Advances in Waterbased Flame Retardant Coating Technology

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Agenda

- Background
- Regulatory
- Objective
- Performance

USS Bonhomme Richard (LHD-6)

Flame Retardant Definition

Flame retardant is “substance added, or a treatment applied, to a material in order to suppress or delay the appearance of a flame and/or reduce the flame-spread rate.”[1]

1. Vapor phase inhibition
   a) Brominated flame retardants
2. Solid phase char flame retardants
   a) Intumescent coatings
3. Quench and cool systems
   a) Hydrated minerals

Hexabromocyclododecane

1. V. Babruskas, R. Fuoco. A. Blum, Polymer Green Flame Retardants, 2014. pages 87-118.

Commercial Shipping

- Major container ship fires every 60 days
- Supply chain disruption
- Liability, environmental impact, salvage costs

Moskva

Cruiser
11,490 tons
611’ length x 68’ beam

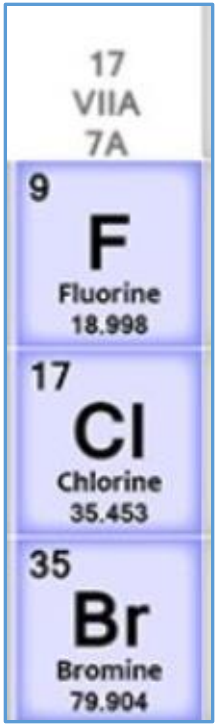
Current MIL-Spec Technology

1. Interior habitability spaces (low smoke density, low toxicity, low flamespread)
2. MIL-DTL-24607C
   a) Solvent based
   b) Chlorinated alkyd resin
   c) Contains parachlorobenzotriflouride (Oxsol 100) exempt solvent
3. MIL-PRF-24596C
   a) Waterbased
   b) F25A
   c) Polyvinyldiene chloride acrylic emulsion

Regulatory Concerns

1. Perflouroalkyl Substances (PFAS)
   a) Eliminate Oxsol 100 exempt status?
   b) EPA (Federal and California) - summer 2023

2. Halogenated Compounds
   a) Detrimental to human health and the environment
   b) 2030 Greenhouse Gas Pollution Reduction Act
   c) 50% reduction in emissions from 2005 levels by 2030
   d) The US will also reduce non-CO_2 greenhouse gases, including methane, hydrofluorocarbons and other potent short-lived climate pollutants



Objective

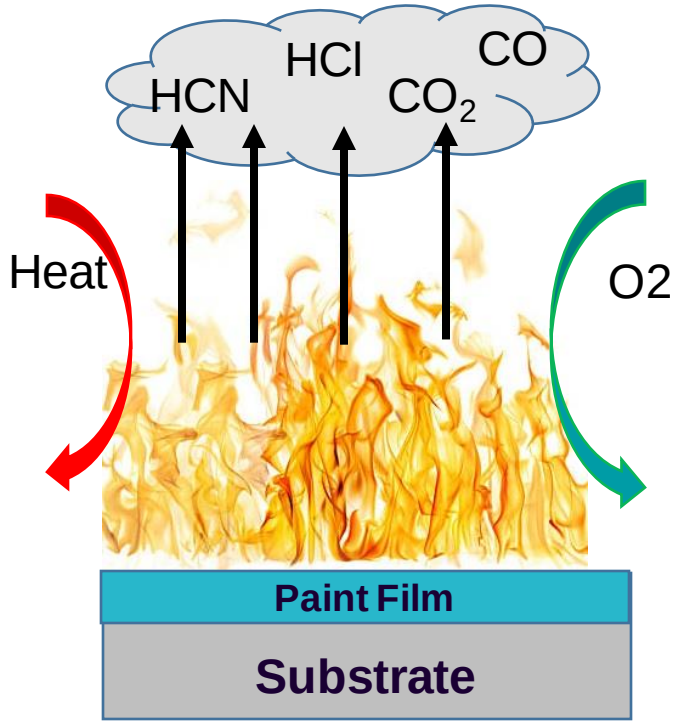
GOAL: Enhance interior habitability space coatings

1. Maximize **crew safety**
2. Maximize **ship safety / survivability**
3. Enhance **application and performance properties**
4. Meet **current (and future) environmental and regulatory** concerns

Novel Flame Retardant Latex
MIL-PRF-24596

Class 1	Surface ships
Class 2	Submarines
Grade A	Waterbased, air dry, < 175 g/L
Application A	Steel
Application B	Aluminum
Application C	FRP
Application D	Wood
Application E	Elastomeric foam insulation

Hazardous Gas Emission - Safety



ASTM E800
Toxic gas emission

Compound	Maximum IDLH (PPM)	Soft White w/o pilot flame	Soft White with pilot flame
HCN	50	Not detected	Not detected
HCl	100	Not detected	Not detected
CO_2	50,000	Not detected	1611
CO	1,500	Not detected	85

Thermal Properties – Safety and Survivability

Property	Target	Next Gen (soft white)
ASTM E662 Smoke Density	15 (flame)	4.7
Max Ds @ 4 min for Application A	15 (non-flame)	6
ASTM E162 Critical Radiant Panel (Surface Flammability)	5	0

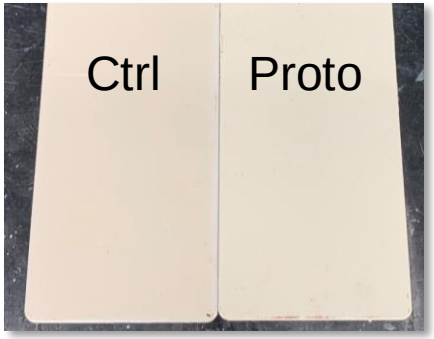
Smoke density – very low
Enhances crew visibility
Safety

Surface Flammability
Zero flame spread
Does not propagate flame
Safety/Survivability

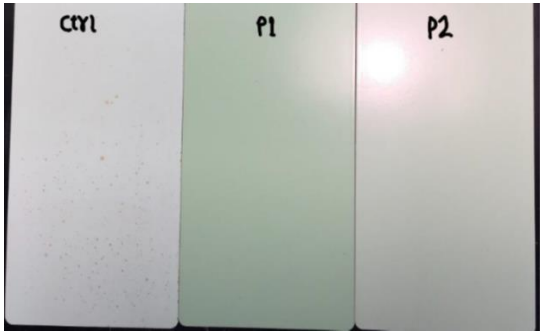
Improved Properties

Property	Target	Navy F25A legacy control (soft white)	Next gen (soft white)
Yellowness Index	dE < 3.0	**3.41**	**0.38**
Sag Index (mils)	> 4	**8**	**11**
Viscosity in KU	<90	**140+**	**69.9**
Contrast Ratio	>0.90	**0.960**	**0.98**
Dry to Touch (Hrs)	< 3	1	50 min
Flash Rust Resistance	No rust spots	Rust spots observed	Pass
Shelf Life (Months)	12-24 months	**12**	**24**

Yellowness Index



Flash Rust Resistance



Regulatory Features

1. Lower VOC
   a) < 175 g/L
   b) MIL-DTL-24067 (250 or 340 g/L)

2. Non-halogenated
   a) No chlorinated resins
   b) No brominated FR

3. Oxsol 100 free

4. Water clean-up

CalEPA
California Environmental
Protection Agency

Reduced Environmental Impact

Life Cycle Analysis

Life Cycle Analysis Indicator	Next Gen (soft white)	% Reduction
	Reduction per 10,000 gallons annually, when compared to Navy legacy formula	
Global Warming Potential	44,839 kg CO_2 eq	**~32% reduction**
Smog (Photochemical Ozone Potential)	1,993 kg O_3 eq	**~33% reduction**
Acidification Potential	23,769 kg SO_2 eq	**~60% reduction**

LCA modeled using GaBi 9.2 Software TRACI 2.1 method were used as characterization factors

Conclusion

1. **Objective achieved**
2. **MIL-PRF-24596** qualified
3. **Improved** smoke density, flammability, toxicity
   a) Zero flame spread index
4. **Enhanced** application and performance properties
   a) Minimal yellowing, lower viscosity
   b) Improved shelf stability & flash rust
5. **Non-halogenated**
6. **Oxsol 100 free, low VOC**
7. **Environmentally sustainable**

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Thank You

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Extra Slides

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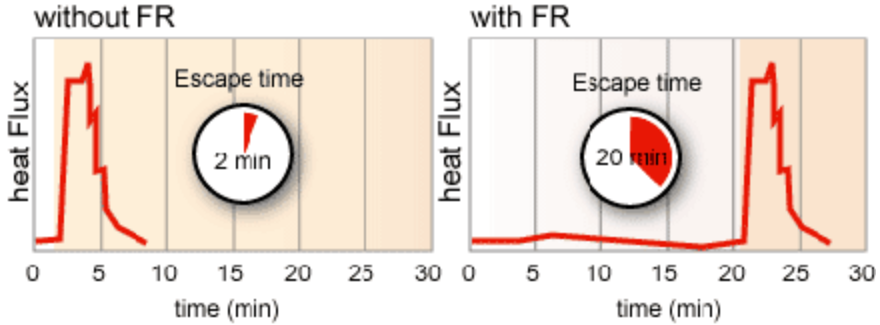
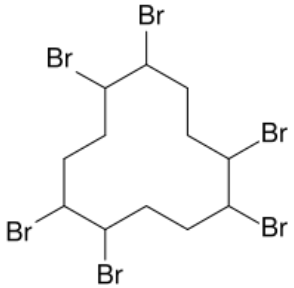
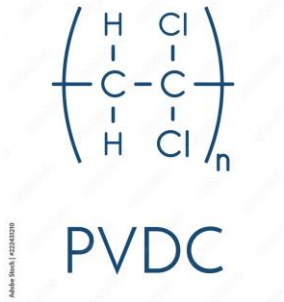
Safety

- June 2014, EPA releases flame retardant alternatives for HBCD-containing insulations
  - Butadiene styrene brominated copolymer
  - TBBPA-bis brominated ether derivative
  - TBBPA bis(2,3-dibromopropyl) ether
- But these alternatives release heavy smoke and contribute to Optical smoke density
- Chlorinated resins are considered environmentally undesired
- Provide safer environmentally friendly alternative

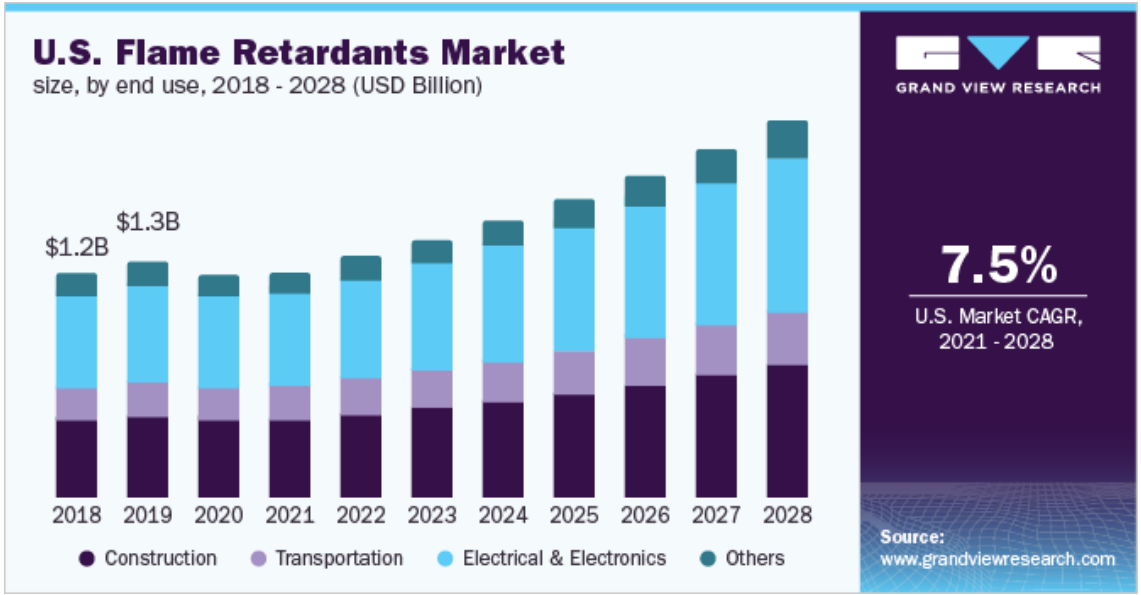






Opportunity Statement – Halogen Free FR

- Global flame retardant market size valued at $7.46B in 2020[1]
- Current halogenated FR generates corrosive smoke during combustion along with toxic gases
- Global flame retardant market seeking halogen free alternatives
- Global market value for halogen free expected to reach $6.9B by 2024[2]



1. https://www.grandviewresearch.com/industry-analysis/flame-retardant-market
2. https://www.marketwatch.com/press-release/halogen-free-flame-retardant-market-size-2021-share-estimation-trend-analysis-industry-growth-rate-company-profiles-with-strategies-global-sales-and-revenues-future-demands-production-scenario-and-supply-forecast-2027-2021-12-31