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Ionic Liquids as Novel Lubricant Additives for HVAC Compressors for Enhanced Efficiency and Durability

TRANE TECHNOLOGIES

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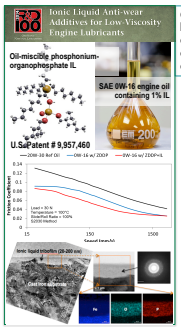
Background

Advanced lubricants are desired for HVAC compressors to reduce the efficiency losses due to friction and wear in multiple moving parts within the system and to facilitate the deployment of environmentally friendly refrigerants to enhance the efficiency and life cycles of compressors.

Approach

Oak Ridge National Laboratory (ORNL) previously developed oil-soluble ionic liquids (ILs) as novel lubricant additives.[1,2] The objective of this ORNL–Trane CRADA is to assess the technical feasibility of developing the IL lubrication technology specifically for HVAC compressors for reduced efficiency losses and environmental impact.

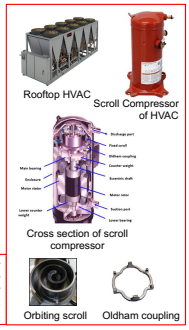


ORNL had previously developed ionic liquids based lubricant additives and demonstrated improved fuel economy and wear protection for automotive engines.

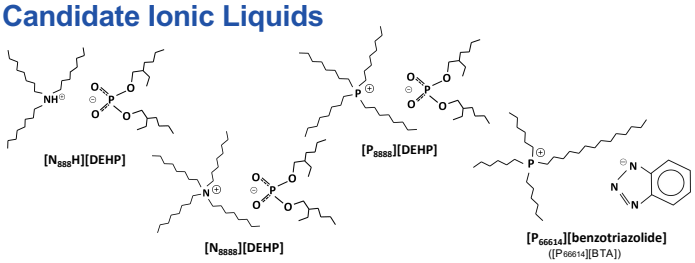
ORNL ionic liquids lubrication technology for HVAC compressors

CRADA between ORNL and Trane NFE-20-07976

Ionic liquids are expected to facilitate the deployment of environmentally-friendly refrigerants and enhance the efficiency and lifecycle of HVAC compressors.

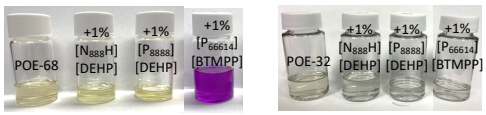


Candidate Ionic Liquids



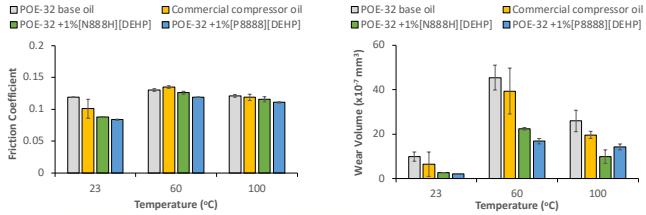
Ionic Liquids' Solubility in HVAC Compressor Oil

All candidate ILs have solubilities >5 wt % in different polyolester (POE) oils, although color change in certain POE + IL combinations indicates chemical reactions.



Ionic Liquids' Superior Lubricating Performance

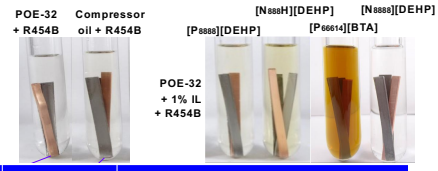
Adding 1% IL to a POE base oil made the oil outperform a commercial compressor oil by 3%–17% in friction coefficient and 27%–68% in wear protection.



Ionic Liquids' Compatibility with Refrigerants

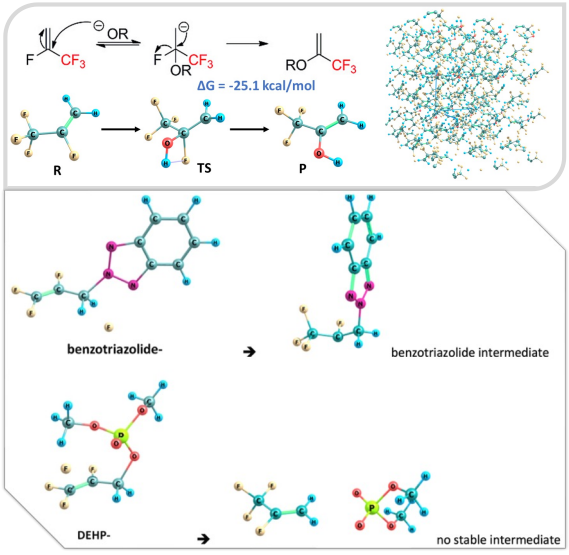
Chemical instability and corrosivity were observed when mixing the POE oil containing ILs with a refrigerant.

- Test method: ASHRAE '97
- 80% (POE-32 + 1% IL) + 20% R454B
- Al, Cu, and Fe strips
- 175°C for 2 weeks



Fluid Description	Fluoride in the Refrigerant (ppm)	Total Acid Number (mg KOH/g Oil)	Dissolved Elements (ppm)				
			Al	Fe	Cu	P	Ca
POE-32 base oil	<10	0.12	<3	<1	<1	<5	<1
Compressor oil	<10	0.17	<3	<1	1	1711	1
POE-32+1%[P_{8888}][DEHP]	177	0.47	7	1	14	986	2
POE-32+1%[N_{888}H][DEHP]	22	1.11	<3	5	2	491	2
POE-32+1%[P_{66614}][BTA]	716	Further analysis not pursued due to fluoride content					
POE-32+1%[N_{8888}][DEHP]	17	0.35	<3	26	2	227	<1

Quantum-chemical calculations and molecular dynamics simulations revealed energetically plausible pathways for the reaction between the ILs and refrigerants. Discrete Fourier transform simulations indicated a higher reactivity for benzotriazolide than DEHP, in agreement with the experimental observation.



Summary

Candidate ILs showed good solubility in POE oils and demonstrated superior friction reduction and wear protection. However, chemical instability and corrosivity occurred when the ILs and fluorine-containing refrigerants were mixed at elevated temperatures. Quantum-chemistry simulations and validating experiments provided insights for future development.

References

1. US Patents #10,435,642 (2019) and #11,760,766 (2023)
2. ORNL, Ionic liquid anti-wear additives for fuel-efficient engine lubricants, 2014 R&D 100 Award

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