Formulation Development for the Flexible Manufacture of High Nitrogen Gun Propellants

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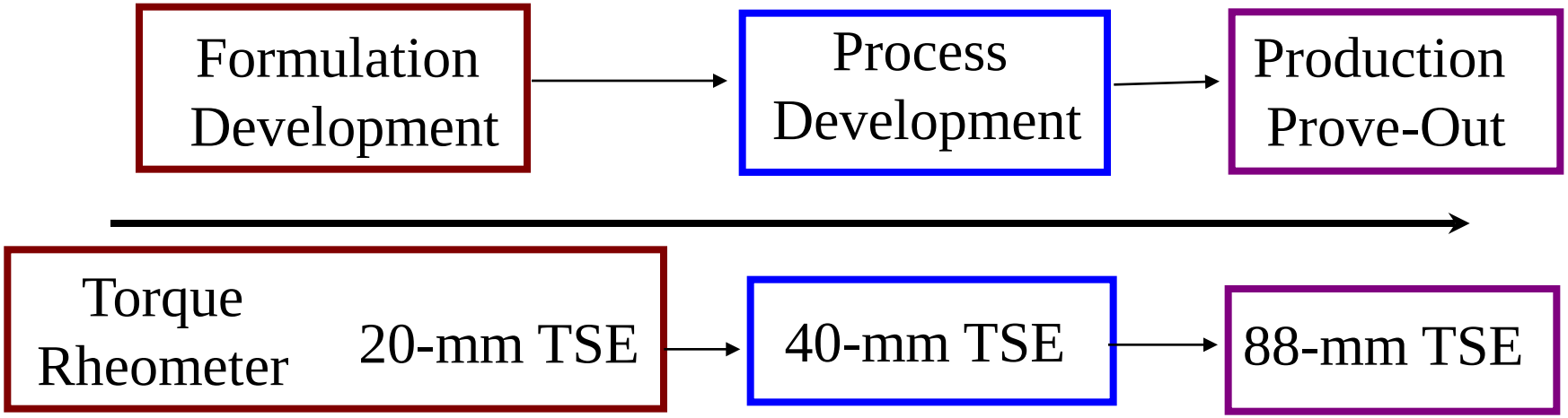
Picatinny Arsennal

Background

- Current US Navy Thrusts for Gun Propellant
  - Decreased Barrel Wear $\Rightarrow$ Decreased Flame Temperature
  - Insensitive Munitions

Objective

- Formulate Specifically for Twin Screw Extruders
- Manufacture Two Granulations: Pellets and Slotted Stick
- Develop Scale-Up Methodology



Formulation Development - Ingredient Selection (8 Mixes)

- **Evaluated**:
  - Two Different Polymers (Cellulose Acetate and Hytrel® 8184)
  - Two Plasticizers (#1 and #2)
  - Two High Nitrogen Compounds (#1 and #2)

- **Evaluation Criteria**:
  - Meeting Performance Requirements
  - Processing (Mixing, Extruding, & Cutting)
  - Ingredient Cost & Availability
  - Contribution to IM
  - Mechanical Properties
  - Ingredient Compatibility

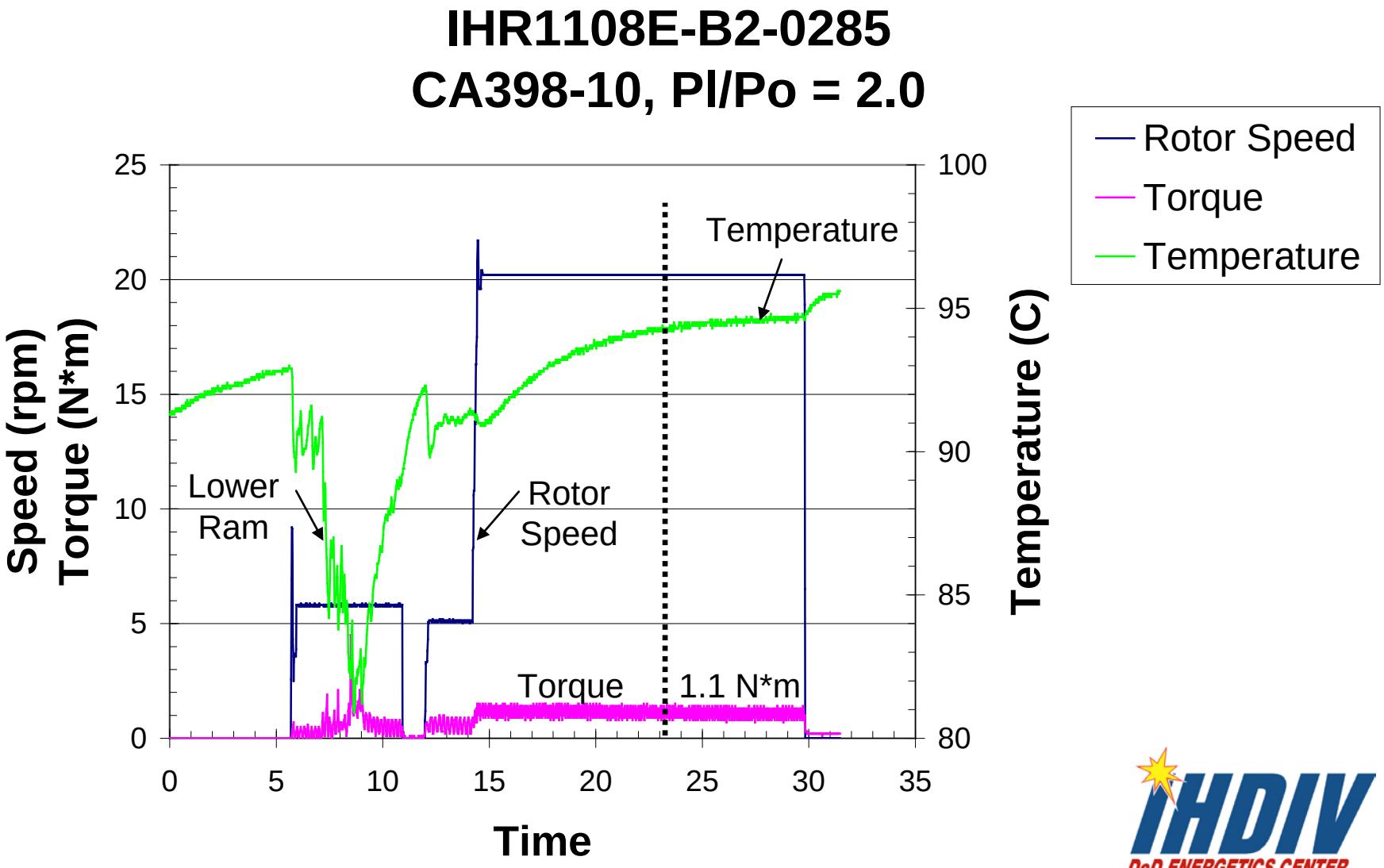
Selected Ingredients

- HiN_2 #2
  - IM – Slower Burning Rate – Smaller Grains
  - Cost
  - Small-Scale Sensitivity
  - Not Soluble in Water
- CA
  - Cost
  - Commercially Available
  - Feeding
- Plasticizer #2
  - Processability
  - Energy
  - Commercially Available

Binder Screening
CA Type, Pl:Po Ratio, Max Solids

- 2-liter Master Batches of CA (3 Types) and Plasticizer @ 2.5 Pl:Po ratio
  - CA398-03, CA398-10, & CA398-30
- Processed binder with Pl:Po = 1.5, 2.0, 2.5 in torque rheometer (constant volume)
- Processed mixes with Dechlorane Plus® – vary solids loading, plasticizer to polymer ratio, CA type

Typical Binder Mix



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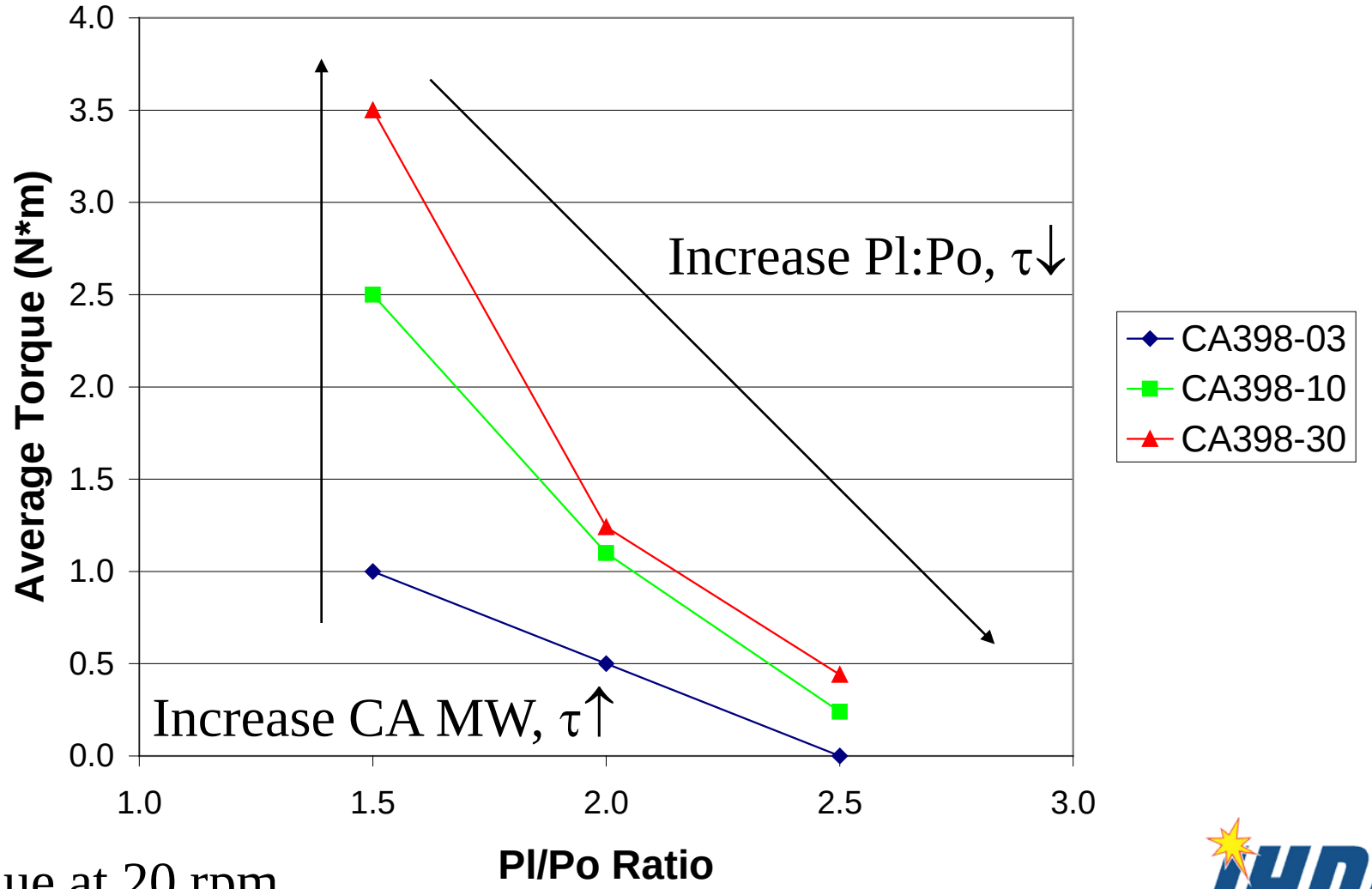
Torque vs Plasticizer to Polymer Ratio



Torque at 20 rpm

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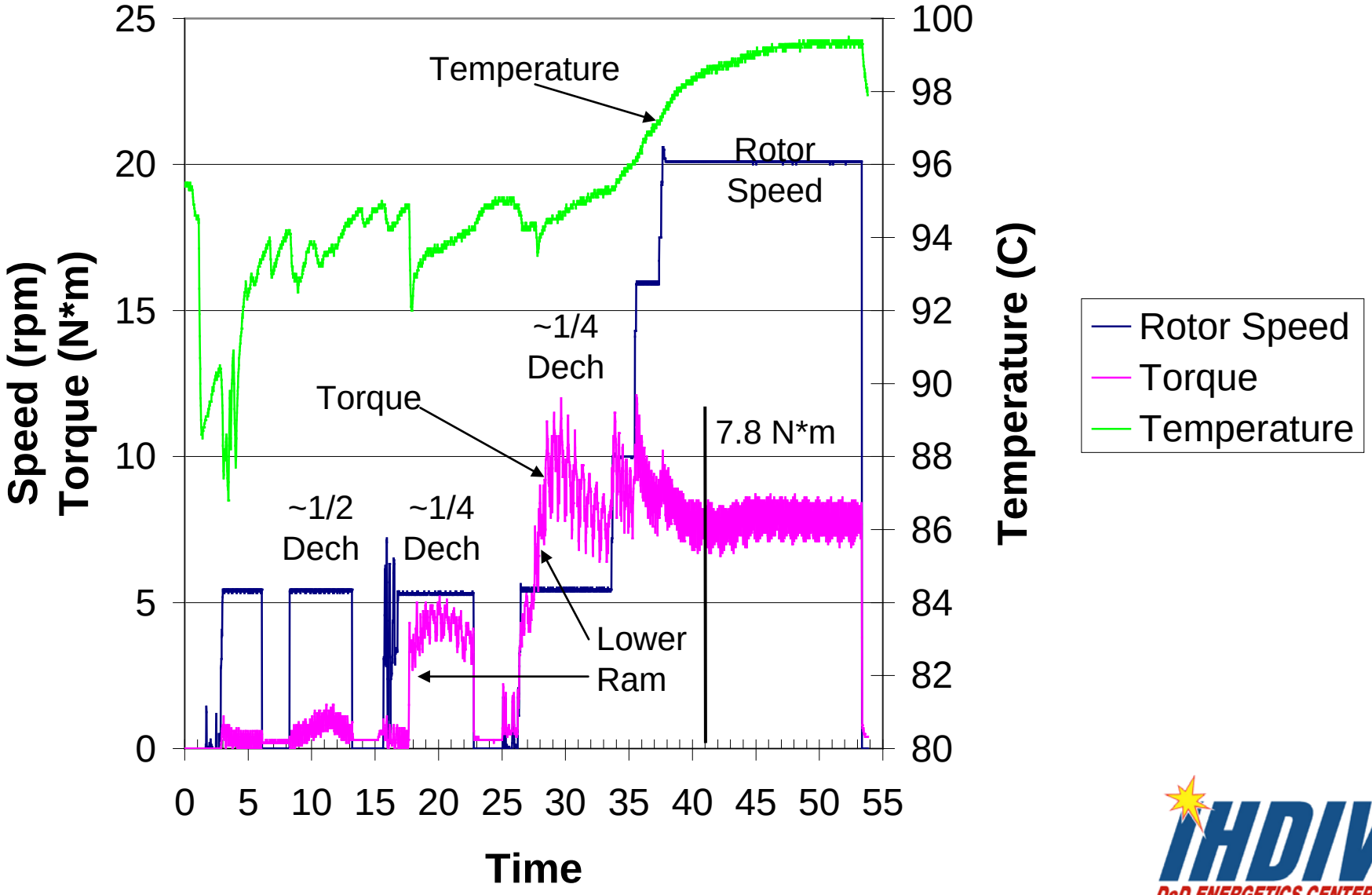
Typical Dechlorane Plus® Mix
D3-0292, 76% Solids, CA-10, Pl:Po = 2.5



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Seven Torque Rheometer Mixes w/Dechlorane Plus® (Constant Volume)

Pl:Po Ratio

Designation	%Solids	Pl/Po	CA Type	Torque (N*m)	Speed (rpm)
D5-0294	76	2.5	3	5.5	20
D2-0291	76	2.0	3	8.6	20
D1-0290	76	**1.5**	3	**>20**	**6**
Pl:Po = 1.5 TOO LOW					

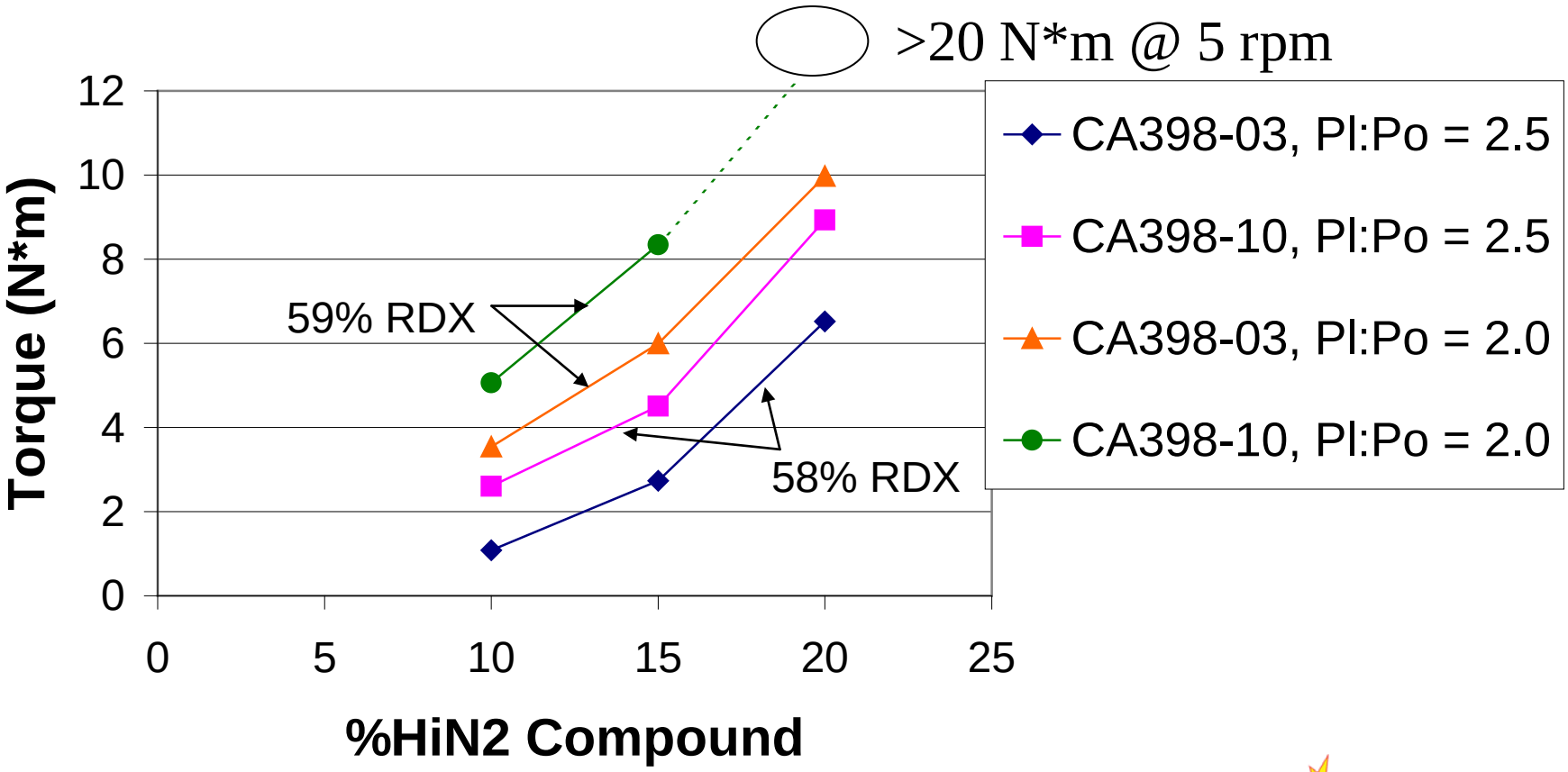
Solids Loading

Designation	%Solids	Pl/Po	CA Type	Torque (N*m)	Speed (rpm)
D7-0299	72	2.5	3	1.4	20
D5-0294	76	2.5	3	5.5	20
D6-0300	**80**	2.5	3	**>20**	**2**
80% Solids TOO HIGH					

CA Type

Designation	%Solids	Pl/Po	CA Type	Torque (N*m)	Speed (rpm)
D5-0294	76	2.5	3	5.5	20
D3-0292	76	2.5	10	7.8	20
D4-0293	76	2.5	**30**	**9.1**	20
CA-30 Too High MW??					

High N_2 Gun Propellant Torque vs %HiN_2 Compound



Torque @ 20 rpm after solids addition

Preliminary Down Select

- Removed from Consideration (Torque “too high”):
  - 1.5 Plasticizer to Polymer Ratio
  - Solids Loading of 80 wt%
  - CA398-30
- 12 Energetic Torque Rheometer Mixes (Constant Volume):
  - CA398-10 & CA398-03
  - Pl:Po = 2.0 & 2.5
  - 3 Levels of HiN_2 Compound – Formulated to Constant Impetus (varied solids loading)

Intermediate Down Select

- Removed 20% HiN_2 Formulations from Consideration based on Torque Rheometer Processing
- Extruded Remaining Eight Formulations in 2” Vertical Press
  - Mixes (4) with Pl:Po = 2.5: Plasticizer Bled after ~3 weeks

Mix Designation	%RDX	%HiN2	CA Type	Pl:Po	Comments from Extrusion
PC10-0362	59	10	3	2.0	Smooth, flexible strand.
PC15-0363	59	15	3	2.0	Smooth. Crumbly at end of cutting.
PD10-0365	59	10	10	2.0	Smooth surface. On the brittle side.
PD15-0366	59	15	10	2.0	**Very brittle. Sharkskin on one side.**

Compression Test Results

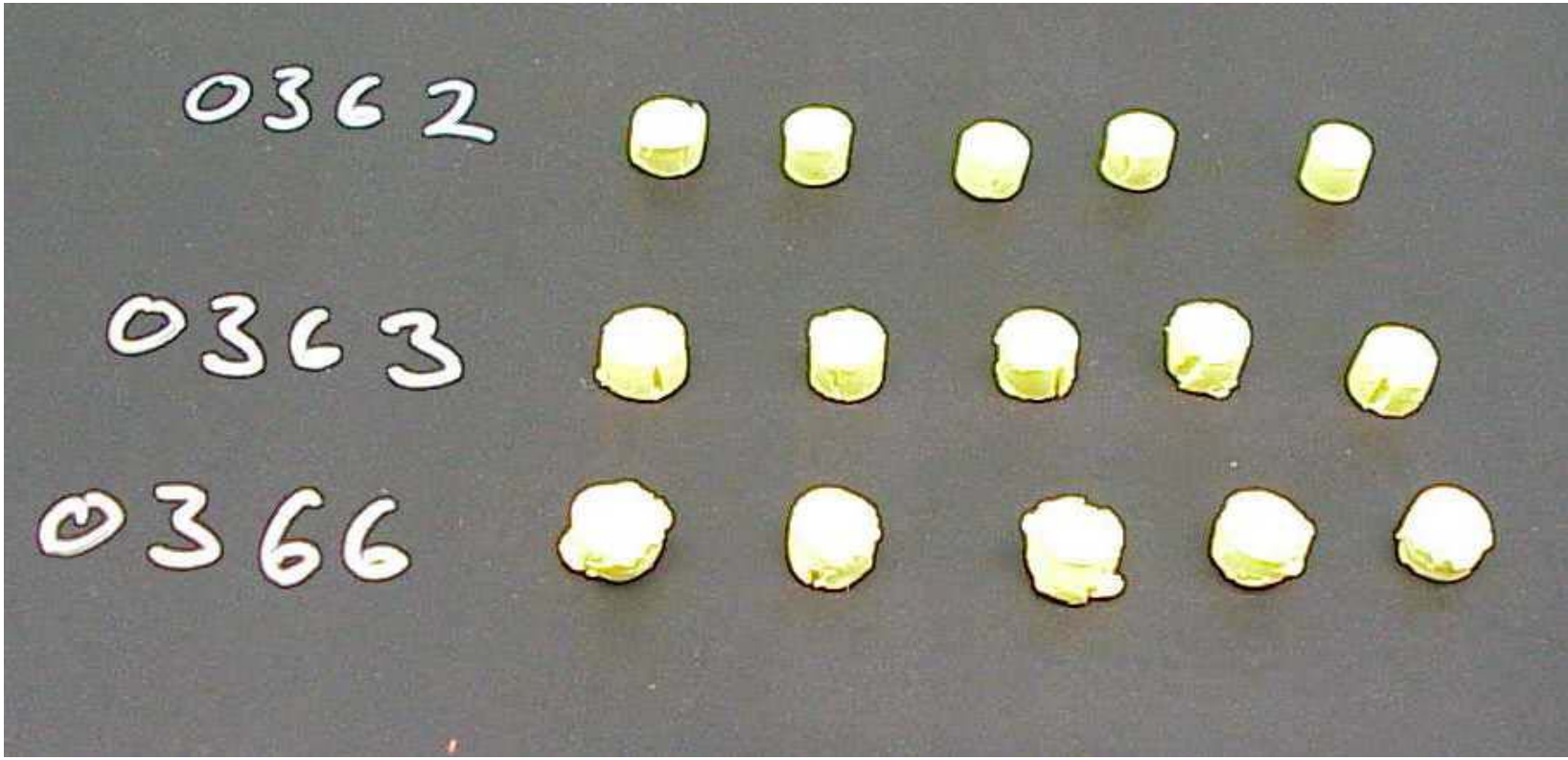
Mix Number	PC10-0362	PC15-0363	PD15-0366	Lova
Peak Load (lbf)	47.684	44.301	53.222	179.387
Peak Stress (psi)	1192.9	1032.3	1225.0	4986.3
Elongation @Peak (in)	0.044	0.036	0.045	0.040
Modulus (psi)	12114.252	12136.973	12035.314	69692.363
Strain @Peak Stress (%)	17.588	14.224	17.788	18.994

Samples After Compression Testing

10% HiN_2
CA-03

15% HiN_2
CA-03

15% HiN_2
CA-10



Pl:Po = 2.0, 59% RDX

Down Select
(Final Decision Awaiting BR Testing)

- Polymer = CA398-03
- Starting Point for TSE Process Optimization Trials (2 Maximum):
  - 10 – 15% HiN_2 Compound
  - Plasticizer to Polymer Ratio = 2.0

Future Work

- Preparations for 20-mm and 40-mm TSE Propellant Runs
  - Thermal Testing of Gun Propellant (TGA/DTA)
  - Pump Testing with Energetic Plasticizer
  - Feeder Testing with CA398-03
  - Feeder Testing with High Nitrogen Compound
  - One Binder Trial
  - One Dechlorane Plus® Processing Trial
- Gun Propellant Optimization Trials
  - Burning Rate
  - Process Responses
- Slit Die Rheometer Trials
  - Rheological Parameters
  - Die Design