DE-EE0000167
GED Integrated Solutions

Project Title: ***Energy Efficient Tripe IG Automation EEE (Triple-E)***

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Final Scientific/Technical Report: Feb 28, 2013

Executive Summary:

GED Integrated Solutions collaborated with US window and door manufactures to investigate, design and verify technical and cost feasibility for producing high performance, high volume, low material and labor cost window, utilizing a modified window design containing a triple insulating glass unit (IGU). This window design approach when combined with a high volume IGU manufacturing system, can produce R5 rated windows for an approximate additional consumer cost of only $4/ft^2 when compared to conventional Low-E argon dual pane IG windows, resulting in a verify practical, reliable and affordable high performance window for public use.

<u>Project Objectives:</u>

GED Integrated Solutions proposed to design, develop and commercialize a high volume, low material and labor cost automation manufacturing system ("Triple E" EEE : Energy Efficient triple Insulating Glass Unit (IGU) assembly System) later renamed IGAMS Insulating Glass Automation Machine and System for the production of reliable triple glazed Insulating Glass (IG) units in conjunction with an optimized sash and frame system. This system was designed to use sash and framed window designs that incorporate glazing pockets optimized for thermal and low cost material performance. This product should result in an approximate overall R5 value window system. Reasonable incremental costs will enable this high performance window to be incrementally sold to the end consumer for less than an additional $4/ft^2 compared to conventional Low-E argon filled dual pane IG windows.

Project Objective Accomplishments:

GED was successful in developing and commercializing a high volume , low material and low labor cost automation manufacturing IG system called ATLAS (Automated Tri-Lite Automation System) that was introduced to the market in September 2011.

The system was commercialized in spring of 2012, resulting in implementing commercialized IGUs for the use in the fenestration industry. The Insulating Glass units are used in various energy efficient window styles and designs by multiple window manufactures.

Cost Models were validated with customers showing the capability to offer an R5 performance window for an increase of $4/ft^2 compared to conventional Low-E argon filled dual pane IG windows.

Anticipated high performance residential window demand did not develop as anticipated at the time origin of this proposal (2008). The lack of demand for higher efficiency windows is due to poor housing economies that significantly reduced the demand for remodeled and new housing windows, coupled with the housing bubble in the United States. Housing prices in general peaked in early 2006, started to decline in 2007, and reached new lows in 2012. The sustained decline on demand for new and remodeling windows was not anticipated at the proposal of this project. In addition to the US housing bubble, Energy Star performance requirements for windows did not develop quickly or as stringently as originally anticipated, furthermore reducing the market urgency to commercialize R5 windows. The technologies and products that were developed to produce low cost, high performance R5 windows are now available today and can be implemented and commercialized as a result of this project.

Phase I Planned Goals and Accomplishments:

In Phase I, GED and PPG planned to conduct an exhaustive comparison of options, including the double Intercept® (2-spacer – Triple IGU) technology based on the Intercept® spacer technology, PPG's Trinium™ IGU technology, modifications to these technologies, and other commercial triple glazing technologies. This effort was to deduce a solution to identify the lowest cost option that will satisfy the R5 requirement while meeting the customer and market needs. Based on this evaluation, PPG and GED would then design, model, build and extensively test insulated glass units according to industry standards.

Planned Goals:

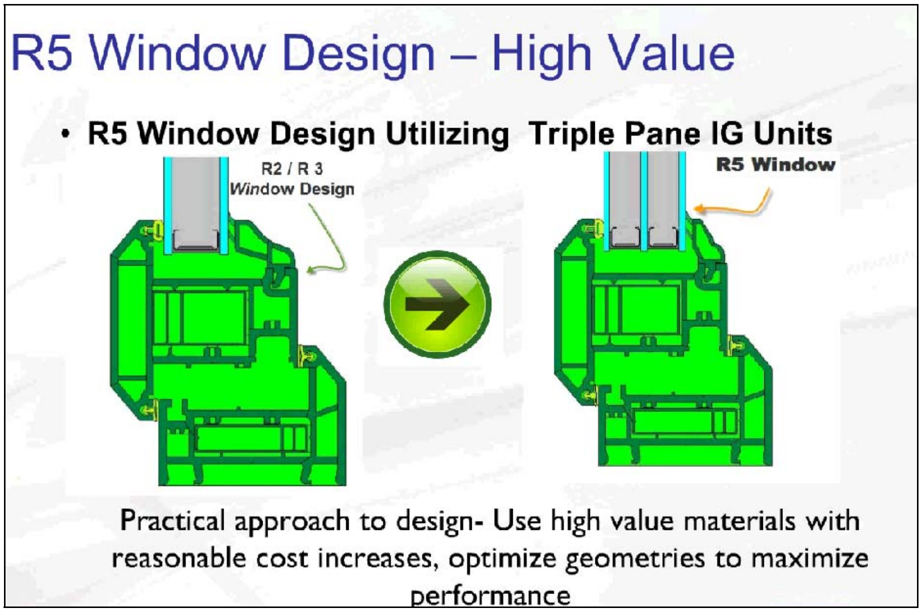
- Optimized Product Definition and Material Selections
- Product Performance Verification and Reliability Testing

Expected Results:

- Quality of Product, ASTM and PPG Testing
- Performance of Product R=5 Window
- Cost of Window change (Cost target of <$1.00/ft^2 to producer)

Optimize Product Definition and Material Selections

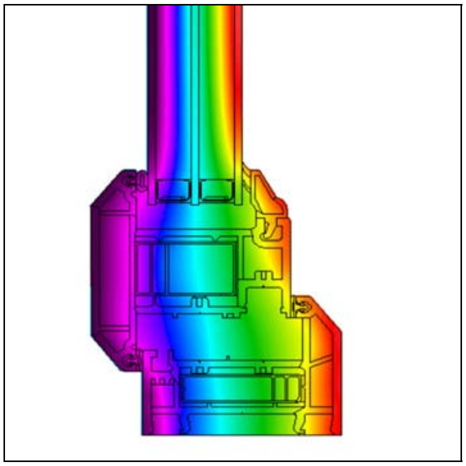
- Modeling Analysis of Candidate Window Designs
  - Several design and material window permutations for frame, sash and IG were modeled and thermally evaluated using computer simulation programs (Windows & Therm - Version 5) in modified (PVC) and wood window designs. Design selection considerations were narrowed down based upon performance and cost to satisfy the DOE goal of increasing the thermal performance of a window from U=0.34 to U=0.20 on average for $4 per sq-ft retail increase over standard 2008 Energy Star rated window.

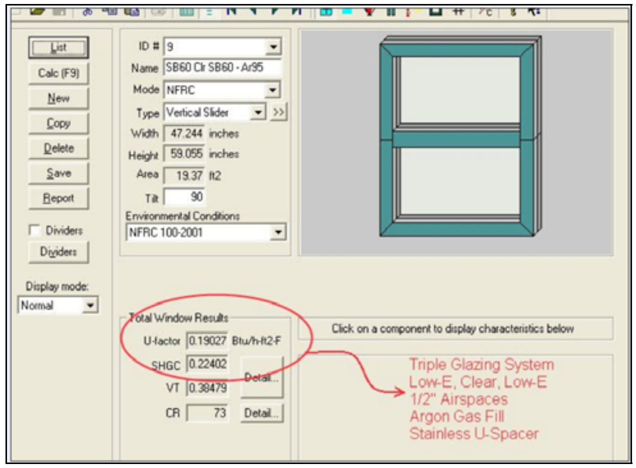


Optimized R5 Design Characteristics:

- Optimized Argon space between glass = 0.460”
- Dual Low E Glass, Preferably on Surfaces 2 and 5 (Surface 1 reference is the exterior side of the window)
- Avoid surface 3 and 4 to prevent heat build up in center of IG causing additional stress from thermal expansion

- Thermal baffles in sash and frame – Optimize the Nusselt Number in chambers towards 1.0 or unity (Convective/Conductive Heat Transfer)
- GED Ultra Stainless Steel Intercept Spacer
- Favor location of sash Inside vs. outside to maintain conventional frame buck dimensions and gain thermal efficiencies





R5 Double Hung - High Performance Window Design Simulation

- **IG and Window Cost Analysis**

  - Several cost models were investigated for Dual, Single Hung, Picture, and Casement window styles. Cost models tracked and compared the increased cost of the high performance R5 window by calculating material variances and changes in assembly labor, utilizing triple IGU in newly designed R5 window frames and sashes compared to R3 windows. Costs were accumulated for the component and labor costs of the complete window.

  - Optimized additional material cost variance for the R5 window are comprised of:

    - High Performance Low E Glass – Solar Ban 60
    - Dual Low E, Preferably on Surfaces 2 and 5
    - Material Glass Cutting Yield Drop (Low E) from additional lite
    - Assembly Labor for Triple vs. Dual IGU – Utilizing the ATLAS Automation system vs. conventional methods
    - Warm edge Stainless Steel Ultra Intercept® Spacer Frame vs. warm edge Intercept® coated steel

        - Additional desiccated matrix and sealant for a triple IGU
        - Increase force performance for window balancers (Constant force coil design)
        - Addition vinyl material due to larger window frame and sash components to house winder and heavier triple IGU package.
        - Increased vinyl waist in process (drop from processing heavier lineal components)

    - It was confirmed in 2010 that existing state of the art IGU assembly equipment and production methods limited throughput to service the any demands of high volume window plants in the proposed R5 design. A new low cost, high reliability triple IGU system would be required to service the high volume low cost R5 production model. The ATLAS system gives the capability to the window manufacture to produce high volume, high performance dual and triple IGUs at a reduced cost.

- GED discussed cost models with several (window manufacturer) to validate cost assumptions.

Results:

- GED discussed the approach in technology with several US window manufactures to validate the technical approach and implementation of Triple IGU designs with modified window frame and sash components. Thermal analysis was simulated independently by window manufactures to verify performance results. Projected cost models were validated to reflect cost projections in their proprietary designs.
- GED verified that the cost models approached cost target required to potentially meet the $4/sq-ft cost increase for R5 vs. R3 windows to the customer.
    - Cost targets for all window styles were projected. The potential to meet cost and price goals for window manufactures for an R5 window to the DOE requirements.
    - Focus was given to a Double Hung Window design since it is the most popular designed currently being shipped by volume.

Proprietary designs with two customers demonstrated examples of utilizing triple IGU with overall glass thickness at 1-3/8” glass packages, yielding R-5 performance. Vinyl and wood window technologies were simulated with results achieving thermal performance of a highly insulating glass window.

Corrections and adjustments were made to the cost models using customer feedback and standard cost data from their associates and enterprise resource programs. Although the component costs increased slightly in some areas such as amount of additional vinyl and or cost of glass, other areas were reduced (such as labor) resulting in similar net sum incremental cost as modeled.

Incremental Cost of R5 - DH Window with Triple IG (Larger Width IG) & Dual Low - E glass

Window Type	Double Hung DH		
Double Hung 47-1/4W x 59H	30	58	Inches
R=5.0	2.50	4.83	Feet
		12.08	Sq-Ft

Incremental Window Cost Increases due to Larger IG Pocket and Weight					Notes:
	Per Window Unit		Per Sq-ft		Incremental cost of R5 window compared to conventional R3
IG Cost Increase	$	7.84	$	0.65	Incremental cost for Triple vs. Dual IGU and Labor Using EEE IGAMS
Other IG					
Glass Labor	$	0.10	$	0.01	Additional glass to process, 1/3 extra labor
Glass Yield	$	0.40	$	0.03	Assume 90% yield on extra glass required for Low E
Vinyl Extrusion Cost Increase	$	2.80	$	0.23	Based Upon average increase in vinyl (2 lbs @ $1.40/lb)
Hardware (Balance Increase)	$	1.52	$	0.13	Validated with Customer $ 0.38 per balance
Total Increase in Cost per DH Unit	*$*	*12.66*	*$*	*1.05*	
Price = 2x cost	$	25.31	$	2.09	Goal is < $4.00 Sq-ft
Price = 3x	$	37.97	$	3.14	Goal is < $4.00 Sq-ft
Price = 4x	$	50.63	$	4.19	Goal is > $4.00 Sq-ft

3x well within Goal of <$4/sq-ft

4x close to goal of <$4/sq-ft

Incremental Product Cost Summary Analysis for a R5 Double Hung Window Design compared to R3 window Double Hung Window with dual pane IG

Window Cost and Price Summary:

The Double Hung window example above shows the ability to produce a R5 window for $1.05 per sq-ft additional material and labor cost over a R3 rated window. This window can be sold through various distribution channels to builders, retailers and installers and still be obtainable to end consumers for approximately $4/sq-ft. For average size windows, installation costs are anticipated to be equivalent.

Product Performance Verification and Reliability Testing

Verify Window Designs to show potential to meet Thermal Performance:

Goals were to approach and preferably meet the R5 window performance measure for a typical residential Double Hung Window. Use Window Simulations to validate projected results along with cost and price estimates.

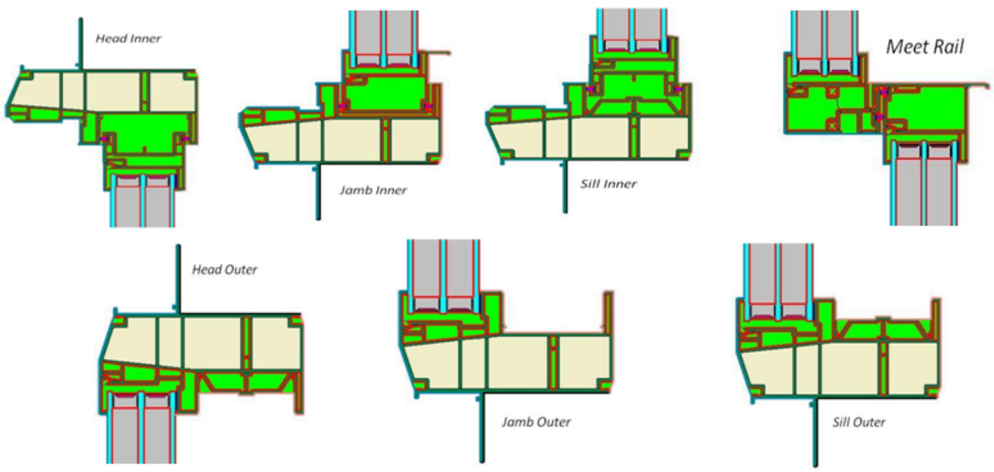
Results were validated through window simulations

- Window Simulations verified that the technical approach to utilizing a triple IGU with a wider sash and frame product reached desired R5 thermal performance.

Below is in example of Thermal Simulation Performance with a commercially available vinyl window system.

SIMULATION SUMMARY 28-SS-Triple 1-Feb-10

Spacer System	OAT	outer glass	gap	middle glass	gap	inner glass	gas fill	U-Factor	R	SHGC	CR
Stainless Intercept-002	1.39	3mm PPG SB-60	0.573	3mm PPG clear	0.463	3mm PPG SB-60	Argon 90%	0.17	5.92	0.254	70.8
Stainless Intercept-003	1.39	3mm Guard 7138	0.573	3mm PPG clear	0.463	3mm Guard 7138	Argon 90%	0.17	5.99	0.256	71.0
Stainless Intercept-004	1.39	3mm PPG SB-70	0.573	3mm PPG clear	0.463	3mm PPG SB-70	Argon 90%	0.17	5.99	0.188	71.0
Stainless Intercept-022	1.39	3mm PPG SB-60	0.573	3mm PPG clear	0.463	3mm PPG SB-60	AIR	0.19	5.24	0.255	68.5
Stainless Intercept-023	1.39	3mm Guard 7138	0.573	3mm PPG clear	0.463	3mm Guard 7138	AIR	0.19	5.26	0.257	68.7
Stainless Intercept-024	1.39	3mm PPG SB-70	0.573	3mm PPG clear	0.463	3mm PPG SB-60	AIR	0.19	5.26	0.190	68.7



Initial Technology Assessment and Prototype Selection:

Reliability Testing:

Results of Actual vs. Planned Goals:

Planned: We planned to configure triple IGU units that were capable of passing the ASTM 2190 weather durability standards.

Actual Results: GED Integrated Solutions along with PPG tested and determined which IGU configurations pass the ASTM 2190 requirements, and selected these product configurations to perform additional testing to exceed the reliability requirements by performing the weathering test twice on select configurations with passing results.

Product Performance and Reliability Testing Approach:

GED and PPG constructed approximately 200 IG units to test that were comprised of both Dual and Triple IGU configurations. Configurations included cut back center lite and standard non-cut back glass constructions. In addition, different sealant suppliers and products were used to evaluate weathering and durability performance.

The configurations variables for the units included:

- Sealant type : Hot melt and Modified Poly Urethane Sealants from different manufactures
- Triple IGU center lite with and without cut back (center glass) (cutback units included a secondary Dual Seal)
- Triple IGU with ¼" airspaces and with ½" airspaces
- Dual IGU as baseline test controls
- All units were filled with Argon Gas and measured for initial Argon (> or = 90 %) fill to track Argon retention over time and weathering.

ASTM 2190 Test Results:

First Round ASTM 2190 Test Results:

All units and configurations and sealant types passed the ASTM # 2190 test and gas retention requirements through the first industry required test sequence. Two different manufactures of sealant were compared.

Second Round ASTM 2190 Test Results:

Test results concluded that one manufacture of sealant yielded a 100% pass rate for all IGU configurations (Dual and Triple Units with and without cutback middle lite). The other manufacturer sealant resulted in passing results for dual unit IG configurations, but failed the additional testing for dew point and argon retention requirements for the triple IG configurations.

Both sealant companies performed to weathering and durability requirements when tested to ASTM E 2190. One sealant indicates a more robust weathering performance pattern and characteristics over time. We feel confident that the triple IGU weathering and seal durability testing shows the technology can be used for successful commercialized R5 windows.

No increase in failure or issues for triples was seen with ½" airspaces compared to ¼" airspaces.

Conclusion:

Based upon test results and manufacturability assessment, the standard IGU triple configuration with out cutback is the configuration of choice.

IGU Modeling and Material Testing:

The goal was to simulate IGUs through FEA modeling to identify potential failure points on glass, spacer and sealants caused from extreme pressure and temperature variations.

Summary: Materials Modeling (glass, spacer, and thermal shock) – FEA modeling work was completed for a select number of cases to be considered for this task. A low probability issue was identified for the case of high positive internal unit pressure, in which the maximum sealant stress exceeds the tensile strength of the material in extreme environmental low probability conditions. Further review concluded no additional analysis is required due the low probability of this type of unit being implemented.

Mechanical Integrity Testing:

A dynamic load test was developed for fully supported IGUs in a frame and run for 5,000 slams (cycles) at three different temperature settings -20 ^{o}F, 70 ^{o}F, and 120 ^{o}F. The "fully supported" configuration is one in which setting blocks support all 3 panes of glass. The testing for the "offset" configuration only supported one pane of glass and was tested for 1,000 slams at each of the same three temperatures. There was a total of eight different configurations under test.

Mechanical Integrity Test Results:

All permutations resulted in no degradation of dew point, visual shifting of lites and or signs of sealant degradations.

Phase II

In Phase II of the project, GED Integrated Solutions and PPG used the results of Phase I to estimate the long-term performance of the IGU design and also design, develop a high speed triple manufacturing system.

Phase II Planned Goals:

- Work with select customer base to design Glazing Pocket for optimized glass package

- Design, Development and Test of EEE (ATLAS) Triple Assembly System Equipment
  - Triple Assembly Station
  - IG Cooling Conveyor
  - IG Argon Gas Filling (Positioning, Filling and Sensing)
  - Argon Gas Port Closure
  - Integration of Triple Seal Application
  - System Integration of Complete Line
  - Field Test at Customer location

- Implement EEE ATLAS system at customer

Phase II Expected Results:

- Window system designed to use EEE Glass pack with a net cost increase <$1.00/ft^2 per window (Manufacturing)
- Field Test EEE system at Customer for field testing

Phase II Planned vs. Actual Goals:

The development of the high speed IGAMS system (today renamed ATLAS) was the main focus in this phase of the project. Several integrated stages of automation machinery was planned to complete the process, including glass washing, assembly of insulating spacers to glass, triple IG assembly, IR heat and overall IG press to size units with additional processing, in-process IG cooling, gas filling, argon fill validation, gas port closing, and final triple seal application. In addition to machinery development, field testing, process validation, and product testing will be conducted prior to commercialization.

Changes in Approach and goals affecting the IGAMS (ATLAS) Functionality:

With market conditions changing between 2008 when the grant was first proposed through 2012, the United States and global window and door industry economy eroded and continued to be suppressed, changing our customers capital investment for their manufacturing plants. Most of these decreases in residential window and door demands were results of the housing bubble and credit crises that were facing and still present in the United States building markets. Capital expenditures and investments significantly diminished. With window sales being scarce, only critical key projects are being implemented, resulting in less projects being initiated and planned from most Window and Door customers. Taking this market condition and trend into consideration, GED had the foresight to refine the modularity of the IGAMS system and focus on IG assembly first with the intent to add post processes at a later date to reduce initial capital investments and help spread out capital over time to the window and door manufacturer. Not having the complete IGAMS solution up at first did not significantly impact the cost of the final R5 window, thereby preserving the plan to provide an R5 window to the customer for less than $4 incremental cost per square ft to the end consumer.

The ATLAS system can be utilized as a starting module to provide the manufacture the key components for assembling both triple and dual IGU in an efficient manner. In addition, software to configure, control and track IG components in the system, will be a necessary system function to effectively conduct the process.

It was also expressed during this time period with window and door manufactures, that our customers would not be able to justify capital for a new system that was dedicated to only making triple IGUs. The IGAMS functionality was enhanced with flexibility to not only run triple IGUs, but also produce Dual IGUs efficiently. The IGAMS functionality was expanded to produce both dual and triple IGUs in any sequence on a just in time demand sequence. Our customers expressed that the market would gradually ramp up on higher efficiency window demand, and the requirements for triple IGU will increase accordingly over time as energy efficiency standards evolve and are implemented throughout the residential building envelope.

Actual Goals:

- (Planned) Work with select customer base to design Glazing Pocket for optimized glass package

- (Actual) Results
  - GED worked with different vinyl and wood window manufactures in the United States. Design optimization methods and optimized design criteria was reviewed with their design groups, which resulted in modified window

design options that accepted larger overall width of the IGU to accommodate possible triple IGU a product option.
    - GED also worked with different vinyl extrusion suppliers in the residential window industry, giving manufactures of windows new design and extrusion window component options, reducing the up front design and tooling costs to introduce a new R5 window series to the market.

- (Planned) Design, Development and Test of EEE (ATLAS) Triple Assembly System Equipment
  - (Actual) Results
    - Triple Assembly Station – Design, Development, and Testing Completed
    - IG Cooling Conveyor –Investigation and Design Completed, development deferred
    - IG Argon Gas Filling (Positioning, Filling and Sensing) – Investigation Completed, Use available commercialized semi-automatic systems
    - Argon Gas Port Closure – Initial Design and Development completed Field Testing deferred
    - Integration of Triple Seal Application – Not Required without Cut-back IGU design
    - System Integration of Complete Line - Completed
    - Field test at customer location - Completed

- Implement EEE ATLAS system at customer - System Implementation completed at customer

Details of Phase II - Design and Development of the ATLAS process:

IGAMS (ATLAS) Triple Assembly System:

GED investigated methods which resulted in the design and construction of a prototype Glass Washer, Assembly Line (Dual and Triple IG), Glass Handling Stations, Glass Transfer to an IR Oven and overall IG Press. In addition, a software system that details and orchestrates product flow with graphic Human Machine Interfaces (HMI) for directing system operators was designed and programmed. The assembly line system from the glass washer through and including the IR oven was commissioned and refined for logic flow, speed performance and glass handling verification. There was also additional design work completed on the completion of the IG unit construction including IGU cooling after the IR oven press, gases filling and verification, 4th comer fastener and sealant patch application. These modules of the system were deferred for commercialization and planned for commercialization by GED at a later date.

The assembly method approach in the original system design included glass washing, spacer placement, HMI stations, glass/spacer assembly, transfer conveyors and IR heating and press. (Figure 1)

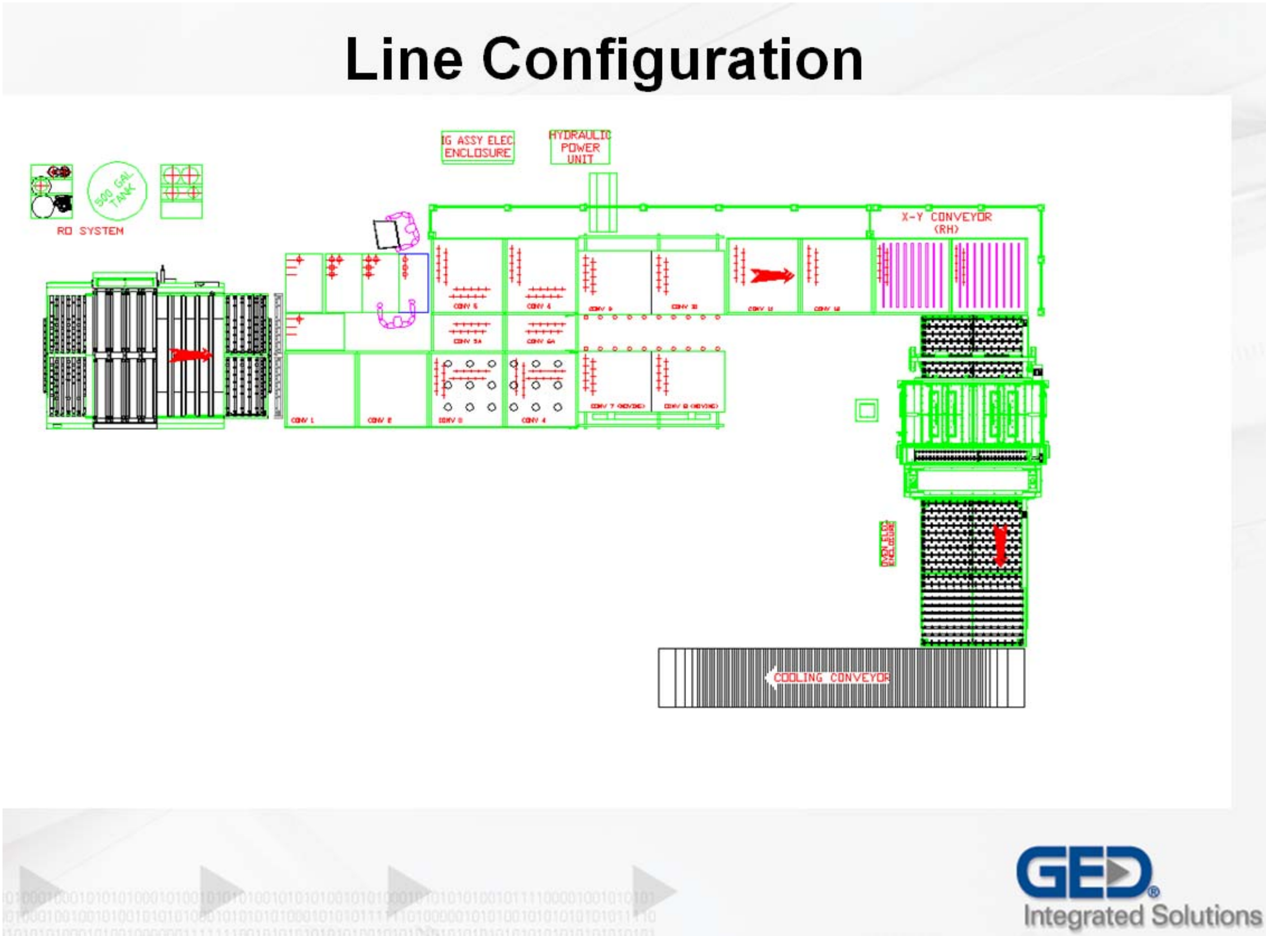


Figure 1 - Original IGAMS Plan View of System

The final line configuration of the ATLAS system evolved, into the following layout shown in Figure 2.

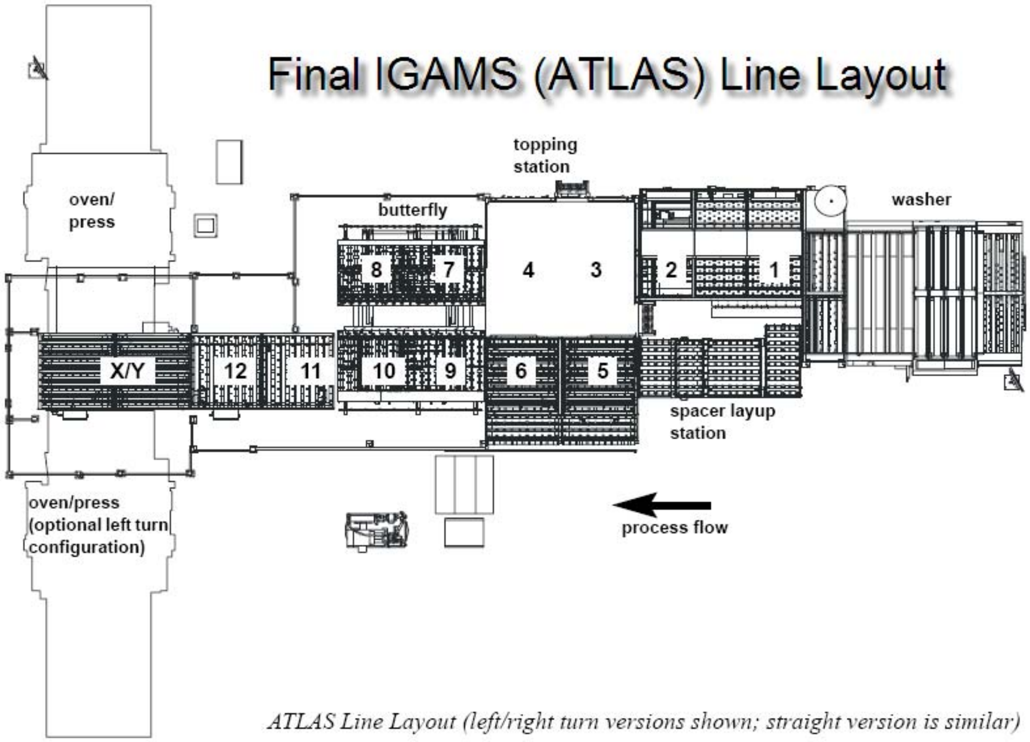


Figure 2

The simplified process sequence for the ATLAS system can be summarized as follows:

1. Glass is loaded into the glass washer from a predefined sequence that is generated from WinIG 5, a GED scheduling software system that coordinates IGU flow for all individual components and process aspects of the IGU assembly. The glass lites (individual pieces) are then loaded by an operator into the glass washer as defined by the Glass Washer HMI screen.

2. IGU spacer(s) that pair up with the glass size, are applied (also defined in the WinIG sequence) by operators on the glass lite at the spacer layup station.

3. Glass is automatically conveyed and assembled together through the glass topping station. (Triple IGU only) where the middle lite is applied for triple IGU. (Stations 3 and 4 in Figure 2)

4. The IGU partial assembly and matching glass lites are transported to the butterfly assembly station (Stations 8-10) where they are assembled into a final configuration for final transport (11,12 and optional X-Y) conveyors into the oven press station.

5. The Infrared Heat and Oven, heats the sealant and presses out the sealant to a precise dimension to provide a seal between the glass lites for the IGU.   Cooled IGUs are then offloaded for post processing to add Argon gas, a fastener and a final seal to the IGU.

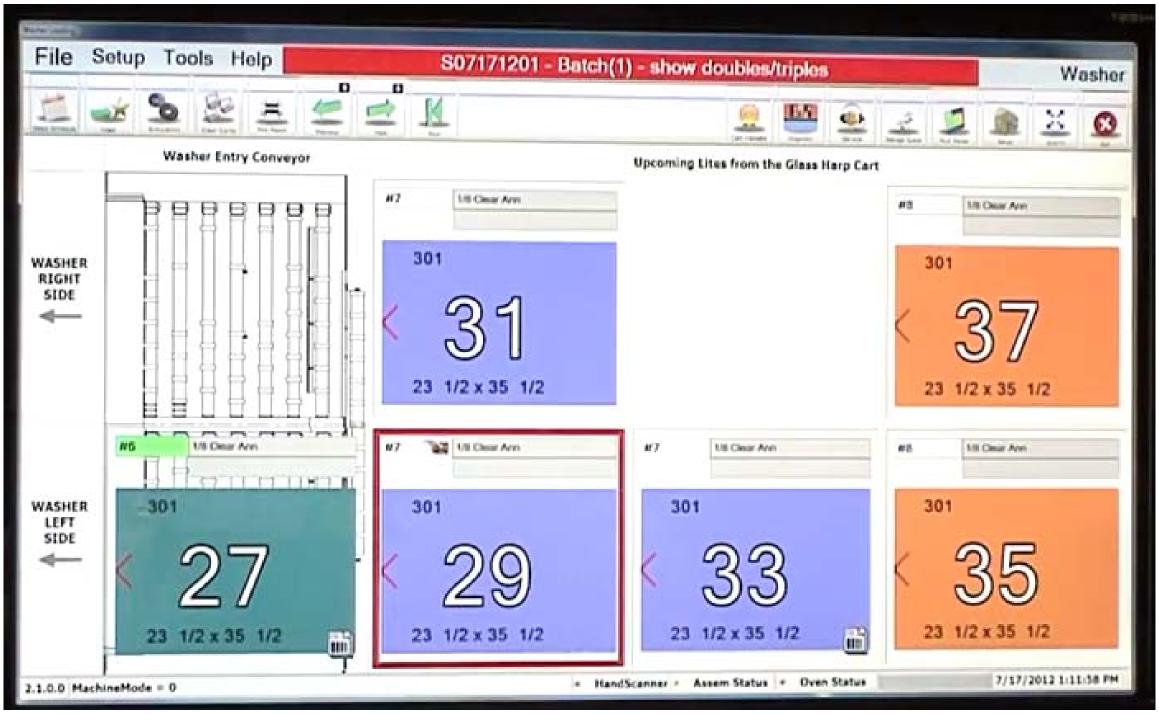
Several new technologies resulted from investigations and research that were implemented into the design of the IGAM (ATLAS) system. The following describes the technologies and process in a more detailed manner.

The IGU assembly process begins with sequencing pre-cut glass from a vertical storage cart that can be easily unloaded from the numbered cart slot into the ATLAS glass washer. Below is a photo showing glass lites being loaded into the horizontal glass washer for a Dual IGU assembly sequence. The sequence starts by loading glass on the left hand site and simply alternates glass location for units that are less than 42” wide.

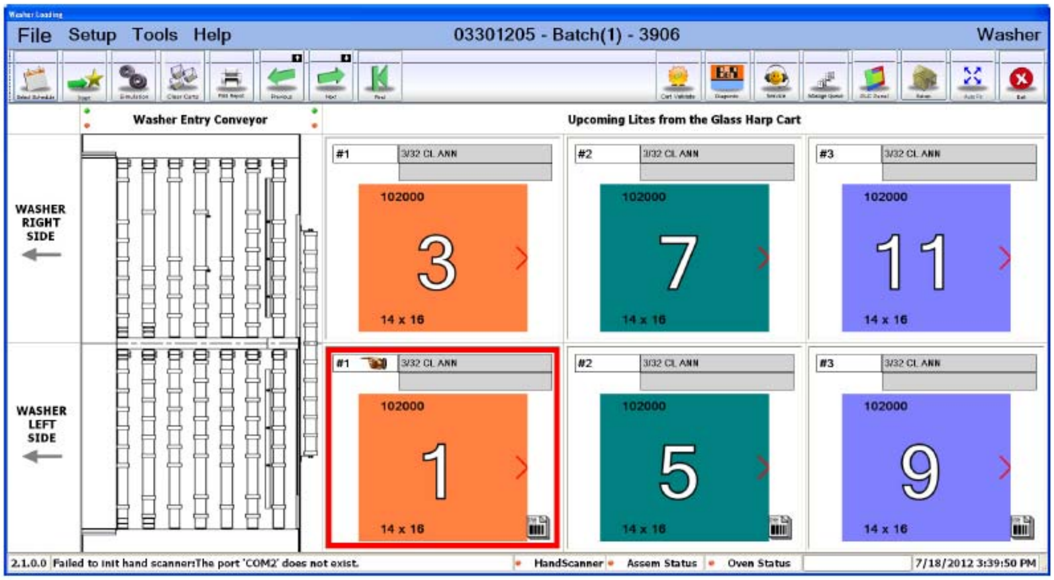
If the IGU is larger than 42” wide, then the glass is referenced to the left hand side of the washer and shifted over by the operators at the next station. The ATLAS glass washer can accommodate glass panels up to 96” wide. The green indicator lite shows the operator where to load the panel.

The Triple IGU Sequence is a similar sequence, the difference is the 3rd glass lite is loaded again on the left hand side.

The operator is informed how to load the glass from the computer monitor screen that is dedicated for the glass washer operator.



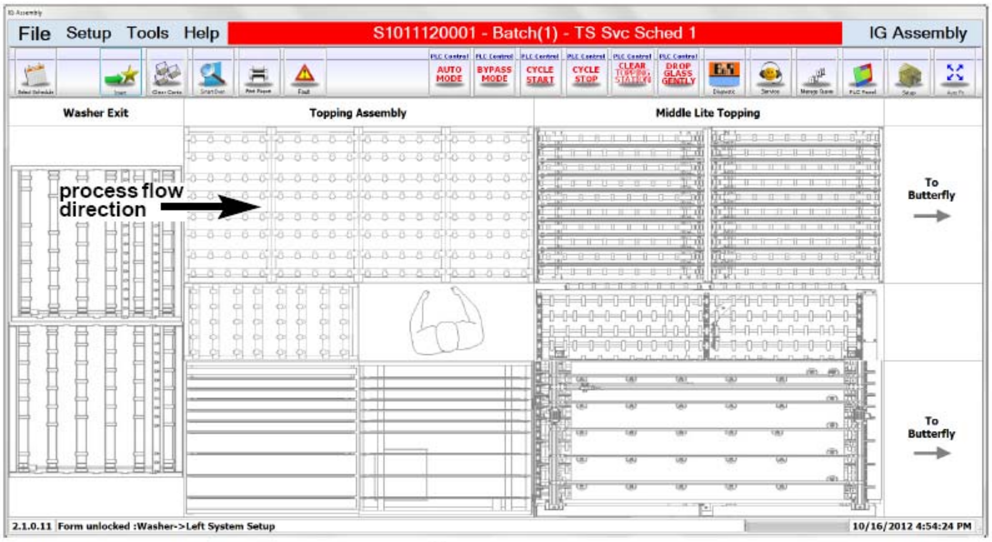
Visual HMI operator Interface Stations – Human Machine Interfaces are used to direct the system operators on what products and sequence to load glass (size, thickness, type) and spacers (size, type, color) and mutton bar (size, color, grid location and pattern type) grid assemblies into the system to execute assembly of the product in a one piece flow sequence. This software system also contains and orchestrates information for the assembly line such as processing speed, sizing information to pick and place the center lite in a triple IGU, IR emitter control to seal the IGU and also final pressure data to the press that controls the overall press height. Below is an example of the HMI screen at the entry of the Glass Washer (Figure 3).



Washer Loading Screen

Figure 3

This HMI interface is located at conveyor 5 where operators apply IG spacer and optional decorative muntin bar grid assemblies on the glass lite to be processed. (Figure 4)

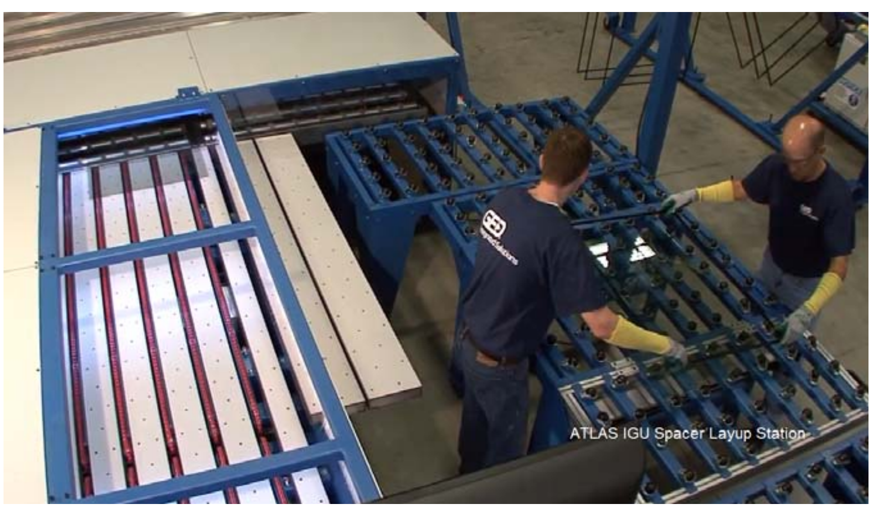


IG Assembly Screen

Figure 4

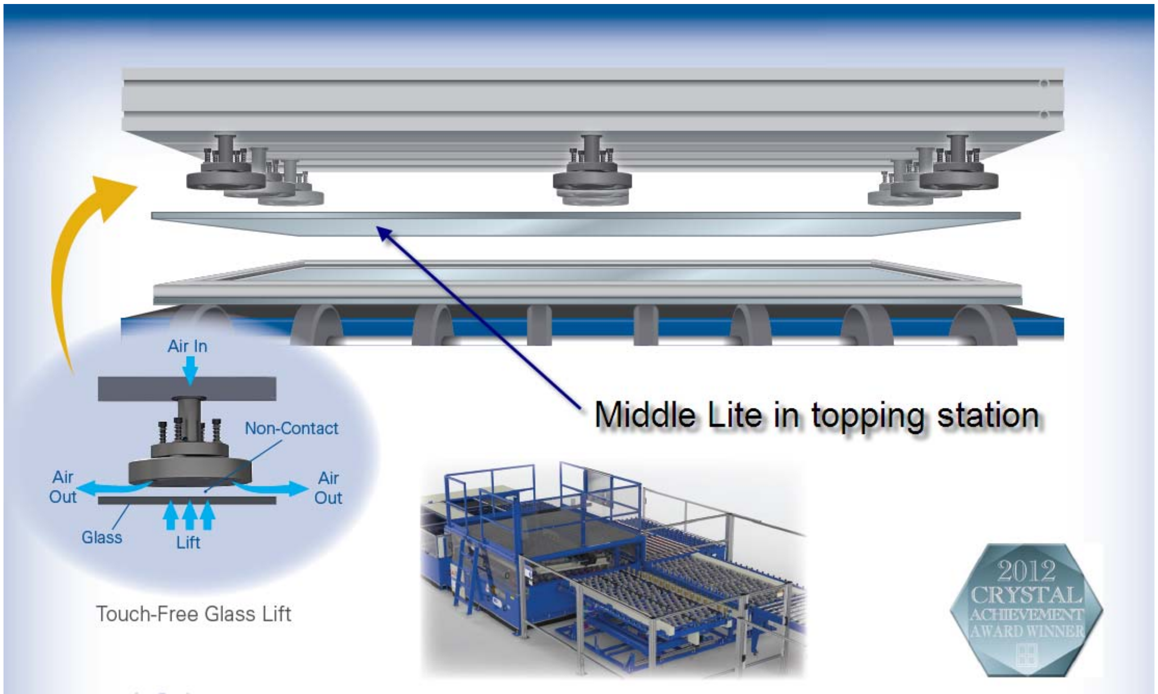
IGU Spacer application Station -

Once the glass lites are properly washed and dried, the units that are placed on the left hand side of the system are conveyed to an operator spacer layup station. At this station, the IGU spacer and Muntin Grid assemblies are placed on the glass lite, and then transported to the topping assembly station depending on the construction type (triple or dual IGU). The units that were loaded on the right hand side of the washer are automatically transferred to the next station.



Middle Lite Glass Topping Station –

One of the key requirements in manufacturing triple IGU, is ensuring that the middle glass lite is clean and assembled without any conveyor roll marks or finger prints common in hand assembly methods. GED has developed a method and machine for assembling the middle glass into an IGU in the manufacturing process. What is unique and inventive about this method, is the pneumatic vortex lifting mechanisms that are integrated into the system for lifting glass without touching the glass, during the assembly sequence. This assembly station also indexes the edges of the glass into position, independent of its size and thickness, and places the glass with precise controls onto the spacer below it to create the first chamber of the IGU on a triple IGU. This portion of the process is also contained by a positive pressure chamber that filters air particles with a dual stage 0.3 micron HEPA filter, preventing dust and air born dirt on the middle lite.



IGU Automatic Assembly Station:

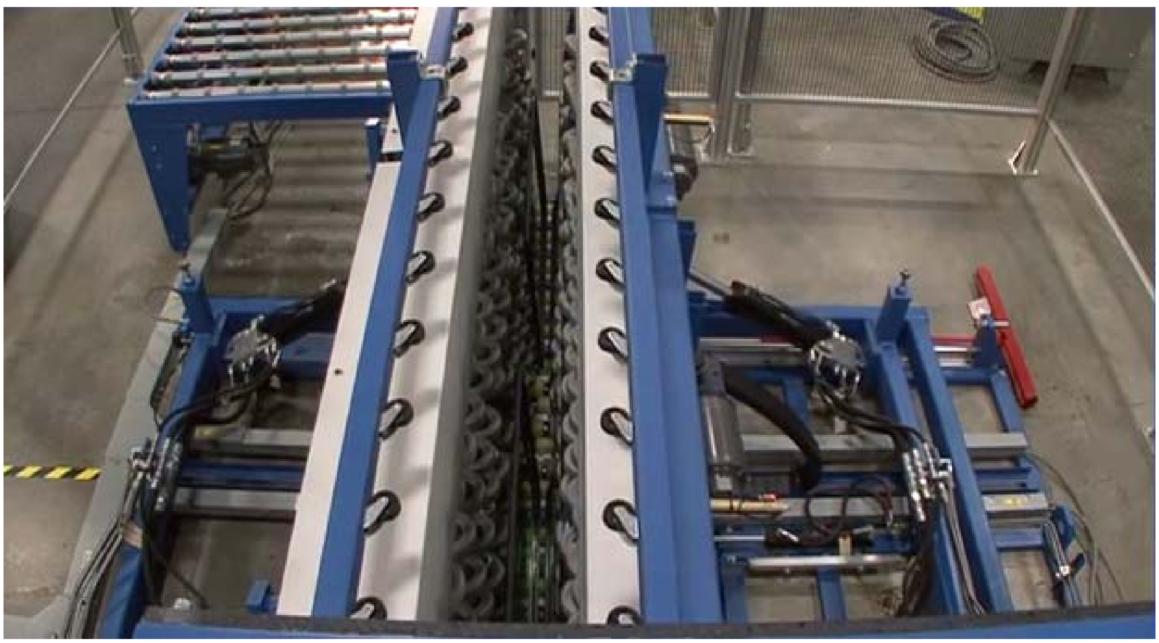
Once the IG spacer is placed on the glass, the adjacent piece of glass or dual IGU from the triple assembly process has to be matched up with it and assembled in a precise manner to preserve a square edge for the IGU, that will be properly glazed into a window sash. The ATLAS butterfly assembly station performs this task for both dual and triple IGUs. Below is a sequence of assembly motions illustrating the process. The glass edges of the IGU are used to position each edge of the glass against positive references, then automatically positioned together and precisely assembled.

One of the major technical advancements GED deployed in this development was the implementation of servo hydraulic dynamic controls.

Since ATLAS process software (WinIG 5), has knowledge of the IGUs (glass type, thickness, size and airspace…..), the machine is programmed to use optimized acceleration, velocity and motion profiles to assemble each unit. The result is a machine that can assemble up to 6 dual IGUs less than 48” in length per minute, three dual IGUs over 48” up to 102” long, or three triple IGUs per minute up to 102” long. The original design goal was to assembly one triple IGU per minute.   GED far exceeded the one triple unit per minute goal, accomplishing 3 triple IGUs per minute.

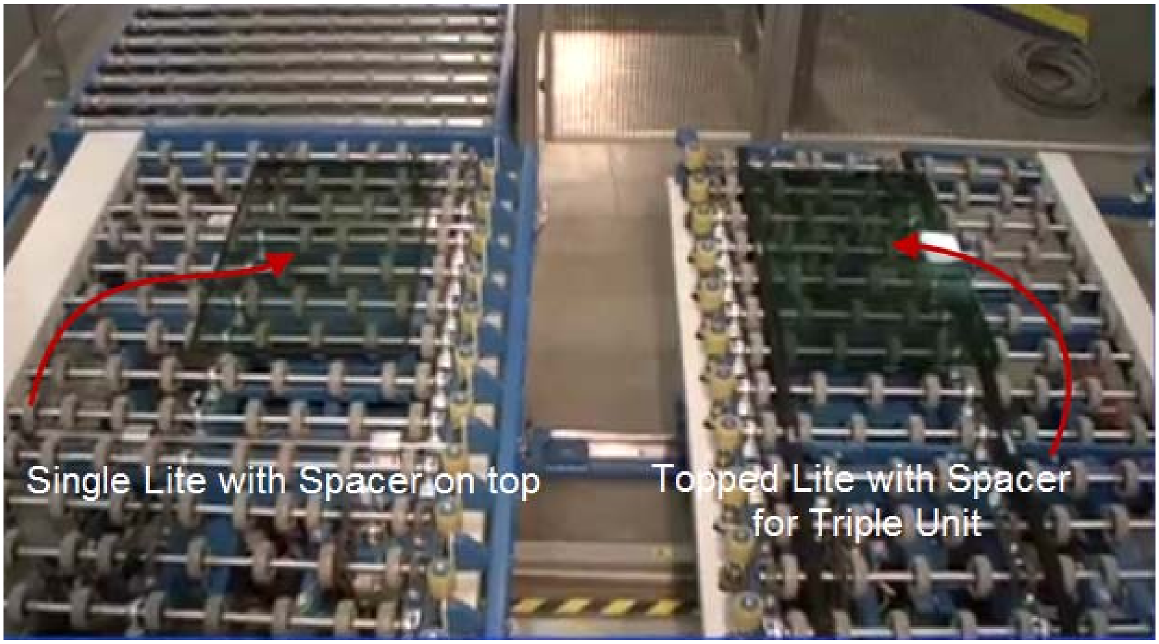
Past methods and technologies limited the rate of movement for large size IGUs, since it was fixed for most sizes or classified into small and large most sizes, resulting in an assembly method that was good for most, but not optimized for each unit.

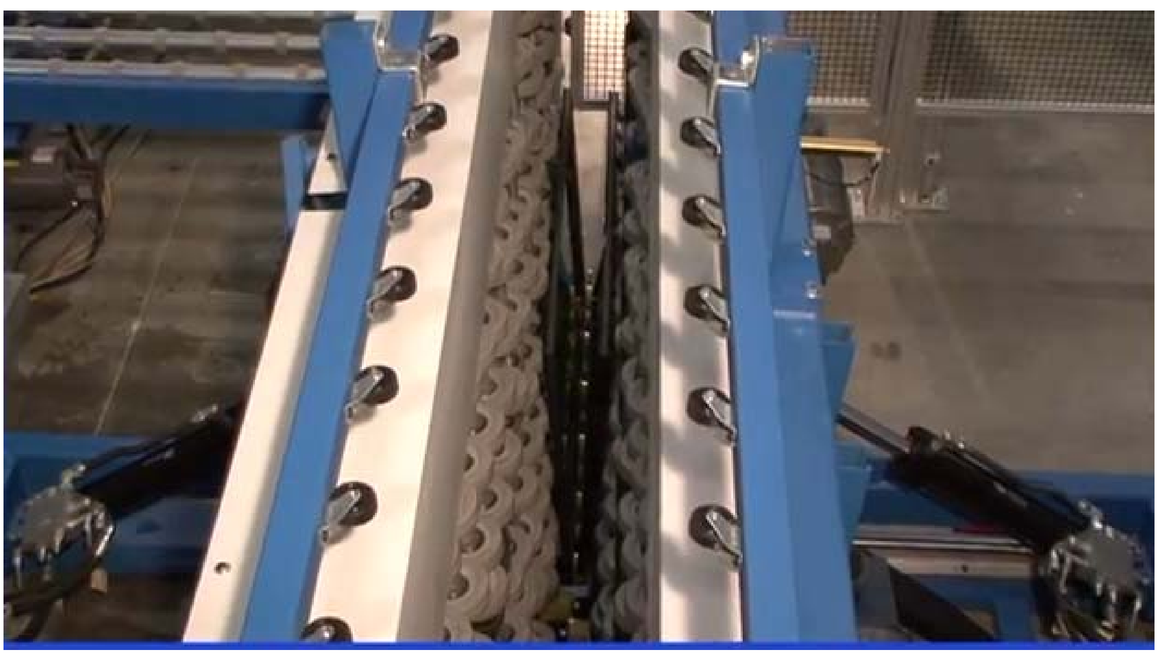
Sequence of Assembly for Dual IGUs:

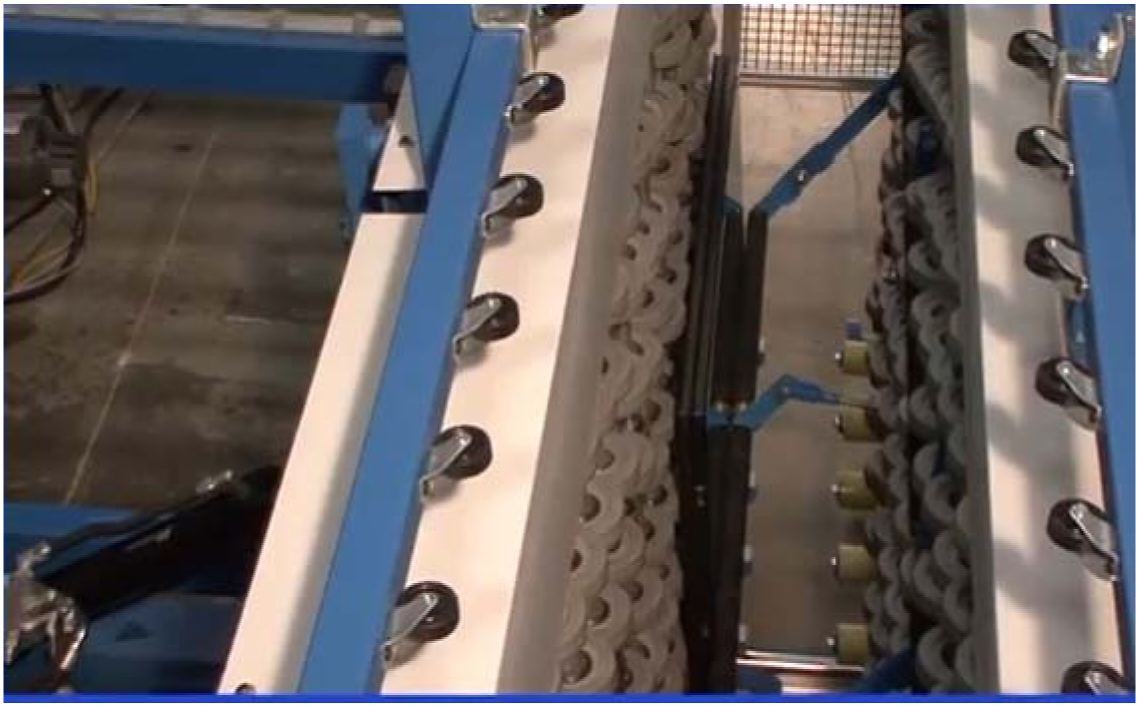


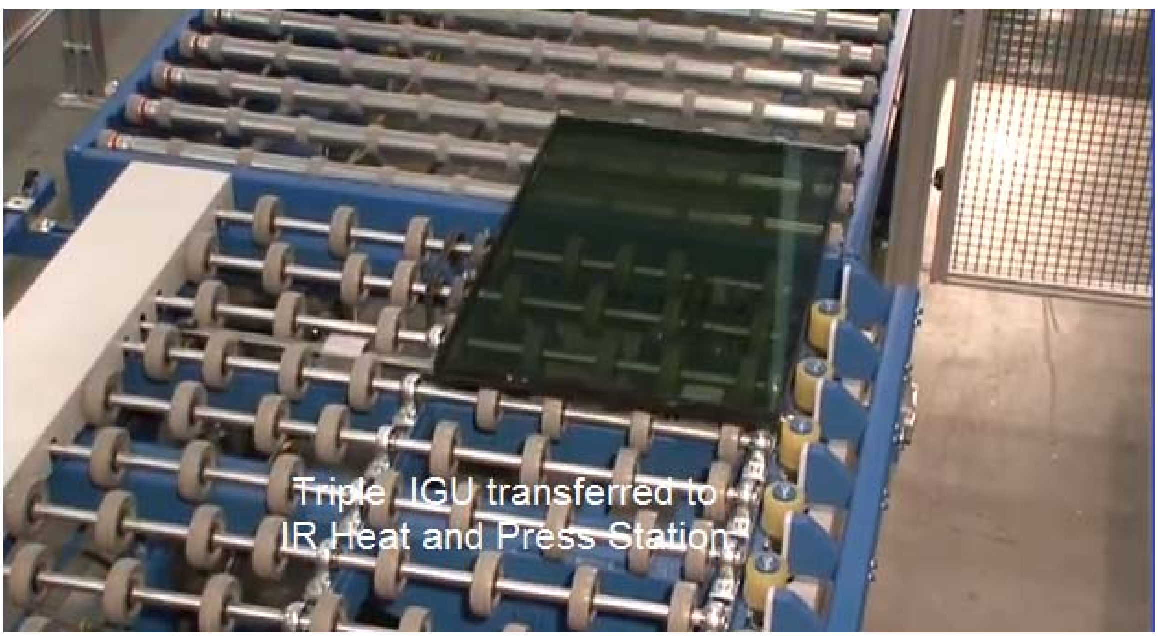
The assembled dual IGUs can next be sent to the IR Heat and Press to be sealed and sized for glazing.

Assembly Sequence for Triple IGU:

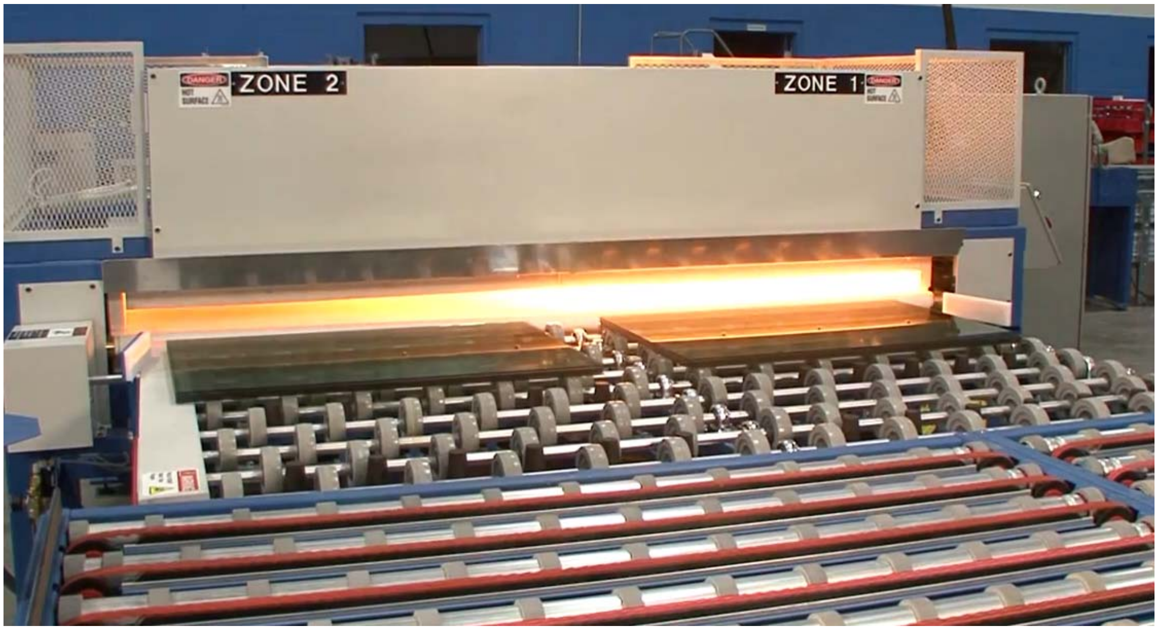






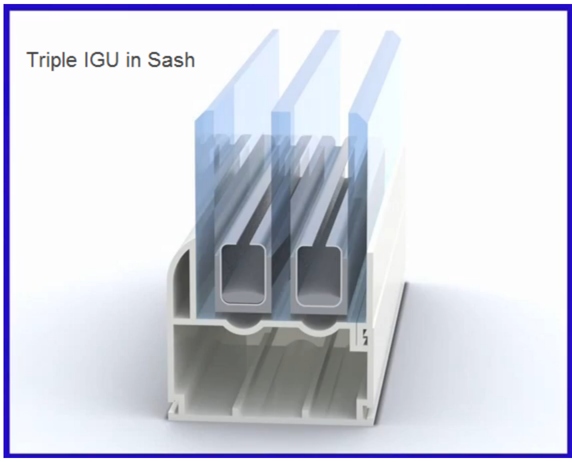

Triple IGU transferred to
IR Heat and Press Station

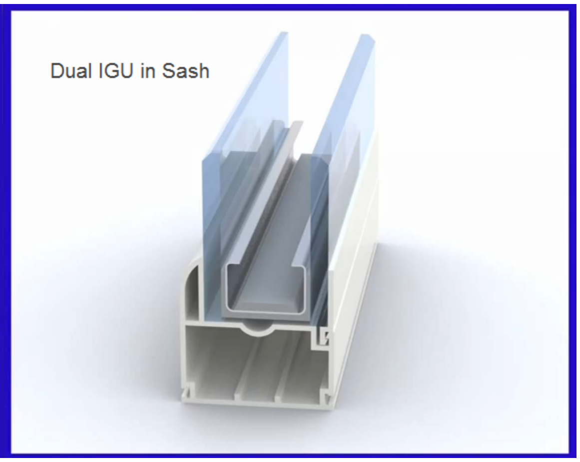
IR Heat and Press:



The GED oven press uses a combined energy transfer sources comprised of primarily infrared (IR) radiant emitters, heat conduction and convectional energy to reheat the sealant on the spacer and in the IGU.

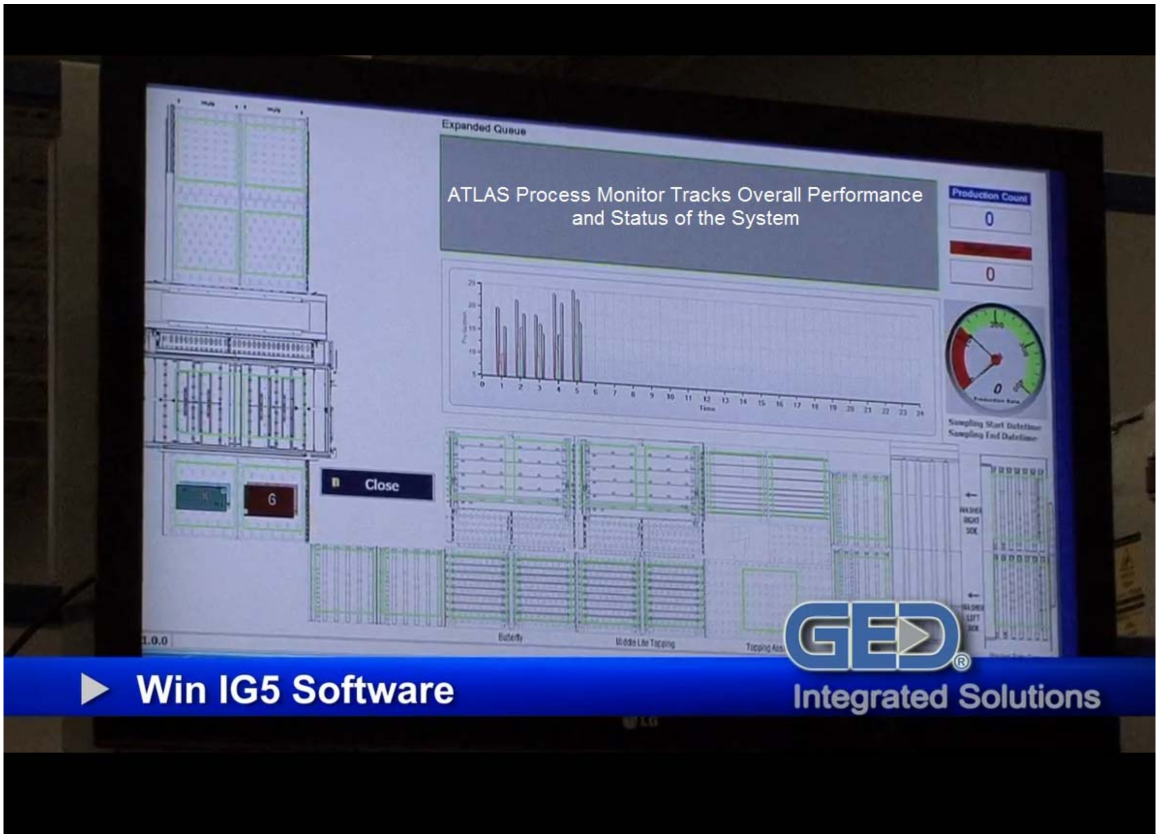
After the sealant temperature is heated to the proper level, it is pressed out by a series of compression rollers to flatten out the sealant to proper width dimensions, resulting in an IG unit that is precisely fabricated for the glazing process during the window assembly process. The GED Smart Oven Press is downloaded information from WinIG for each IGU. This information contains the proper process information for what IR emitters to power and properly control the dose of energy to the top and bottom side of the IGU, the process speed, and also the final IGU width for press.





Process Overview Monitor:

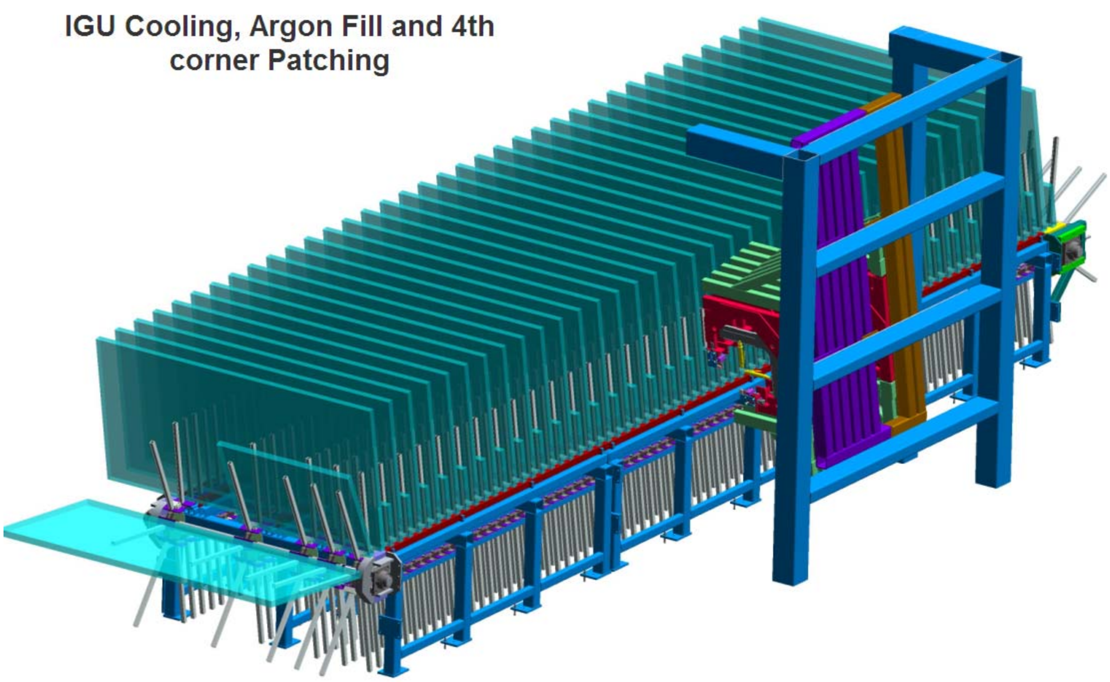
In addition to the three individual HMI screens, Atlas has a main overview of the machine monitor that displays where each glass lite, partially processes unit and finished IGU is located in the system. The display also has a configurable production monitor that illustrates how many units are on average are being manufactured for each hour.



Research completed outside the of the ATLAS process:

IGU Cooling Prior to Gas Filling:

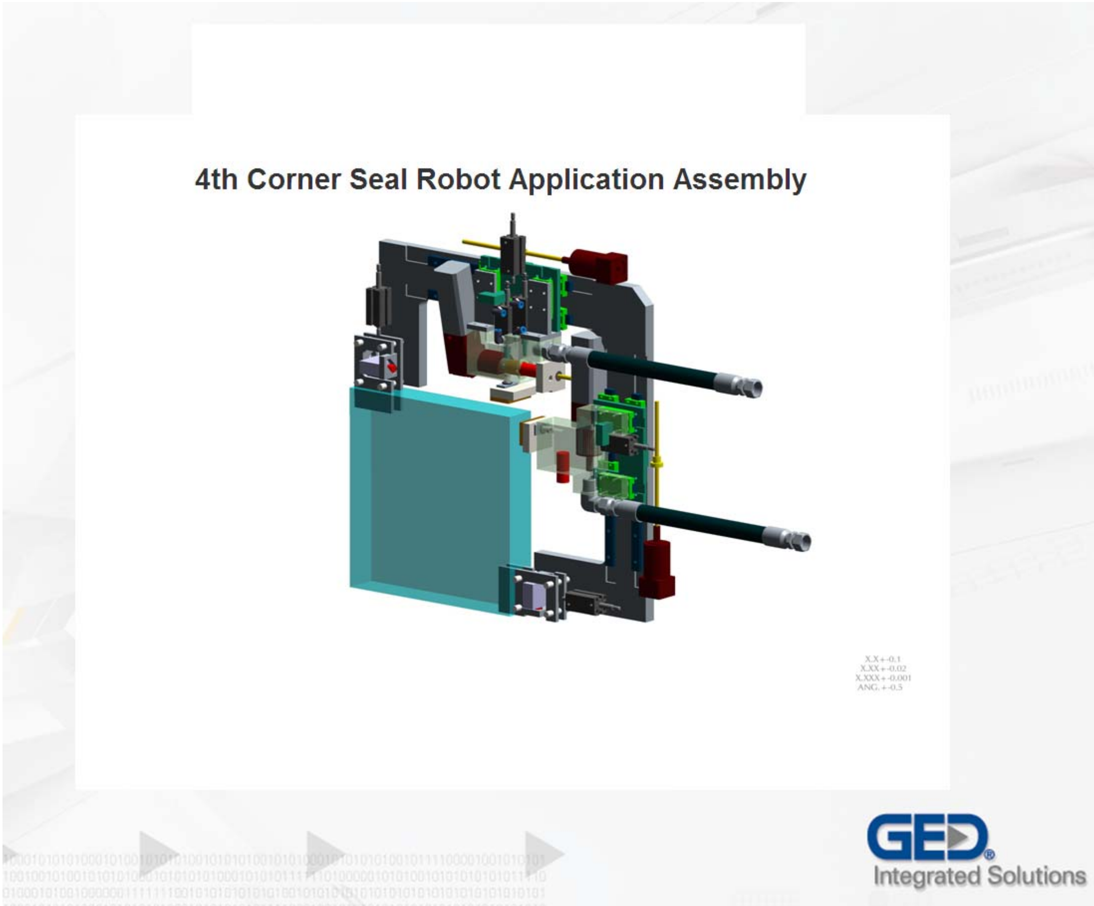
After IGUs are processed in the Infrared (IR) oven and press, they are cooled to ambient temperature before they are filled with argon gas. This is to prevent the units from imploding from negative pressure if they are sealed at an elevated temperature. After the cooling cycle, the units are Argon gas filled, a fastener is added, and the 4th corner is sealed. This cooling station contains gas fill stations with vacuum ports to sense the return flow of Argon gas to ensure proper filling levels are achieved before closure and final seal.



4th corner IGU Seal –

The 4th corner of an IGU unit needs to be closed and hermetically sealed to prevent moisture and moisture vapor from penetrating the IGU over time and to prevent inert gases like argon from escaping. An automatic seal robot was investigated and prototyped to prove feasibility and functionality for sealing IGUs. This robot applies a final sealant application to the 4th corner, working its way out from the corner and down the side and top of the IGU by applying consistent heat, amounts of material and pressure to displace trapped air that can lead to a breach in the future.

The common technique deployed in our development was modeling machine concepts using a 3D CAD system. This tool gave us and the customer visibility how the process and machine will function in the assembly plant for the operators.



Below is photo from GED Integrated Solutions R&D laboratory where the ATLAS system was designed, developed, tested and refined prior to Beta test.

- Process and Machine Specifications

The initial process and machine specifications were developed with inputs from customers, marketing and engineering. This document was initially used by the design team as a foundation to develop a functional specification for the ATLAS system.

One major change that unfolded during the development of ATLAS, was expanding the functionality of the IGAMS system from a line the produced triple IGU exclusively, to an assembly line that can produce both dual and triple IGU in a one piece flow sequence. This extended functionality was apparent due to the market not immediately calling for high demand and volume of triple IGUs, but a slow initial demand that is anticipated to grow over time in the market.

Specifications for the IGAMS (ATLAS) System:

IG Unit Size Capacity *Note: Triple-lite IGU can only be run one at a time through the Butterfly*	
With X-Y (90°) Conveyor at Oven Entrance	
One IGU (one double- or triple-lite IGU at a time on Butterfly)	Note: “High” refers to the lite’s edge that is vertical when the butterfly table closes. Min Size: 16” long x 14” high (40.64cm long x 35.56cm high) Max Size: 80” long x 72” high (203.20cm long x 182.88cm high) Maximum IG Unit Thickness: 1.75” (4.45cm)
Two IGU (two double-lite IGU at a time on Butterfly conveyors)	Min Size: 16” long x 14” high (40.64cm long x 35.56cm high) Max Size: 49” long x 50” high (124.46cm long x 127cm high) Maximum IG Unit Thickness: 1.75” (4.45cm)
With Straight-Thru Conveyor at Oven Entrance	
One IGU (one double- or triple-lite IGU at a time on Butterfly)	Min Size: 16” long x 14” high (40.64cm long x 35.56cm high) Max Size: 100” long x 72” high (254cm long x 182.88cm high) Maximum IG Unit Thickness: 1.75” (4.45cm)
Two IGU (two double-lite IGU at a time on Butterfly conveyors)	Min Size: 16” long x 14” high (40.64cm long x 35.56cm high) Max Size: 49” long x 50” high (124.46cm long x 127cm high) Maximum IG Unit Thickness: 1.75” (4.45cm)

Glass Thickness Capacity	
Maximum Glass Thickness (outer lites)	0.250" (6mm) Top Lite ** 0.406" (10mm) Bottom Lite ** ** As oriented through oven.
Maximum Glass Thickness center lite	0.187" (5mm)

Problems encountered and departure from planned methodology:

Our initial partnering customer rescinded to participate in the Beta test of the ATLAS due to residential market volume declines between the 2009 through 2012 coupled with delays of more stringent EnergyStar programs for Residential Windows. Many residential window companies have continued to design and cautiously commercialize R5 energy efficient window designs, but do not anticipate initial high volume demand for R5 windows. These companies have continued to express interest in the high speed ATLAS system and want to invest in this capital once triple IGU demand are established at a higher and consistent level. Manual IG assembly and window methods will become a production throughput and design constraint, then high volume triple IGU assembly ATLAS processes will provide a quicker capital payback justification. Until high volume R5 windows are established in the market, payback on high speed machinery will result in longer payback time periods.

After a short delay in the project seeking a new customer to test the system, GED partnered with PPG Industries (Carlisle, PA) who manufactures IGU for commercial use in final window assemblies to test the ATLAS system. This Beta test lasted approximately 5 months. This Beta test consisted of software WinIG-5.0, system configuration and training, and the installation of the ATLAS System. The system was commissioned to manufacture IGUs for the Window and Door market in 2012. During that period, the system was tested, refined and verified to work efficiently and reliably at the customer.

Engineering Release Process:

During the Beta Test, documentation to commercialize the system and process commenced in order to reproduce the ATLAS machine for commercial use in a repeatable and reliable manner. This process included the completion of Bills of Materials (B.O.M.s), individual mechanical component drawings, assembly drawings and initial set up procedures. Hydraulic, pneumatic component drawings, assemblies, schematics and set up procedures were also completed and reviewed. Electrical B.O.M.s, schematic drawings, Programmable Logic

Controllers, PLC and Human Machine Interface software programs were refined and released production for a commercial build.

GED Integrated Solutions also designed and verified the ATLAS system to be certified for UL 508 and CE compliant for machine requirements for safety and operation.

UL 508: These requirements cover industrial control devices, and devices accessory thereto, for starting, stopping, regulating, controlling, or protecting electric motors. These requirements also cover industrial control devices or systems that store or process information and are provided with an output motor control function(s). This equipment is for use in ordinary locations in accordance with the National Electrical Code, NFPA 70.

CE: Overall, the Machinery Directive harmonizes the safety requirements of the European Union and European Norms and is the vehicle used to show compliance with these harmonized requirements.
This safety standard is recognized by many factories as an effective safety standard. The goal of this directive is to ensure the safety of people, or property from threat of endangerment produced by machinery or safety components.

A second ATLAS system was manufactured, assembled, tested and commissioned at GED Integrated solutions for the purpose of support and training both internal and external customers. This system enhances GED to support our customers when calls are received for troubleshooting and verification of possible issues and solutions as they arise with the evolution of the product.

Training Materials:

Internal and Customer training videos were produced to document the initial set up, configuration and maintenance of the machinery.

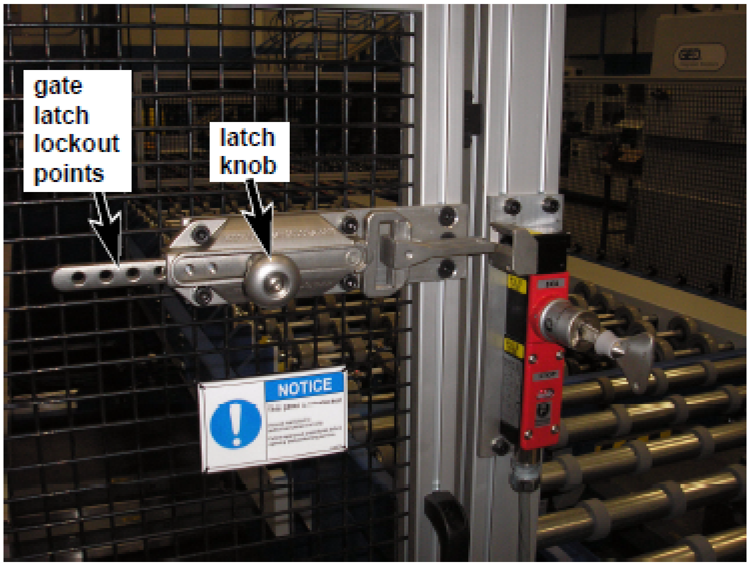
Product Manual:

An ATLAS operator manual was developed that contains critical information including a product overview, equipment installation, operation, set up and adjustment, periodic maintenance, and troubleshooting information.

Excerpts of the operator training manual are illustrated below:

Atlas Overview: Review of machine and safety aspects.

Then, Lockout / Tagout the latch on the gate. The machine cannot operate when the latch is open. See photo below.



Safety Gate Latch Lockout Points

The key cannot be turned clockwise to enable the machine while the gate is unlatched.

ATLAS Machine Installation:

Important Notes

- The equipment is pre-assembled and tested before shipping. Components may have loosened or dislodged during shipping.
- Make sure all pre-made connections are secure before the machine is powered up and put into operation.
- Each component must be level.
- All equipment must be correctly positioned. Measurements are critical. They must be exact.
- Use a spreader bar or other support to unload and move the equipment. Attempting to move the equipment without some type of extra support will result in damage.

Document any special information for your setup on the drawings. Retain them for future reference.

Note: It is the responsibility of the purchaser to secure and fasten objects to floors, walls, ceilings, and other structures. GED assumes no liability for the durability of any such connection, anchor, or fastener, nor for any damage that may result from the installation of any connection, anchor, or fastener.

Preparing the site

1. Make sure the electrical service lines ("drops") are in place before installing the machine. Refer to layout drawing as necessary.
2. Confirm that the voltage of the electrical power source is correct.
   - The actual voltage coming from the electric supplier varies from area to area. Check the voltage on the circuits that will be used to power the equipment.
   - The tolerance limit on the power variance is +/- 10%. If the power from the electric company is outside this range, it must be adjusted before the equipment can be operated.
   - Voltages outside this range will damage the equipment or result in improper operation.

   Note: The consequences of using this equipment with voltages and/or electrical service that fails to conform to these specifications is the sole responsibility of the purchaser. GED assumes no liability for equipment damage, malfunctions, nor for any consequences of damage or malfunction due to improper voltages and/or electrical services.

x 11.00 in

Atlas Emergency Stop Locations:

Switches and Controls

The switches and controls on the machine are described below.

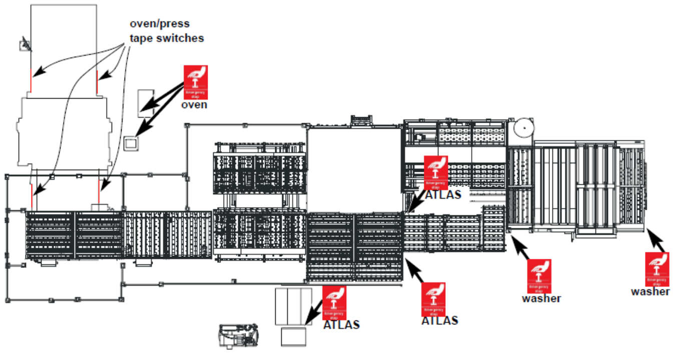
E-Stop Switches

The ATLAS system will not run unless all E-stops are reset (twist clockwise and pull).

The ATLAS system's E-stops are divided into three groups:

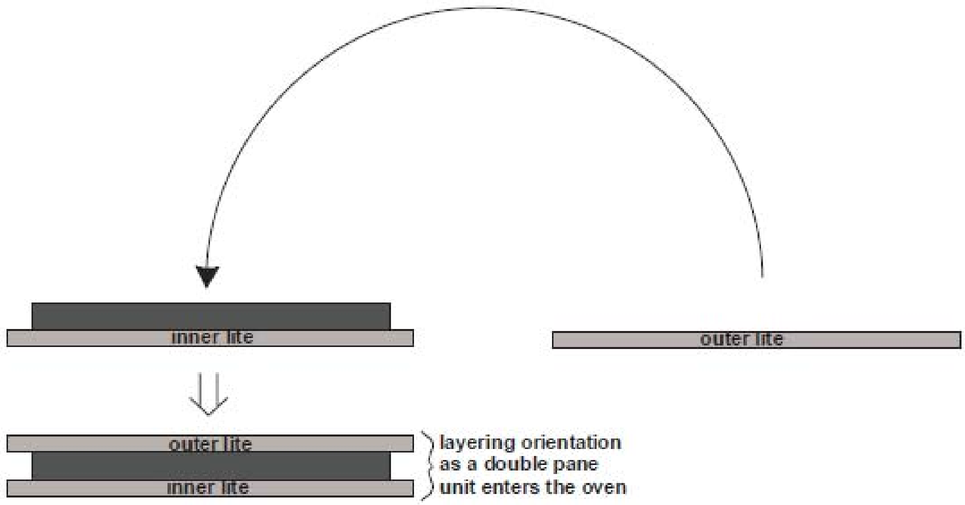
- Washer
- ATLAS, and
- Oven.

The E-stop locations are shown below.



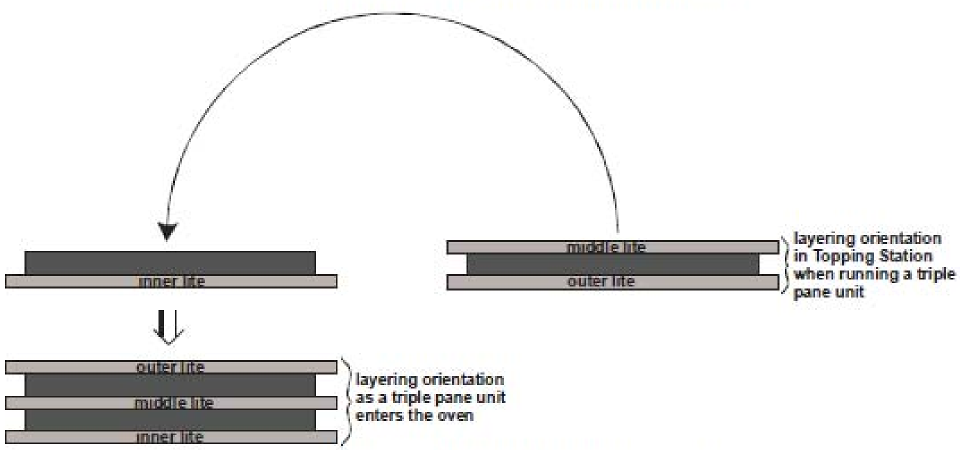
Locations of E-Stop Buttons

Terminology and Operation Overview of making an IGU on ATLAS:



Double pane IG unit - layering orientation

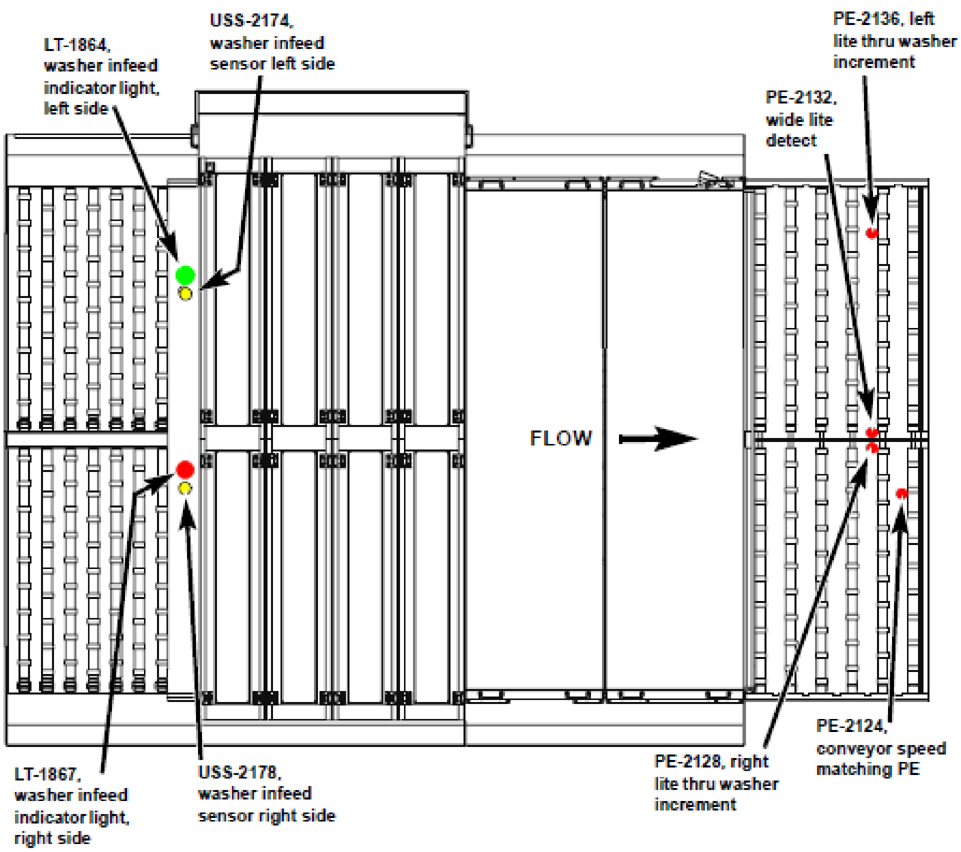
A triple pane IG unit consists of three lites referred to as the inner, middle and outer lites. See illustration below.



Triple pane IG unit - layering orientation

ATLAS Glass Washer Photo Eye locations and Schedule Operation:

Washer sensors are described below. Refer to following illustration.



Washer - Top View

Washer Infeed Sensors - Two washer infeed sensors (USS-2174 and USS-2178) are mounted at the washer entrance on the left and right sides to detect when and where lites have been loaded.

Washer Exit Photoeyes - Four photoeyes (PE-2124, PE-2128, PE-2132, and PE-2136) are located at the washer exit to detect lites leaving the washer.

PE-2136 - This PE tells ATLAS when each lite on the left side of the washer has exited the washer.

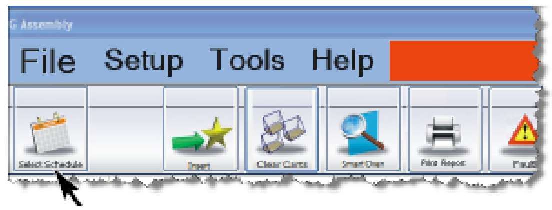
PE-2128 - This PE tells ATLAS when each lite on the right side of the washer has exited the washer.

PE-2124 - This is a conveyor speed matching PE. It tells ATLAS there is a lite transferring from the washer to conveyor 1, and therefore the speed of conveyor 1 needs to be reduced to match the speed of the washer. Otherwise, conveyor 1 runs faster than the

Selecting Schedules and Batches

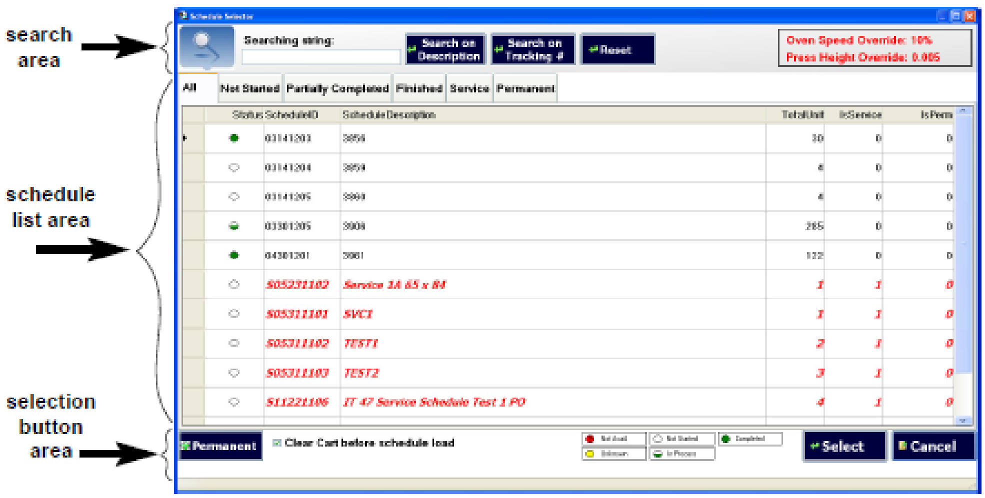
Before you can run production, you must select a schedule created by WinIG 5 software.

You begin the schedule selection process by choosing the Schedule Selection button on the main tool bar shown below.



Schedule Select Button

The Schedule Selector Screen will appear as shown below.



Schedule Selector Screen

Once inside the Schedule Selector screen, a variety of ways of selecting the desired schedule are available. The Schedule Selection screen is divided into 3 areas:

1. Search Area: This area allows you to type in or scan in a schedule description or a tracking number. Upon pressing the enter key, ATLAS will search through all the imported schedules in its database and find the schedule or schedules that match the search string. All 4 tab screens in the "Schedule List Area" are affected by the sort.

ATLAS Trouble Shooting Section:

Troubleshooting Machine Functions

The Troubleshooting Table below lists potential symptoms and possible solutions to machine functional issues.

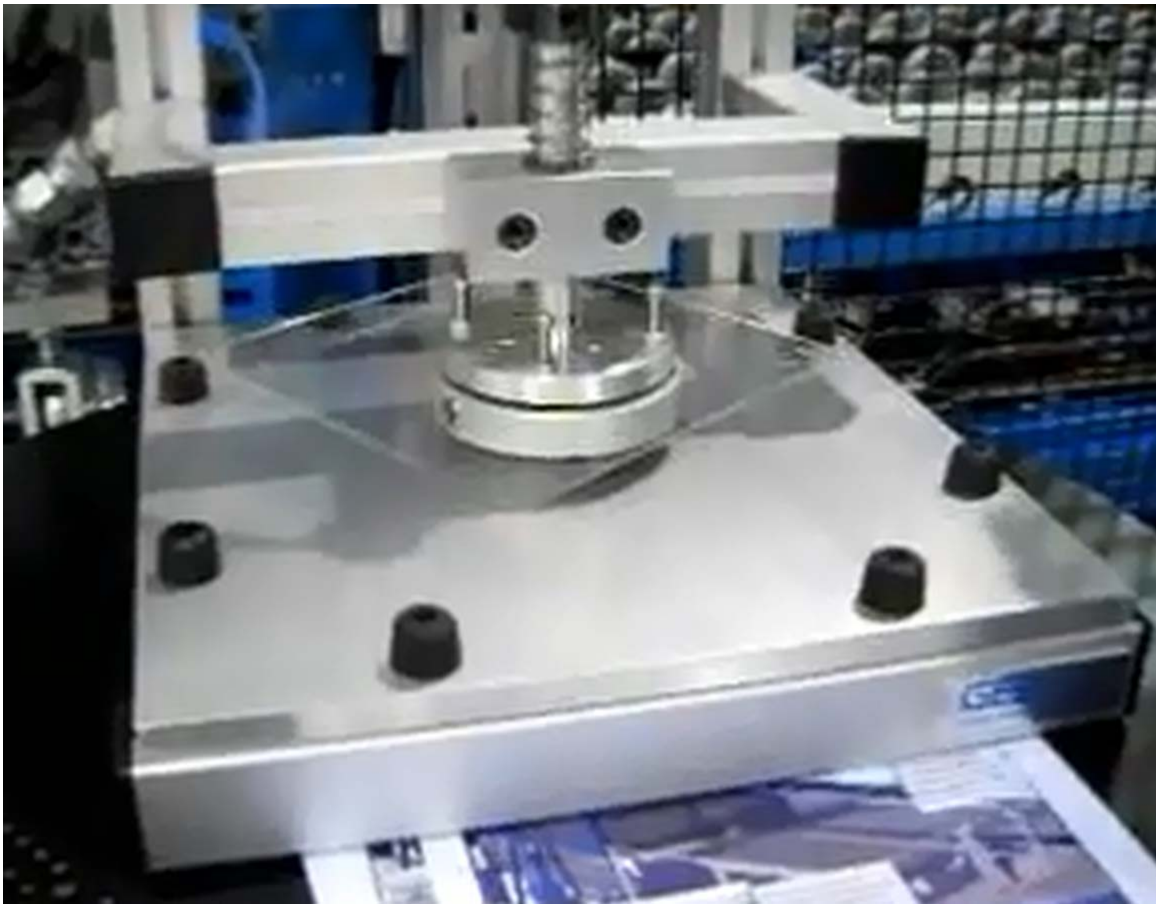
Table 6-1: Troubleshooting Machine Functions

Symptom	Solution
The machine will not power up.	• Make sure the Main Power Disconnect is ON. • Make sure the main fuses are not blown. Check the voltage coming into the machine. • Check the transformer primary fuses. • Check the transformer secondary fuses. (Refer to electrical drawings.)
The computer comes on, but MASTER START does not come ON.	• Check all EMERGENCY STOP buttons, make sure they are pulled out. • Make sure all safety guards are securely fastened in the correct place, and limit switches are "made". • Reset the Safety Relay by pressing and releasing the Main E-Stop. • Check fuses. Replace blown fuses.
Machine not functioning correctly in Auto Mode.	• Check settings in Automatic Controls Screen. See page 4-82.
Audible Alarm at Oven	The following will cause an audible alarm from the oven: • Oven does not receive oven code data from ATLAS for an incoming IG unit. • Any thermocouple temperature sensor signals lost from the oven or the oven's main electrical enclosure. • An emitter or its associated fuse fails. • An over-temperature condition occurs in the oven.
touch screen control is intermittent	• Mouse is stored in an area of vibration. • Two or more people are trying to use a touch screen at the same time. See "Using the Touch Screens" on page 3-11.

Commercialization of ATLAS system:

- The ATLAS system was exhibited at the Glass Build America industry trade show September 11th through the 14th 2011 at the Georgia World Congress Center. This system won the "Best in Show" for the most innovative machine.

  http://www.glassonweb.com/news/index/13985/



Also see Phase III (Trade Shows and Industry Publications)

Discrepancy to planned budget:

- GED has developed additional software that was not planned in the original project budget to synchronize the IGAMS process to the demands of the window plant. This has not impacted the federal share expenses of this project since GED has incurred these additional development expenses.

Changes in Approach:

- With market conditions in the window and door industry remaining suppressed, capital expenditures and investments have significantly diminished. Only critical key projects are being implemented, resulting in less projects being initiated from our customers. Taking this market trend into consideration, we believe it was critical to refine the modularity of the IGAMS system and focus on IG assembly first with the intent to add optional post processes at a later date to reduce initial capital investments and help spread out capital investment to the window and door manufacturer. Not having all steps automated initially will not significantly impact the cost of the final R5 window, thereby still preserving the plan to provide an R5 window to the customer for less than $4 incremental cost per square ft to the end consumer.

- The ATLAS System can be utilized to provide the manufacture the key components for assembling triple and dual IGU in an efficient manner. In addition, WinIG 5 software is needed to configure, control and track IG components in the system to effectively conduct and coordinate the process flow.

Anticipated Problems, Delays and Required Actions:

- Our initial partnering customer rescinded to participate in the original Beta test of the ATLAS during the project. This customer has continued to design and commercialize their R5 window designs, but don't anticipate an initial high volume demand for these R5 products in the next two years. They are interested in the high speed system once demand is established at a high level. Manual IG assembly and window methods will become a production throughput constraint, then high volume triple IGU assembly (IGAMS) processes will provide a quicker capital justification. Until high volume is established in the market, payback on high speed machinery will result in longer payback. GED established additional customers and partnered with PPG to Beta test the ATLAS system prior to commercialization.

Phase III

In Phase III, PPG and GED promoted the High Efficiency Triple Design and Automation System (ATLAS) and promoted it to wide spread commercialization audience.

Goals:

- Commercialize EEE System into Window and Door Companies
- Develop Literature and Promotional Campaign
- Accelerate Market Acceptance through established broad industry networks

Expected Results:

- Convert Window and Door Customers to EEE technology to implement the high efficiency triple design into their window systems

Actual Results:

- Commercialize EEE System into Window and Door Companies

GED Integrated solutions started promotion of the ATLAS system using an E-mail distribution service, announcing the news to over 720 direct North American contacts in the Window and Door Industry.

Our promotional teams made personal visits to our customers in the IG, Window and Door industry with our direct sales staff and technical associates. Customer visits commence to see the operational ATLAS manufacturing system at PPG to gain more first hand knowledge about the capabilities of the system.

- Develop Literature and Promotional Campaign
- Accelerate Market Acceptance through established broad industry networks

Industry Trade Shows:

- The ATLAS system was exhibited at the Glass Build America industry trade show September 11th through the 14th 2011 at the Georgia World Congress Center. This system won the "Best in Show" for the most innovative machine.

  http://www.glassonweb.com/news/index/13985/

- On a global scale, the ATLAS system was exhibited and demonstrated at the Glastec October 2012 show which was held in Dusseldorf Germany. This show reported approximately 43,000 visitors.
  GED demonstrated the ATLAS functionality of making both Dual and Triple IGU units being produced, boasting the fastest production rate in the world for producing both triple and dual IGUs.

  GED to showcase its InterceptÂ® Warm Edge Spacer production systems at Glasstec 2012

  GED Integrated Solutions

  Just ten months after a triumphant appearance at GlassBuild, Atlanta, USA, where its newly launched Automated Tri-Lite Assembly System (ATLAS), won the " Best in Show" ™ Award, GED Integrated Solutions has confirmed that it is to exhibit at the world's largest international glass exhibition, Glasstec, in Duesseldorf, Germany, 23 - 26 October 2012.

  http://www.gedusa.com/1349-Glasstec.php

Publications Distributions In North America:

- Window & Door Manufacturer Magazine
- Door & Window Manufacturer Magazine
- Window & Door Manufacturer magazine
- U.S. Glass magazine
- Glass magazine
- Canadian Window & Door Manufacturer
- Glass Canada

ATLAS Product Video and product information on GED's Website -

http://www.gedusa.com/atlas.php

Related Products Information and Video Links:

GED Stainless Steel Glass Washer used with the ATLAS System:

http://www.gedusa.com/ssgw.php

GED i3 Smart Oven and Press used with ATLAS System:

http://www.gedusa.com/smartoven.php

GED ATLAS System YOUTUBE VIDEO LINK:

ATLAS – Automated Tri-Lite Assembly System:

http://www.youtube.com/watch?v=IG4JKeK55KU

Expected Results:

- Convert Window and Door Customers to EEE technology to implement the high efficiency triple design into their window systems

Actual Results:

Our success to convert window and door customers to triple IGU technology is a continuing process that has taken and will continue to take several years to implement. Current economic conditions in the United States Window and Door Market continue to be down, relative to the housing growth rates of 2001 to 2006 and the trend to invest in existing homes. Our customers recognize the benefits of the R5 thermal performance system at a very reasonable cost differential, but they are reluctant to invest capital in new window systems with questionable consumer demand.

There are several window companies who have stepped forward and have designed window systems that can accept triple IGUs in the last two years with approximate 1 and 3/8 inch IG sash pockets, anticipating the market will migrate towards wanting and needing this level of window performance in the future. Catalysts in the market that can influence the demand for R5 window performance includes; increased performance building code mandates (Energy

Star guidelines requiring R5 performance), and increase energy costs of heating and cooling homes (natural gas, oil and electricity).