Abstract ID: **9967**

Title: Shuttle Environmental Assurance : Brominated Flame Retardants - Concerns, Drivers, Potential Impacts and Mitigation Strategies

Category: Build Your Own Session

Sub-Category: Environment

Abstract Text: Brominated Flame Retardants (BFRs) are widely used in the manufacture of electrical and electronic components and as additives in formulations for foams, plastics and rubbers. The United States (US) and the European Union (EU)have increased regulation and monitoring of of targeted BFRs, such as Polybrominated Diphenyl Ethers (PBDEs) due to the bioaccumulative effects in humans and animals. In response, manufacturers and vendors of BFR-containing materials are changing flame-retardant additives, sometimes without notifying BFR users. In some instances, Deca-bromodiphenylether (Deca-BDE) and other families of flame retardants are being used as replacement flame retardants for penta-BDE and octa-BDE.

The reformulation of the BFR-containing material typically results in the removal of the targeted PBDE and replacement with a non-PBDE chemical or non-targeted PBDE. Many users of PBDE -based materials are concerned that vendors will perform reformulation and not inform the end user. Materials performance such as flammability, adhesion , and tensile strength may be altered due to reformulation. The requalification of newly formulated materials may be required, or replacement materials may have to be identified and qualified.

The Shuttle Enviornmental Assurance (SEA) team indentified a risk to the Space Shuttle Program associated with the possibility that targeted PBDEs may be replaced without notification. Resultant decreases in flame retardancy, Liquid Oxygen (LOX) compatibility, or material performance could have serious consequences.

Shuttle Environmental Assurance:
Brominated Flame Retardants *– Concerns , Drivers, Potential Impacts and Mitigation Strategies*

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June 14, 2010

Shuttle Environmental Assurance Initiative (SEA)

SEA Objectives:

- Develop and implement a comprehensive SEA team that provides environmental insight into Space Shuttle Program (SSP) operations.
- Communicate significant SSP-related EH&S risks, environmentally driven materials obsolescence issues, and materials replacement efforts to the SSP.
- Assess emerging/changing environmental regulations to identify potential areas of impacts to the SSP.
- Assess changes which occur within industry and identify potential areas of impact to the SSP.
- Identify, track and mitigate SEA issues based on the associated risk level assigned by the SEA team.
- Promote resources awareness across SSP organizations for current SEA projects and future improvements/mitigations.

Background: PBDEs

- **Polybrominated Diphenyl Ethers (PBDEs) :**
  - Targeted class of Brominated Flame Retardants (BFRs)
  - Bioaccumulative: Persistent in the environment
  - Additives: Plastics, Rubbers, Foams
  - Provides Stability
  - Inhibits or prevents combustion
  - Applications: Electronics, Epoxy Fillers, Insulation Sleeving

Space Shuttle Launch

SEA BFR Sub-Team

- **SEA identified a risk to the Space Shuttle Program (SSP) from BFRs**
  - Increasing domestic & international regulations
  - SSP requirements for flame retardancy in materials
  - Product formulation changes within BFR industry and uncertainty on schedule / timeline for changes
  - Uncertainty on performance of replacement materials/ products
  - 5 to 7 years needed to qualify a replacement material
- **SEA established a BFR Sub-Team (Civil Servant & Contractor) to proactively:**
  - Evaluate the potential impacts with the increased regulation of BFRs.
  - Perform a risk assessment.
  - Identify potential mitigation strategies.
  - Document findings in technical working papers.

Regulatory Drivers

The European Union (EU) , United States (US) Environmental Protection Agency (EPA) & State Governments within the US are increasing their regulation of the use of PBDEs.

United States

- **Toxic Substances Control Act (TSCA)/ Significant New Use Rule (SNUR)**
- **Emergency Planning & Community Right–to–Know**
  - **Toxic Release Inventory Reporting of Deca-BDE**
- **EPA's 3-Year Voluntary Phase-out of Deca-BDE**
- **States enacting legislation for phase-out of Octa-BDE & Penta-BDE**
  - **CA, HI, IL,ME, MD, MI, NY, OR, RI, WA**
- **EPA's Voluntary Children's Chemical Evaluation Plan**

European

- **Restrictions on Hazardous Substances (ROHS)**
- **Directive on Waste Electrical & Electronic Equipment (WEEE)**
- **EU Water Framework Directive (WFD)**
- **Marketing & Use Directive, 24th Amendment**
- **Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH)**

Flammability Requirements

- **SSP materials are tested for flammability properties per NASA Handbook 8060.1C or NASA- STD-(I)- 6001A *"Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion".***
  - **Test #1/Upward Flame Propagation for evaluation of non-metallic materials used in Habitable Flight Compartments and areas outside of Habitable Flight Compartments.**
  - **Test #4/ Electrical Wire Insulation Flammability**
  - **Test #17/Upward Flammability of Metallic Materials in Gaseous Oxygen Environments**

Purpose of Tests: ***To determine if a material, when exposed to a standard ignition source, will self-extinguish and not transfer burning debris.***

BFR/PBDE Identification Effort

- **Identification of PBDEs in materials is difficult.**
  - −Searches conducted in materials databases & Material Safety Data Sheets
  - −Hamilton Sundstrand provided lists of materials containing PBDEs.
- **Focused on critical applications (eg. Thermal curtains, Habitable Crew Compartment)**
  - −Data gap in electrical /electronics
- **SSP elements identified following PBDE-containing materials**
  - −Polyolefin based heat-shrinkable tubing reformulated with **deca-BDE *(Orbiter/Logistics)***
  - −Self extinguishable two part epoxy containing **pent-BDE *(Orbiter)***
  - −**Deca-BDE** in electronic molding compound ***(Space Suits)***

Identifying BFRs/PBDEs in materials may seem as if "searching for a needle in a haystack".

SIRMA Risk Statement

"Given the fact that some Polybrominated Diphenyl Ethers (PBDEs) have been banned in the European Union and are facing increasing regulation in the United States, there is a possibility that these PBDEs may be replaced without notification and with a potential decrease in materials performance or flame retardancy."

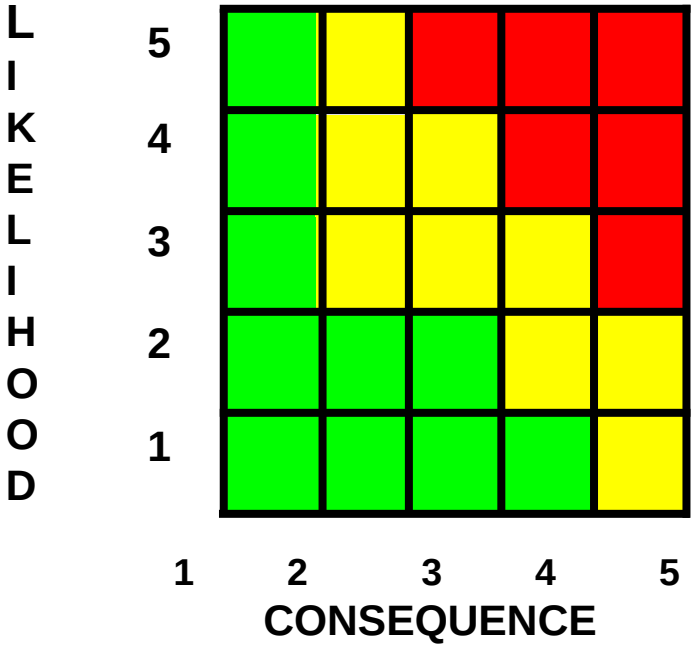
SIRMA : Shuttle Integrated Risk Management Application

Risk Scenarios

PBDEs used in SSP applications are replaced without notification resulting in:

1. ***Reduction in Flame Retardancy.***
2. ***Reduction in Liquid Oxygen (LOX) Compatibility.***
3. ***Decreased Material Performance.***

SSP Risk Scorecard



Green - Low Risk	
Yellow – Medium Risk	
Red – High Risk	
Likelihood	**Consequence** •*Safety* •*Mission Success* •*Supportability* •*Schedule* •*Cost*

BFR Risk for SSP Elements & Organizations

External Tank

Scenario	Score
1	N/A
2	N/A
3	N/A

Note: N/A (Not Applicable)

Reuseable Solid Rocket Motors

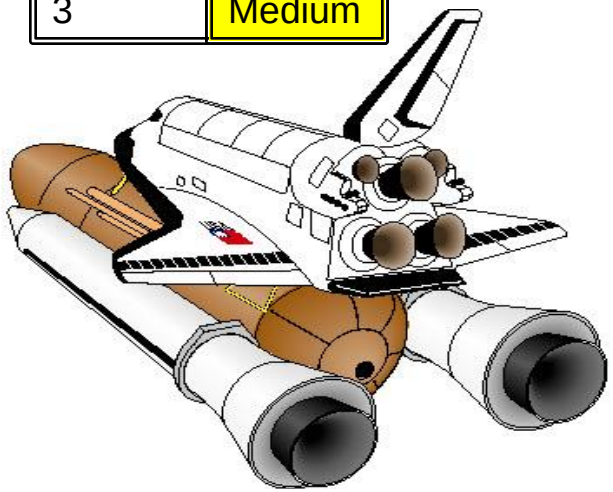
Scenario	Score
1	N/A
2	N/A
3	N/A

Ground Support

Scenario	Score
1	Low
2	Low
3	Low

Orbiter

Scenario	Score
1	Medium
2	Low
3	Medium



Space Shuttle Main Engines

Scenario	Score
1	Low
2	N/A
3	Low

Solid Rocket Boosters

Scenario	Score
1	Low
2	N/A
3	Low

Flight Crew Equipment

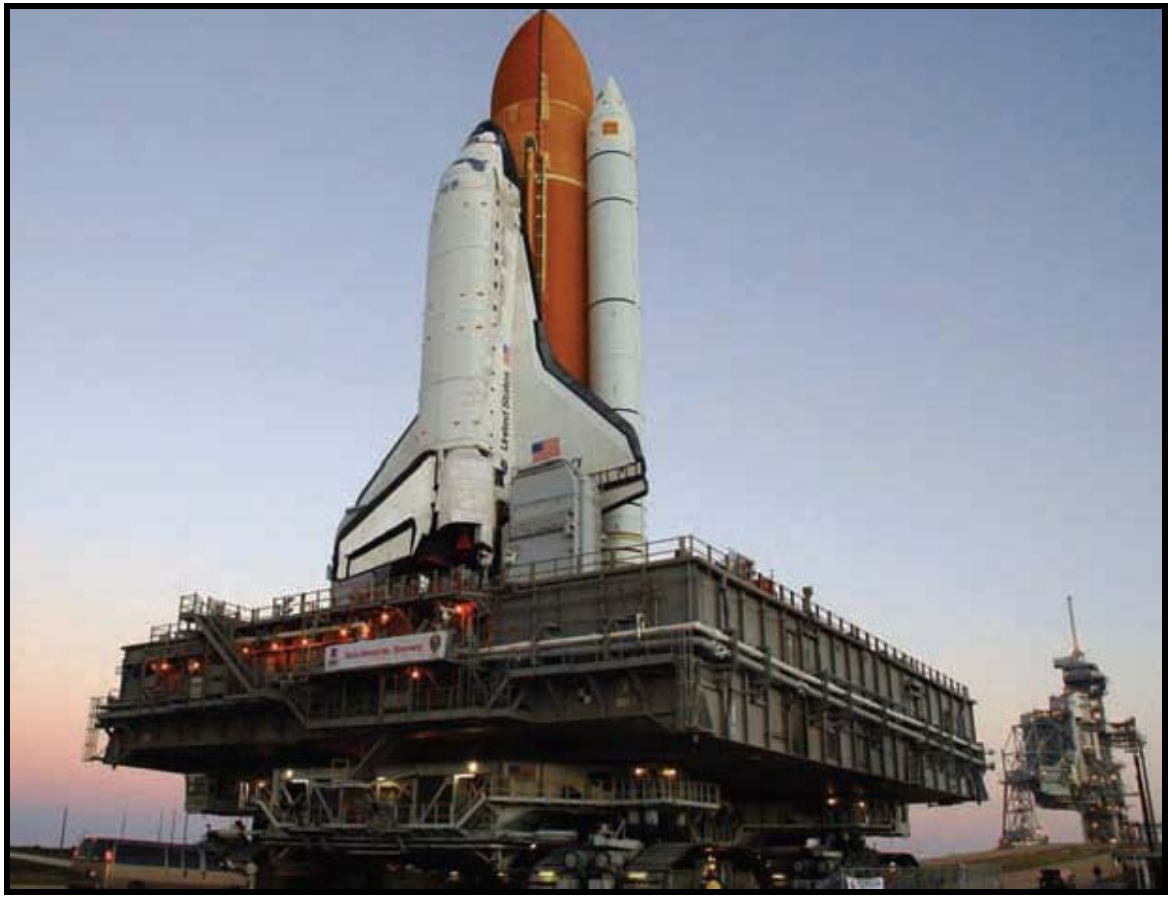
Scenario	Score
1	Medium
2	N/A
3	Medium

Space Suits & EMU

Scenario	Score
1	Low
2	N/A
3	Low

BFR Risk : “Big Picture”

- **SSP is nearing completion and many long- term procurements are completed (e.g. stockpiles).**
- **SSP elements /organizations have materials acceptance and mitigation practices in place.**
- **Risk assessment does not identify a red risk (high) from the reformulation of materials containing PBDEs.**
- **Most elements scored green (low) for risk scenarios.**
- **Orbiter,& Flight Crew Equipment scored yellow (medium) for certain risk scenarios.**
- **BFR risk was recently accepted due to small risk, available stockpiles and current schedule.**
- **This risk is maybe higher for follow-on space transportation programs: increasing emphasis on regulation of deca-BDE.**



Space Shuttle on Mobile Launch Crawler

SSP Mitigation Practices

SSP Elements are utilizing several mitigation approaches and practices to minimize unforeseen risks from materials that have been reformulated with different PBDEs or different BFRs altogether.

- **Inspection During Receiving**
- **Chemical Fingerprinting**
- **Materials Acceptance Testing**
- **Materials Performance Testing**
- **Communication with suppliers / vendors on product reformulation schedules.**

- **Flammability Batch Testing**
- **Requalification of Materials with Alternate PBDEs or BFRs**
- **Qualification of Replacement Materials**
- **Implementation of Additional Flame Retardant Measures**

Mitigation: *Orbiter, Flight Crew & Space Suits*

- **Orbiter:**
  - **Heat shrinkable tubing was reformulated with a Deca-BDE. The following mitigation practices were incorporated:**
    - ✓ ***Materials Performance Testing*** **: Flammability Testing was conducted on the reformulated tubing. The testing resulted in a lower flammability rating for the reformulated tubing, however, the rating was still acceptable for the Orbiter Project in the "as-used" environment.**
  - **A self-extinguishable two part epoxy, contained Penta-BDE. The mitigation approach was:**
    - ✓ ***Qualification of a Replacement Material*****: Replacement epoxy does not contain PBDEs.**
- **Flight Crew Equipment (FCE):**
  - **FCE utilizes several mitigation approaches due the large potential for reformulation of commercial –off-the-shelf hardware / materials :**
    - ✓ **Additional flame retardant measures**
    - ✓ **Stowage/handling requirements**
    - ✓ **Materials Acceptance/ Performance Testing on higher criticality component systems**
      - **- NASA, Military, and Commercial Industry Specifications are utilized**
- **Space Suits**
  - **Molding compound contains Deca-BDE.**
    - ✓ **Space Suits is stockpiling the molding compound as a mitigation strategy.**

Conclusion

- The reformulation of materials containing PBDEs and the potential impact to SSP was a formal SEA issue.
  - Foams, Epoxies, Tapes, Electronics and Electrical Components.
- The SEA-BFR Sub-Team performed a risk assessment on the potential impact to SSP from the reformulation of materials with different PBDEs or different flame retardant additives.
  - Medium (Yellow) was highest risk score for an SSP element.
- The SSP elements are implementing mitigation practices.
- Increased monitoring and regulation of PBDEs may have a greater impact for follow-on Programs and the existing International Space Station.

Contact Information

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BACK-UP

Recent Regulation

December 17, 2009:

- **EPA announced a 3-year voluntary phase-out of Deca-BDE for use as flame retardant.**
  - **Resulted from negotiations with industry.**
- **EPA has following concerns about continued use of Deca-BDE**
  - **Persistent in the environment.**
  - **Potentially causes cancer.**
  - **May impact brain function.**
  - **Can degrade to more toxic chemicals.**
- **To date, BFR Sub-Team has identified only 2 SSP materials containing Deca-BDE**
  - **Tubing, Molding Compound**

European Union Regulations

- **RoHS:** ***Restriction of Hazardous Substances***
- **WEEE:** ***Directive on Waste Electrical and Electronic Equipment***
- **EU Directive/Water Policy:** ***Establishes a listing of 33 substances in the field of water policy for monitoring or phase-out***
- **24th Amendment:** ***Restricts the marketing and use of certain dangerous substances***
- **4th Amendment:** ***Prohibits use of Polybrominated Biphenyl (PBBs) in textile applications***

Flammability Requirements

- **Flammability ratings for materials incorporate the following test results / test observations**
  - **Burn length of material**
  - **Self extinguishing properties**
  - **Ignitability**
  - **Propagation paths**
  - **Heat release**
  - **Smoke obscuration**
- **If a material fails to meet the NHB 8060.1or NASA STD 6001 requirements, two options may exist**
  - **Materials Usage Agreement for “as used” environment/condition**
  - **Waiver**