"The Anatomy of Sealants and their Relative Performance with Building Materials in Different Environments"

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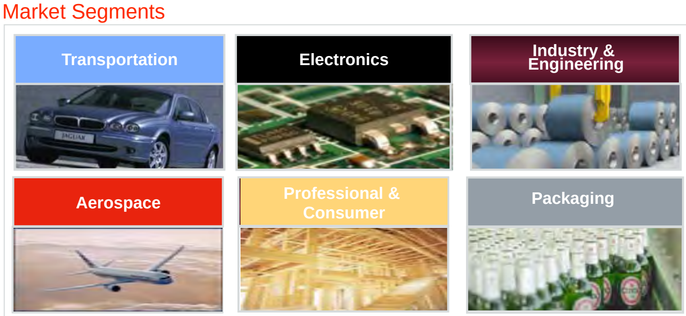
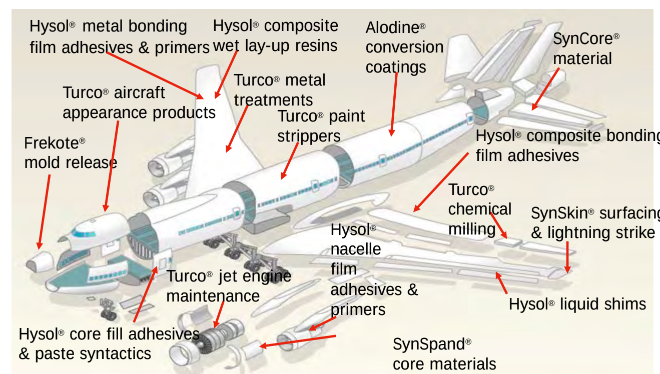
World's Largest Adhesive & Sealant Company

North American Adhesive Market Segments



Aerospace Example



Presentation Outline

- Sealant physical (movement) properties and chemistry.
- Types of Joint
- Thermo-mechanical Effects
- Sealant Use Considerations
- Sealant Failure Modes

Building Idioms Change Over Time

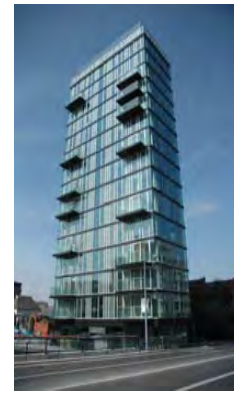
6-9th Century AD

- Exterior (walls 1.2 meters thick)

- Interior

21st Century AD

- Exterior



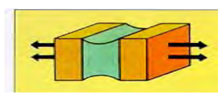
- Interior

Sag in wall –

Likely caused by harsh prevailing winds. Structure deformed over time to alleviate applied stress. High mass allows for high energy dissipation. **Lack of elasticity leads to permanent deformation**.

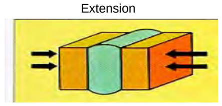
Types of Sealant Joint Movement

Sealant extension: Usually as temperatures drop materials shrink.



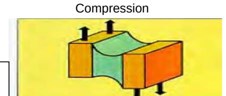
Extension

Sealant compression: Usually as temperatures rise materials lengthen or swell.

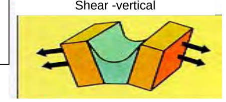


Compression

Heating / Cooling Effects



Shear -vertical



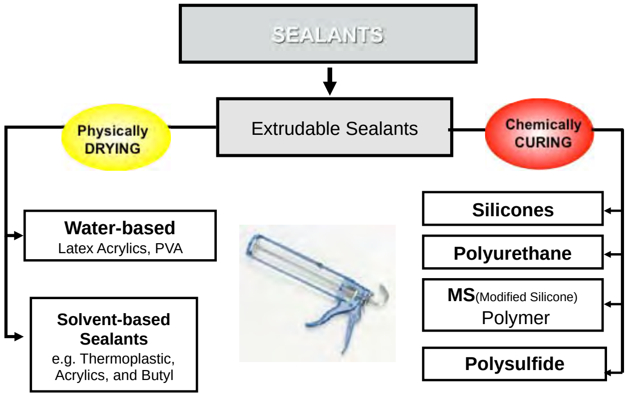
Shear -horizontal

Heating / Cooling Effects
Load bearing differences
External mechanical forces - wind

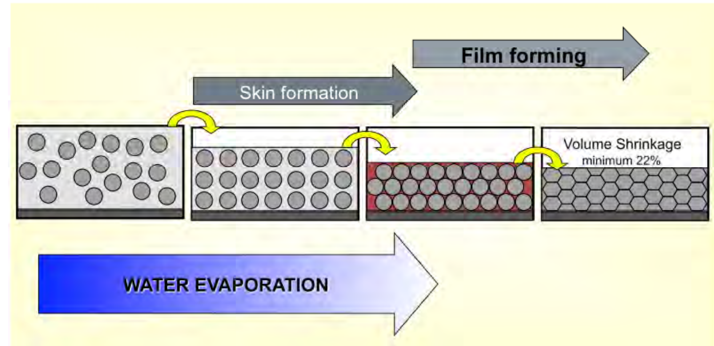
Total movement Comparison:

Sealants: up to 25 %
Mortar: up to 0.4 %

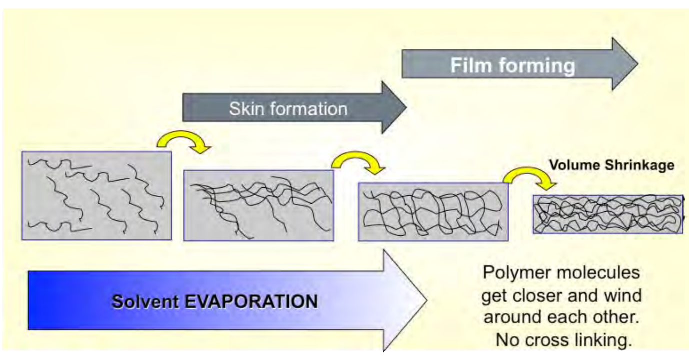
Sealant Chemistry Impacts Suitability for Certain Applications



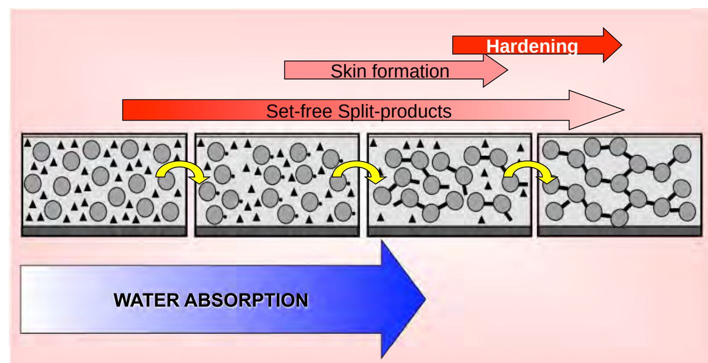
Physically Drying Sealants: Latex



Physically Drying Sealants: Solvent Based



Chemically Curing Sealants: Silicone & Polyurethane



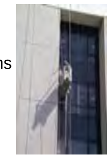
What is a Sealant?

- A sealant is a material that has the adhesive and cohesive properties to form a seal between surfaces while permitting limited movement of the substrates
  - Flexible material, polymer based
  - Installed in a "wet" or soft form
  - Fills gaps
  - Compensates for movements between different elements of the construction
  - Provides airtight joint, protects against wind.
  - Waterproofs joint
  - Prevents ingress of microorganisms, pollutants, smoke, fire
  - Improves building aesthetics
  - Helps dampen noise

Types of Joints

Expansion Joints:

- Connects large construction elements i.e. Facade coverings, building extensions like garages or balconies
- Sealant requires a high degree of elasticity

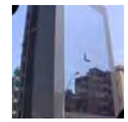


Sanitary Joints:

- Sealing of bathtubs and showers, sinks, tiled walls and floors
- The joints are attacked by water, cleansers and mechanical loading.

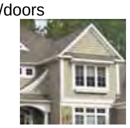
Glass Joints:

- Sealing, supporting glass to window frames
- Sealant requires high durability in terms of UV and temperature resistance



Connecting Joints:

- Connection of construction elements, such as bricks. siding, stairs, decking as well as window frames/doors
- Minimal movement.



Thermomechanical Effects

Coefficients of Thermal Linear Expansion (CTLE) of Building Materials

Building Material	(m/m °C x 10-6)
Acrylic glass	80
Aluminum	24
Concrete / concrete steel	11
Glass	8.5
Wood, lengthwise to the fiber	7
Wood, crosswise to the fiber	40 - 50
Brick	5

Building Material	(m/m °C x 10-6)
Sand lime brick	8.5
Tiles	6
Copper	16.5
Brass	18.4
Polyester	25 - 40
PVC - windows	78
Steel	12

Mismatched CTLE's, particularly of contacting materials in a structure, can lead to development of deforming strains upon heating.

The temperature of application of a sealant (the temperature at which an interface is developed between different materials) can have a profound impact on performance

Sealant Use Considerations

Ease of Extrusion at Various Temperatures:

- As the product temperature is dropped extrusion can become very difficult. This may require heating of the product.
- At higher temperatures the sealant consistency may become too sloppy resulting in poor control by the applicator.

Sagging and Leveling:

- In vertical and over head joints the product must not sag after application. This affects aesthetics of the job and the performance of the sealant.
- Higher temperatures will tend to increase sag.
- In horizontal butt joints (pavement seams), a sealant that flows to form a level surface is desirable. This type of sealant is not suitable for vertical and over head applications.

Sealant Use Considerations

Skinning and Skin Formation Time:
As a sealant dries or cures it develops a dried film on the outside before the inside material dries out or cures. Skinning minimizes dirt pickup. The time to achieve this property is the skin formation time. Excessively fast skinning impedes tooling should tooling be required.

(Typical value -10 to 20 minutes)

Curing Speed:
Indicates the amount of time that a sealant layer requires to reach its intended performance properties. Refers to both chemically reactive and physically drying sealants. The speed depends on sealant chemistry, cure temperature and relative air humidity.

(Typical value - Latex Acrylics per 5 mm = Approx. 2 days)

Adhesion to Different Substrates:
Certain sealant chemistries have inherently poor adhesion to certain substrates or under certain conditions, i.e. Acetoxy silicones because of the acetic acid by product during cure show poor long term adhesion to substrates such as cement and concrete.

Long term adhesion can be affected by
(1) water, (2) plasticizer migration from
(2) substrates, fatigue
(3) from repeated movement,
(4) effects of sunlight,

Various sealant types and formulations will show different bonding characteristics to various substrates. (Measured by peel strength)

Tips for Sealant Application

Application Environment: Temperature

- Apply sealant in moderate temperatures between 41°F (5°C) and 86°F (30°C). When this is not possible changes in application method, joint design or sealant choice may be required.
- Applying sealant to joints at temperature extremes – either high or low – will reduce the joint movement capability.
- Low temperatures will prevent proper curing (coalescence) of water based sealants.
- Excessively hot weather may accelerate the sealant cure time resulting in bubbling and shortened working life and tooling time. It may also cause sagging.

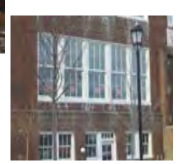
Sealant Failure Factors

Surface Condition & Preparation:

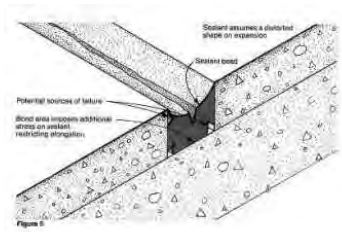
- Application surface not clean
- Coatings completely dry before sealant (i.e. paint, primers)
- Coatings may interfere with sealant adhesion
- Release agents (bath tubs and tub surrounds), surface sealers and coatings (water proofing compounds)
- Raw wood not sealed. Raw wood expands and contract due to moisture changes - probably more then the sealant can handle
- Application substrate was not sound – i.e. rotten wood, crumbling concrete

Weather Factors:

- Applying latex sealant in cold weather – will not cure properly
- Sealant is too cold to flow
- Not enough moisture in air (hot and dry or cold and dry) for sealant cure
- Applying at extremes of temperature range results in loss of movement capability
- High temperatures may result in sagging or may cause premature skinning of the sealant resulting in blistering
- Applying to wet or frozen surfaces
- Exposure to water too soon after application (i.e. rain or from shower). Latex sealant will wash away



Sealant Failure Factors

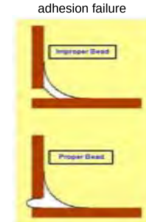


Poor Joint Design:

- Joint too narrow **(less than ¼"):** Expansion of substrate causes the joints to close too much forcing the sealant out of the joint
- **Joint was too wide (greater than 1-2 inches depending on the sealant):**
  - Sealant may sag out of the joint
  - A joint that is too wide requires a deeper sealant bead to avoid cohesive failure - makes the sealant less able to stretch causing failure at the substrate. For example: Two rubber bands of the same length but one is thin and one is thick. The thicker one will not stretch as easily
  - If the sealant bead is too thick it will take a very long time to dry. Joint movement before sealant is cured may cause adhesion failure

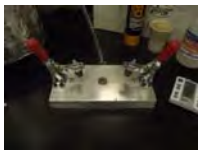
Incorrect Sealant Selection:

- Sealant lacks sufficient movement capability for intended use
- Incompatibility between sealant and substrate, i.e. staining or etching of the substrate, negative effects on the sealant due to migration from substrate, i.e. discoloration
- Poor adhesion to substrate, i.e. acetoxy silicone to concrete or galvanized metal

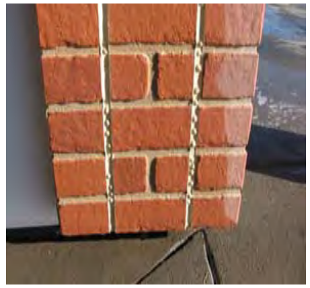


Thermomechanical Effects – Sealant Deformation

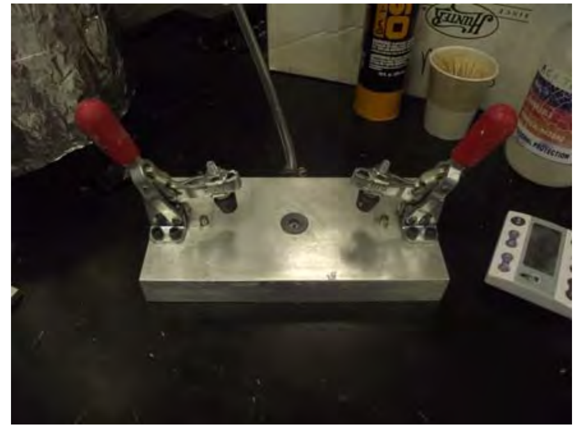
Apparatus designed to measure pressure required to deform a sealant -> bubble



Deformation Example

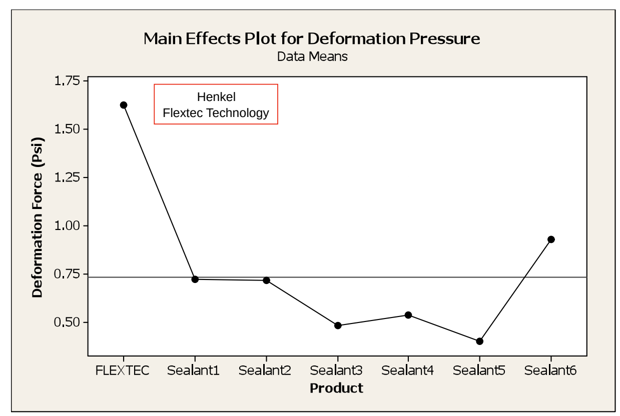


Sample Holder for Bubble Measurement

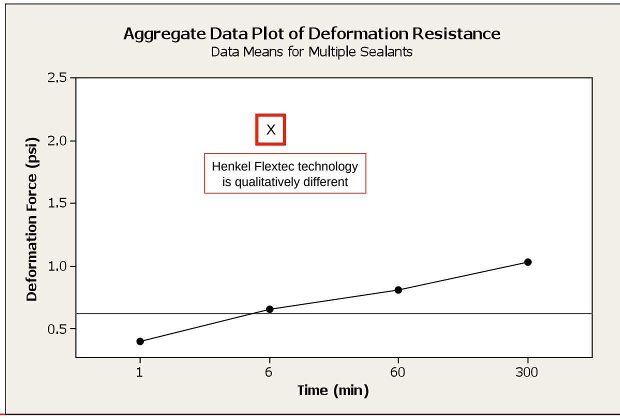


Examples of holes where vapor exits – blowing out sealant

Flextec Technology Has Superior Deformation Resistance



Aggregate Data – More curing takes place in the first 6 minutes



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Sealant Formulations: Guess Which Technology?

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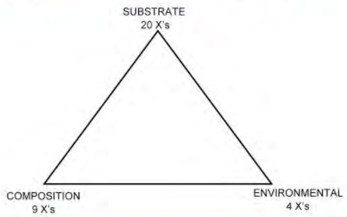
Many contributing variables are substrate related

Classified Variables – Look for Interactions
substrate S, environment E, Sealant C

Majority of contributing variables are substrate-derived



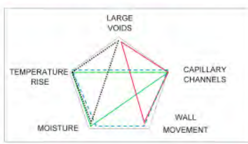
Major Risk Factors

Key: C = Composition (sealant) related variable; E = Environmental; S = Substrate related

TYPE X	Major Risk Factor (X)	Rank
S	Rising Surface Temperature	1
E	Wall temperature Rise	1
S	Sealant dry time, age, Cure	3
S	Moisture - in substrate	4
S	Direct Sunlight	4
S	Type of Substrate	5
S	porosity of trim / siding	7
S	Cedar	8
S	Pine	9
C	Trim vs Siding	10
S	Wall Movement / Loading	11

Slide 8 July 31, 2012 Title and author of presentation Sealant Bubbling – CONFIDENTIAL: Henry C. Ashton Henkel

5 Major Variables interact in 4 Mechanisms



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Experiment to Measure impact of Direct Sunlight

4PM Tuesday, 5/31/2011

Fastened a finish coated Western Red Cedar trim piece (dark brown) to a piece of OSB. To that was fastened a 30 inch piece of uncoated Western Red Cedar trim. Applied sealant to the joint between the two pieces of Cedar. Stapled a thermocouple (thermometer sensor) to the surface of the cedar to measure surface temperatures. This was done in the lab at 72 degrees F and the boards were immediately moved outside and leaned up against the building's brick wall.

The video was then started. Note that the thermocouple (the wire end) and the sealant joint both start out in the shade. Surface temperature was ~ 90F (within a minute! in the shade!) and by 9 minutes had risen to over 100F). The initial shot was interrupted as we repositioned the board to avoid lengthening shadows interfering with the shot. This video clip begins at about 10 minutes into the exposure with both the thermocouple and the cedar boards in the shade. As the shadow retreats from left to right more and more of the finished board, the joint, and finally the uncoated board are exposed to direct sunlight.

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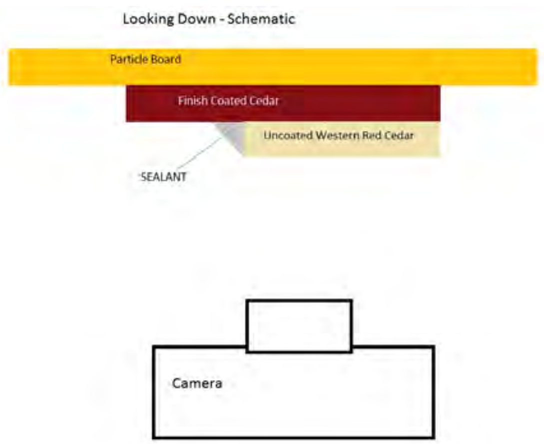
Schematic Diagram: Sealant Bubbling Experiment



Experiment to Measure impact of Direct Sunlight

Impact of temperature on sealant deformation is Clearly seen

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Sealant Deformation and Bubbling: Cause, Effect, and Recommendations

Summary: ***What Do We Know? What Have We Learned? What Can We Do?***

Resources: R&D + QC + Engineering + Technical Services + Sales/ Marketing + Building-Industry Scientists + Forensic Building Consultants

Test/Sample Environments: Field + Job-Site + Laboratory/Technical

Conclusions:

1) There is No Single Cause of Deformations.
2) All Sealants Experience Deformation.
3) Major Job-Site/Environmental Variables Must Occur.
4) Solutions are Complex -- because Substrates, Material Composition, and the Environment Interact and Change.

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Sealant Deformation: FAQs and Points of Interest

Is There a "Silver Bullet" Sealant Solution?:

- All Sealant Technologies Bubble
  - ✓ Some are Slightly More "Resistant" (Dry, Cure Faster)
- Manufacturing Issues are Negligible
  - ✓ Bubbles aren't "pre-loaded" into a tube of sealant
- Formulation Changes? . . .
  - ✓ VOC formulations show no meaningful difference
- Thermoplastics, MS Polymers, Polyurethanes, etc. ALL BUBBLE

The Role of Sealants:

- "Resistance" to Bubbling Builds Over Time (Due to Drying and Curing)
  - ✓ **300 minutes** builds good resistance (over 1 PSI resistance) for most technologies
  - ✓ Thermoplastics (both "regular" and VOC formulations) take longer to dry and cure, which may leave them more vulnerable to **immediate** bubbling pressures
  - ✓ MS Polymers and Polyurethanes show slightly more resistance due to faster drying and curing times, but **aren't significantly better solutions**
- Only ONE Current Sealant Formulation Showed Significantly Better Resistance to Bubbling vs. Any Other Sealant Formulation
  - ✓ Henkel's FlexTec Technology (Proprietary)

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Sealant Deformation: Understanding Risk-Factors

"Other" Variables Include:

- Substrates
  - ✓ 20 Types of Contributing Substrates Currently Identified
- Compositions (of Sealant)
  - ✓ 9 Types of Composition Factors Currently Identified
- Environmental
  - ✓ 4 Types of Environmental Factors Identified

- Again – No Single "Smoking Gun"
- It is the ***Interaction*** of these Variables that Matters

Risk-Factors, Force-Ranked: Which Matter Most?

- Rising Surface Temperature
- Environmental/Job-Site Presence of Water
- Rising Wall Temperature
- Moisture in Substrate
- Direct Sunlight
- Type of Substrate
- Sealant: Dry Time, Aging, Curing
- Porosity of Siding and/or Trim
- Cedar Surface
- Pine Surface
- Siding and Trim Interaction
- Wall Movement and Loading
- Damaged Backer Rod

- Moisture and Direct Sunlight Can Cause Certain Risk-Factors to Move Up in Rank

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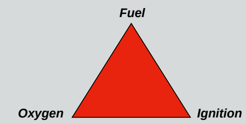
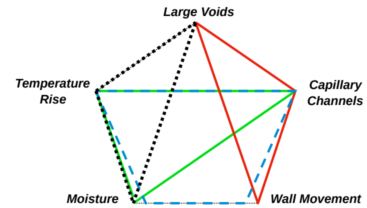
Sealant Deformation: Major Variables Must Interact



The "Fire Triangle"

- Three Variables to Create Fire:
  - Ignition Source (eg. "spark")
  - Fuel (eg. gasoline, wood)
  - Oxygen
- Absence of ANY of these variables means that a fire will not occur



The "Bubbling Pentagon"

- Five Major Variables to Create Bubbling
  - *Four Primary Combinations of Variables:*
    1. Temperature Rise + Capillary Channels + Moisture
    2. Large Voids + Capillary Channels + Wall Movement
    3. Capillary Channels + Wall Movement + Moisture + Temperature Rise
    4. Moisture + Temperature Rise + Large Voids
- If Any of Four Primary Variable Combinations is Existent, Bubbling Can Occur
- Issue: Detection of Primary Combinations

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The FlexTec "Intel Inside"

Henkel FlexTec Advantages:

- Henkel's Flextec **Resists Bubbling After 6 Minutes** as Well as ANY OTHER Sealant Technology Resists Bubbling After 300 Minutes
  - In addition to drying and curing capability, Henkel's FlexTec proprietary formulation has built-in properties to resist deformation and bubbling
- Not "fool-proof" . . . Remember that All Sealants can Bubble
  - Henkel Technology offers over twice the resistance to bubbling vs. any other sealant

Recommended Steps for Bubbling Remediation:

- Allow for Drainage Plain Behind Cladding
- Time of Day for Application
  - Avoid direct sunlight, if possible
  - Screen from sunlight, if possible
- Control (if Possible) Moisture on Substrate
- Control (if Possible) Temperature on Substrate
- Avoid Tooling or Thinning Thermoplastics
- If Painting with Latex – Wait 3-7 Days for Sealant to Dry and Cure
- Avoid Installing Damaged Trim
- Avoid Installing Damaged Backer Rod
- Create a Capillary Interruption Between the Foundation and the Wall

- **Henkel technology constantly improves the property balance of sealant materials**

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Summary: What Do We Know? What Else Can We Learn?

OSI Professional Grade Adhesives & Sealants

Henkel/OSI Commitment:

- Henkel/OSI is committed to delivering home system solutions
  - ✓ Even when the research and the solutions are difficult
- More Detailed Information is Available from Henkel
  - ✓ Testing Procedures/Results
  - ✓ Current R&D Efforts
  - ✓ Customer/Alliance Partner Joint Projects
  - ✓ Industry Collaborative Efforts

Industry Education:

- Water Management
- Heat/Sunlight Impact
- Substrates and Materials Impact
- Composition (of Sealant) Impact

- Combination of Variables
- Risk Factors
  - ✓ Continued Study and Remediation

- Integrated Solutions
  - ✓ With Customers
  - ✓ With Manufacturers
  - ✓ With Alliance Partners

- Building Science
  - ✓ Industry Expertise
  - ✓ Full Engagement and Transparency/ Visibility

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Thank You