High Performance Building

Dow Performance Silicones

Dow Americas Insulating Glass Technical Manual

The Use of Silicone Sealants in Dual-Sealed Insulating Glass Units

Dow Insulating Glass Technical Manual Americas
Table of Contents

Preface

Introduction

Silicone sealants have been used in various applications throughout the construction industry for many years. Their superior durability and longevity relative to their organic-based counterparts are the basis for their use. Over the last 25 years, the use of silicone sealant as a secondary seal in dual-sealed insulating glass (IG) has steadily increased. This trend is the result of both a general increased awareness of the durability and capabilities of silicone sealants and the increased use of structural silicone glazed curtainwall designs.

This technical manual is intended to provide an understanding of silicone sealants and their properties including their capabilities and limitations, and an explanation of IG application procedures for use with silicone sealants.

Product Offering – Silicone Sealants for Secondary Seal in IG Units

Dow has several high performance silicone sealants that may be used as secondary seals in IG units. Following is a brief summary of each Dow product offered. Product information is available at consumer.dow.com/construction to be used in selecting the appropriate product for specific applications.

DOWSIL™ 982 Silicone Insulating Glass Sealant
DOWSIL™ 982 Silicone Insulating Glass Sealant is a two-part, fast-cure, neutral-curing silicone sealant intended for use as a secondary sealant in dual-sealed insulating glass units that will be structurally glazed. Available in black and gray.

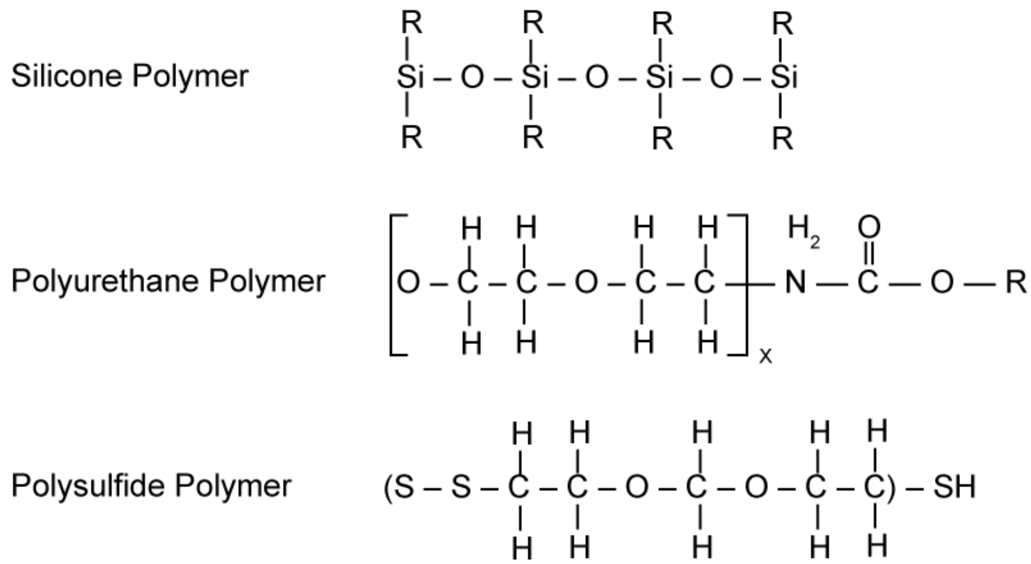
DOWSIL™ 982-FS Silicone Insulating Glass Sealant
DOWSIL™ 982-FS (Fast Snap) Silicone Insulating Glass Sealant is a two-part, fast-cure, neutral-curing silicone sealant intended for use as a secondary sealant in dual-sealed insulating glass units that will be structurally glazed. Available in black and gray, DOWSIL™ 982-FS Silicone Insulating Glass Sealant is also used for Heat Mirror Applications.

DOWSIL™ 3-0117 Silicone Insulating Glass Sealant
DOWSIL™ 3-0117 Silicone Insulating Glass Sealant is a one-part, RTV-cure, neutral-curing silicone sealant intended for use as a secondary sealant in dual-sealed insulating glass units that will be structurally glazed. Available in black and gray.

Silicone Sealant Chemistry

The basis for the use of silicone sealants for insulating glass sealing is the silicone, or “siloxane” polymer backbone. Unlike organic sealants such as polyurethanes and polysulfides, silicone polymer is composed of a series of silicon atoms bonded to oxygen atoms; hence, the chemical term siloxane. See examples of sealant polymer formulations in Figure 1.

Figure 1: Sealant Polymer Formulations[1]



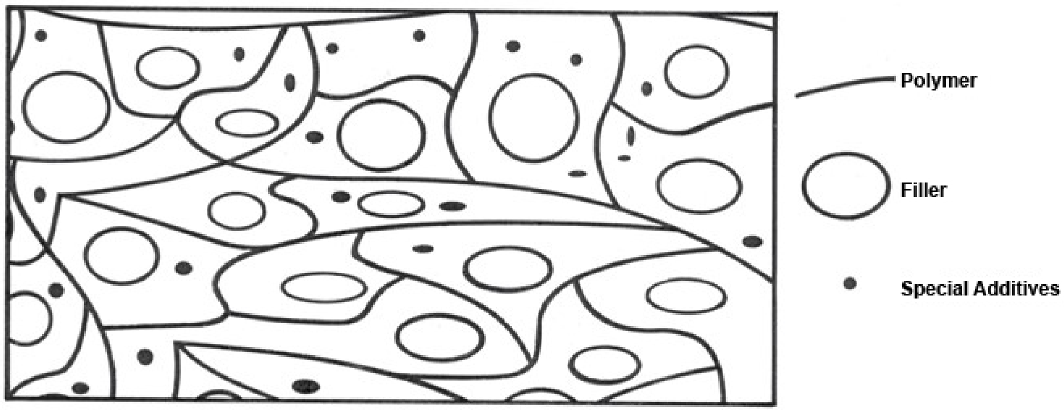
Although specific sealant formulations vary between silicone sealant suppliers, the basic silicone sealant formulations generally contain the following ingredients:

- **Siloxane Polymer –** A large molecule, based on the repetition of silicon and oxygen atoms; the basic raw material required for the formation of an elastomeric seal.
- **Filler** – Silica, calcium carbonate, or diatomaceous earth added to improve sealant reinforcement, strength, and flexibility.
- **Crosslinker –** Added to cause curing, polymer network intertwining, and elastomer formation.
- **Catalyst –** Metal-based ingredient that accelerates the crosslinking reaction and elastomer formation.
- **Adhesion Promoter –** Improves sealant adhesion to glass and spacer surfaces.
- **Pigment –** Added for color specifications.
- **Plasticizer –** Enhances shelf stability, tool-ability, and flexibility.

During cure, silicone sealants intertwine, harden, and form solid elastomers. Once cured, silicone sealants resemble a molecular fishnet, with marbles or pebbles (filler) uniformly dispersed. See example of cured sealant composition in Figure 2.

[1] Klosowski, Jerome M., *Sealants in Construction*, Marcel Dekker, New York and Basel, 1989

Figure 2: Cured Sealant Comparison[2]



Variations in the ingredient types and levels alter the silicone sealant properties. For example, some silicone sealants are available in one-component form, while others are available in two-component forms. A comparison of one-part and two-part silicone sealant properties is given in Table I.

Table I: Silicone Insulating Glass Sealant Property Overview

Sealant Property	One-Part	Two-Part
Cure Mechanism	**Neutral (Alcohol)**	**Neutral Catalytic (Alcohol)**
Products	DOWSIL™ 3-0117 Silicone Insulating Glass Sealant	DOWSIL™ 982 Silicone Insulating Glass Sealant and DOWSIL™ 982-FS Silicone Insulating Glass Sealant
Corrosive	No	No
Tack-Free or Working Time, minutes	20-60	20-60
Extrusion Rate, grams/minute	80-200	150-250
Deep Section Cure, 24 hour	80-120 mils	Complete cure typically in 1 day or less
Tensile Strength, psi ASTM D 412	150-350	200-250
Adhesion to Glass*	Clear, Tinted, and Coated	Clear, Tinted, and Coated
Spacer System		
Anodized Al.	Yes	Yes
Mill Finish Al.	Yes	Yes
Stainless Steel	Yes	Yes
Swiggle	**	**
TPS	***	***
Galvanized Steel	Yes	Yes
Silicone SuperSpacer	Yes	Yes

*Edge deletion is strongly recommended for all "soft" coated glass for structural IG applications, unless the coated glass manufacturer (not the IG manufacturer) provides a full warranty for long term durability and stability of their coating under the appropriate accelerated weathering conditions. Both low-E and "combi" coats (reflective soft coats) contain silver layers that can corrode under moisture exposure, typically starting at the edge.
**Sealant approved by Swiggle manufacturer for use as a secondary seal. Contact Swiggle manufacturer.
***Thermal Plastic Spacer (TPS) manufacturer must be contacted to confirm compatibility of sealant with their specific TPS material.

Note: Significant variations in adhesion performance can occur within a class of sealants and within a class of substrates. Therefore specific sealant/substrate combinations should be verified through testing.

[2] Klosowski, Jerome M., *Sealants in Construction*, Marcel Dekker, New York and Basel, 1989

One-part silicone sealants cure by the reaction of moisture vapor in the air with the sealant. As a result, they cure from the top surface down. Depending upon the seal depth, these sealants may not attain full cure for up to a week or more. Two-part silicone sealants, on the other hand, can provide more rapid cure as they begin crosslinking throughout the sealant depth as soon as the two components are mixed. Generally, the two-part silicone sealants give full cure in less than one day.

Ingredient types and levels also affect other critical sealant properties such as extrusion rate, cure rate, tensile strength, and adhesion. For example, higher filler loadings can provide greater reinforcement and higher strength sealants. However, higher filler levels can also mean lower extrusion rates.

Acetoxy-cure silicone sealants give off acetic acid and a vinegar odor during cure while neutral-cure silicone sealants give off alcohol, oxime, or other non-acetic vapors. Acetic acid vapors are corrosive, and therefore limit the use of acetoxy-cure silicone sealants. Acetoxy-cure silicone sealants should not be used with certain coated glasses and galvanized steel spacers. Neutral-cure silicone sealants are non-corrosive and offer excellent adhesion to coated glasses, galvanized steel and anodized aluminum spacers. Before using a coated glass in an insulated glass application the coating manufacturer should be contacted to determine if the coating must be edge deleted.

Silicone Sealant Key Properties

The superior durability and weatherability of silicone sealants differentiate them from their organic sealant counterparts. The silicon-oxygen bonds that are the backbone of silicone sealants are very strong. One way to measure the relative bond strength of different bonds is through the use of bond energies. Simply stated, the bond energy of a chemical bond (such as the silicon-oxygen bond) is the energy required to cause a physical breaking of the bond. As the bond strength increases, so does the amount of energy required to break the bond. The relative bond energies of silicone and organic bonds are shown below in Table II.

Table II: Bond Energy Comparisons[3]

Bond Type	Bond Energy, kcal/mole
Silicon-Oxygen	128
Silicon-Carbon	88
Carbon-Carbon	80
Carbon-Oxygen	81

As seen in the relative comparison, the bond found in the silicone sealant polymers (silicon-oxygen) is much stronger than the bonds found in the organic (carbon-carbon OR carbon-oxygen) and siliconized organic sealants. Therefore, the silicone sealants are more stable under extreme temperatures and ultraviolet light exposure.[4] Additionally, the size of the atoms and the bond angles in the silicone sealant polymers are much larger than those of the organic sealants. Typical bond angles between silicon-oxygen molecules are 130-170 degrees, whereas, the bond angle between a carbon-carbon bond is only 109 degrees[5]. The larger bond angle attributed to the silicone sealant allow for freer rotation of the elements in the structure. This, combined with the higher energy required to break a silicon-oxygen bond allows silicone sealants to remain more durable and flexible over a wide range of temperatures.

[3] Wolf, Andreas T. and Waters, Leslie J. "Factors governing the life expectancy of dual-sealed insulating glass units," *Construction and Building Materials,* 1993, Volume 7, Number 2

[4] Wolf, Andreas T. and Waters, Leslie J. "Factors governing the life expectancy of dual-sealed insulating glass units," *Construction and Building Materials,* 1993, Volume 7, Number 2

[5] Brook, A. Michael, *Silicon in Organic, Organometallic, and Polymer Chemistry*, Wiley Interscience, 2000

Silicone Sealant Durability

Environmental conditions and factors influence secondary seal adhesion and overall performance. Throughout the insulating glass unit's life, secondary seals are exposed to a number of factors including UV radiation, wind loading, thermal movement, and temperature extremes. Silicone sealants are better able to withstand the stresses after years of field life because silicone sealants maintain their properties better than organic sealants.[6]

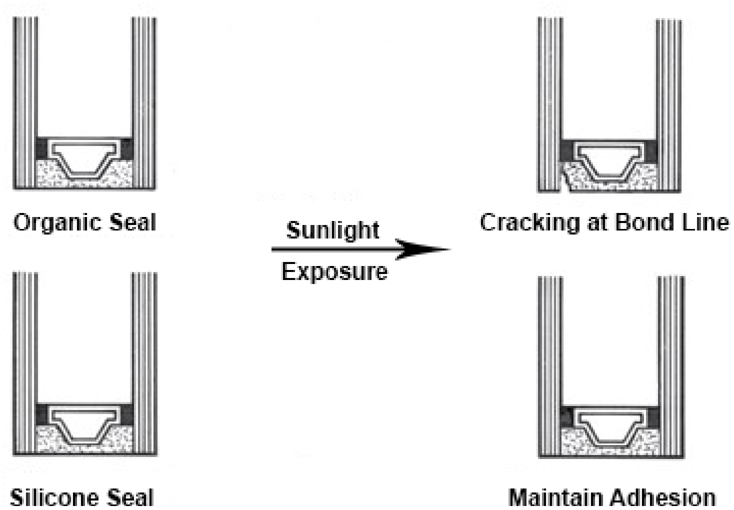
Ultraviolet Radiation

Ultraviolet light with a wavelength of 0.29 - 0.35 nanometers has sufficient energy to break carbon-carbon and carbon-oxygen bonds, the bonds on which organic sealant polymers are based.

When an organic sealant is exposed to sunlight, the radiation can induce a photochemical excitation in the polymer causing the material to either soften or turn brittle. The sealant bond to glass can be the first part degraded because most radiation occurs at the interface of the sealant and the glass. Cracking and adhesion loss can result.[7]

Silicone sealants are composed of an inert, inorganic polymer (silicon-oxygen), and therefore do not contain the carbon-carbon or carbon-oxygen bonds. Extended testing in both UV chambers and QUV weatherometers indicates that silicone sealants do not exhibit dramatic changes in adhesion or strength upon aging. See Figure 3.

Figure 3: Sunlight Effect on Insulating Glass Unit Seals[8]



Temperature Extremes

At moderate temperatures, all common secondary sealants remain elastomeric and have sufficient movement capability to withstand stressing. However, at extremely high or low temperatures, organic sealants can experience significant physical property changes.

At low temperatures, organic sealants become more plastic as sealant durometer and modulus values increase and ultimate elongation decreases, i.e., organic sealants become much more stiff and brittle. At high temperatures, organic sealants soften and lose considerable strength. However, at prolonged high-temperature exposure, some organic sealants also become brittle and stiff. See Figure 4.

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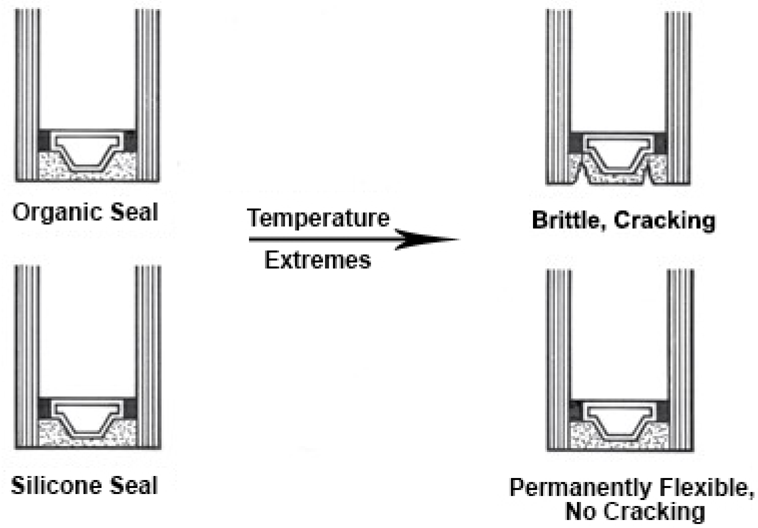
[6] Wolf, Andreas T. and Waters, Leslie J. "Factors governing the life expectancy of dual-sealed insulating glass units," *Construction and Building Materials,* 1993, Volume 7, Number 2

[7] Wolf, Andreas T., *Studies of the Aging Behavior of Gun-grade Building Joint Sealants – The 'State of the Art'*

[8] Bridgewater, Todd J. and Carbary, Lawrence D. *Accelerated Weathering and Heat Stability of Various Perimeter Sealants,* ASTM Technical Publication 1200, Philadelphia, PA, 1993

Figure 4: Temperature Effect on Insulating Glass Unit Seals[9]



Moisture Vapor and Gas Transmission Rates

Due to their high permeability, silicone sealants can only be used as a secondary seal in dual-seal insulating glass units. Silicone sealants allow moisture vapor to permeate at a higher rate than organic sealants and therefore cannot be used as a single seal in single seal insulating glass units. This is largely due to the wide bond angles and free volume of the siloxane polymer that also give silicone sealants their excellent movement capability and long-term weatherability. See Table III for a relative comparison of moisture vapor transmission rates for the common sealant families.

TABLE III: Sealant Moisture Vapor Permeability Rates at Room Temperature[10]

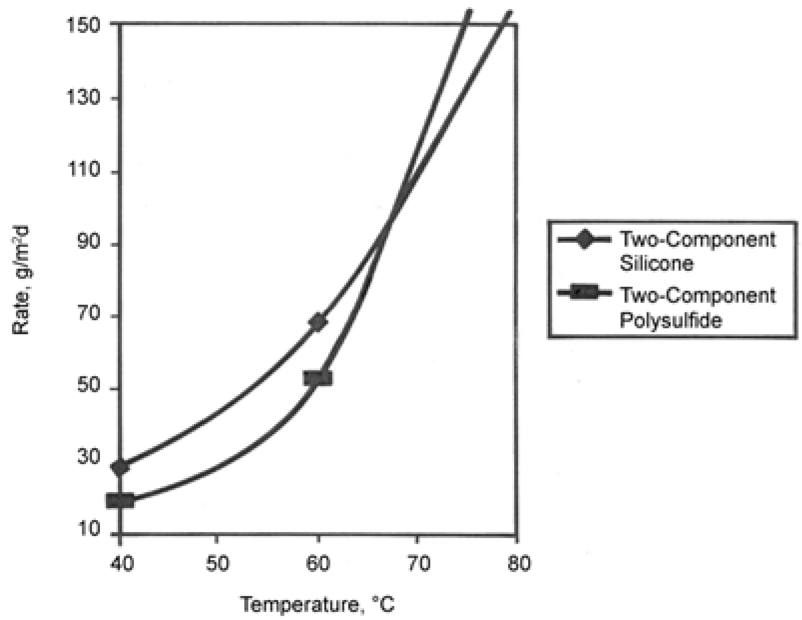
Sealant Type	Moisture Vapor Permeability (grams/day/sq. meter)
Hot Melt Butyl	1-1.5
Polyurethane	3-4
Polysulfide	4-10
Silicone	15-25

A primary seal of polyisobutylene (PIB) must be used in conjunction with the silicone secondary seal. It is this dual seal configuration that offers excellent insulating glass unit working life, combining the extremely low moisture vapor transmission rate of the polyisobutylene for a long-term moisture and gas barrier, along with the excellent durability and long-term adhesion characteristics of the silicone sealant to maintain the IG unit seal.

While some organic sealants have a lower moisture vapor permeability than silicone when measured at room temperature, it is important to understand that moisture vapor transmission can be a function of temperature, and at higher temperature when there is more moisture in the air the MVP of polysulfide can actually be as high or higher than silicone. See Figure 5.

[9] Wolf, Andreas T., *Studies of the Aging Behavior of Gun-grade Building Joint Sealants – The 'State of the Art'*
[10] Amstock, Joseph S., "Sealant Selection," *Glass Magazine*, July 1990

Figure 5: Silicone and Polysulfide Water Vapor Permeability for a 3-mm Membrane[11]



Combining the performance contributions of PIB and silicone completes a weather-resistant unit capable of meeting the ASTM E-2190 specification which is part of the requirement for NFRC 706 certification. A comparison of IG unit sealant configurations is given in Table IV, showing the superior performance of the PIB/silicone combination in insulating glass units.

TABLE IV: Relative IG Seal Durabilities as Tested in P1 Chamber[12]

Edge Seal	Longevity	Mode of Failure
Single Seal: PIB	1 Day	Adhesion Bond Loss
Single Seal: Polysulfide, Polyurethane	6-8 Weeks	Adhesion Bond Loss
Dual Seal: PIB/Polysulfide PIB/Polyurethane	12-15 Weeks	Adhesion Bond Loss
Dual Seal: PIB/Silicone with Keyed Corners	15-20 Weeks	Frost Point Fail
Dual Seal: PIB/Silicone with Improved (Bent) Corners	40 + Weeks	Frost Point Fail

Note: Aged with P-1 Chamber: 140°F, Water Spray, UV Radiation.

11 Wolf, Andreas T. "The Temperature Dependency of Water Vapour Diffusion Through Insulating Glass Sealants," *Kautschuk and Gummi Kunstsoffe*, Vol. 38 (1985), No. 9, Dr. Alfred Huthig Verlag, Heidelberg

12 Larsen, Jim, "Can Argon Gas-Filled Units Be Sealed with Silicone?" *Glass Magazine,* November 1989

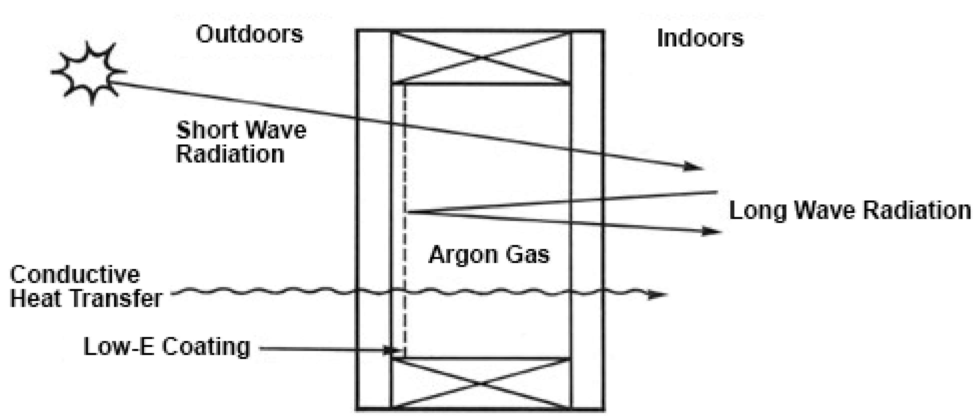
Gas Filling with Silicone Seals

Why Gas Fill?

Heat is transferred through insulating units via radiation, conductive or convective heat transfer routes. The use of low-E (low-emissivity) coatings has dramatically improved the radiation heat transfer through glass by selectively allowing only some types (or wavelengths) of radiation to pass, see Figure 6. The theory behind the low-E coatings is well documented in published literature.

The purpose of gas filling is to reduce the heat transfer and improve the energy efficiency of the insulating glass unit. Gas filling can also be a means of reducing the sound transfer through an insulating glass unit and improving the acoustical properties.

Figure 6: Heat Transfer Through IG Units[13]



The additional incorporation of gas filling further improves insulating glass unit heat transfer by reducing the conductive heat transfer. This is accomplished by the use of gases having lower thermal conductivities than air. (Air is approximately 79 percent nitrogen, 21 percent oxygen.) The gases typically used are argon, for heat transfer reasons, and sulfur hexafluoride (SF_6), for acoustic purposes. A comparison of relative gas thermal conductivities is shown in Table V.

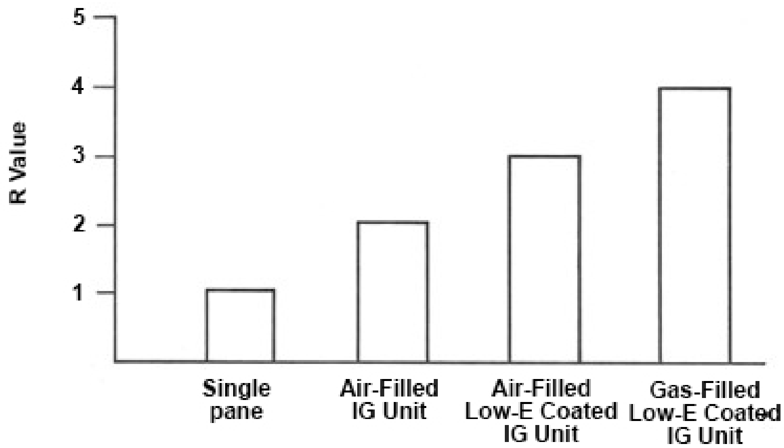
TABLE V: Gas Thermal Conductivity[14]

Gas	Thermal Conductivity (calorie) (cm) (sec)(°C)(cm^2)
Air	60.3
Oxygen	61.6
Nitrogen	60.3
Argon	41.3

[13] Larsen, Jim, "Can Argon Gas-Filled Units Be Sealed with Silicone?" *Glass Magazine,* November 1989
[14] *Handbook of Chemistry and Physics*, 60th Edition

A comparison of R-values for various glazing combinations is shown in Figure 7. A single-pane window has an R-value of approximately 1 (U value = 1.0). By going to a non-coated, air-filled dual pane insulating glass unit, the R-value is increased to approximately 2 (U value = 0.50). Adding a low-E coating to the insulating glass unit increases the R-value to approximately 3 (U value = 0.33). Finally, by gas filling the coated insulating glass unit, the R-value can be raised to approximately 4 (U value = 0.25).

Figure 7: Insulating Glass Unit R Values[15]



Gas-Filling Equipment

The two current methods for gas filling include the vacuum method and the probe method[16]. Each requires state-of-the-art equipment, and each has its own unique advantages and disadvantages.

The Chamber Method

In the chamber method, the insulating glass units are initially evacuated with vacuum and then backfilled with the inert gas of choice. The efficiency of gas filling by this method depends on the number of units that can fit into a chamber as well as the speed at which the chamber can be evacuated and backfilled with gas. Some insulating glass unit manufacturers that utilize this method also hold patents on the method.

Lance and Probe Method

An alternative method to the vacuum method is the lance and probe method. The general intent of this method is to fill the insulating glass units with gas via one lance, while evaluating the exiting air via a probe in a second location. When the exiting samples contain a high concentration of the inert gas, as tested by a gas chromatograph, the units are assumed to be fully filled.

The locations of the lances or probes vary, depending upon unit size and fabrication processes. Both can be placed along one vertical side, along the top, at diagonal corners, or one along a vertical side with the other at the top. These are just a few of the probe location combinations possible. The location combination affects the filling efficiency. Work with gas-filling equipment suppliers to determine the most efficient locations for production.

Once the sensor indicates that the units are filled with gas, the lances and probes are removed, the holes immediately filled with polyisobutylene (PIB), and any final sealing performed. Care must be taken to prevent the gas from entering the unit so fast that turbulence occurs in the unit, as this could give inaccurate sensor sample evaluations and filling efficiency predictions.

[15] Ernst, Randi, "Gas Filling of IG Units," *Advancements through Education 1996,* SIGMA Educational Seminar, April 15,16, Rosemont, IL
[16] Ernst, Randi, "Gas Filling of IG Units," *Advancements through Education 1996,* SIGMA Educational Seminar, April 15,16, Rosemont, IL

Gas-filling equipment for the lance and probe method is available from several suppliers, including Ratio, Technik, Pector and Lisec. A more detailed description of the lance and probe method and its advantages and disadvantages is available from these equipment suppliers.

Application Recommendations

Several factors, including unit design and workmanship, affect the success of gas filling insulating glass units.

Design

Insulating glass unit design affects the success of gas-filled insulating glass units. The loss of gas can be reduced by increasing the resistance to gas leakage. Gas leakage can be slowed by decreasing the area available for gas transmission and increasing the path length required for gas transmission.

Workmanship

Workmanship plays an important role in determining the success of gas filling, much as it does in ensuring success of manufacturing a normal air-filled insulating glass unit. Glass lites and spacers must be properly cleaned to ensure that the primary and secondary sealants attain satisfactory adhesion. Improperly cleaned insulating glass units, regardless of sealant choice, can potentially have premature failure and gas loss due to sealant adhesion failure.

Spacers must be properly aligned. Failure to do so will result in less than desired secondary seal depths. PIB primary seal stressing and failure can occur if insufficient secondary seal is present to maintain unit structural integrity.

Bent corners are typically used to maintain a solid, uniform spacer. Corner keys and any probe holes located in the spacer should be butyl injected to eliminate voids or openings of any kind through which gas could migrate. Any voids or openings will act as open doors through which the gas will migrate with minimal resistance.

It is essential that IG units have a uniform, consistent primary seal. The seal cannot contain voids or skips. Any voids or skips will also act as open pathways for gas migration.

The secondary seal must also be free of voids or skips. Any inconsistencies may allow undue stressing or failure of the PIB seal, the primary barrier to gas leakage. Two-part sealants must be properly mixed and used at the proper mix ratio.

The initial efficiency of the insulating glass units will also affect the long-term performance of the units. In simplistic terms, the more inert the gas used to fill units, the higher the R-value of the units.

Secondary Sealant Selection
During the consideration of the secondary sealants, a large difference between permeability of the sealant families is noticeable. See Table VI.

TABLE VI: Sealant Permeability's ($g/m^2/day$).[17]

Sealant	Gas	
	Oxygen	**Argon**
PIB	0.7	1.0
Polysulfide	5.0	4.0
Polyurethane	50	45
Silicone	750	650

The key to choosing the proper sealants is focusing on the gas leakage through the insulating glass unit as a whole, and not necessarily through individual components. A properly applied polyisobutylene (PIB) primary seal will sufficiently act as the main barrier to prevent the inert gas from leaking. The secondary sealant then becomes the structural component that holds that unit together and protects the primary seal from harsh environmental conditions and premature degradation.

Silicone sealants demonstrate superior performance in regards to maintaining adhesion, tensile strength, and flexibility after exposure to ultraviolet radiation, water immersion, temperature extremes, and stressing when compared to their organic counterparts. Although silicone sealants may have relatively high gas permeation rates, when used in combination with a low permeability polyisobutylene (PIB) primary seal, these dual seal silicone insulating glass units have proven to retain inert gas exceptionally well. Field testing of argon-filled insulating glass units by Cardinal IG demonstrates 97 percent argon retention after over 2-1/2 years of aging.[18]

Industry Testing for IG Unit Gas Leakage

In the United States, ASTM E-2649, *"Standard Test Method for Determining Argon Concentration in Sealed Insulating Glass Units Using Spark Emission Spectroscopy"* is becoming more broadly accepted as the method used to determine argon concentration in Insulating Glass Units.

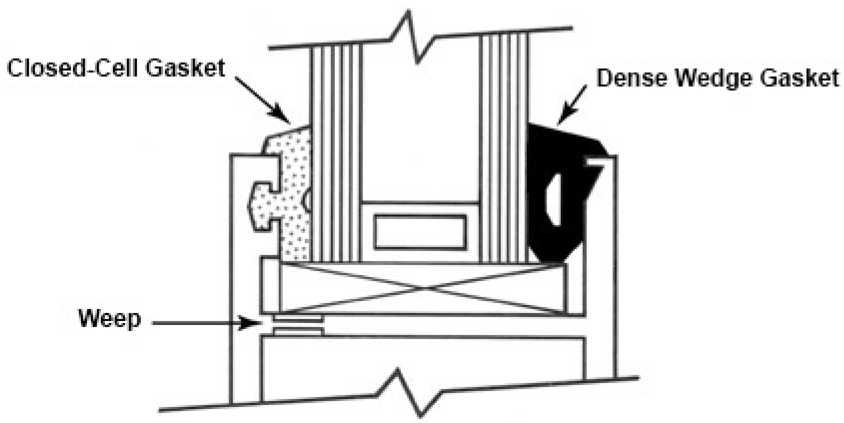
In Europe, test methods DIN1286 Part 2, 52 983 and EN 1279-3 are used to determine gas leakage rates from insulating glass units. To accomplish this, the edge of an insulating glass unit is captured in a metal channel of a given control volume. The control volume is initially purged with helium. The unit is then maintained in this condition for a given time period. After the specified time, a sample of the gas in the control volume is extracted, separated, and analyzed for gas concentrations. By determining the gas concentrations in the control volume, the gas leakage rate out of the insulating glass unit can be approximated and extrapolated for the unit's lifetime. Since the test requires relatively short time duration, testing can be performed quite rapidly to determine the rate of gas leakage out of an insulating glass unit. However, the short duration and potential for experimental error in the helium purge can result in high error rates when extrapolating data for expected gas leakage over many years.

[17] *Handbook of Chemistry and Physics*, 60th Edition
[18] Larsen, Jim, "Can Argon Gas-Filled Units Be Sealed with Silicone?" *Glass Magazine,* November 1989

Insulating Glass Unit Applications

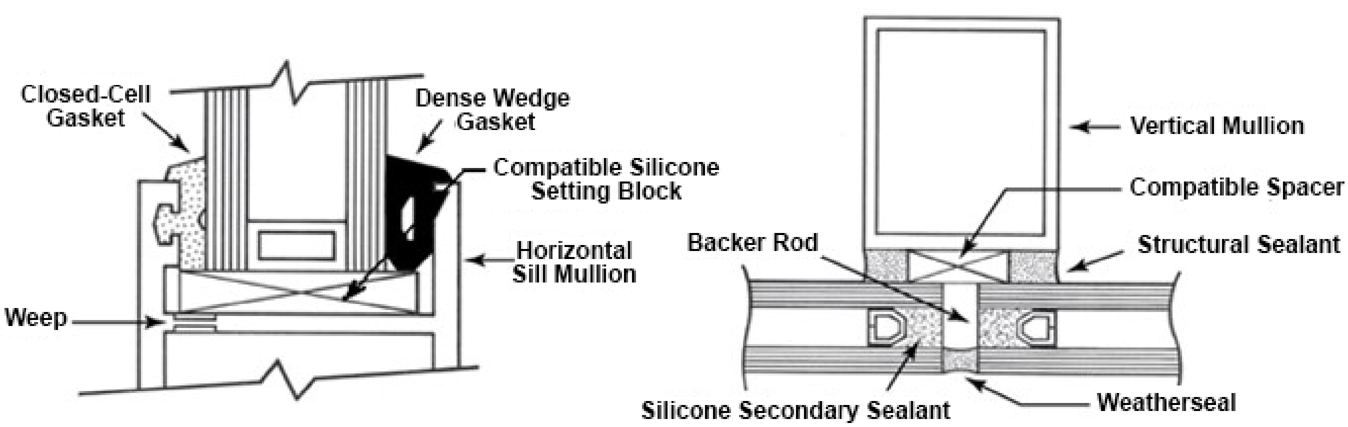
The vast majority of insulating glass unit applications in residential and commercial building systems is either *conventional dry glazed* or *structurally silicone glazed* applications. Conventional dry glazing involves structurally holding insulating glass units in place within a frame system by using dry spacers and gaskets. See Figure 8.

Figure 8: Sill Detail for Conventional Dry Glazing[19]



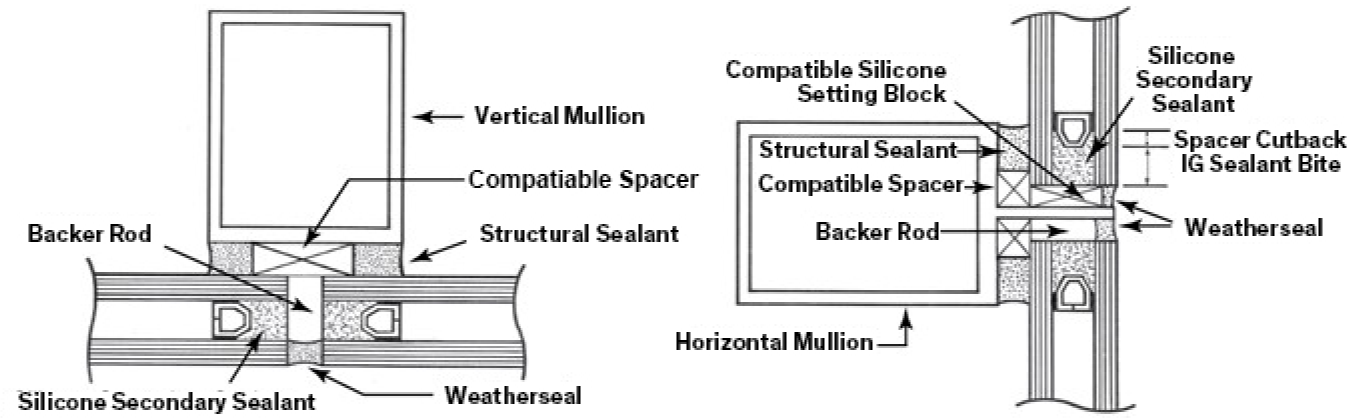
In structural silicone glazing, a silicone sealant is used to structurally attach insulating glass units to a frame system. Structural silicone glazing is typically two-sided or four-sided. Two-sided structural silicone glazing refers to the use of a silicone sealant to attach two opposite insulating glass unit sides, usually the vertical sides, to a frame system. See Figure 9. Four-sided structural silicone glazing refers to the use of a silicone sealant to attach all four insulating glass unit sides to a frame system. See Figure 10.

Figure 9: Detail for Two-Sided Structural Glazing[20]



[19] Dow Americas Technical Manual, Form No. 62-1112-01
[20] Dow Americas Technical Manual, Form No. 62-1112-01

Figure 10: Detail for Four-Sided Structural Glazing[21]

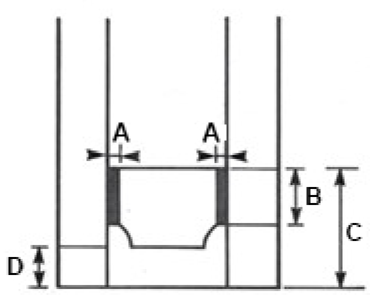


A sufficient secondary seal depth and a well-designed system are required if an insulating glass unit is used in either a conventional dry glazing or a structural silicone glazing application. Each of the glazing options has its own requirements and areas of consideration.

Conventional Dry Glazing

In 1989, the Sealed Insulating Glass Manufacturers Association (SIGMA) performed a sealant dimension survey of major sealant suppliers for applications such as residential and conventional dry glazing applications. The survey summary recommended minimum sealant dimensions for either single or dual seal insulating glass units as specified by key hot melt butyl, polyurethane, polysulfide, and silicone sealant suppliers in the United States. A summary of the results for silicone sealants is provided in Figure 11.

Figure 11: SIGMA Survey Recommended Seal Dimensions for Conventional (Dry Glazed) Dual Seal Unit, Silicone Secondary Seal[22]



Dimension	Minimum Value, inch
A	0.010-0.016
B	0.188-0.240
C	0.438-0.585
D	0.125

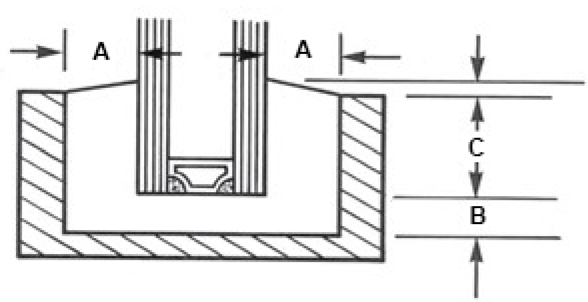
[21] Dow Americas Technical Manual, Form No. 62-1112-01

[22] Sealed Insulating Glass Manufacturers Association, Technical Publications, Technical Bulletin TB-1201-89(91), Chicago Il

Curtainwall system and IG unit design recommendations are outlined and discussed in industry manuals such as SIGMA's Glazing Guidelines for Sealed Insulating Glass Units (TM-3000), the Glass Association of North America (GANA) Glazing Manual, and the American Architectural Manufacturers Association (AAMA) Aluminum Curtain Wall Series and IGMA (Insulating Glass Manufacturers Alliance) TM 3000-90, *North American Glazing Guidelines for Sealed Insulating Glass Units for Commercial & Residential Use*. Several points worth reviewing from these industry manuals include:

- The weep system must be adequate to drain water faster than it is infiltrated. This usually requires weep holes of approximately 3/8" diameter.
- Insulating glass units must have adequate clearance and be free to move in the frame. Glass contact with the frame can cause excessive point stressing.
- Recommended minimum clearances are shown in Figure 12.

Figure 12: Typical Edge and Face Clearance and Bite Dimensions[23]



Dimension	Minimum Size, inches
Face Clearance, A	3/16
Edge Clearance, B	1/4
Bite, C	1/2

- Identical setting blocks of 85 + 5 durometer should be used at sill quarter points. Under no circumstance should the outer ends of the setting block be located closer than eight points or 6" from the insulating glass unit corners. The setting blocks should be of proper size and design to ensure full bearing of the unit, yet allow water drainage[24].
- Based on historical testing and success, most silicone setting blocks, composed of 100 percent silicone, are found to be compatible for full contact with structural silicones. Other materials such as EPDM, Neoprene, *Santoprene*, *Kraton*, SCR (Silicone Compatible Rubber – an EPDM-based material), and other similar organic materials may cause discoloration of light-colored silicone sealants. In these cases, gray silicone secondary sealant is not recommended. Where discoloration is severe, even dark-colored silicone sealants may not be approved for the applications.
- If the structural sealant is in contact with the setting blocks, (i.e. two-sided horizontal and four-sided structural glazing), then silicone setting blocks composed of 100 percent silicone are highly recommended and may be required by the insulating glass manufacturer. Check with your insulating glass manufacturer to understand their policies on setting blocks.
- Edge blocking in vertical channels is required to limit lateral movement (side walking) of insulating glass units. The blocks should be of 65 durometer and at least 4" in length. A nominal 1/8" clearance between the glass and block is recommended[25].

[23] Sealed Insulating Glass Manufacturers Association, *Glazing Guidelines for Sealed Insulating Glass Units,* TM-3000(97), Chicago IL

[24] Sealed Insulating Glass Manufacturers Association, *Glazing Guidelines for Sealed Insulating Glass Units,* TM-3000(97), Chicago IL

[25] Sealed Insulating Glass Manufacturers Association, *Glazing Guidelines for Sealed Insulating Glass Units,* TM-3000(97), Chicago IL

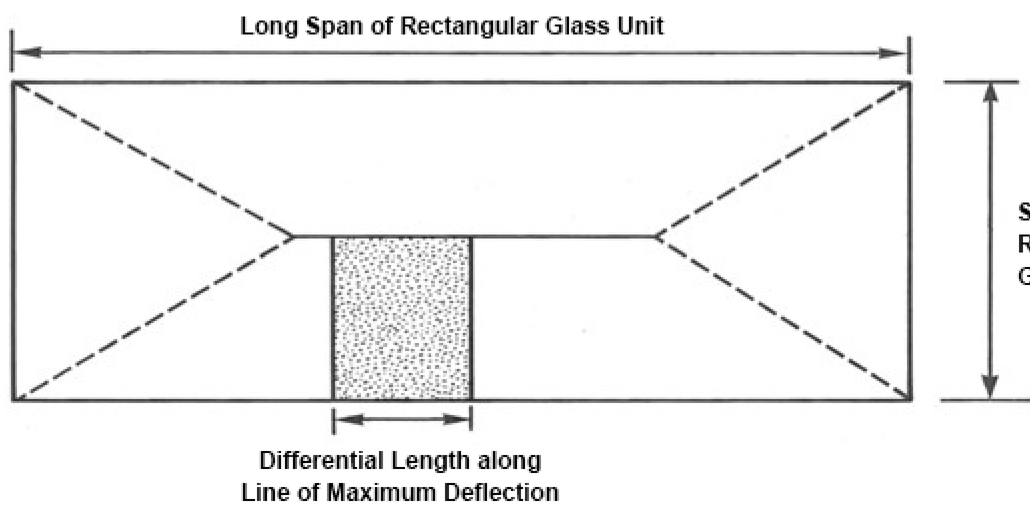
Structural Silicone Glazing (SSG)

The silicone secondary sealant is the major, if not the only, component attaching the exterior lite of an insulating glass unit to the curtainwall frame. Due to the superior durability and weatherability of silicone sealants, only silicone dual sealed insulating glass units are approved by the industry for use in structural glazing applications.

Sealant dimension guidelines for insulating glass units used in structural silicone glazed applications require extra attention. For IG units used in structural glazing applications, it is the responsibility of the insulating glass manufacturer to determine the amount of structural silicone sealant required for the secondary sealant bite. The IG manufacturer's engineering design/project team shall approve the appropriate method of calculating bite requirements of the IG secondary seal such that maximum silicone sealant design-strength of 20 psi[26,27] is not exceeded.

For structurally glazing panels to mullions, the accepted industry method used to calculate the structural sealant contact dimension or bite is based on the trapezoidal load distribution rule, which assumes that a monolithic glass lite or an insulating glass unit deflects under windload in a way that bisects the angles and results in a maximum deflection along a line in the center of the lite. The idealized unit deflection[28] is shown by the dotted lines in Figure 13.

Figure 13: Trapezoidal Load Theory Deflection Pattern on a Rectangular Glass Unit[29]



As the deflection varies along the side of the unit, so does the stress placed on the structural sealant holding the unit to the curtainwall mullion. The method for calculating the structural sealant bite involves calculating the amount of sealant required over a differential area in the region of maximum deflection, as shown in the shaded region in Figure 13.

[26] *Structural Sealant Glazing, ASTM STP 638,* J. R. Hilliard, C. J. Parise and C.O. Peterson, Jr., Eds., American Society for Testing and Materials, Philadelphia.

[27] Klosowski, J. and Schmidt, C., "The Role of Adhesive Sealants in Structural Glazing, "U.S. Glass, Metal & Glazing, July/August 1984.

[28] Haugsby, Michael H., Schoenherr, William J., Carbary, Lawrence D., Schmidt, Christine M., "Methods of Calculating Structural Silicone Sealant Joint Dimensions," *Science and Technology of Glazing Systems*, Parise, Charles J., Editor, ASTM 1054 1989

[29] Haugsby, Michael H., Schoenherr, William J., Carbary, Lawrence D., Schmidt, Christine M., "Methods of Calculating Structural Silicone Sealant Joint Dimensions," *Science and Technology of Glazing Systems*, Parise, Charles J., Editor, ASTM 1054 1989

Using the appropriate mathematical derivation, the following calculation can be used to determine structural sealant bite (which holds the IG unit to the curtainwall mullion):

$$\text{Structural Sealant Bite (in)} = \frac{\frac{1}{2} \times \text{Smallest Leg of Largest Lite (ft)} \times \text{Windload (lb/ft}^2\text{)}}{\text{Sealant Design Strength (= 20 psi)} \times 12 \text{ in/ft}}$$

$$= \frac{\text{Smallest Leg of Largest Lite (ft)} \times \text{Windload (lb/ft}^2\text{)}}{480}$$

In simplest terms, the structural sealant bite for rectangular units is based on a calculation which requires knowing the smallest leg of the largest unit and the wind load. The sealant design-strength used for structural glazing is 20 psi[30] which has been accepted and successfully used by the US industry for over 30 years.

50/50 Load sharing Principle for Insulating Glass Units

An insulating glass unit pressurized by wind loading deflects very similarly to the assumed trapezoidal load distribution rule. In IG units where the thickness of the inboard glass lite is equal to or greater than the outboard lite, the IG industry generally accepts that the insulating glass secondary seal bite carries 50 percent of the maximum wind load based on the 50/50 load-sharing principle. Thus, the secondary seal bite is calculated as one half that of the structural silicone sealant bite.

The 50:50 load-sharing principle concludes that if the insulating glass unit is made of two symmetrical, well-sealed glass lites, where the inboard glass lite is in size and thickness equal to or greater than the outboard lite, then the insulating glass unit secondary sealant absorbs approximately 50 percent of the maximum windload forces placed on the installed unit in the field, while the silicone structural glazing sealant that attaches the insulating glass unit to the curtainwall mullion carries 100 percent of the maximum windload. The 50:50 load-sharing principle is well documented and has been published by university studies.[31] This principle is generally accepted throughout the North American construction and insulating glass industry. Therefore, as a minimum, insulating glass units are designed with a secondary seal depth sufficient to withstand at least 50 percent of the maximum windload specifications for a specific structural silicone glazed building.

The industry accepted structural IG secondary sealant bite calculation for 50/50 load sharing is as follows:

$$\text{IG Sealant Bite (in)} = 50\% \; \frac{[\frac{1}{2} \times \text{Smallest Leg of Largest Lite (ft)} \times \text{Windload (lb/ft}^2\text{)}]}{\text{Sealant Design Strength (= 20 psi)} \times 12 \text{ in/ft}}$$

$$= \frac{\text{Smallest Leg of Largest Lite (ft)} \times \text{Windload (lb/ft}^2\text{)}}{960}$$

The bite dimension may include the "cutback" or shoulder area of the IG spacer.[32,33]

Similar equations can be derived for triangular and other quadrilateral unit shapes. Information is provided in the article "Methods of Calculating Structural Silicone Sealant Joint Dimensions" in *Science and Technology of Glazing Systems*.[34]

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30 ASTM C-1249 "Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications"

31 Chou, David G., Minor, Joseph E., and Vallabhan, C.V. Girija, "The Structural-Mechanics Behavior of Insulating Glass Units," Texas Tech University, Glass Research and Testing Laboratory, Lubbock, Texas, July 1986. NTIS Document Number – PB86234614.

32 Sandberg, L. Bogue and Carbary, Theresa M., "Spacer Geometry Effects on Strength of Insulating Glass Joints for Structural Glazing Applications," *Science and Technology of Glazing Systems*, Parise, Charles J., Editor, ASTM 1054 1989

33 ASTM C-1249 "Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications

34 Haugsby, Michael H., Schoenherr, William J., Carbary, Lawrence D., Schmidt, Christine M., "Methods of Calculating Structural Silicone Sealant Joint Dimensions," *Science and Technology of Glazing Systems*, Parise, Charles J., Editor, ASTM 1054 1989

50/50 Load Sharing Exceptions

In cases where the thickness of the outboard lite is greater than that of the inboard lite, the 50/50 load sharing principle is no longer a valid method and the load-sharing of the silicone structural bite of the IG unit must be independently determined. The North American IG Industry has generally accepted the Texas Tech University paper, "The Structural-Mechanics Behavior of Insulating Glass Units[35]" as the basis for determining the secondary sealant bite in these calculations. The information found in this paper should be reviewed and understood by the IG manufacturer's engineering design team to determine its appropriateness in their IG designs. The calculations and graphs are based on a number of assumptions that may or may not be appropriate to a particular IG design. Thus, these calculations and graphs should not be simply used without a complete understanding of the underlying assumptions.

Additional Considerations for IG Manufacturers

Design Review – It is the IG manufacturer's responsibility to review and approve structurally glazed IG units for projects. The glass supplier should work closely with all other parties involved to prevent overlooking any critical points. The structural silicone supplier's responsibility is to calculate the bite requirements to attach the IG unit to the mullion. Check with the structural silicone supplier to see if blueprints have been reviewed and approved. The structural silicone supplier reviews the blueprints and approves the structural silicone joint dimensions and designs. This helps prevent improper structural silicone design which could result in field problems. The IG manufacturer has the responsibility to ensure the units have sufficient secondary silicone sealant bite and are installed appropriately. As an IG manufacturer, it is recommended that a review of the prints and design for all silicone structurally glazed systems as well as mechanically captured systems is conducted. When performing design/print reviews, Dow excludes review of the IG bite requirements.

Laminated Glass Compatibility – Laminated glass with polyvinyl butyrol (PVB) interlayer may delaminate up to ¼" (6 mm) and occasionally more at the edges when in contact with any sealant. For further information, contact the laminate manufacturer. Two sources include www.saflex.com and www.dupont.com/safetyglass/products/index.html. Dow design/print reviews exclude review of sealant effects on PVB interlayers.

Polycarbonate Compatibility – Direct sealant contact with laminated polycarbonate IG units may result in stress cracking of the polycarbonate. This is especially important to consider in restricted or confined cure applications. Sealant contact with the polycarbonate should be avoided unless a design review and testing has been completed to support the application. Dow design/print reviews exclude review of sealant effects on polycarbonate.

Sealant Choices – The secondary sealant and structural sealant suppliers must approve the proposed structural sealant choice for the structural sealant glazing applications for compatibility (See Product Offering, page 4, for silicone IG sealants suitable for structural applications.) For example, under certain conditions, the corrosive vapors liberating from acetoxy cure silicone sealants can cause degradation of two-part silicone secondary sealants, which might potentially lead to premature failure of the insulating glass unit.[36] Dow does not approve the use of neutral-cure IG silicone sealants in the presence of acetoxy silicone sealants. Dow also does not approve the use of acetoxy silicone sealants as structural secondary IG sealants.

[35] Chou, David G., Minor, Joseph E., and Vallabhan, C.V. Girija, "The Structural-Mechanics Behavior of Insulating Glass Units," Texas Tech University, Glass Research and Testing Laboratory, Lubbock, Texas, July 1986. NTIS Document Number – PB86234614.

[36] ASTM C-1249 "Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications

Adhesion – It is the IG manufacturers' responsibility to:

- Confirm adhesion performance to commonly used substrates
- Monitor adhesion performance to substrates through a quality assurance program
- Recognize changes in substrates (glass, metal, etc.) and retest adhesion when changes occur
- Identify new substrates, or substrate suppliers, and submit substrates to the structural silicone sealant supplier for adhesion testing.

Most structural silicone sealant suppliers perform a version of the 14-day ASTM C 794 adhesion-in-peel test upon request. Sealant adhesion is tested after initial 7-day room temperature dry conditions, 1-day water immersion followed by 7-day water immersion. This test allows the structural sealant supplier to make recommendations on surface preparation and priming, ensuring good sealant adhesion to the glass and metal surfaces.

Compatibility – Check with the secondary sealant and structural sealant suppliers to confirm and approve the compatibility of the sealants and any accessory materials they may contact, such as setting blocks, gaskets, spacers, and weatherseals. Most silicone sealant suppliers perform the 22-day ASTM C 1087 compatibility test upon request. The sealant is applied in direct contact with the accessory material in question. Two test specimens are placed in a chamber with high-intensity ultraviolet radiation and elevated temperature. One specimen has the sealant exposed directly to the ultraviolet light; the second has the exposure occur through the glass. After the test period, samples are inspected for compatibility in the form of observed sealant discoloration and qualitative adhesion. Please note that non silicone setting and edge blocks commonly cause discoloration of IG secondary seals and field applied silicone weather seals.

Exposure to Solvents – Silicone insulating glass sealants are susceptible to swelling when in contact with solvents such as Isopropanol, Volatile Siloxane fluids, Methylethylketone, and terpenes. These solvents will not decompose the silicone; however they may permeate the silicone and cause a negative effect to the PIB primary seal. Wood treatments, solvent extended sealants and solvent based sealants contacting the Secondary Seals of an IG unit has been documented to cause PIB flow within a unit.[37] Solvent based water repellents that are post applied to a masonry building and allowed to enter the glazing weep system may contribute to PIB flow within a sealed IG unit. Setting blocks and edge blocks that are saturated with solvent may also have similar effects on the PIB within the unit. PIB flow within a unit is unsightly and may result in premature IG unit fogging.

Sealant Quality Control Testing

Quality control testing should be performed to ensure that the sealant selected will consistently perform as required in insulating glass units. The silicone sealant supplier should conduct some of the testing with the remaining testing conducted by the insulating glass manufacturer at the time of insulating glass unit production. Performance testing of insulating glass units should be conducted in accordance to industry-accepted standards to ensure that units perform acceptably.

Silicone Sealant Supplier Testing

Silicone sealant suppliers typically perform quality control testing on each lot of sealant they manufacture to verify that the sealant will perform adequately and consistently and to ensure that sealant production is monitored to statistical process control criteria and specification limits. The silicone sealant supplier should be able to forward the certificate of analysis (C of A) results of testing done on any sealant lot used in production upon customer request. The silicone sealant supplier testing is generally done in accordance with accepted ASTM standard test methods. See Table VII for the more commonly used test methods. Sealant type (i.e. one-part or two-part) often determines what testing protocol is conducted.

[37] Cardinal IG Technical Service Bulletin #IG15, *"Wood Treatment Compatibility with Insulating Glass Sealants"*

Particular sealant properties tested often include:

- **Sealant Flow –** Extrusion rates or viscosity, slump.
- **Sealant Cure Rate –** Tack-free time, skin over or working time, snap time, deep section cure time.
- **Sealant Bulk Properties –** Durometer, tensile strength, elongation.
- **Sealant Adhesion –** Peel adhesion, tensile adhesion (usually conducted on customer substrates at customer's request).

TABLE VII: ASTM Standard Test Method Number and Titles for Sealant Properties

Sealant Property	ASTM Test Number	Title
Tack-Free Time	C 679	Standard Test Method for Tack-Free Time of Elastomeric Sealants
Extrusion Rate	C 603	Standard Test Method for Extrusion Rate and Application Life of Elastomeric Sealants
Slump	C 639	Standard Test Method for Rheological (Flow) Properties of Elastomeric Sealants
Durometer	C 661	Test Method for Indention Hardness of Elastomeric-Type Sealants by Means of a Durometer
Tensile Strength	D 412	Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension
Elongation	D 412	Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension
Tear	D 624	Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers
Peel Adhesion	C 794	Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants

National Fenestration Rating Council (NFRC) Certification

NFRC 706 under its Product Certification Program requires insulating glass units used in NFRC certified and labeled products to be certified as meeting certain performance requirements by an independent IG certification program listed by NFRC. For a listing of independent labs authorized to conduct the certification consult the NFRC website at www.nfrc.org/IGCertification.aspx.

Industry Specifications and Test Methods

The insulating glass industry has established several standard specifications and test methods used to determine the durability and performance of insulating glass units. Many of the industry specifications and test methods relating to insulating glass and structural glazing are shown in Table VIII.

TABLE VIII: ASTM Specifications and Test Methods for Insulating Glass and Structural Glazing

ASTM Designation	Description
E 2188	Standard Test Method for Insulating Glass Unit Performance
E 2189	Standard Test Method for Testing Resistance to Fogging in Insulated Glass Units
E 2190	Standard Specification for Insulating Glass Unit Performance and Evaluation
C 920	Standard Specification for Elastomeric Joint Sealants
C 1184	Standard Specification for Silicone Structural Sealants
C 1249	Standard Guide for Secondary Sealed Insulating Glass Units for Structural Glazing Applications
C 1265	Standard Test Method for Determining Tensile Properties of Insulating Glass Edge Seal for Structural Applications
C 1392	Standard Guide for Evaluating Failure of Silicone Structural Glazing
C 1369	Standard Specification for Secondary Edge Sealants for Structurally Glazed Insulating Glass Units
C 1394	Standard Guide for In-Situ Silicone Structural Glazing Evaluation
C 1401	Standard Guide for Structural Sealant Glazing; Annual Guide of ASTM Standards Book 4.07

Sealant Application Recommendations

Sealant selection, testing and quality control principles both at the sealant manufacturers' location and on the insulating glass production line contribute to the long-term performance of insulating glass units.

Sealant Screening

Contact the silicone sealant supplier's technical service and development group to review sealant features and choices and to outline the sealant testing that will be necessary to confirm that the silicone sealant will perform properly in a unit prior to qualifying the sealant for production. The silicone sealant supplier can perform a variety of tests to help assist the customer in the sealant selection process. These tests commonly include, but are not limited to:

- Peel adhesion testing on glass, pyrolytic coated glass, edge deleted glass and spacers
- Tensile adhesion testing on glass, pyrolytic coated glass and edge deleted glass
- Tensile adhesion testing on glass with selected spacer inclusion
- Compatibility with glass, glass coatings and spacer
- Compatibility with Polyisobutylene (PIB)

Performing this testing will help prevent unexpected sealant performance issues in units and will help to shorten the production qualification process.

Insulating Glass Unit Qualification

After the sealant selection process, test units are often made and submitted to testing facilities capable of qualifying the units to industry accepted standards. This step may or may not be required for NFRC certification, but it is critical for the insulating glass manufacturer to understand the NFRC requirements prior to changing sealants. Even if external qualification is not required, insulating glass manufacturers often perform similar testing to re-qualify their insulating glass units. This ensures that they maintain their reputation in the industry.

The sealant manufacturer can assist in these efforts by supplying sealant samples for the purpose of making the test units required for qualification. Additionally, the sealant manufacturer may work with equipment vendors to assist in the set up of pumps and mixing systems to ensure the material is properly applied to the test units. Often, the sealant manufacturers' technical representative will be present during the process of manufacturing test units for qualification to provide inspection and guidance for material handling issues that might arise due to the novelty of the sealant selected.

Production Workmanship

During qualification and as an on-going policy, production workmanship is critical to the continued success of sealing insulating glass units with silicone sealants. Proper cleaning, assembling, and equipment maintenance of other insulating glass unit components used in conjunction with the silicone sealant is essential. A partial list of component key points to remember when assembly units include:

Corner Keys

- Corner keys must be dry and clean.
- Corner keys must fit tightly into the spacer bar.
- Soldering or butyl injection of corner keys is recommended.

Spacers

- Spacers must be clean, dry, and free of grease, forming fluids, finger prints, etc.
- Spacers must be properly aligned to the edge of the glass.

Desiccant

- Proper amounts of desiccant should be used.
- Desiccant must be dry at the time of installation; do not use already spent desiccant.

Glass

- Glass surfaces must be properly cleaned and free of fingerprints. Proper maintenance of glass cleaning equipment and cleaning solution is essential.
- Glass lites should have no edge defects or inconsistencies.
- Glass lites must be properly aligned with the spacer and opposing glass lite.

PIB Primary Seal

- Primary seal must be applied in a continuous, uninterrupted bead, free of voids or skips. Excess PIB should not protrude into the secondary seal cavity.
- Primary seal must be uniformly and sufficiently pressed to give an even thickness and good adhesion to the glass and spacer surfaces.
- PIB consistency is probably the single most important factor in ensuring that the IG unit maintains the internal environment as constructed and does not exhibit fogging or other signs of premature failure in the IG unit's lifetime.

Silicone Secondary Seal

- All sealants should be properly stored prior to use and used within their established shelf life period.
- Multicomponent sealants must be fully mixed and used at the proper mix ratio.
- Sealant must be applied in a continuous, uninterrupted bead, free of skips or voids.
- For proper sealant performance sealants should be free of incorporated air.
- Sealant should be immediately tooled into position.

Application Temperatures for Two-Part Silicone Sealants

It is recommended that DOWSIL™ Silicone Insulating Glass Sealants be applied between temperatures of 12 to 35°C (50 to 95°F). These products should not be used in unheated shops/buildings during the winter as variable adhesion properties may result when the product is applied to insulating glass units. Containers of base and catalyst should be stored indoors in cool storage areas to ensure adequate shelf life. Since the packaged materials are usually transported in unheated trucks, which will be cold in the winter the material should be quickly brought indoors and allowed to acclimate for a few days prior to using. Doing so helps to maintain consistency of snap, cure and adhesion times. Cold base and cold catalyst will cure slower even if the shop temperatures are warm. For each drop of 10°C, the reaction rate (snap time, cure and adhesion) will decrease by approximately one half. It is not uncommon to see these properties drop during the winter from typical properties seen in the summer. This change in initial properties will not affect the cured performance of the sealant.

In-House Quality Control Testing

Although silicone sealant suppliers perform quality control testing to ensure a lot-to-lot consistency in silicone insulating glass sealants, the insulating glass unit manufacturer should also perform and record tests in-house to confirm that the silicone sealant is being used properly. Good quality control habits and record keeping will assist troubleshooting in the event that a problem occurs.

Always ensure that the sealant is within the established shelf life as reported by the manufacturer. Sealant suppliers usually mark drums with a “use by” date. Never use material out of shelf life and rotate your stock to ensure that you are always using the older material first.

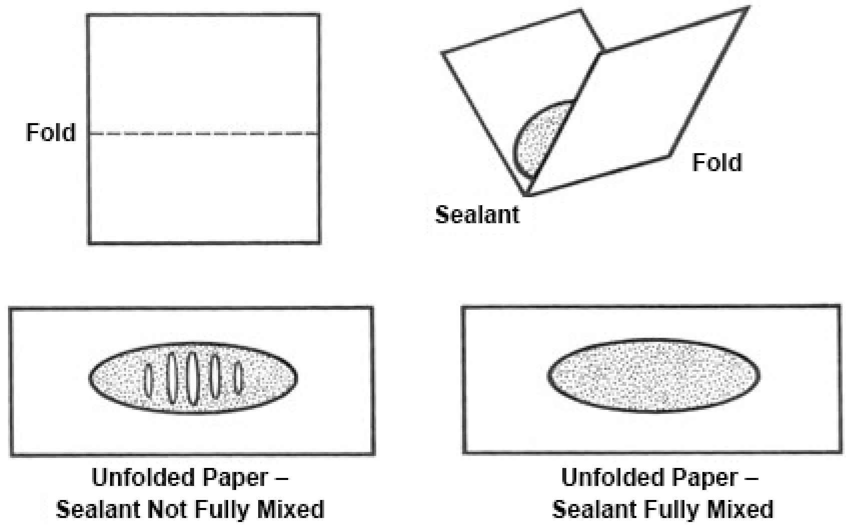
Record the sealant lot number (for both the base and catalyst if using a two-part technology) in a log book and establish a tracking system that allows identification of the lot number used on every IG unit manufactured.

Butterfly Test

For multi-component sealants, butterfly tests should be performed every time a pump is started, and intermittently throughout the day’s production. The purpose of the butterfly test is to check for an adequate mix of base and curing agent components.

The butterfly test is performed by dispensing a bead of sealant onto a piece of paper folding the paper in half and smearing down the sealant bead, then reopening the paper. Visually inspect the sealant smear. When a pump is first started up, the smear may appear predominantly white. This is because the equipment lines should have been base purged at the previous shutdown and there is no catalyst present in the mix. Continue to make sealant smears and inspect for white streaks or striations. When the sample appears to be uniform in color with no observable white streaks, the sealant is fully mixed. See Figure 14.

Figure 14: Butterfly Test Procedure[38]



Alternately, the butterfly test can be performed with two pieces of clear glass. Apply a bead of sealant onto one of the glass pieces and press the second glass piece on top of it. Visually inspect for mix. Initially, a white marbling may occur, indicating an incomplete mix. Eventually, the compressed sealant will become a uniform in color, verifying full sealant mix.

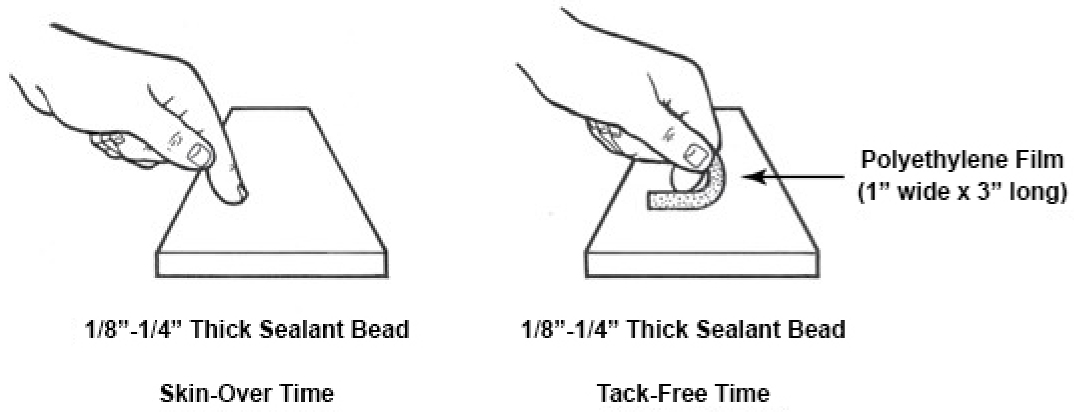
The time required to get a proper mix depends on the type of equipment used. As a general rule, the time to achieve full mix will decrease as the distance between the mixing elements and dispensing gun is decreased. Failure of the sealant to achieve full mix implies a problem with the static mixers. If unable to get a full mix of the sealant, disassemble and clean out the static mixer area. Reassemble and retry the butterfly test. If mixing problems persist, there may be an issue with injectors, ratio control cylinders, or other components of the two part pump. Contact your pump rep for assistance in troubleshooting persistent pump problems.

Cure Rate Tests for One-Part Sealants – Skin Over and Tack-Free Time

Perform in-house cure rate testing to ensure the silicone sealant cures at the expected rate. A skin over or tack-free time test should be performed for every shift one-part sealants. Tool a bead of sealant to a thin film and every few minutes; touch the sealant film with your finger. The sealant will initially adhere to your finger. When it no longer adheres to your finger, the sealant has skinned over. When the sealant no longer adheres to a piece of polyethylene film (approximately 1" x 3") placed on the film with an even weight, it has become tack free. See Figure 15.

[38] Dow Americas Technical Manual, Form No. 62-1112-01

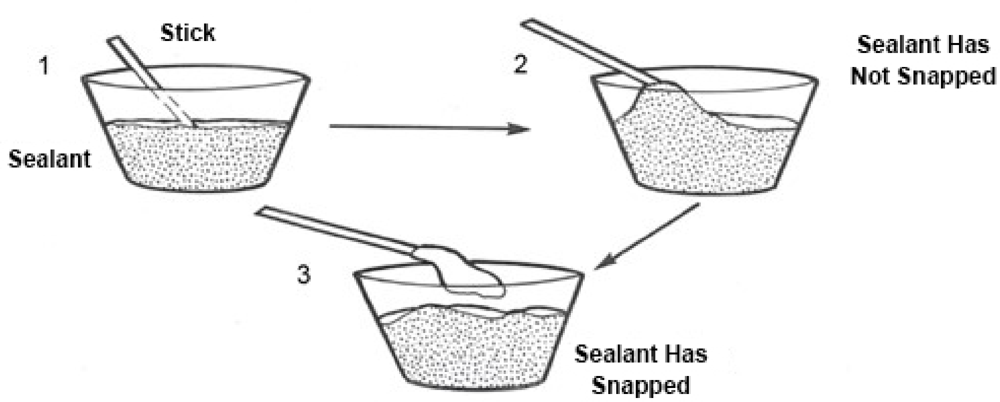
Figure 15: Skin Over and Tack Free Time Tests[39]



Cure Rate Test for Two-Part Sealants – Snap Time

Two-component sealants require a snap time to evaluate cure rate. The snap time test is performed by filling a cup or container with well mixed sealant. Insert a stick into the sealant and every five to ten minutes; pull slowly on the stick, observing how the sealant is breaking apart. If the sealant does not tear within itself (cohesively, demonstrating elastic recovery properties, aka "snap") when the stick is pulled out, the sealant has not snapped. The time at which the sealant tears within itself is termed the snap time. See Figure 16.

Figure 16: Snap Time Test[40]



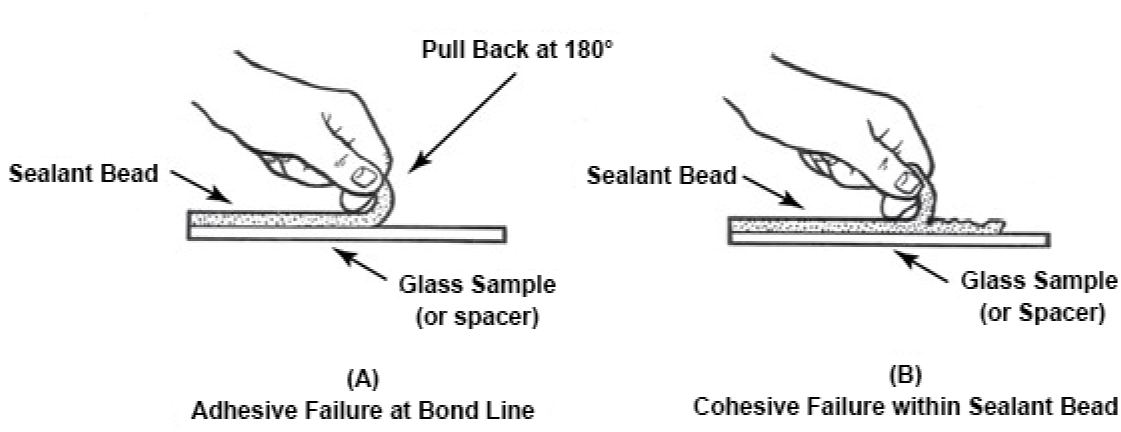
Adhesion Testing

An adhesion test should be performed to ensure that the sealant gives acceptable adhesion to glass and spacer surfaces. A production-grade clean piece of glass or spacer should be used. The testing can be performed on a peel adhesion sample containing a mesh screen that can be pulled back at 180° or a tooled bead of sealant that can be undercut and then pulled back with your finger Apply a bead of silicone sealant to the cleaned surface. Allow the sealant to fully cure. After the sealant has cured, pull on the sealant and visually inspect for the mode of sealant failure. "Cohesive failure" where the sealant tears within in itself and remains adhered to the substrate is desirable versus "adhesive failure" where it pulls cleanly away at the substrate interface. See Figure 17.

[39] Dow Americas Technical Manual, Form No. 62-1112-01

[40] Dow Americas Technical Manual, Form No. 62-1112-01

Figure 17: Tab Adhesion Test[41]



Adhesion testing should be performed every sealant lot used in production. Testing should also routinely be performed on all the substrates that the sealant is expected to adhere to. The sealant should demonstrate cohesive failure and not fail adhesively at the bond surface. Causes of adhesive failure include inadequate surface cleaning, variability in the glass or spacer surface, or in some cases sealant variability. To determine if adhesive failure was caused by inadequate cleaning of a substrate, perform adhesion testing with a production-grade clean substrate side-by-side with a production grade substrate that has been solvent cleaned using IPA or other suitable surface cleaners.

An example of a lot book record with all the pertinent data recorded is shown in Table IX.

TABLE IX: Quality Control Log Book Examples[42]

(a) One-Part Silicone Sealants

Date/Time	Sealant Lot Number	Tack-Free Time	Glass Adhesion	Spacer Adhesion
2/6 8:00 AM	2885623	10 min.	100% CF	100% CF
2/7 8:30 AM	2885623	8 min.	100% CF	100% CF

(b) Two-Part Silicone Sealants

Date/Time	Base Lot Number	Curing Agent Lot Number	Butterfly	Snap Time	Glass Adhesion	Spacer Adhesion
2/6 8:00 AM	3256546	3245670	Full Mix	40 min.	100% CF	100% CF
2/7 7:30 A.M.	3256546	3245670	Full Mix	45 min.	100% CF	100% CF

[41] Dow Americas Technical Manual, Form No. 62-1112-01
[42] Dow Americas Technical Manual, Form No. 62-1112-01

Insulating Glass Unit Handling and Packaging

To help ensure proper IG unit performance as designed by the IG manufacturer, the secondary silicone sealant should be sufficiently cured before subjecting it to forces from shipment, handling, installation, or windloads. The cure time will depend on the specific silicone cure chemistry as well as environmental conditions of temperature and relative humidity. Excessive forces on the silicone sealant interface before full cure could compromise adhesion performance and durability. Excessive forces on the IG unit prior to full cure may also shift glass panes out of parallel and/or strain the PIB sealant joint beyond a point where it can perform adequately as a primary moisture/gas barrier. In most cases, the PIB primary seal is strong enough to allow careful immediate movement of the IG unit from the IG line into the shipping crates. Ensure that the units are blocked and spaced to maintain squareness and prevent excessive strain on the PIB seal while the secondary seal is curing. Units should be packaged with adequate, compatible, setting block to support the glass lites and prevent glass slippage during sealant cure. All packaging crates should be open enough to allow good ventilation, which will assist the sealant cure process during shipment.

Sealant Dispensing, Equipment and Maintenance

Packaging Options

Single component silicone sealants are available in 55-gallon straight-sided steel drums or fiber packs.

Two component silicone sealants are packaged in non-lot matched base and catalyst containers. They are not kitted; in other words the base and the catalyst containers should be changed out when they are empty and not in pairs. The base components are available in either 55-gallon straight-sided steel drums or 55 gallon fiber packs. The curing agent or hardener component is available in 5-gallon steel pails or 55-gallon steel drums.

Packaging Considerations

Do not use dented sealant drums or pails. When the follower plate gasket reaches the dented area of the drum, sealant could potentially flow around the pump gasket or the follower plate could become jammed. This is especially true for curing agent which has a relatively low viscosity. Always ensure the gaskets around the pump follower plate are in good condition, as gaps between the gasket and the sides of the drums could allow for sealant flow around the follower plate.

Procedure for Changing Sealant Containers

Always follow pump manufacturers published procedures for pump operation and change-over. Listed below is a brief procedure with a few pointers that will assist you in sealant container changes.

- Inspect drum for dents that would prevent follower plate from emptying drum.
- Open lid on drum of new material. If a poly wrap is present, do not open poly wrap until ready to place new drum under platen.
- Remove empty container from pump.
- Clean platen top of any dirt and debris left over from previous drum.
- Lightly smear DOWSIL™ high vacuum grease around perimeter of platen seal to ease insertion of follower plate into new drum.
- Open poly wrap (if present) on new drum and remove top liner if present.
- Within 5 minutes of opening new drum, place new drum under platen.
- Immediately lower pump platen into new drum.
- Carefully remove ALL air in the pump headspace per pump manufacturers' procedure.

One Part Silicone Sealants
Changing over containers for one-part silicone sealants must be done in a timely manner (no more than 5 minutes). One-part silicone sealants cure by reacting with the atmospheric moisture and can form a skin within several minutes if their containers are left open. These skins could clog pump lines and could also result in one or more of the following problems:

- Slower than desired sealant flow rates
- Chunks in insulating glass unit seals
- Reduced performance of the insulating glass secondary seal
- Increased maintenance time and costs (to clean the equipment lines)

Two-Component Silicone Sealants
Base - For two-part sealants, the base component is not reactive with atmospheric moisture, so it does not require a rapid transfer.

Curing Agent - Upon opening the curing agent container, you may notice some fluid separation of the curing agent. Using a wooden paint stick, carefully mix the fluid back into the surface of the curing agent until the mixture is of a uniform appearance on the surface.

The curing agent component of a two-part silicone sealant is also reactive with atmospheric moisture and should be changed as quickly as possible. Failure to do so could result in one or more of the following problems:

- Curing agent forming a brittle, crystallized skin
- Slower than desired sealant flow rates
- Potential variations from the desired mix ratio
- Reduction in mix quality
- Chunks in the insulating glass unit seals
- Reduced performance of the insulating glass secondary seal
- Excessive wear of the pumping equipment
- Increased maintenance time and costs (to clean the equipment lines)

Dispensing Pumps – Descriptions and Maintenance

Common Components of Mixing Pumps
Hoses – Hoses that run from the pump to the dispensing gun should be rated for the maximum pressure of the pump system (generally 5000 psi), have an interior that is *Teflon*-coated (for low moisture permeability), and utilize double braiding for reinforcement. Stainless steel braiding is preferred, because strong cleaning solvents may affect aluminum braided hoses adversely. Failure to use proper hoses can result in sealant performance issues, such as curing in the lines. Improper hose selection can also lead to hose deformation or premature hose failure.

System Configuration – The pressure required to transfer a sealant from its original container through the lines to the dispensing gun is related to the sealant bulk flow rate, sealant viscosity, hose inside diameter, length of hose, and the number and types of hose configurations (expansions, contractions, elbows, fittings, valves, etc.). The pressure requirement increases with:

- Increased sealant bulk flow rate requirements
- Increased sealant viscosity
- Increased hose lengths
- Reduced hose diameters
- Increased number of corners, fittings, valves, expansions, and contractions

To minimize the pressure requirement to pump sealant at the desired production rates, the following should be considered when designing a production set-up:

- Minimize the hose length between the pump and dispensing gun.
- Increase the hose diameter.
- Minimize the number of elbows, valves, fittings, expansions, and contractions.

One Component Sealant Pumps

Dispensing equipment for one-part silicone sealants are usually single or double action ram pumps.

A single-action ram pump transfers the sealant from the container through the lines to a dispensing gun while the pump is in the downward stroke. This one-direction pumping could create non-continuous sealant flow that would increase and decrease with relation to the pump position. This can be compensated for by incorporating a gear pump or other component to minimize sealant flow variation.

A double-action ram pump transfers sealant from the container through the lines to the dispensing gun in both the up and down strokes. This pumping action provides a more continuous sealant flow through the dispensing gun and eases sealant application.

Two Component Sealant Pumps and Metering and Mixing Systems

Dispensing equipment for two-component silicone sealants is more involved and intricate than that for one-part silicone sealants because the equipment must also properly meter and mix the two components to produce uniformly mixed sealant at the correct mix ratio.

Pumps – The base component of a two-part silicone sealant is transferred through the lines by either a single or double-action ram pump, similar to those used for one-part silicone sealants. The curing agent or hardener component of a two-component sealant is also transferred by the single- or double-action pump. Both the base and the curing agent pump feed the metering system of the two component sealant pumping system.

Metering Systems – The metering system of the base and curing agent components is usually performed by a slave cylinder system. In this system, a metering arm is attached to both the base and curing agent pumps. By varying the point at which the metering arm pivots, the ratio of base to curing agent (by volume) can be varied. Hence, the mix ratio can be easily adjusted to fit the product mix needs. It is important to regularly monitor the mix ratio to ensure the pump is delivering the product per the sealant suppliers' recommendations.

An alternative metering system, the Loading Meter system regulates the sealant mix by continuously transferring each component through cylinders of set relative volumes. In a Loading Meter system, the mix ratio of a system is set for a given pair of cylinders. This further prevents accidentally varying the mix ratio. The downside of a Loading Meter system is the only way to adjust the mix ratio is to replace one of the cylinders.

Mixing Systems – The mixing of the two components is accomplished through the use of static mixers. Static mixers are a simple and efficient way to uniformly mix the components. The static mixers are located in the sealant line immediately after the two components meet in the mixing head. Static mixers are commonly composed of plastic, *Teflon* or metal. When properly designed and installed, the swirling action of the static mixers will sufficiently mix the two components.

Cleaning of Pumping and Mixing Equipment

Base Purging – Pump equipment used for two-part silicone sealants should be base purged during prolonged breaks and at the end of each working day. Since the base is unreactive, it will adequately to clean the static mixing equipment for a period of time. Other more aggressive cleaning methods will eventually be required for metal mix (non disposable) systems when the mixers become filled with a buildup of mixed material. This buildup could result in slower than desired sealant flow rates so monitoring static mixer life must be a part of any equipment maintenance and overhaul program.

Solvent Cleaning – When overhauling or performing periodic maintenance, cured and uncured sealants can be removed from the equipment by solvent cleaning.

Note: Where solvents or any cleaning material are in use, please review the solvent Safety Data Sheet (SDS) for proper storage, handling and disposal procedures. Solvent disposal varies from state to state. Contact the local government function such as the Environmental Protection Agency (EPA) for appropriate disposal methods.

Solvents will not actually dissolve the silicone sealant, but will cause the sealant to swell, making it easier to remove. Products such as DSR-5™ are available that will digest and break down the silicone and may be more effective than solvents in some circumstances.

Mini-Purge Gun/Static Mixer Cleaning – Cleaning of mini-purge guns and their static mixers should be done on a weekly to monthly basis, depending on the type of equipment used and base purging frequencies. Remove the mixer elements from the line or gun and clean the elements in solvent to remove accumulated sealant. Since the cleaning process will take time, it is good practice to have an extra mini-purge gun that can be swapped out in the production line while the other purge gun and mixing elements are being cleaned.

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