Insulating Glass Durability

Insulating glass was developed and introduced to the residential and commercial marketplace in the late 1930's. From this time, it has been shown that insulating glass units with Low-E coatings and argon filling offer the following benefits over single glazed windows:

- Reduced U-Factor (Saves in wintertime energy use)
- Reduced Solar Heat Gain Coefficient (Saves in summer-time air conditioning costs)
- Improved Acoustical Properties (Better sound attenuation)
- Reduces UV transmission (Reduces the potential for fading of furnishings)
- Increases the room-side temperature of the IG unit in winter climates (Reduces the potential for condensation on the indoor pane of glass)
- Reduces the room-side glass temperature in summer-time conditions (Improves comfort)
- Increases the room-side glass temperature in wintertime conditions (Improves comfort)

In the approximately 70 years of Insulating Glass use, it has been determined that there are 3 basic things required to make a long lasting insulating glass unit. These things are:

- Material Selection of IG unit components
- Workmanship of IG unit fabrication
- How the units are glazed

Material Selection

The sealant(s) used to bond glass to the spacer system is the most important material used in the IG unit construction to produce a long lasting insulating glass unit. The sealant(s) must be resistant to temperature extremes, UV radiation, moisture ingress into the airspace and retain any inert gas in the airspace i.e. argon. Cardinal has chosen a dual seal system with Polyisobutylene (PIB) as the primary seal, and silicone as the secondary seal as shown in Fig. 1. The PIB primary seal stops moisture from entering the airspace, and has the lowest moisture vapor transmission and argon permeation of all known sealants used in the manufacturing of insulating glass. Silicone is used as the secondary seal and it is a specifically designed silicone for Insulating Glass. Silicone is an inorganic sealant while other sealants used in the manufacturing of insulating glass are organic sealants. Silicones are recognized as the best sealant for weathering and adhesion to glass substrates.

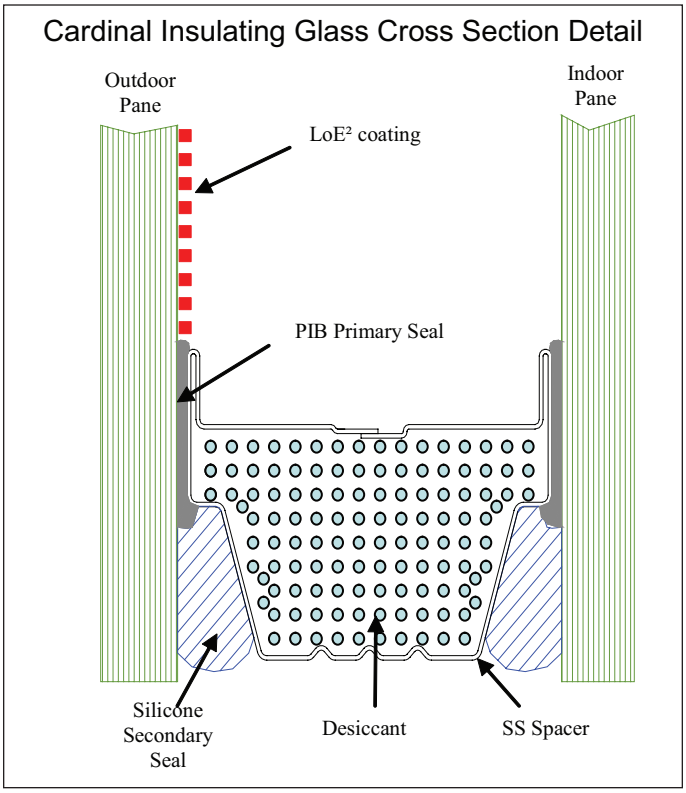


Fig. IG20-01

In addition to sealant choice, spacer design and processing are also very important in the overall long term weatherability of the IG unit. Cardinal's IG spacer system consists of a 4 bent corner construction with only one assembly joint, which is located on one of the legs and not at a corner. Many other IG manufacturers use corner keys to attach the 4 pieces of spacer together. Having 4 joints instead of one significantly increases the potential for moisture ingress into the IG unit airspace.

Workmanship

To have a long lasting Insulating Glass Unit, the fabrication of the unit must be consistent with no voids in the seal system. Cardinal's quality control system reduces the opportunity to have anomalies in the fabrication process. Cardinal manufacturers the insulating glass production equipment to assure that the units are fabricated with consistent high quality.

How the Units are Glazed

If the window manufacturer permits the insulating glass unit to sit in water or over stress the seal system, there is no insulating glass unit construction that will give long term performance. Cardinal believes that their dual system construction is the most versatile of IG seal systems because of the excellent weatherability of the PIB primary and silicone secondary seal. Cardinal's IG unit construction is most likely over designed for some window manufacturers that use good glazing practices. However, Cardinal believes that its unit construction is not under designed for any window manufacturer because it has been shown that Cardinal's dual seal system will out perform other IG unit constructions when exposed to simulated weathering conditions.

Industry Test Standards

The American Society of Mechanical Engineers (ASTM) has developed a testing protocol to determine the weatherability of insulating glass constructions. Passing this standard is considered to be the minimum requirement for insulating glass units. As shown in the chart below, Cardinal's dual seal system passes 7 times this test without failure. All other seal systems tested lasted anywhere from 1 to 4 times. A failure in this test is when the dew point of the unit is 0°F or higher. These tests were performed independently and show that Cardinal's IG unit construction is superior to competitive IG unit constructions.

IG Comparison Testing

PIB SILICONE E/D	DSE A INTERCEPT N/E/D	DSE A INTERCEPT E/D	PIB POLYSULFIDE N/E/D	PIB POLYSULFIDE E/D	DSE B INTERCEPT N/E/D	DSE B INTERCEPT E/D
7.1*	1.8	4.0	2.8	2.9	2.0	2.9

PIB SILICONE E/D	DSE C INTERCEPT N/E/D	DSE C INTERCEPT E/D	H/M BUTYL INTERCEPT N/E/D	SILICONE FOAM E/D	PIB POLYSULFIDE INTERCEPT E/D
7.1*	4.0	4.1	3.4	4.2	4.4

*** Testing stopped but units had dew points below 0°F**
- **Values - # of times units went through ASTM E-773, E-774 Seal Longevity**
- **N/E/D – Non Edge Deleted**
- **E/D – Edge Deleted**

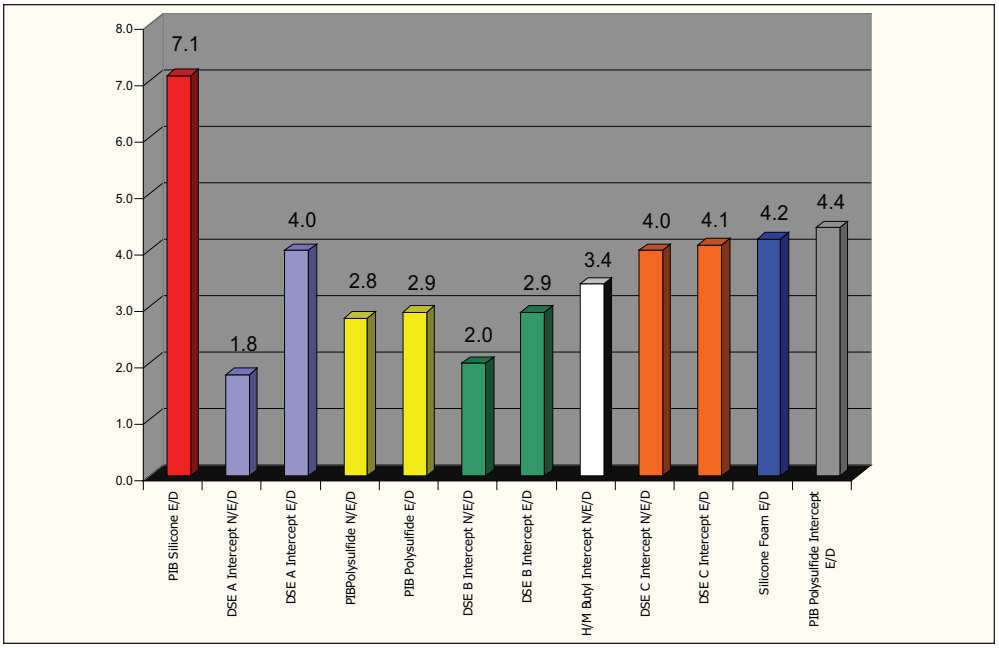


Fig. IG20-2

SIGMA Study and Cardinal Field Experience

The Insulating Glass Manufactures Alliance or IGMA (formerly SIGMA) conducted an independent 5, 10, and 15 year study of approximately 2,500 units installed in various cities throughout the US. Various unit constructions including Cardinal's construction in 1976 were evaluated for seal failure. As Fig. 2 indicates, the industry seal failure rate was 0.8% after 5 years, 3.7% after 10 years and 9.2% after 15 years.

Cardinal's IG unit construction in 1976 was a Dual Seal PIB primary seal and a polysulfide secondary seal with an aluminum spacer and corner keys. Cardinal produced approximately 450,000 IG units in 1976 and our reported seal failure rate after 20 years of field exposure was 8.6%.

In 1978, Cardinal developed and introduced an IG unit construction with a silicone secondary seal that replaced polysulfide. In 1978 Cardinal produced approximately 675,000 IG units. The seal failure rate of Cardinal's 1978 product was approximately 1% after 20 years of field exposure. This field data indicated that Cardinal's IG unit construction of a silicone secondary seal produced very low field failures.

In 1993 Cardinal developed and introduced a Stainless Steel spacer system with a PIB Silicone seal system with 4 bent corners. In 1993 Cardinal produced approximately 8 million Insulating Glass Units. It is projected that the seal failure rate of this IG unit construction will be approximately 0.25% after 20 years.

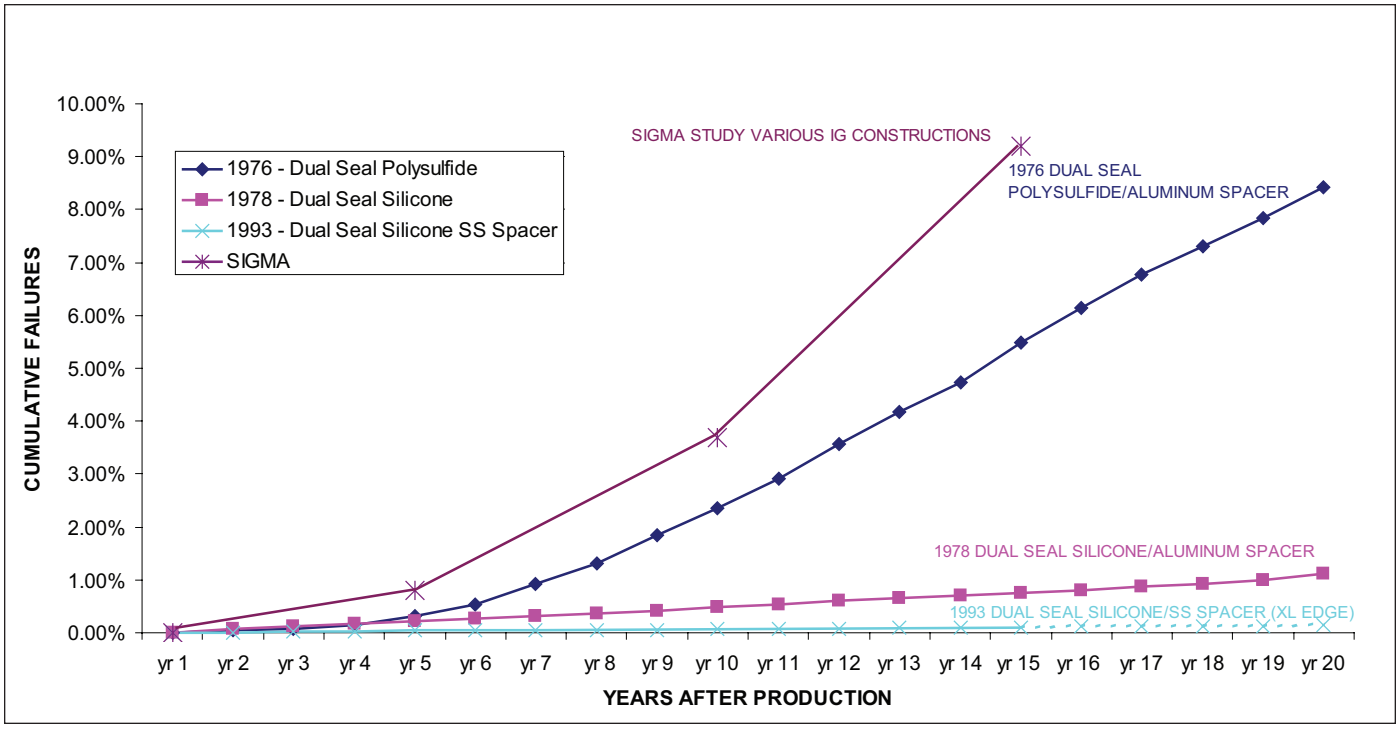


Fig. IG20-3

Fig. IG04-4 is a projection of actual and forecasted warranty claims for installed industry and Cardinal IG Units due to Seal Failure. This projected seal failure rate includes the IGMA study and Cardinal's field experience. The data indicates the following:

- The industry as a whole will have 17.37% failures after 20 years and 100% failure after 43 years
- Product made by Cardinal with an Organic Sealant and an aluminum spacer will have 8% failures in 20 years and 22% failures in 50 years
- Product made by Cardinal with a dual seal of PIB and Silicone with an aluminum spacer will have 2% failures in 20 years and 3.9% failures in 50 years
- Product made by Cardinal with a dual seal of PIB and Silicone with a SS spacer will have 0.3% failures after 20 years and 0.74% failures after 50 years

This data is compelling in that if a window company has a brand name and they wish to protect that name, the longevity of our units will not tarnish their reputation.

Many insulating glass manufactures do not logo their glass products. This makes it difficult for a home owner to determine the manufacturer of the glass and when the insulating glass product was produced. Cardinal logo's our insulating glass products with a date code so that the homeowner, window manufacturer and Cardinal knows when the glass was fabricated. This is important information for any warranty claim.

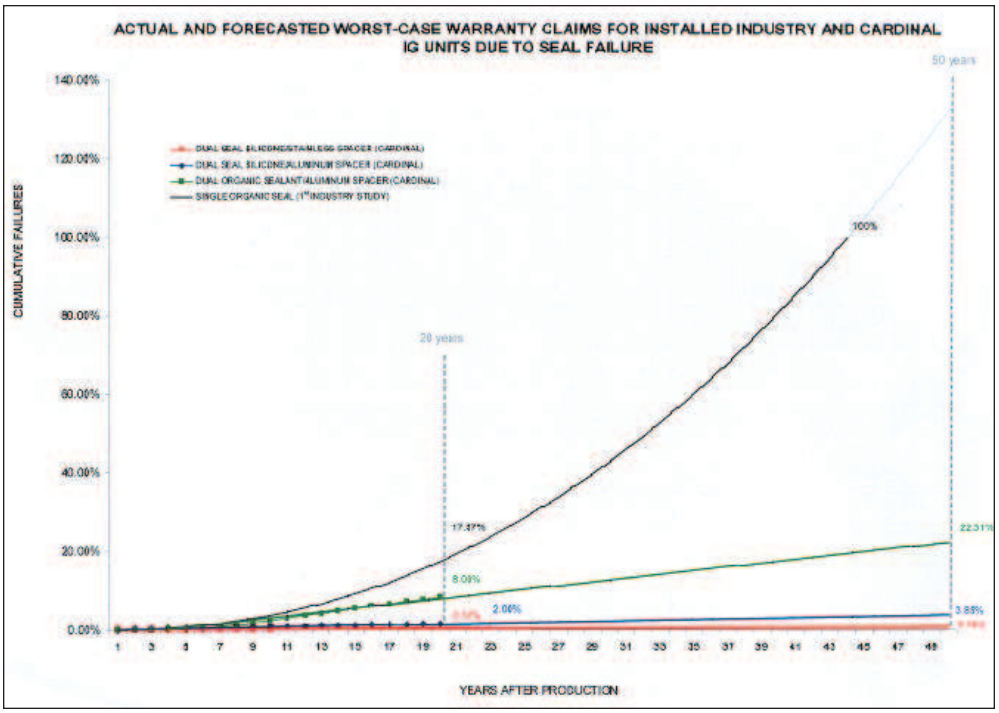


Fig. IG20-4

Service Costs vs. Field Failure Rates

A chart of service costs vs. field failure rates is shown in Fig. IG20-5. Assuming a $200 service call to reglaze a failed IG unit under warranty, it is shown that if a window company has an 8% seal failure rate under warranty, it needs to add $16.00 to the cost of the window to cover the warranty costs. If the seal failure rate is 1%, the window manufacturer must add $2.00 to the cost of the window to cover warranty claims. If the seal failure rate is 0.25% (Cardinal's projected failure rate in 20 years), the window manufacturer must add $ 0.50 to the cost of the window to cover the warranty claims.

With Cardinal's IG unit construction, the window manufacture significantly benefits from the very low projected seal failure rate.

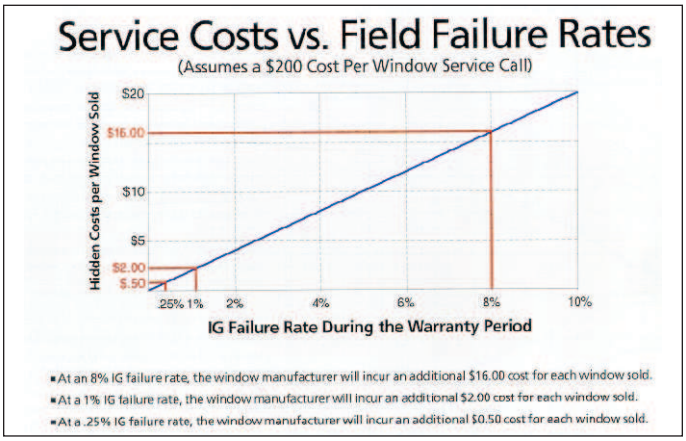


Fig. IG20-5

Cardinal P-1 Testing

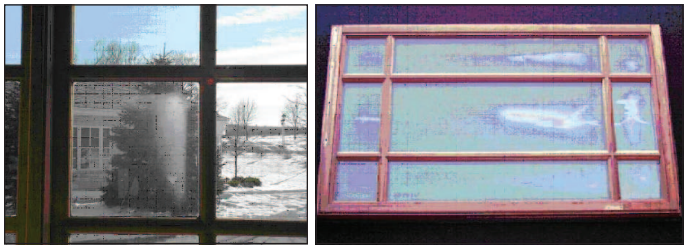
Cardinal uses an industry accepted test called the P-1 test to determine the weatherability of IG unit constructions. This test exposes the IG unit construction to a temperature of 140°F; constant UV exposure and water spray that produces 100% humidity. Cardinal testing of competitive unit constructions against the Cardinal SS spacer system with a PIB – Silicone seal system is indicated in Fig. 6. This data shows that competitive organic seal systems (polysulfides, polyurethanes, hot melt butyls, and dual seal equivalent sealants) fail from a bond loss of the sealant to the glass. These failures occurred from 8 to 22 weeks in this test. The Cardinal IG unit construction in this test still had a dew point below 0°F after 80 weeks of this test. This again showed the excellent weatherability of the Cardinal SS PIB-Silicone sealed IG units.

Unit Type	Longevity	Failure Mode
Single Seal PIB only	24 hours	Ruptured seal, unit filled with water
Single Seal, Butyl Spacer	2 weeks	Ruptured seal, unit filled with water
Single Seal, Silicone	3 weeks	Dew point failure
Single Seal, Polysulfide or Polyurethane	6-8 weeks	Bond loss to glass, unit filled with water
Single Seal, Hot Melt Butyl	6-8 weeks	Ruptured seal, unit filled with water
Dual Seal Polysulfide or Polyurethane	12-18 weeks	Bond loss to glass, unit filled with water
Dual Seal Silicone, unsealed corners	15-20 weeks	Dew point failure
Dual Seal Butyl Spacer, silicone secondary	25 + weeks	Dew point failure
Dual Seal Silicone, sealed corners	40 + weeks	Dew point failure

Fig. IG20-6

Fogging of Insulating Glass Units

Any material used in an insulating glass unit i.e. sealants, grilles, spacer systems, desiccants, etc. can produce a fog in the insulating glass unit. A typical IG unit with fog in the IG unit is shown in Fig. IG20-7. An industry accepted test called the Canadian Fog Box Test is used to determine the fogging potential of these materials. A diagram of this test is shown in Fig. IG20-8. The test is for one week and uses a temperature of 140°F and a condenser plate of 70°F. Cardinal developed a rating system of 1 to 5 to indicate the degree of fog in the insulating glass unit. Cardinal does not permit a fog level above 2 to be used in the IG units that they produce. (See also TSB #IG10)



Internal Condensation Chemical Fog

Fig. IG20-7

Canadian Fog Box

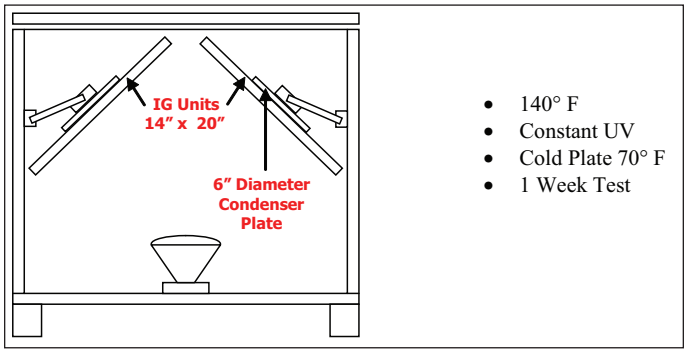


Fig. IG20-8

Edge Deletion of LoE™ Coatings

Cardinal is a proponent of deleting the edge of LoE™ coatings. These coatings are based on silver and although the durability of these coatings has been significantly improved since the introduction of these coatings in the early 1980's, edge deletion provides safety that the IG unit sealants are bonded to glass rather than a coating. Without edge deletion, the LoE™ coatings will extend to the edge of the glass and corrosion of the coatings can propagate past the IG seal system when the IG unit is exposed to high humidity conditions or is sitting in water. (See also TSB #CG01)

Insulating Glass Warranties

Manufacturers of Insulating Glass warrant their products against an obstruction of vision in the IG unit. An obstruction of vision can be considered to be internal condensation or a Chemical fog in the IG unit. (See also Cardinal's Warranties and Terms & Conditions)

IQ Quality System

Cardinal has developed an on-line quality control system throughout its vertically integrated product line of Float Glass, Coated Glass, Heat Treated Glasses (Heat Strengthened and Tempered), Laminated Glasses, and Insulating Glass. The IQ system measures IG unit color, defects in the glass, argon fill level, tempered distortion and airspace dimensions. This provides to Cardinal's customers the highest quality and consistency of fabrication.