



Ionic Liquid Materials as Base Fluid Lubes and Greases

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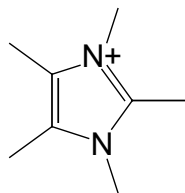
*Presented at the Intertec-Pira Ionic
Liquids Conference*

Orlando, Florida

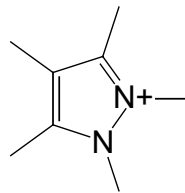
December 11-13, 2006



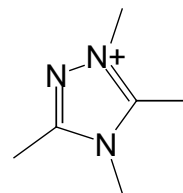
Covalent's Ionic Liquid Cations



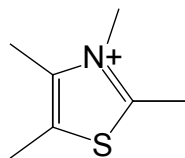
Imidazolium



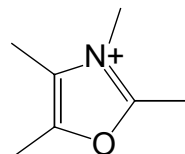
Pyrazolium



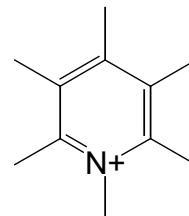
Triazolium



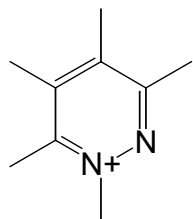
Thiazolium



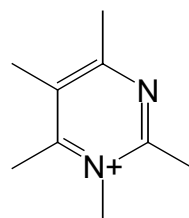
Oxazolium



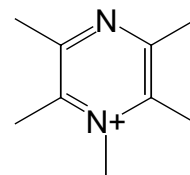
Pyridinium



Pyridazinium



Pyrimidinium



Pyrazinium



Some of Covalent's Large Ionic Liquid Anions

Inorganic



Organic

Sulfonate



Imide



Methide



R = halide, CF_3 , C_2F_5 , and other electron withdrawing alkyl, aryl substituents



Advantages of Covalent's *Hydrophobic* IL Technology

- **Non-flammable**
- **Hydrolytically stable**
- **Thermochemically stable**
- **Wide liquid range**
- **Negligible vapor pressure**
- **Tunable viscosity**



Base Fluid Lubes and Greases

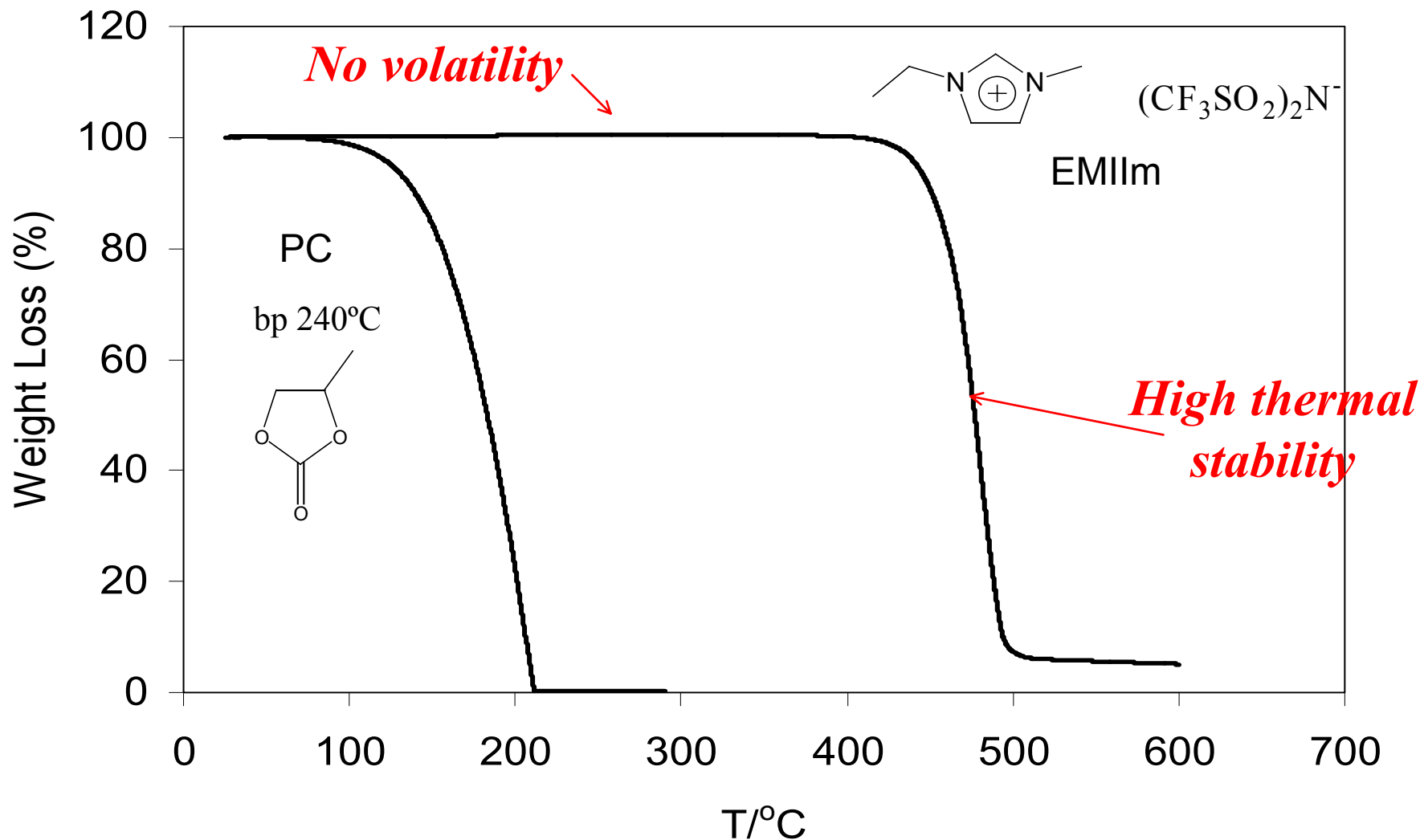
- **For this project, 50 new IL base fluid lubes were synthesized, purified and characterized.**
- **A number of IL-based greases have been prepared and tested; these greases (with and without additives) are presently being evaluated by the industry.**



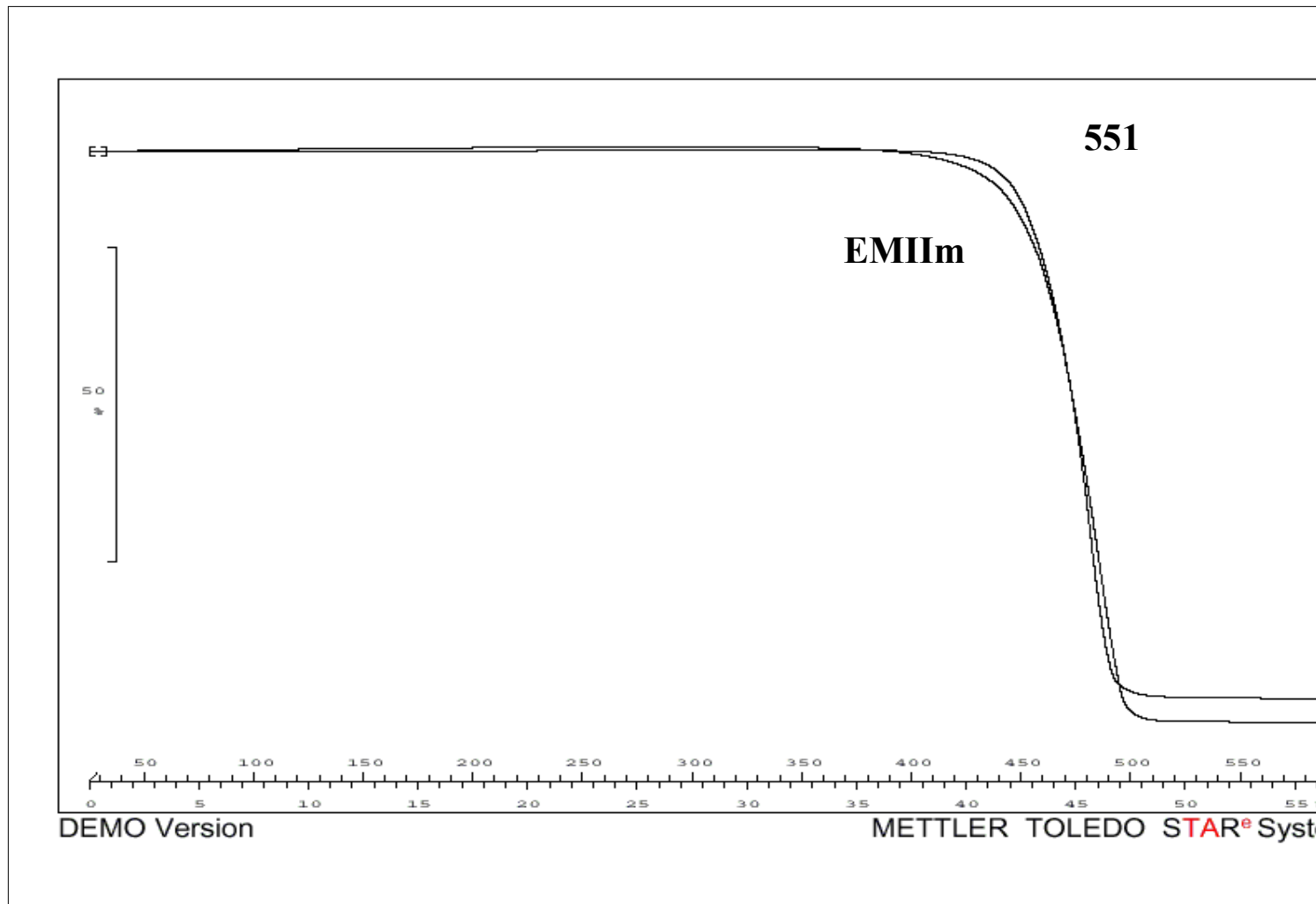
Specialty Lube and Grease Markets

- **Military and aerospace**
- **Disk drive industry**
- **Automotive industry**
- **Microelectromechanical systems (MEMs)**

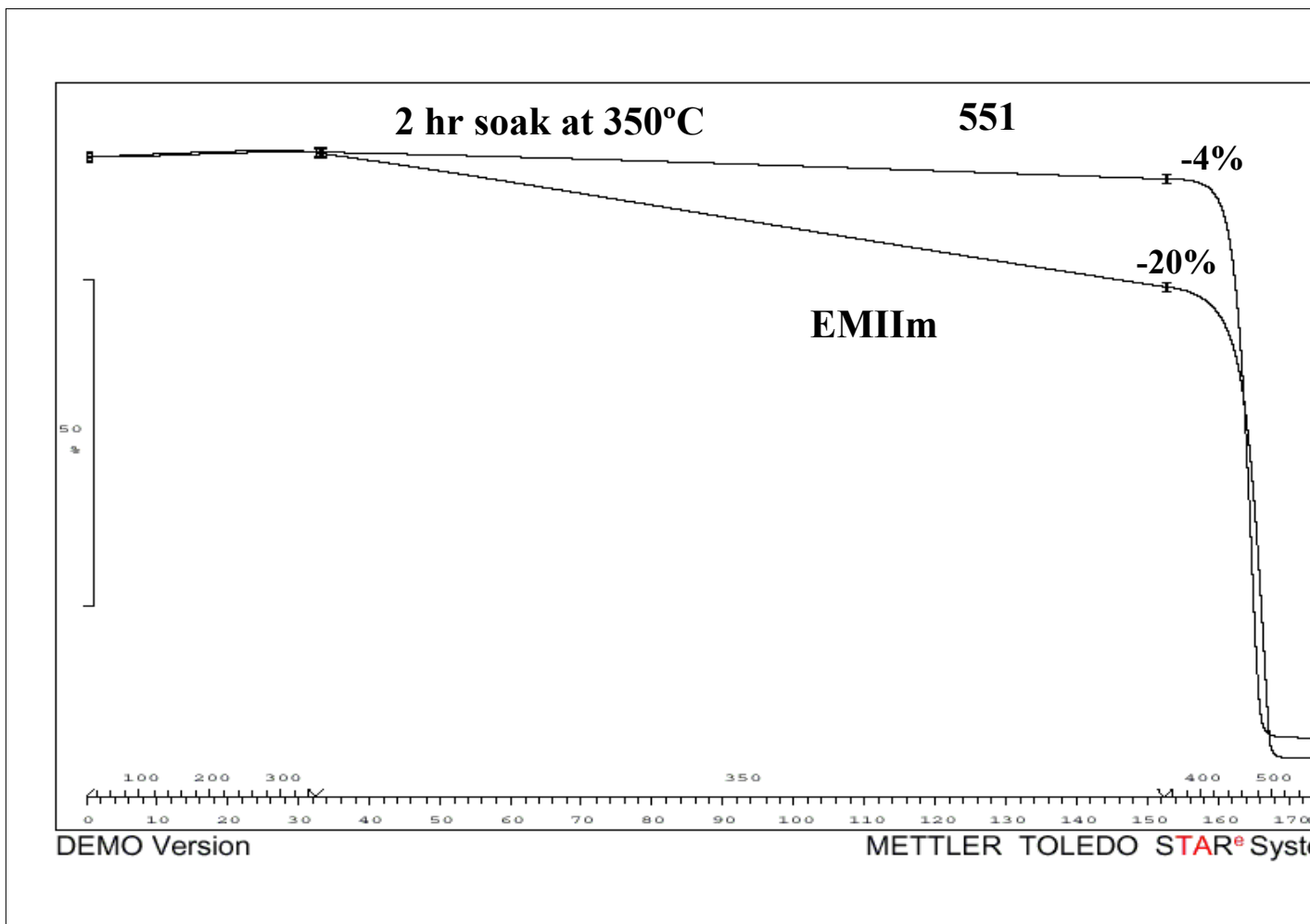
Critical Thermal Stability



Scanning TGA



Scanning and Isothermal TGA





Isothermal TGA Results

Base Fluid Lube	% Weight Loss, 2 hr at 350°C under N₂ and (air)
EMIIIm	20.0 (21.6)
551	4.0 (6.0)
552	1.2 (4.0)
557	0.7 (1.0)
558	0.3 (1.4)
559	0.3 (1.3)
Krytox[®] XHT- 1000	8.0 (9.5)

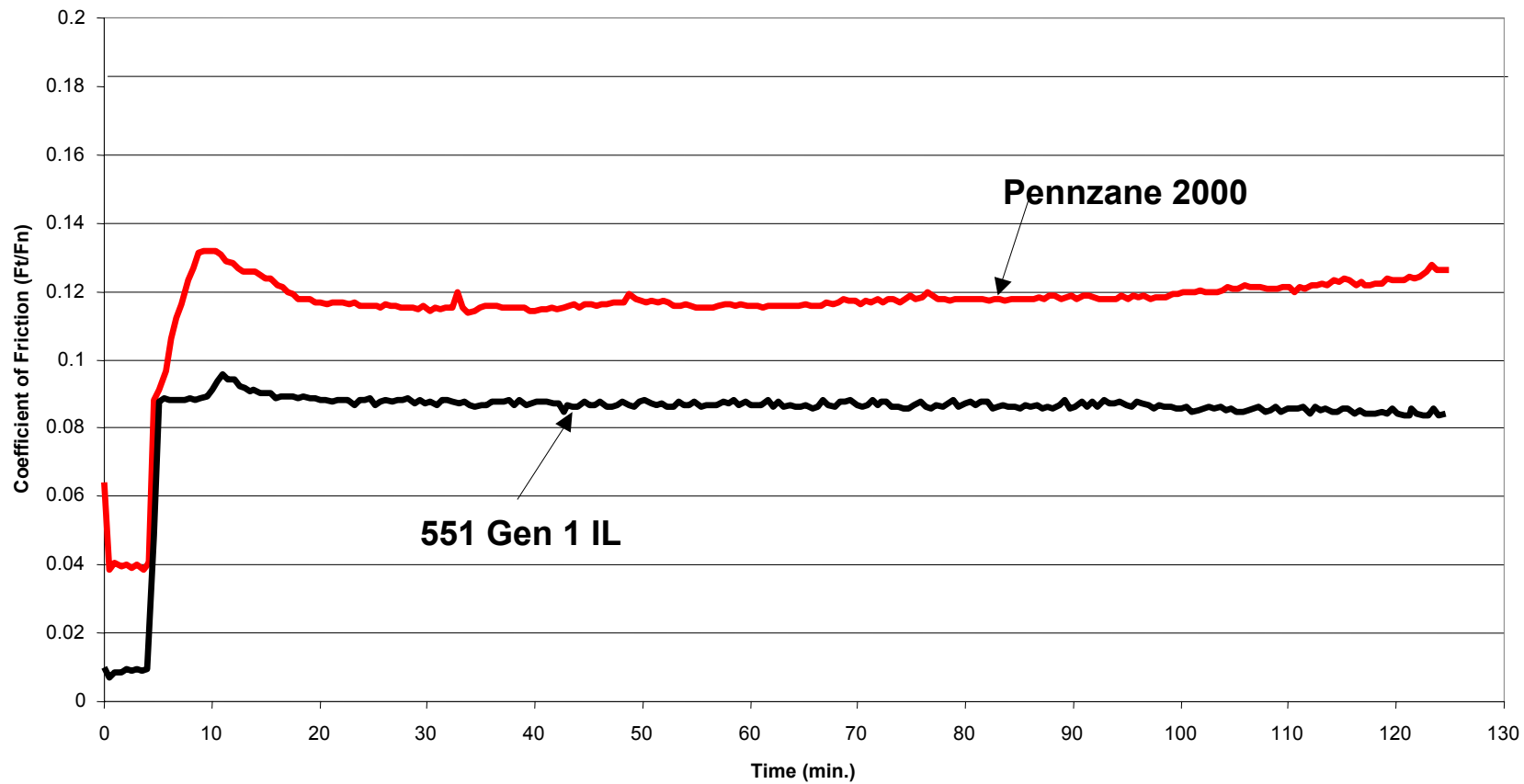
Gen 2 ILs



IL Viscosity/Tribology Data

Test	551	552	557	Krytox [®] 105
Viscosity, 40°C	179 cSt	33 cSt	204 cSt	160 cSt
Viscosity, 100°C	19 cSt	6 cSt	22 cSt	18 cSt
VI	189	144	126	134
4-Ball Wear	0.48 mm	0.59 mm	0.44 mm	0.3 mm
COF	0.086	0.083	0.070	0.07

Friction vs. Time Plots

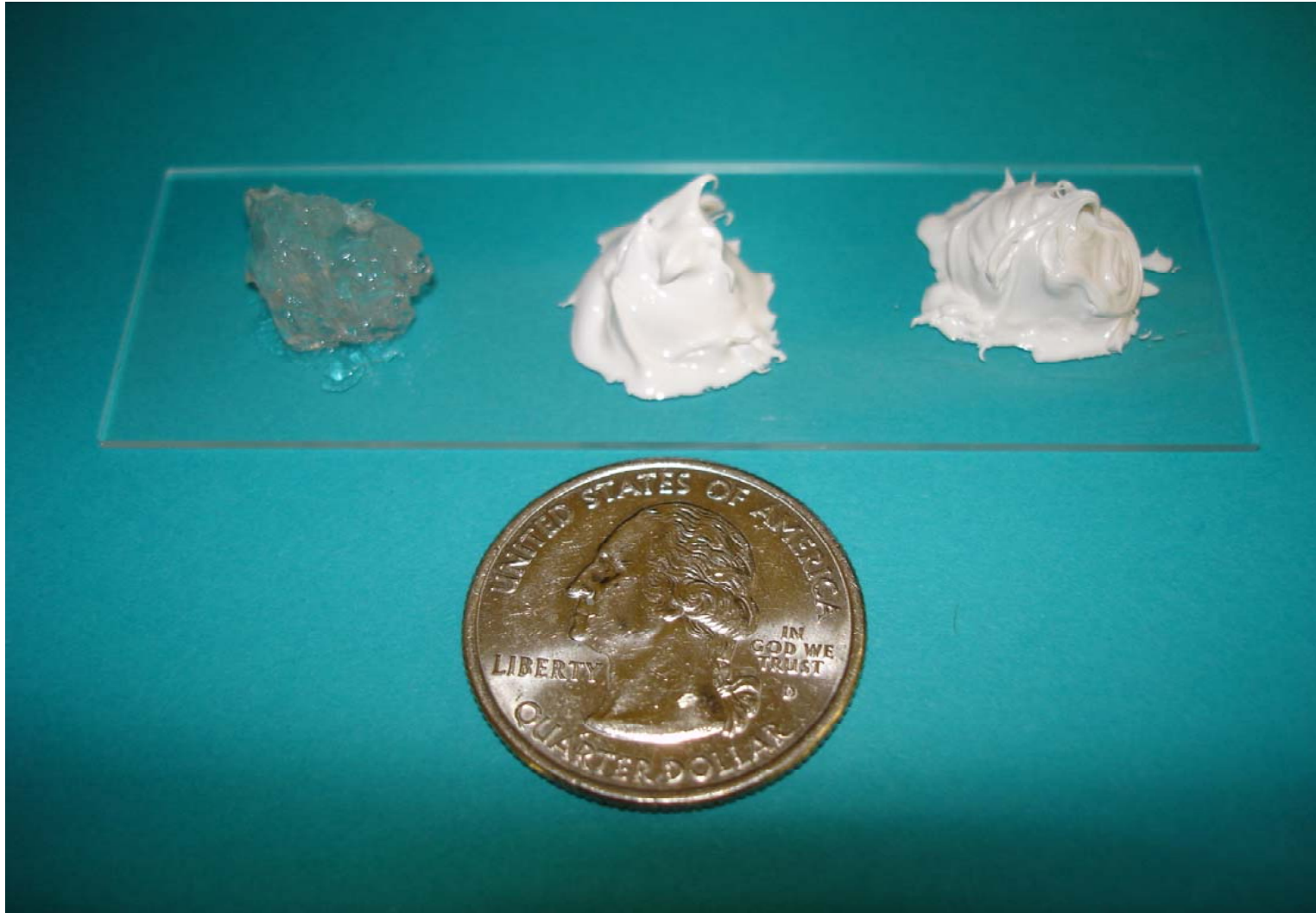




IL Viscosities/Tribology

Base fluid lube	η , cSt @ 40°	Cameron-Plint, mm ²	Vacuum TGA, °C	PDSC, °C	4-Ball wear, mm
Pennzane[®]	106	1.92	294	213	2.6
551	35	0.166	418	458	0.4
553	156	0.172	411	446	---
558	488	0.604	451	408	0.34
559	2481	0.506	442	412	0.33

IL-based Greases

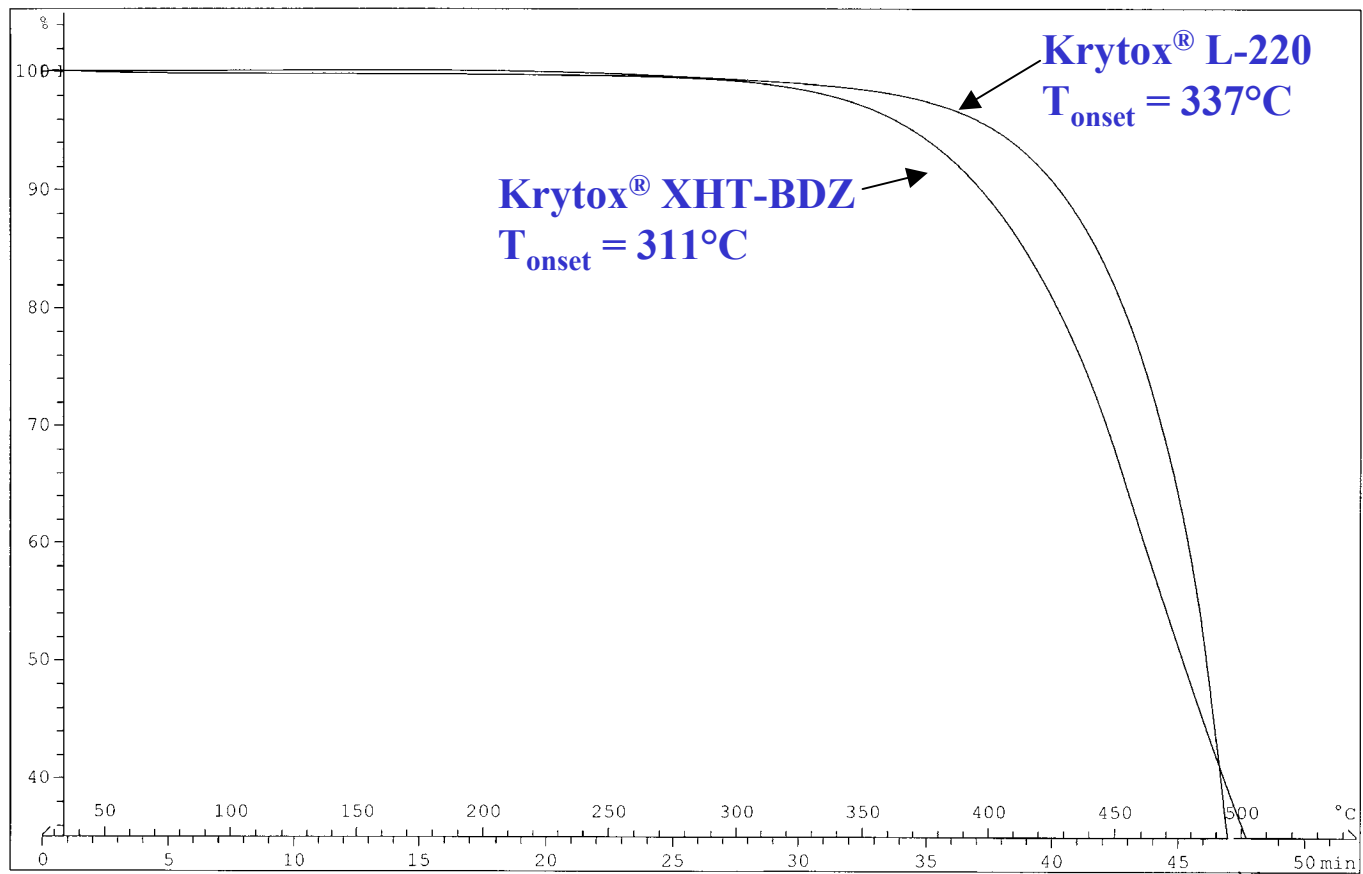




IL-based Grease Thermochemistry

Material	Lot #	T _{1%} (N ₂)	T _g (°C)	% wt loss (N ₂) (350°C, 2 hr)	% wt loss (air) (350°C, 2 hr)
IL base fluid	558	410	-47	0.3	1.4
Grease 1	558-1	403	-47	1.3	2.7
Grease 2	558-2	409	-46	1.3	2.6
Grease 2 + additive	558-2a	397	-46	1.8	2.9

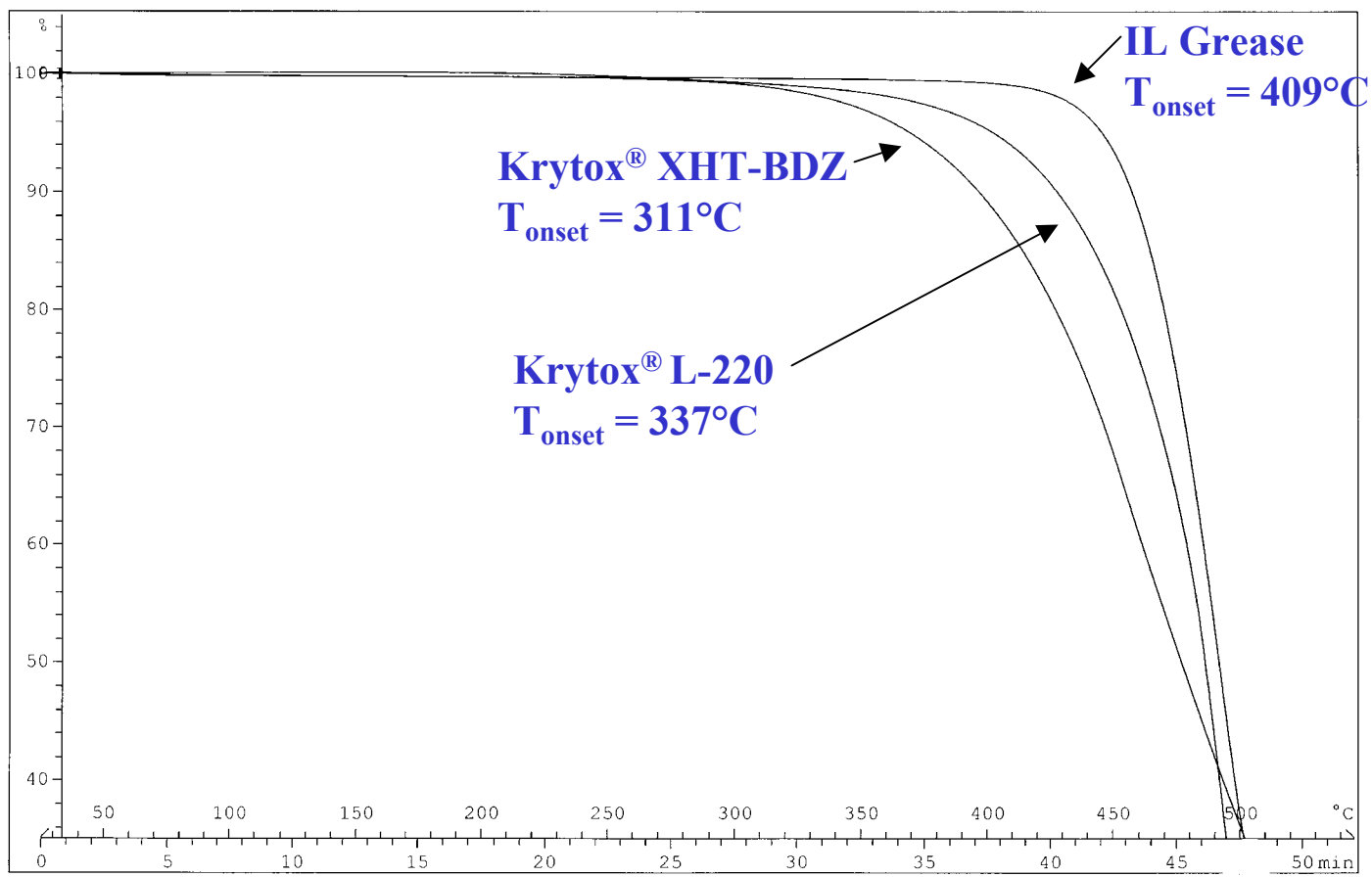
Scanning TGA



Lab: Test

METTLER TOLEDO STAR[®] System

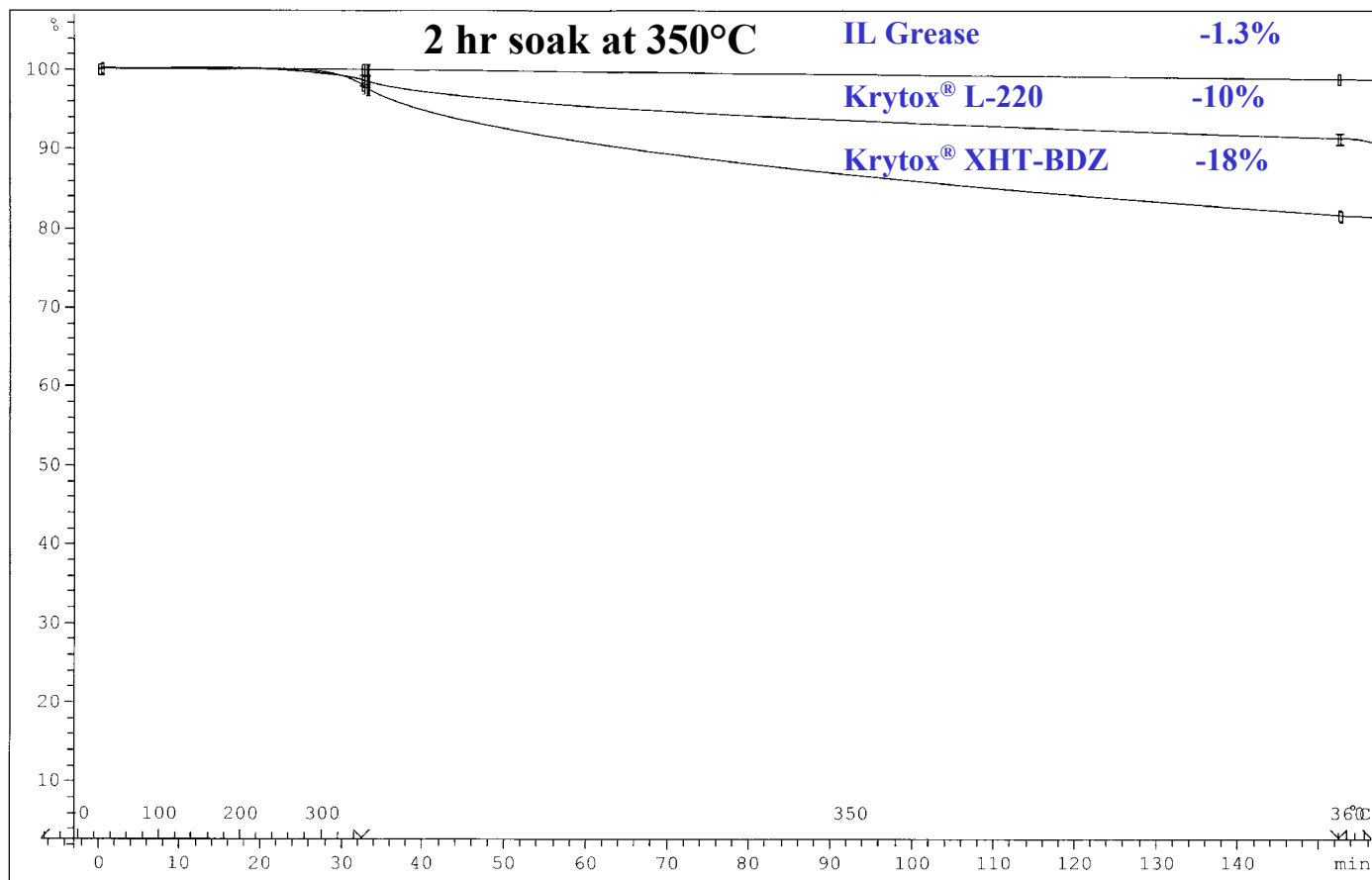
Scanning TGA



Lab: Test

METTLER TOLEDO STAR[®] System

Isothermal TGA



Lab: Test

METTLER TOLEDO STAR[®] System



Grease Properties

<u>Test</u>	<u>Grade 2 grease</u>
P0	261
P60	267
Oil separation, 100°C	0.07%
Evaporation, 100°C	0.08%
4-Ball wear	0.57 mm
Rheometry	33000 cPs at 30 s ⁻¹
COF	0.132



Summary

- ***Thermochemistry:*** Under conditions of isothermal soak Covalent's new Gen 2 ILs are 2 orders of magnitude more stable than commercially available ILs and 1 order of magnitude more stable than Krytox[®] oils and greases.
- ***Tribology:*** IL wear scars are similar to those derived from the PFPEs and up to 1 order of magnitude smaller than those measured for Pennzane[®].
- ***Lubes and Greases:*** Our understanding of the relationship between IL structure and tribological properties has facilitated the development of advanced lube and grease products based on ILs.
- ***IL Cost:*** Gen 2 Covalent ILs are less expensive than PFPE and Pennzane[®] base fluids making IL-based lubes and greases highly competitive in the specialty lubricants market.