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Laboratory Evaluation of Drop-in Solvent Alternatives to n-Propyl Bromide for Vapor Degreasing

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*Environment, Energy Security, & Sustainability Symposium
New Orleans, LA
May 21-24, 2012*



Acknowledgements

- This study was performed for the U.S. Army Research Laboratory
 - MIPR Number: MIPR2AO80BW013
- Alternative solvents for these tests were supplied by:
 - 3M
 - DuPont Fluoroproducts
 - AGC Chemicals Americas, Inc.



Ground rules for this study

- Test solvent effectiveness in the vapor phase only
 - Effectiveness using spray, immersion, ultrasound, etc. were not evaluated in this study
- Alternative solvent candidates must:
 - Have lower expected toxicity than nPB
 - Not be a Hazardous Air Pollutant (HAP)
 - Not be an Ozone Depleting Substance (ODS)
 - Have no flash point
 - Be compatible with existing vapor degreasers



Solvents Tested

- Ensolv[®] n-Propyl Bromide (baseline)
- Alternative solvents tested were all azeotropes or azeotrope-like blends of trans-1,2 dichloroethylene with other solvents.
 - tDCE is an effective solvent on greases and oils but is too flammable for use in vapor degreasers
 - Non-flammable solvents are blended with tDCE to suppress flammability while maintaining solvency
 - Blending may also lower VOC content, GWP and cost, and improve exposure limits.

Alternative Solvents Tested:

	Boiling Point
• Novec™ HFE 72DE (3M)	113°F
• Vertrel® SDG (DuPont)	109°F
• Azeotrope A1 R&D Solvent (DuPont)*	118°F
• AE3000ATE (Asahi Glass Co., Ltd)*	108°F
	(nPB 156°F)

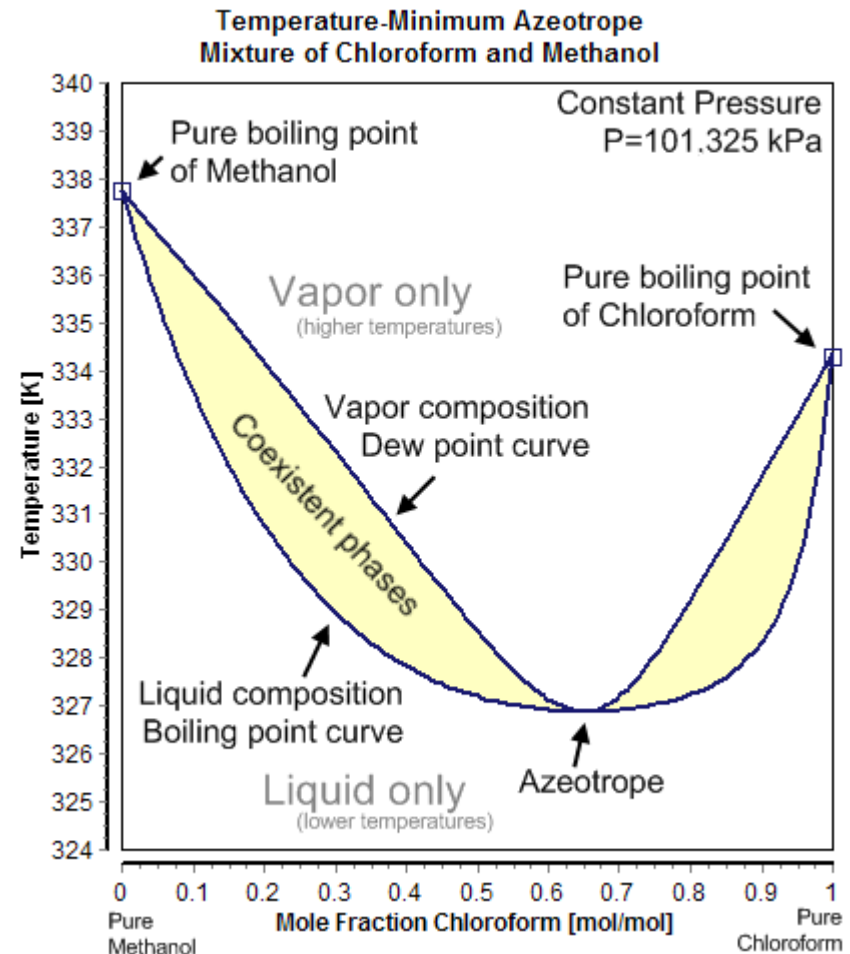
*These solvents are not yet approved by the EPA for use in the United States. Samples were provided by the suppliers “for laboratory use only”.

Note: Perfluorobutyl Iodide was to be included in this study but a suitable sample was not available in the required time frame.

What is an Azeotrope?

- A mixture of two or more liquids at a ratio where, when boiled, the resulting vapor has the same composition as the liquid.
- This lends stability to maintain the properties of the blend over time, critical in vapor degreasing applications.

Curves calculated by mod. UNIFAC (Dortmund)



Graphic attribution: WilfriedC at en.wikipedia 2-24-2012



Materials Compatibility Tests

- Test coupons were immersed in boiling solvent for 30 minutes; observed and weighed before & after
- Materials Tested:
 - Aluminum 7075-T6
 - Magnesium AZ31B-H24
 - Steel Maraging C-250
- No degradation was observed with any of the solvents.

Cleaning Effectiveness Tests

- A standard contaminant was applied to aluminum 2219 coupons and baked for 2 hours at 130°F.
- All coupons were photographed and weighed:
 - Before contamination
 - After contamination and baking
 - After vapor degreasing for 30 minutes
- Photos were taken in bright white and long wave ultraviolet light
- Clean control coupons, degreased and not degreased, were included.



Standard Contaminant per ADS-61A-PRF*

White light

Black light

Mixed, brushed on, and baked two hours at 130°F:

2 parts* MIL-PRF-83282

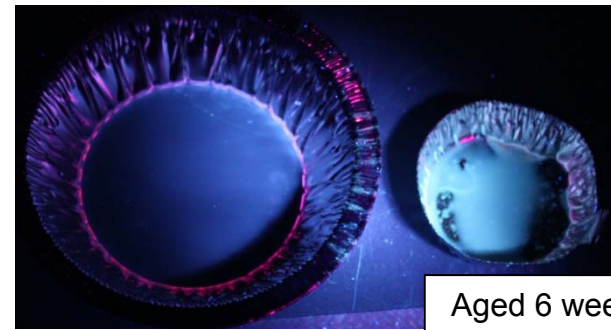
Fire resistant, synthetic hydrocarbon base hydraulic fluid

1 part* MIL-PRF-81322

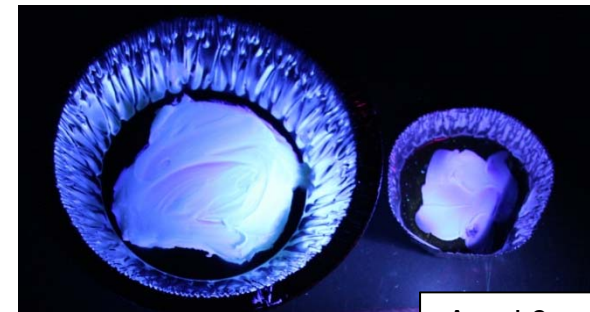
General purpose aircraft grease

1 tenth* part Carbon Black

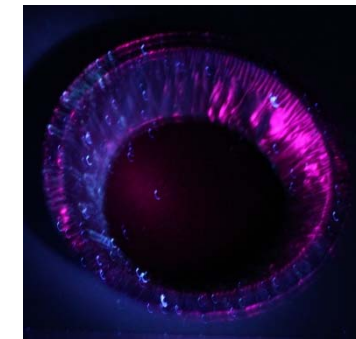
*by weight



Aged 6 weeks

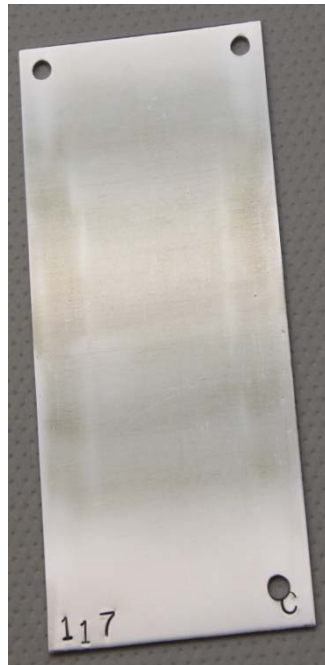


Aged 6 weeks

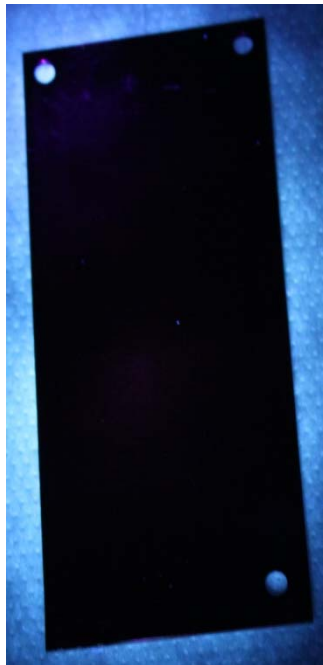


*ADS-61-PRF Performance Specification, Cleaners, Aqueous and Solvent, For Army Aircraft

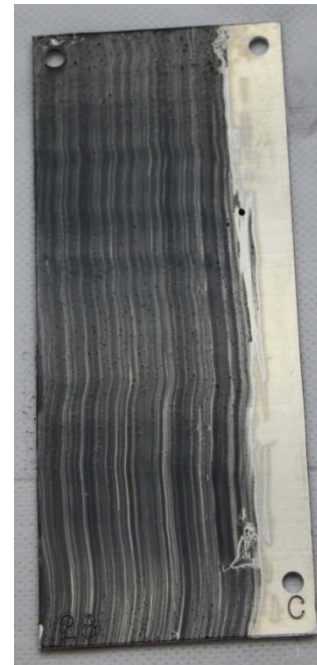
Contaminant applied to test coupons



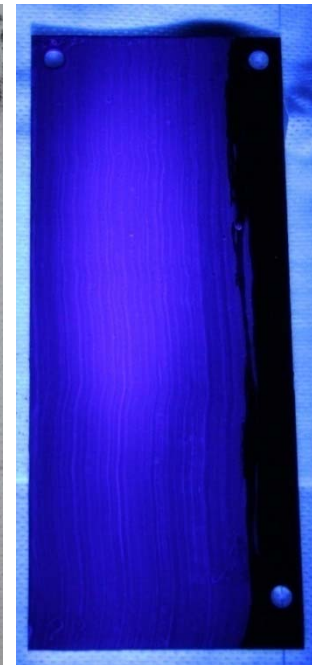
Clean – White
Light



Clean – UV Light



Contaminated –
White Light



Contaminated –
UV Light

Aluminum 2219 sheet – 2.5 in. x 6 in.

Cleaning Results – Set 1

Smooth coupon surface, contaminant removed same day as applied
(Typical visual appearance and average percent removal)



Ensolv nPB
98.2%
removed

Novec HFE 72DE
97.3%
removed

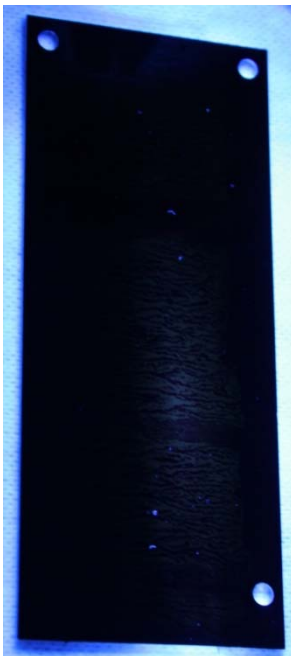
Vertrel SDG
99.4%
removed

Azeo A1
99.2%
removed

AE3000ATE
99.2%
removed

Cleaning Results under UV – Set 1

Smooth coupon surface, contaminant removed same day as applied
(Typical appearance under UV and average percent removal)



Ensolv nPB
98.2%
removed



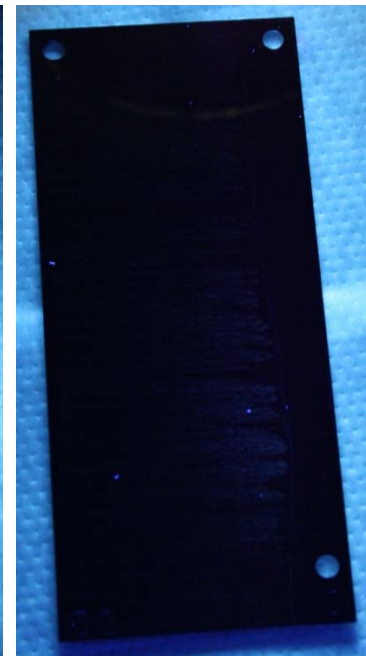
Novec HFE 72DE
97.3%
removed



Vertrel SDG
99.4%
removed

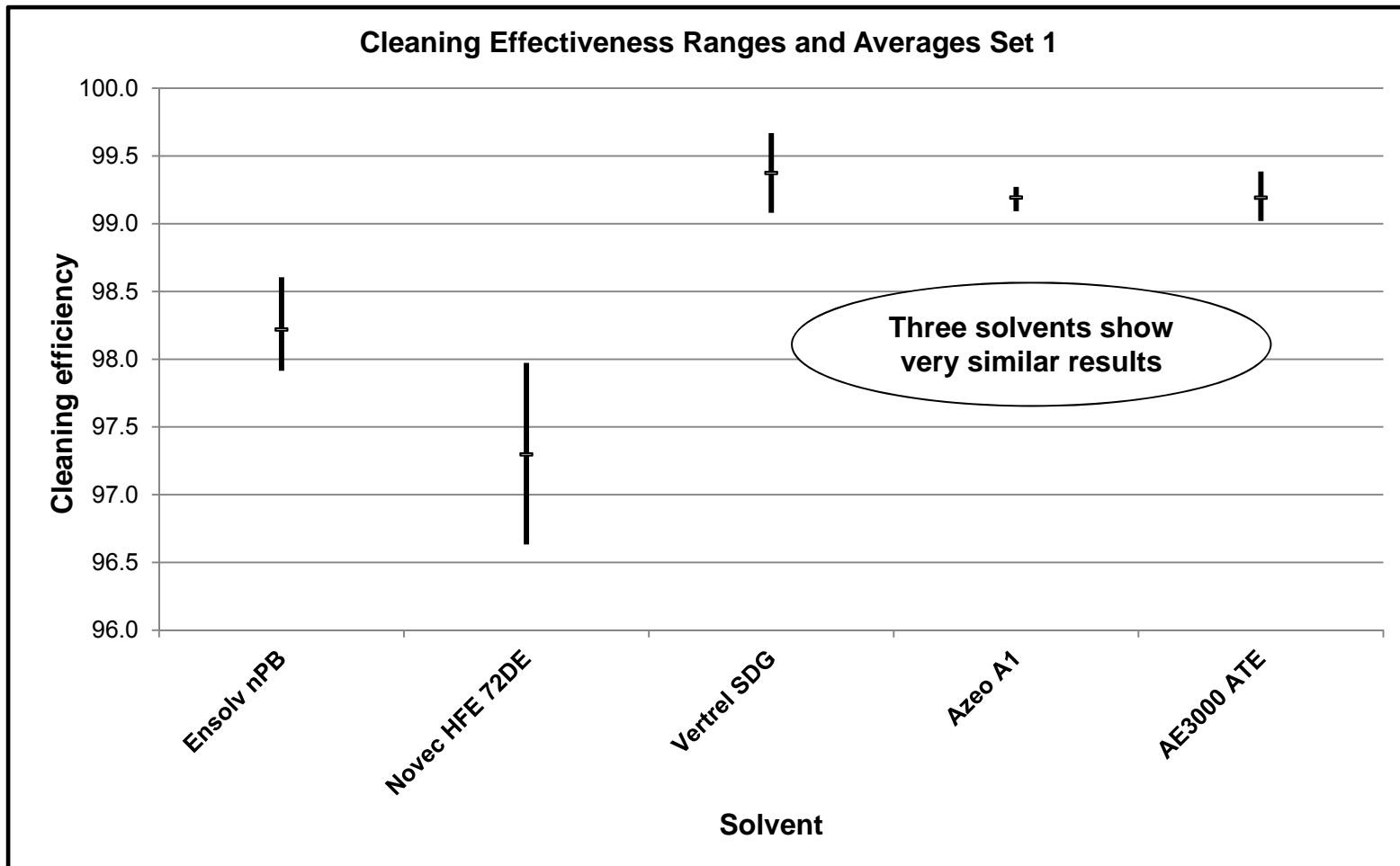


Azeo A1
99.2%
removed



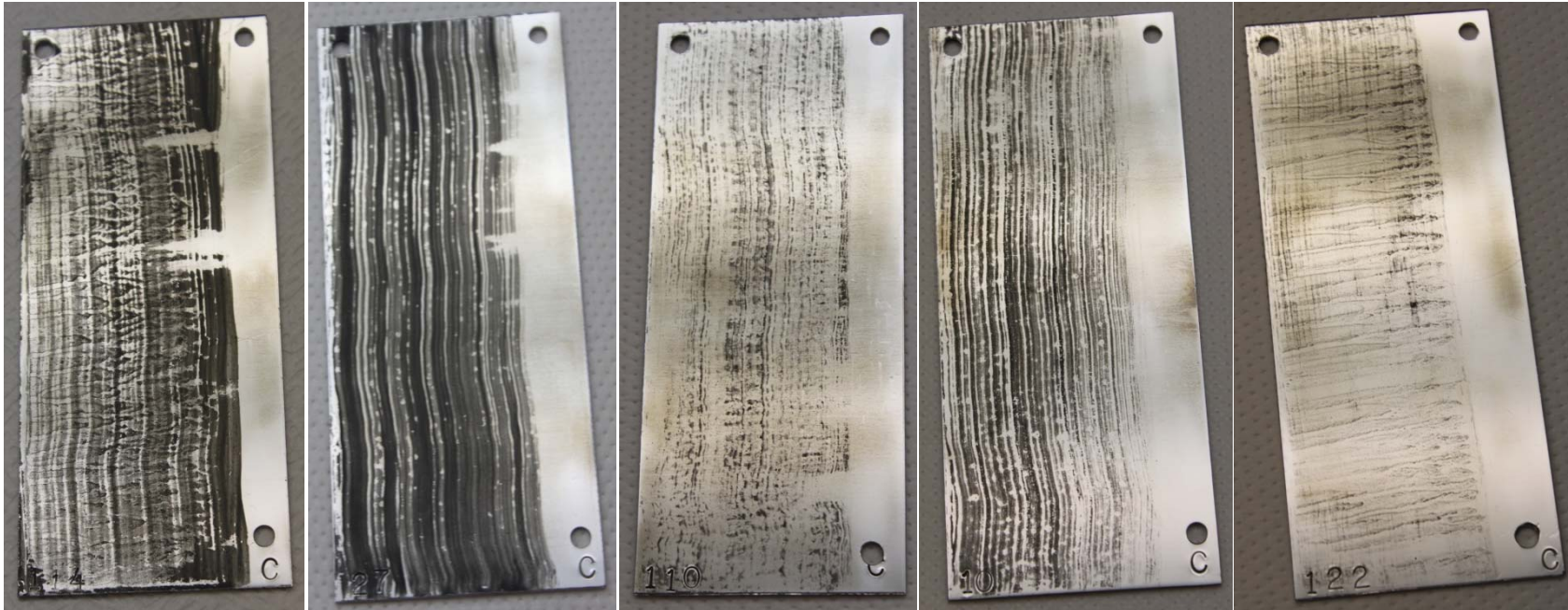
AE3000ATE
99.2%
removed

Cleaning Results – Set 1



Cleaning Results – Set 2, aged contaminant

Smooth coupon surface, contaminant removed 7 days after application
(Typical visual appearance and average percent removal)



Ensolv nPB
96.2%
removed

Novec HFE 72DE
94.8%
removed

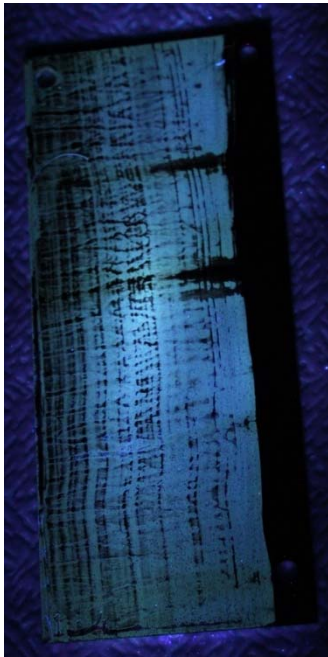
Vertrel SDG
99.1%
removed

Azeo A1
97.5%
removed

AE3000ATE
98.9%
removed

Cleaning Results – Set 2, aged contaminant

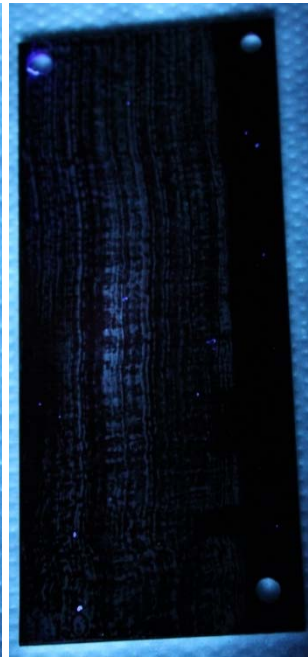
Smooth coupon surface, contaminant removed 7 days after application
(Typical appearance under UV and average percent removal)



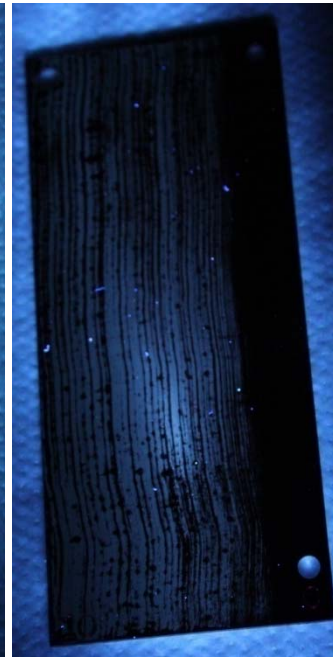
Ensolv nPB
96.2%
removed



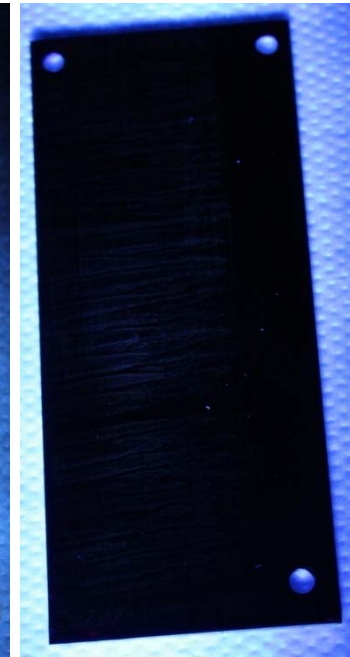
Novec HFE 72DE
94.8%
removed



Vertrel SDG
99.1%
removed

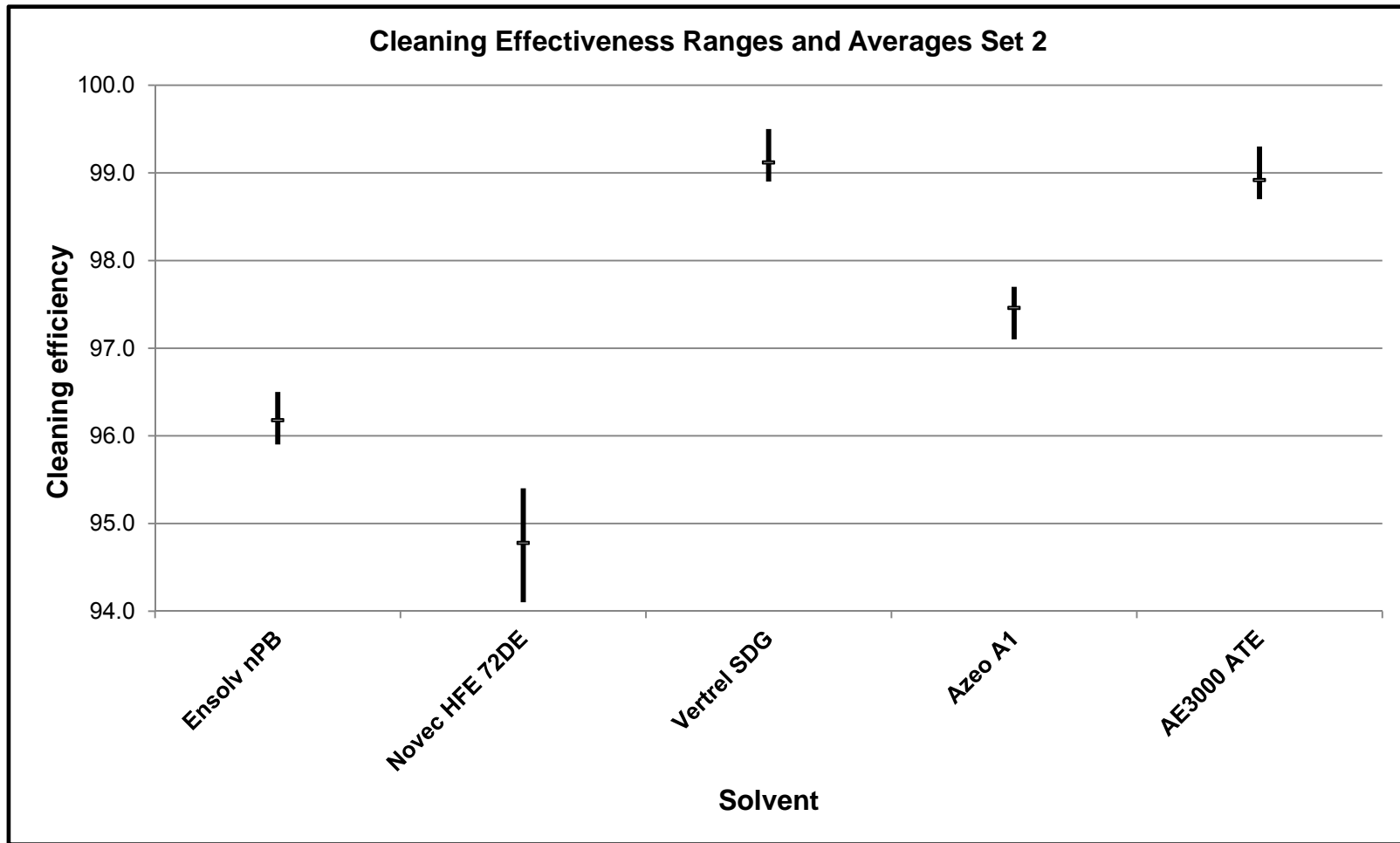


Azeo A1
97.5%
removed



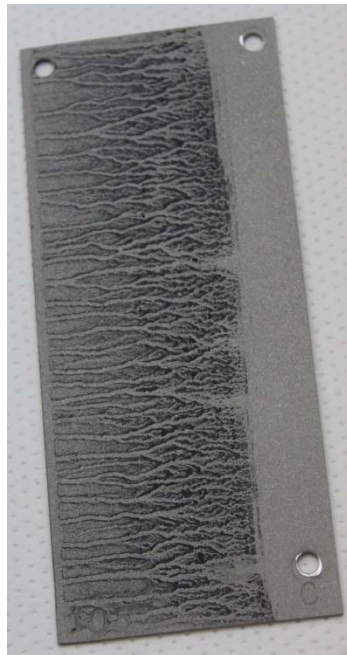
AE3000ATE
98.9%
removed

Cleaning Results – Set 2, aged contaminant



Cleaning Results – Set 3, rough surface

Grit blasted coupon surface, contaminant removed same day as applied
(Typical visual appearance and average percent removal)



Ensolv nPB
97.7%
removed



Novec HFE 72DE
99.7%
removed



Vertrel SDG
99.4%
removed



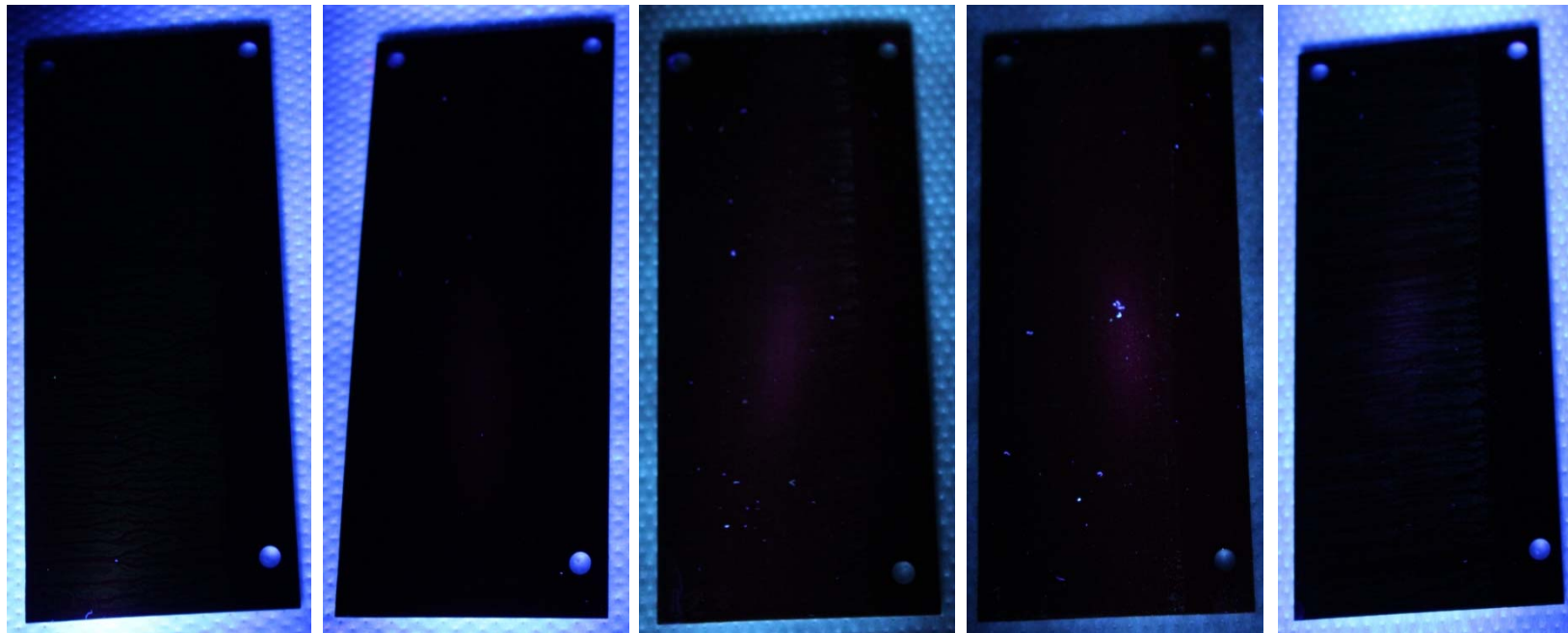
Azeo A1
99.5%
removed



AE3000ATE
98.5%
removed

Cleaning Results – Set 3, rough surface

Grit blasted coupon surface, contaminant removed same day as applied
(Typical appearance under UV and average percent removal)



Ensolv nPB
97.7%
removed

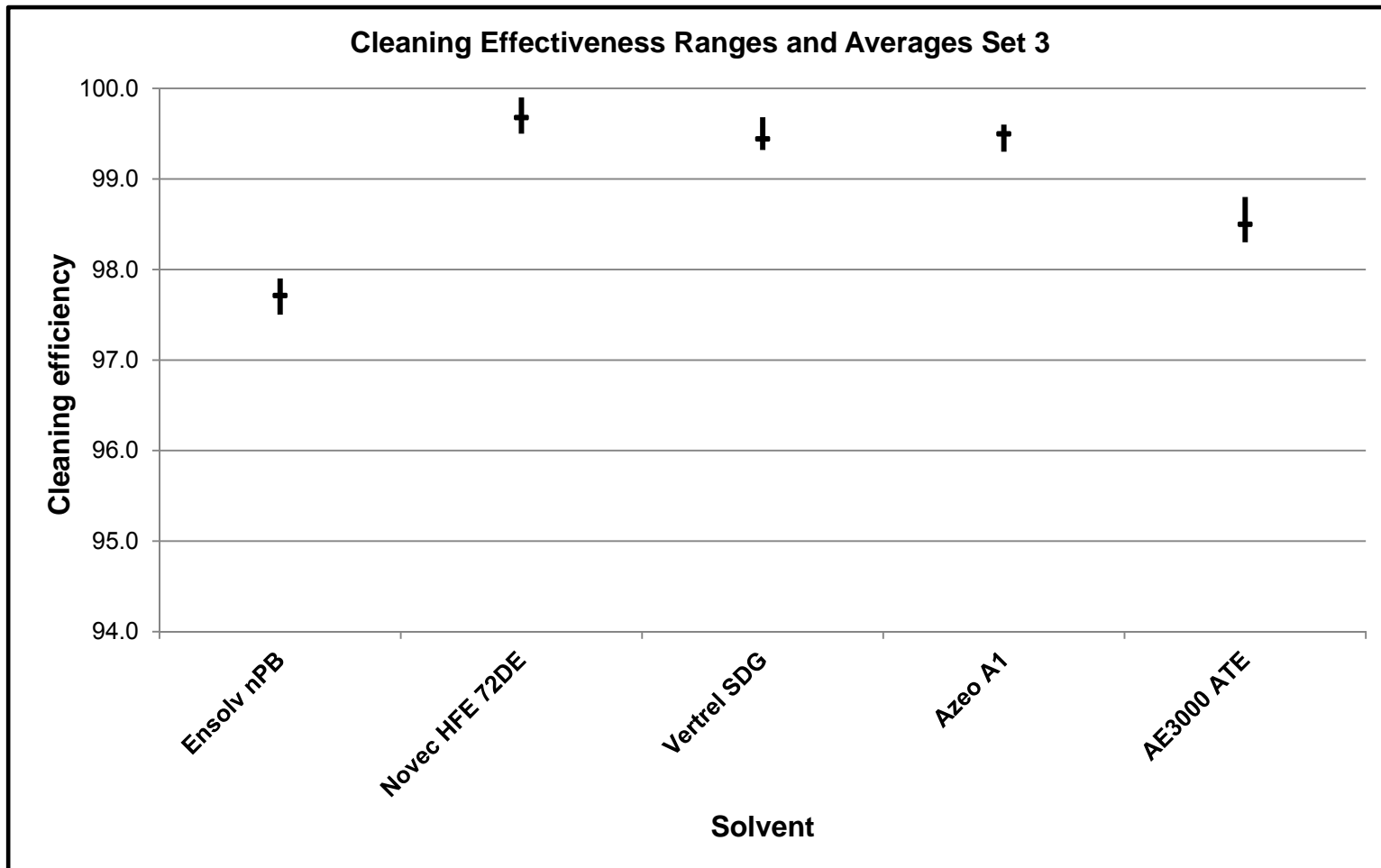
Novec HFE 72DE
99.7%
removed

Vertrel SDG
99.4%
removed

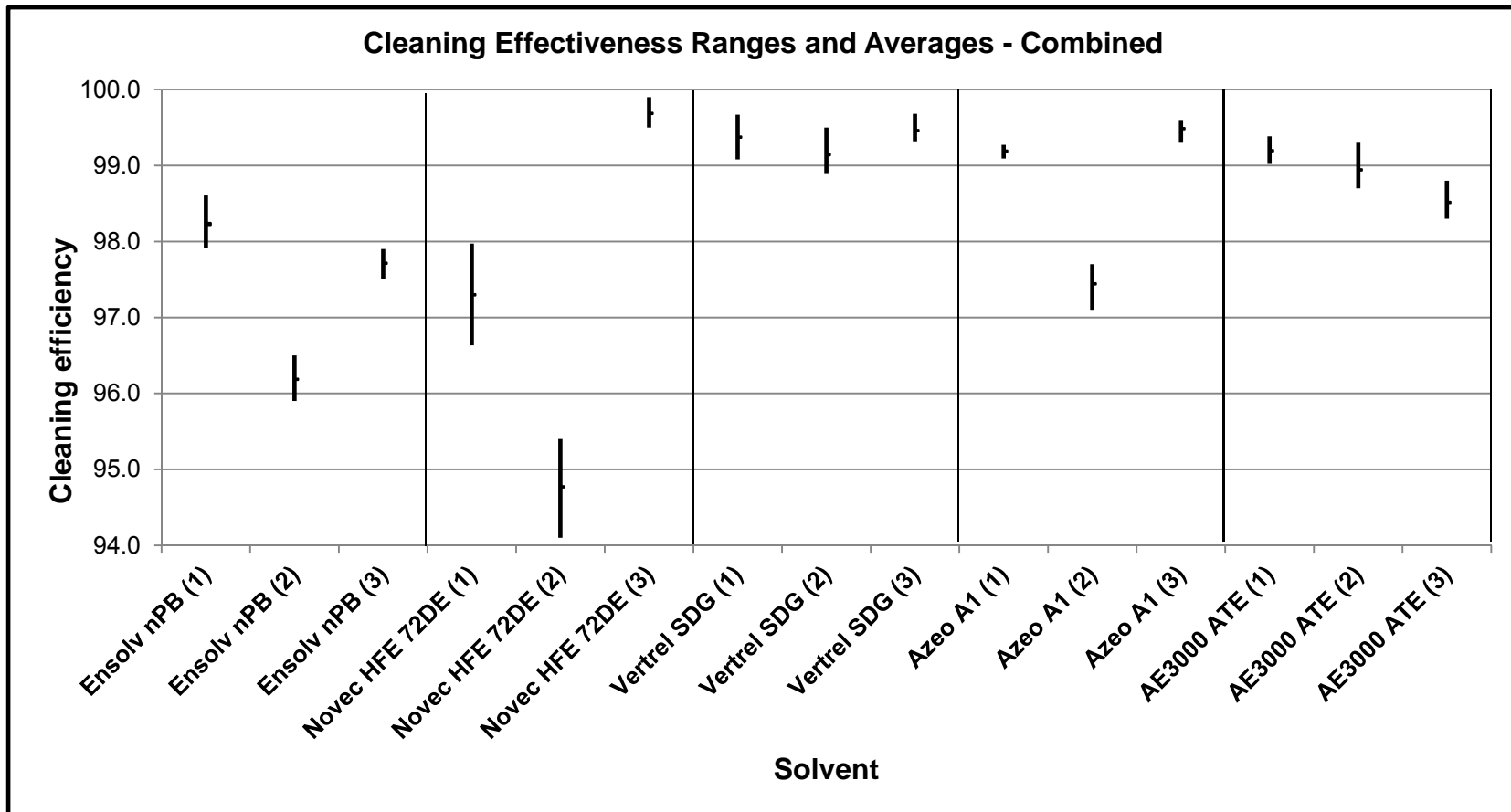
Azeo A1
99.5%
removed

AE3000ATE
98.5%
removed

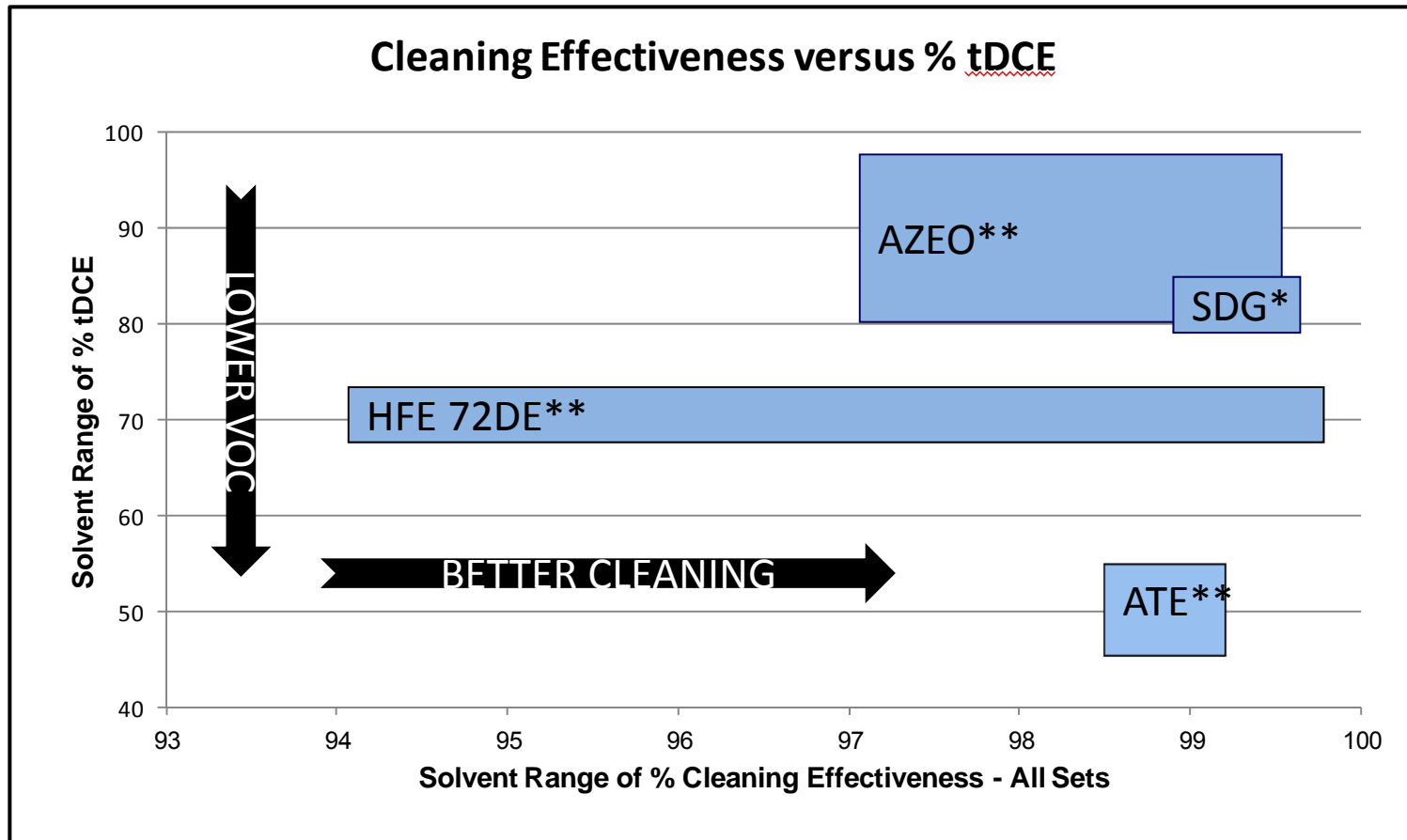
Cleaning Results – Set 3, rough surface



Combined Cleaning Results



Cleaning effectiveness versus tDCE content



*tDCE% as shown in the Vendor Technical Data Sheet

** tDCE% as shown in the Material Safety Data Sheet

Results

- All solvents were compatible with metals tested
- All solvents cleaned in the range of or better than n-propyl bromide
 - Vertrel SDG cleaned the most consistently; AE3000ATE was very close.
 - All but Vertrel SDG showed reduced cleaning effectiveness on aged contamination
 - Cleaning effectiveness did NOT correlate with tDCE%
 - Cleaning effectiveness of any of these solvents may be adequate for the end use
- Results may vary with other materials, contaminants, and hardware configurations



Observations about the test method

- Both carbon black and ultraviolet light were useful visual indicators of contaminant residues
- Despite the two-hour bake, contaminant aged just a few days was more difficult for some solvents to remove.
- Results varied between smooth and roughened test coupons.
- Contaminant aging had a more significant impact on cleaning effectiveness than surface roughening

Conclusions

- Based on this limited laboratory study, solvent blends of trans-1,2 dichloroethylene with HFEs, HFCs, or PFCs appear to be viable alternatives to n-propyl bromide for vapor degreasing.
 - The lower boiling points of these blends may lead to greater solvent loss during use.
 - Additional factors must be considered when selecting a solvent substitute, including stability over time, VOC, GWP, toxicity, and business considerations.



Questions?



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