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Performance Of Co-layered ETPE Propellant In Medium Caliber Ammunition

Prepared For

2006 IM/EM Symposium

April 24-28, 2006

Bristol, UK

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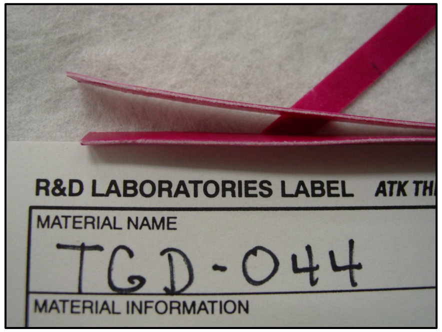

Acknowledgements

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- ***The work presented in this paper has been sponsored by ARDEC under the direction of Ms. Thelma Manning***

Outline

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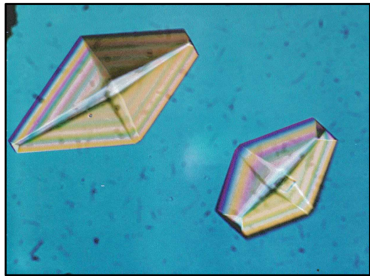
- Background and introduction
- Formulation selection and initial grain design
- Propellant characterization
- Test firings
- Summary

Background and Introduction

- **Nitrocellulose (NC) based gun propellants have been used in a wide range of gun systems for well over a century**
  - Compositions have many favorable properties
- **NC propellants typically used in medium caliber gun systems often contain toxic and carcinogenic materials such as diphenylamine and barium nitrate**
- **Concern over the use of these materials resulted in a study being funded to evaluate the feasibility of using non NC-based propellants in medium caliber gun systems**
  - ETPE propellants were selected for this study as they don't utilize stabilizers or ballistic additives and have excellent processibility

Formulation Selection

- **Several factors were considered when selecting formulations to be evaluated in this study**
  - Binder systems
    - BAMO-AMMO and BAMO-GAP
  - Energetic solids
    - RDX, TEX, FOX-7, NQ, CL-20, HMX
  - Cost, availability, compatibility of solids with binder systems, and performance



- **After evaluation both binders and one solid were selected:**
  - BAMO-GAP, BAMO-AMMO and RDX

Initial Grain Design Studies

- **Grain design studies were performed to aid in the initial formulation selection**
- **Fixed parameters used in this analysis included:**
  - Pressure < Pmax for the selected systems
  - 100% burn back
  - Fixed charge mass equal to current baseline used
  - Muzzle velocity ≥ current system muzzle velocity

- **Two propellants were selected:**
  - TGD-043 (BAMO-GAP/RDX)
  - and TGD-044 (BAMO-AMMO/RDX)

Comparison With Baseline Propellants

- **Calculated values for selected ETPE propellants compare favorably with typical NC based compositions (RP-36 and RP-1315)**
  - Higher impetus
  - Similar flame temperature
  - Higher density
  - Potential for lower charge weight

Propellant:	RP-36	RP-1315	TGD-043	TGD-044
Caliber (mm)	25	30	25 / 30	25 / 30
Density (g/cc)	1.5871	1.6290	1.5920	1.5901
Impetus (J/g)	926	999	1177	1175
Flame Temperature (ºK)	2506	2888	2800	2800
Ballistic Energy (J/g)	3502	4067	4259	4268
25 mm Charge (g)	98.5		77	77
30 mm Charge (g)		145	122	122

Initial Calculation Summary

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- **Calculations indicate it may be possible to achieve desired muzzle velocity with a substantial reduction in pressure**
  - Higher velocity is predicted if pressure is allowed to reach the maximum allowable value

Caliber (mm)	***Target/ Propellant***	***Max Press. (Mpa)***	***Muzzle Vel. (m/s)***
25	**Target**	**<402**	**1075-1125**
25	**TGD-043**	**316**	**1100**
25	**TGD-044**	**312**	**1100**
30	**Target**	**< 423**	**1008-1032**
30	**TGD-043**	**377**	**1020**
30	**TGD-044**	**373**	**1020**

Propellant Manufacture

- **Initial samples of both propellants were processed using a proven methodology**
  - – Batch mixing
  - – Ram extrusion
  - – Rolling
- **Propellant density was maximized to ensure high quality data**
  - – All samples evaluated in closed bomb testing had densities > 98.5% TMD
- **Propellant for gun firings was mixed and extruded in a small twin screw extruder**

Laboratory Safety Test Results

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Propellant	RP-36	RP-1315	TGD-043	TGD-044	-044 ribbons
ABL Impact (cm)	13	6.9	21	33	26
ABL Friction (lb @ 8 ft/sec)	800	800	800	800	800
ESD (J)	>8	>8	>8	>8	>8
SBAT (°F)	255	249	307	313	315

- **New ETPE propellants were found to be relatively insensitive to initiation via friction, impact, thermal and electrostatic stimuli**
  - Propellants are more thermally stable than conventional double base formulations

Potential Grain Geometries

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- **Several grain geometries were considered in this effort**
  - Co-layered ribbons were ultimately selected!

Calculations Using Single Perf Grain Geometry						
TGD-	Cal. (mm)	O.D. (in)	Perf Diam. (in)	Length (in)	Web (in)	Muz. Vel. (m/s)
43	25	0.085	0.043	0.255	0.021	1100
43	30	0.11	0.054	0.33	0.028	993
44	25	0.06	0.029	0.18	0.016	1101
44	30	0.08	0.04	0.24	0.02	995

Calculations Using Co-Layered Ribbon Geometry							
				Thickness (in.)			
TGD-	Cal. (mm)	Width (in.)	Length (in)	Inner	Outer	Mass (g)	Muz. Vel. (m/s)
43	25	0.191	3.5	0.013	0.004	77	1100
43	30	0.191	4.6	0.015	0.005	122	993
44	25	0.191	3.5	0.012	0.004	77	1101
44	30	0.191	4.6	0.014	0.005	122	995

TGD-043 Propellant Burning Rate

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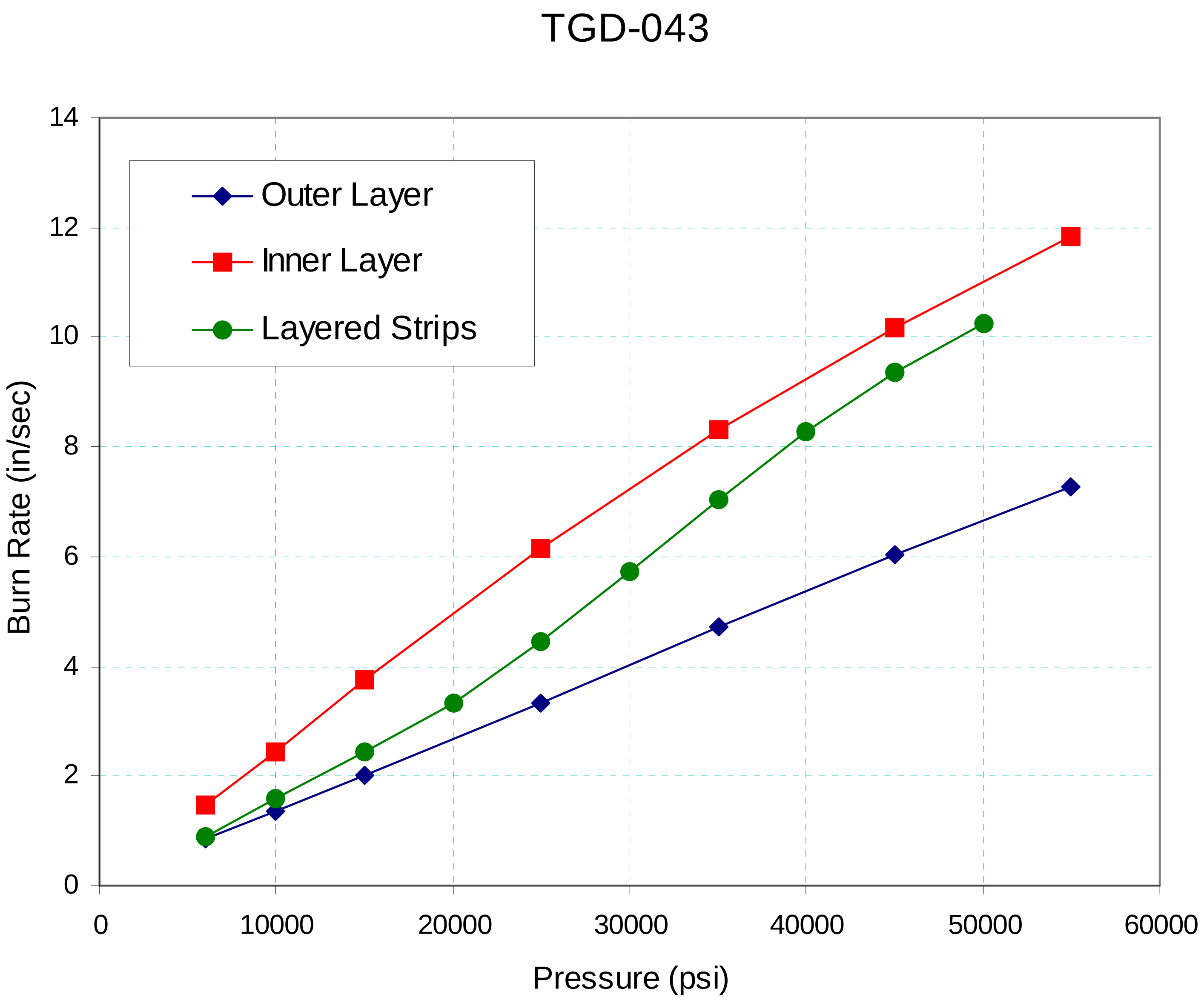
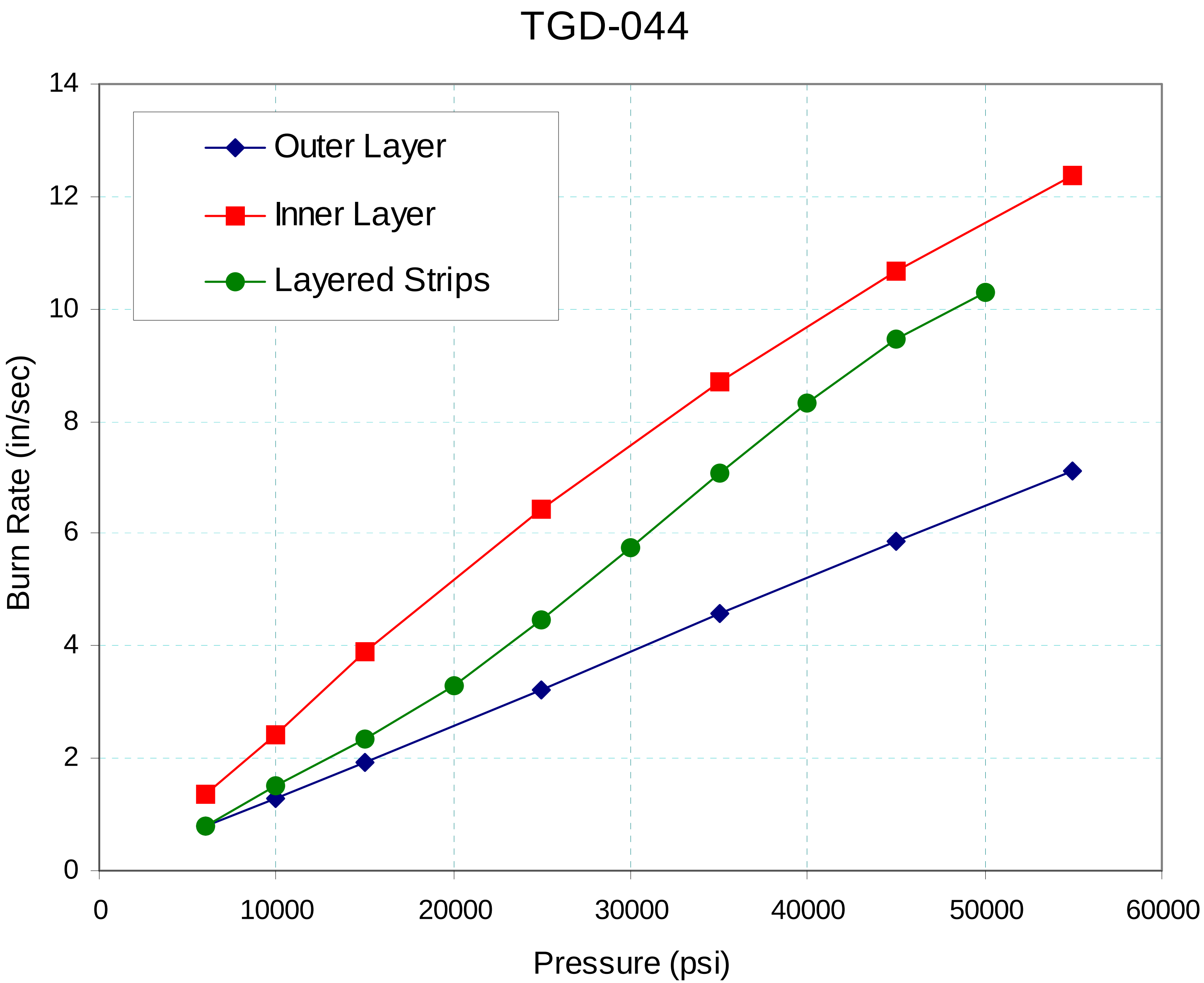


TGD-044 Propellant Burning Rate



Burning Rate Comparison (ETPE vs RP-36)

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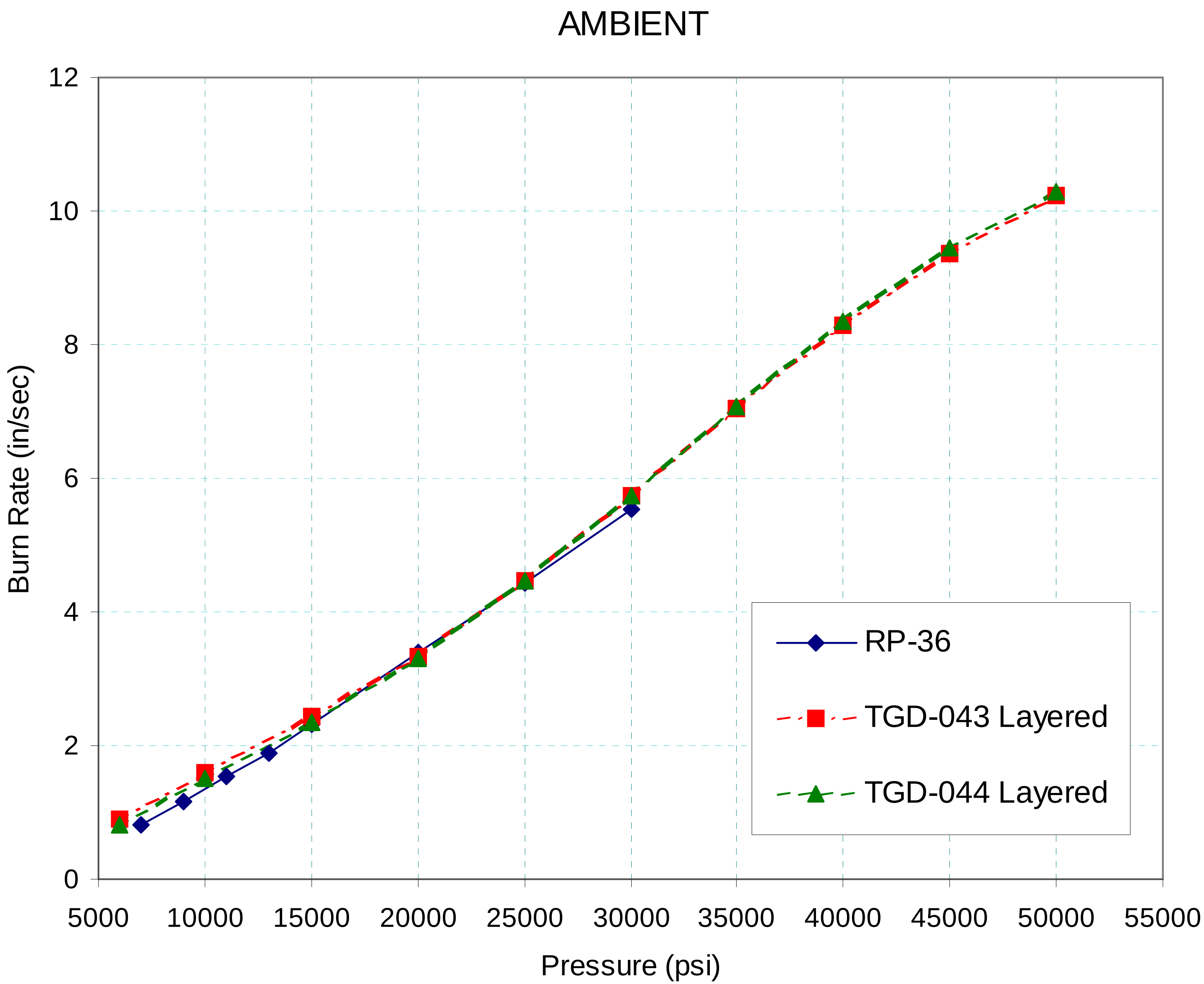

Rb Comparison (ETPE vs RP-1315)

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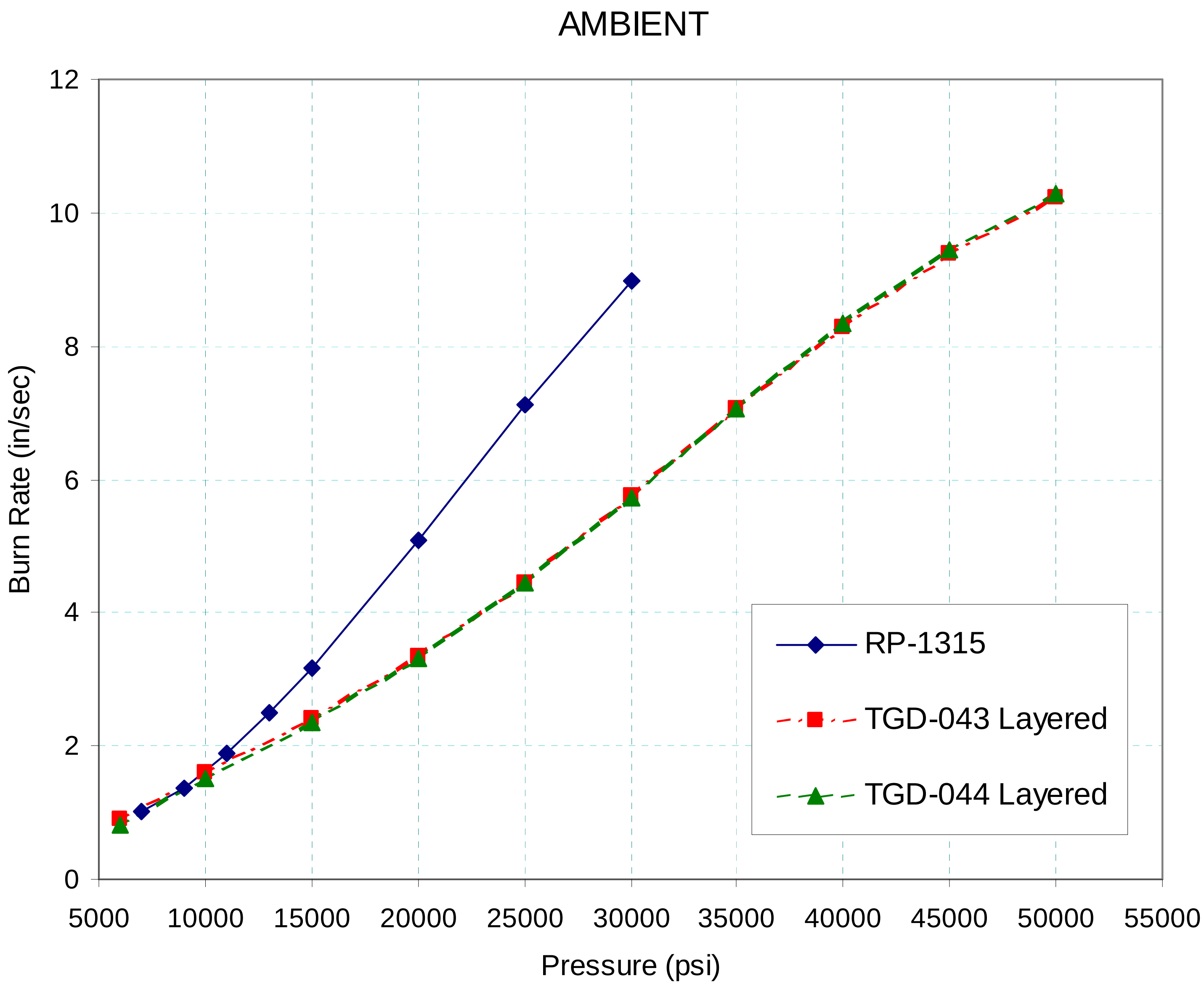

Gun Testing

- **TGD-044 propellant was selected for initial evaluation in both 25- and 30-mm guns**
  - Due to the similarity in burning rate it was determined to only test one composition
- **Layered strip geometry was used in both gun systems**
  - Different layer thicknesses were utilized
- **All testing was conducted at ambient temperature**
- **Baseline testing was performed using NC based compositions**

Gun Testing Summary

- **25-mm testing**
  – ETPE propellant performed well but would need an optimized grain
- **30-mm testing**
  – Propellant was difficult to ignite… would require additional work!

25 mm gun	**Avg. action time (ms)**	**Avg. muzzle velocity (m/s)**	**Avg. maximum chamber pressure (MPa)**
RP-36 (10 rounds)	3.89	1100	365
Standard Deviation	1.30%	0.30%	2.10%
TGD-044 (12 rounds)	4.58	904	202
Standard Deviation	4.80%	5.60%	2.80%
30 mm gun	**Avg. action time (ms)**	**Avg. muzzle velocity (ft/s)**	**Avg. maximum case pressure (kpsi)**
RP-1315 (11 rounds)	4.14	3405	51.9
Standard Deviation	2.10%	0.30%	1.30%
TGD-044 (11 rounds)	13.14	2822	26.2
Standard Deviation	66.20%	2.80%	6.70%

Summary and Observations

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- **Two new ETPE propellants have been evaluated for use in medium caliber gun systems**
- **Propellants had several favorable characteristics**
  - Processibility, safety, handling, etc.
    - Layered strip propellant geometry utilized very thin propellant layers
  - Gun test results were encouraging
    - Additional work with grain geometry and ignition system would be needed
- **Results of this study open the door for future work involving ETPE propellant in medium caliber ammunition!**