



**DOE Award DE-EE0004024:
High Reliability R-10 Windows Using
Vacuum Insulating Glass Units (VIGUs)**

**All Of EverSealed Windows' (ESW's) Intellectual Property
Disclosed in this File is Patented or Patent Pending in the U.S.
and Numerous Foreign Nations**

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DE-EE0004024: High Reliability R-10 Windows Using Vacuum Insulating Glass Units (VIGUs)

Project Purpose and Objective

- Prove the viability of a Vacuum Insulating Glass Unit (VIGU) which will allow a residential whole window to achieve R-10

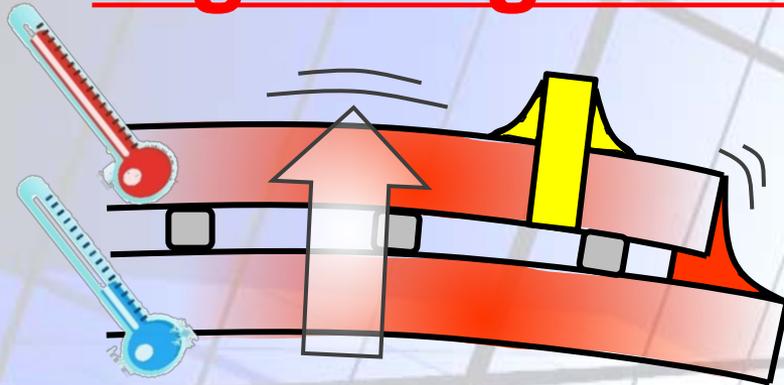
Scope of Work

- Develop and test the R-value of a flexible-edge-sealed VIGU and a whole window using the EverSealed Windows (ESW) flexible-edge-sealed VIGU technology

Total Cost of Project

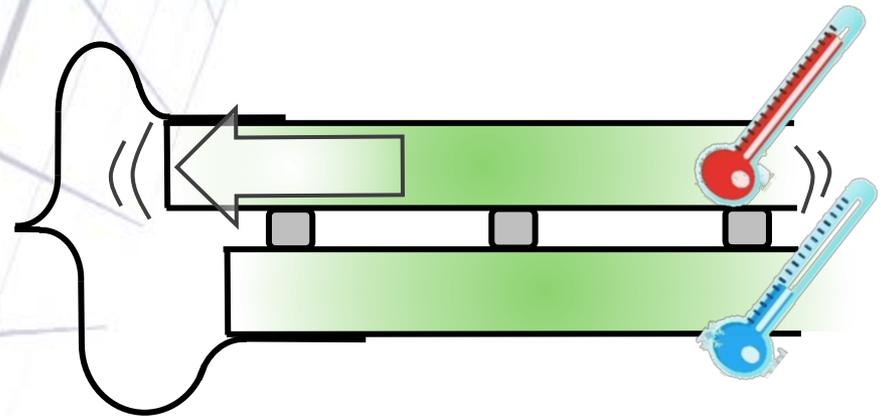
Government Share	\$ 2,142,327
EverSealed Windows (ESW) Share	\$ 565,387
<hr/> Total Project Cost	<hr/> \$ 2,734,714

Rigid Edge Seal



Expansion results in glass bowing and **high stresses** – thus limited to **mild climates only**

Flexible Edge Seal



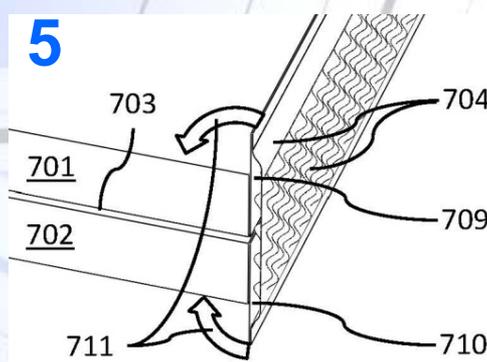
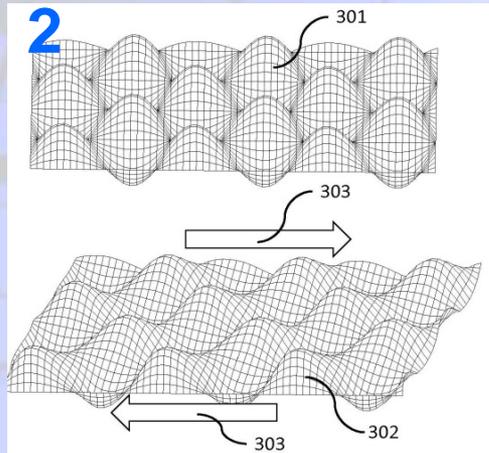
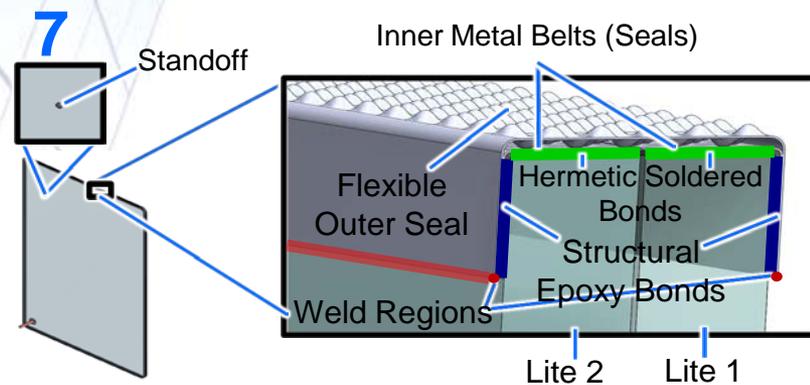
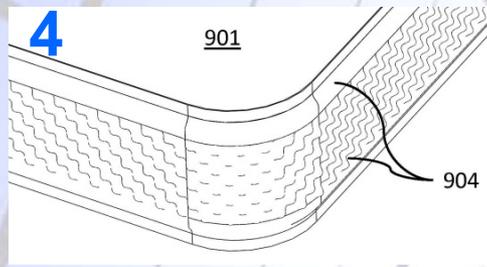
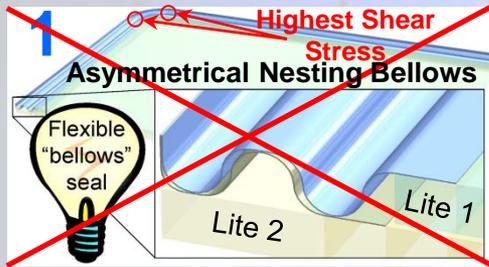
Expansion results in glass sliding and **low stresses** – thus applicable to **all U.S. climates**

- Requires stand-offs (lite separators) to have low coefficient-of-friction coating so they slide on surface 2 and/or 3

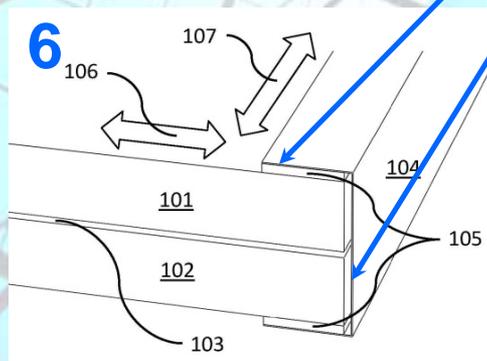
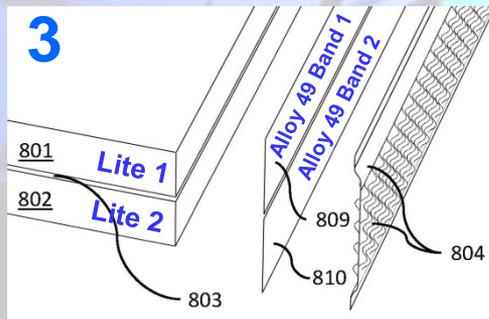
Significant Accomplishments and Milestones

- **EverSealed Windows' VIG Enables Whole Window \geq R-10**
- **Uses Tempered and Low-E Glass**
 - No loss of fully-tempered strength from assembly processes and materials
 - All assembly processes compatible with both tin-side and non-tin side of clear glass
- **Assembled Using Off-The-Shelf Materials And Processes**
 - Commercially-available lead-free materials and catalogue equipment
- **Suitable For Any Traditional Residential Or Commercial Application**
 - Same Form/Fit/Function As Today's Double-Pane IGs
 - Fits in current sash designs with limited sash modifications
 - The ESW VIG Is thinner than a conventional IG
 - No new material handling or packaging requirements for window producers
- **Tested and Demonstrated Practical For Use In Any Climate**
- **40 Years' Performance And Reliability in the Harshest Environments**
 - ❖ EverSealed's Collaborators Include: Cardinal Glass Industries (Cardinal IG), Marvin Windows and Doors, Pella Corporation, TRACO, VELUX Greenwood, LBNL and NREL

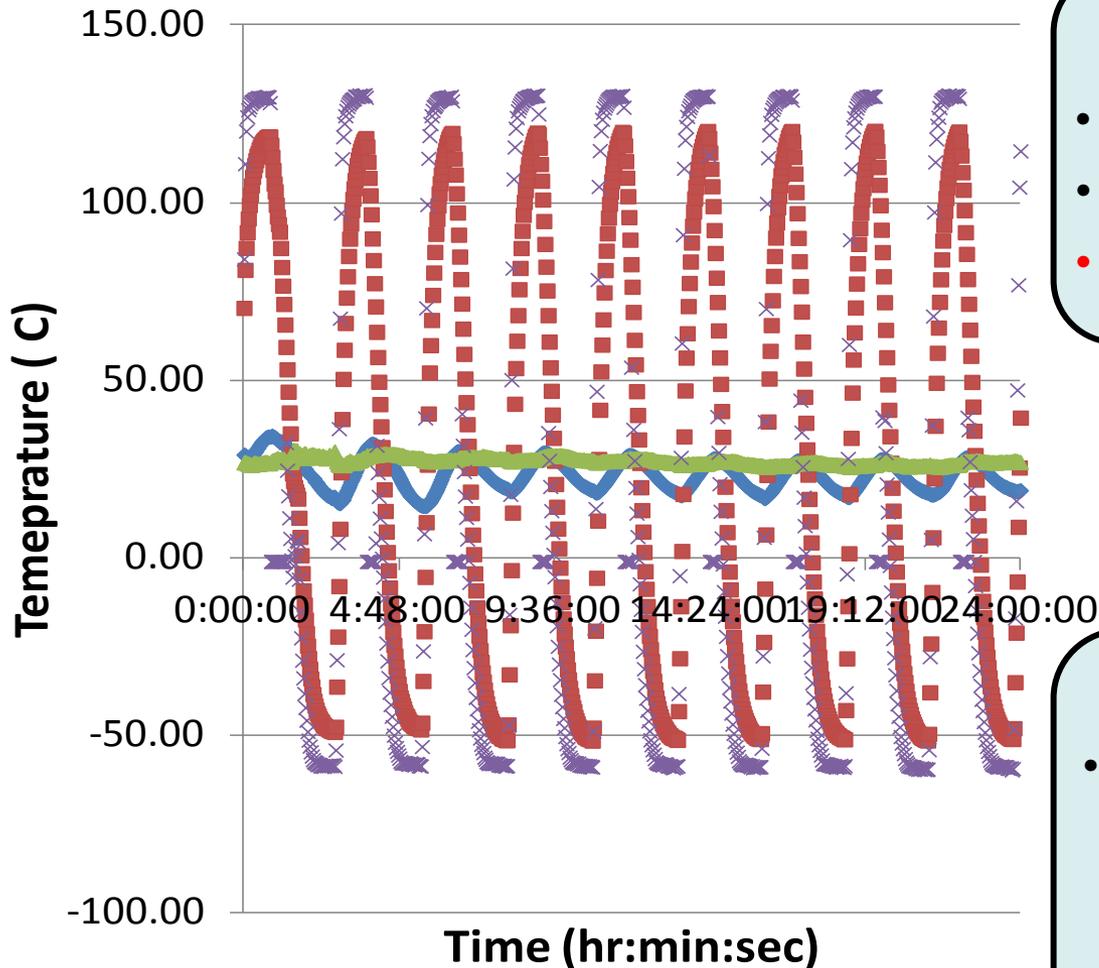
ESW's Flexible Seal System



Maximum thickness of the Seal System above the Glass Surfaces < 0.15"



Tested and Demonstrated Compatibility with Extreme Climates



40 years = 14,600 days
Eli, Nevada:

- 35° C diurnal temperature change in late June/July
- 1.93 factor for solar heat gain on surface 1
- **67.6° C worst-case diurnal temperature change for 14,600 days**

- ◆ Surface 4
- Surface 1
- ▲ Room Temp
- × Chamber

229 Thermal Cycles From -60°C To +130°C:

- Yields 90% confidence in 95% reliability for 40 years (14,600 days) in Eli, Nevada (according to Baye's Success Run Statistics)

Tests Stopped after 305 Thermal Cycles with NO FAILURES

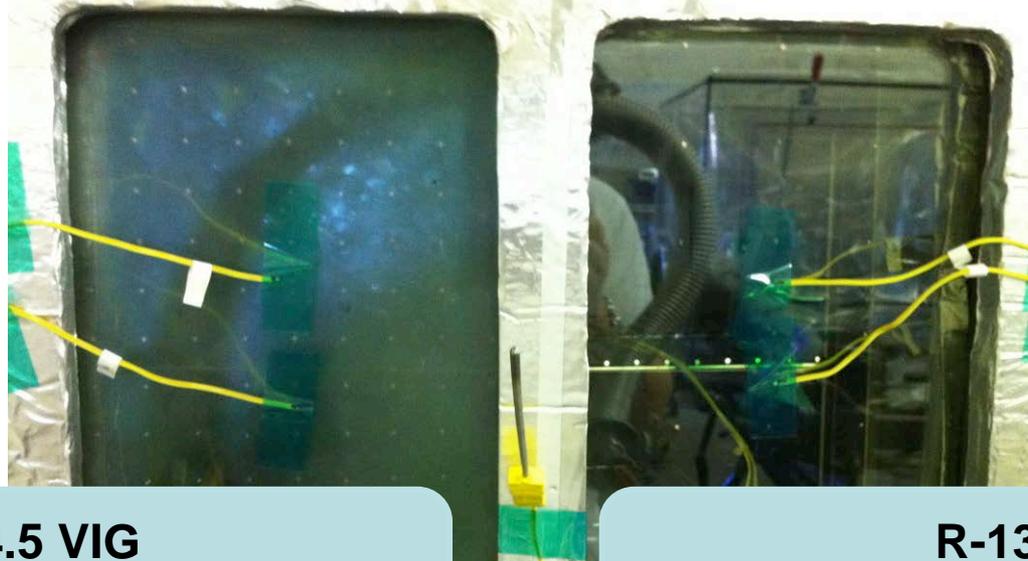
Supplemental Materials

Key Accomplishment:

R-13 VIG's Sub-Scale Manufacturing

Two VIGs with Low-E Coating on Surface 2, Shown with the Thermal Cycle Chamber at -60°C

- Surface 1 is exposed to chamber's -60°C convection air flow
- Surface 4 exposed to ambient (room temperature $\sim 23.5^{\circ}\text{C}$)



R-4.5 VIG

- Annealed glass and spacers on 1" centers
- Note the condensation on Surface 4

R-13 VIG

- Tempered glass and spacers on 2" centers
- No condensation on Surface 4

Off-the-Shelf Materials and Manufacturing Processes

Hermetic Glass-to-Metal Bond Using Low-Temperature Lead-Free and Flux Free Metal-Alloy Solders Applied With Ultrasonic Soldering Equipment

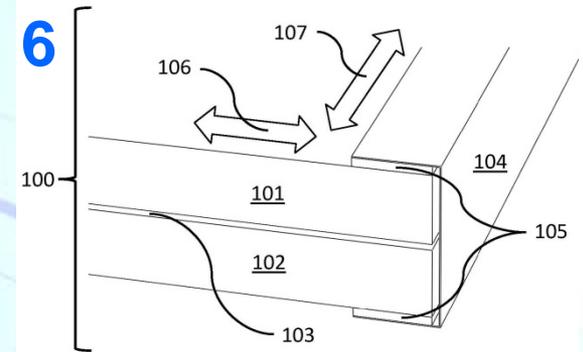
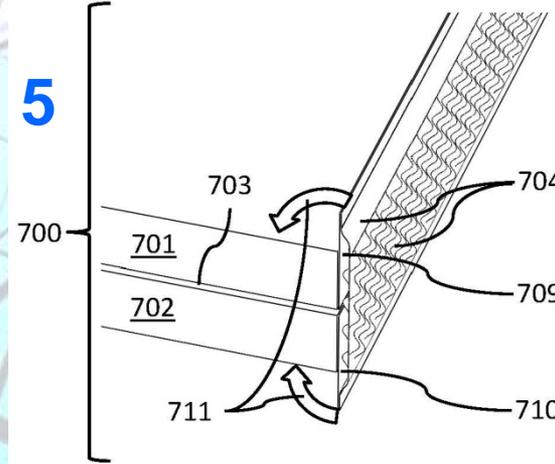
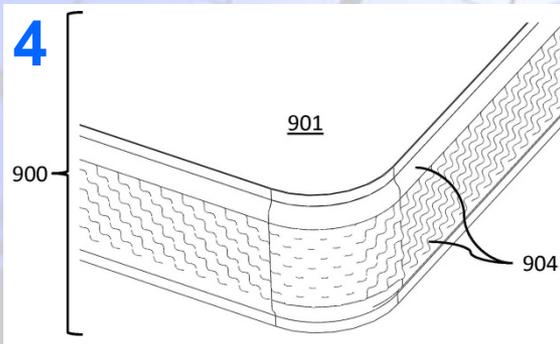
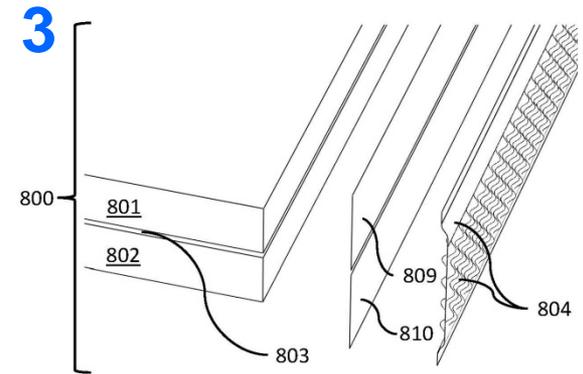
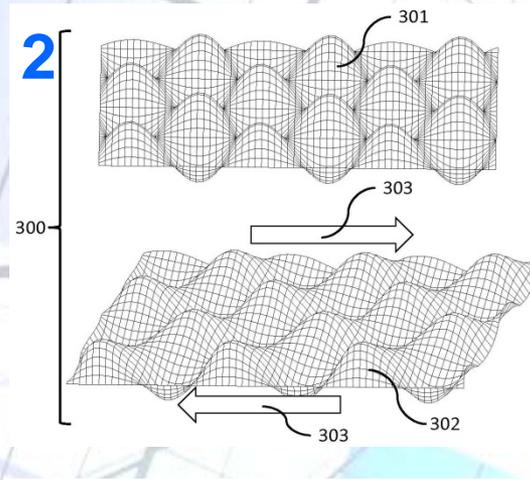
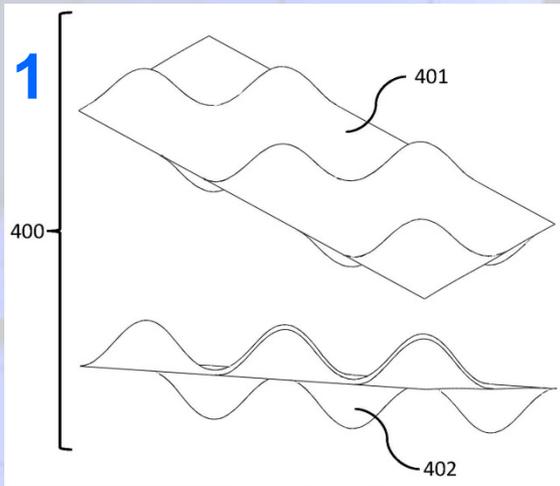
Low temperature metal-alloy test samples *consistently* have a helium fine-leak rate of $<10^{-13}$ cc/sec

He LeakRate	Pass Fail
4.00E-14	PASS
4.00E-14	PASS
4.00E-14	PASS
6.87E-14	PASS

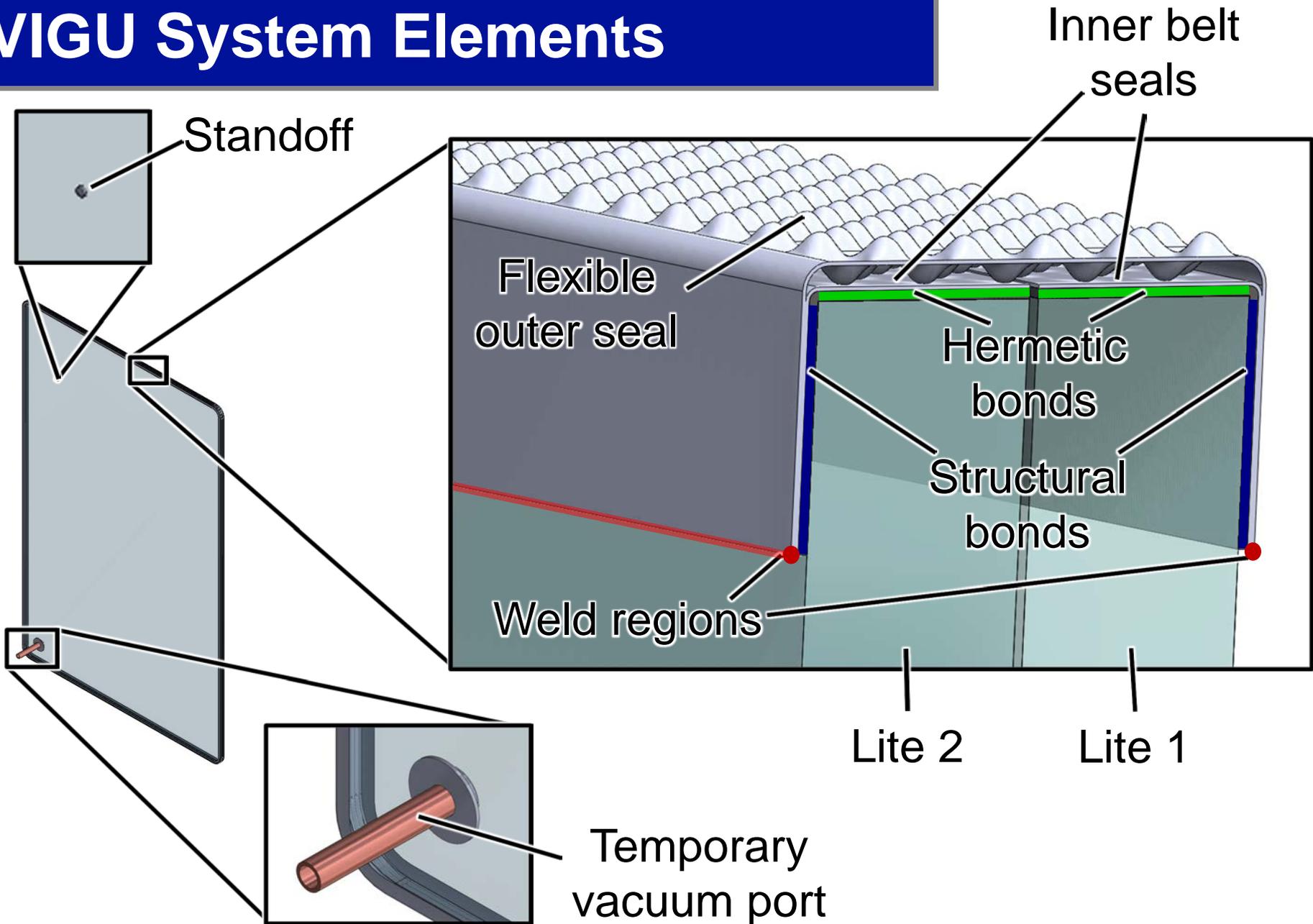


Solution: Flexible Metal Foil Seal System

Figures of ESW's Proof-of-Feasibility Seal System Used for First Generation VIGs

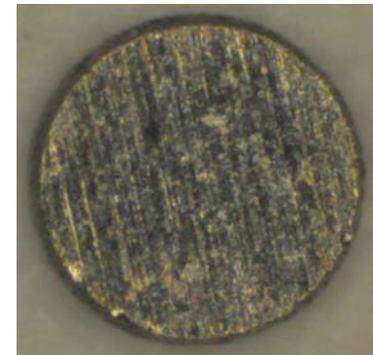


VIGU System Elements

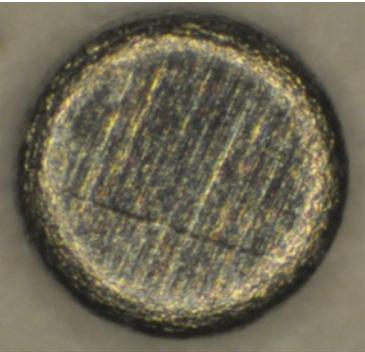
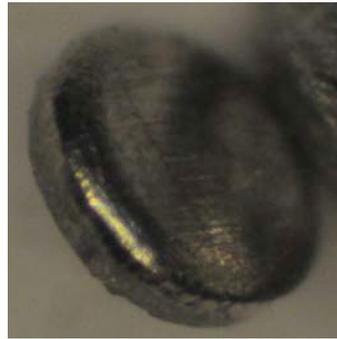
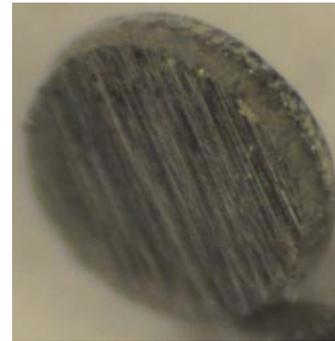


Standoffs Have a Low-Friction, Solderable Coating

**Bottom
Side is
Soldered
Onto
Lite's
Surface**



**Solderable to
Both Clear
and Low-E
Surfaces**

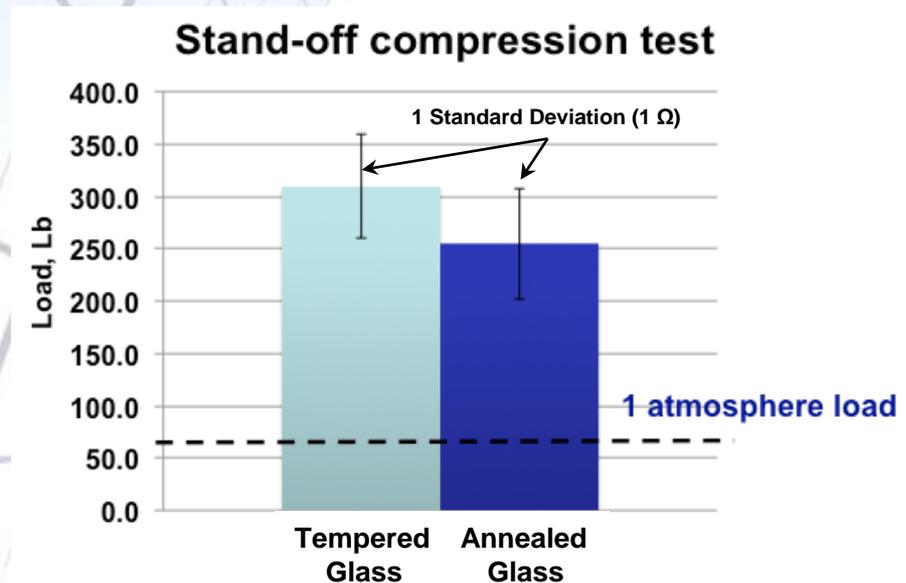


**Top Side,
Facing
Away From
Lite's
Surface**

Other Standoff Developments

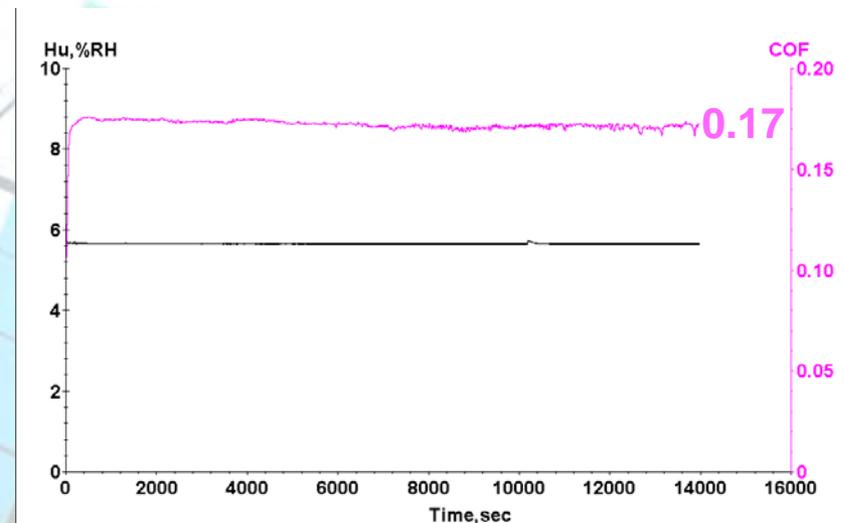
Compression Strength:

- >4x Safety Margin vs. the atmospheric load of the standoff-to-glass interface
 - Compressive stress at the interface
 - Tensile stress in the glass adjacent to the interface



Tribology Testing

- Surface Friction
 - Coefficient-of-Friction (COF) of 0.17 is close to the COF of graphite-on-glass
 - Stable COF over 14,600 abrasion cycles



Successfully Completed All Program Deliverables

Development Activity	2010		2011				2012	
	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q
→ Flexible Seal								
Asymmetrical Bellows	█							
→ New Flexible Seal Design			█					
→ Stand-off System		█						
→ Hermetic Glass-to-Metal Sealing								
Lead-Free Solder Glass	█							
ALD-Coated Adhesives & Epoxies			█					
→ Lead-Free and Flux-Free Metal-Alloy Ultrasonic Soldering						█		
→ System Assembly: Proof of Feasibility					█			