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Additives and Catalysts VOC Low-Emission Automotive Polyurethanes

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Performance Products

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Huntsman Performance Products

- Over 350 products
- 15+ chemical process technologies
- Over 900 customers
- Approximately 2 billion pounds of annual production capacity through many different chemistries
- 2020 revenues of USD 1 billion
- 10 manufacturing locations
- Approximately 800 associates worldwide

Key Products and Markets

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- **AMINES**: Leading global producer of specialty amines used in gas treating, fuel and lube additives, PU additives, coatings, adhesives and composites.
- **MALEIC ANHYDRIDE**: Largest global producer and supplier into markets such as unsaturated polyester resins (UPR), food, lube additives, and coatings.
- **CARBONATES:** One of the largest global producers of alkylene carbonates and the only producer in the US; used for high purity applications in electronics and as electrolyte solvents for lithium-ion batteries.

ADVANCED TECHNOLOGY
Battery, Electronics

COATINGS, ADHESIVES & COMPOSITES

CONSTRUCTION
UPR, Industrial Applications

FUELS & LUBRICANTS
Fuels , Lubes, Metalworking

GAS TREATING
Gas Processing Chemicals & Licensing

PU ADDITIVES
Amine Catalyst Technology

R&D Approach – How we do it

Strategy and areas of focus

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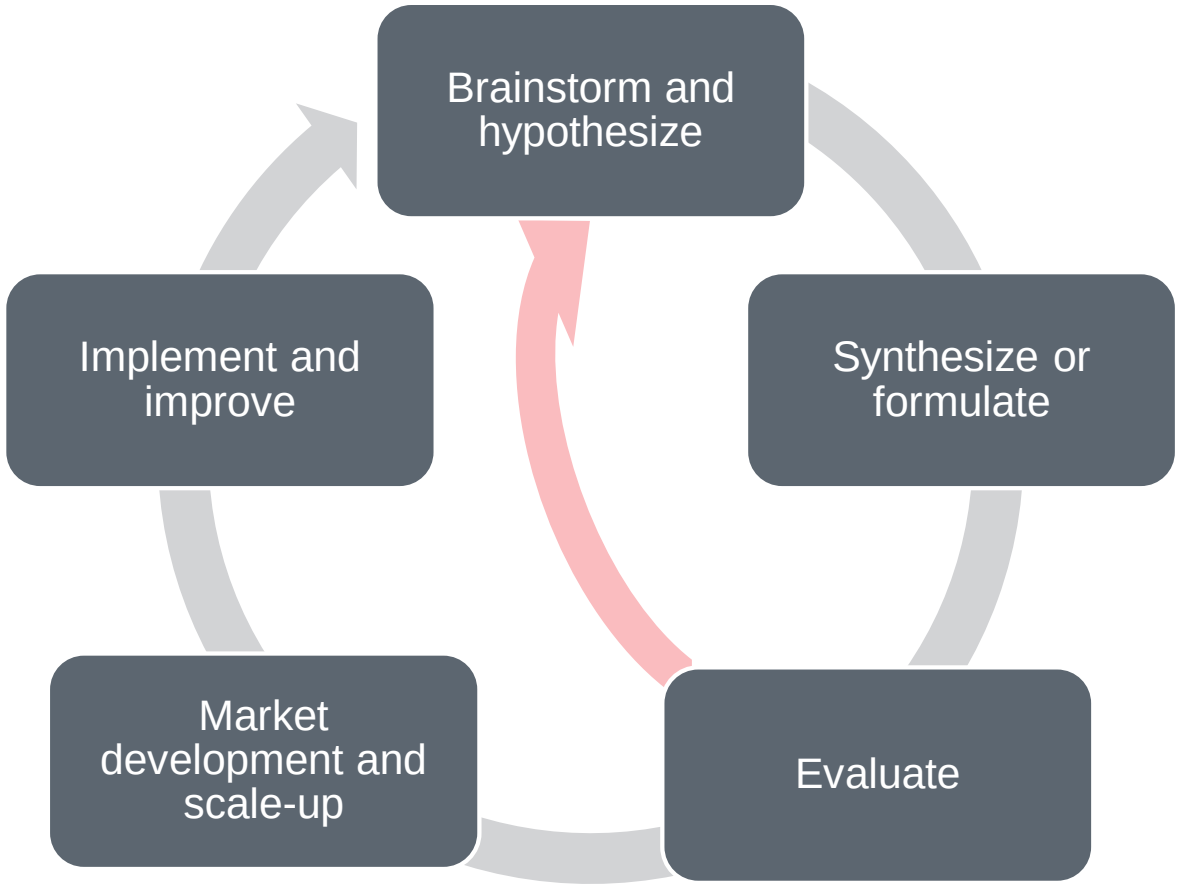
- Low-emission catalysts
  - Lower odor and VOCs
  - React into the foam (non-fugitive)
- Expanding chemistry portfolio
  - New tools for customers
  - New, differentiated molecules



- Aldehyde reduction strategies
  - Regulatory pressure to reduce aldehydes
  - Reduce aldehydes during and after foaming
- HFO-stable spray-foam catalysts
  - New blowing agents not stable
  - Large growth opportunity

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VOC Reduction Strategies

HPP Polyurethane Additives: A portfolio of innovative solutions

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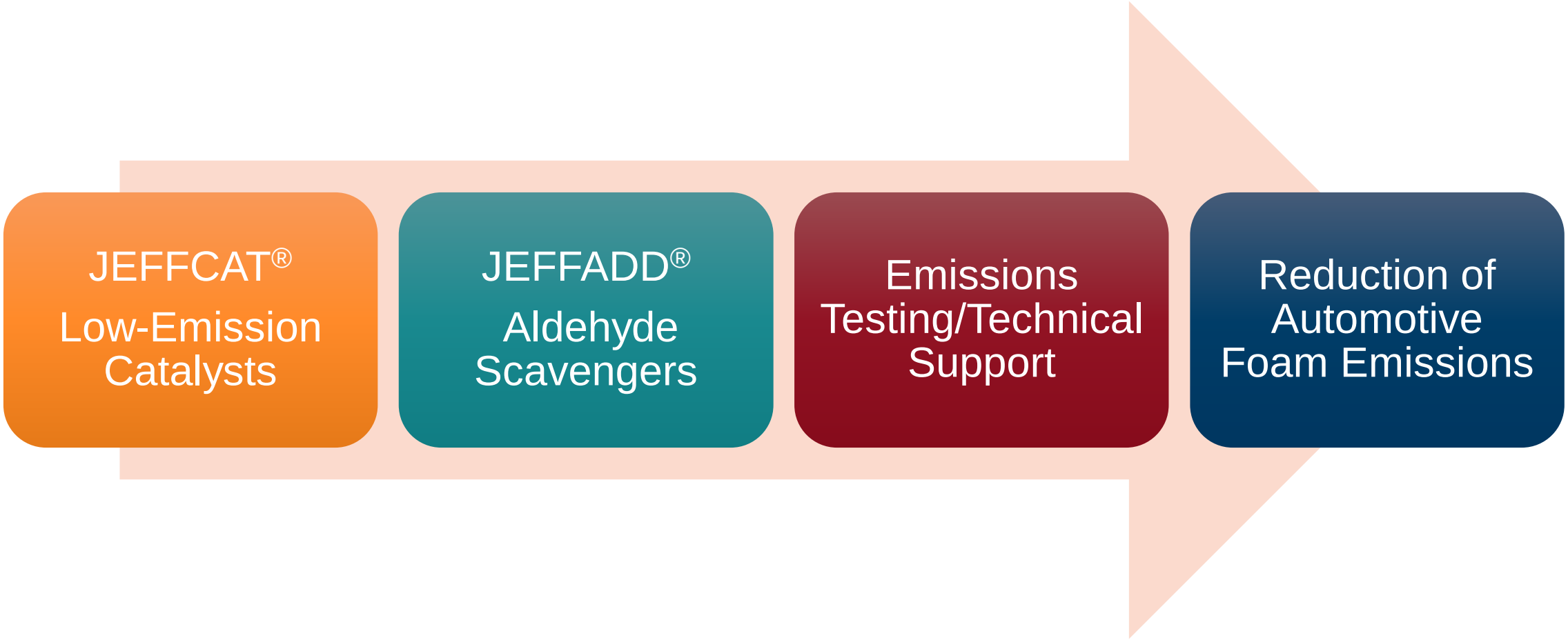

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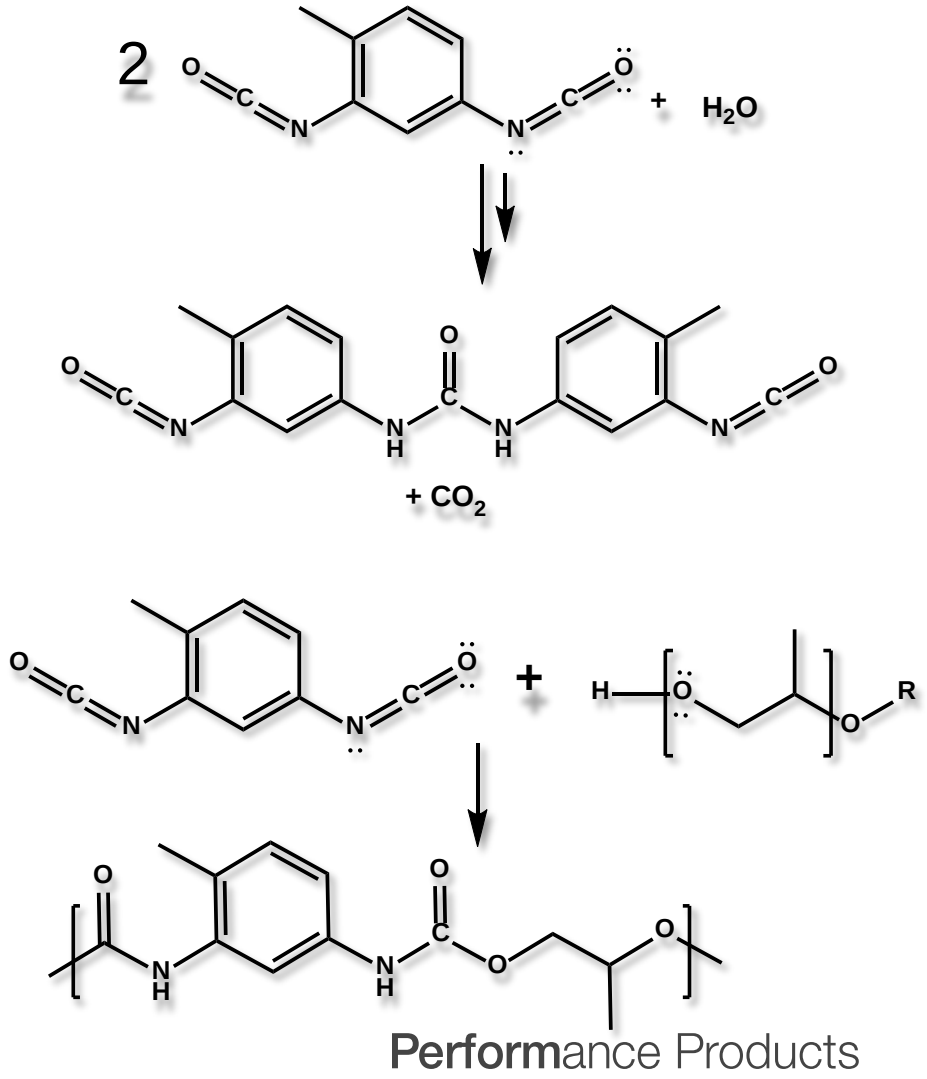
Polyurethane Foam Chemistry

Foam formation reactions

- Polyurethane foam formation is a balancing act between two reactions
  - Isocyanates reacting with water to produce CO_2 and a urea linkage
    - **“Blowing” reaction**
    - **Generates CO_2 gas that contributes to foaming**
    - **Also builds molecular weight**
  - Isocyanates reacting with polyols to form a polymer
    - **“Gelling” reaction**
    - **Needed to build strength to support rapidly expanding foam**
- These reactions happen in concert with each other
  - Too much blowing results in large splits or blow-holes, resulting in possible foam collapse
  - Too much gelling and the foam will be too closed, resulting in shrinkage and/or foam collapse
- How are these reactions controlled?
  - Catalysts!



JEFFCAT® Catalyst Portfolio

Blow / Gel balancing

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Newer Catalysts
- JEFFCAT® H-73
- JEFFCAT® LE-30
- JEFFCAT® LE-220
- JEFFCAT® LE-225
- JEFFCAT® LE-340

Delayed-Action Catalysts
- JEFFCAT® LED-103
- JEFFCAT® LED-104
- JEFFCAT® LED-204
- JEFFCAT® ZF-54

Formulated Catalyst Blends
- JEFFCAT® H-1
- JEFFCAT® LE-310
- JEFFCAT® LE-355
- JEFFCAT® Z-131
- JEFFCAT® ZF-53

Back-End Cure Catalysts
- JEFFCAT® TR-52
- JEFFCAT® TR-90

*blue = non-reactive/emissive
*green = reactive/non-emissive
*yellow = only low-emission under certain test conditions

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Polyurethane Foam

Macroscopic, microscopic, and atomic levels

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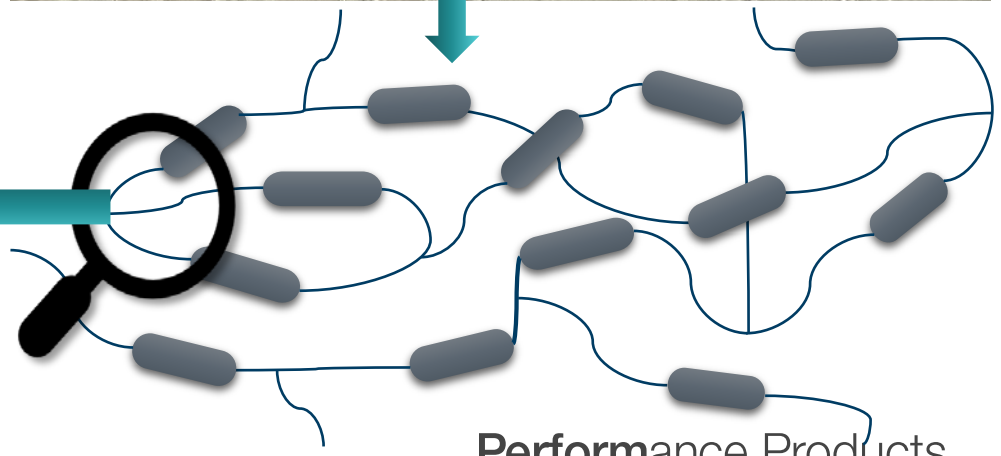
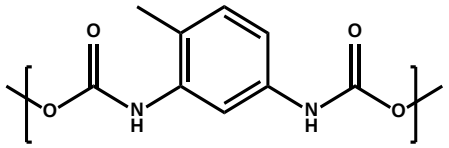


Hard segments =



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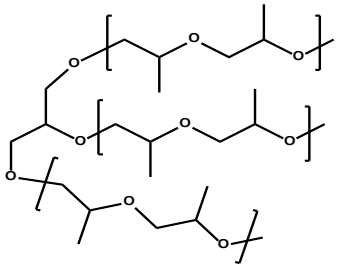

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JEFFCAT® Polyurethane Catalysts

The tuning knobs of the foam formation process

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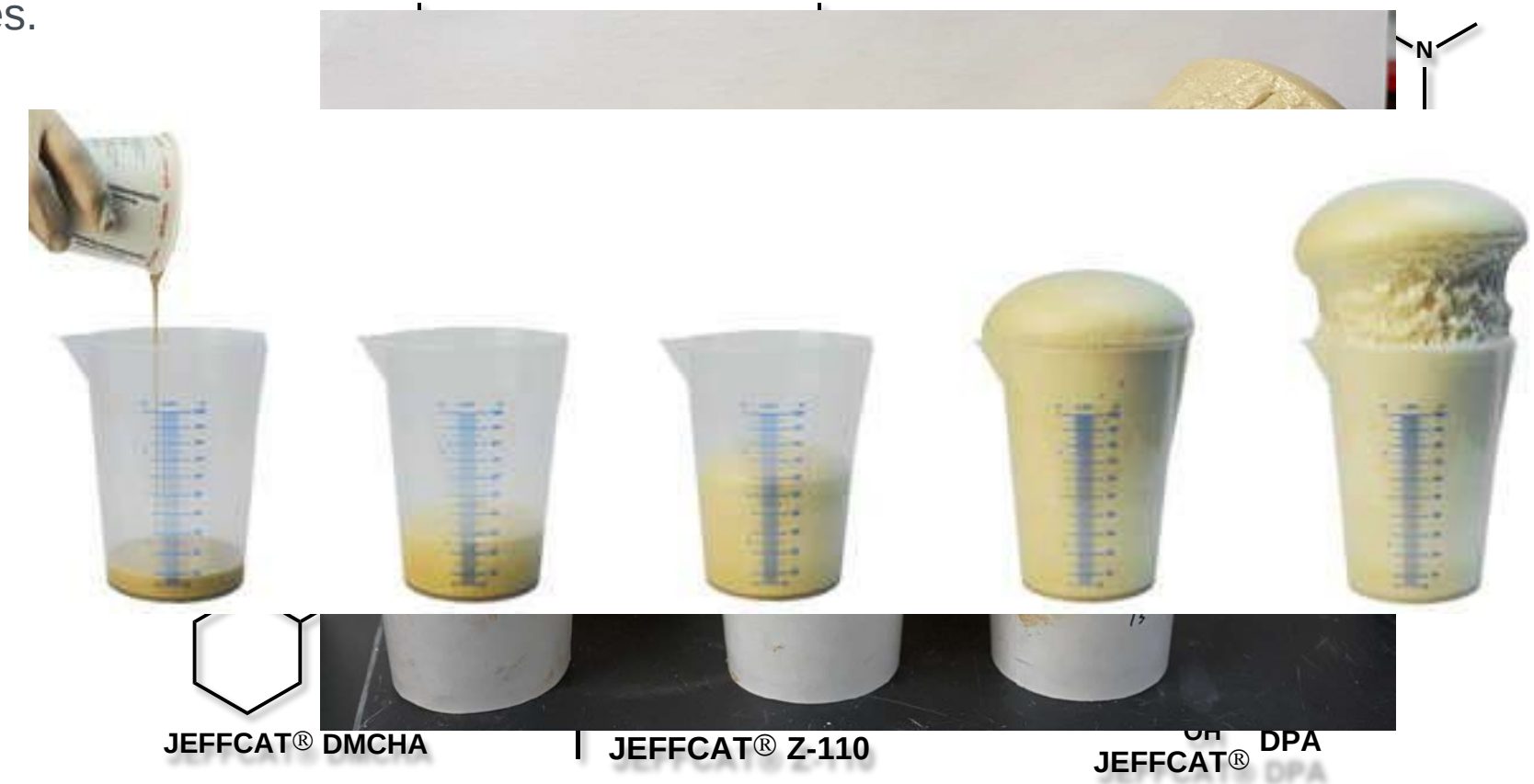
- Why are there so many JEFFCAT® catalysts???
- JEFFCAT® catalysts are a small part of foam formulations but have a drastic effect on foam processing and properties.

- Factors affecting catalyst function
  - Acid blocking
  - Alkalinity
  - Amine equivalent weight
  - Atom arrangement
  - End group
  - Mobility
  - Molecular structure
  - Nucleophilicity
  - Number of active centers
  - Solubility
  - Steric Hindrance
  - Volatility



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PU Foam Emissions

Background and Solutions

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Polyurethane Foam Formulations

Typical components in flexible foams and emissive considerations

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Component	Parts	Function
Isocyanate (TDI or MDI)	30 - 50	Reacts (A-side)
Base polyol	80 - 100	Reacts, controls physical properties
Secondary polyol	0 - 30	Addnl. physical properties
Silicone surfactant	0.5 - 1.5	Stabilizes foam and controls cell size
Tin catalyst	0.0 - 0.8	Promotes gelling reaction, synergy with amines
JEFFCAT® amine catalysts	0.5 – 2.0	Blowing and gelling reactions, synergy with tin
Auxiliary blowing agent	0 - 7	Density control, cooling, softness
Water	2 - 5	Blowing, urea reaction
Other additives	0 - 5	chain extenders, flame retardants, pigments, fillers

- **Formulations vary greatly depending on the specific type of foam, the machinery used, the desired physical properties, and the manufacturer's experience**

- **Flexible foam uses**
  - Automotive
    - **Seats, arm rests, head rests, chair backs, etc.**
    - **Can be molded or slab foam**
  - Furniture and Bedding
    - **Mattresses, sofa cushions, etc.**
    - **Standard or viscoelastic grades**
  - Carpet underlay

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- **Emissions from each component:**
  - Production impurities or foam reaction by-products such as MDA or TDA
  - Low MW glycols and aldehydes from alkoxylation process
  - Aldehydes and low MW silicones
  - Carboxylates like 2-ethylhexanoic acid
  - Non-reactive amines and aldehydes
  - Antioxidant by-products and flame retardants commonly observed

Polyurethane Catalyst Emissions

Catalyst volatility implications

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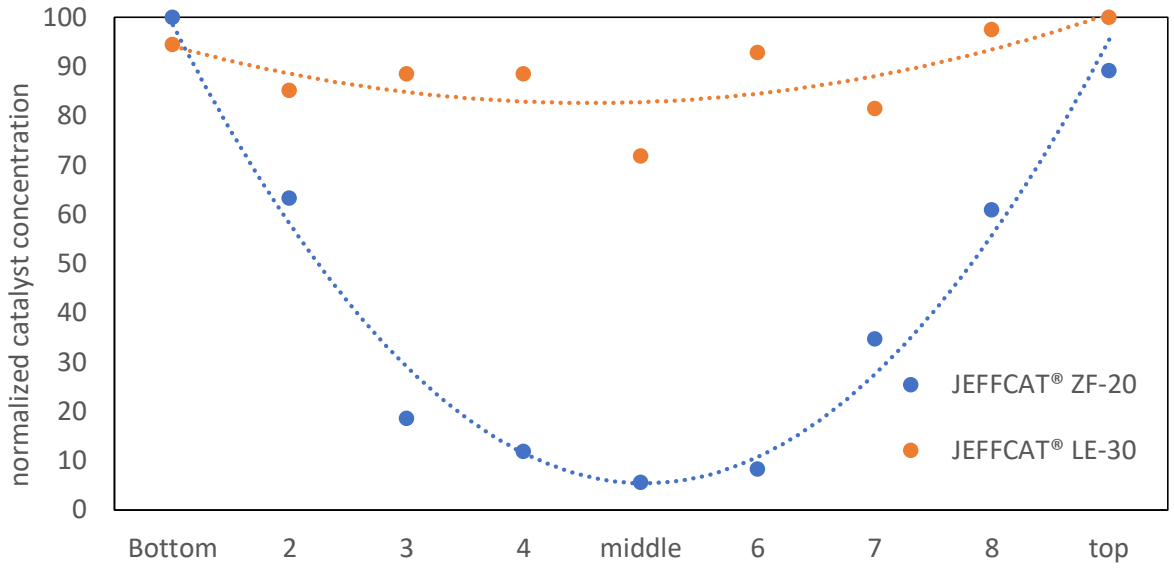
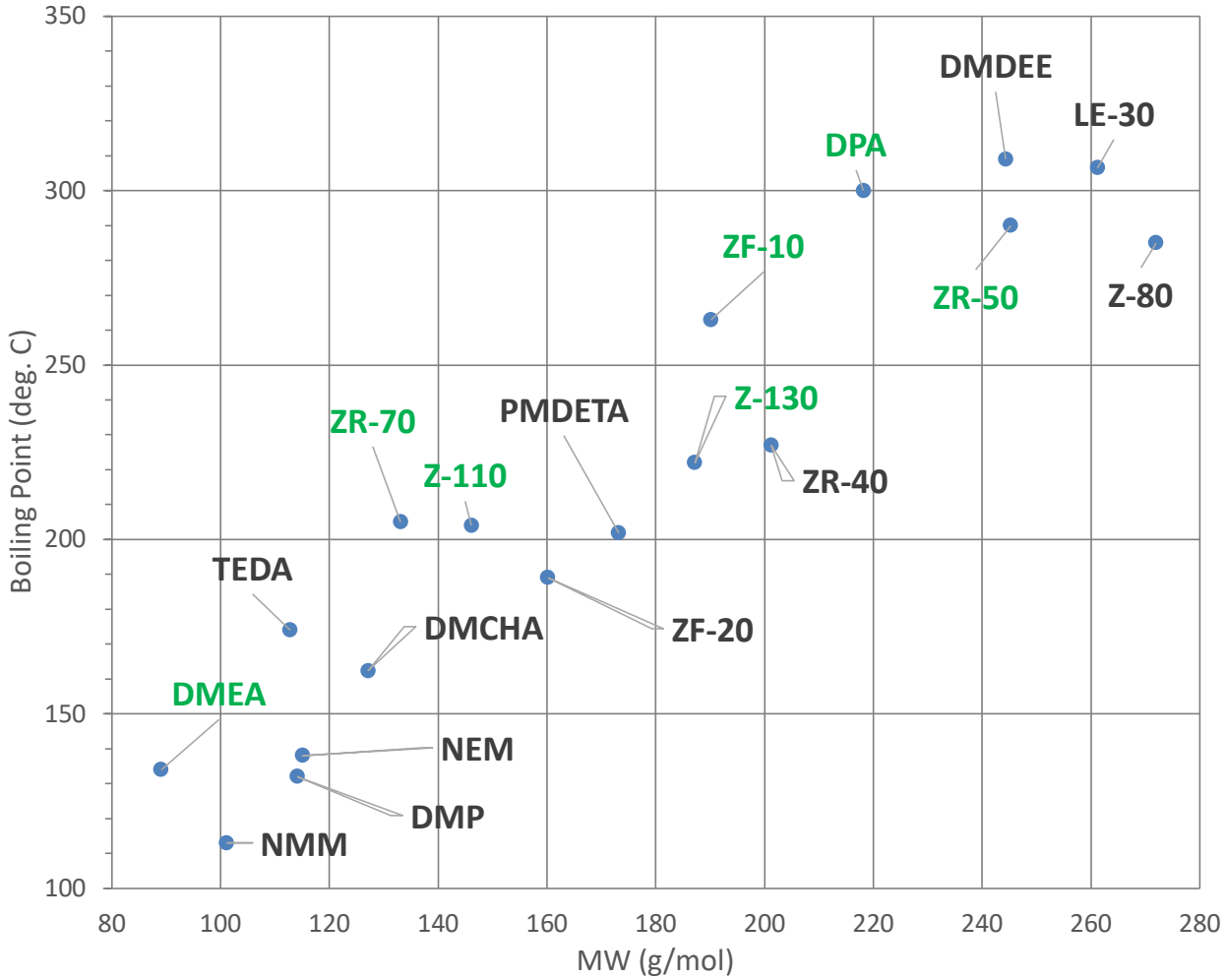
- Catalyst volatility *can* play a role in emissions and odor
  - Lower MW = lower boiling point and higher vapor pressure
  - Volatile catalysts migrate to the surfaces of the foam (can influence surface cure) – makes odor worse at surface
  - Less volatile catalysts migrate less
  - Reactive catalysts are not though to migrate





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JEFFCAT® ZF-10

Reactive vs. non-reactive emissions data

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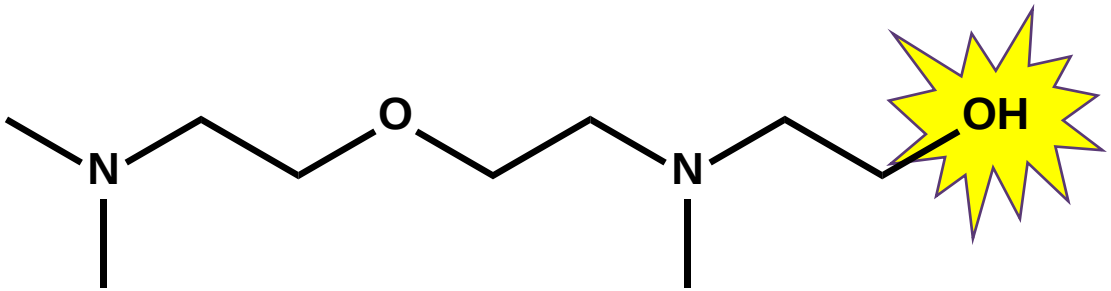
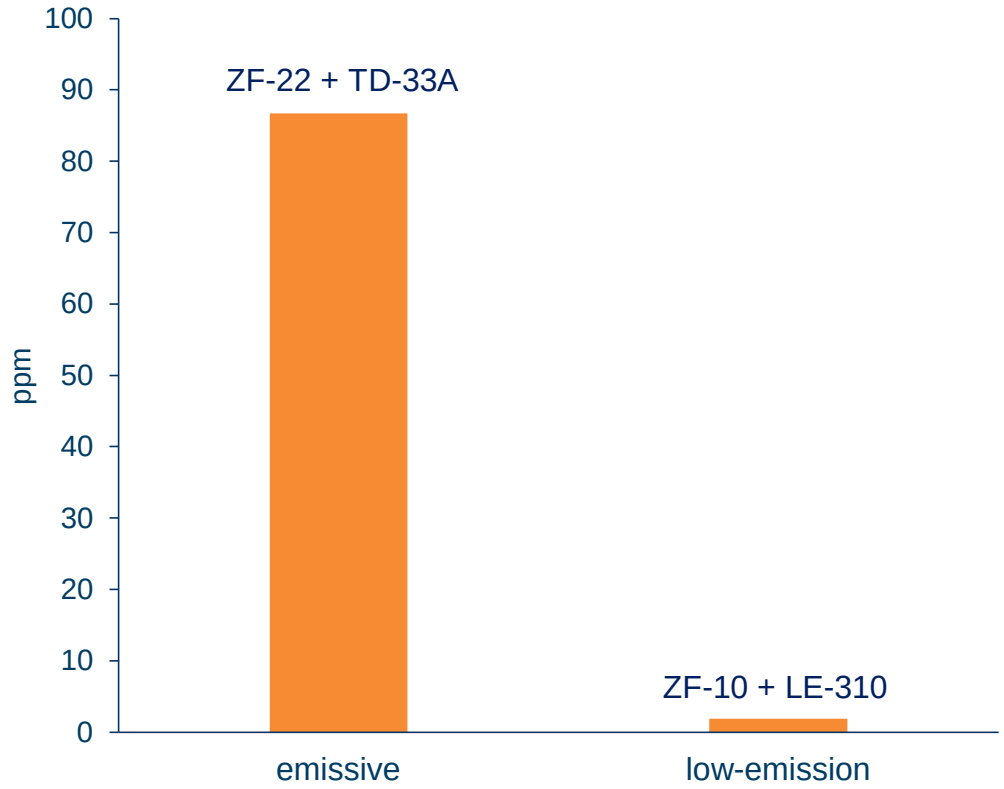


Typical Physical Properties

Boiling point, °C (°F)	255 (491)
Flash point, PMCC, °C (°F)	118 (245)
pH	11
Specific gravity, 20/20°C	0.95
Vapor pressure, mmHg, 20°C (68°F)	< 0.1
Viscosity, cSt, 25°C (77°F)	13
Water solubility (%)	> 10

- Flexible Foam

  Amine catalyst emissions
  - Lower absolute levels due to lower catalyst use rate



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Reactive, Low-Emission Gel-Biased Catalysts

JEFFCAT® LE-310, ZR-50, Z-81

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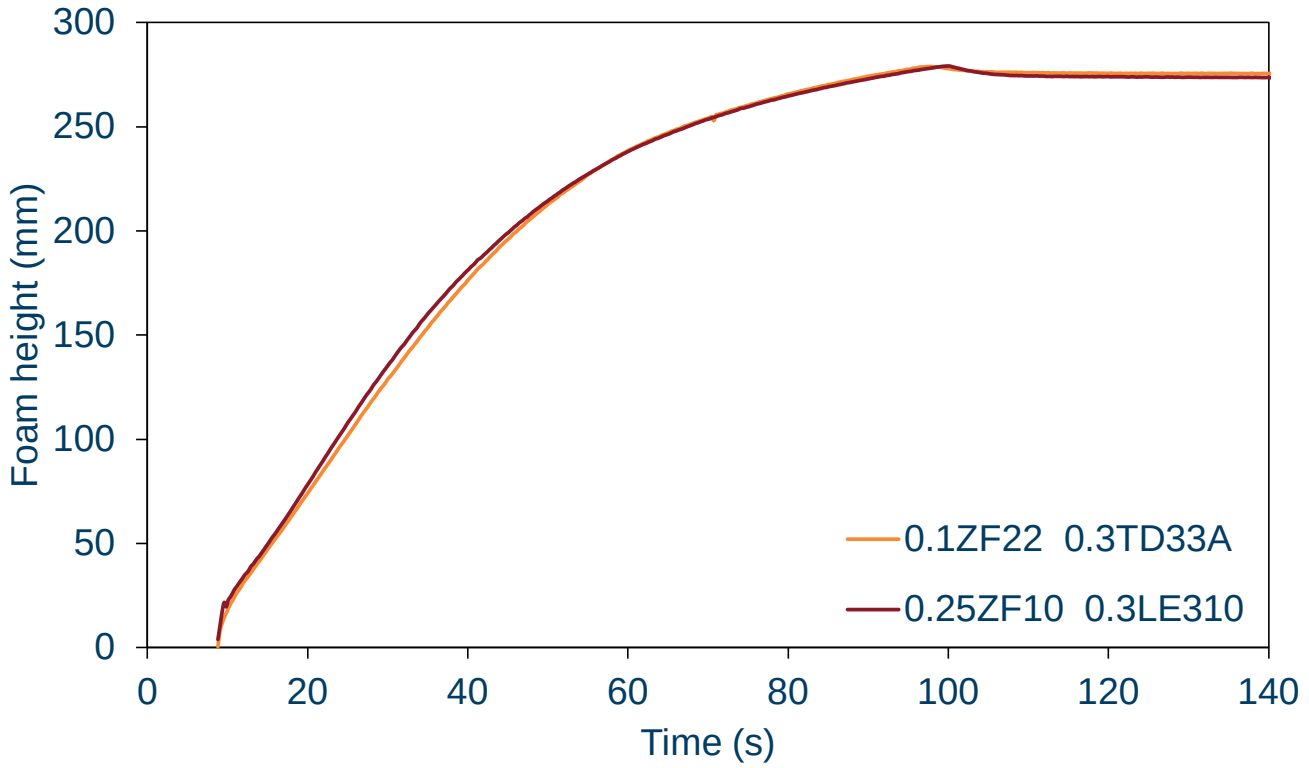
- JEFFCAT® LE-310 catalyst designed to be a close “drop-in” for JEFFCAT® TD-33A (or equivalent)
  - Combination with JEFFCAT® ZF-10 allows for almost exact reaction profile matching with standard emissive catalyst system that many formulators use
- JEFFCAT® DPA catalyst is another industry standard
  - Slower than JEFFCAT® LE-310, but more processing latitude
- Other LE gelling catalyst options
  - JEFFCAT® ZR-50, JEFFCAT® Z-131



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JEFFADD® AS-76 and AS-53

High-performance aldehyde scavengers

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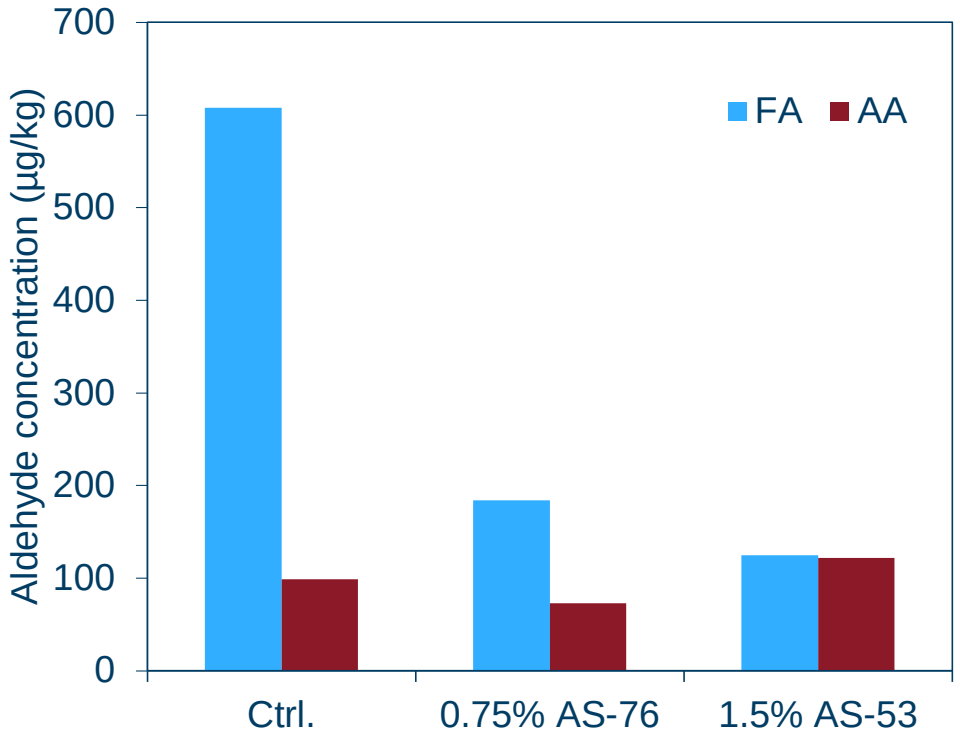
- JEFFADD® AS-76
  - Patented technology based on a partially neutralized, reactive polyamine[1]
  - Water-based system with no flammability concerns
  - Does not contribute to emissions (VDA-278)
  - Low usage rate of 0.75-1.0%
- JEFFADD® AS-53
  - Water-free and acid-free system for more sensitive polyol blends
  - Enhanced long-term stability in polyol formulations
    - o **No phase separation**
    - o **Optimal for systems that must be stored for long periods or without temperature control**



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(1) US Pat. US10472456B2

Delayed Action Catalysts

Background and Chemistry

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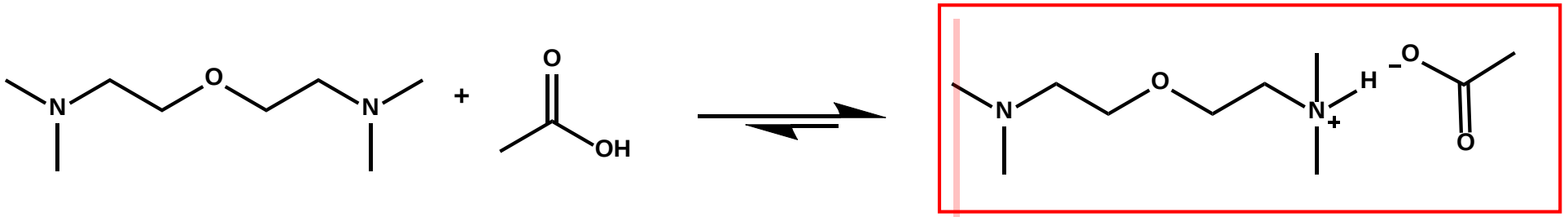
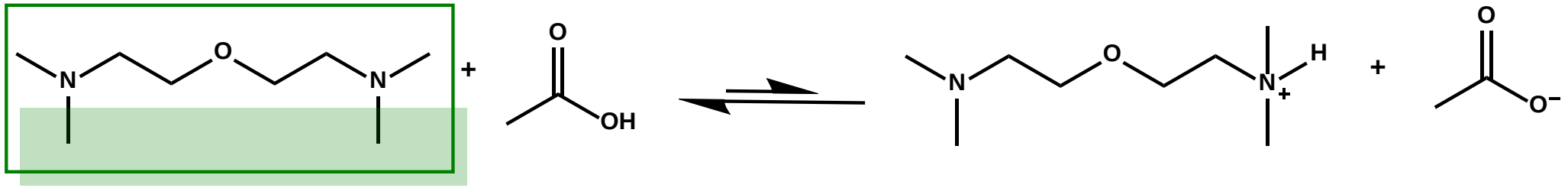
- Sometimes foam formation needs to be “delayed”
  - Filling cavities or molds
  - But, once the delay is achieved, reactivity needs to take off rapidly for quick de-mold times

At lower T, the "blocked" catalyst salt complex dominates



As T increases, equilibrium shifts to free catalyst and acid species



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Low-Emission Delayed Action Catalysts

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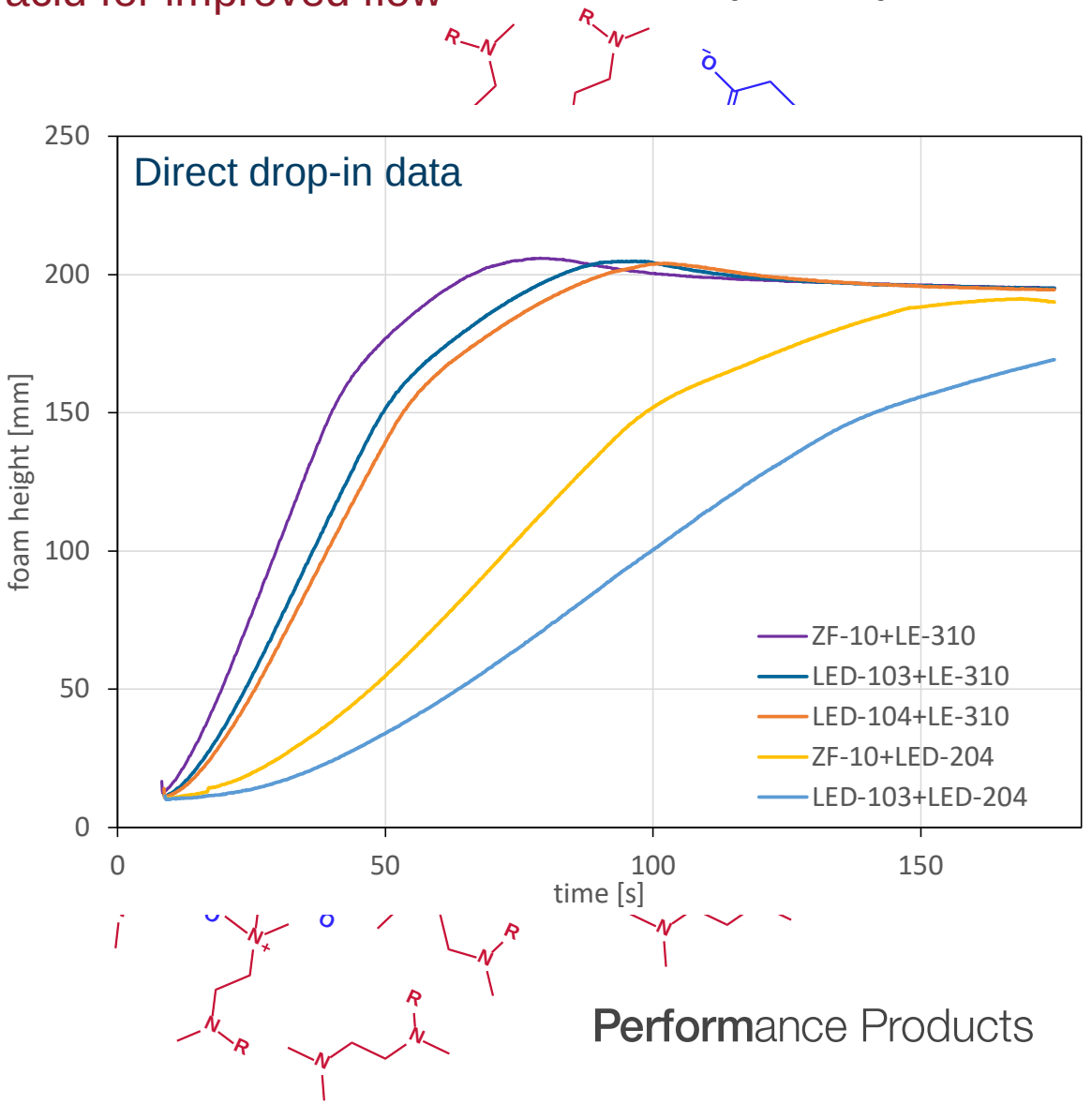
Amine catalysts pre-reacted with a zero-emission polymeric acid for improved flow

- JEFFCAT® LED-103
  - Industry standard LE blowing catalyst with a blocking level of 19%
- JEFFCAT® LED-204
  - Industry standard gelling catalyst with 50% blocking level
  - Significant delay when dropped in for JEFFCAT® LE-310
- **New Product**: JEFFCAT® LED-104
  - Industry standard LE blowing catalyst with higher blocking level of 50%
  - Stronger slow-down on front end of creaming reaction to keep viscosity ultra-low and promote flowability
- No contributions to emissions
- Polymeric acid shown to lower aldehyde levels in amine catalysts[1]
- Improvements in physical properties[2]



(1) *US Pat*. 9856344
(2) *Eur. Pat.* EP2106415B1

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JEFFCAT® LE-340

Low-odor gel catalyst

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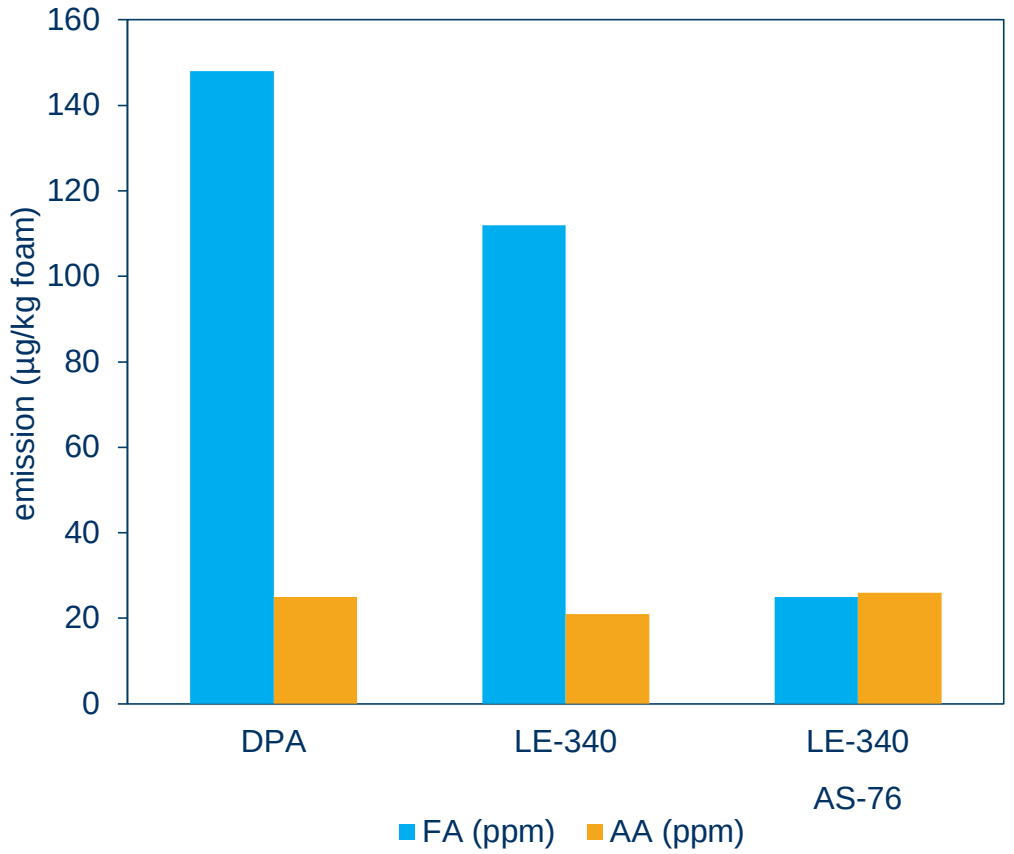
- Low-emission, low odor gel catalyst, 99% pure
- Paired with JEFFCAT® ZF-10 and JEFFADD® AS-76 for excellent low-emission, low-odor catalyst package
  - Excellent
- Reduces or eliminates amine odor in freshly cut foam
- Consistently < 50 ppm formaldehyde content in neat amine (not a spec)
- Designed for HR molded and polyether slabstock foams
- Typically used at 0.5-1.0 pbw in B-side

Typical Properties	Value
Flash point (closed cup)	135°C
Viscosity, 25°C	140
Density, 20°C	0.92 g/mL
Hydroxyl value	514 mgKOH/g



VDA-276-type chamber test

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Next-Generation Aldehyde Scavengers

Focusing on acetaldehyde and matching reactivity

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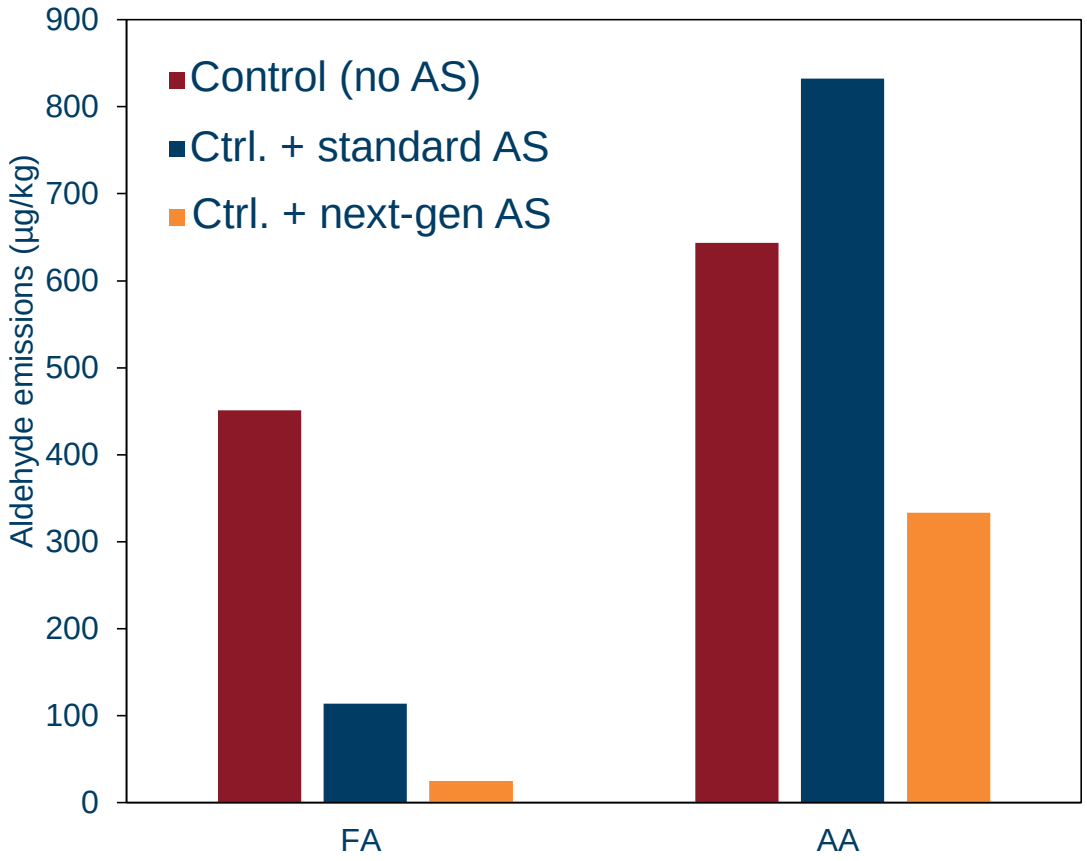
- Existing AS technology is established – it will take a significant improvement in one or two areas to create a new product
- Many amine-based aldehyde scavengers alter the reactivity of the system, which is not optimal and requires reformulation
  - Focus on keeping reactivity the same with next gen
- Acetaldehdye less reactive than formaldehyde, more difficult to scavenge
  - Requires different chemistry
  - Solution will require multiple mechanisms of scavenging in one product
- Promising new results indicate ultra-efficient formaldehyde scavenging *and* lower acetaldehyde



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Conclusions

Keeping the pipeline full of low-VOC solutions

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- Low-VOC amines and additives are core to advancing automotive foam technology
- HPP continues to develop solutions and improve on industry standards
  - Established low-emission catalysts
    - o **JEFFCAT® ZF-10 (blowing)**
    - o **JEFFCAT® LE-310 (gelling)**
  - New low-emission catalysts
    - o **JEFFCAT® LE-340**
  - New delayed action catalysts
    - o **JEFFCAT® LED-104**
  - New aldehyde scavenging technology
    - o **JEFFADD® AS-76**
    - o **Next-gen scavengers to tackle acetaldehyde emissions**

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