at strain rates of 0.1, 1.0, 10.0, and 100.0 s^{-1}. The materials were tested at 21 °C to an end strain of 80%. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density, and the fracture assessment values were recorded for each test.

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1. Introduction

The U.S. Army Research Laboratory (ARL), Aberdeen Proving Ground, MD, received two lots of trinitrotoluene (TNT) and Composition-B (Comp-B) high-explosive molded pellets that had been cast into right-circular cylinders. Both lots had diameters of 9.80 mm. The explosives were shipped to Dr. Robert Lieb at ARL and were last tested for mechanical response evaluation during April/May 1999. It was decided by Dr. Pat Baker, also of ARL, that uniaxial compressive testing at strain rates of 0.1, 1.0, 10.0, and 100.0 s^{-1}, while conditioned at 21 °C and ambient pressure, would be performed on the materials to 80% end strain.

2. Approach and Results

The TNT and Comp-B high-explosive lots were received as right-circular cylinders or pellets that had been cast by the Explosives Modeling Facility on Spesutie Island at ARL. The cast materials were cut into test specimens using a double-bladed low-speed Isomet diamond saw that resulted in test specimens with a length-to-diameter ratio of 1.61 and a mass of 1.780 grams.

The Material Testing Systems (MTS) Servo-Hydraulic Tester (SHT) (Figures 1 and 2) was used to conduct MTS SHT mechanical properties tests [1–9] on five specimens per lot, per strain rate (40 tests) at 21 °C. Strain rates of 0.1, 1.0, 10.0, and 100.0 s^{-1} were achieved. The specimens were taken to 80% end strain while at ambient pressure. The stress at failure, the strain at failure, the modulus, the failure modulus, the incremental energy density, and the fracture assessment values were recorded for each test. The average engineered values recorded and the standard deviations are listed in Table 1.

3. Conclusions

Two lots of TNT and Comp-B high-explosive molded pellets were received at ARL. The lots were cut into right-circular cylinder test specimens with a length-to-diameter ratio of 1.61

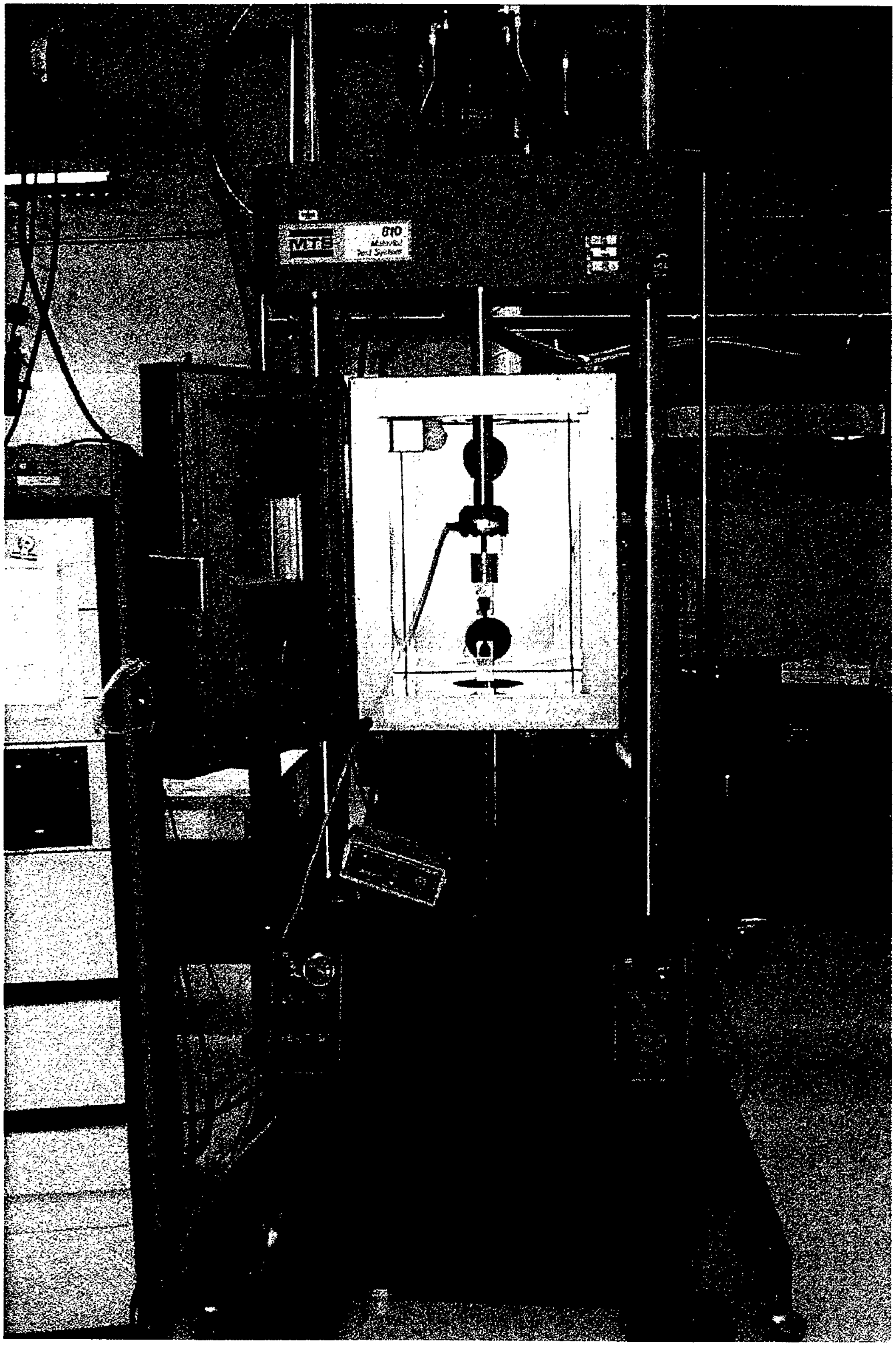

Figure 1. Material Testing System for Energetic Materials.

Figure 2. Energetic Material Being Loaded for Testing.

and a mass of 1.780 g. The specimens were tested in uniaxial compression to 80% end strain using strain rates of 0.1, 1.0, 10.0, and 100.0 s^{-1} (Figure 3) while conditioned at 21 °C.

The TNT and Comp-B specimens tested at 0.1 s^{-1} strain rate showed poor mechanical integrity, only achieving ~3.0 MPa stress at failure and ~2.0% strain before fracturing/collapsing into smaller shards and powdered remains (Figures 4 and 5). A visual observation of the tested remains suggested the TNT and Comp-B materials likely lacked binder constituents which would improve the mechanical strength and cohesion of the specimens. The TNT stress at failure and modulus values were slightly higher than the Comp-B values, possibly due to the differences in the formulation of the TNT and Comp-B lots.

At 1.0 s^{-1} strain rate, the TNT and Comp-B stress at failure values showed a small increase when comparing the stress values achieved at 0.1 s^{-1} strain rate. The compressive modulus and failure modulus values also showed higher values. The increased values achieved were a result of the higher strain rate and indicated the TNT and Comp-B lots showed strain rate sensitivity.

Table 1. MTS SHT Mechanical Properties Test

Lot Number	Stress at Failure (MPa) (±)	Strain at Failure (%) (±)	Modulus (GPa) (±)	FMOD[a] (GPa) (±)	IED[b] (MPa) (±)	FAV[c]
at 21 °C						
0.1 s^{-1} TNT ABY99CO31S009	3.98 0.67	1.94 0.35	0.304 0.06	-0.216 0.04	0.109 0.04	7AS[d]
0.1 s^{-1} Comp-B ABY99CO31S010	2.74 0.58	2.38 0.65	0.214 0.05	-0.163 0.01	0.179 0.04	7AS
1.0 s^{-1} TNT ABY99CO31S009	4.46 0.33	3.05 0.56	0.319 0.03	-0.228 0.03	0.186 0.04	7AS
1.0 s^{-1} Comp-B ABY99CO31S010	4.61 0.79	2.28 0.30	0.232 0.03	-0.207 0.02	0.248 0.03	7AS
10.0 s^{-1} TNT ABY99CO31S009	4.16 1.40	2.82 0.77	0.281 0.06	-0.186 0.04	0.268 0.03	7AS
10.0 s^{-1} Comp-B ABY99CO31S010	5.47 0.53	2.27 0.85	0.272 0.05	-0.337 0.10	0.364 0.11	7AS
100.0 s^{-1} TNT ABY99CO31S009	7.81 1.60	3.49 1.01	0.448 0.19	-0.373 0.11	0.457 0.09	7AS
100.0 s^{-1} Comp-B ABY99CO31S010	5.54 1.25	2.12 0.85	0.372 0.08	-0.252 0.09	0.448 0.04	7AS

[a] The slope of the curve after yield. Generally, a negative value indicates the material is unable to sustain load. A positive value indicates a positive failure slope (i.e., material is better able to support load).

[b] The IED (incremental energy density) value reported is the amount of energy absorbed at 25% strain. This includes a portion of the area located under the stress/strain curve (Figure 3).

[c] The tested specimens were assigned a fracture assessment value (FAV). The values assigned range from 0 (no fracture/splitting/barreling) through 9 (severe fracture/splitting/barreling).

[d] The mode of failure was also characterized using the following:

A = axial fracture, S = shear fracture, B = barreling, R = radial splitting (i.e., 7AS would indicate the tested specimens suffered moderate to severe amounts of axial and shear fracture damage).

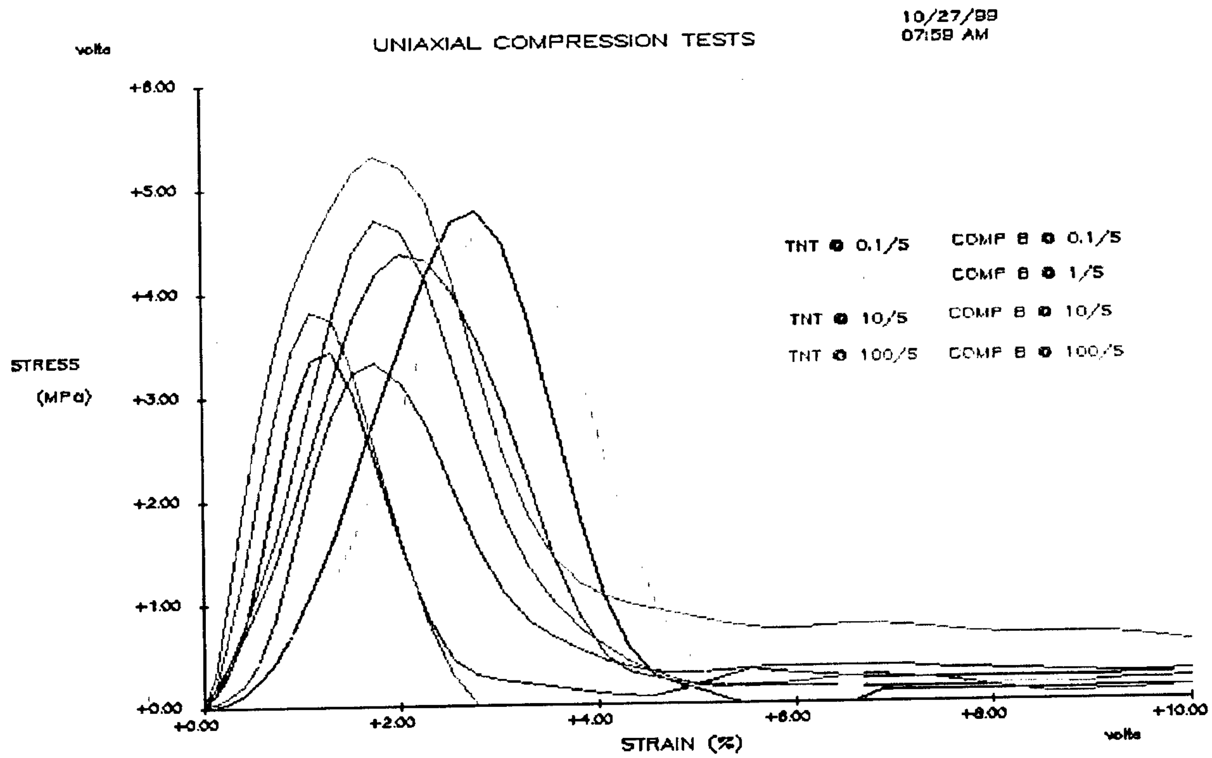

Figure 3. TNT and Comp-B Stress vs. Strain Plot.

The tested specimens yielded similar fracture damage, shards, and powdered remains, as was observed at 0.1 s^{-1} strain rate.

At 10.0 s^{-1} strain rate, the TNT stress and modulus showed a slight decrease when comparing the 10.0 s^{-1} with the 0.1 and 1.0 s^{-1} strain rate values. This was atypical as slight increases were expected. Specimen irregularities and void content could account for the unexpected decrease in stress and modulus results. The standard deviation numbers were slightly higher than usual for the TNT lot at 10.0 s^{-1} strain rate indicating more spread in the values achieved. The Comp-B stress at failure and modulus values at 10.0 s^{-1} showed increases when comparing the values achieved at 0.1 and 1.0 s^{-1} strain rates.

At 100.0 s^{-1} strain rate, both lots showed significant increases in the stress at failure and modulus values. This was likely due to the increased strain rate and suggested that the TNT and

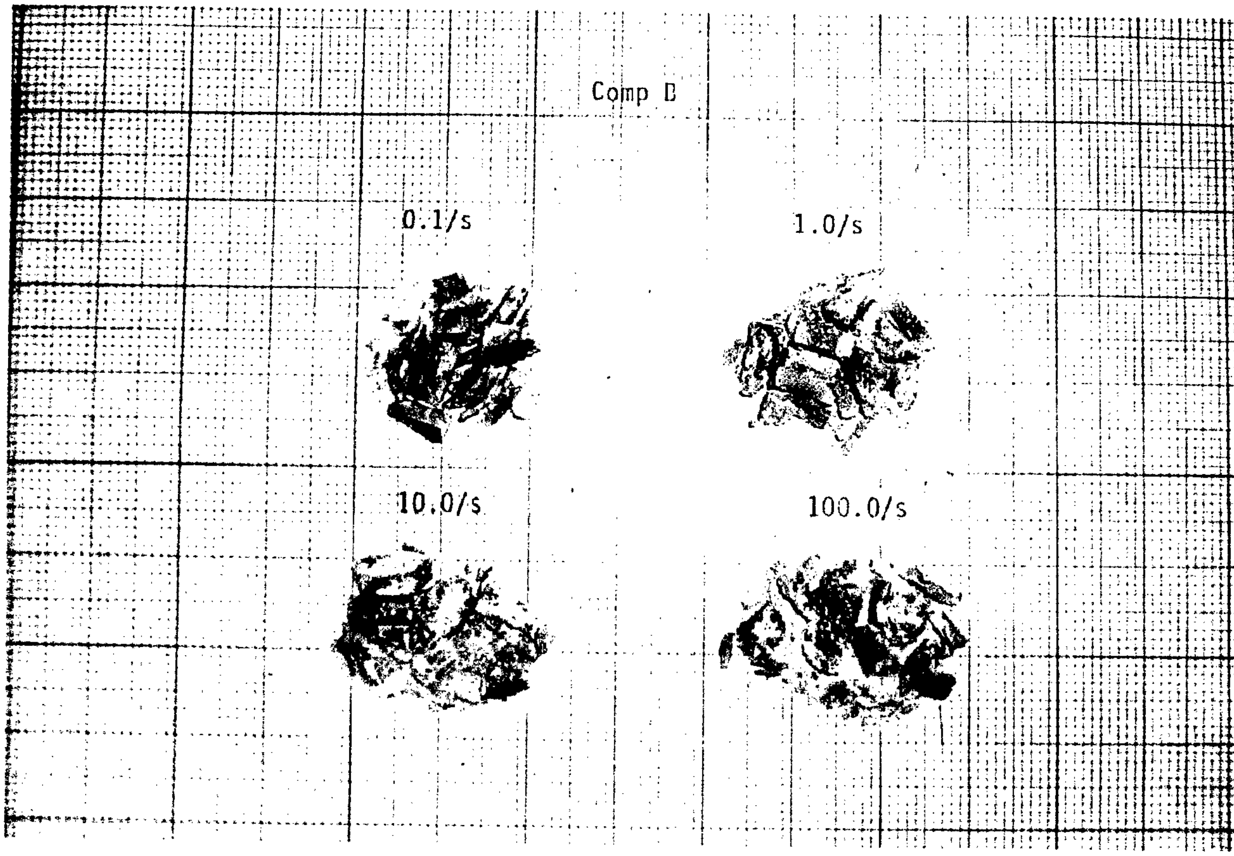

Figure 4. Photograph of Tested Comp-B Materials.

Comp-B lots were somewhat sensitive to the increased strain rate. Significant increases were also noted in the standard deviation values at 100.0 s^{-1} strain rate.

The fracture assessment values (FAV) indicated the amount of physical damage visually observed in the tested materials (Figures 2 and 3). It was noted that the FAVs were similar at all four strain rates. This was likely due to secondary loading after initial failure as the specimens were subjected to 80% end strain. Additional testing at ~10% end strain with closed bomb burning is recommended to determine more accurate fracture assessment and surface area evaluation.

The appendix contains several lots of quasi-similar materials that were tested in uniaxial compression at 21 °C using strain rates of 100.0 s^{-1}. The values may be used for comparing the TNT and Comp-B values achieved at 100.0 s^{-1} strain rate.

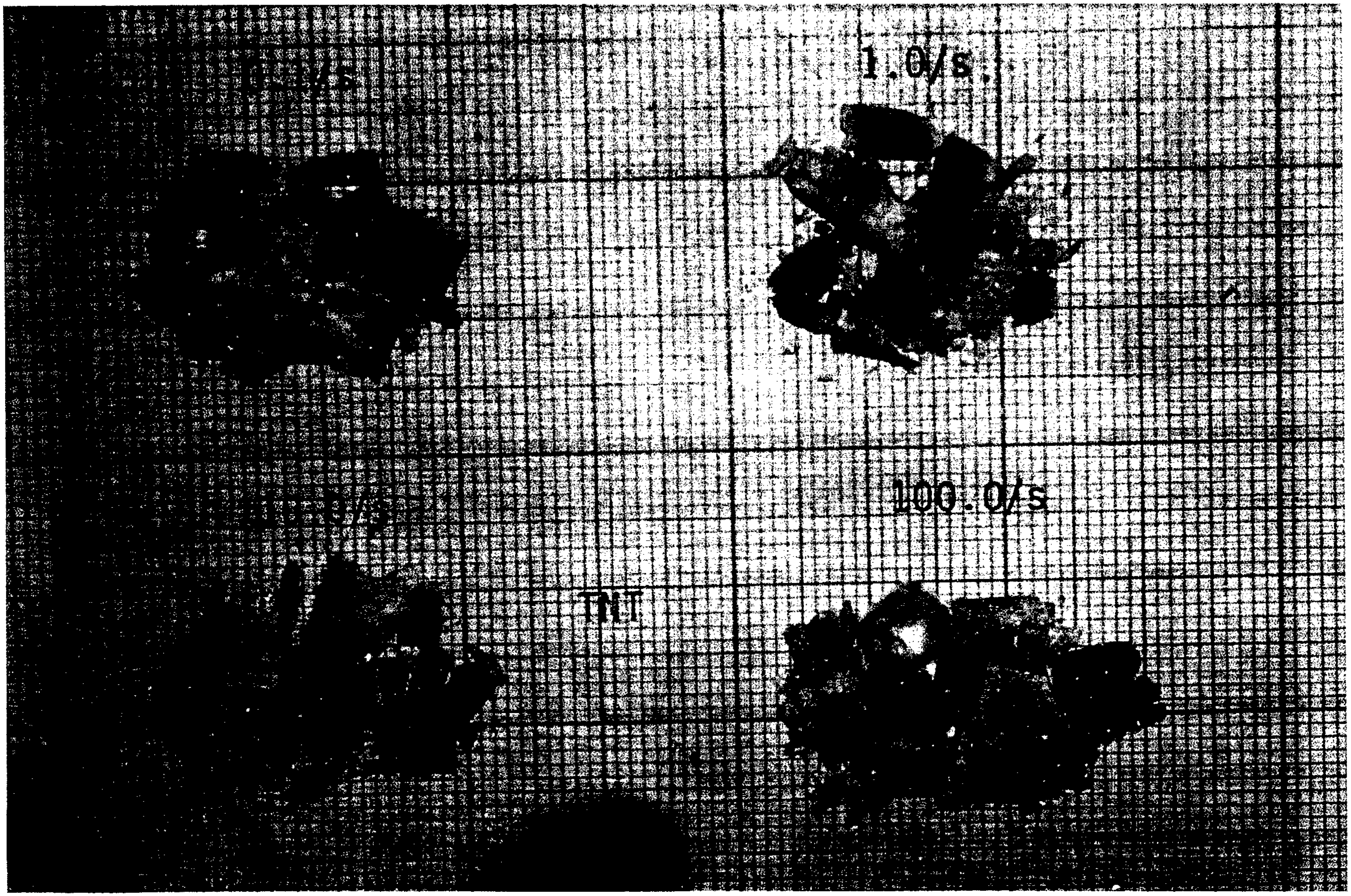

Figure 5. Photograph of Tested TNT Materials.

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Appendix:

Quasi-Similar Materials Tested in Uniaxial Compression at 21 °C Using Strain Rates of 100.0 s^{-1}

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Table A-1. Mechanical Response of Detasheet and AX Classic HE at Strain Rates of 100.0 s^{-1}

Lot Number at 21 °C	Maximum Stress (MPa) (±)	At Strain (%) (±)	Modulus (GPa) (±)	FMOD (GPa) (±)	IED (MPa) (±)	FAV
100.0 s^{-1} Detasheet C-6 SN137500A013496	98.91 5.65	69.04 3.05	0.0515 0.001	0.315 0.002	2.06 0.013	7B
100.0 s^{-1} AX Classic 4X26SE96G1-001 1/4 RDX/PETN	12.75 0.91	64.34 3.55	0.0095 0.004	-0.098 0.002	0.550 0.035	0

Table A-2. Mechanical Response of JA2 Gun Propellant at Strain Rates of 100.0 s^{-1}

Lot Number at 21 °C	Stress at Failure (MPa) (±)	Strain at Failure (%) (±)	Modulus (GPa) (±)	Failure Modulus (GPa) (±)	IED (MPa) (±)	FAV
100.0 s^{-1} RAD-PE-472-123 JA2 Granular	22.23 1.78	3.52 0.32	0.673 0.088	0.030 0.002	4.94 0.34	3B
100.0 s^{-1} RAD-PDI-002-1F JA2 Stick	23.58 0.55	4.55 0.17	0.574 0.031	0.049 0.005	5.28 0.13	2B

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Two lots of TNT and Comp-B explosives were tested in uniaxial compression at strain rates of 0.1, 1.0, 10.0, and 100.0 s^{-1}. The materials were tested at 21 °C to an end strain of 80%. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density, and the fracture assessment values were recorded for each test.

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