ENERMAX 150

GRANDVIEW WINDOW WALL

MAY 24, 2019

DESIGN AND PERFORMANCE OVERVIEW

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

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INTRODUCTION

JRS Engineering Ltd. (JRS) is providing this report to document the development of the system and testing process which has led to the successful completion of the mock-up testing in March 2019 of the ENERMAX 150 window wall system by Grandview EA Systems Corp. We understand that this report will be utilized to describe the attributes of the design and tested performance of the window wall system to developers, architects and engineers.

DESIGN PROCESS

Background

Grandview's window wall system was designed to be a state-of-the-art fenestration system that maximizes the performance characteristics achievable by a window wall system, while enhancing durability, constructability, aesthetics, and economic value. The design team consulted with stakeholders from all aspects of the industry. Manufacturers, testing agencies, specialty contractors, window installers, developers, building envelope specialists, and structural engineers helped develop the design of the system. The combined experience and expertise of the design and consulting teams provided critical lessons of past failures and successes with window wall assemblies. The ENERMAX 150 window wall was created to exemplify the best characteristics of existing window wall technologies and demonstrate form and function that meets evolving project energy performance targets.

The design and consulting team included:

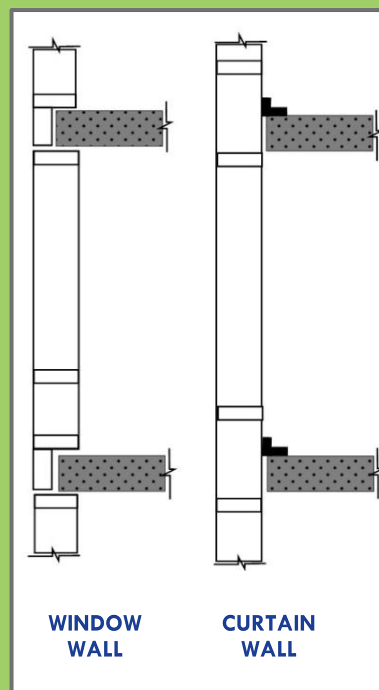
- Grandview EA Systems
- JRS Engineering
- GG Construction Services
- Namsun Aluminum
- Alpro Aluminum
- ATA Testing Korea

Historical Perspective: Window Wall or Curtain Wall?

When it comes to high-rise building fenestration systems there are generally two types: the window wall and the curtain wall. Historically, the difference between these two cladding systems has been readily apparent. The window wall is typically supported structurally between slabs, and the curtain wall is hung off the slab edge. However, modern window wall systems have begun to blur these lines by mimicking the sleek aesthetic look of curtain walls while remaining cost-effective and maintaining ease of installation.

In general, early designs of window wall systems showed poor thermal performance, as they left the slab edge exposed or sometimes included uninsulated slab cover panels. Design innovations introduced insulated slab panels, adding thermal breaks to aluminum frames, and pushing the window wall further outward to better line up the planes of thermal resistance and limit thermal bridging. Modern window wall systems with improved spandrel bypass panels and interior insulation have been able to achieve higher thermal performance than typical curtain wall systems.

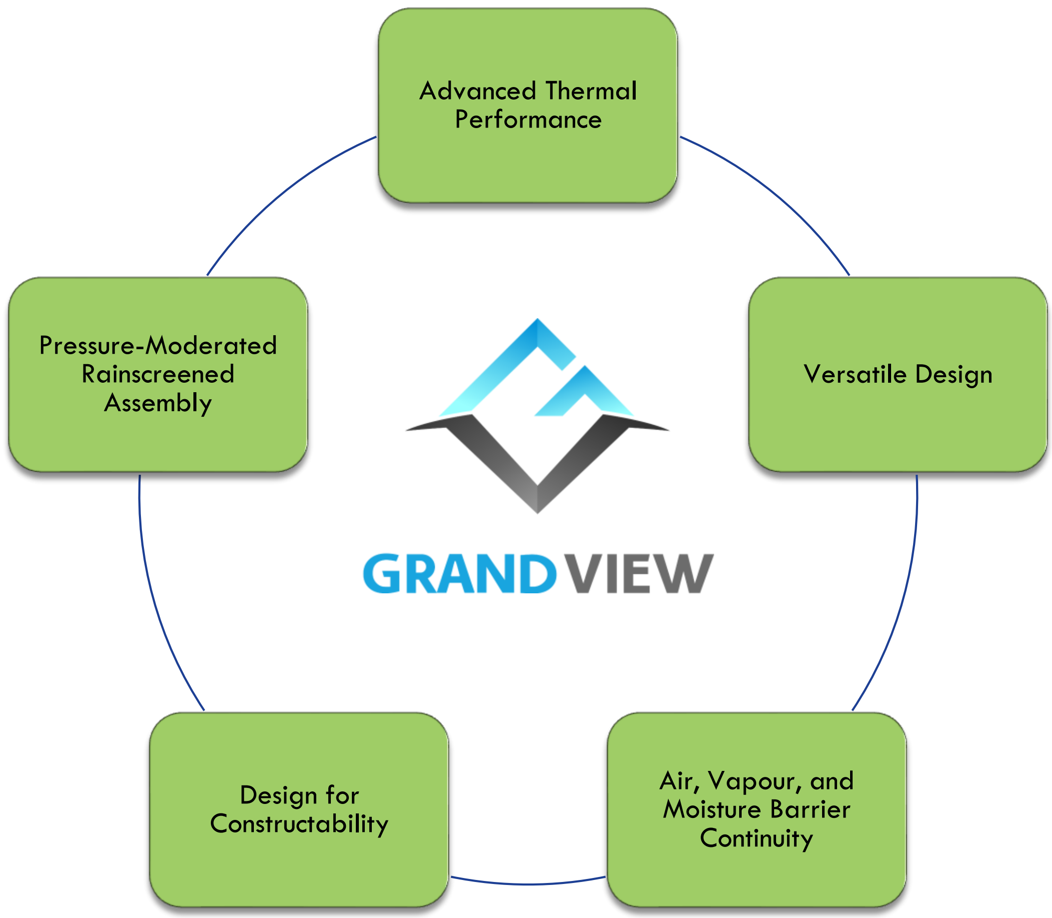
In terms of water resistance and airtightness, modern window wall systems have moved from relying on perfectly installed site-applied sealants at the exterior face of the system (face sealed), to an internally drained approach which decouples the exterior weather seals from the interior air/moisture barrier seals (rainscreened). Modern window walls use factory-installed gaskets, butyl tapes and sealant joints combined with some site-applied weather seals to provide building envelope controls that are less reliant on the quality of site workmanship.



Modern window walls are now capable of providing effective envelope controls that are comparable or surpass the common curtain wall. Advances in the thermal performance, aesthetics, and the use of rainscreen and pressure moderation principles, are a few of the key design innovations that are characteristic of the modern window wall and which allow it to be a very effective high-rise fenestration system.

Performance Attributes

The best performing design attributes of the modern window wall were reviewed, debated and then distilled, with a few key attributes emerging. These attributes formed the foundation from which the conceptual design of the ENERMAX 150 window wall was created. As the design of the system was refined through an iterative process, these principles continued to inform every step of the design.



Conceptual Design

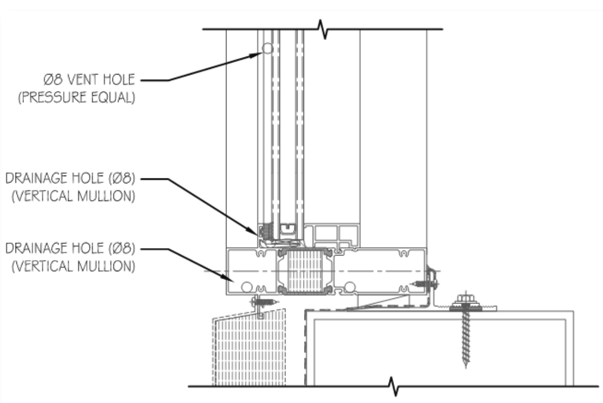
The window wall was designed as a unitized split-mullion system. The consulting team created the conceptual design to focus on building envelope performance concepts with respect to water penetration, air leakage, and vapour diffusion. This section highlights some of the decisions made for the initial design of the ENERMAX 150 window wall.

Pressure Moderation and Drainage

Pressure Moderation Concepts
Pressure moderation reduces the amount of water penetration into the window wall assembly by reducing the pressure difference across the exterior plane of the system. Venting the exterior frame cavities to the exterior allows the air pressure within the window wall framing to equalize with the outside air pressure. By reducing the pressure difference, the driving force on water is diminished and vertical drainage is promoted.

Protected air vents into the drained/vented vertical mullion cavities promote moderation of the pressure difference across the exterior plane of the window wall system. To achieve a true pressure-moderated assembly, the air vent openings were designed as a separate system from the moisture drainage network. As incidental moisture flows through the drainage network, the air vents are not impeded, and pressure moderation can effectively occur.

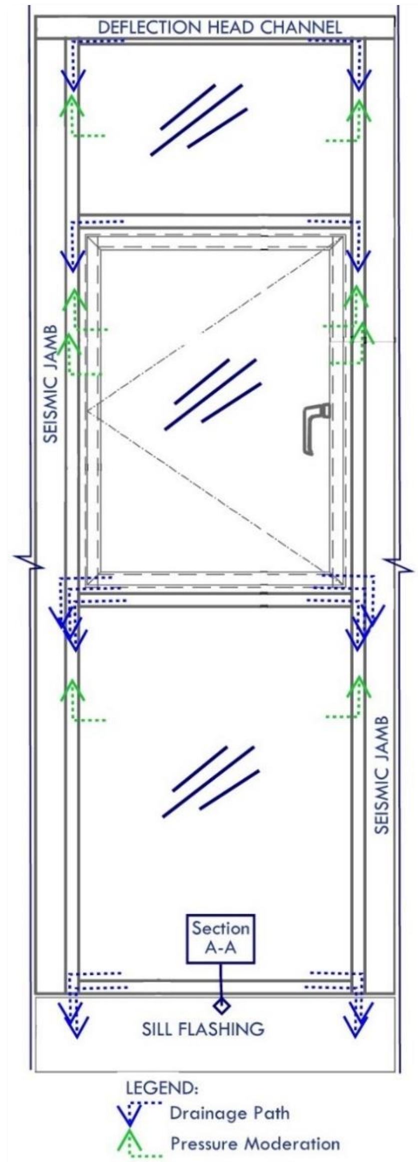
The window wall was designed to provide a continuous internal drainage network that can sufficiently drain the maximum volume of water penetration expected.



Section Detail A-A at Sill

Internal drainage holes were located to capture any incidental moisture that makes it past the exterior weather seals.

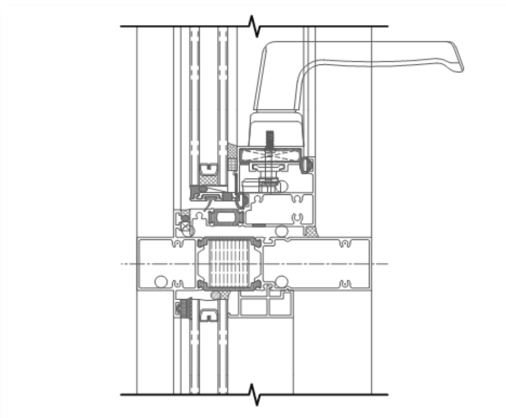
The internal drainage holes connect horizontal mullions to the vertical mullions where water can then exit the system at the sill or bypass membrane flashing.



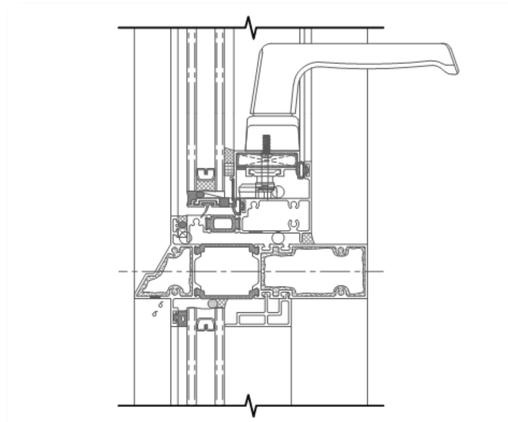
Pressure Moderation and Drainage Network

Climbability

Horizontal mullions where the glass unit is recessed greater than 3/8" from the exterior plane of the frame can create a toe-hold that can lead to climbability concerns when the window wall is installed near guard rails. Previous projects experience shows that an effective solution is to install a 60° sloped toe guard break-shape at these areas. As an alternative, horizontal mullion profiles with a sloped exterior face have been designed at operable vents where a toe guard would impact operability. This is a valid approach that can address climbability concerns, exemplifying the versatility of the ENERMAX 150 system.



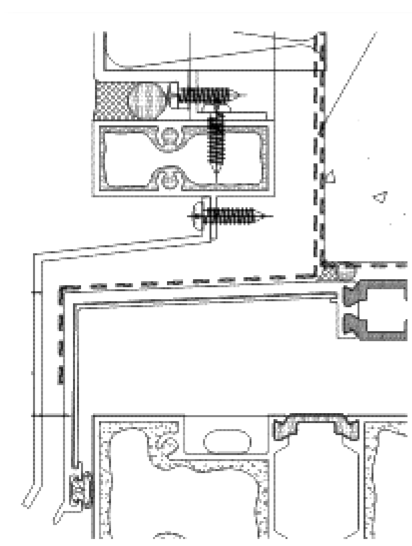
Standard Horizontal Mullion at Operable Window



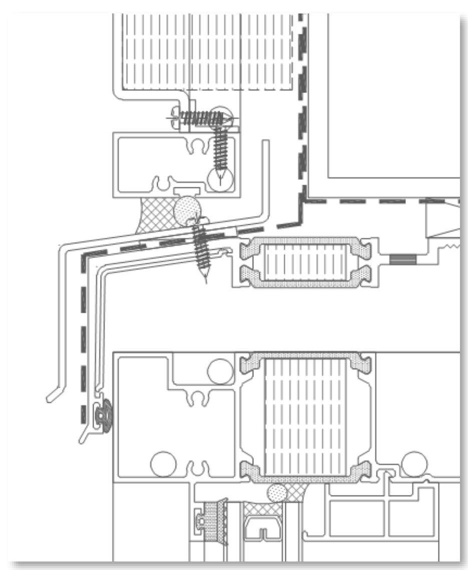
Optional Horizontal Mullion at Operable Window Near Balcony

Bypass Flashing

One common issue confronted during installation, occurs at the slab bypass panel. The bypass flashing is typically designed to be fastened to the vertical leg of the framing. This results in the need to install the bypass flashing from the exterior of the building, usually requiring a suspended stage, near the end of the project. The bypass flashing was redesigned to be installed right after the sill/bypass self-adhered membrane detailing for the respective floor is complete but prior to the window wall module for the respective floor being installed. This way, the flashing can be installed progressively at each floor during the project duration.



Typical Bypass Flashing Connection

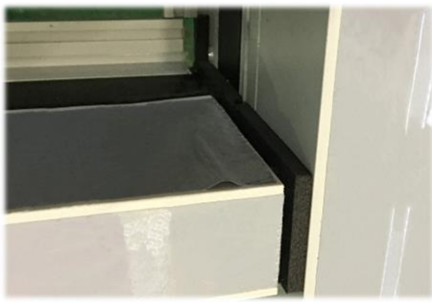


Improved Bypass Flashing Connection

Revised Design

Following the development and review of the Conceptual Design, a Revised Design was developed which further refined the system according to the performance attributes described below. This section highlights the continual evolution of the design and the reasoning behind the design decisions. The Revised Design concluded in the fabrication of a full-scale prototype that was tested as part of the Research and Development procedure described below.

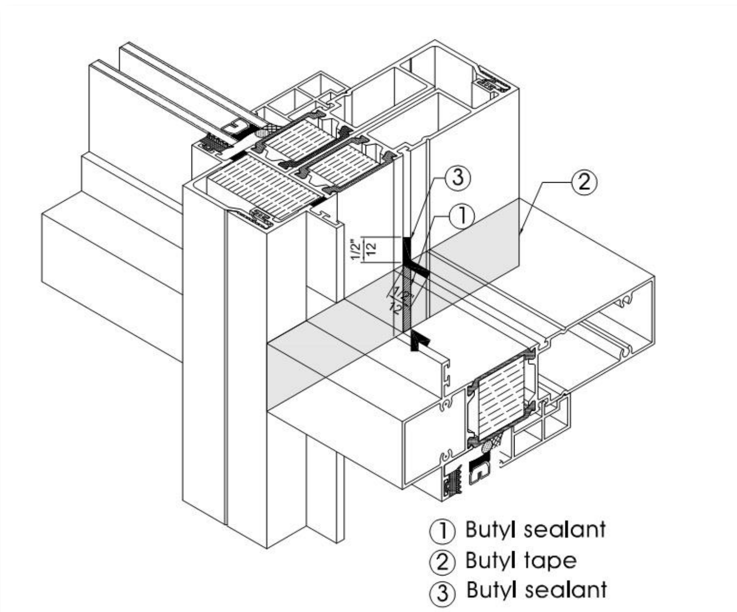
Horizontal-to-Vertical Mullion Connection



Initial Design Using Foam Gasket

The mechanical joint between the horizontal and vertical mullions is often a difficult detail to design correctly in unitized window wall systems. Previous experience shows that this is a sensitive area that needs to be carefully designed and constructed to provide continuity in the moisture and air barrier as well as allow for internal drainage.

The original design of the horizontal-to-vertical connection included the use of a preformed foam gasket that was installed onto the side of the vertical mullion with the horizontal mullion compressing the gasket. A prototype of the connection found that the gasket could not provide an adequate seal and additional silicone sealant would need to be applied along the perimeter of the connection.



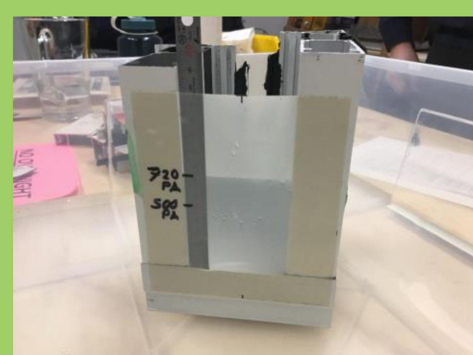
Revised Design – Isometric Horizontal-to-Vertical Mullion Connection

The connection was redesigned to use a butyl tape combined with butyl sealant installed within the vertical mullion reveals. The sealant provides a secondary barrier against moisture penetration. The different design solutions for this connection were evaluated according to the effectiveness of the seal, material compatibility, and for simplicity of construction that can provide consistent results.

Material Compatibility/Performance Testing

The early prototype showed that additional effort was needed to effectively seal a reveal in the vertical mullion (see item No.1 in the adjacent isometric image). Several sealant products were considered. A modified ASTM C794 peel adhesion test was used to evaluate sealant compatibility and adhesion, which found that butyl sealant performed best.

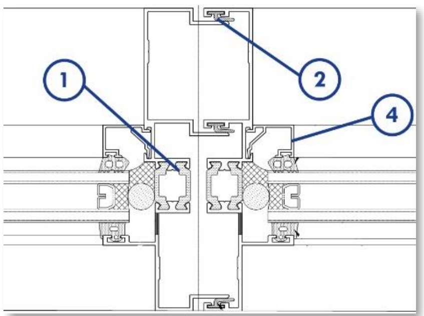
The prototype of the final designed horizontal-to-vertical mullion connection detail was built and tested to hold standing water. The height of the standing water was measured to simulate a static water penetration resistance pressure test of 720 Pa.



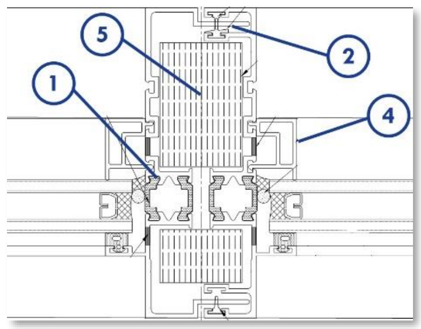
Simulated Water Penetration Resistance Test

Vertical Mullion Coupler

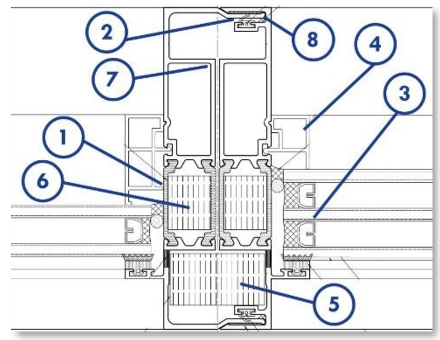
The design of the vertical mullion coupler connection was thoroughly reviewed, with regards to several key considerations, such as, site handling, site storage, continuity of building envelope primary air and moisture seals, secondary weather seals, thermal performance, pressure moderation, the use of gaskets versus sealant joints, structural connection and reinforcement, construction tolerance, and aesthetics.



Conceptual Design



Revised Design



Final Design

1 - Thermal Break
2 - Male-to-female connection (air/moisture seal)
3 - Triple glazed IGU
4 - Glazing stop
5 - Frame cavity insulation
6 - Thermal break cavity insulation
7 - Structural revision
8 - Barbed connection

Typically, window wall modules are stored on site on the male end of the vertical mullion coupler. Therefore, the thickness of the male profile extrusion was increased to provide a stiffer, more durable extrusion. The redesigned female coupler profile allows the male coupler section to be fully captured within a frame reveal. This helps the installer confirm that the male is engaged with the female section and that the primary air seal gasket is compressed. The female coupler also allows the installation of silicone sealant within the pocket for increased redundancy in the air barrier. The resulting profile minimizes the apparent gap between the two mullion couplers, improving the interior aesthetic appearance.

The connection between the male and female mullions was also crucial in terms of the structural performance of the assembly. The connection was revised to include barbed profiles that improve the system's structural capacity as it allows for the assumption that the mullions operate as a stronger rectangular section rather than weaker independent C-profiles. Finally, an additional structural reinforcement revision was added to the final design for the mullion profiles, to provide additional structural capacity when using the deeper thermal break.

Triple Glazing

One of the main goals for the window wall design was to provide a versatile universal system for North American markets, where the levels of thermal performance required by building codes are steadily becoming more stringent. As such, the window wall system needed to allow for the use of triple-glazed insulated glazing units (IGUs) with respective thermal breaks. The mullion extrusions were modified to include deeper profiles with larger thermal breaks. The corresponding glazing stops for double-glazed IGUs can be easily swapped for smaller ones to accommodate a thicker triple-glazed IGU. The glazing stops are PVC extrusions which have lower thermal conductivity compared to aluminum, and provide easier installation, site adjustments, servicing, and maintenance. The resulting final design provides versatility for projects requiring higher levels of thermal performance.

Design for Constructability

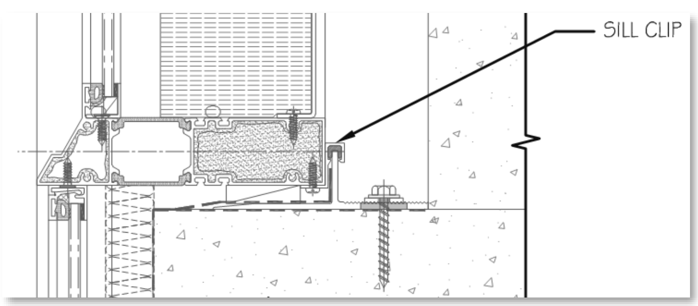
The design team consulted with experienced professional window wall installers throughout the design process to ensure the constructability of the window wall system is maximized. As a result, common construction issues and improvements for installation were able to be anticipated and addressed. This section highlights several of the window wall design components that provide improved constructability and installation, some of which are further described in other sections of this report.

In general, window wall systems are easier to install compared to unitized curtain wall systems, since they can typically be installed from the interior of the building without a crane. However, many window wall systems include components that can only be installed from the exterior of the building. For instance, the bypass flashing usually requires installation at the end of the project via exterior suspended access. The ENERMAX 150 Window Wall includes an improved bypass flashing design that allows for progressive installation of the bypass flashing during construction from the interior (see bypass flashing images on page 4).

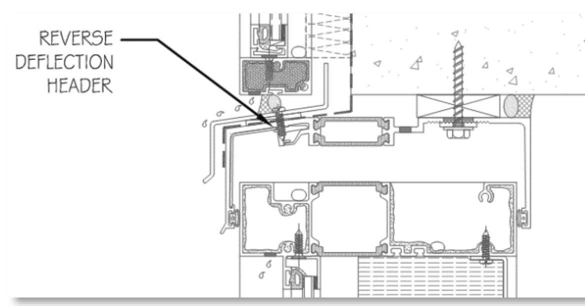
The design of the window wall attempts to account for all stages of construction, including on-site storage. Experience shows that incidental damage to the vertical mullion coupler can occur as the modules are typically stored on their side, with the male extrusion bearing on the concrete floor slab. The thickness of the male extrusion was increased to enhance the strength and durability of the component to account for site storage considerations.

Construction tolerance was a key consideration for designing the vertical mullion coupler. For instance, the design allows for adjustment of 1/8" laterally between modules during installation, while maintaining continuous engagement of the air barrier and weather barrier seals. This provides a more adaptable assembly that can better account for construction tolerances.

With concrete superstructures a common interior work clearance issue is encountered during window wall installation adjacent to concrete columns. The columns are often located at the perimeter of the floor plates, in close proximity to the window wall system, leaving minimal interior clearance to complete the structural attachment and air seal work. A sill clip accessory has been developed, which can be added to the sill mullion to provide structural attachment and facilitate air seal continuity for column locations. For the head, a reversed deflection head channel is currently in design, with the fixed leg at the interior, allowing for the interior air seal caulking to be completed prior to the window wall module installation. The structural attachment at the head will then be finalized by the exterior deflection head clip. Both the sill and head low interior clearance accessories are indicated below.



Sill Clip Accessory

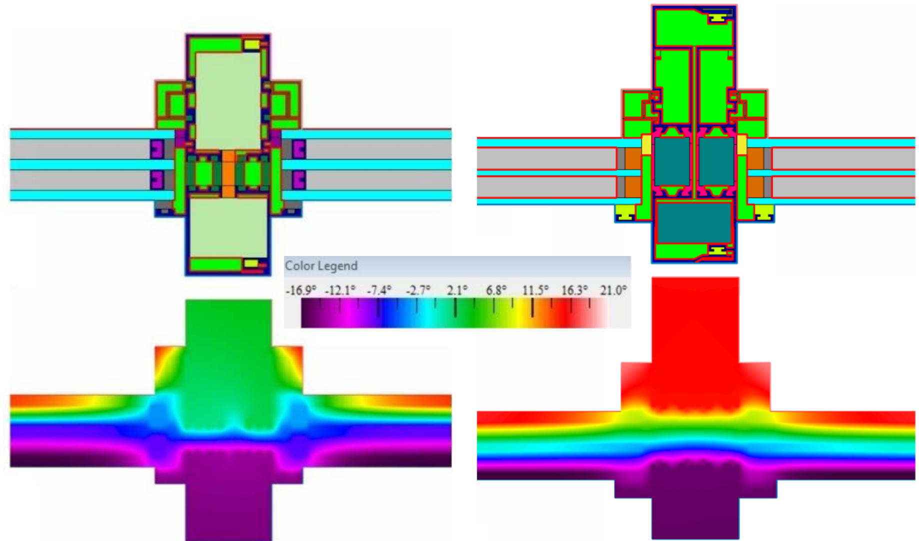


Reverse Deflection Header

Inevitably, the window wall system will need to be serviced to replace an IGU, either from construction related damage or decades down the road for maintenance. ENERMAX 150 Window Wall is glazed from the interior, allowing service work to be completed from within the suite. The glazing stops, which restrain the IGU from the interior, would need to be unclipped to allow for access to the IGU. To facilitate the ease of service work even further, the glazing stops are fabricated out of PVC for ease of installation and removal, compared to alternative aluminum glazing stops. Along with the ease of service, the PVC glazing stops also provide the added benefit of better thermal performance compared with aluminum glazing stops.

Design for Thermal Performance

Thermal performance modelling was completed as per National Fenestration Rating Council (NFRC) standards. The NFRC thermal modelling confirmed that the thermal performance of the Conceptual Design is similar to the thermal performance of existing window wall systems currently on the market. In order to further enhance thermal performance, the design of the window wall's thermal break was revisited.



IGU: 4mm/12.7mm Argon/4mm/12.7mm Argon/6mm
LoE: surface 2 and 4
U value: **1.82 W/m2k (0.32 BTU/hr.ft2.F)**

Conceptual Design

IGU: 4mm/12.7mm Argon/4mm/12.7mm Argon/6mm
LoE: surface 2 and 4
U value: **1.06 W/m2k (0.19 BTU/hr.ft2.F)**

Final Design

The framing was originally designed to include a typical 20 mm polyamide thermal break aligned with the plane of the IGU. In order to accommodate a triple-glazed IGU and provide more efficient thermal performance, a larger thermal break was needed. As a result, the design was updated to include a 40 mm deep polyamide thermal break. Moisture-resistant mineral wool insulation was added to the frame and thermal break cavities which resulted in a significant improvement in thermal performance.

The window wall was modelled using various typical IGU configurations including double and tripled glazed units. Electrochromic IGUs were also modelled to show the performance achievable by using innovative technologies. The NFRC model demonstrated an approximate 40% improvement in thermal resistance for the Final Design compared to the Conceptual Design, using similar IGUs.

Grandview EA Systems - EnerMax 150 Window Wall NFRC Simulation Results

	IGU Description	U value (W/m2K)	U value (Btu/hft2F)	R value (hFt2F/Btu)	SHGC	Tvis	Spacer Description
Double	6 clear/14.3 Ar/ 4 clear; loE on 2	1.68	0.30	3.37	0.34	0.59	Super Spacer
Double	6 clear/14.3 Ar/ 4 clear; loE on 2 and 4	1.35	0.24	4.20	0.31	0.36	Super Spacer
Double	6 View* / 12 Ar/ 6 clear;loE on 3	1.65	0.29	3.44	0.08	0.04	Super Spacer
Triple	4 clear/12.7 Ar/ 4 clear/ 12.7 Ar/ 6 clear; loE on 2 and 4	1.06	0.19	5.38	0.47	0.33	Super Spacer
Triple	4 clear/12.7 Ar/ 4 clear/ 12.7 Ar/ 6 clear; loE on 2 and 4	1.18	0.21	4.80	0.47	0.33	Stainless Steel
Triple	6 View*/ 12 Ar / 6 clear / 12 Ar / 6 clear; loE on 5	1.13	0.20	5.02	0.06	0.04	Super Spacer

** View Dynamic Glass electrochromic glass*

R&D Test

A Research and Development ("R&D") testing procedure was developed following the standard AAMA 501-15. The test procedure is thoroughly explained in the Testing Process section below. The test specimen was designed based on the Typical Unit Layout for Unitized/Modular Systems described in the AAMA 501-15 standard. As shown in the adjacent image, the test specimen includes two stories with one interior and one exterior corner. JRS further recommended to include multiple sizes of spandrel panels and operable windows to simulate the performance of the actual window wall system.

The R&D test was performed in January 2019 and was successful at highlighting areas of the window wall system that could be improved, as discussed in the Final Design section.

Test Specimen for AAMA 501 Test

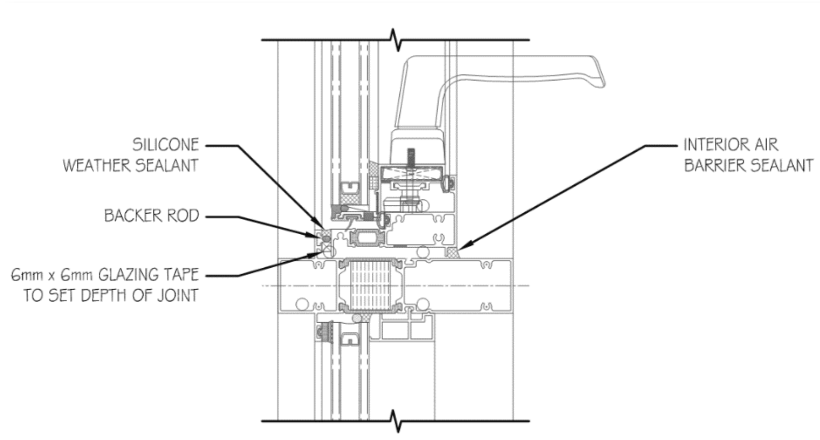
Final Design for Mock-Up Certification Test

The R&D test successfully highlighted key manufacturing and design areas to improve. The issues found are described in detail in the Testing Process section below. This section shows the resulting design solutions that were key to the successful completion of the Final Design for the Mock-Up Certification Test.

Operable Vent Weather and Air Seals

The exterior weather seal gasket between the operable vent adapter frame and the horizontal and vertical mullion glazing flange was susceptible to irregular compression during the R&D test. A revised weather seal approach included using 6mm x 6mm glazing tape to set the appropriate dimensions for a silicone weather sealant joint.

The interior air seal at operable vents was also improved. The sealant reveal depth was increased to provide a wider sealant bite (minimum 6 mm) for the air barrier sealant onto the frame components.



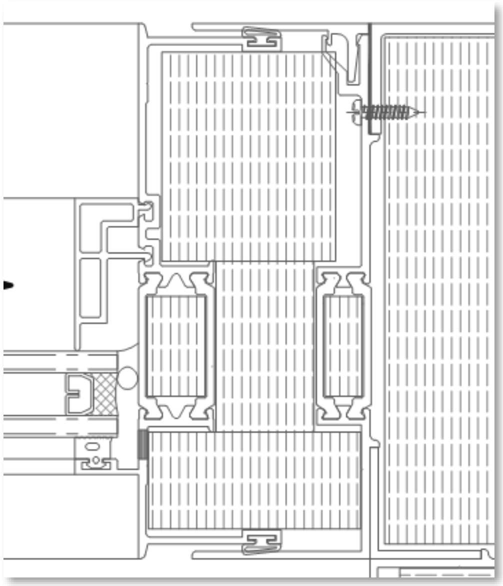
Improvement Mark-Ups on Operable Vent Section Detail

Seismic Jamb

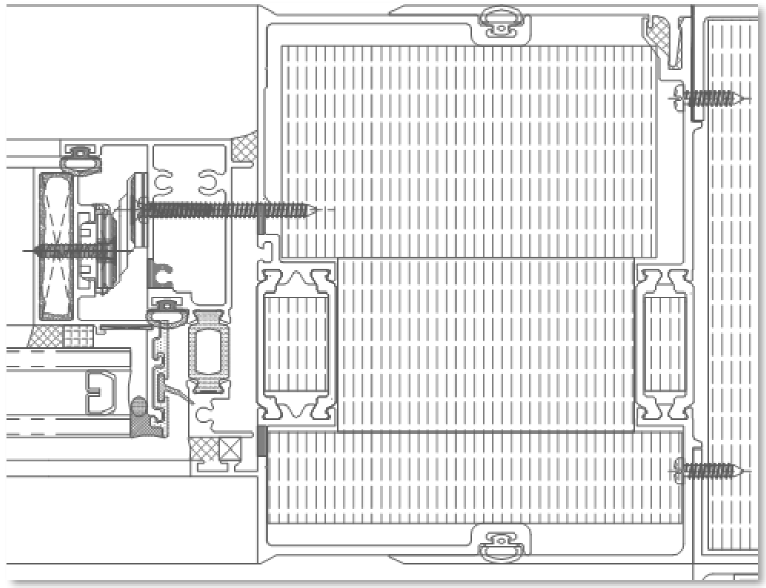
The seismic jamb design had to be revised to meet the typical seismic displacement requirements for the west coast of North America. It was also determined during the R&D test that improvements to the air barrier components at the seismic jambs were needed.

The following items were included in the seismic jamb revision:

- Profile design revised to allow for ± 30 mm (30 mm in both lateral directions) elastic design displacement as well as ± 45 mm plastic displacement. If less design displacement is needed the seismic jamb section can also be installed to provide a reduced jamb width appearance, allowing for versatility to meet specific project performance and aesthetic requirements.
- The male-to-female flanges were revised to be tight together with the air barrier seal provided by a bulb-type gasket that remains engaged during lateral displacement.
- The edge of the male flange and the corner of the female extrusion are chamfered to provide a softer aesthetic appearance as well facilitate a better air seal between the seismic jamb and the deflection head gasket.



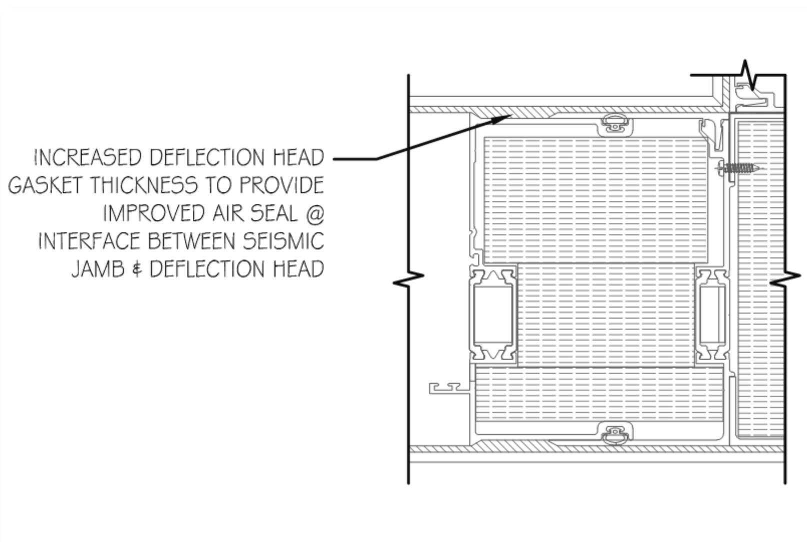
Revised Design



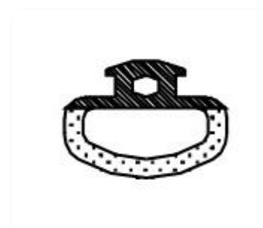
Final Design

Head Gasket

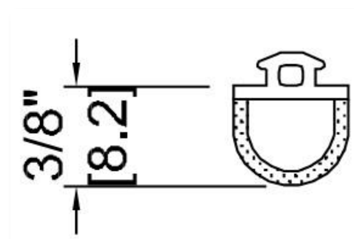
The size and profile of the deflection head gasket was modified to provide an improved air seal at the interface between the seismic jamb and the deflection header.



Plan Section at Seismic Jamb to Deflection Head Gasket Interface



Revised Design



Final Design

TESTING PROCESS

The ENERMAX 150 window wall was successfully tested according to *ASTM E 2099-00 Standard Practice for the Specification and Evaluation of Pre-Construction Laboratory Mockup of Exterior Wall Systems* as well as the stringent procedure listed in *AAMA 501-15 Methods of Test for Exterior Walls*. The testing performance criteria was selected to be the maximum North American Fenestration Standard (NAFS) test values for the air and water penetration resistance testing, with the structural test pressure and interstory lateral/vertical displacement selected based on general performance criteria for common high-rise buildings in North America.

AAMA 501.1 – Water Penetration Test Under Dynamic Pressure

AAMA 501 vs NAFS

AAMA/WDMA/CSA 101/I.S.2/A440-11, "North American Fenestration Standard / Specification for windows, doors, and skylights" (NAFS) and AAMA 501-15 *Methods of Test for Exterior Walls* are the two most commonly specified mock-up evaluation standards for fenestration systems in North America.

The AAMA 501-15 standard includes testing for structural adequacy, water penetration resistance, and air leakage. Typically, the scope of this testing standard is generally reserved for curtain walls, storefront and sloped glazing. This testing regiment was selected to demonstrate high levels of performance of the EnerMax 150 Window Wall that match typical unitized curtain wall specifications.

With regards to NAFS in Canada, the National Building Code 2018 and BC Building Code 2018 do not consider window wall as being within the scope of NAFS. However, the 2011 version of NAFS refers to window wall as included within the standard, classified as "mulled windows", and requires the testing of composite units or mulled combination assemblies (window wall assemblies). In JRS's opinion, the AAMA 501 test procedure provides a more comprehensive understanding of how a fenestration system performs under service conditions for a high-rise project and actually exceeds the testing procedure requirements of NAFS. NAFS testing has not been completed as of the timing of this report however is planned to be completed in the near future.

In addition to the tests required by the above-referenced standards, JRS recommended a mock-up test procedure, illustrated in the Certification Test section below, to complete multiple optional tests described in the AAMA 501-15 standard including:

- AAMA 501.4 – Interstory Lateral Displacement
- AAMA 501.5 – Thermal Cycle Testing
- AAMA 501.7 – Interstory Vertical Displacement
- ASTM E283 – Air Infiltration & Exfiltration by Static Pressure (multiple tests in addition the base requirements)
- ASTM E331 – Water Penetration under Static Pressure (multiple tests in addition the base requirements)

The sections below describe the results of the R&D Test and the Certification Test for a full-scale mock-up of the window wall system. The mock-up specimen was designed as per the testing standard to represent in-service performance of the system.

R&D Test – January 2019

The R&D test of the full-scale window wall mock-up took place in Korea at the Architectural Testing Asia (ATA) facilities, under the supervision and direction of JRS Engineering. In attendance, were representatives from Grandview EA Systems Corp, Namsun Aluminum, Alpro Aluminum, and GG Construction. The R&D test was conducted to stress test the design of the window wall to identify any weaknesses that needed to be addressed.

Smoke Testing to Identify Air Barrier Discontinuities

During air-leakage testing, completed as per the ASTM E283 standard, the prototype revealed discontinuities in the air barrier. A smoke machine was used in combination with a depressurized chamber to pinpoint the location of areas where the continuity of the air barrier could be improved.

ASTM E331 – Water Penetration Test Under Static Pressure

The water penetration testing, completed as per the ASTM E331 standard, demonstrated improvements were needed at the horizontal-to-vertical mullion connections, interior air seal at the perimeter of the operable vents, and at the seismic jamb connection. The testing highlighted areas that need to be improved and further emphasized the need to revise the design of the seismic jamb, as discussed above.

The structural tests performed under ASTM E330, AAMA 501.7, and AAMA 501.4, demonstrated adequate structural performance. The vertical and lateral interstory drift tests visually performed well, with the window wall system not suffering noticeable damage even at +/- 45mm lateral displacement.

The results of the test were analyzed, and highlighted manufacturing and design improvements that helped further develop the window wall design as described in the Design Process Section of this report

Certification Test – March 2019

Following the design improvements from the R&D Test, a mock-up test specimen was fabricated to attempt to meet the full testing procedure outlined above. The testing conditions in place followed the AAMA 501-15 testing criteria as described in the preceding section as well as in the test summary table below.

The layout of the mock-up test chamber included a two-storey chamber with both 9ft and 10ft approximate vertical spans, as well as an inside corner, outside corner, and operable vents.

ENERMAX 150 WINDOW WALL MOCK-UP TEST SUMMARY (TEST DATES: MAR 26 - 29, 2019)				
Sequence	**Test Standards**	**Description**	**Test Performance**	
			~9 ft Vert. Span (2695mm)	**~10 ft Vert. Span (3013mm)**
1	ASTM E-330	Structural Performance by Static Pressure (50% Positive design Load)	+/- 25 psf (1200 Pa)	+/- 20 psf (960 Pa)
2	ASTM E-283	Air Infiltration & Exfiltration by Static Pressure (measure flow rate at 300 Pa air pressure diff.)	A3 @ 300 Pa (6.24 PSF: Fixed 0.04 CFM/ft2; Operable 0.1 CFM/ft2)	
3	ASTM E-331	Water Penetration under Static Pressure (Max NAFS test pressure)	720 Pa (15 PSF)*	
4	AAMA 501.1	Water Penetration under Dynamic Pressure (Max NAFS test pressure)	720 Pa (15 PSF)*	
5	AAMA 501.7	Interstory Vertical Displacement (80% of total expected vertical movement)	+/- 15mm	
6	ASTM E283	Air Infiltration & Exfiltration by Static Pressure	A3 @ 300 Pa (6.24 PSF: Fixed 0.04 CFM/ft2;Operable 0.1 CFM/ft2)	
7	ASTM E331	Water Penetration under Static Pressure	720 Pa (15 PSF)*	
8	AAMA 501.4	Interstory Lateral Displacement (Design disp. width or 0.010 X max story height)	+/- 30mm	
9	ASTM E283	Air Infiltration & Exfiltration by Static Pressure	A3 @ 300 Pa (6.24 PSF: Fixed 0.04 CFM/ft2;Operable 0.1 CFM/ft2)	
10	ASTM E331	Water Penetration under Static Pressure	720 Pa (15 PSF)*	
11	AAMA 501.5	Thermal Cycle Testing (Default high and low ambient air temps)	+82C to -18C: 3 cycles	
12	ASTM E283	Air Infiltration & Exfiltration by Static Pressure	A3 @ 300 Pa (6.24 PSF: Fixed 0.04 CFM/ft2;Operable 0.1 CFM/ft2)	
13	ASTM E331	Water Penetration under Static Pressure	720 Pa (15 PSF)*	
14	ASTM E-330	Structural Performance by Static Pressure (100% Positive and negative design load)	+/- 50 psf (2400 Pa)	+/- 40 psf (1920 Pa)
15	ASTM E-283	Air Infiltration & Exfiltration by Static Pressure	A3 @ 300 Pa (6.24 PSF: Fixed 0.04 CFM/ft2;Operable 0.1 CFM/ft2)	
16	ASTM E-331	Water Penetration under Static Pressure	720 Pa (15 PSF)*	
17	ASTM E-330	Structural Performance by Static Pressure (150% Positive and negative design load)	+/- 75 psf (3600 Pa)	+/- 60 psf (2880 Pa)
18	AAMA 501.4	Interstory Lateral Displacement (150% Design lateral displacement)	+/- 45mm	

*Equivalent to B7 rating under the older CSA A440-00 fenestration standard for water tightness ratings.

As per the AAMA 501 standard procedure, in-situ repairs can be completed during the testing of a fenestration assembly. During the test, a few issues were noted that required attention:

- During the first water penetration test (ASTM E331), there was a minor leak at the lower corner of the casement operable's IGU heel bead that amounted to less than 15mL, as allowed by the testing standard. The heel bead was repaired with sealant and the test was restarted which resulted in a pass.

- During the third water penetration test (ASTM E331), there was a minor leak at the mitered operable vent adapter frame for the awning vent that amounted to less than 15mL, as allowed by the testing standard. The leak was repaired with sealant and the test was restarted which resulted in a pass.

- During the structural test to 100% loading (ASTM E330), the corner post was noted to be shifting due to an error by the testing facility which failed to reset the intermediate floor slab after the vertical interstory displacement test (AAMA 501.7). The intermediate floor was readjusted, and the test was restarted. The testing passed at 40 psf for the 10ft span and 50 psf for the 9ft span.

AAMA 501.4 – Interstory Lateral Displacement

ASTM E330 – Deflection Gauge at Interior of Vertical Mullion

CONCLUSION

The design of the ENERMAX 150 Window Wall by Grandview was developed through an iterative process, with consultation from experienced professionals belonging to all aspects of the fenestration industry. The goal was to create a product that builds on decades of design innovation, incorporating the best aspects of modern window wall design, and provide design solutions to common challenges faced by the industry. The result was the development of a system that is based on state-of-the-art design principles and provides superior performance in terms of envelope control, thermal comfort, safety, and constructability while maintaining sleek aesthetics. Multiple rounds of redesign, prototyping, and engineering reviews were carried out with input from the entire design and consulting team.

Thermal modelling showed the design of the window wall can provide leading thermal performance to meet the evolving building code requirements for energy efficient, sustainable design. The window wall was then subjected to a rigorous mock-up testing procedure, normally applied to high-rise curtain wall systems, that tested for water penetration, air leakage, and structural capacity. Following the final design improvements highlighted during the research and development testing, the ENERMAX 150 Window Wall successfully passed the AAMA 501 testing standard, meeting the stringent performance criteria typically specified for high-rise buildings in North America.

As a part of the design and consulting team, JRS has provided building envelope expertise, drawing from extensive experience in the evaluation, design, manufacturing, testing and installation of both North American and off-shore fenestration systems. JRS and Grandview set out to create a state-of-the-art window wall system, which has been successful due to Grandview's priority of quality, which has been paramount in each step of the design process.

CLOSURE

This report was prepared by JRS for Grandview EA Systems Corp. Any use that a third party makes of this report, or any reliance or decisions made based on it, are the sole responsibility of such third parties.

The material in this report reflects the best judgment of JRS in light of the information available at the time of preparation.

Please contact the undersigned if you should require any additional information.

Prepared by:

JRS ENGINEERING

Per:

Christian Flores, EIT, B.ASc.
Project Consultant

Reviewed by:

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA
J. R. SCHWARTZ
21914
MAY 24 2019

Joel Schwartz, P.Eng., FEC, BEP
Principal | Senior Building Science Specialist

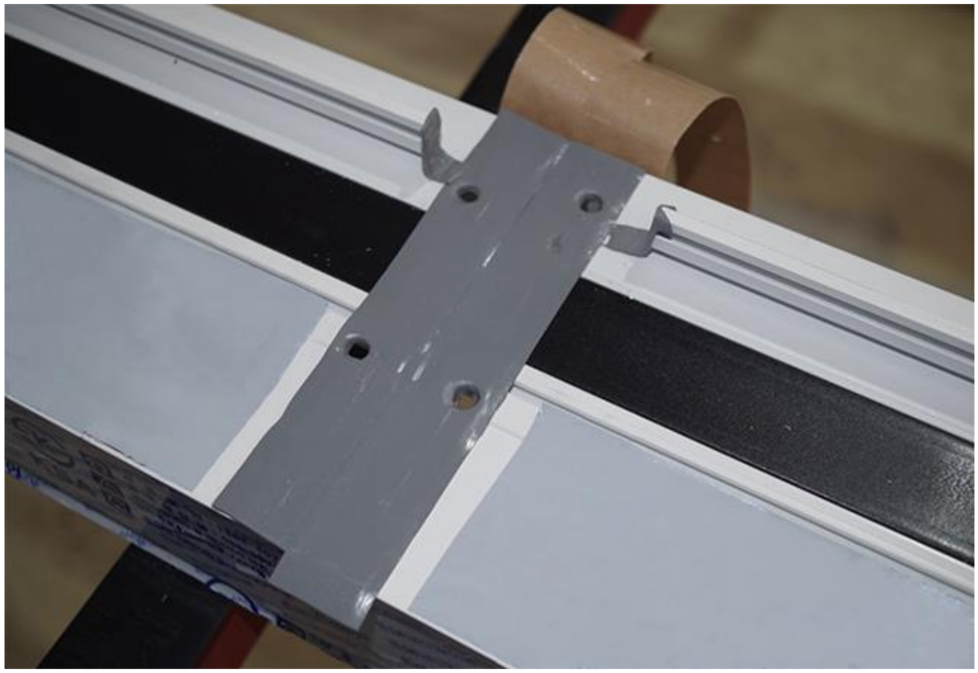
PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA
A. R. JAROLIM
46879
MAY 24 2019

Adam Jarolim, P.Eng., M.Eng., CPHD
Project Manager

Appendix A

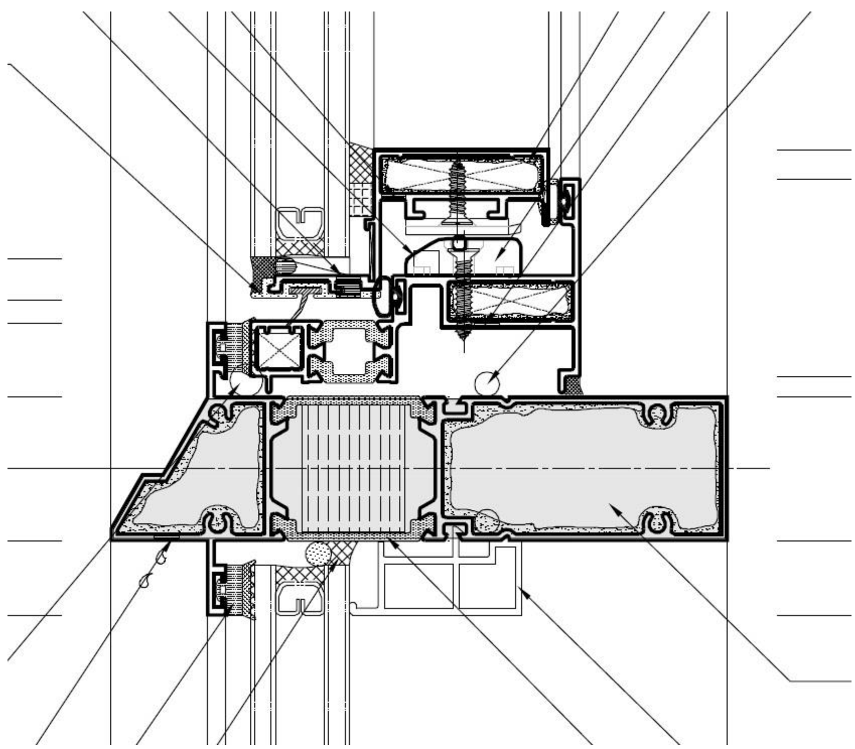
Images

Image 1



Prototype of the vertical-to-horizontal mullion connection showing the butyl tape with punched drainage holes prior to installing horizontal mullion.

Image 2



Section detail of the horizontal mullion at an operable window with a sloped exterior face to prevent climbability concerns

Image 3

Modified ASTM C794 sealant adhesions testing

Image 4

Research and Development Test – Prototype Specimen

Image 5

Mock-up Certification Test – Elevation View of Test Specimen

Image 6

Mock-up Certification Test – ASTM E331 Water Penetration under Static Pressure

Image 7

Mock-up Certification Test – AAMA 501.1 Water Penetration under Dynamic Pressure

Image 8

Mock-up Certification Test – AAMA 501.4 Interstory Lateral Displacement

Appendix B

Window Wall Mock-Up Test Procedure

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GVDC - NAMSUN WW PROPOSED MOCK-UP TEST PROCEDURE		
Sequence	**Test Standards**	**Description**
1	ASTM E-330	Structural Performance by Static Pressure (50% Postive design Load)
2	ASTM E-283	Air Infiltration & Exfiltration by Static Pressure (measure flow rate at 300 Pa air pressure diff.)
3	ASTM E-331	Water Penetration under Static Pressure (NAFS test pressure or 20% of pos. wind load)
4	AAMA 501.1	Water Penetration under Dynamic Pressure (NAFS test pressure or 20% of pos. wind load)
5	AAMA 501.4	Interstory Lateral Displacement (Design disp. width or 0.010 X story height)
6	ASTM E283	Air Infiltration & Exfiltration by Static Pressure
7	ASTM E331	Water Penetration under Static Pressure
8	AAMA 501.7	Interstory Vertical Displacement (100% Design vertical displacement)
9	ASTM E283	Air Infiltration & Exfiltration by Static Pressure
10	ASTM E331	Water Penetration under Static Pressure
11	AAMA 501.5	Thermal Cycle Testing (High and low ambient air temps or defualts. Recording of int. surface temps for dew point calcs.)
12	ASTM E283	Air Infiltration & Exfiltration by Static Pressure
13	ASTM E331	Water Penetration under Static Pressure
14	ASTM E-330	Structural Performance by Static Pressure (100% Positive and negative design Load)
15	ASTM E-283	Air Infiltration & Exfiltration by Static Pressure
16	ASTM E-331	Water Penetration under Static Pressure
17	ASTM E-330	Structural Performance by Static Pressure (150% Positive and negative design Load)
18	AAMA 501.4	Interstory Lateral Displacement (150% Design lateral displacement)

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Appendix C

ATA Testing Reports

Mock-up Test Report / Certificate No. 190314-033

CANADA GRANDVIEW PROJECT

Window Wall

ATA에이티에이주식회사
Architectural Testing Asia Inc.

Contents

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

CANADA GRANDVIEW PROJECT

Mock-Up Test Report / Window Wall

1. Weather Condition

1-1. Date	Mar 26th, 2019	Mar 27th, 2019	Mar 28th, 2019
1-2. Air Temperature	20.1 ℃	13.8 ℃	21.2 ℃
1-3. Relative Humidity	38.5 % R.H.	41.5 % R.H.	25.1 % R.H.
1-4. Atmosphere	1 005.4 hPa	1 007.2 hPa	1 001.1 hPa
1-5. Weather	Fine	Fine	Fine

2. Schedule

2-1. Specimen Install	Mar 19th, 2019 ~ Mar 22th, 2019
2-2. Test	Mar 26th, 2019 18:00 ~ 21:00 Pre-Load, Air, Water(Static, Dynamic), Vertical Movement, Air, Water Test(Static)
	Mar 27th, 2019 09:00 ~ 24:00 Horizontal, Air, Water(Static), Thermal Cycling Test
	Mar 28th, 2019 00:00 ~ 19:00 Thermal Cycling, Air, Water(Static), Structural(100 %), Air, Water(Static), Structural(150 %), Horizontal Movement Test

3. Witness

Test Witness

- Project : CANADA GRAND VIEW PROJECT
- Test Date : Mar 27th, 2019

Company	Name	Signature
ALPRO ALUMINUM PRODUCTS LTD	CATALIN KALI BINA	
Grandview	Gordon Makwich	
JRS Engineering	Joel Schwartz	
"	Adam Jarolim	
GRANDVIEW	Robert Hobson	
Namsun Aluminum	You Byong SUN	
"	Jeong Bae, Ahn	
"	Eun Hee, Jung	

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

4. Specimen Type

4-1. Installation Type	Window Wall
4-2. Glass Type	24 mm Low-E Pair Glass

5. Test Summary

The specimen carried out at the request of namsun aluminum was pass requirements of specification. (Refer to Chapter 8)

6. Test Method

The Specimen Was tested by the ASTM & AAMA standard.

6-1. Air Infiltration Test	ASTM E283 ; Standard Test Method For Determining Rate Of Air Leakage Through Exterior Windows, Curtain Walls, And Doors Under Specified Pressure Differences Across The Specimen
6-2. Water Penetration Test	ASTM E331 ; Standard Test Method For Water Penetration Of Exterior Windows, Curtain Walls and Doors By Uniform Static Air Difference
6-3. Structural Test	ASTM E330/E330M ; Standard Test Method For Structural Performance Of Exterior Windows, Curtain Walls, And Doors By Uniform Static Pressure Difference
6-4. Vertical Test	AAMA 501.7 ; Recommend Static Test Method for Evaluating Windows, Window Wall, Curtain Wall and Storefront Systems Subjected to Vertical Inter-story Movements
6-5. Horizontal Test	AAMA 501.4 ; Recommended Static Test Method For Evaluating Curtain Wall And Storefront Systems Subjected to Seismic And Wind Induced Inter-story Drifts
6-6. Thermal Cycling Test	AAMA 501.5 ; Test Method for Thermal Cycling of Exterior Walls

7. Specimen Description

7-1. Size	-. Full Specimen : 5 260 mm width × 5 880 mm height
	Fixed Area : 29.54 m^2(317.95 ft^2)
	Vent Area(2EA) : 1.39 m^2(14.96 ft^2)
7-2. Finish	-. AL. Frame
	·Exposed : PVDF Coat
	·Non-Exposed : Milled
7-3. Glass	-. 24 mm Pair Glass : 6 mm Low-E Glass + 12 mm Air + 6 mm Glass
7-4. Glazing Material	-. Weather Sealant
	-. Structural Sealant

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

8. Test Result

Design Wind Load

Positive Design Pressure : +40 psf
Negative Design Pressure : -40 psf

8-1. Pre-Load Test

① Test Pressure : 20 psf / 50 % of Positive Design Pressure
② Duration : 10 Seconds
③ Result : *Pass*

Table 1. Unit Conversion

	USCS	SI	CGS
Mass	Slug	kg	kg
Length	ft, inch	m, cm, mm	m, cm, mm
Force	lb(pound)	N(newton)	kgf
Pressure	psf(lb/ft^2)	Pa(N/m^2)	kgf/m^2

※Unit Conversion & Example :
1 m ≒ 3.280 8 feet
1 kg ≒ 2.204 59 lb(pound)
1 psf ≒ 47.9 Pa

※ cfm = Cubic Foot per minute = ft^3/min

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

8-2. Air Infiltration & Exfiltration Test (1st)

① Test Pressure : +300 Pa

② Duration : Until the pressure is stable

③ Measured : Refer to Table 2

④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 0.80 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 1.38 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.06 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.60 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 2. Convert to Standard Condition

1. Weather Condition	-. Temperature : 20.5 ℃ -. Atmosphere : 1 005.5 hPa -. Relative Humidity : 37.8 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	51.24	50.44	0.80	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**0.80 cfm**
Ex★		51.44	50.06	1.38				**1.38 cfm**
In★	Vent Area	51.30	51.24	0.06				**0.06 cfm**
Ex★		52.04	51.44	0.60				**0.60 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2},\ W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$

-. Q_{st} = air-flow corrected to standard conditions

-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)

-. W = density of air at the test site, kg/m^3(lb/ft^3)

-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and

-. T = temperature of air at flowmeter, ℃

In★ : Infiltration

Ex★ : Exfiltration

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

8-3. Water Penetration Test by Static Pressure (1st)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

8-4. Water Penetration Test by Dynamic Pressure

① Test Pressure : 34.22 m/s(+15 psf) / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

8-5. Vertical Movement Test

① Displacement : Up 15 mm Down 15 mm (Total 30 mm)
② Cycle : 3 times
③ Allowance :
-. *No glass breakage and no permanent damage to panels, fasteners or anchors.*
④ Result : *Pass*

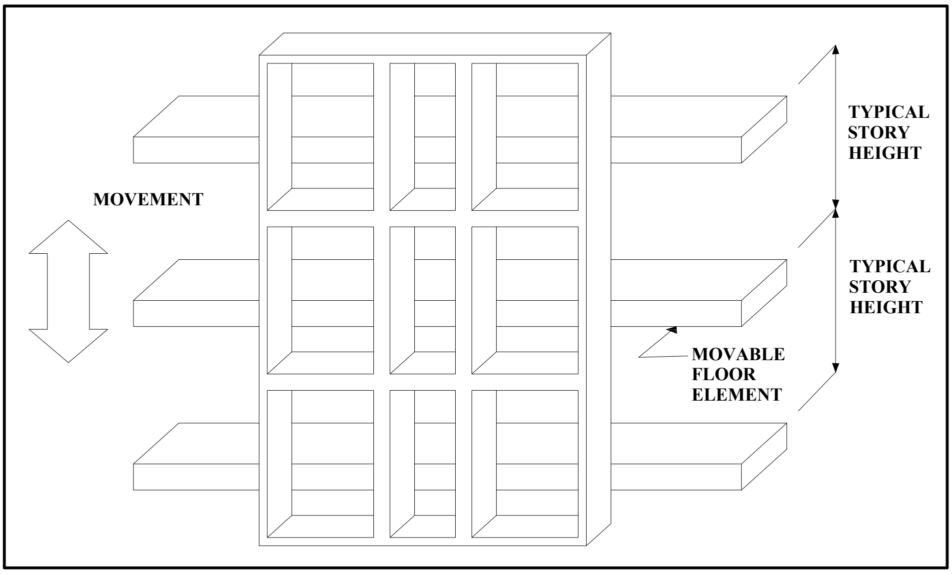

Figure 1. Synopsis of Vertical Movement Test

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Tel. 041-733-4734/5
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8-6. Air Infiltration & Exfiltration Test (2nd)

① Test Pressure : +300 Pa

② Duration : Until the pressure is stable

③ Measured : Refer to Table 3

④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 1.46 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 1.62 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.32 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.63 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 3. Convert to Standard Condition

1. Weather Condition	-. Temperature : 17.6 ℃ -. Atmosphere : 1 006.8 hPa -. Relative Humidity : 48.4 % R.H.

2. Convert to Standard Condition

Part		Measured (cfm) Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	Standard Test Conditions atmosphere	temp	Air density (W_s)	Convert (Q_{st})
In★	Fixed Area	51.90	50.44	1.46	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**1.46 cfm**
Ex★		51.68	50.06	1.62				**1.62 cfm**
In★	Vent Area	52.22	51.90	0.32				**0.32 cfm**
Ex★		52.31	51.68	0.63				**0.63 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2}, W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$

-. Q_{st} = air-flow corrected to standard conditions

-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)

-. W = density of air at the test site, kg/m^3(lb/ft^3)

-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and

-. T = temperature of air at flowmeter, ℃

8-7. Water Penetration Test by Static Pressure(2nd)

① Test Pressure : +15 psf / By specification

② Amount of Water Spray : 3.4 L/(m^2·min)

③ Duration : 15 minutes

④ Allowance : No uncontrolled water

⑤ Result : *Pass*

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

8-8. Horizontal Movement Test(1st)

① Displacement : Left 30 mm Right 30 mm (Total 60 mm)

② Cycle : 3 times

③ Allowance :

-. *No visible damage to framing or trim components or assemblies is allowed*

-. *No glass breakage or glass fallout is allowed*

-. *Full disengagement of gaskets or weatherseals is not allowed at any location*

-. *Air infiltration and water penetration resistance shall remain within specified allowable limits without adjustments or repair, except as specifically noted herein*

-. *No wall components may fall off*

④ Result : *Pass*

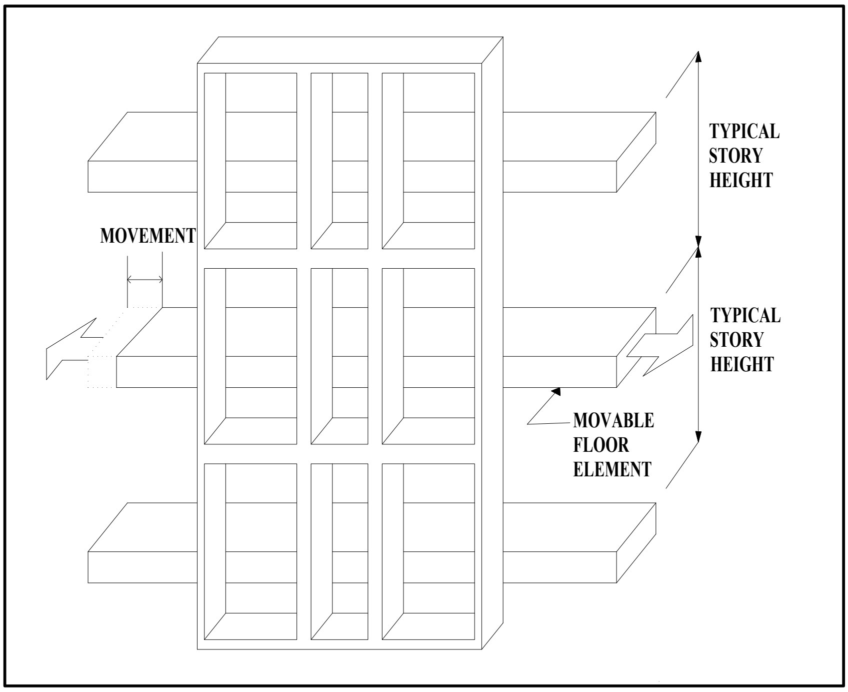

Figure 2. Synopsis of Horizontal Movement Test

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Tel. 041-733-4734/5
Fax. 041-733-4736
http://www.mockuptest.com

8-9. Air Infiltration & Exfiltration Test (3rd)

① Test Pressure : +300 Pa
② Duration : Until the pressure is stable
③ Measured : Refer to Table 4
④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 2.96 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 2.33 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.17 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.26 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 4. Convert to Standard Condition

1. Weather Condition	-. Temperature : 18.0 ℃ -. Atmosphere : 1 003.8 hPa -. Relative Humidity : 46.9 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	53.40	50.44	2.96	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**2.96 cfm**
Ex★	Fixed Area	52.39	50.06	2.33				**2.33 cfm**
In★	Vent Area	53.57	53.40	0.17				**0.17 cfm**
Ex★	Vent Area	52.65	52.39	0.26				**0.26 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2},\ W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$
-. Q_{st} = air-flow corrected to standard conditions
-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)
-. W = density of air at the test site, kg/m^3(lb/ft^3)
-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and
-. T = temperature of air at flowmeter, ℃

8-10. Water Penetration Test by Static Pressure (3rd)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

176 Shinam-ri Yeonsan-myen Nonsan-city Chungnam,KOR
Tel. 041-733-4734/5
Fax. 041-733-4736
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8-11. Thermal Cycling Test

① Test Condition

Out Door : Hot Cycle +82 ℃ ± 3 ℃ at Air Temperature

Cold Cycle -18 ℃ ± 3 ℃ at Air Temperature

In Door : +24 ℃ ± 3 ℃

② Cycle : 3 Cycles

③ Allowance : After thermal cycling test, Air & water test was met the allowance.

④ Result : *Pass*

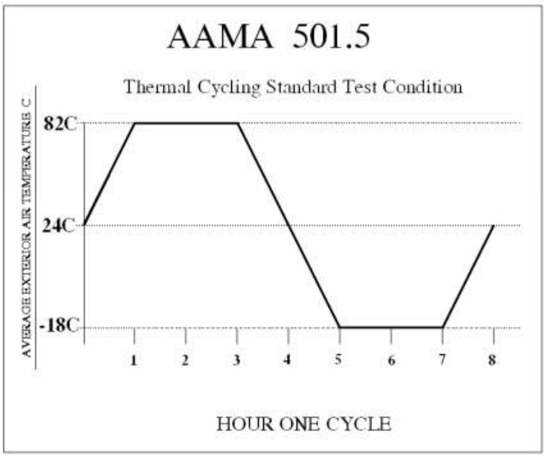

Figure 3. Synopsis of Exterior Temperature

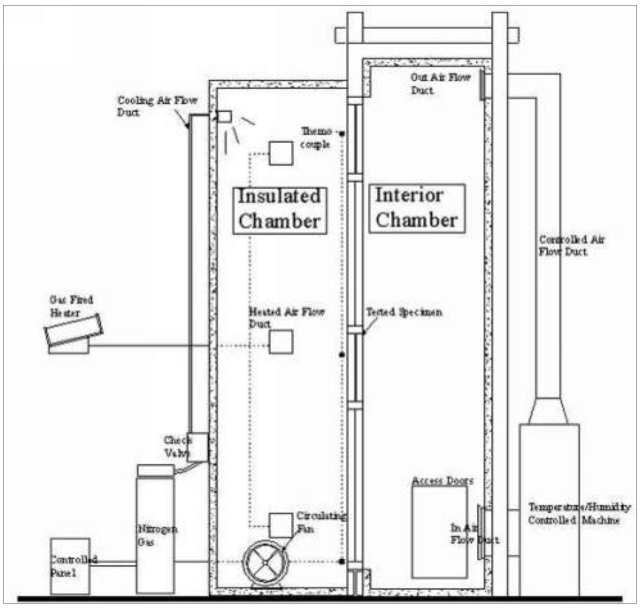

Figure 4. Synopsis of Thermal Cycling Test

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Tel. 041-733-4734/5
Fax. 041-733-4736
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8-12. Air Infiltration & Exfiltration Test (4th)

① Test Pressure : +300 Pa

② Duration : Until the pressure is stable

③ Measured : Refer to Table 5

④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 3.18 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 3.18 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.11 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.54 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 5. Convert to Standard Condition

1. Weather Condition	-. Temperature : 21.5 ℃ -. Atmosphere : 1 001.0 hPa -. Relative Humidity : 25.9 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	53.64	50.44	3.20	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**3.18 cfm**
Ex★		53.26	50.06	3.20				**3.18 cfm**
In★	Vent Area	53.75	53.64	0.11				**0.11 cfm**
Ex★		53.80	53.26	0.54				**0.54 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2}, W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$

-. Q_{st} = air-flow corrected to standard conditions

-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)

-. W = density of air at the test site, kg/m^3(lb/ft^3)

-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and

-. T = temperature of air at flowmeter, ℃

8-13. Water Penetration Test by Static Pressure(4th)

① Test Pressure : +15 psf / By specification

② Amount of Water Spray : 3.4 L/(m^2·min)

③ Duration : 15 minutes

④ Allowance : No uncontrolled water

⑤ Result : *Pass*

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8-14. Structural Test (@100 %)

① Test Pressure : +40 psf / 100 % of Positive Design Pressure
-40 psf / 100 % of Negative Design Pressure

② Duration : 10 seconds

③ Allowance :

-. Framing System for Building Cladding Components(According to AAMA TIR-A11-15) ;

· L / 175 (L≤4 110 mm)

FRAME I (Vertical) : 2 953 mm / 175 = 16.87 mm

FRAME II (Vertical) : 2 635 mm / 175 = 15.06 mm

FRAME III (Transom) : 1 170 mm / 175 = 6.69 mm

-. Glass : No Breakage

④ Measured : Refer to Table 6 & Figure 5.

⑤ Result : *Pass*

Table 6. Measured the Maximum Deflection of Each Element

unit : mm

<table>
<tr><th rowspan="2">Pressure / Gauge No</th><th colspan="2">Positive</th><th colspan="2">Negative</th><th rowspan="2">Allowable</th></tr>
<tr><th>100 %</th><th>Net Deflection</th><th>100 %</th><th>Net Deflection</th></tr>
<tr><td>No. 1</td><td>6.41</td><td rowspan="3">10.06</td><td>7.00</td><td rowspan="3">15.97</td><td rowspan="3">16.87</td></tr>
<tr><td>No. 2</td><td>13.66</td><td>20.21</td></tr>
<tr><td>No. 3</td><td>0.79</td><td>1.48</td></tr>
<tr><td>No. 4</td><td>6.99</td><td rowspan="3">6.93</td><td>6.70</td><td rowspan="3">9.69</td><td rowspan="3">15.06</td></tr>
<tr><td>No. 5</td><td>10.84</td><td>13.47</td></tr>
<tr><td>No. 6</td><td>0.84</td><td>0.86</td></tr>
<tr><td>No. 7</td><td>0.72</td><td>0.72</td><td>0.56</td><td>0.56</td><td>6.69</td></tr>
<tr><td>No. 8</td><td>6.50</td><td>6.50</td><td>7.16</td><td>7.16</td><td>No Breakage</td></tr>
</table>

※ Net Deflection : Gauge No. 2 - [(Gauge No. 1 + Gauge No. 3) / 2]
Net Deflection : Gauge No. 5 - [(Gauge No. 4 + Gauge No. 6) / 2]

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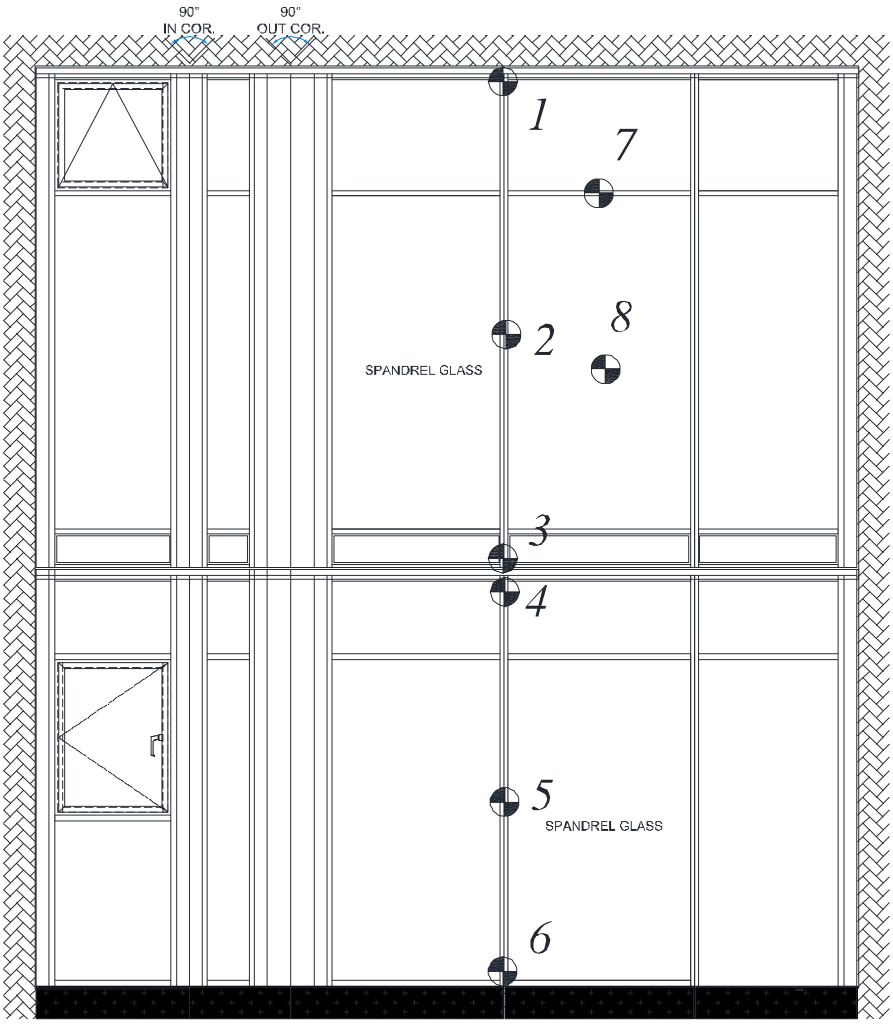
Figure 5. Transducer Location for Structural Test



Location :

No. 1 : Top of Frame I

No. 2 : Mid of Frame I

No. 3 : Bottom of Frame I

No. 4 : Top of Frame II

No. 5 : Mid of Frame II

No. 6 : Bottom of Frame II

No. 7 : Mid of Frame III

No. 8 : Center of Glass

8-15. Air Infiltration & Exfiltration Test (5th)

① Test Pressure : +300 Pa
② Duration : Until the pressure is stable
③ Measured : Refer to Table 7
④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 3.58 cfm(Actual) -----> O.K
Exfiltration : 12.72 cfm(Allowable) > 5.20 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.06 cfm(Actual) -----> O.K
Exfiltration : 1.50 cfm(Allowable) > 0.26 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 7. Convert to Standard Condition

1. Weather Condition	-. Temperature : 20.2 ℃ -. Atmosphere : 1 001.7 hPa -. Relative Humidity : 30.2 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	54.04	50.44	3.60	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**3.58 cfm**
Ex★		55.28	50.06	5.22				**5.20 cfm**
In★	Vent Area	54.10	54.04	0.06				**0.06 cfm**
Ex★		55.54	55.28	0.26				**0.26 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2}, W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$
-. Q_{st} = air-flow corrected to standard conditions
-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)
-. W = density of air at the test site, kg/m^3(lb/ft^3)
-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and
-. T = temperature of air at flowmeter, ℃

8-16. Water Penetration Test by Static Pressure(5th)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

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8-17. Structural Test (@150 %)

① Pressure : +60 psf / 150 % of Positive Design Pressure
-60 psf / 150 % of Negative Design Pressure

② Duration : Maintain target pressure 10 seconds

③ Allowance :

-. Framing Member ; 2L / 1 000

FRAME I (Vertical) : 2 953 mm × 2 / 1 000 = 5.91 mm
FRAME II (Vertical) : 2 635 mm × 2 / 1 000 = 5.27 mm
FRAME III (Transom) : 1 170 mm × 2 / 1 000 = 2.34 mm

-. Glass : No Breakage

④ Measured : Refer to Table 8 & Figure 5.

⑤ Result : *Pass*

Table 8. Measured the Permanent Deflection of Each Element

unit : mm

Pressure / Gauge No	Positive		Negative		Allowance
	150 %	Net Deflection	150 %	Net Deflection	
No. 1	1.10	2.27	0.92	1.93	5.91
No. 2	2.96		2.59		
No. 3	0.29		0.40		
No. 4	0.66	1.91	0.74	2.17	5.27
No. 5	2.32		2.69		
No. 6	0.17		0.31		
No. 7	0.18	0.18	0.24	0.24	2.34
No. 8	0.10	0.10	0.07	0.07	No Breakage

※ Net Deflection : Gauge No. 2 - [(Gauge No. 1 + Gauge No. 3) / 2]
Net Deflection : Gauge No. 5 - [(Gauge No. 4 + Gauge No. 6) / 2]

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8-18. Horizontal Movement Test(2nd)

① Displacement : Left 45 mm Right 45 mm (Total 90 mm)

② Cycle : 3 times

③ Allowance :

-. *No visible damage to framing or trim components or assemblies is allowed*

-. *No glass breakage or glass fallout is allowed*

-. *Full disengagement of gaskets or weatherseals is not allowed at any location*

-. *Air infiltration and water penetration resistance shall remain within specified allowable limits without adjustments or repair, except as specifically noted herein*

-. *No wall components may fall off*

④ Result : *Pass*

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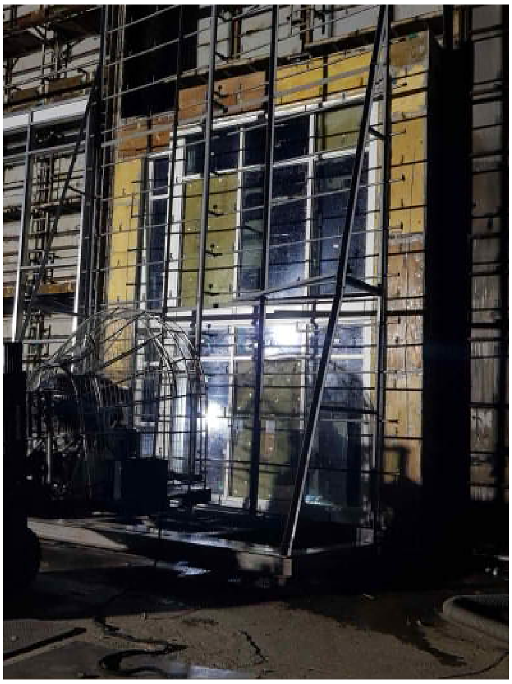
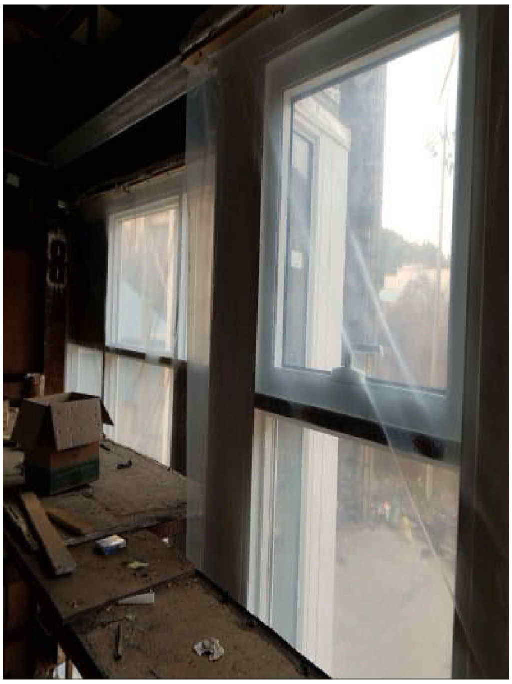
9. Photo

9-1. Pre-load Test
& Air Infiltration Test





9-2. Water Penetration
Test

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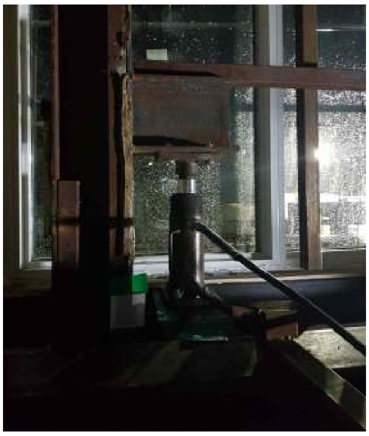
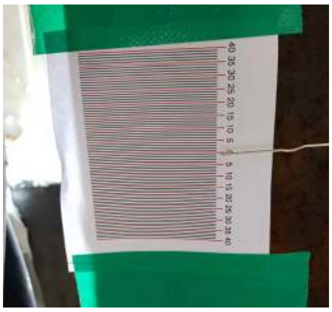
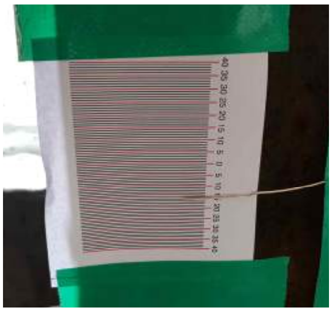
9-3. Structural Test

9-4. Vertical Test







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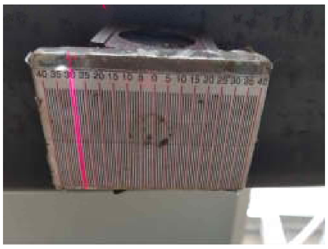
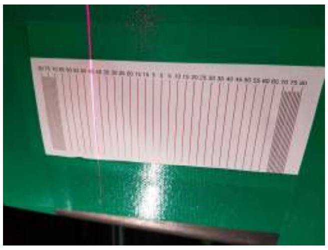
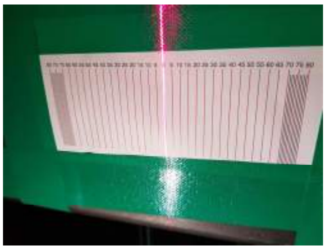
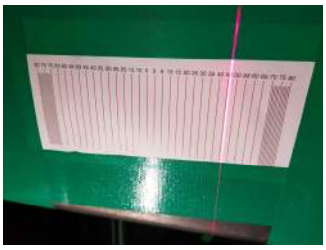
9-5. Horizontal Test









9-6. Thermal Cycling Test

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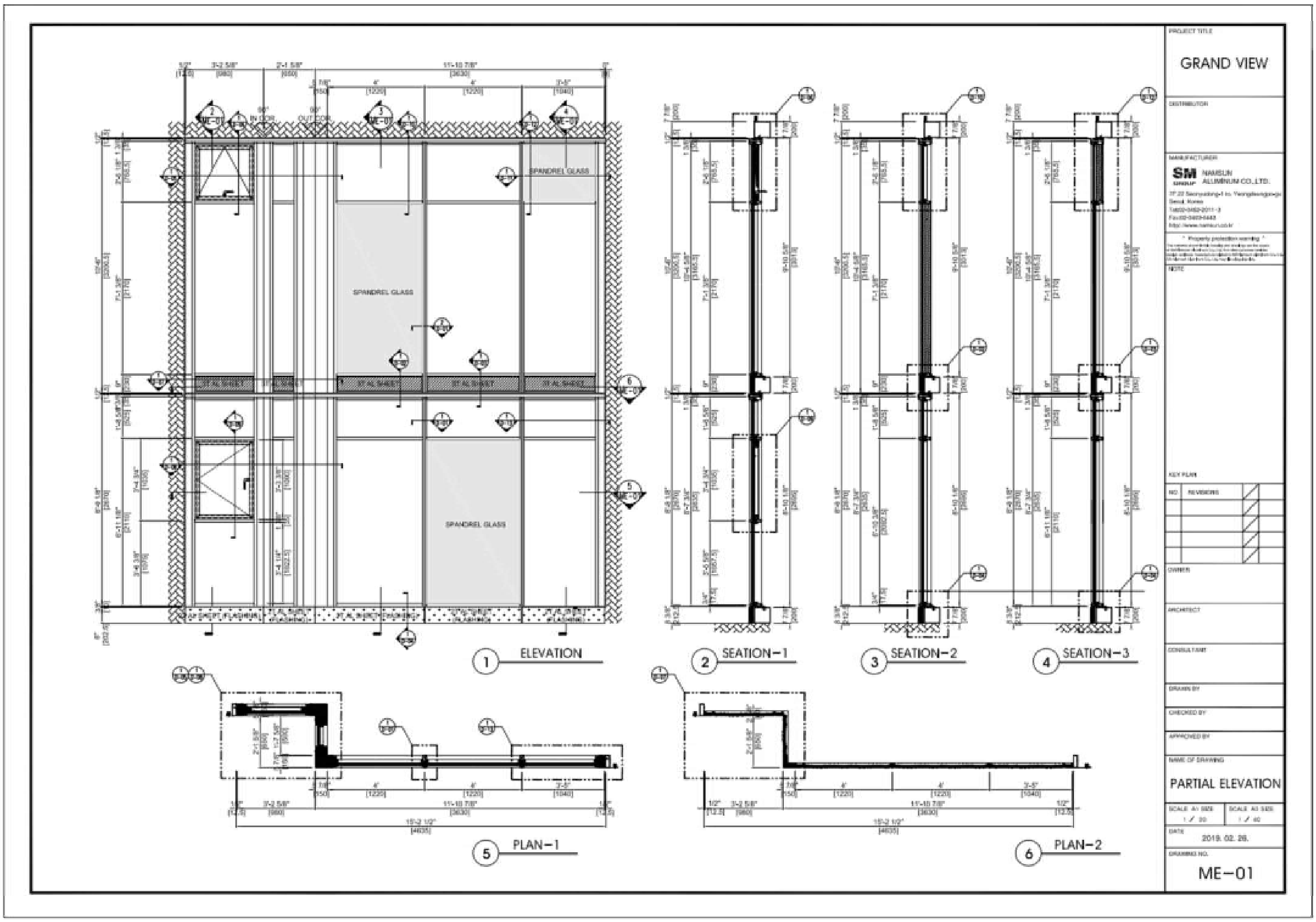
10. Drawings

10-1. Elevation



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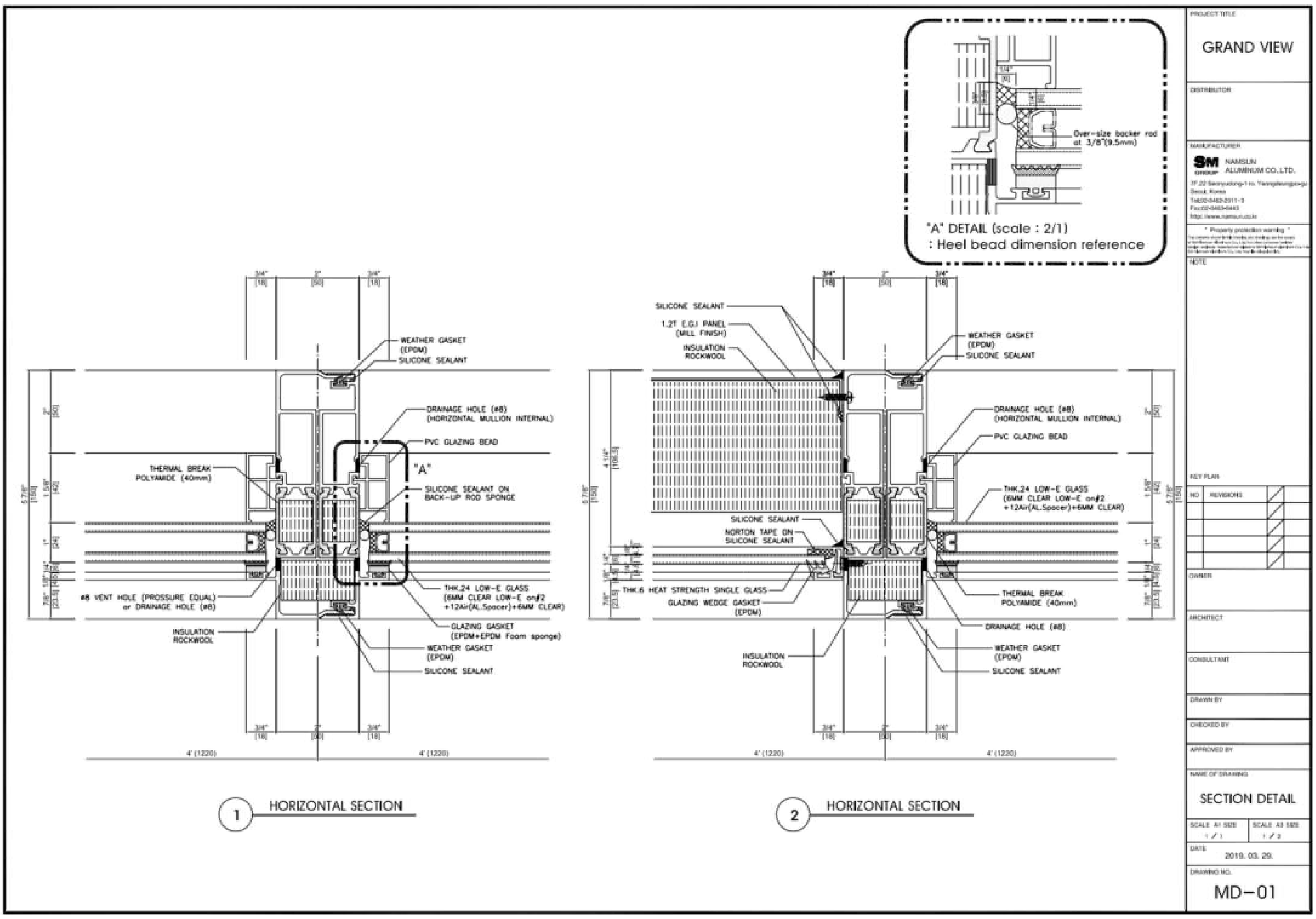
10-2. Detail



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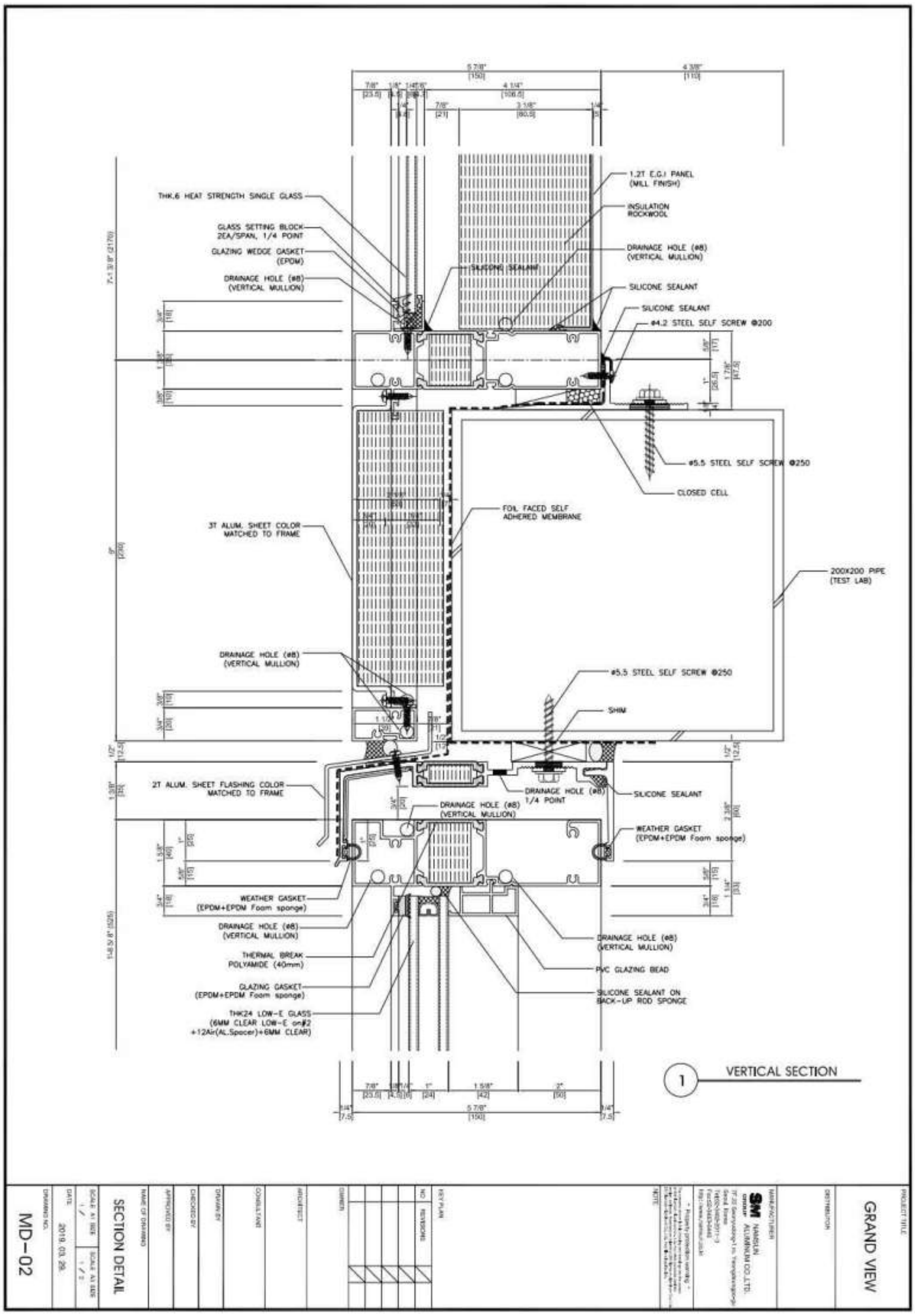
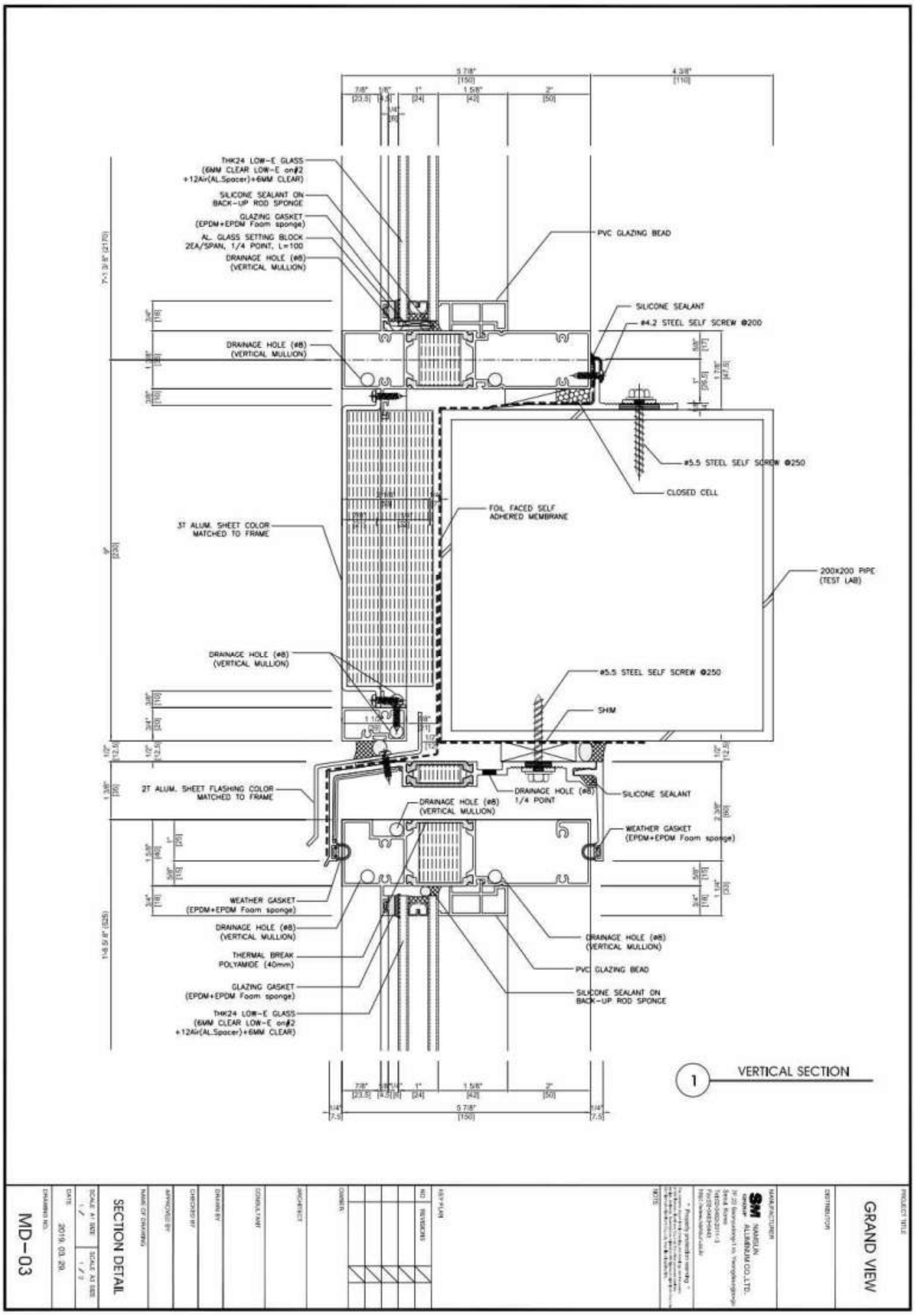
10-3. Detail



10-4. Detail


THK24 LOW-E GLASS (6MM CLEAR LOW-E on#2 +12Air(AL.Spacer)+6MM CLEAR)
SILICONE SEALANT ON BACK-UP ROD SPONGE
GLAZING GASKET (EPDM+EPDM Foam sponge)
AL. GLASS SETTING BLOCK 2EA/SPAN, 1/4 POINT, L=100
DRAINAGE HOLE (Ø8) (VERTICAL MULLION)
PVC GLAZING BEAD
SILICONE SEALANT
Ø4.2 STEEL SELF SCREW @200
Ø5.5 STEEL SELF SCREW @250
CLOSED CELL
FOIL FACED SELF ADHERED MEMBRANE
3T ALUM. SHEET COLOR MATCHED TO FRAME
200X200 PIPE (TEST LAB)
SHIM
2T ALUM. SHEET FLASHING COLOR MATCHED TO FRAME
DRAINAGE HOLE (Ø8) 1/4 POINT
WEATHER GASKET (EPDM+EPDM Foam sponge)
THERMAL BREAK POLYAMIDE (40mm)
VERTICAL SECTION
MD-03
2019. 03. 29.
SECTION DETAIL
GRAND VIEW

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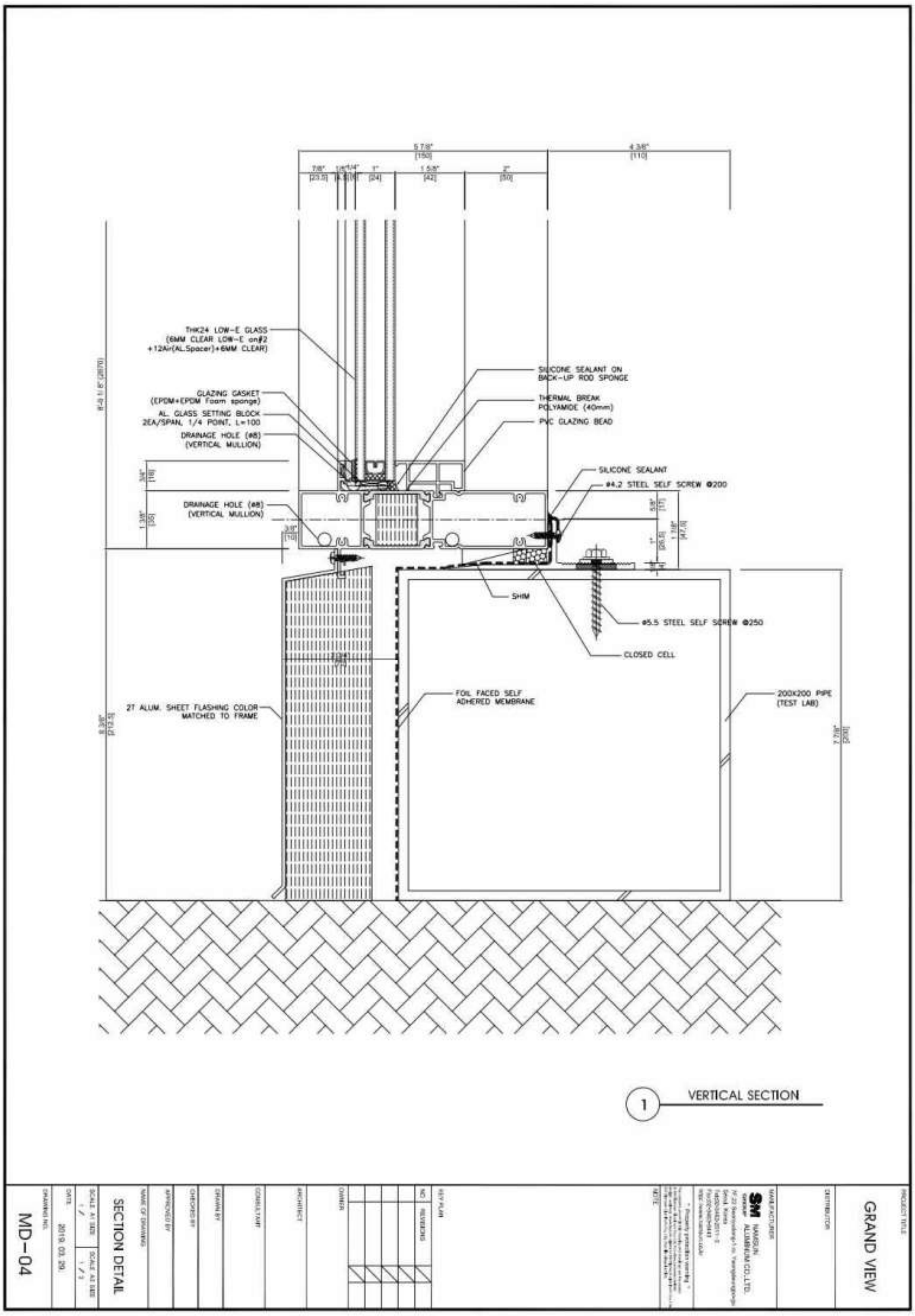
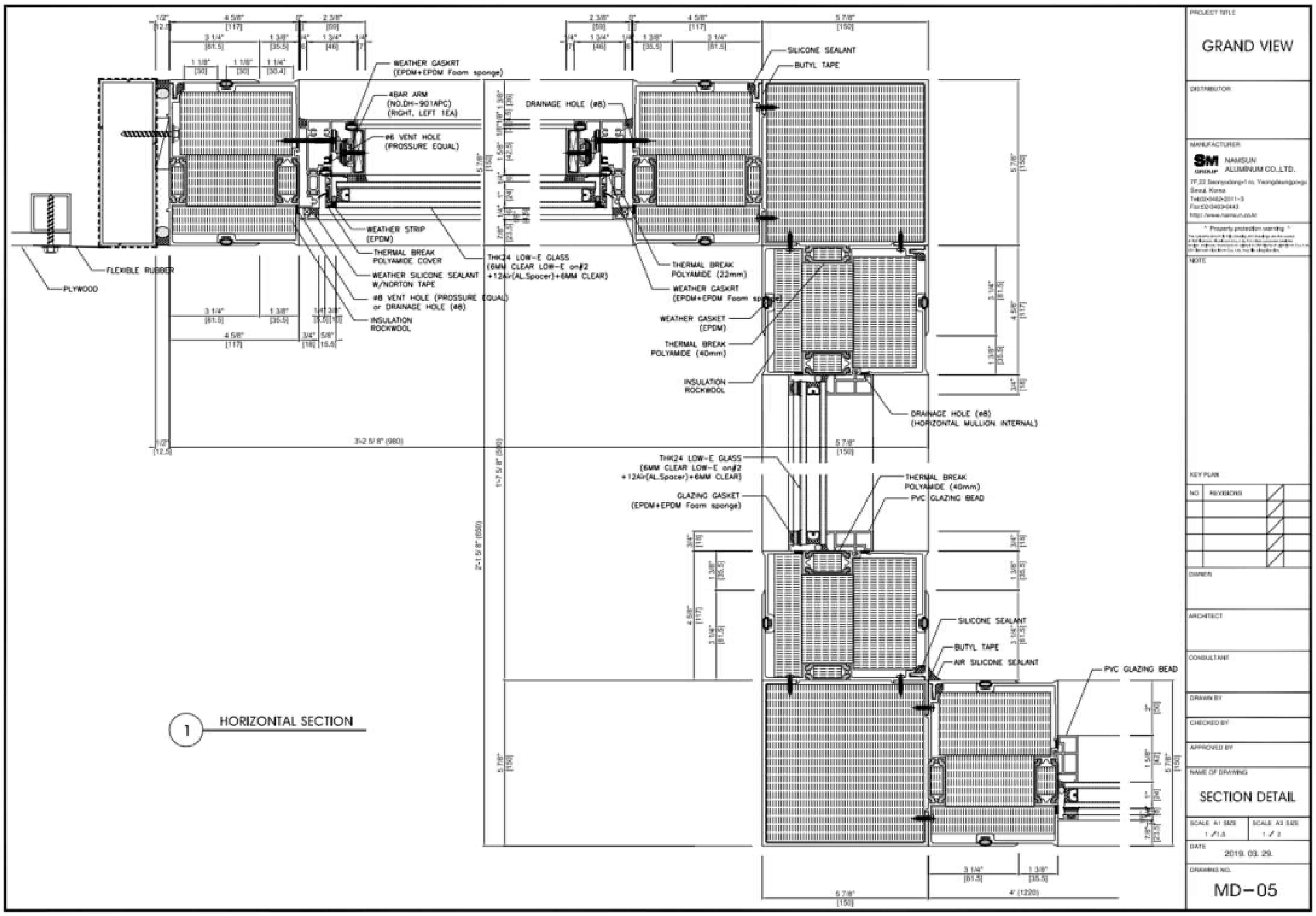
10-5. Detail



10-6. Detail


GRAND VIEW
HORIZONTAL SECTION
SECTION DETAIL
MD-05
2019. 03. 29.
WEATHER GASKRT (EPDM+EPDM Foam sponge)
DRAINAGE HOLE (#8)
SILICONE SEALANT
BUTYL TAPE
WEATHER STRIP (EPDM)
THERMAL BREAK POLYAMIDE COVER
WEATHER SILICONE SEALANT W/NORTON TAPE
INSULATION ROCKWOOL
FLEXIBLE RUBBER
PLYWOOD
THK24 LOW-E GLASS
GLAZING GASKET (EPDM+EPDM Foam sponge)
PVC GLAZING BEAD
AIR SILICONE SEALANT

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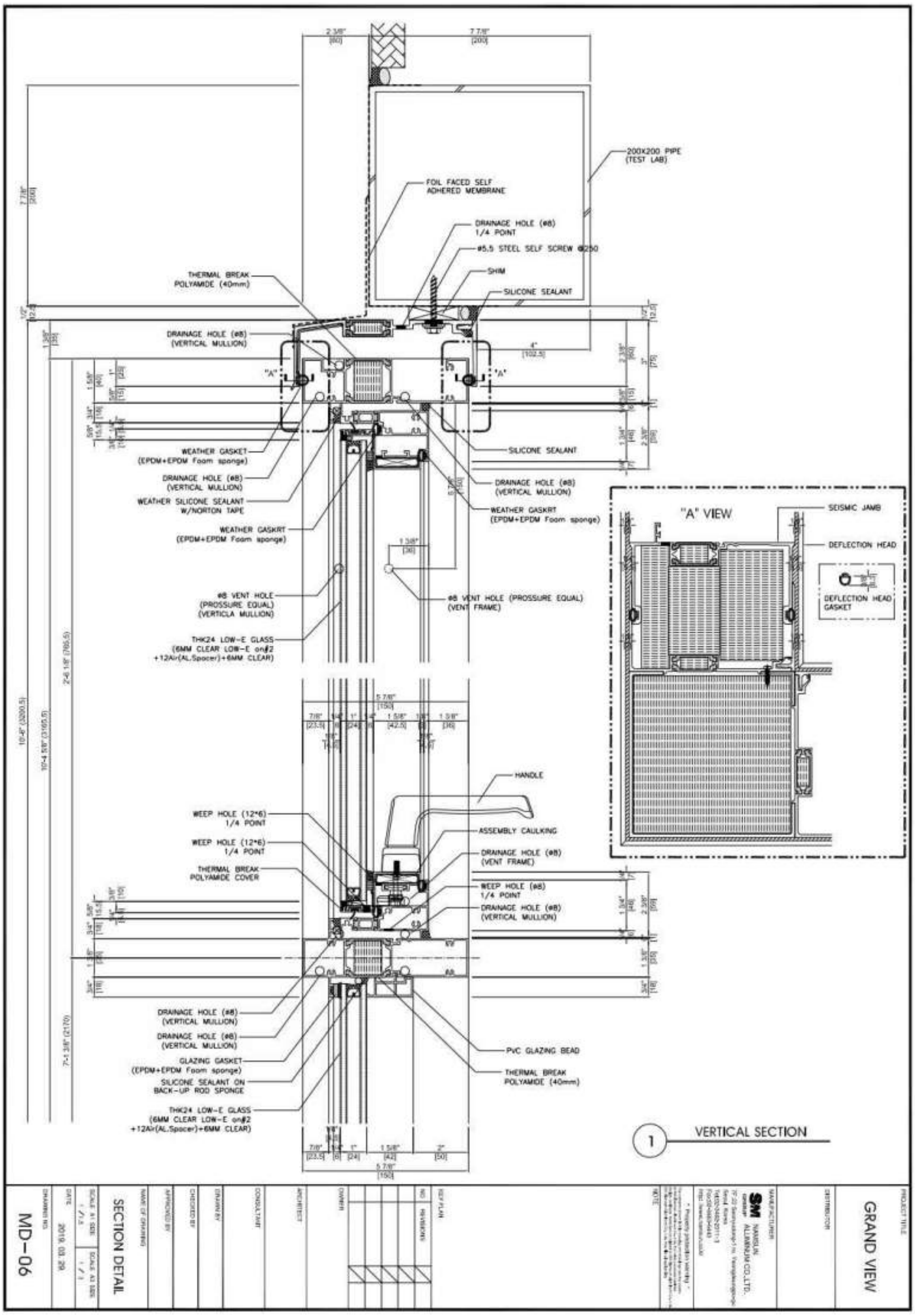
10-7. Detail



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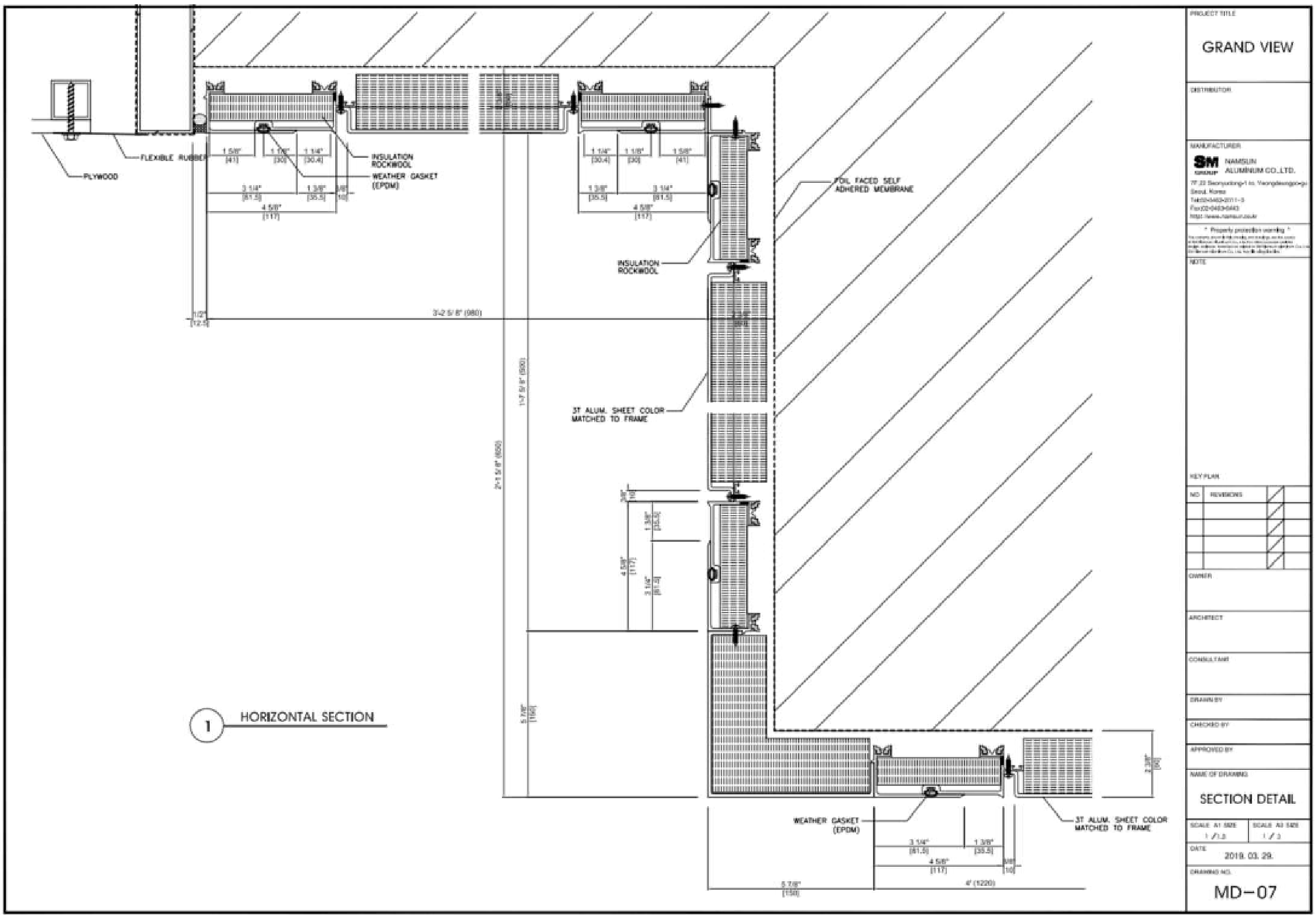
10-8. Detail



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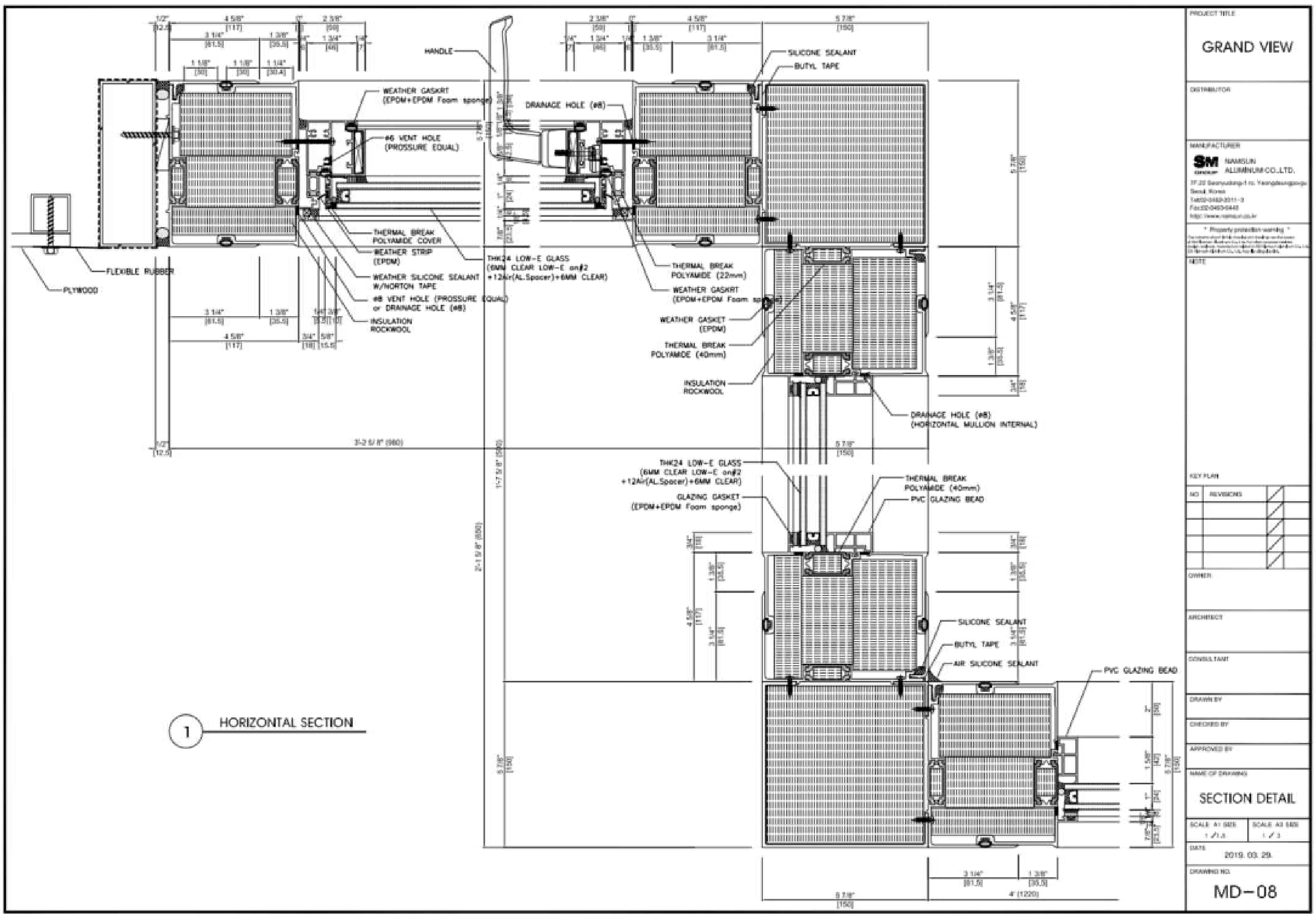
10-9. Detail



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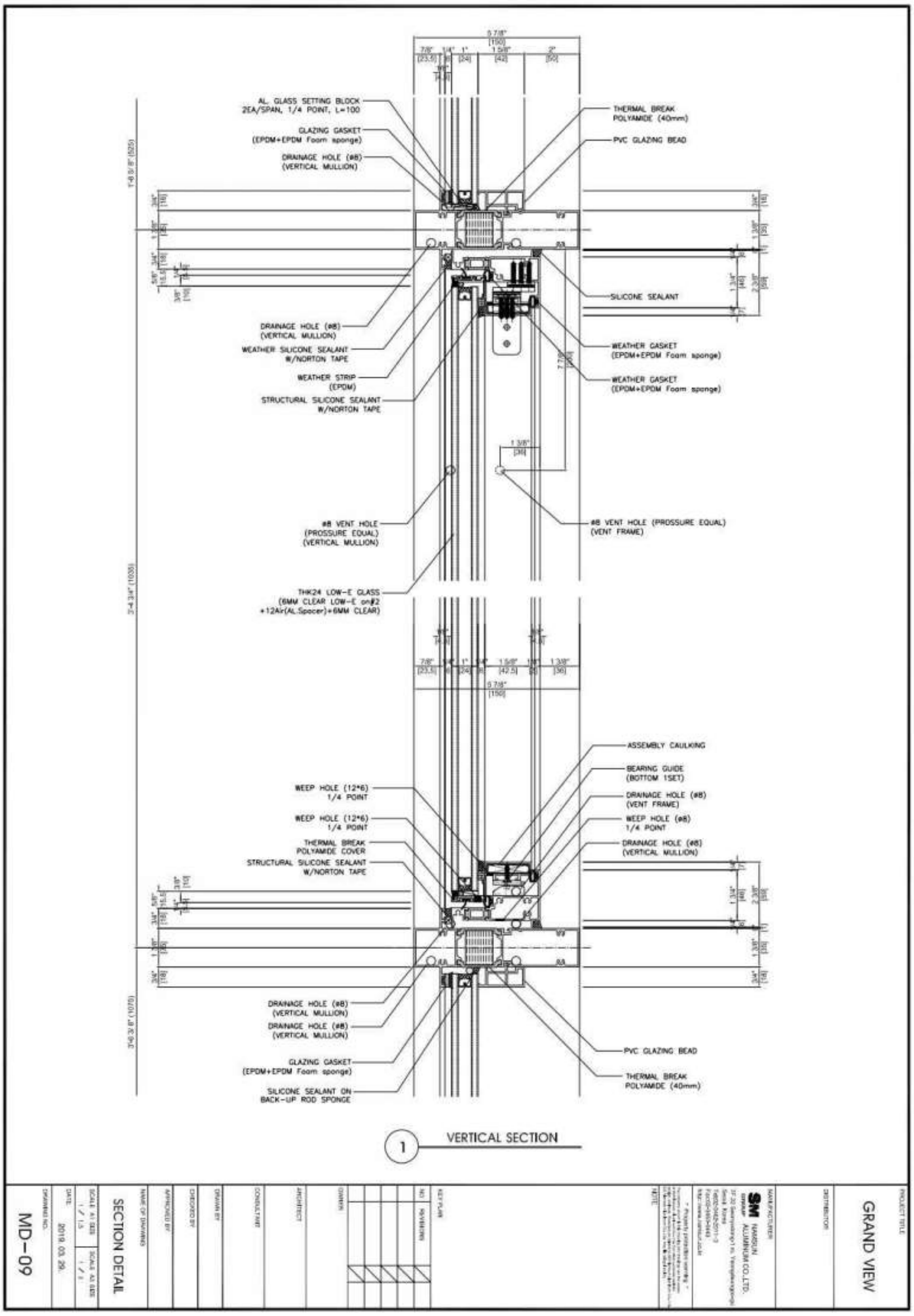
10-10. Detail



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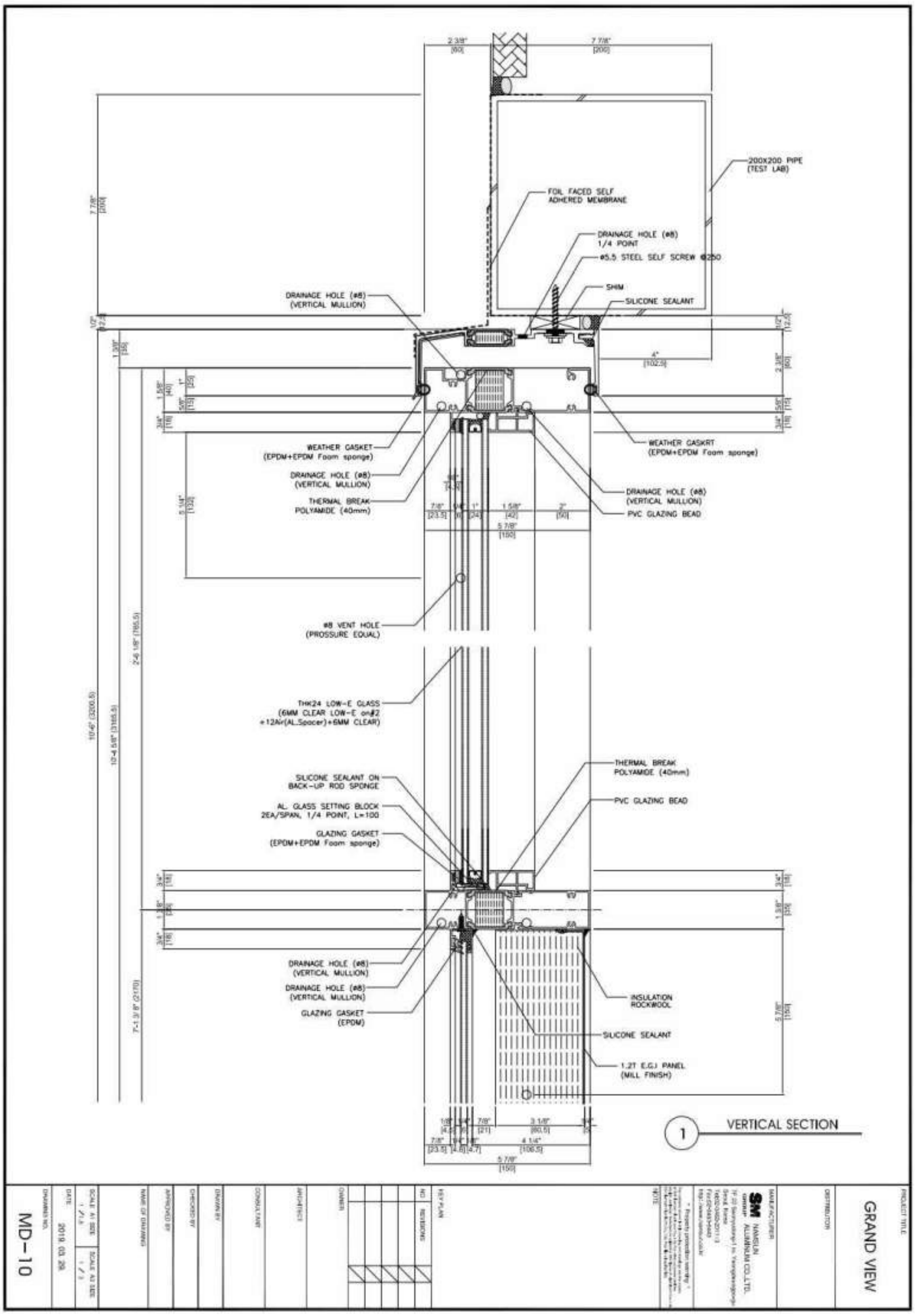
10-11. Detail



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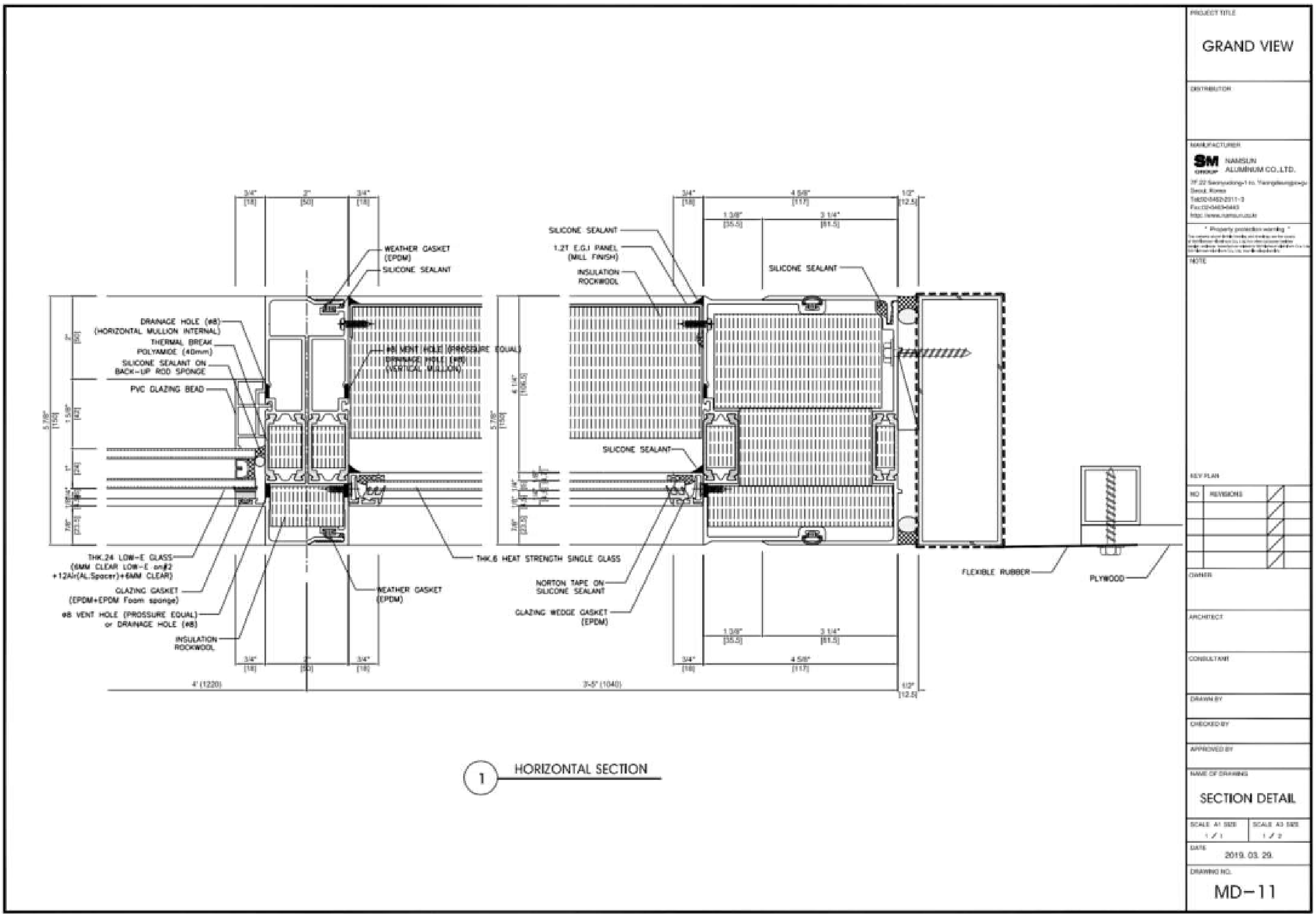
10-12. Detail



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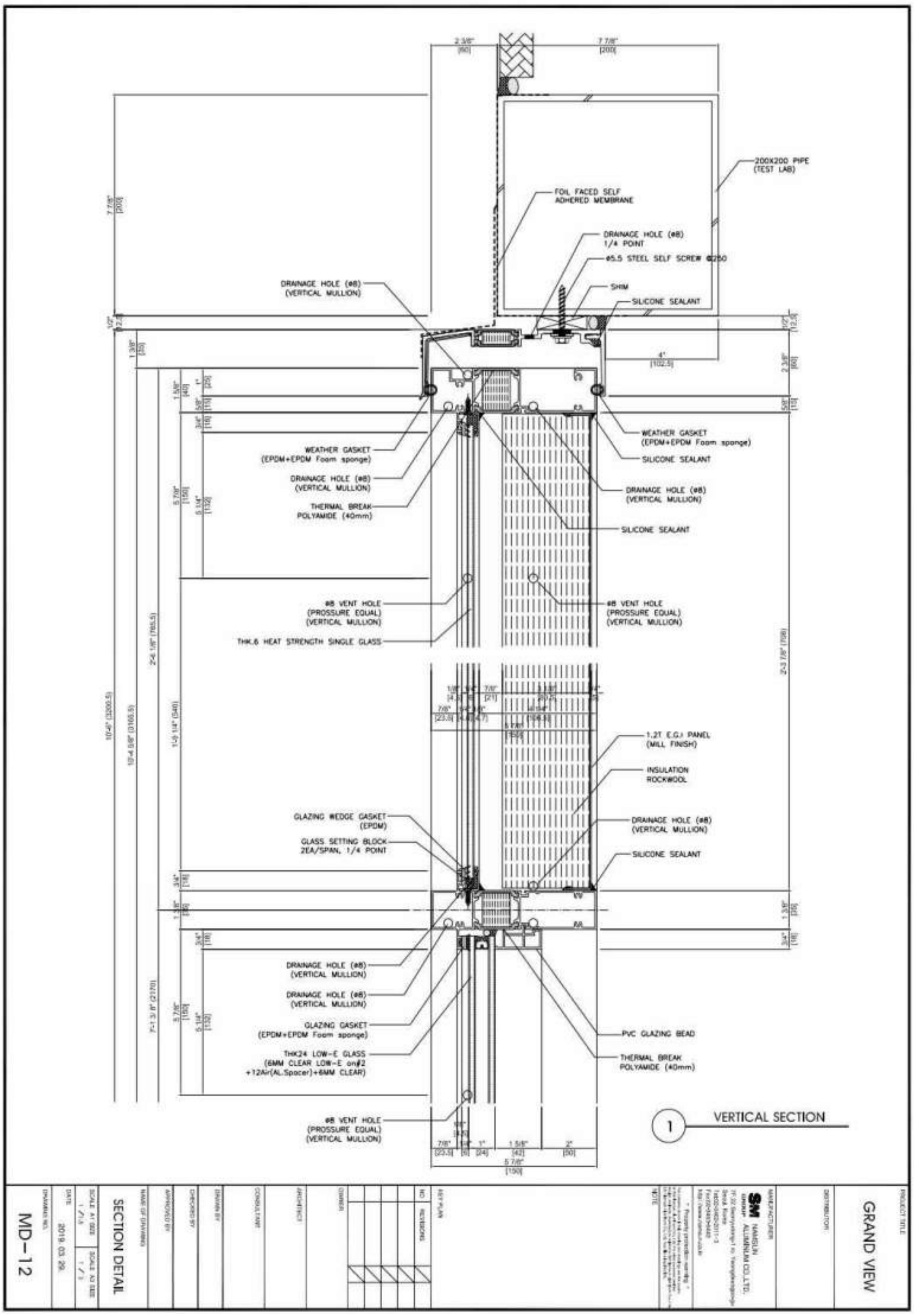
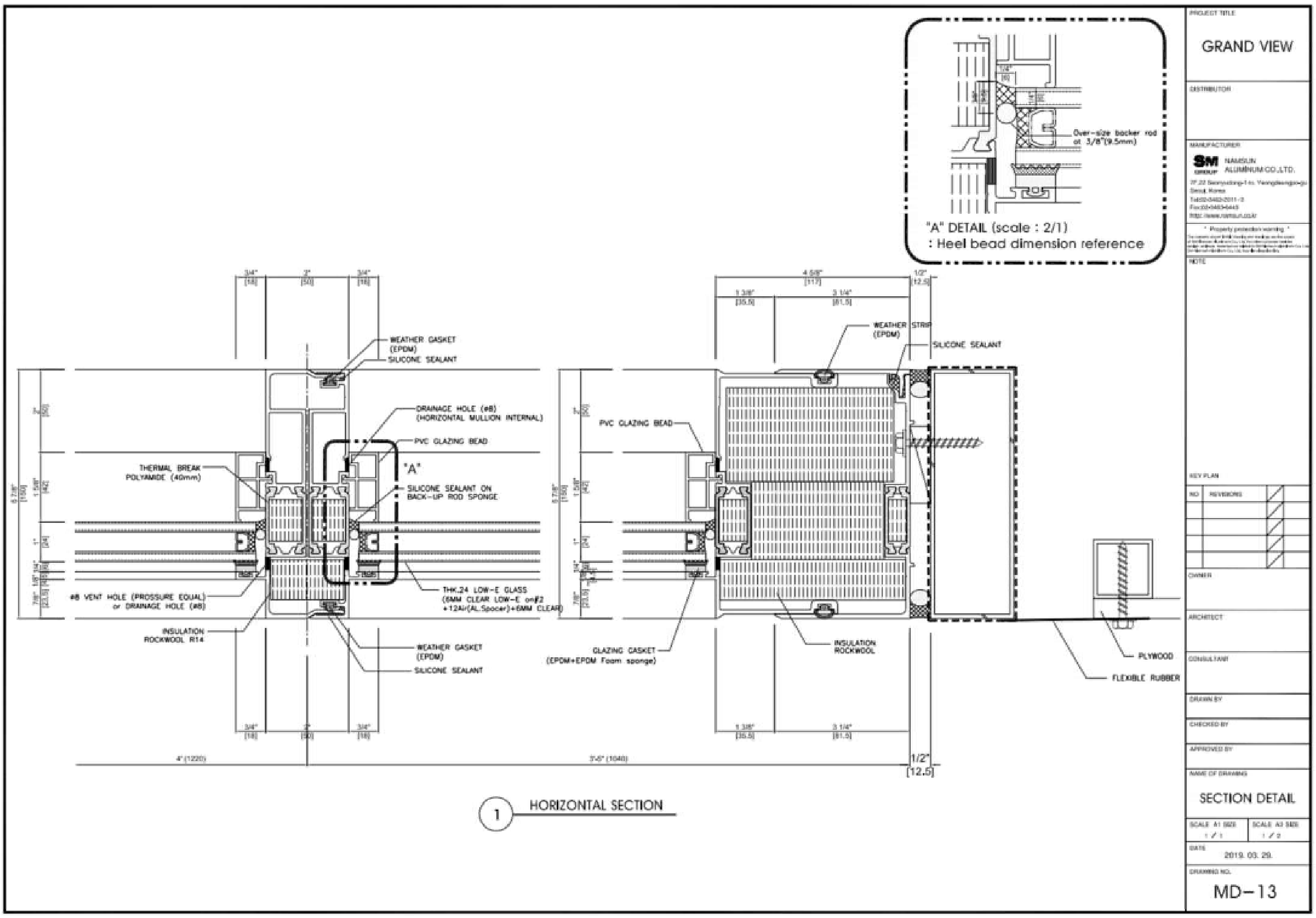
10-13. Detail



10-14. Detail


GRAND VIEW
"A" DETAIL (scale : 2/1)
: Heel bead dimension reference
Over-size backer rod at 3/8"(9.5mm)
WEATHER GASKET (EPDM)
SILICONE SEALANT
DRAINAGE HOLE (#8) (HORIZONTAL MULLION INTERNAL)
PVC GLAZING BEAD
THERMAL BREAK POLYAMIDE (40mm)
SILICONE SEALANT ON BACK-UP ROD SPONGE
THK.24 LOW-E GLASS (6MM CLEAR LOW-E on#2 +12Air(AL.Spacer)+6MM CLEAR)
#8 VENT HOLE (PROSSURE EQUAL) or DRAINAGE HOLE (#8)
INSULATION ROCKWOOL R14
GLAZING GASKET (EPDM+EPDM Foam sponge)
WEATHER STRIP (EPDM)
INSULATION ROCKWOOL
PLYWOOD
FLEXIBLE RUBBER
HORIZONTAL SECTION
SECTION DETAIL
2019. 03. 29.
MD-13

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11. Certification

KOREA LABORATORY ACCREDITATION SCHEME KOLAS

No. 487 (1/2)

CERTIFICATE OF ACCREDITATION

Name of Laboratory : ATA

Representative : Kim, In Kon

Address of Headquarters : 172-30 Hwangnyongjae-ro Yeonsan-myun Nonsan-city Chungchongnam-do, Korea

Address of Laboratory : 172-30 Hwangnyongjae-ro Yeonsan-myun Nonsan-city Chungchongnam-do, Korea

Duration : July 20, 2015 ~ July 19, 2019

Scope of Accreditation
(Scope of Accreditation is described in the accompanying Annex)

This testing laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025 : 2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated 8 January 2009).

May 19, 2015

SEONG SI-HEON

Administrator,
Korea Laboratory Accreditation Scheme(KOLAS)

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No. 487 (2/2)

1. Mechanical Test

1.016 Construction and Material

Test method	Standard designation	Test range or Limits of detection
KS F 2292 : 2013	The method of air tightness for windows and doors	(0~100) Pa (0~250) m^3/h
KS F 2293 : 2008	Test method of water tightness for windows and doors	(50~750) Pa 4 $L/(m^2 \cdot min)$
KS F 2296 : 1999	Windows and door sets－Wind resistance test	(800~3 600) Pa (0.01~100) mm
ASTM E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen	(75~300) Pa (0~250) m^3/h
ASTM E330/E330M-14	Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference	(0.01~100) mm
ASTM E331-00	Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference	(300~720) Pa 3.4 $L/(m^2 \cdot min)$
ASTM E783-02	Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors	(75~300) Pa (0~250) m^3/h
ASTM E1105-00	Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference	(200~720) Pa 3.4 $L/(m^2 \cdot min)$

End.

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Tel. 041-733-4734/5
Fax. 041-733-4736
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The "As Built" mock-up drawings and a copy of this report will be retained by ATA for a period of four years. This report is the exclusive property of the client so named herein and is applicable to the sample tested.
Results obtained are tested values and do not constitute an opinion or endorsement by this laboratory.

For ARCHITECTURAL TESTING ASIA, INC.

Architectural Testing Asia
Technician
Jangjun Han

Issue date : April 5th, 2019

Architectural Testing Asia
Technical Manager
Jingu Yu

Architectural Testing Asia
President
Inkon Kim

Mock-up Test Report / Certificate No. 190314-033-1

CANADA GRANDVIEW PROJECT

Window Wall

ATA에이티에이주식회사
Architectural Testing Asia Inc.

Contents

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Fax. 041-733-4736
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CANADA GRANDVIEW PROJECT

Mock-Up Test Report / Window Wall

1. Weather Condition

1-1. Date	Mar 26th, 2019	Mar 27th, 2019	Mar 28th, 2019
1-2. Air Temperature	20.1 ℃	13.8 ℃	21.2 ℃
1-3. Relative Humidity	38.5 % R.H.	41.5 % R.H.	25.1 % R.H.
1-4. Atmosphere	1 005.4 hPa	1 007.2 hPa	1 001.1 hPa
1-5. Weather	Fine	Fine	Fine

2. Schedule

2-1. Specimen Install	Mar 19th, 2019 ~ Mar 22th, 2019
2-2. Test	Mar 26th, 2019 18:00 ~ 21:00 Pre-Load, Air, Water(Static, Dynamic), Vertical Movement, Air, Water Test(Static)
	Mar 27th, 2019 09:00 ~ 24:00 Horizontal, Air, Water(Static), Thermal Cycling Test
	Mar 28th, 2019 00:00 ~ 19:00 Thermal Cycling, Air, Water(Static), Structural(100 %), Air, Water(Static), Structural(150 %), Horizontal Movement Test

3. Witness

Test Witness

• Project : CANADA GRAND VIEW PROJECT

• Test Date : Mar 27th, 2019

Company	Name	Signature
ALPRO ALUMINUM PRODUCTS LTD	CATALIN KALI BINA	
Grandview	Gordon Makwich	
JRS Engineering	Joel Schwartz	
"	Adam Jarolim	
GRANDVIEW	Robert Hobson	
Namsun Aluminum	You Byong Sun	
"	Jeong Bae, Ahn	
"	Eun Hee, Jung	

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4. Specimen Type

4-1. Installation Type	Window Wall
4-2. Glass Type	24 mm Low-E Pair Glass

5. Test Summary

The specimen carried out at the request of namsun aluminum was not met requirements of specification on structural test.(Refer to Chapter 8)

6. Test Method

The Specimen Was tested by the ASTM & AAMA standard.

6-1. Air Infiltration Test	ASTM E283 ; Standard Test Method For Determining Rate Of Air Leakage Through Exterior Windows, Curtain Walls, And Doors Under Specified Pressure Differences Across The Specimen
6-2. Water Penetration Test	ASTM E331 ; Standard Test Method For Water Penetration Of Exterior Windows, Curtain Walls and Doors By Uniform Static Air Difference
6-3. Structural Test	ASTM E330/E330M ; Standard Test Method For Structural Performance Of Exterior Windows, Curtain Walls, And Doors By Uniform Static Pressure Difference
6-4. Vertical Test	AAMA 501.7 ; Recommend Static Test Method for Evaluating Windows, Window Wall, Curtain Wall and Storefront Systems Subjected to Vertical Inter-story Movements
6-5. Horizontal Test	AAMA 501.4 ; Recommended Static Test Method For Evaluating Curtain Wall And Storefront Systems Subjected to Seismic And Wind Induced Inter-story Drifts
6-6. Thermal Cycling Test	AAMA 501.5 ; Test Method for Thermal Cycling of Exterior Walls

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7. Specimen Description

7-1. Size	-. Full Specimen : 5 260 mm width × 5 880 mm height
	Fixed Area : 29.54 m^2(317.95 ft^2)
	Vent Area(2EA) : 1.39 m^2(14.96 ft^2)
7-2. Finish	-. AL. Frame
	·Exposed : PVDF Coat
	·Non-Exposed : Milled
7-3. Glass	-. 24 mm Pair Glass : 6 mm Low-E Glass + 12 mm Air + 6 mm Glass
7-4. Glazing Material	-. Weather Sealant
	-. Structural Sealant

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8. Test Result

Design Wind Load

Positive Design Pressure : +50 psf
Negative Design Pressure : -50 psf

8-1. Pre-Load Test

① Test Pressure : 25 psf / 50 % of Positive Design Pressure
② Duration : 10 Seconds
③ Result : *Pass*

Table 1. Unit Conversion

	USCS	SI	CGS
Mass	Slug	kg	kg
Length	ft, inch	m, cm, mm	m, cm, mm
Force	lb(pound)	N(newton)	kgf
Pressure	psf(lb/ft^2)	Pa(N/m^2)	kgf/m^2

※Unit Conversion & Example :
1 m ≒ 3.280 8 feet
1 kg ≒ 2.204 59 lb(pound)
1 psf ≒ 47.9 Pa

※ cfm = Cubic Foot per minute = ft^3/min

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8-2. Air Infiltration & Exfiltration Test (1st)

① Test Pressure : +300 Pa

② Duration : Until the pressure is stable

③ Measured : Refer to Table 2

④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 0.80 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 1.38 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.06 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.60 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 2. Convert to Standard Condition

1. Weather Condition	-. Temperature : 20.5 ℃ -. Atmosphere : 1 005.5 hPa -. Relative Humidity : 37.8 % R.H.

2. Convert to Standard Condition

Part		Measured (cfm) Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	Standard Test Conditions atmosphere	temp	Air density (W_s)	Convert (Q_{st})
In★	Fixed Area	51.24	50.44	0.80	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	0.80 cfm
Ex★	Fixed Area	51.44	50.06	1.38				1.38 cfm
In★	Vent Area	51.30	51.24	0.06				0.06 cfm
Ex★	Vent Area	52.04	51.44	0.60				0.60 cfm

※ Note :

$Q_{st} = Q(W/W_s)^{1/2}, W = 3.485 \times 10^{-3}(B/(T+273))$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$

-. Q_{st} = air-flow corrected to standard conditions

-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)

-. W = density of air at the test site, kg/m^3(lb/ft^3)

-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and

-. T = temperature of air at flowmeter, ℃

In★ : Infiltration

Ex★ : Exfiltration

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Fax. 041-733-4736
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8-3. Water Penetration Test by Static Pressure (1st)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

8-4. Water Penetration Test by Dynamic Pressure

① Test Pressure : 34.22 m/s(+15 psf) / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

8-5. Vertical Movement Test

① Displacement : Up 15 mm Down 15 mm (Total 30 mm)
② Cycle : 3 times
③ Allowance :
-. *No glass breakage and no permanent damage to panels, fasteners or anchors.*
④ Result : *Pass*

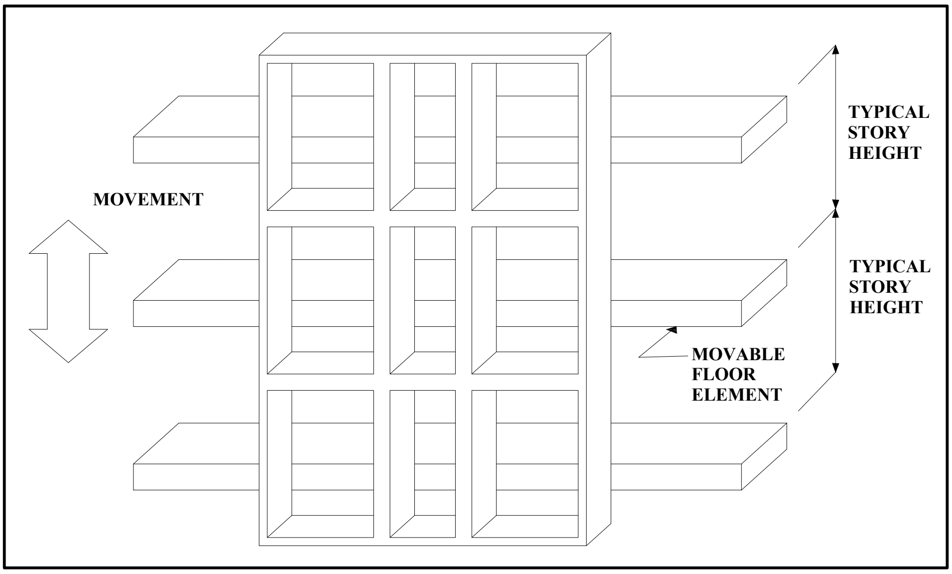

Figure 1. Synopsis of Vertical Movement Test

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8-6. Air Infiltration & Exfiltration Test (2nd)

① Test Pressure : +300 Pa
② Duration : Until the pressure is stable
③ Measured : Refer to Table 3
④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 1.46 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 1.62 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.32 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.63 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 3. Convert to Standard Condition

1. Weather Condition	-. Temperature : 17.6 ℃ -. Atmosphere : 1 006.8 hPa -. Relative Humidity : 48.4 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	51.90	50.44	1.46	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**1.46 cfm**
Ex★	Fixed Area	51.68	50.06	1.62				**1.62 cfm**
In★	Vent Area	52.22	51.90	0.32				**0.32 cfm**
Ex★	Vent Area	52.31	51.68	0.63				**0.63 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2}, W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$
-. Q_{st} = air-flow corrected to standard conditions
-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)
-. W = density of air at the test site, kg/m^3(lb/ft^3)
-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and
-. T = temperature of air at flowmeter, ℃

8-7. Water Penetration Test by Static Pressure(2nd)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

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8-8. Horizontal Movement Test(1st)

① Displacement : Left 30 mm Right 30 mm (Total 60 mm)

② Cycle : 3 times

③ Allowance :

-. *No visible damage to framing or trim components or assemblies is allowed*

-. *No glass breakage or glass fallout is allowed*

-. *Full disengagement of gaskets or weatherseals is not allowed at any location*

-. *Air infiltration and water penetration resistance shall remain within specified allowable limits without adjustments or repair, except as specifically noted herein*

-. *No wall components may fall off*

④ Result : *Pass*

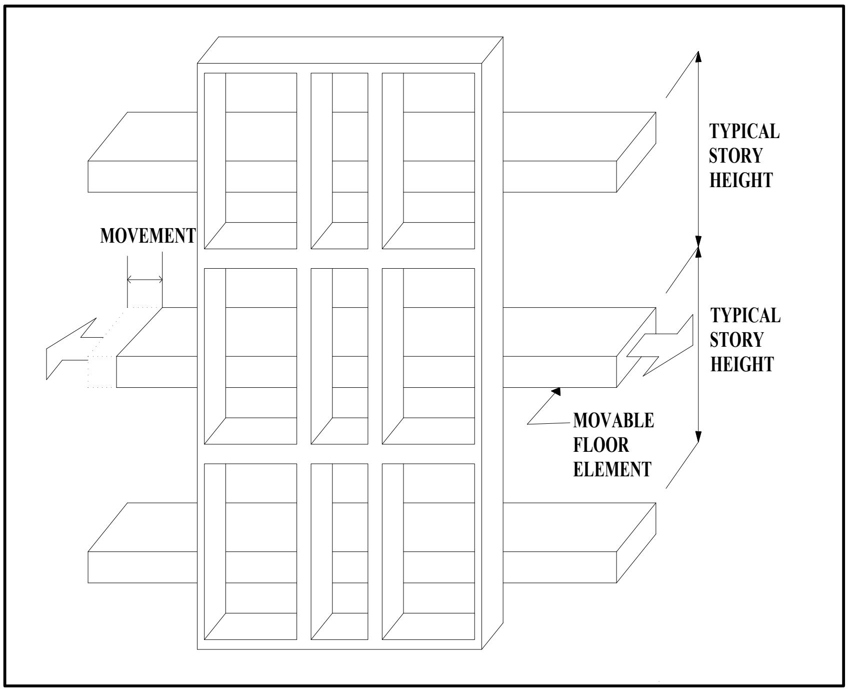

Figure 2. Synopsis of Horizontal Movement Test

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8-9. Air Infiltration & Exfiltration Test (3rd)

① Test Pressure : +300 Pa
② Duration : Until the pressure is stable
③ Measured : Refer to Table 4
④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 2.96 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 2.33 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.17 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.26 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 4. Convert to Standard Condition

1. Weather Condition	-. Temperature : 18.0 ℃ -. Atmosphere : 1 003.8 hPa -. Relative Humidity : 46.9 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	53.40	50.44	2.96	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**2.96 cfm**
Ex★		52.39	50.06	2.33				**2.33 cfm**
In★	Vent Area	53.57	53.40	0.17				**0.17 cfm**
Ex★		52.65	52.39	0.26				**0.26 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2},\ W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$
-. Q_{st} = air-flow corrected to standard conditions
-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)
-. W = density of air at the test site, kg/m^3(lb/ft^3)
-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and
-. T = temperature of air at flowmeter, ℃

8-10. Water Penetration Test by Static Pressure (3rd)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

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8-11. Thermal Cycling Test

① Test Condition

Out Door : Hot Cycle +82 ℃ ± 3 ℃ at Air Temperature

Cold Cycle -18 ℃ ± 3 ℃ at Air Temperature

In Door : +24 ℃ ± 3 ℃

② Cycle : 3 Cycles

③ Allowance : After thermal cycling test, Air & water test was met the allowance.

④ Result : *Pass*

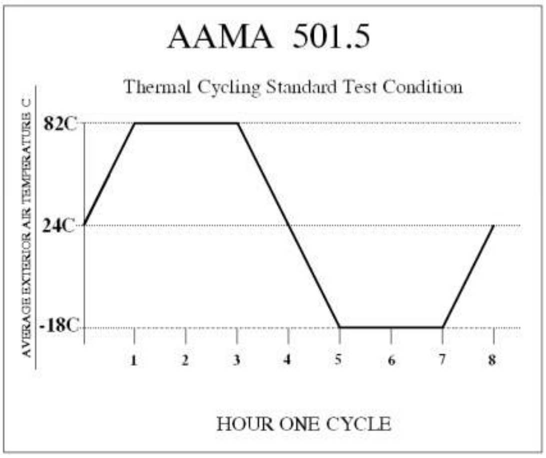

Figure 3. Synopsis of Exterior Temperature

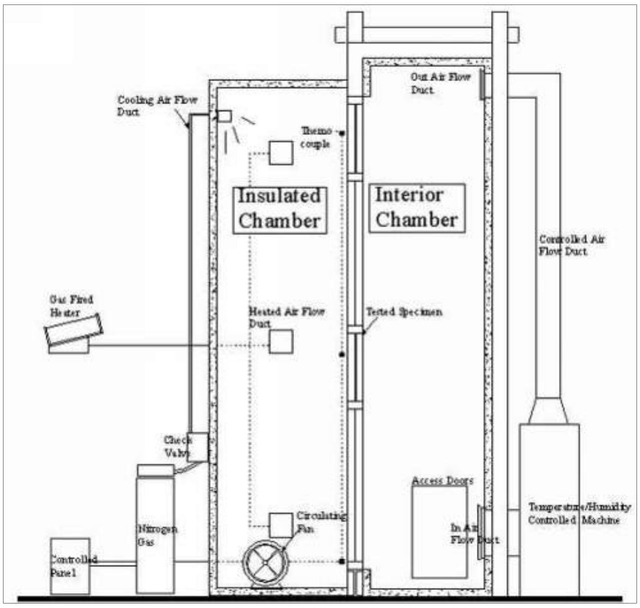

Figure 4. Synopsis of Thermal Cycling Test

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8-12. Air Infiltration & Exfiltration Test (4th)

① Test Pressure : +300 Pa
② Duration : Until the pressure is stable
③ Measured : Refer to Table 5
④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 3.18 cfm(Actual) -----> O.K
Exfiltration : 12.72 cfm(Allowable) > 3.18 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.11 cfm(Actual) -----> O.K
Exfiltration : 1.50 cfm(Allowable) > 0.54 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 5. Convert to Standard Condition

1. Weather Condition	-. Temperature : 21.5 ℃ -. Atmosphere : 1 001.0 hPa -. Relative Humidity : 25.9 % R.H.

2. Convert to Standard Condition

Measured (cfm)					Standard Test Conditions			Convert (Q_{st})
Part		Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	atmosphere	temp	Air density (W_s)	
In★	Fixed Area	53.64	50.44	3.20	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**3.18 cfm**
Ex★		53.26	50.06	3.20				**3.18 cfm**
In★	Vent Area	53.75	53.64	0.11				**0.11 cfm**
Ex★		53.80	53.26	0.54				**0.54 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2},\ W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$
-. Q_{st} = air-flow corrected to standard conditions
-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)
-. W = density of air at the test site, kg/m^3(lb/ft^3)
-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and
-. T = temperature of air at flowmeter, ℃

8-13. Water Penetration Test by Static Pressure(4th)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

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8-14. Structural Test (@100 %)

① Test Pressure : +50 psf / 100 % of Positive Design Pressure
-50 psf / 100 % of Negative Design Pressure

② Duration : 10 seconds

③ Allowance :

-. Framing System for Building Cladding Components(According to AAMA TIR-A11-15) ;

· L / 175 (L≤4 110 mm)

FRAME Ⅰ (Vertical) : 2 953 mm / 175 = 16.87 mm

FRAME Ⅱ (Vertical) : 2 635 mm / 175 = 15.06 mm

FRAME Ⅲ (Transom) : 1 170 mm / 175 = 6.69 mm

-. Glass : No Breakage

④ Measured : Refer to Table 6 & Figure 5.

⑤ Result : *Fail*

9 feet window wall(1st floor) is pass,
but 10 feet window wall(2nd floor) is fail

Table 6. Measured the Maximum Deflection of Each Element

unit : mm

Pressure / Gauge No	Positive		Negative		Allowable
	100 %	Net Deflection	100 %	Net Deflection	
No. 1	8.97	15.82	10.69	19.84	16.87
No. 2	20.80		26.09		
No. 3	1.00		1.82		
No. 4	6.68	8.79	7.28	12.93	15.06
No. 5	12.55		17.19		
No. 6	0.85		1.25		
No. 7	0.83	0.83	0.75	0.75	6.69
No. 8	6.78	6.78	7.95	7.95	No Breakage

※ Net Deflection : Gauge No. 2 - [(Gauge No. 1 + Gauge No. 3) / 2]
Net Deflection : Gauge No. 5 - [(Gauge No. 4 + Gauge No. 6) / 2]

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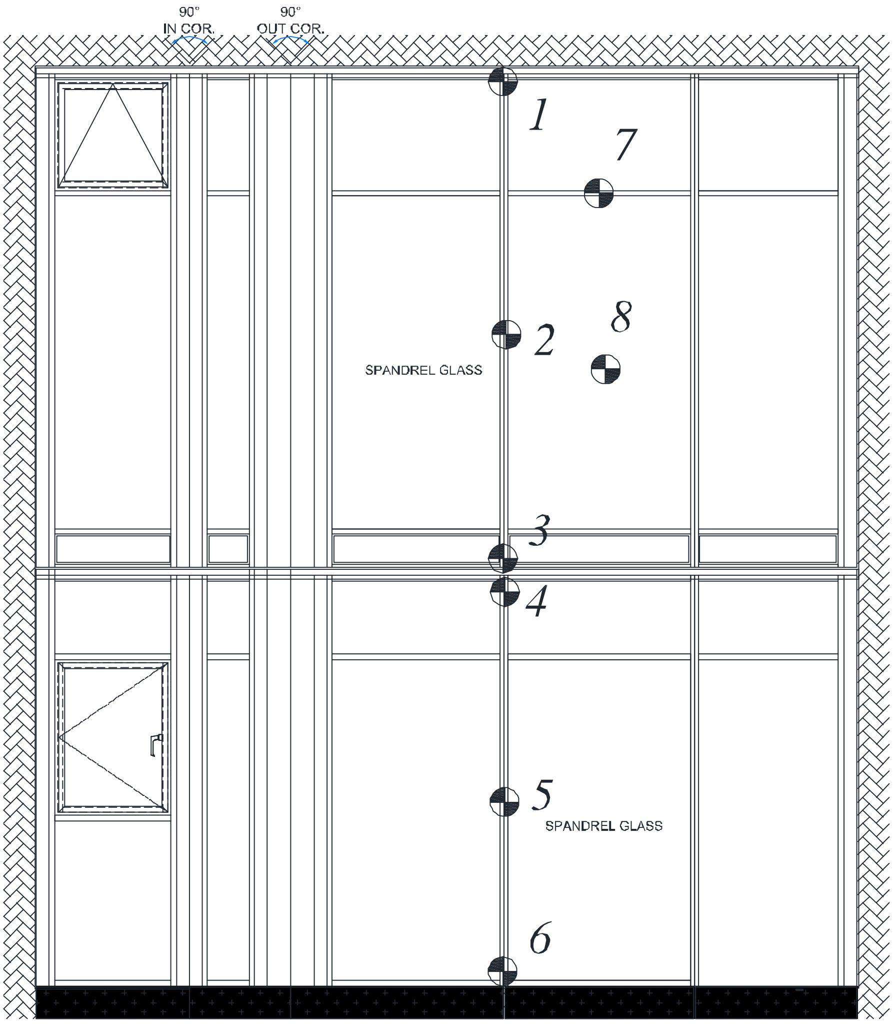
Figure 5. Transducer Location for Structural Test



Location :

No. 1 : Top of Frame I

No. 2 : Mid of Frame I

No. 3 : Bottom of Frame I

No. 4 : Top of Frame II

No. 5 : Mid of Frame II

No. 6 : Bottom of Frame II

No. 7 : Mid of Frame III

No. 8 : Center of Glass

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8-15. Air Infiltration & Exfiltration Test (5th)

① Test Pressure : +300 Pa
② Duration : Until the pressure is stable
③ Measured : Refer to Table 7
④ Compared with Allowance : (The Specimen Area was refer to Chapter 7)

Fixed Area = 317.95 ft^2 × 0.04 cfm/ft^2 = **12.72 cfm**

∴ Infiltration : 12.72 cfm(Allowable) > 3.58 cfm(Actual) -----> O.K

Exfiltration : 12.72 cfm(Allowable) > 5.20 cfm(Actual) -----> O.K

Vent Area = 14.96 ft^2 × 0.10 cfm/ft^2 = **1.50 cfm**

∴ Infiltration : 1.50 cfm(Allowable) > 0.06 cfm(Actual) -----> O.K

Exfiltration : 1.50 cfm(Allowable) > 0.26 cfm(Actual) -----> O.K

⑤ Result : *Pass*

Table 7. Convert to Standard Condition

1. Weather Condition	-. Temperature : 20.2 ℃ -. Atmosphere : 1 001.7 hPa -. Relative Humidity : 30.2 % R.H.

2. Convert to Standard Condition

Part		Measured (cfm) Total (Q_t)	Extraneous (Q_e)	Net Specimen (Q_s)	Standard Test Conditions atmosphere	temp	Air density (W_s)	Convert (Q_{st})
In★	Fixed Area	54.04	50.44	3.60	1 013 (hPa)	20.8 (℃)	1.202 (kg/m^3)	**3.58 cfm**
Ex★		55.28	50.06	5.22				**5.20 cfm**
In★	Vent Area	54.10	54.04	0.06				**0.06 cfm**
Ex★		55.54	55.28	0.26				**0.26 cfm**

※ Note :

$$Q_{st} = Q(W/W_s)^{1/2}, W = 3.485 \times 10^{-3}(B/(T+273))$$

-. Q = air-flow at non-standard conditions, $Q_s = Q_t - Q_e$
-. Q_{st} = air-flow corrected to standard conditions
-. W_s = density of air at reference standard conditions - 1.202 kg/m^3(0.075 lb/ft^3)
-. W = density of air at the test site, kg/m^3(lb/ft^3)
-. B = barometric pressure at the test site corrected for temperature, Pa(in.Hg), and
-. T = temperature of air at flowmeter, ℃

8-16. Water Penetration Test by Static Pressure(5th)

① Test Pressure : +15 psf / By specification
② Amount of Water Spray : 3.4 L/(m^2·min)
③ Duration : 15 minutes
④ Allowance : No uncontrolled water
⑤ Result : *Pass*

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Fax. 041-733-4736
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8-17. Structural Test (@150 %)

① Pressure : +75 psf / 150 % of Positive Design Pressure
-75 psf / 150 % of Negative Design Pressure

② Duration : Maintain target pressure 10 seconds

③ Allowance :

-. Framing Member ; 2L / 1 000

FRAME Ⅰ (Vertical) : 2 953 mm × 2 / 1 000 = 5.91 mm

FRAME Ⅱ (Vertical) : 2 635 mm × 2 / 1 000 = 5.27 mm

FRAME Ⅲ (Transom) : 1 170 mm × 2 / 1 000 = 2.34 mm

-. Glass : No Breakage

④ Measured : Refer to Table 8 & Figure 5.

⑤ Result : *Pass*

Table 8. Measured the Permanent Deflection of Each Element

unit : mm

Pressure / Gauge No	Positive		Negative		Allowance
	150 %	Net Deflection	150 %	Net Deflection	
No. 1	1.74	2.67	1.26	2.28	5.91
No. 2	3.67		3.26		
No. 3	0.29		0.71		
No. 4	1.20	2.79	1.30	2.59	5.27
No. 5	3.61		3.42		
No. 6	0.44		0.36		
No. 7	0.18	0.18	0.18	0.18	2.34
No. 8	0.18	0.18	0.08	0.08	No Breakage

※ Net Deflection : Gauge No. 2 - [(Gauge No. 1 + Gauge No. 3) / 2]
Net Deflection : Gauge No. 5 - [(Gauge No. 4 + Gauge No. 6) / 2]

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8-18. Horizontal Movement Test(2nd)

① Displacement : Left 45 mm Right 45 mm (Total 90 mm)

② Cycle : 3 times

③ Allowance :

-. *No visible damage to framing or trim components or assemblies is allowed*

-. *No glass breakage or glass fallout is allowed*

-. *Full disengagement of gaskets or weatherseals is not allowed at any location*

-. *Air infiltration and water penetration resistance shall remain within specified allowable limits without adjustments or repair, except as specifically noted herein*

-. *No wall components may fall off*

④ Result : *Pass*

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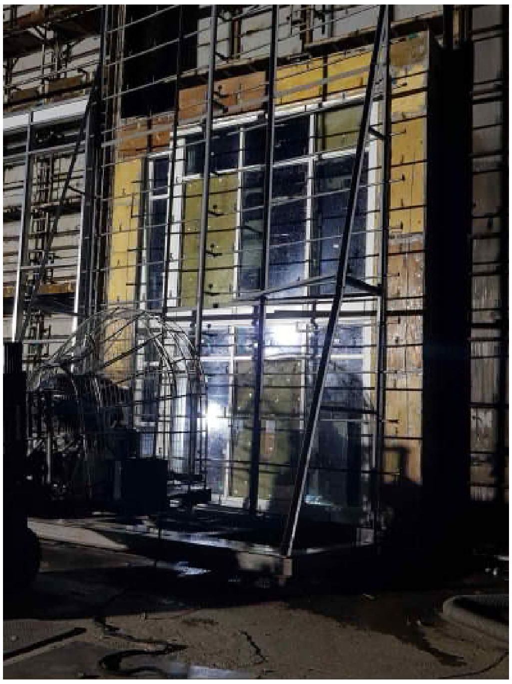
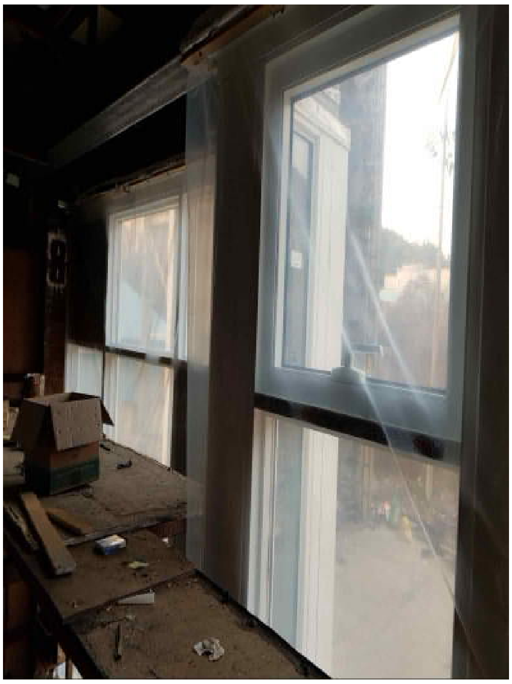
9. Photo

9-1. Pre-load Test
& Air Infiltration Test





9-2. Water Penetration
Test

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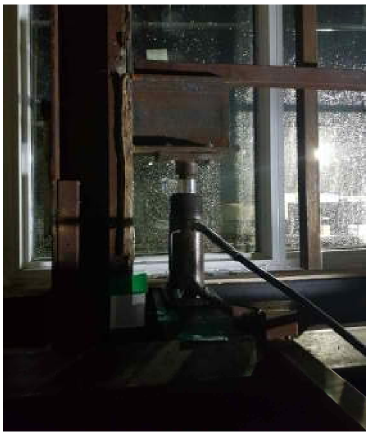
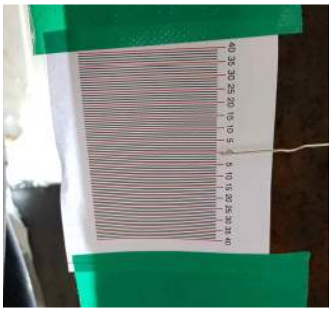
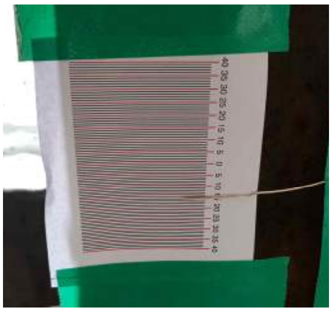
9-3. Structural Test

9-4. Vertical Test







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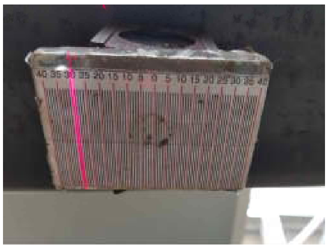
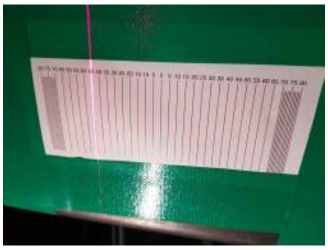
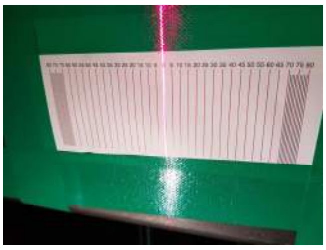
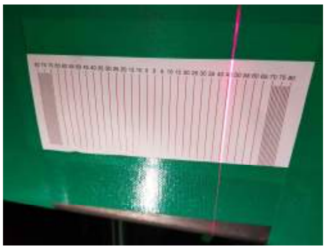
9-5. Horizontal Test









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9-6. Thermal Cycling Test



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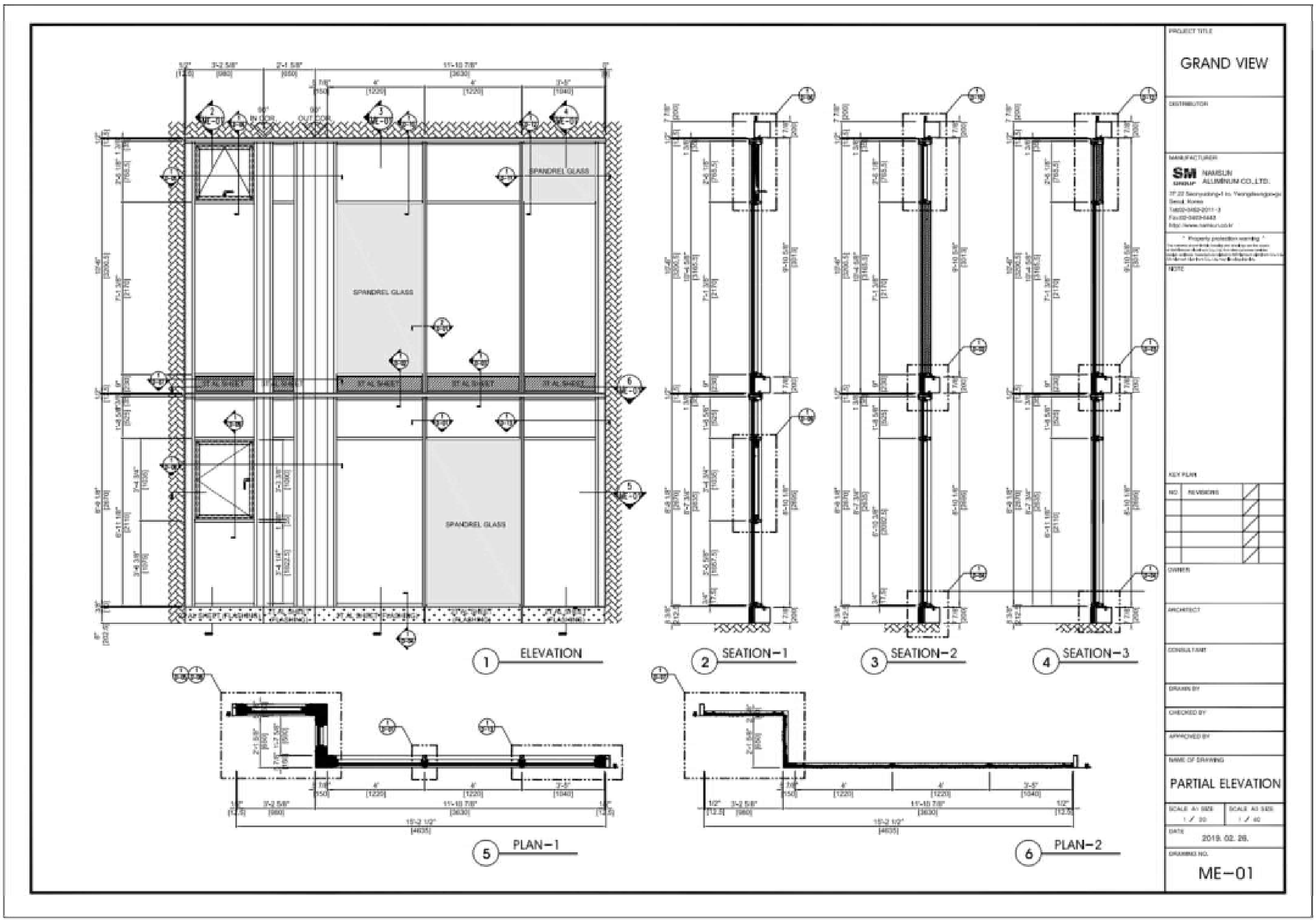
10. Drawings

10-1. Elevation



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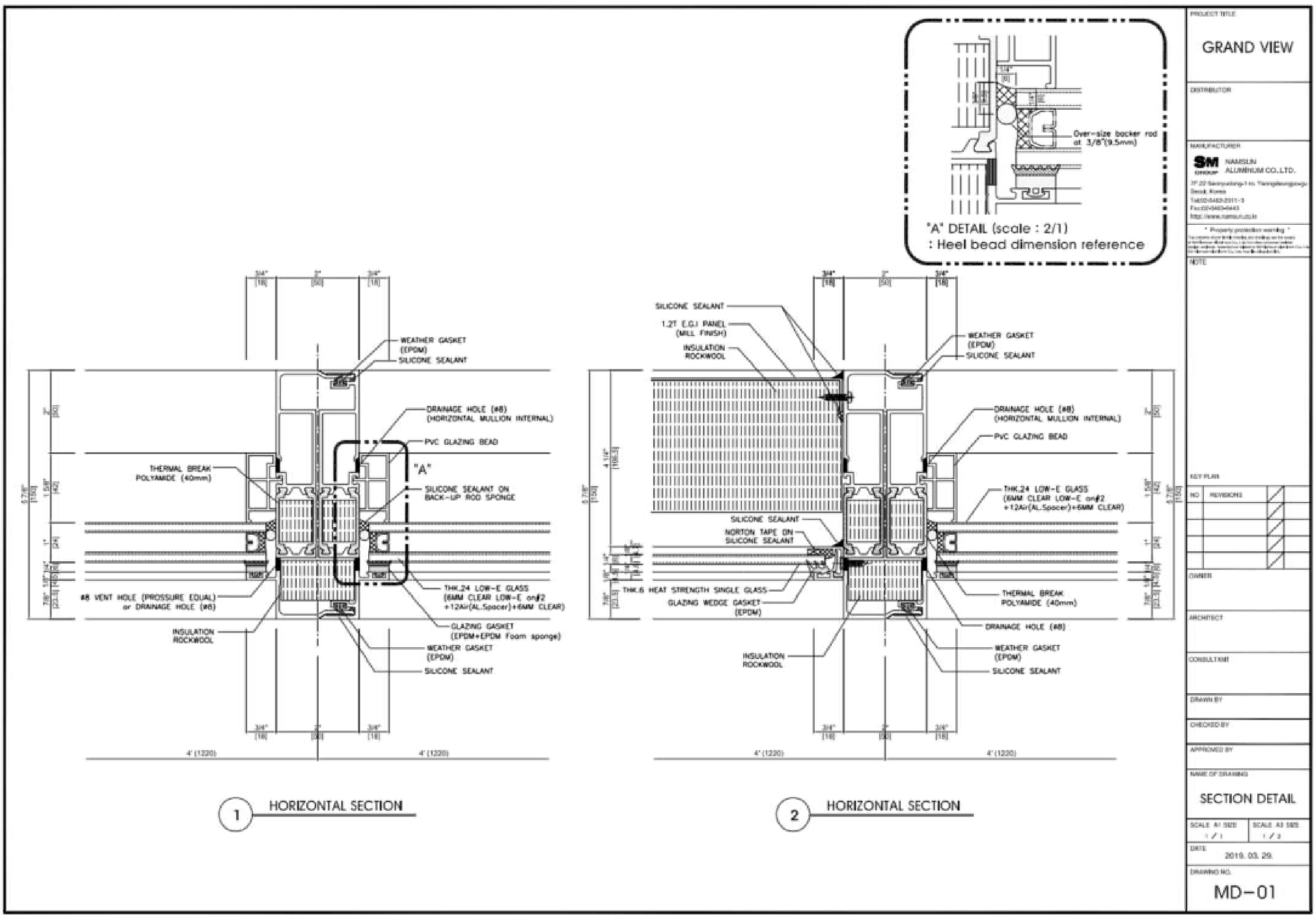
10-2. Detail



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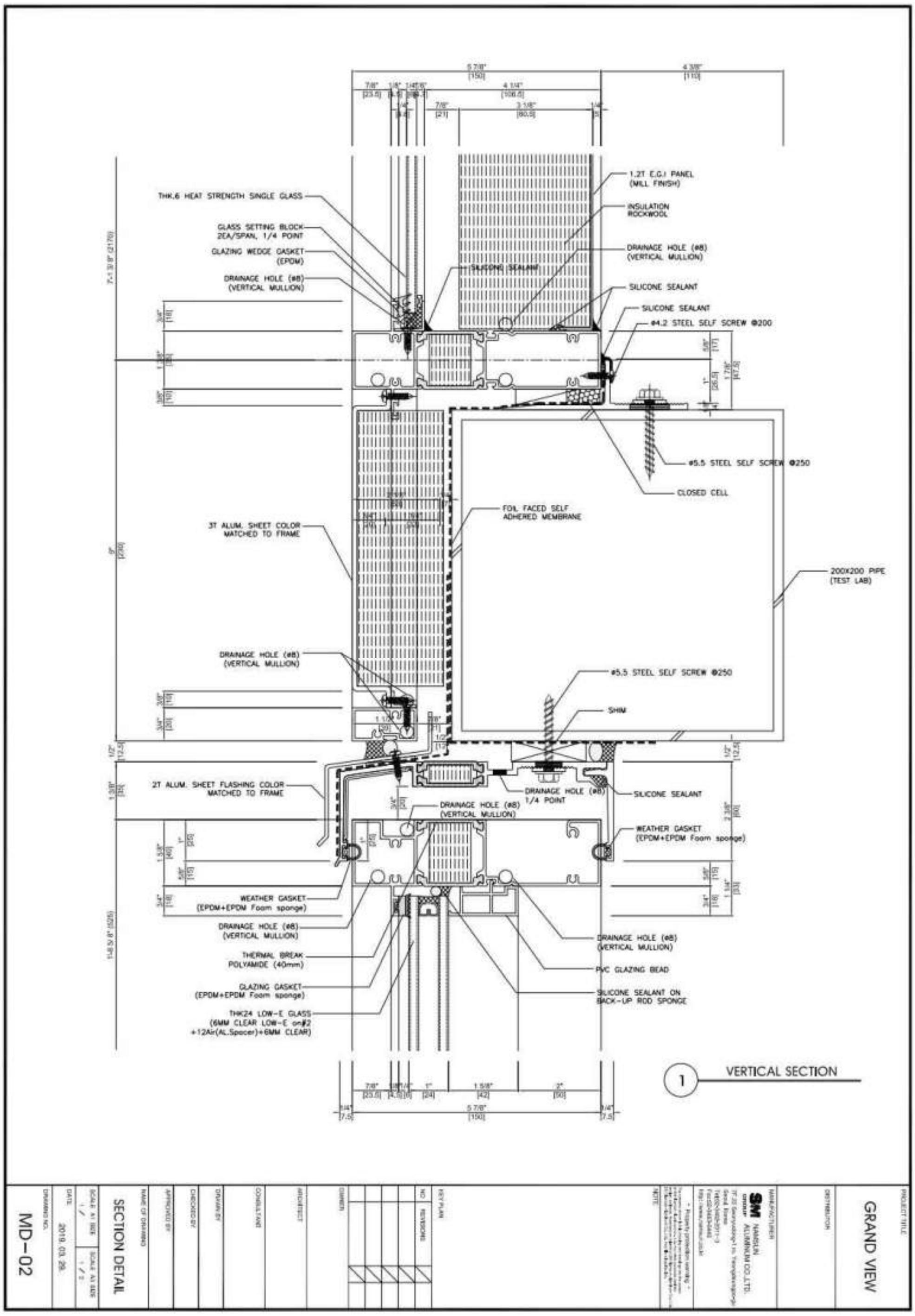
10-3. Detail



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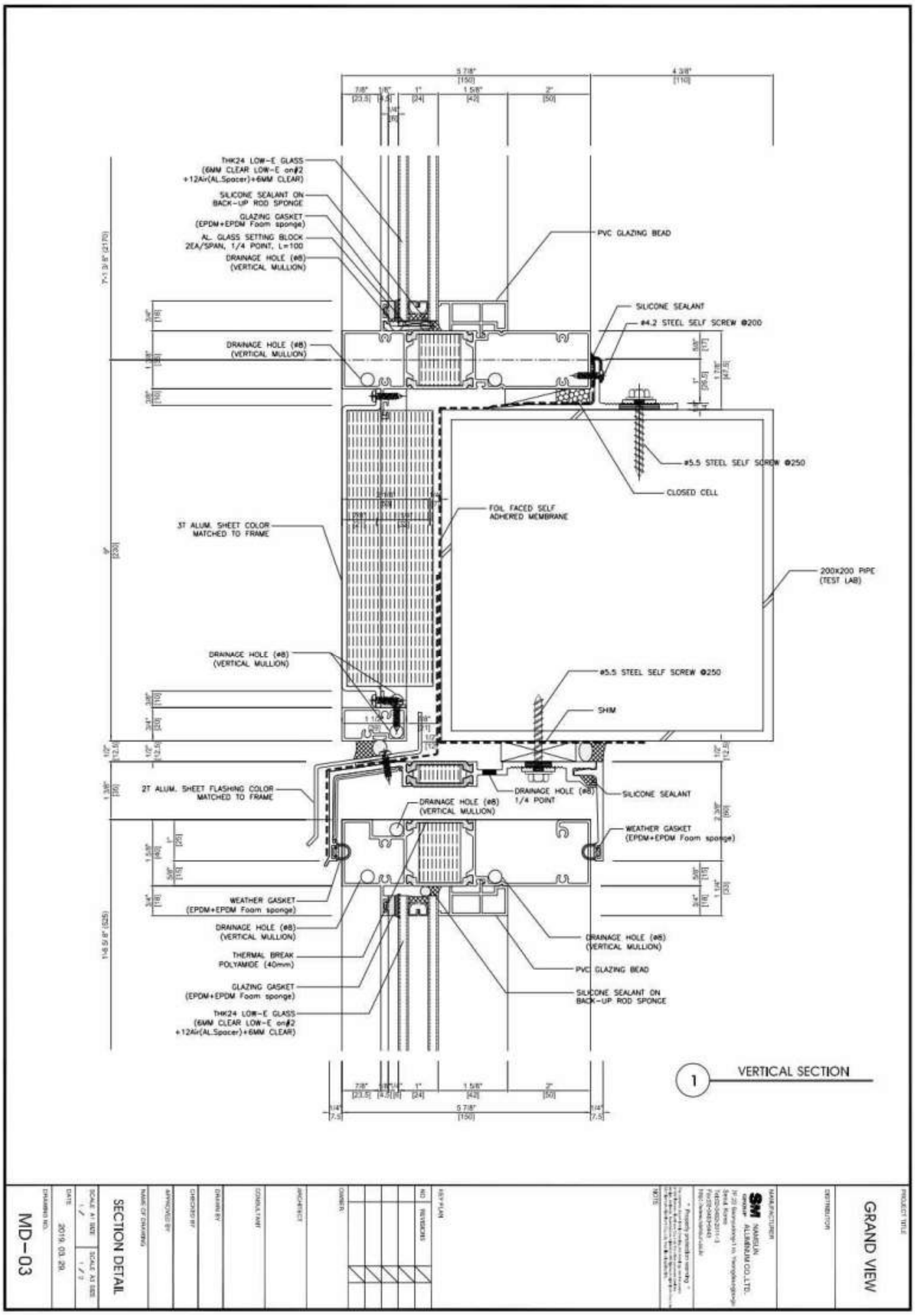
10-4. Detail



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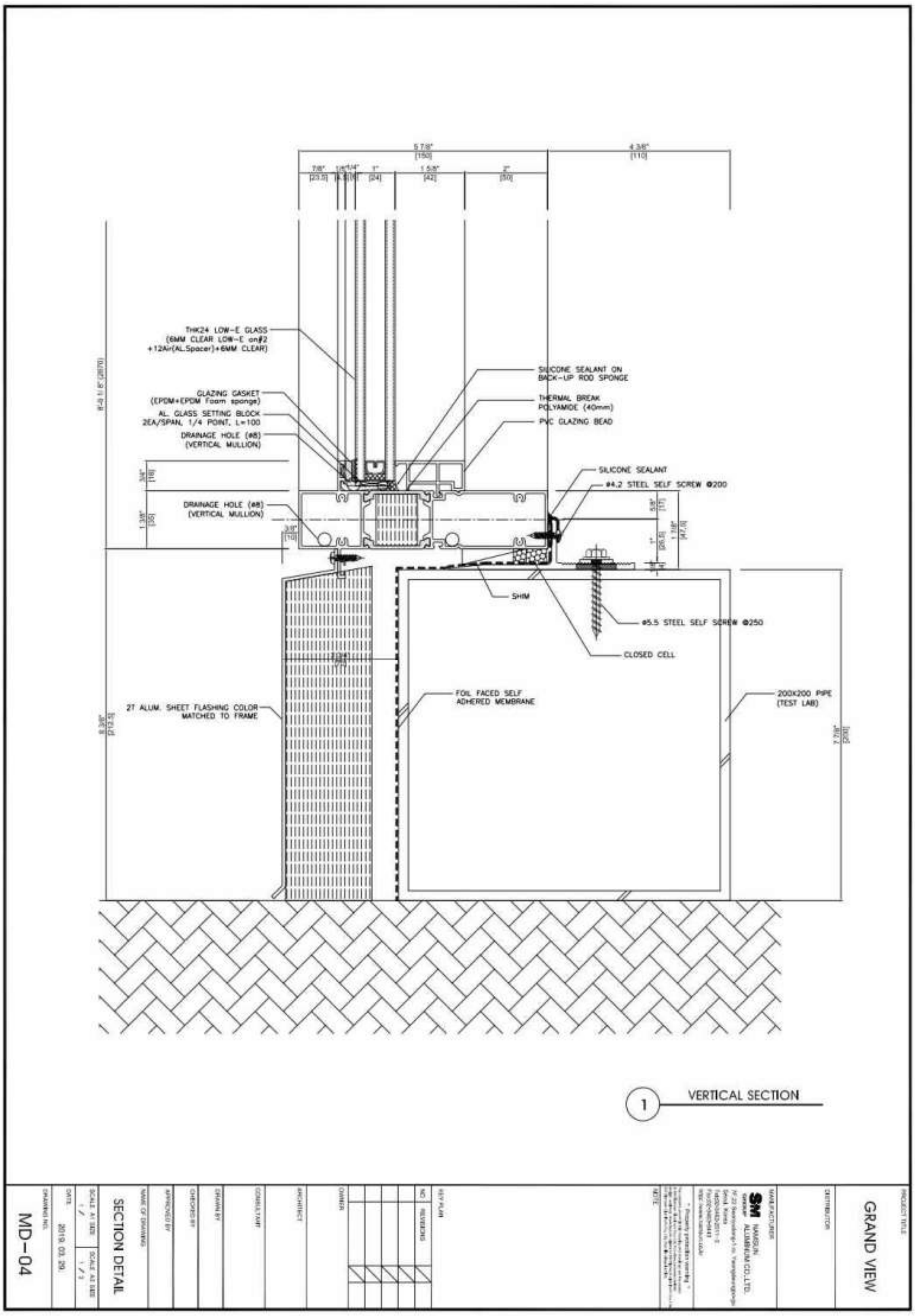
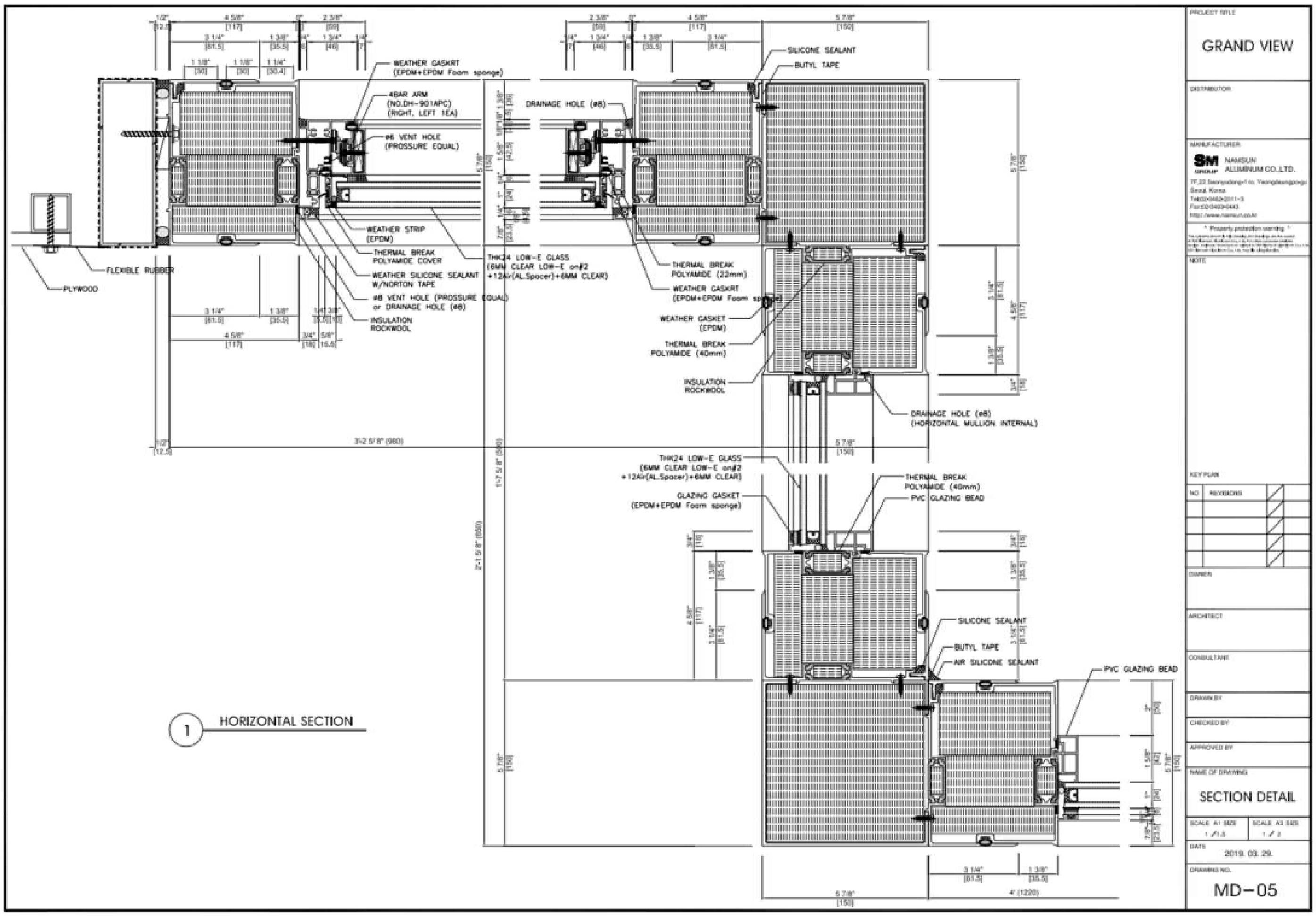
10-5. Detail



10-6. Detail


GRAND VIEW
SECTION DETAIL
MD-05
2019. 03. 29.
HORIZONTAL SECTION
WEATHER GASKRT (EPDM+EPDM Foam sponge)
DRAINAGE HOLE (#8)
SILICONE SEALANT
BUTYL TAPE
WEATHER STRIP (EPDM)
THERMAL BREAK POLYAMIDE COVER
WEATHER SILICONE SEALANT W/NORTON TAPE
INSULATION ROCKWOOL
FLEXIBLE RUBBER
PLYWOOD
THK24 LOW-E GLASS (6MM CLEAR LOW-E on#2 +12Air(AL.Spacer)+6MM CLEAR)
GLAZING GASKET (EPDM+EPDM Foam sponge)
PVC GLAZING BEAD
AIR SILICONE SEALANT

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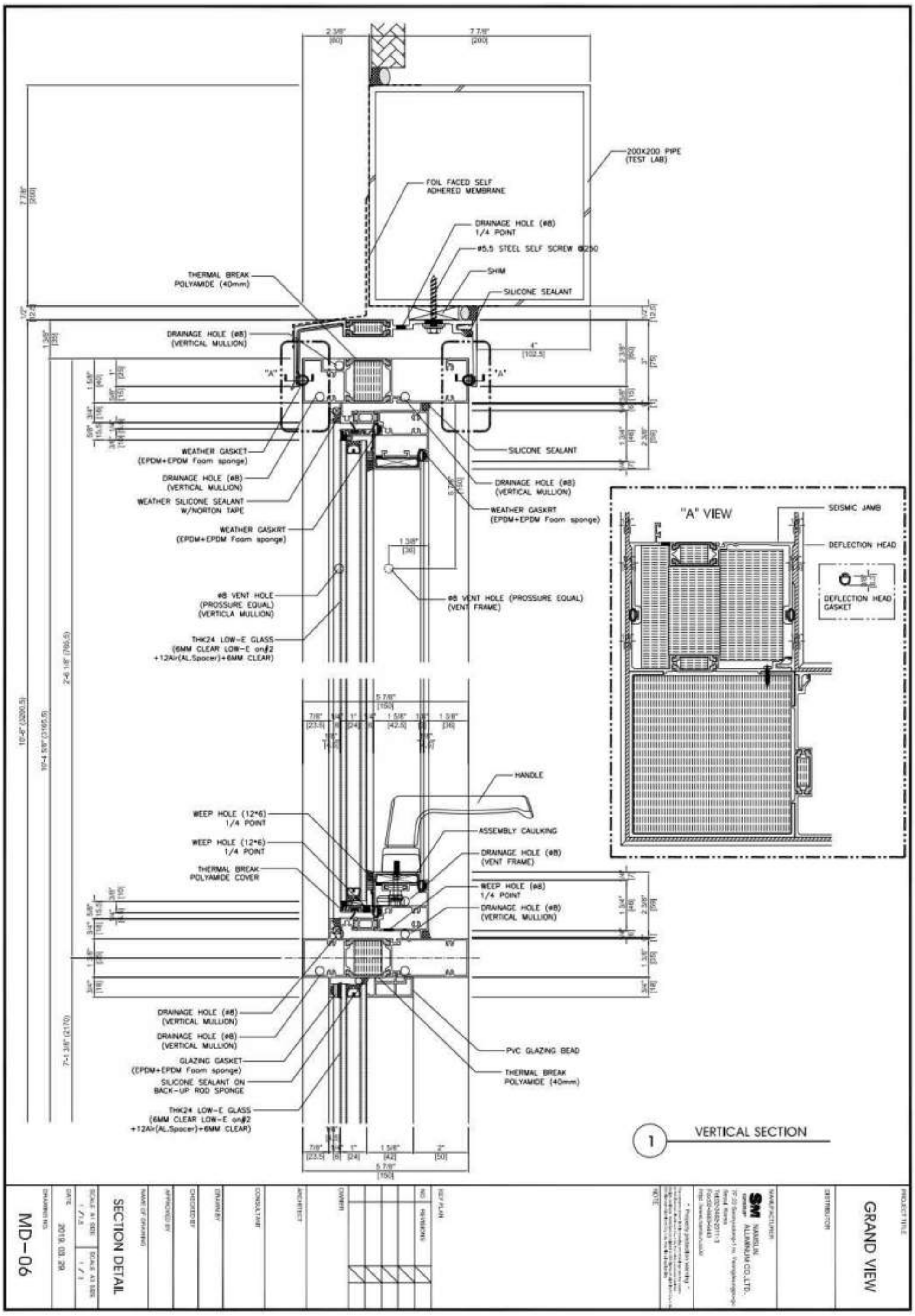
10-7. Detail



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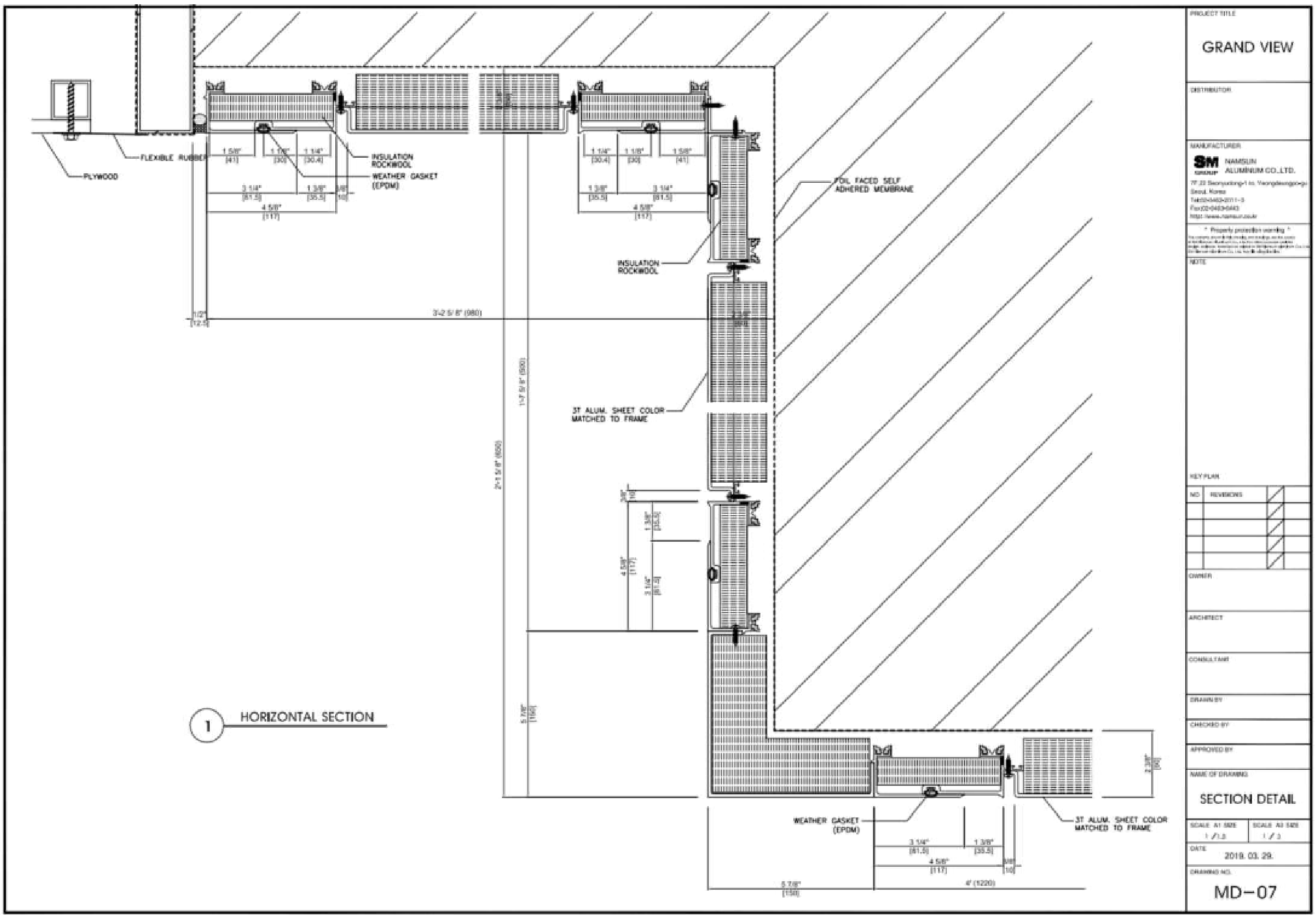
10-8. Detail



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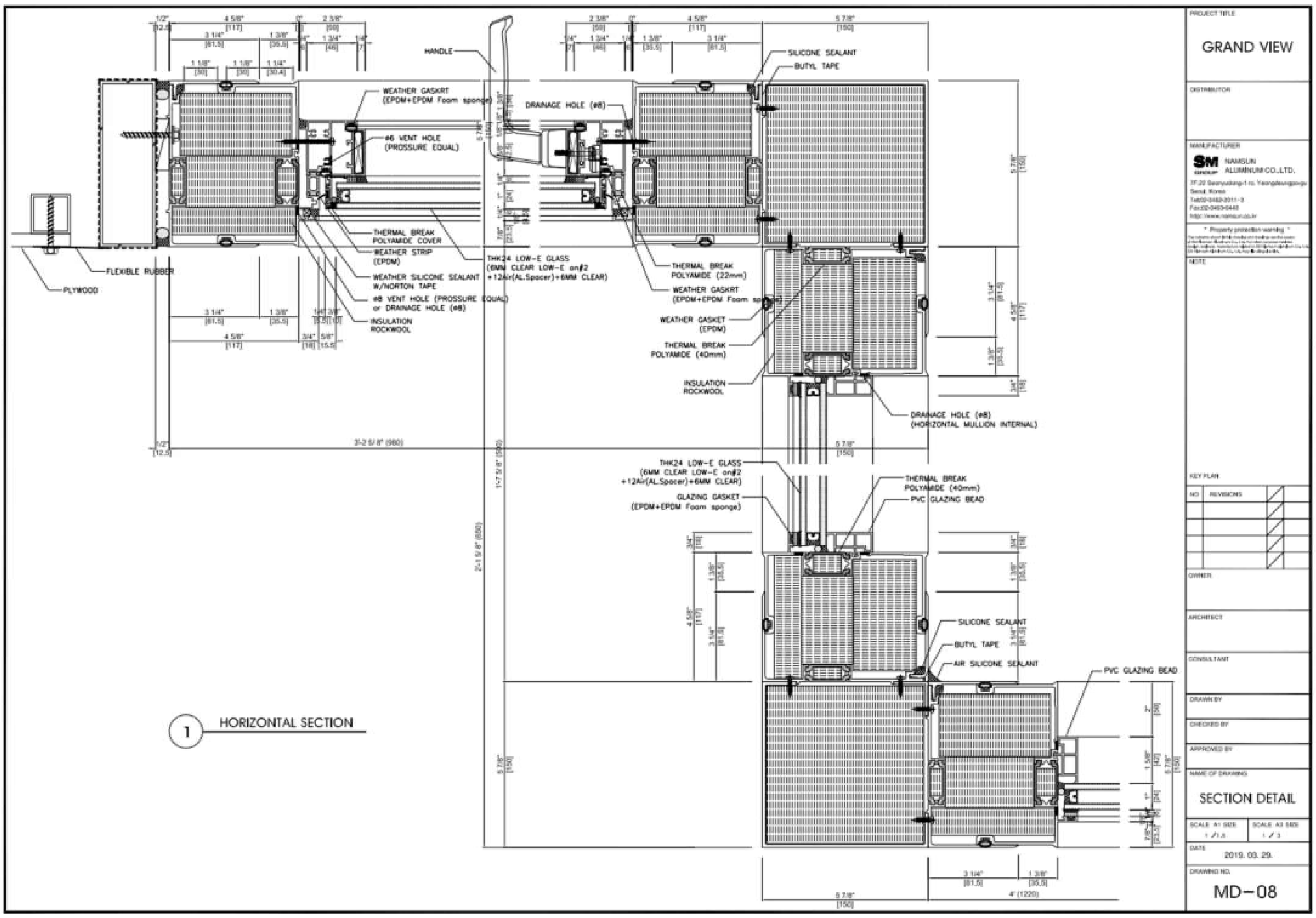
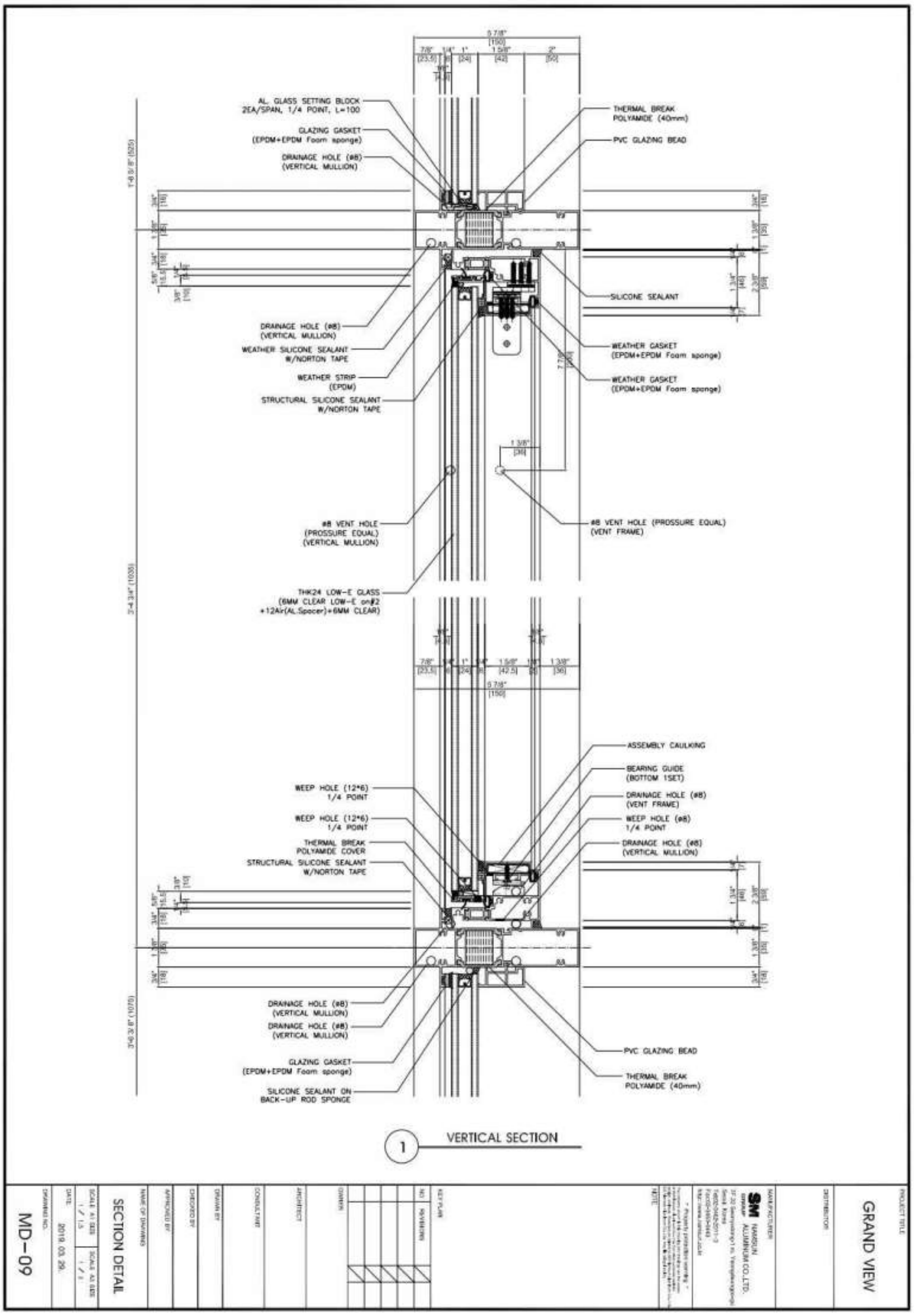
10-9. Detail



10-10. Detail


AL. GLASS SETTING BLOCK 2EA/SPAN, 1/4 POINT, L=100
GLAZING GASKET (EPDM+EPDM Foam sponge)
DRAINAGE HOLE (#8) (VERTICAL MULLION)
THERMAL BREAK POLYAMIDE (40mm)
PVC GLAZING BEAD
SILICONE SEALANT
DRAINAGE HOLE (#8) (VERTICAL MULLION)
WEATHER SILICONE SEALANT W/NORTON TAPE
WEATHER STRIP (EPDM)
STRUCTURAL SILICONE SEALANT W/NORTON TAPE
WEATHER GASKET (EPDM+EPDM Foam sponge)
WEATHER GASKET (EPDM+EPDM Foam sponge)
#8 VENT HOLE (PROSSURE EQUAL) (VERTICAL MULLION)
#8 VENT HOLE (PROSSURE EQUAL) (VENT FRAME)
THK24 LOW-E GLASS (6MM CLEAR LOW-E on#2 +12Air(AL.Spacer)+6MM CLEAR)
ASSEMBLY CAULKING
BEARING GUIDE (BOTTOM 1SET)
DRAINAGE HOLE (#8) (VENT FRAME)
WEEP HOLE (#8) 1/4 POINT
DRAINAGE HOLE (#8) (VERTICAL MULLION)
WEEP HOLE (12*6) 1/4 POINT
WEEP HOLE (12*6) 1/4 POINT
THERMAL BREAK POLYAMIDE COVER
STRUCTURAL SILICONE SEALANT W/NORTON TAPE
DRAINAGE HOLE (#8) (VERTICAL MULLION)
DRAINAGE HOLE (#8) (VERTICAL MULLION)
GLAZING GASKET (EPDM+EPDM Foam sponge)
SILICONE SEALANT ON BACK-UP ROD SPONGE
PVC GLAZING BEAD
THERMAL BREAK POLYAMIDE (40mm)
1
VERTICAL SECTION
MD-09
2019. 03. 29.
SECTION DETAIL
GRAND VIEW
SM NAMSUN ALUMINIUM CO.,LTD.

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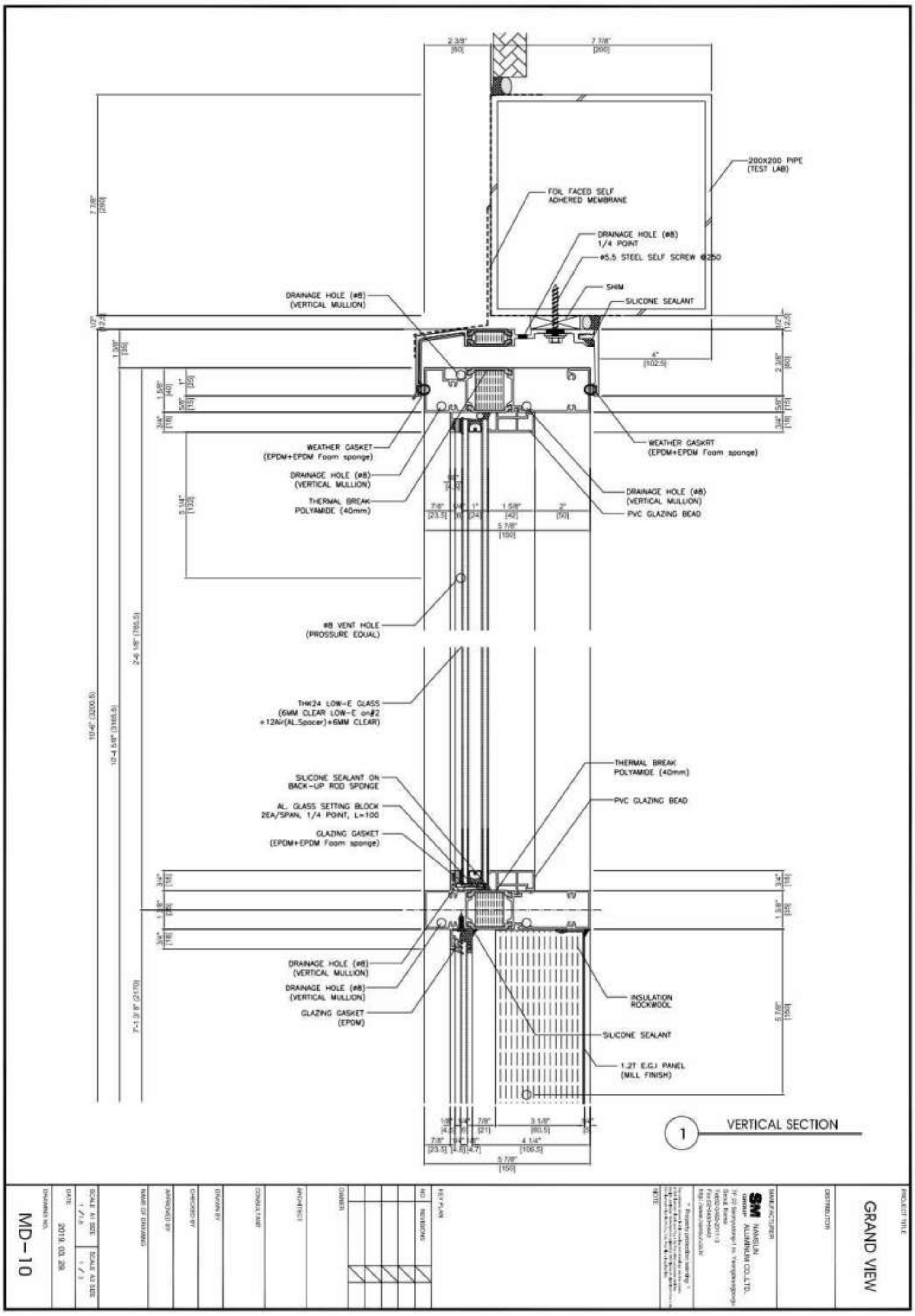
10-11. Detail



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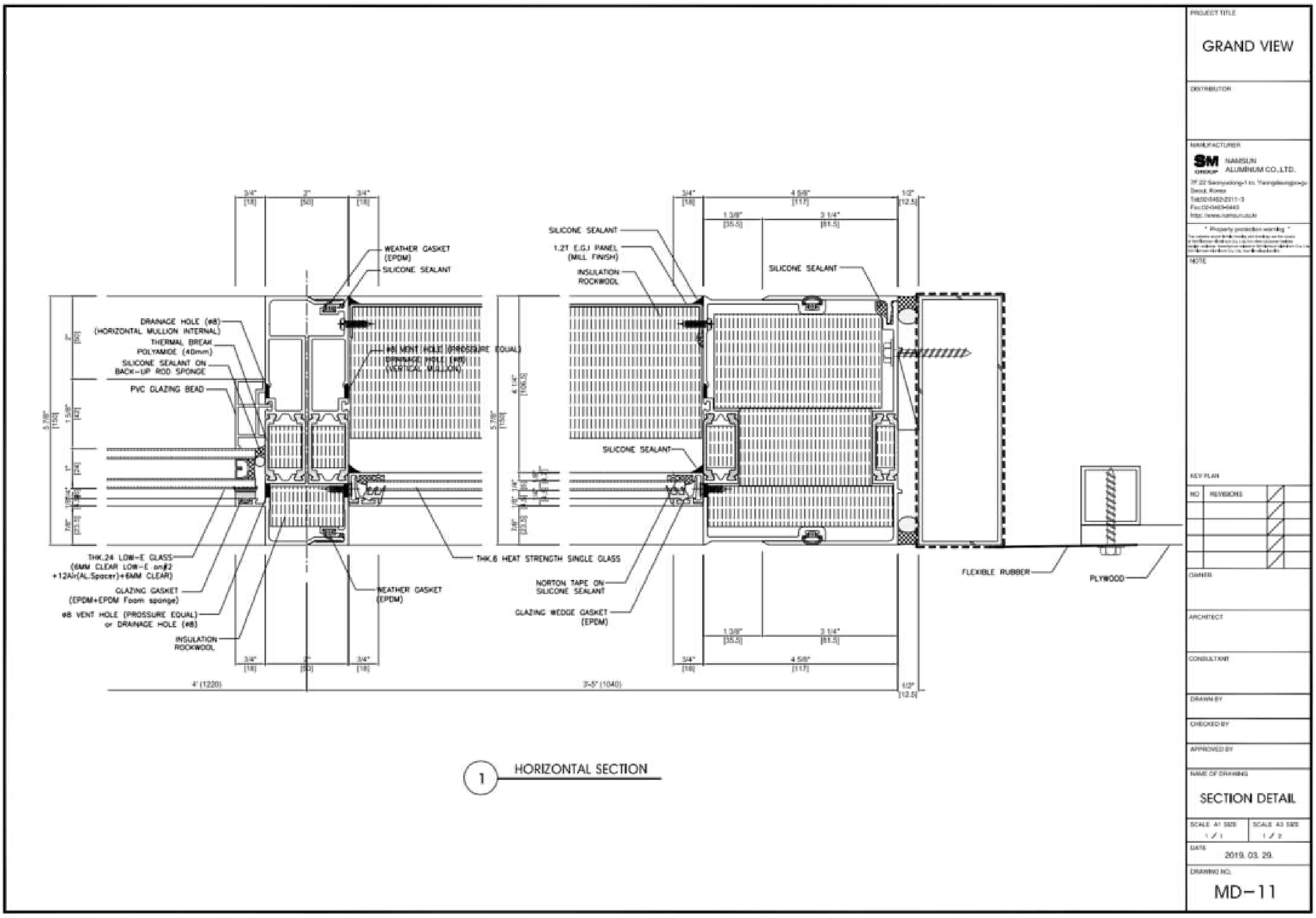
10-12. Detail



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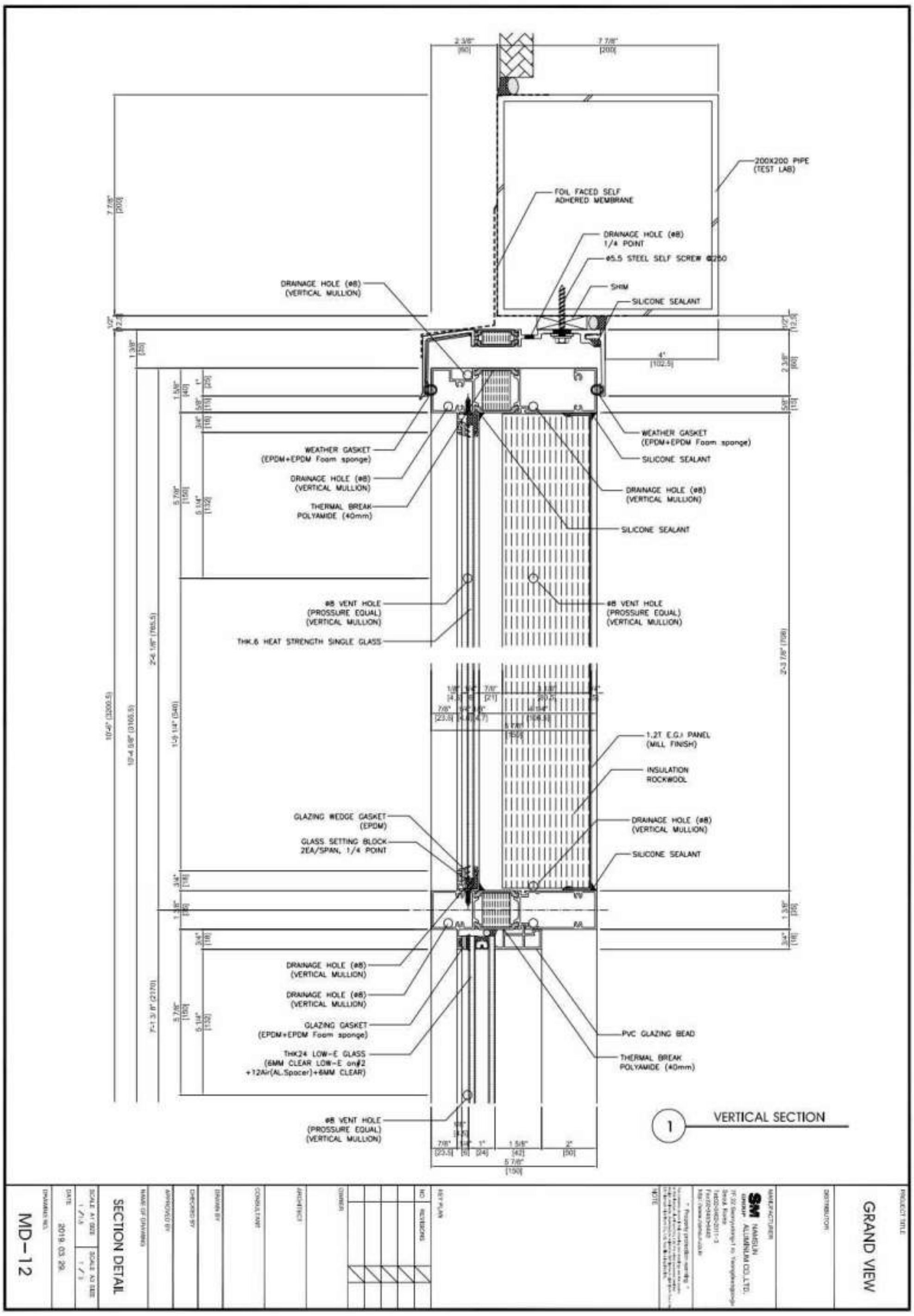
10-13. Detail



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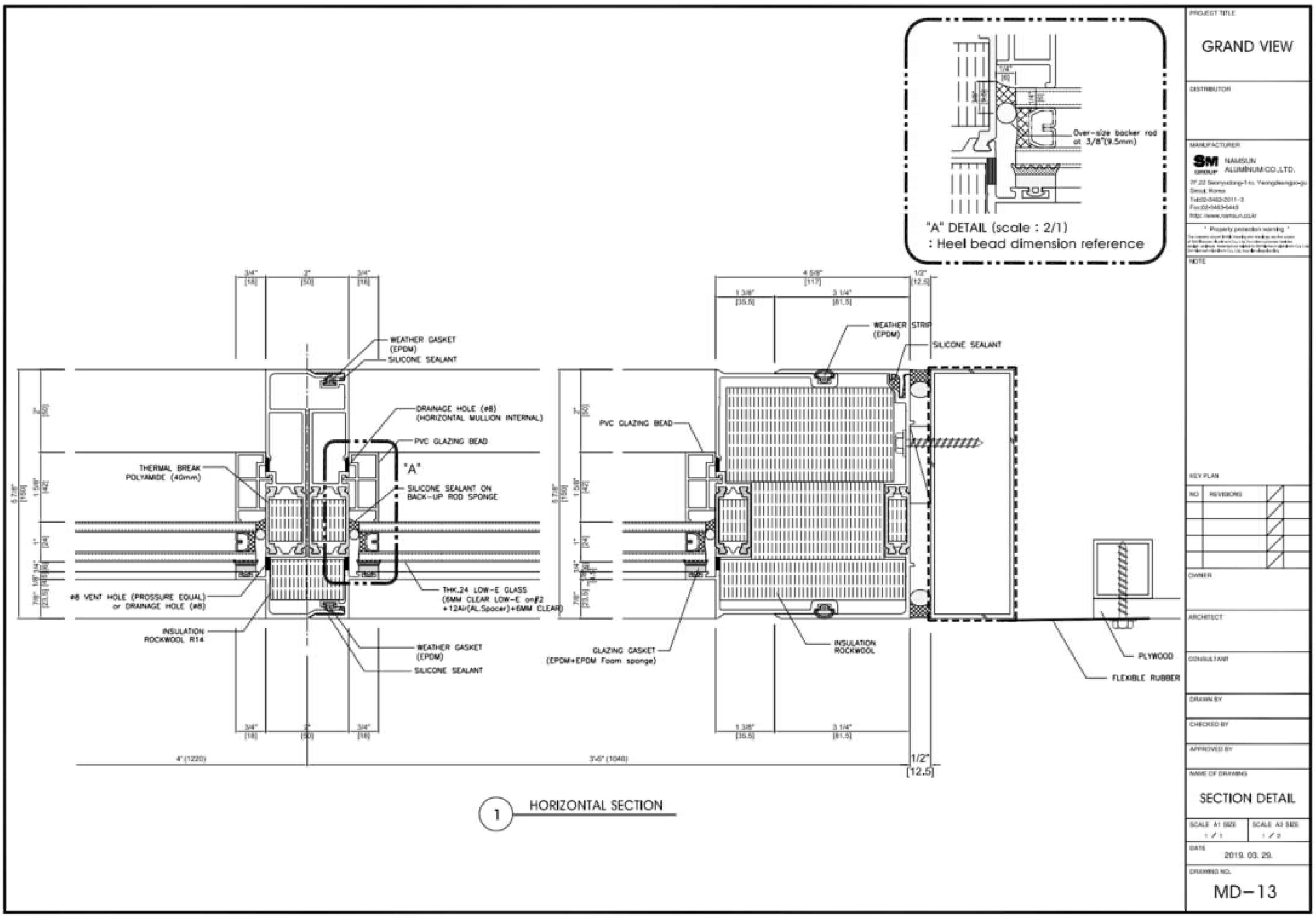
10-14. Detail



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11. Certification

KOREA LABORATORY ACCREDITATION SCHEME
KOLAS

No. 487 (1/2)

CERTIFICATE OF ACCREDITATION

Name of Laboratory : ATA

Representative : Kim, In Kon

Address of Headquarters : 172-30 Hwangnyongjae-ro Yeonsan-myun Nonsan-city Chungchongnam-do, Korea

Address of Laboratory : 172-30 Hwangnyongjae-ro Yeonsan-myun Nonsan-city Chungchongnam-do, Korea

Duration : July 20, 2015 ~ July 19, 2019

Scope of Accreditation
(Scope of Accreditation is described in the accompanying Annex)

This testing laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025 : 2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated 8 January 2009).

May 19, 2015

SEONG SI-HEON

Administrator,
Korea Laboratory Accreditation Scheme(KOLAS)

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No. 487 (2/2)

1. Mechanical Test

1.016 Construction and Material

Test method	Standard designation	Test range or Limits of detection
KS F 2292 : 2013	The method of air tightness for windows and doors	(0~100) Pa (0~250) m^3/h
KS F 2293 : 2008	Test method of water tightness for windows and doors	(50~750) Pa 4 $L/(m^2 \cdot min)$
KS F 2296 : 1999	Windows and door sets－Wind resistance test	(800~3 600) Pa (0.01~100) mm
ASTM E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen	(75~300) Pa (0~250) m^3/h
ASTM E330/E330M-14	Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference	(0.01~100) mm
ASTM E331-00	Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference	(300~720) Pa 3.4 $L/(m^2 \cdot min)$
ASTM E783-02	Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors	(75~300) Pa (0~250) m^3/h
ASTM E1105-00	Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference	(200~720) Pa 3.4 $L/(m^2 \cdot min)$

End.

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The "As Built" mock-up drawings and a copy of this report will be retained by ATA for a period of four years. This report is the exclusive property of the client so named herein and is applicable to the sample tested.
Results obtained are tested values and do not constitute an opinion or endorsement by this laboratory.

For ARCHITECTURAL TESTING ASIA, INC.

Architectural Testing Asia
Technician
Jangjun Han

Issue date : April 5th, 2019

Architectural Testing Asia
Technical Manager
Jingu Yu

Architectural Testing Asia
President
Inkon Kim

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

Appendix D

NFRC Modelling Report

NFRC Modelling Report
In Progress

Appendix E

Structural Review Report

Structural Review Report
In Progress