Evaluation of R8002, an Alternate Energetic Plasticizer to BDNP A/F, for use in DOD munitions

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Objectives

- Evaluate alternate energetic plasticizer to BDNP A/F for use in DOD munitions
- Possible candidate: R8002-Energetic Plasticizer, being developed by BAE at Holston AAP
- Test, evaluate, characterize and compare PAX-3 explosives formulated with R8002 and BDNP A/F

Background

- BAE has performed some preliminary studies, using PAX-2A as the vehicle formulation to evaluate alternative energetic plasticizer R8002 (50% of 2,4-dinitroethylbenzene and 50% trinitroethylbenzene by weight).

- HSAAP has the technology and capability to produce this material in small quantities.

- Some work has also been done with cast-cure thermobaric explosiveYJ05 using R8002 at Ensign-Bickford Aerospace and Defense.

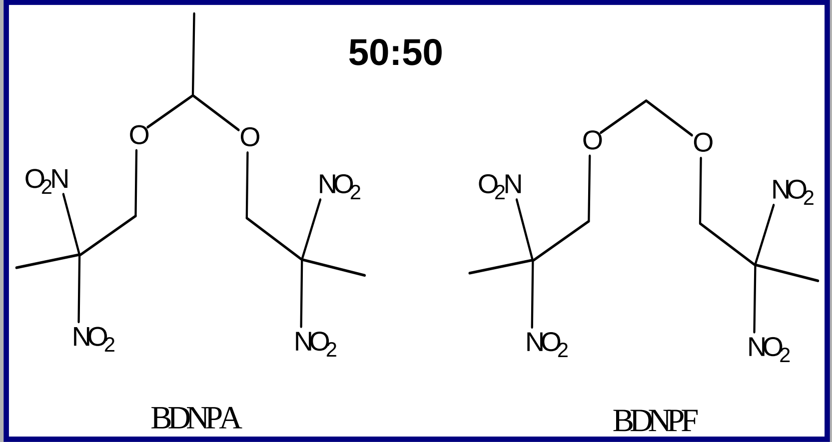
Materials

BDNP A/F

• BDNP A/F is an energetic Plasticizer: 50% bis(2,2-dinitropropyl) acetal (BDNPA) and 50% bis(2,2-dinitropropyl) formal (BDNPF) used in various DOD propellant and explosive formulations (LOVA propellants, Navy PBX 106 Formulations, IM Explosives: PBXN-106, PAX-2A and PAX-3)

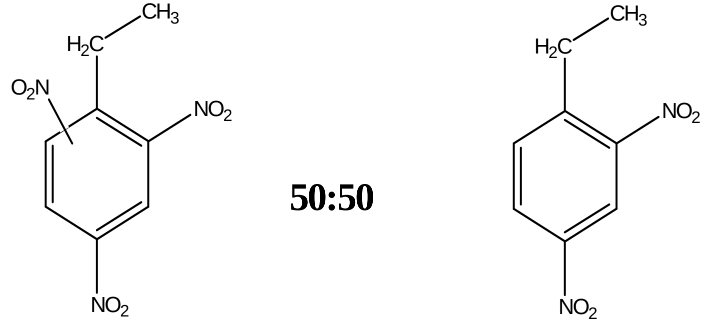
• First Manufactured by U.S. Navy (Indian Head) and Aerojet in the 1960’s

• Later manufactured by Thiokol in the 1990’s



R8002

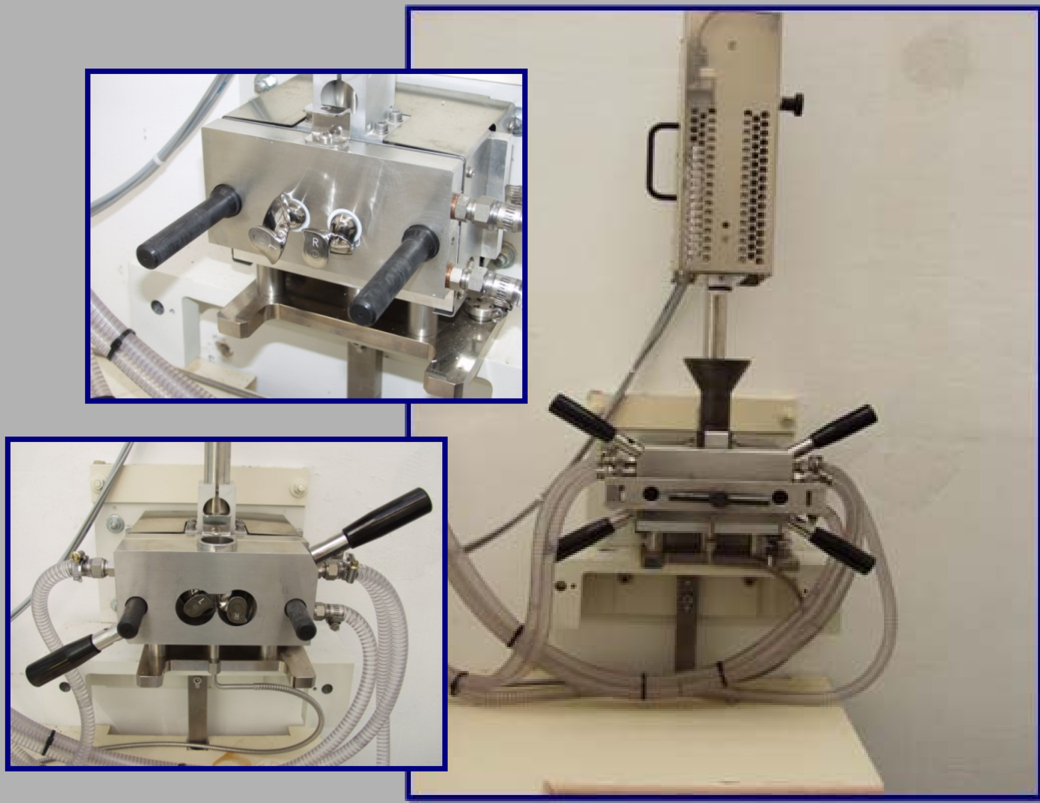
• R8002 is a 50:50 Mixture of Dinitroethylbenzene (DNEB) and Trinitroethylbenzene (TNEB)
• R8002 is similar to K10 (65:35 DNEB:TNEB)
• R8002 used in international formulations development efforts
• Synthesis routes developed by OSI scientists



$C_8H_7N_3O_6$
Mol. Wt.: 241.16
C, 39.84; H, 2.93; N, 17.42; O, 39.81

$C_8H_8N_2O_4$
Mol. Wt.: 196.16
C, 48.98; H, 4.11; N, 14.28; O, 32.63

Instruments

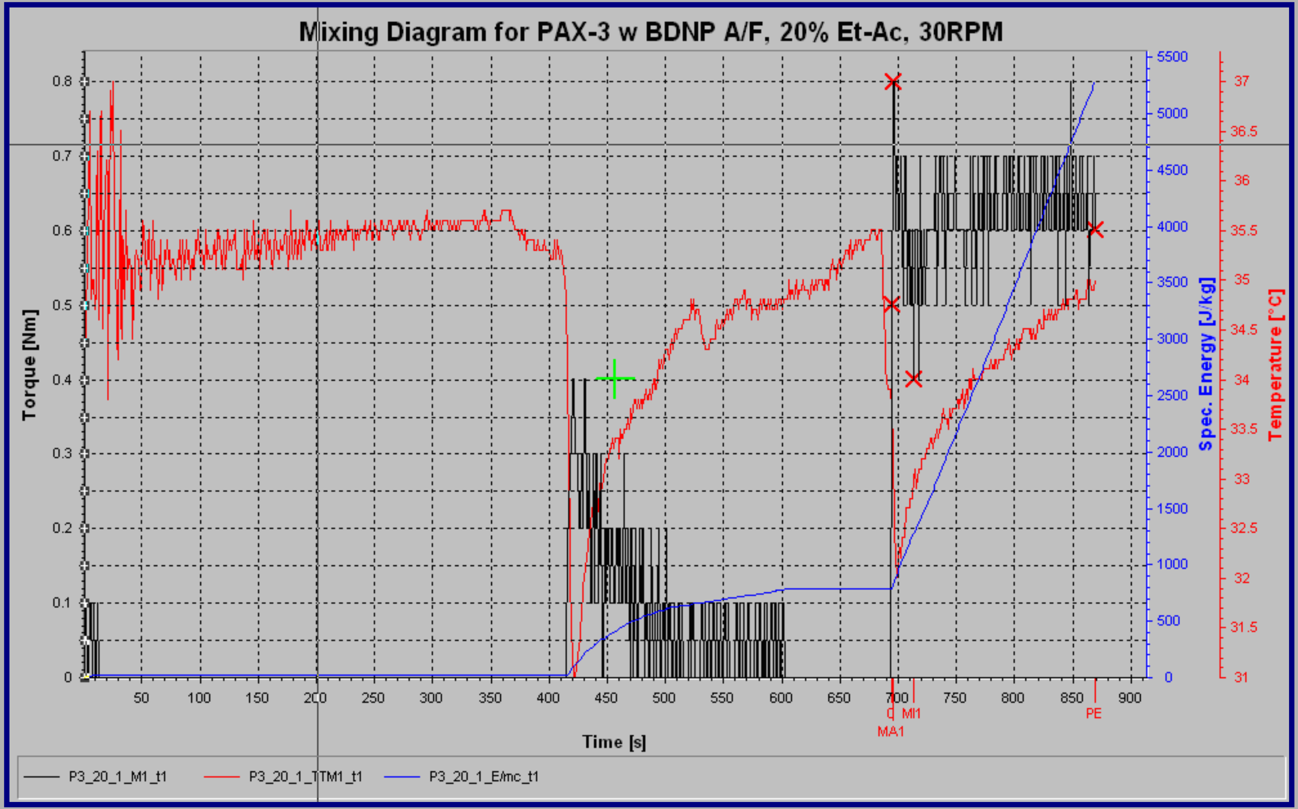


Thermo Haake Poly-Lab 300p System

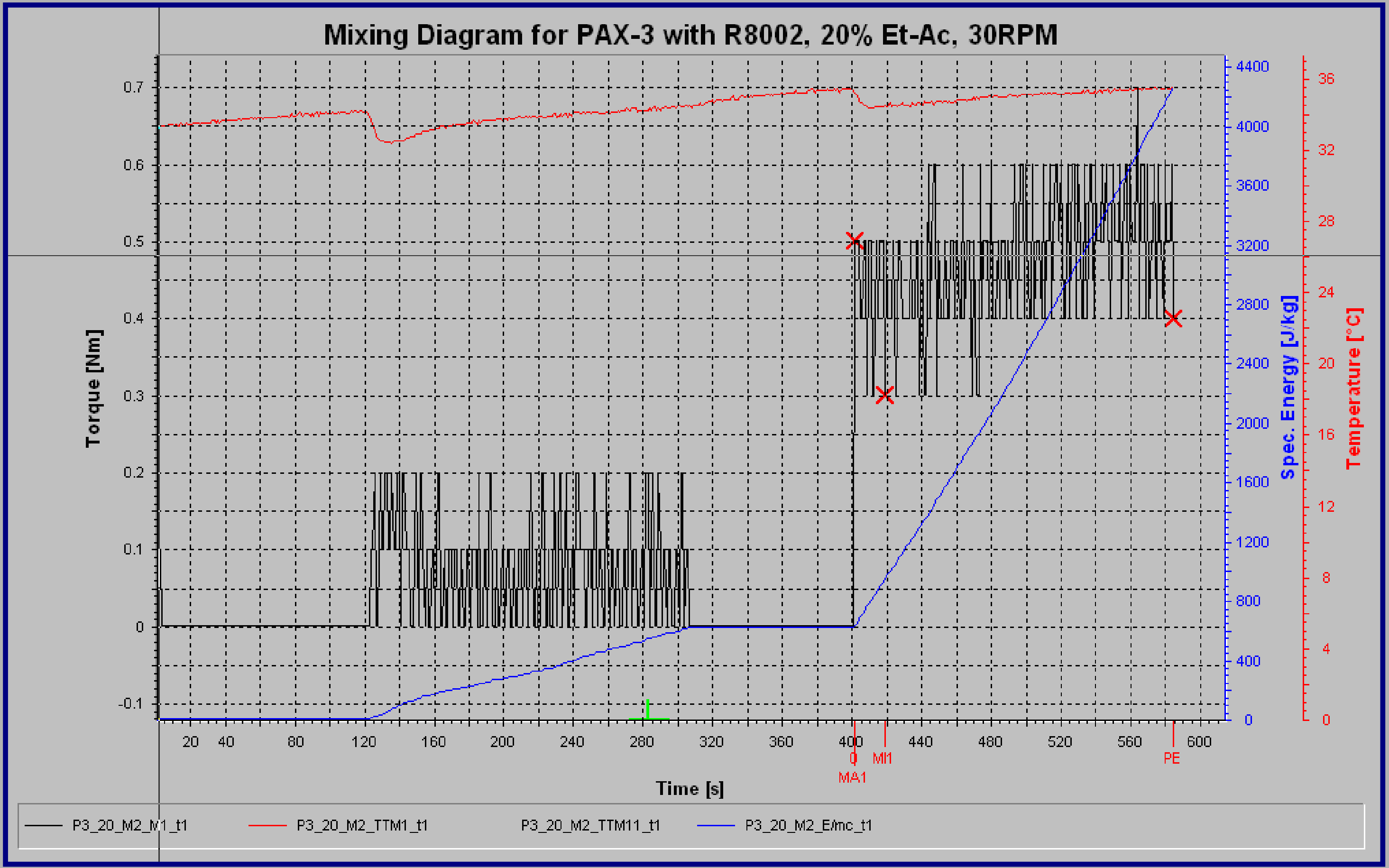
Torque Rheometer

- Investigate mixing protocols for multi-component systems to achieve optimum conditions for homogenization of end products.
- Study the mixing characteristics of energetic mixtures under different conditions (blade type, temperature, rpm, mixing time)
- Prepare new formulations that can improve the performance of existing materials.
- Evaluate material response during mixing.
- Provide homogeneous mixture for rheological analysis.
- Measures the following:
  - ✓ Dynamic viscosity depending on shear load
  - ✓ Melt behavior in the extruder
  - ✓ The influence of additives
  - ✓ Temperature and shear load behavior
- PolyViewTM software
- Specific energy input (SEI) is readily obtained for mixing.

Sample Preparation



Sample Preparation



Instruments (cont'd)

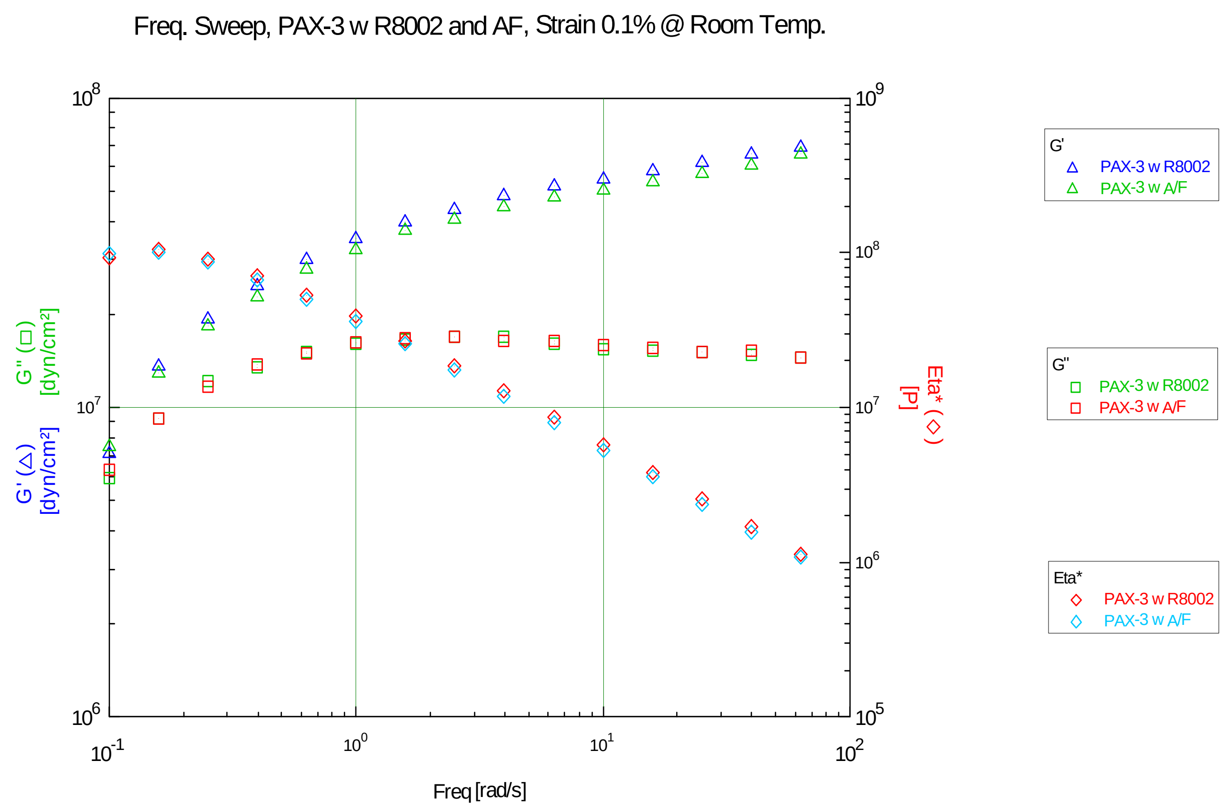
Rheometric Scientific Dynamic Analyzer- RDA III

Dynamic Rotational Rheometer: RDA III

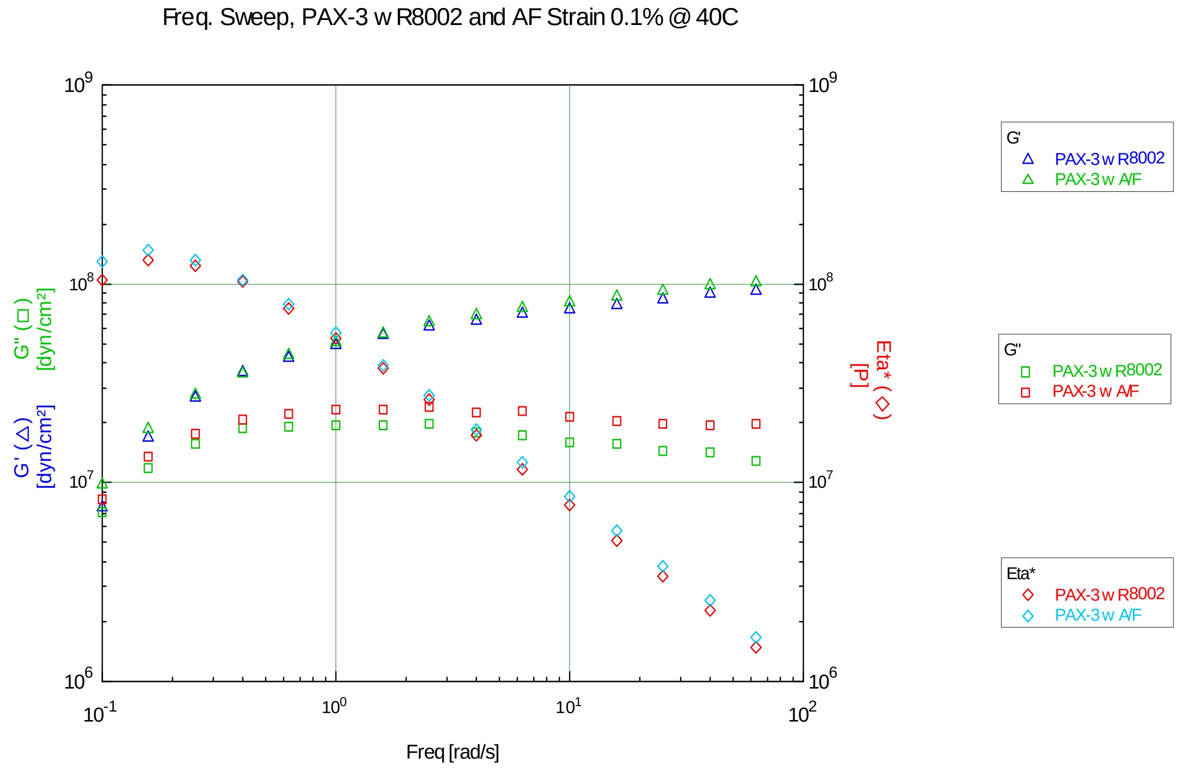
- Measure the properties related to the molecular structure of the polymers, such as molecular weight and molecular weight distribution.
- Measure the viscoelastic behavior of materials using dynamic mode.
- Measure the curing kinetics in a real time fashion of dynamic systems that can lead to optimizing the handling such materials.
- Serve as a tool for quality control for incoming and out-going materials.
- Assist in trouble-shooting problems associated with off-specification materials.
- Measures both dynamic and steady shear viscosities of energetics.

  Measure dynamically the low temperature performance of materials as related to its glass transition temperature to evaluate performance of newly developed energetics.
- OrchestratorTM software

Rheological Characterization



Rheological Characterization



Rheological Characterization

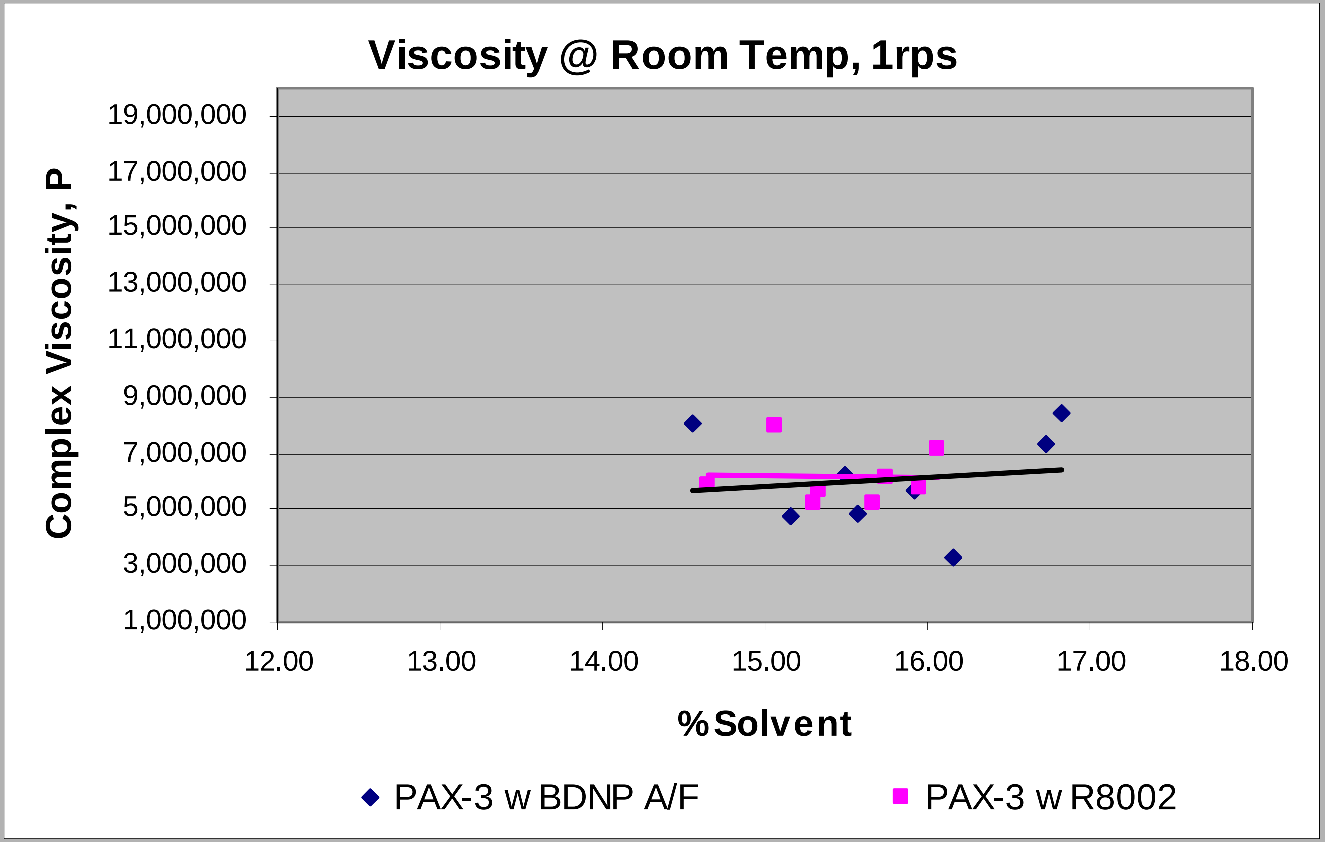
		BDNP A/F-based PAX-3		R8002-based PAX-3	
Temp ºC	Frequency rps	%Solvent	Complex Viscosity, Pa.S	%Solvent	Complex Viscosity, Pa.S
Condition 1					
RT	1	**16.73**	7,340,000	**15.30**	5,256,700
RT	1	**16.16**	3,268,400	**15.96**	5,743,100
RT	1	**15.93**	5,692,600	**15.67**	5,240,000
RT	1	**15.49**	6,254,100	**16.07**	7,176,900
RT	1	**14.55**	8,038,700	**15.06**	8,017,200
RT	1	**15.16**	4,722,100	**15.33**	5,674,100
RT	1	**16.83**	8,475,200	**14.66**	5,886,200
RT	1	**15.57**	4,827,600	**15.75**	6,134,400
Condition 2					
RT	5	**16.35**	2,112,300	**14.90**	822,990
RT	5	**15.56**	1,452,300	**14.12**	1,267,200
RT	5	**15.56**	2,247,700	**14.76**	328,830
RT	5	**16.61**	2,018,300	**13.97**	1,011,300
RT	5	**15.71**	2,027,900	**14.56**	1,178,000
RT	5	**15.49**	2,059,300	**14.40**	829,880
RT	5	**15.64**	2,322,600	**12.63**	940,120
RT	5	**14.06**	2,321,400	**13.43**	1,103,800
RT	5	**16.16**	1,607,000	------------	-------------

Rheological Characterization

		PAX-3 w BDNP A/F		PAX-3 w R8002	
Temp ºC	Frequency rps	%Solvent	Complex Viscosity, Pa.S	%Solvent	Complex Viscosity, Pa.S
Condition 3					
40	1	**16.62**	10,191,000	**14.43**	5,500,200
40	1	**15.94**	7,788,100	**14.83**	2,984,100
40	1	**17.29**	12,936,000	**14.15**	2,783,800
40	1	**17.08**	6,100,500	**15.13**	3,237,100
40	1	**16.50**	9,382,400	**14.16**	2,761,600
40	1	**16.11**	9,451,300	**14.37**	3,572,700
40	1	**16.53**	5,917,400	**13.79**	2,907,500
40	1	**17.08**	7,992,800	**13.92**	3,125,200
40	1	**14.03**	6,744,700	------------	-------------
Condition 4					
40	5	**16.41**	1,669,000	**14.56**	1,873,800
40	5	**16.56**	3,285,000	**15.27**	1,973,700
40	5	**15.52**	3,120,200	**15.99**	1,672,900
40	5	**15.93**	2,752,000	**14.63**	1,246,200
40	5	**16.36**	1,985,000	**15.28**	1,423,600
40	5	**16.53**	1,725,200	**15.45**	1,578,200
40	5	**15.85**	1,771,800	**14.49**	993,030
40	5	**15.56**	1,311,200	**14.86**	1,173,100
40	5	**15.69**	2,263,900	------------	-------------

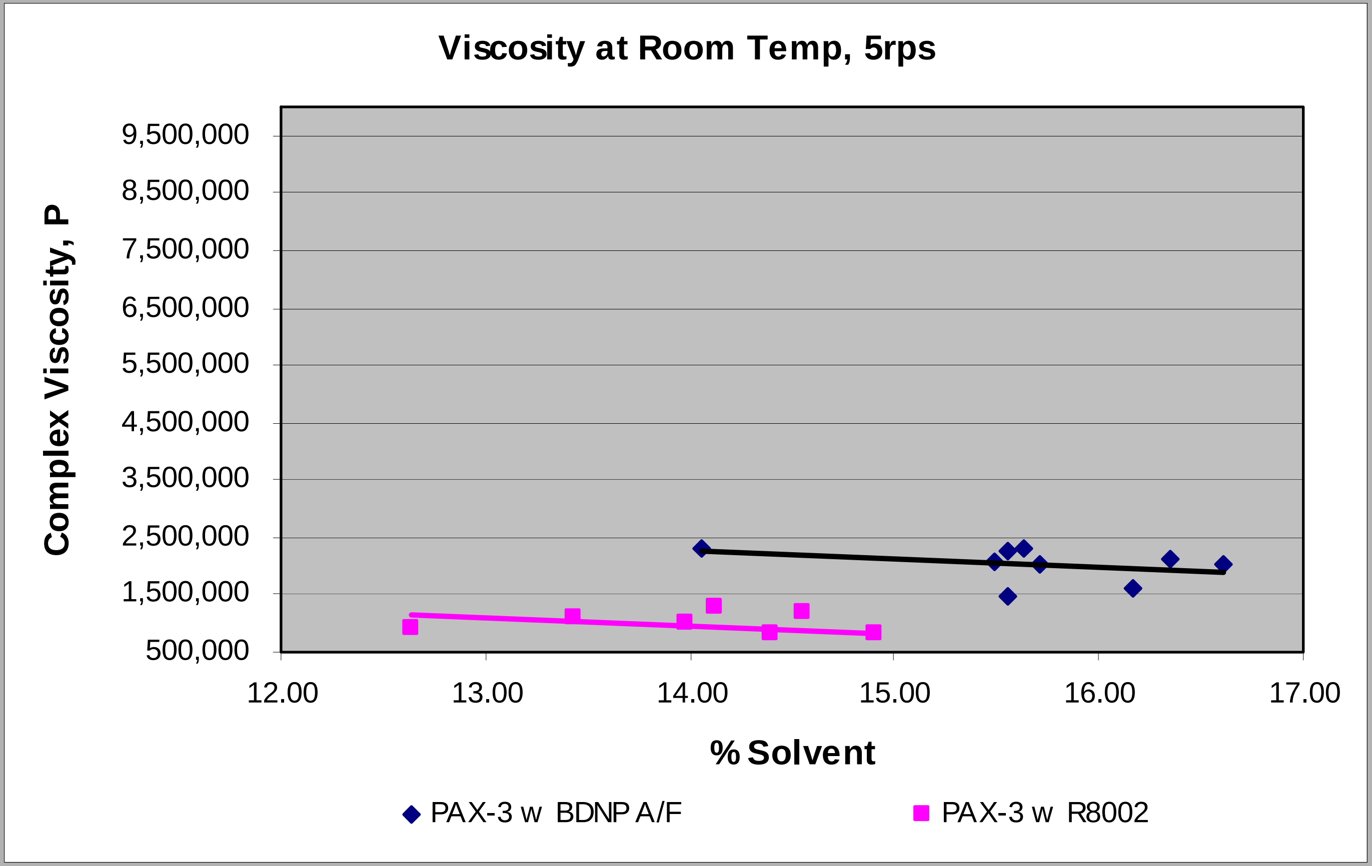
Rheological Characterization

Complex viscosity vs. %Solvent @ room temperature and 1rps frequency.



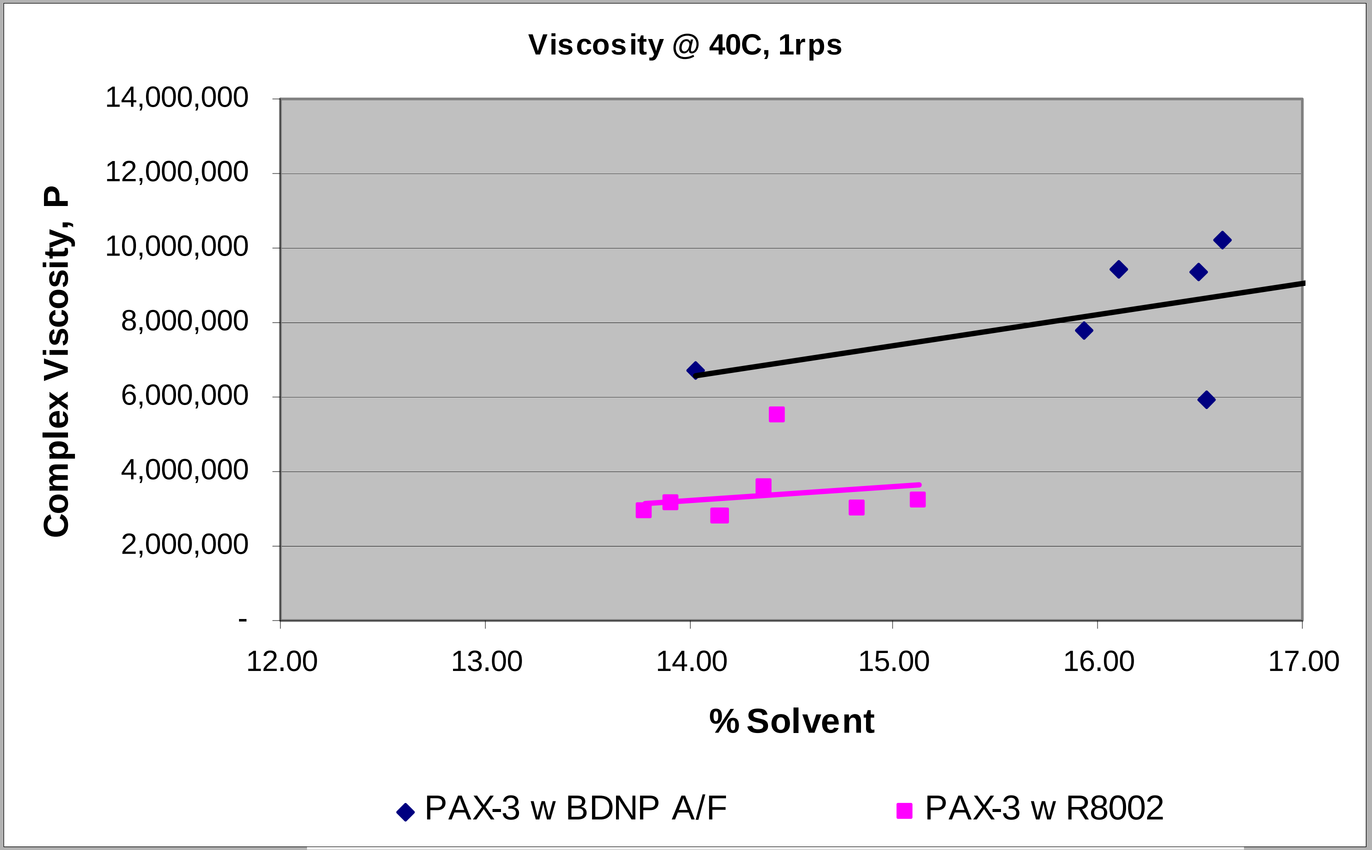
Rheological Characterization

Complex viscosity vs. %Solvent @ room temperature and 5rps frequency.



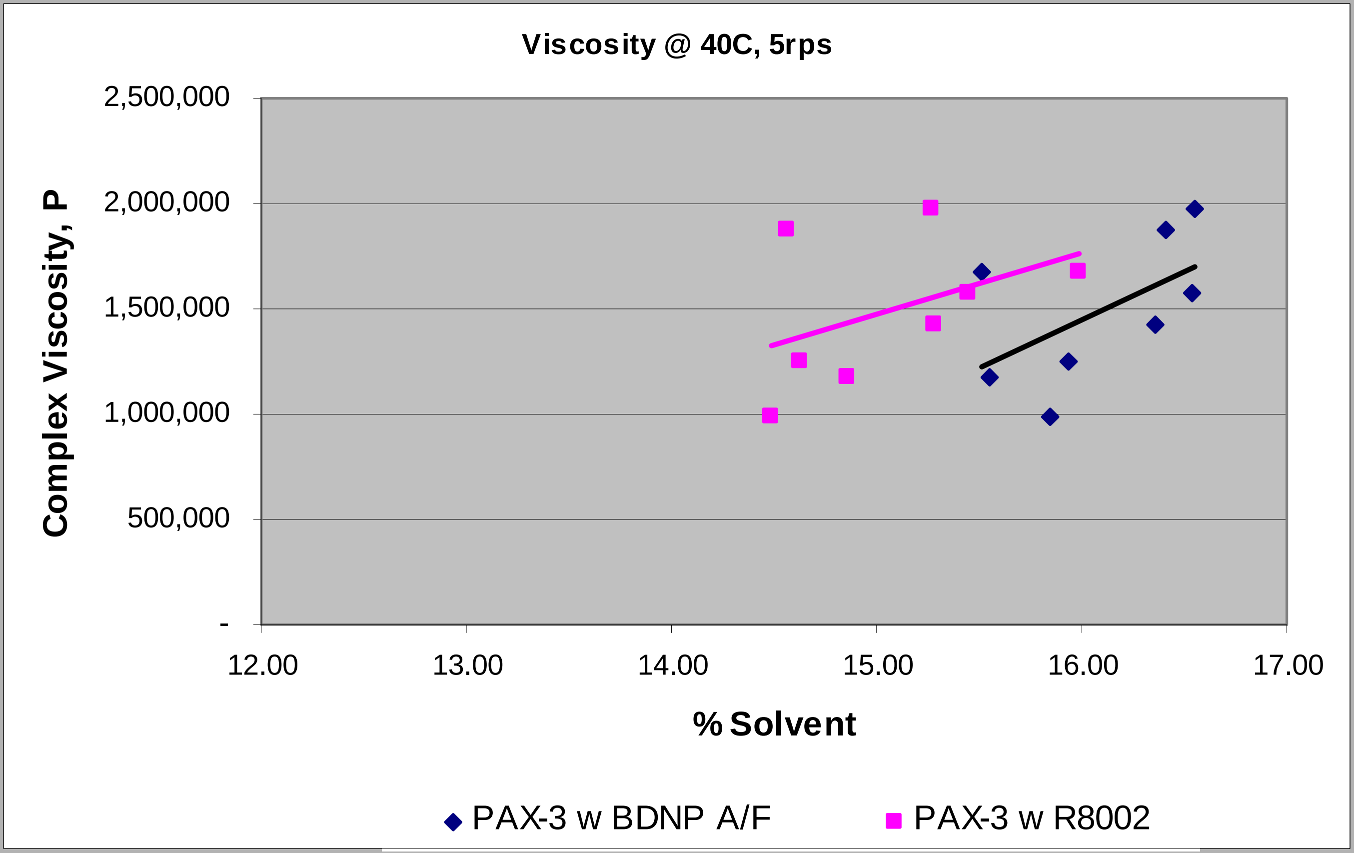
Rheological Characterization

Complex viscosity vs. %Solvent @ 40C and 1rps frequency.



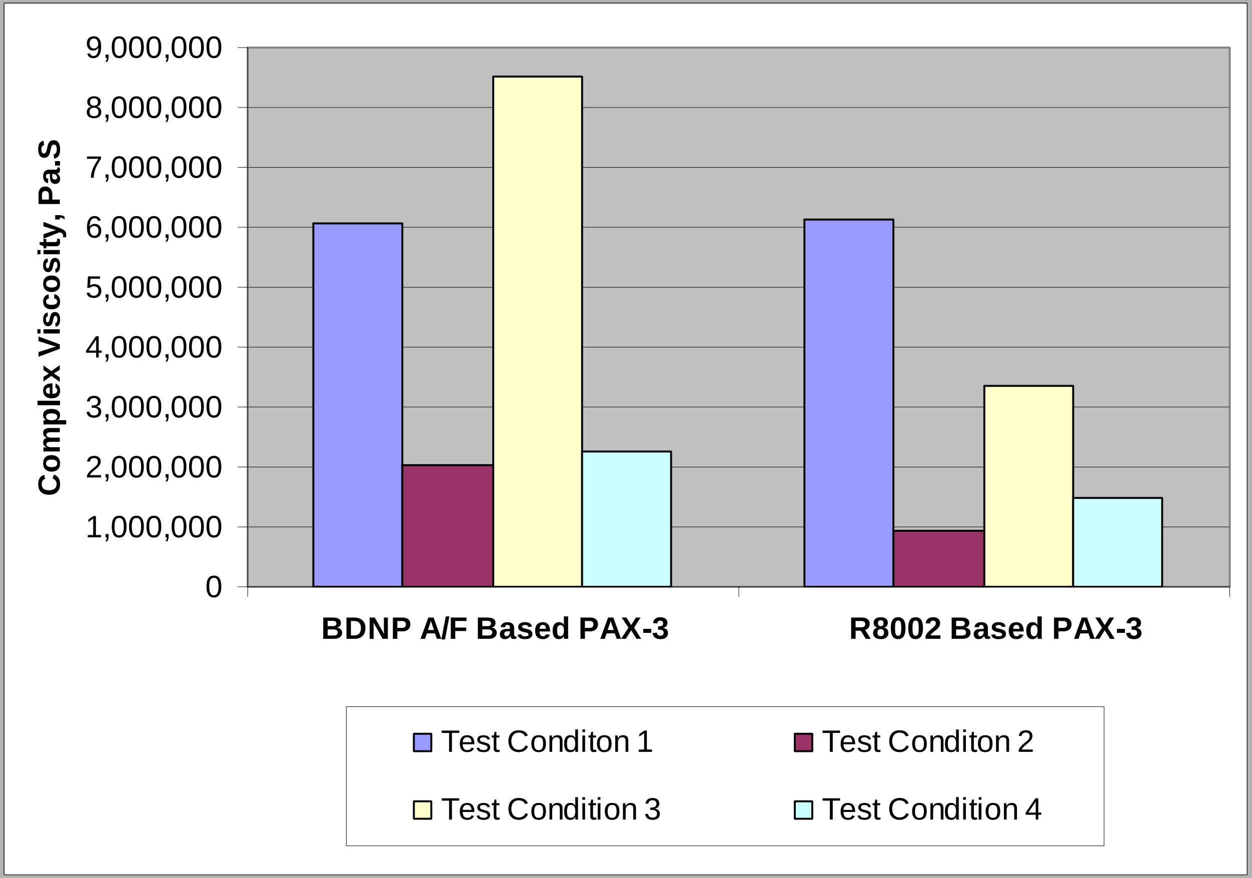
Rheological Characterization

Complex viscosity vs. %Solvent @ 40C and 5rps frequency.



Rheological Characterization

Average Complex viscosity for the four test conditions.



Impact, Friction and Electrostatic Sensitivity Testing

	PAX-3 w BDNPA/F	PAX-3 w/R8002
Impact Sensitivity	Impact height 29.8cm	Impact height 28.7cm
Friction Sensitivity	reacted at a load of 288N and did not react in 10 trials at 240N	reacted at a load of 324N and did not react in 10 trials at 252N
Electrostatic Sensitivity	Did not react in 20 trials at 0.25 Joule (max. energy level)	Did not react in 20 trials at 0.25Joule (max. energy level)

Preliminary Conclusions

- R8002-based PAX-3 is more fluid than BDNP A/F-based PAX-3 under the same mixing condition which takes less effort to process during mixing and pressing operations.
- R8002 is comparable to BDNP A/F and is a less expensive alternate energetic plasticizer.
- BDNP A/F and R8002-based PAX-3's have identical density.
- R8002-based PAX-3 is 3.7 % more impact sensitive than BDNP A/F-based PAX-3.
- R8002-based PAX-3 is 11.1 % less friction sensitive than BDNP A/F-based PAX-3.

Planned Work

- Continue testing, evaluating, and comparing flow characteristics of BDNP A/F and R8002 based PAX-3.
- Perform additional mixing of both BDNP A/F and R8002 formulations PAX-3 for Press Tests.
- Perform Press Tests.
- Analyze Press Tests data.
- Incorporate Press Tests results into final report.
- Present recommendation.