Sustainable Flame Retardant Development For Aircraft Cabin Safety

Susan D. Landry – susan.landry@albemarle.com
Albemarle Corporation

2009 Net Sales - $2.0 billion

POLYMER SOLUTIONS
Electronics, Construction, Packaging, Automotive, National Security
- Flame-retardants
- Antioxidants
- Curatives
- Stabilizers (Stannica LLC)

CATALYSTS
Energy, Transportation, Packaging
- FCC
- HPC
- Polyolefin and Chemical Catalysts
- Alternative Fuel Technologies

FINE CHEMICALS
Agrochemicals, Oilfield chemicals, Solvent cleaners, Paper chemicals, Biocides…
- Fine chemistry services
- Pharmaceuticals
- Bromine chemicals
- Other industrial specialties

We have a broad, innovative Flame Retardant Portfolio
- Bromine
- Mineral
- Phosphorus
Balanced and Far Reaching

- Consumer Electronics 16%
- Const/Furnish 13%
- Auto/Trans 8%
- Household/PC 3%
- Pharma/Nutr 6%
- Ag Science 5%
- Energy/H2O 6%
- Chem Scv 7%
- Fuel Quality 17%
- Fuel Conversion 11%
- Packaging 5%
- Other 3%

% of 2008 Net Sales

Over 4,100 employees, in over 45 facilities, serving customers in more than 100 countries
Why are Flame Retardants Needed?

- Flame retardants are used to help:
  - Prevent ignition
  - Delay the spread of fires
  - Delay the time of flashover to enable people time to escape

Toronto, Canada, August 2, 2005: Flame retardants were credited with increasing escape times for all 309 passengers from this jet, which was ultimately completely consumed by fire.

Washington Post, Aug. 5, 2005

Fire Safety is a challenge, but is achievable in home, office, commercial, and transportation environments
Why are Flame Retardants Needed?

- Fire prevention is essential from a number of perspectives:
  - Protection of life
  - Protection of property and the environment
  - Prevention of immediate local pollution to air and water
  - Prevention of lesser-known long-term environmental effects

Combustion gases generated during fires (whether or not flame retardants are present) that contribute to acute toxicity include CO, HCN, HCl, and acrolein. Carbon monoxide is responsible for > 90% of all fire deaths.*

The most important pollutants generated in fires are Polycyclic Aromatic Hydrocarbons (PAHs) and polyhalogenated dibenzodioxins and furans (PHDDs/PHDFs). Measurements have been made in large fires and have shown that the PAHs have an up to 500 times higher cancer risk than the PHDDs/PHDFs. PAHs are generated in all fires and many are carcinogenic compounds.*

Common Flame Retardant Classes

- Halogenated
  - Brominated
  - Chlorinated
- Mineral
  - Al
  - Mg
- Phosphorus
- Others...

- Based on natural elements
- There are many different flame retardants in each of these classes
- Each individual flame retardant has its own unique set of environmental, human health, physical, and chemical properties
- The distinct nature of individual flame retardants requires that each be treated on its own merits
Common Flame Retardants

- Decabromodiphenyl ether – Deca-BDE
  - Electronics plastic parts, wire & cable, textile backcoating
- Tetrabromobisphenol A – TBBPA
  - Printed wiring boards (used in laminates – fully reacted with epoxy resins) and some plastic parts
- Hexabromocyclododecane – HBCD
  - Polystyrene foam and textile backcoating
- Other Br, P, or Cl FRs
  - Housings, PWB, connectors, wire & cable, adhesives, PU foam
- Mineral Flame Retardants
  - Wire & cable
- Antimony Trioxide - Sb$_2$O$_3$
  - Synergist typically used with additive BFRs
North American Regulator Activity

- State-by-state regulations - limited number of flame retardants
- TSCA Reform
- EPA
  - “Chemicals of Concern” Action List announced Dec 2009
    - Include phthalates, short-chain chlorinated paraffins, polybrominated diphenyl ethers (PBDEs), and perfluorinated chemicals, including PFOA
  - Process could lead to risk reductions actions under section 6 of TSCA
  - EPA also announced that three companies agreed to phase out Deca-BDE
  - Reinforcing the Deca-BDE phase-out – with requirements to ensure that any new uses of PBDEs are reviewed by EPA prior to returning to the market.
  - “Polybrominated Diphenyl Ethers (PBDEs) Project Plan”
  - High Production Volume (HPV) Challenge (~2200 HPV chemicals)
  - Design for Environment (DfE) program
    - Partnership with a broad range of stakeholders - Several have and are currently including flame retardants
    - Upcoming DfE will review Deca-BDE alternatives
North American Regulator Activity

- CA – Green Chemistry
  - On June 23, it was announced that “The Green Chemistry Draft Regulation for Safer Consumer Products” was now available for review and comment (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/gc_draftRegs.cfm)
  - The draft regulation specifies the processes for DTSC to scientifically and systematically identify and prioritize chemicals and consumer products, for manufacturers to conduct alternatives assessments, and for DTSC to impose regulatory responses for alternatives selected by manufacturers.
  - DTSC may revise the draft regulation based on comments received and will release the revised draft following the July 15 comment deadline. The formal Administrative Procedures Act (APA) rulemaking process will begin with the release of that draft.

- Canada - Implementation of Chemical Substances Plan
June 2, 2010 Vote

- European Parliament Environmental Committee voted to support amendments that require further evaluation instead of a ban on the use of certain organobrominated materials and PVC in EEE
- MEPs voted in favor of an open scope (all EEE would be covered by the legislation, unless specifically excluded)
  - Exclusions recommended
  - Renewable energy generation
  - Certain large-scale installations and industrial tools
  - Materials for military purposes and vehicles
- MEPs also called for a ban on nanosilver and carbon nanotubes and that other EEE material containing nanomaterials should be labelled (manf also supply safety data to the EC)

Next Steps - Amendments will now

- Be considered by the full plenary session of the European Parliament
- Also has to be agreed on by the EU Council of Ministers to become law
EU – RoHS Recast & flame retardants

Recast Processes Timeline

Council of the Member States

Dec 2008 EC proposal

Nov 2009

Mar 2010

Apr 2010

June 2010

Oct 2010

End 2010

2011

Regular RoHS & WEEE working group meetings

Common position at the Council?

Final agreement?

European Parliament

Rapporteur

Rapporteur’s draft report

Deadline for amendments

Final draft report

Debate in EP Environment committee

Environment committee on the report

Plenay vote on the report

Final Environment committee report

Final EU Parliament report

Final EU Parliament report

Final agreement?
Flame retardants have already been through an official EU risk assessment under regulation 793/93 (EC). Risk assessment conclusions are recognised by REACH.

**No restriction for 5 substances**
1 substance classified as PBT, 1 substance classified as CMR cat. 1-2

<table>
<thead>
<tr>
<th>Substance</th>
<th>Finalized Year</th>
<th>Category</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deca-BDE</td>
<td>2005</td>
<td></td>
<td>No restriction on use</td>
</tr>
<tr>
<td>TBBPA</td>
<td>2008</td>
<td></td>
<td>No restriction on use</td>
</tr>
<tr>
<td>HBCD</td>
<td>REACH transitional system</td>
<td>PBT (REACH Authorization)</td>
<td></td>
</tr>
<tr>
<td>TCPP</td>
<td>2008</td>
<td></td>
<td>No restriction on use</td>
</tr>
<tr>
<td>TDCP</td>
<td>2008</td>
<td></td>
<td>No restriction on use</td>
</tr>
<tr>
<td>V6</td>
<td>2008</td>
<td></td>
<td>No restriction on use</td>
</tr>
<tr>
<td>TCEP</td>
<td>REACH transitional system</td>
<td>CMR cat. 1-2 (REACH Authorization)</td>
<td></td>
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</tbody>
</table>

DecaBDE = Decabromodiphenyl ether
HBCD = Hexabromocyclododecane
TBBPA = Tetrabromobisphenol A
TCPP = tris(2-chloro-1-methylethyl) phosphate
TDCP = tris[2-chloro-1-(chloromethyl)ethyl] phosphate
TCEP = Tris(2-chloroethyl) phosphate
V-6 = 2,2-Bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate)
Albemarle committed to register all its FRs portfolio under REACH

- First deadline of 1st Dec. 2010 will be met for the 28 high volume substances
- **TL-10ST**, Albemarle’s TL-10ST (2,2-Bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate)) has successfully completed registration (REACH Registration # 01-2119419991-33-0000)
REACH Flame Retardant Summary

- **HBCD (Hexabromocyclododecane)**
  - Classified as a PBT - On the 1st Candidate List for Authorization
  - Used in EPS & XPS, with no available alternatives
    - Authorization is being sought for this application due to the importance of insulating foam
    - Application for Authorization due mid-2012
  - Current sunset date is late 2013 for all applications without Authorization

- **TCEP (Tris(2-chloroethyl) phosphate)**
  - Classified CMR cat. 1-2 after EU risk assessment
  - Not sustainable under REACH - alternatives available for all uses
Informed Substitution

Informed Substitution Goals

- Minimize likelihood of unintended consequences
- Choose a course of action based on the best environmental and human health information that is available or can be modeled

Critical Decision Elements

Alternatives should:
- Be technologically feasible;
- Deliver the same or better value in cost and performance;
- Provide an improved profile for health and environmental issues;
- Account for economic and social considerations; and
- Have potential to result in lasting change.
Deca-BDE Phase-Out

- Albemarle will phase out production and importation of Deca-BDE
- Our commitments to EPA include the following:
  - We will stop manufacturing Deca-BDE by December 31, 2013

<table>
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<tr>
<th>End-Use Application</th>
<th>Deadline for completion of Deca-BDE phase-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire &amp; Cable (except transportation or military)</td>
<td>December 31, 2010</td>
</tr>
<tr>
<td>All other uses (except transportation or military)</td>
<td>December 31, 2012</td>
</tr>
<tr>
<td>Transportation and military uses</td>
<td>December 31, 2013</td>
</tr>
</tbody>
</table>

- We will submit to EPA annual progress reports
- After the phase-out period, EPA intends to impose additional Deca-BDE testing requirements on remaining producers/importers
- After the phase-out period, EPA intends to impose a “significant new use rule” or SNUR on Deca-BDE and articles containing Deca-BDE
SAYTEX® 8010 Flame Retardant

- Most widely applicable alternative to Deca-BDE
  - Almost a direct drop-in replacement
  - UK Risk Evaluation in 2007 recommended that no risk reduction measures be taken

- Performance benefits:
  - Thermal stability
  - Non-blooming
  - Recyclability
  - UV stability for color applications

- Dust Free Saytex® 8010
  - Pellet form with a proprietary, thermally stable binder
  - Reduces cost, enhances performance, and minimizes environmental emissions
Advantages of BT-93 (ethylene bis-tetrabromophthalimide):

- Excellent thermal stability, suitable for T4/T5 applications
- Outstanding electrical properties
- Non-blooming, even in polyolefins
- Superior UV light stability
- Efficient flame resistance
  - Contains 67% Bromine compared to 81% for Saytex 8010.
  - Despite lower Br content, BT-93 requires same wt.% loading as Saytex 8010 to achieve similar FR performance.
- Environmental profile
  - ROHS compliant
  - Not considered a “PBT” substance
  - Insoluble; excellent chemical resistance
Albemarle’s Polymer Solutions Market Segments

**Electrical Connectors**
- High performance, high thermal stability FR’s
- Polymeric

**Wire & Cable**
- Broad technology focus (Br, ATH, MDH)
- Leading position in EU
- New product in rollout phase

**Molded Thermoplastics**
- #1 deca replacement today (Saytex 8010)
- New technology launch in 2010
  - Polymeric
  - Easy to use
  - Broad range of applications

**Polyurethane Foams**
- Broad technology focus (Br-Cl-P)
- Production & Technical presence in fastest growing market
  - State of the art technology center
  - Manufacturing consolidation
Safety & Sustainable Use of Flame Retardants

- Flame Retardant Selection
  - Physical, Mechanical, and Flammability Properties; Stability; and Recyclability of Polymer Formulations
  - Commercial Availability of FR
  - Cost

- Human Health and Environmental Criteria
  - Meets Current Regulations
  - Meets Anticipated Regulations?

- How do you measure environmental impact of various FR’s in use?
  - Life Cycle Assessment
  - Carbon Footprint, Global Warming, Energy Consumption, Ozone Depletion, Air Acidification, etc…
Albemarle Sustainability Thoughts

- Fire Safety is an important societal good
- We are a fire safety company
  - ALB will provide the right solution; we do not limit ourselves to particular products or chemistries.
- The choice of technology used to achieve fire safety should be based on sound principles
  - Full life-cycle analysis
  - Non-toxic, non-bioaccumulative products
  - Consideration of environmental and societal impacts
- We must solve the end-of-life problem for products, including electronic products
  - Products should enable recyclability
### Energy Consumption

The calculations indicate that HIPS has the least environmental impact per kilogram produced. ABS comes second, and PC falls a distant third, coming in last in nearly all of the impact categories. The U.S. and European data are not that far off from each other. The final analysis to determine the best choice must be completed by factoring in the mass of each polymer needed for the specific application.
To achieve sustainability...

- **Our new product development will focus on**
  - Polymeric solutions, big molecules
  - Reactive products that become bound to the final polymer
  - Mineral products

- **Releases of all product to the environment must be minimized**
  - We will champion the implementation of measures throughout the supply chain to minimize emissions of persistent compounds
  - Engage distributors, customers, and competitors in programs such as VECAP to eliminate all products from the environment
The next generation of eco-friendly fire safety

GreenArmor™

• First product in our family of green solutions

• non-bioaccumulative
• superior toxicity profile
• excellent recycle capability
• exceptionally broad application profile

• Polymeric flame retardant

• Highly stable product lends itself to efficient recycling of plastics

• Emissions to the environment are minimized, when combined with other good practices such as the Voluntary Emissions Control Action Program
VECAP™ is an Industry Program that can be applied to all polymer additives to prevent potential emissions and save valuable raw material.

Eliminating Emissions To The Environment Is Of The Utmost Importance For Sustainability

- **Voluntary Emissions Control Action Program**
  - **Voluntary** – producer and user implemented
  - **Emissions** – identify sources of BFR emissions
  - **Control** – reduce, minimize and where possible eliminate emissions
  - **Action** – dynamic, continuous process
  - **Program** – focus on best practices to eliminate emissions
Reduce Levels of Environmental Emissions of Flame Retardants

**VECAP** addresses many stages of the Life-Cycle

- **Manufacturing**
  - Production
  - Packaging
  - Shipping

- **Processing**
  - Dust from unloading and feed operations
  - Leaks in feed equipment
  - Improper clean-up of spills

- **Waste disposal**
  - Residues in packaging
  - Poorly treated wastewater from system wash-outs
  - Waste not reprocessed
We are asking users to:

- Commit to **VECAP** Code of Good Practice
- Create and implement emissions reduction plan
- Perform self assessment and Mass Balance; develop baseline emissions to ensure progress is measurable
- Utilize third-party verification audits as needed
VECAP in Action – Best Available Practices for Handling Packaging

Problem

• Discarded packaging can retain small amounts of product
• Product has the potential to get into the environment, depending on end-of-life practices for empty packaging

Solution

**VECAP** Best Available Technique (BAT) for Emptying Packaging Document and Poster

These techniques can be applied to all polymer additives to prevent potential emissions and save valuable material for use, rather than waste
Conclusions

- Flame Retardants provide a valuable role in our society
  - Prevent ignition
  - Delay the spread of fires
  - Delay the time of flashover to enable people time to escape

- It is important that Flame Retardants are safe in use

- Regulations that are being developed worldwide provide the platform to achieve this goal with a level of confidence

- Emissions of polymer additives to the environment must be minimized

- GreenArmor™ is the first product in Albemarle Corporation’s Earthwise™ family of sustainable solutions
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