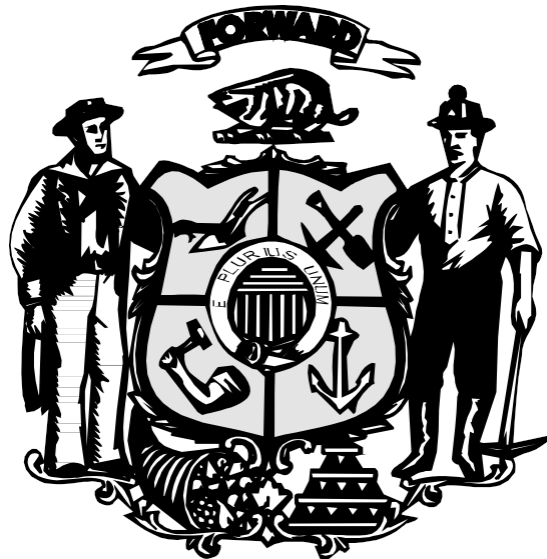


DESIGN REQUIREMENTS AND GUIDELINES FOR FENESTRATION IN BUILDING EXTERIOR ENCLOSURES

**STATE OF WISCONSIN
DEPARTMENT OF ADMINISTRATION**

DIVISION OF FACILITIES DEVELOPMENT & MANAGEMENT



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TABLE OF CONTENTS

SECTION ONE – INTRODUCTION	2
1.A Intent	2
1.B Purpose.....	2
1.C Application	2
1.D Organization & Use	2
1.E Updates	3
SECTION TWO - REQUIREMENTS CHECKLIST	4
2.A Project General Information.....	4
2.B Exterior Enclosure Criteria	4
2.C Commissioning of Fenestration Systems in the Building Exterior Enclosure.....	5
2.D Design.....	5
2.E Materials	7
2.F Installation	7
2.G Energy Efficiency.....	7
SECTION THREE - REQUIREMENTS COMMENTARY	8
Introduction	8
Definitions.....	8
General References.....	9
3.A Project General Information	10
3.B Exterior Enclosure Criteria	13
3.C Commissioning of Fenestration Systems in the Building Exterior Enclosure	15
3.D Design.....	19
3.E Materials.....	31
3.F Installation.....	36
3.G Energy Efficiency	38
SECTION FOUR - GUIDELINES.....	39
4.A Control Layer and Drainage Plane Guideline.....	39
4.B Window Performance Classification and Grade Guideline	41
4.C Prequalification of Fenestration Systems Guideline	43
SECTION FIVE - WAIVERS.....	45
5.A Waiver Requests	45
5.B Waiver Request Limitations.....	45
5.C Situation Examples for Waiver Requests.....	45
5.D Waiver Request Submittal.....	46
APPENDIX A – FENESTRATION CONTROL LAYER DIAGRAMS	47

SECTION ONE – INTRODUCTION

1.A Intent

Public institutions, by their very nature, are meant to be lasting endeavors for the public good. As a public sector entity, the State of Wisconsin plans and constructs for a term longer than that of the private sector. Because of this, the State recognizes the cost of operations and maintenance of a building can be just as important as the initial design and construction costs. To avoid wasting the initial building investment on an unmaintainable or energy inefficient building, the State of Wisconsin aims for buildings that are not only well designed for use and aesthetics, but also structurally sound, watertight, energy efficient, maintainable, and cost effective over the full life cycle of the building. This maximizing of return on investment requires careful planning and constructing, the use of time-tested and long-lived materials, products, and methods, and constructing in a manner that facilitates repair and cyclical maintenance.

1.B Purpose

A building's exterior enclosure separates the building interior environment from the exterior or outdoor environment. It consists of a number of systems, including roof/deck systems, soffitted floor and roof systems, exterior wall systems, foundation wall systems, and foundation slab systems. Fenestration systems are also an exterior enclosure system, but they are unique in that they can either be used in the exterior wall system as a subset of that system (a window in a wall) or as the system itself (curtain wall).

The *Design Requirements and Guidelines for Fenestration in the Building Exterior Enclosure* establish and communicate the expected quality and execution of design, construction, and performance to be achieved for the fenestration systems. They are an outgrowth of knowledge and experienced gained by the Division of Facilities Development & Management during the field review of building exterior enclosures as well as industry standards and best practices from leading design and construction industry and governmental sources. NOTE: This document is not a quality or regulatory standard that may be cited in the construction documents. The Architect/Engineer must actually consider, develop, verify, and include the specific requirements and criteria asked for in this document as part of their specific design and construction documentation.

The design requirements and guidelines are not all encompassing, but represent design, materials, techniques, and workmanship that have proven successful on building construction in the Upper Great Lakes region. They are not meant to stifle creativity or innovation. On the rare occasion where the Architect/Engineer, Client Agency, or DFDM Project Managers believe the design requirements and guidelines present a conflict, issue, or restriction, and they believe it appropriate, they may submit a written request for waiver of the specific requirement or time-in-use limitation as outlined in *Section Five - Waivers*.

1.C Application

The Requirements are to be complied with, as applicable, on all Wisconsin state-owned building projects, whether planned and developed directly by the state, as part of a third party or turnkey development, or as acquired by the state and now subject to work on the building.

1.D Organization & Use

This document is divided into five sections as outlined below:

Section One – Introduction & Application: This section introduces the guidelines and requirements for fenestration in the building exterior enclosure and explains their purpose and intent. This section also explains how to use this document.

Section Two - Requirements Checklist: Simply put, the checklist gathers and organizes information for the successful use of fenestration in the project. By being in the form of a checklist, it serves as a reminder to the Architect/Engineer as to what criteria to consider and what practices DFDM requires or prohibits in its buildings. It starts with the collecting of general project information, as it is this information that will guide the development of the entire project and not just that of the fenestration systems. It serves as a reminder that the fenestration systems must be compatible with the overall project, its goals, its design, and its construction. From there the checklist becomes more specific to the fenestration systems. It asks the Architect/Engineer to develop and identify the criteria for the design, fabrication, installation, and performance of the fenestration systems in light numerous factors, and to verify they are addressing DFDM required practices and avoiding discouraged practices:

- Their appropriateness and compatibility with the buildings structural, exterior enclosure systems.
- The expected performance requirements of the fenestration as installed in the exterior enclosure and how the meeting of those requirements will be verified.
- The expected aesthetic, performance, use, and reliability of the fenestration system itself.
- What general design and detail conditions are to be provided and what are to be avoided.
- The fenestration system materials and components.
- Their appropriateness and compatibility with the materials and practices used to flash, join, and seal them to the surrounding construction.
- What installation practices are to be provided and what practices are to be avoided.
- What energy efficiency practices or programs are involved.

As previously stated, these criteria and practices are not all inclusive and do not relieve the Architect/Engineer from developing and including additional criteria or practices. Rather, these are criteria and practices that DFDM has learned through prior experience need special attention to reduce problems with design, product selection, installation, performance, and maintenance. The checklist is a program aide or reminder to the Architect/Engineer when designing, specifying and detailing them, and when determining the manner of verifying their proper use and installation through product testing, installation mockups, and in-place testing. At each phase of the project the Architect/Engineer must review and verify that the work of the current phase does not conflict with or omit the established criteria and requirements incorporated the previous phases, nor with the longevity, quality, and performance requirements for the building in general and for the fenestration systems in particular.

It is important to note that not all items on the checklist are pertinent to every State project. On rare occasions, even the checklist itself may not be pertinent to a specific State project. Therefore, the first and most crucial step in the use of the checklist is it being edited by DFDM staff to make it project specific. Depending on the size, complexity, and nature of the project, the checklist may be edited with assistance from the Architect/Engineer and/or Client Agency, or other third parties as deemed necessary. Once the checklist has been edited, DFDM staff then issues it to the project Architect/Engineer and the Client Agency, making it a documented official project requirement.

Section Three – Requirements Commentary: Because the various items on the checklist may not be self-explanatory or the reason for their inclusion in the checklist may not be readily apparent, the *Requirements Commentary* section is provided. It follows the layout and numbering of the Requirements Checklist for easy reference. Its purpose is to explain and give insight as to why the requested information is needed and how it may impact the project. This will assist DFDM staff in determining what criteria and requirements may be pertinent to a project and it will assist the Architect/Engineer in making better-informed decisions regarding the design, selection, and installation of appropriate building fenestration. Where an explanation is simply too long for the commentary or contains additional information that may touch upon related topics, it has been incorporated into a guideline in *Section Four – Guidelines* and is referenced as such in the commentary.

Section Four - Guidelines: The guidelines are included to provide in-depth or additional explanation or background into pertinent topics encountered in the commentary. For those unfamiliar with the topics or wish to review their understanding, it is strongly recommended to review these guidelines.

Section Five - Waivers: As previously mentioned, the design requirements and guidelines are not meant to stifle creativity or innovation. Waiver Requests are a means for such conflict to be addressed. The Waivers section explains what a waiver is, who may submit one, and why and when a waiver may be appropriate. This section also provides examples of why waivers may be submitted and contains a copy of the waiver form itself.

1.E Updates

Updates to this document and other standards and guides may be found at the DFDM Master Specifications / Design Guidelines webpage, at <https://doa.wi.gov/Pages/DoingBusiness/MasterSpecsDesignGuide.aspx>. If there are questions on any portion of this document or a need to discuss its importance/relevancy, contact: Owen Landsverk, Engineering Specialist Management, by telephone: 608/266-1438, cell 608/575-6439, or via e-mail: owen.landsverk@wisconsin.gov.

Previous revisions: April 20, 2015; August 9, 2000; November 1997

SECTION TWO - REQUIREMENTS CHECKLIST

Instructions to the DFDM Project Manager: The Checklist is to be filled out by the DFDM Project Manager. Click on the shaded boxes and fill in the project identifying information below and then proceed to editing the Checklist. Please note that by default, all boxes are selected. Click on the checked box to uncheck it for those items not required for the project. Upon completion of the checklist editing, create a PDF copy of the document and forward copies to the Client Agency and the Architect/Engineer.

Instructions to the Architect/Engineer: Checked boxes indicate DFDM required information to be provided, criteria to be considered and developed as applicable, and practices to be adhered to or avoided as noted per section heading. They do not constitute all the information, criteria, or practices that may need to be gathered, developed, or established by the Architect/Engineer for the proper design and construction of the project. Items not checked merely indicate that DFDM does not require them, does not relieve the Architect/Engineer from pursuing them if they are required for the proper design and construction of the project.

Building Location/User Agency:

Building Or Project Name:

DFDM Project Number:

Date of Checklist Issuance:

DFDM Project Manager:

Is this project required to adhere to the Checklist requirements? Yes No

2.A Project General Information

A.1 BUILDING GENERAL INFORMATION

- A.1.a Required Lifespan Of Building:
- A.1.b Type Of Project:
- A.1.c Type(s) Of Construction Per IBC Chapter 6
 - 1) Existing Construction:
 - 2) New Construction:
- A.1.d Project Scale And Magnitude:

A.2 HISTORIC RESOURCE INFORMATION

- A.2.a How Project Involves An Historic Resource:
- A.2.b Type(s) Of Historic Resource(s) Involved:
- A.2.c Status Of Resource:
- A.2.d Level(s) Of Listing/Eligibility And Oversight Provider:
- A.2.e Designate Which Of The *Secretary Of The Interior's Standards For The Treatment Of Historic Properties* The Project Will Conform To:
- A.2.f Type Of Federal Involvement:
- A.2.g Indicate If Section 106 Review Is Required Per Appropriate Agency HPO:

2.B Exterior Enclosure Criteria

B.1 STRUCTURAL DESIGN CRITERIA:

- B.1.a Project established or mandated wind speed:
- B.1.b Importance factor of wind load:
- B.1.c Project exposure category:
- B.1.d Wind loads on frame:
- B.1.e Wind loads on cladding for each tributary area:
- B.1.f Seismic Performance Category and Components Performance Criteria Factor:
- B.1.g Movement limiting design criteria:
- B.1.h Deflection control limits:

- B.1.i Inter-story and total height drift limits:

B.2 ENVIRONMENTAL DESIGN CRITERIA:

- B.2.a Seasonal interior and exterior Design Temperatures:
- B.2.b Seasonal interior and exterior Relative Humidity levels:

B.3 CONTROL LAYER PERFORMANCE AND DESIGN CRITERIA:

- B.3.a Water Control Layer:
- B.3.b Air Control Layer:
- B.3.c Thermal Control Layer:
- B.3.d Vapor Control Layer:

B.4 EXTERIOR ENCLOSURE WALL SYSTEM DESCRIPTIONS

- B.4.a Type Of Wall System:
- B.3.b Exterior Enclosure Wall System Materials List
- B.4.c Descriptive Full Height Exterior Enclosure Wall Sections

2.C Commissioning of Fenestration Systems in the Building Exterior Enclosure

C.1 COMMISSIONING STANDARDS AND GUIDELINES

- C.1.a Commissioning Standards And Guidelines To Be Used:

C.2 TEST STANDARDS

- C.2.a Fenestration Product Rating Standards/Lab Performance Test Standards:
- C.2.b Fenestration Installation Test Standards:
- C.2.c Forensic Test Standards:
- C.2.d Building Envelope Test Standards:

C.3 LEVEL OF COMMISSIONING:

- C.3.a Level of Commissioning To Be Performed:

C.4 MINIMUM REQUIRED COMMISSIONING ACTIVITIES FOR FENESTRATION SYSTEMS:

- C.4.a Pre-Design Phase Primary Activities:
- C.4.b Design Phase Primary Activities:
- C.4.c Construction Phase Primary Activities:

2.D Design

D.1 FENESTRATION SYSTEM CRITERIA TO BE PROVIDED

- D.1.a Aesthetic Criteria:
- D.1.b Fenestration Performance Criteria:
- D.1.c Functional Criteria:
- D.1.d Finish Criteria:
- D.1.e Reliability Criteria:
- D.1.f Delegated Design Criteria:

D.2 GENERAL DESIGN TO BE PROVIDED

- D.2.a Incorporation Of Owner's Project Requirements (OPR)
- D.2.b Establish Minimum Window Performance Class And Grade
- D.2.c Extension Of Design Requirements To Nontraditional Components Of Fenestration System
- D.2.d Fenestration Located And Placed To Readily Accommodate Regular Maintenance
- D.2.e Selection Of Appropriate Fenestration System For Each Application
- D.2.f Fenestration System From Manufacturer's Standard Or Modified-Standard Products With Proven Track Record
- D.2.g Appropriate Fabrication Techniques Of Fenestration Systems Outlined
- D.2.h Selection Of Fenestration Systems With Frame Profiles Conducive To Proper Perimeter Sealant Joint Geometry
- D.2.i Future Maintenance And Replacement Capacity

- D.2.j Glass Installation And Glazing Methods To Facilitate The Replacement Of Glass
- D.2.k Fenestration Systems To Facilitate Replacement Of Sealants
- D.2.l Weatherstripping System To Facilitate The Replacement Of Weatherstripping
- D.2.m Verification Of Compatibility Of Building Exterior Enclosure Materials, Products, And Finishes
- D.2.n Thermal Breaks and Barriers Within Elements
- D.2.o Fenestration System Control Layers and Drainage Plane Identification, Location, And Coordination
- D.2.p Control Layers And Drainage Plane Continuity Verification
- D.2.q Coordination Of Required Raceways In Storefront And Curtain Wall Systems
- D.2.r Perform Required Level 2 Commissioning Design Phase Activities
- D.2.s Establish Specification Gateway Requirements For Manufacturers/Products
- D.2.t Establish Bidding Criteria And, Where Approved, Prequalification Criteria And Procedures
- D.2.u Establish Required Guarantees From Fenestration System Manufacturers And Installers

D.3 DESIGN DETAILS TO BE PROVIDED WHERE APPLICABLE

- D.3.a Structural Calculations
- D.3.b Anchorage Materials And Methods With Avoidance Of Anchorage Penetrations Through Sill And Sill Pan Flashing
- D.3.c Provision For Differential Movement Between Building And Fenestration
- D.3.d Permanent Closing And Sealing Of Wall Cavity Openings Along With Proper Termination Of Control Layers At Openings And Prior To Fenestration System Installation
- D.3.e Detail the Continuity Of Building Exterior Enclosure Control Layers Between Wall Systems And Fenestration Systems
 - 1) At inboard set fenestration:
 - 2) At outboard set fenestration:
- D.3.f Head, Jamb, Mullion, And Sill Details
- D.3.g Sequential Details Of Flashing Of Fenestration Drainage Plane Into Exterior Wall Drainage Plane
- D.3.h Provide Properly Sloped And Terminated Through-Wall Flashing At Window Heads And Sills
- D.3.i Proper Insulation Of Curtain Wall Spandrel Panels
- D.3.j Isolation Of Fenestration Systems From Parapet And Roofing Systems
- D.3.k Isolation Of Fenestration Systems From Interior Wall And Ceiling Materials
- D.3.l Sealant Geometry And Detail Review and Verification
- D.3.m Glass Installation Review And Verification
- D.3.o Glazing Materials And Replacement Procedures Provided In The Project O&M Manuals
- D.3.p Hardware Options With Respect To Entrance Doors
- D.3.q Hardware Requirements With Respect To Operating Vents Within Fenestration Systems
- D.3.r Proper Fabrication And Installation Of Receptor Frames Where Used
- D.3.s Detailing For Miscellaneous Non-Typical Fenestration Or Fenestration Opening Conditions

D.4 DESIGN CONDITIONS AND DETAILS TO BE AVOIDED

- D.4.a Exterior Fenestration Sills Projecting Into The Interior Air Space Or Bridging Control Barriers Of The Exterior Enclosure Systems
- D.4.b Single Lines Of Sealants As The Sole Means Of Preventing Water Penetration
- D.4.c Noncontinuous Water, Air, Vapor, And Thermal Control Layers
- D.4.d Noncontinuous Thermal Break In Fenestration Systems
- D.4.e Thermally Unbroken Through-Wall Metal Flashing Exposed To The Interior
- D.4.f Exposed Splices And Joints In Receptor Framing Elements
- D.4.g Concealed Overhead Closers For Doors
- D.4.h Single Pane Glazing And Glass Spandrel Panels
- D.4.i Four-Sided Field Structural Glazing
- D.4.j Blind Seals
- D.4.k Glazing Without Weeps
- D.4.l Dissimilar Metals In Direct Contact Or In Contact Formed By Standing Water
- D.4.m More Noble/Cathodic Metals Upstream Of Or Able To Splash On Less Noble/More Anodic Metals
- D.4.n Glazing Sills Less than 18" Above Grade
- D.4.o Specified Acceptable Manufacturers/Products Not Compatible With Specified Gateway Requirements

2.E Materials

E.1 FENESTRATION COMPONENTS

- E.1.a Receptor Frames, where applicable:
- E.1.b Frame Type, Material, Construction:
- E.1.c Finishes:
- E.1.d Glass and Glazing:
- E.1.e Hardware
 - 1) Fenestration Hardware:
 - 2) Entry and Door Hardware:

E.2 FLASHING SYSTEMS

- E.2.a Flashing Systems (Flashing Material And Additional Installation Materials):

E.3 SEALANTS

- E.3.a Types Of Joints, Widths, And Movement:
- E.3.b Material Compatibility And Testing:
- E.3.c Sealant Systems (Sealants And Additional Materials):
- E.3.d Surface Preparation And Field Adhesion Testing:

2.F Installation

F.1 INSTALLATION PRACTICES TO BE PROVIDED

- F.1.a Roles Of Fenestration Manufacturer And Approved Installer Defined
- F.1.b Reference Manufacturer Installation Instructions, Industry Training, And Installation Programs (ASTM E2112, AAMA InstallationMasters, AAMA Commercial Training Manual)
- F.1.c Rough Opening Preparation
- F.1.d Proper Preparation or Termination of Flashing and Control Layers
- F.1.e Perform Sealant Pull Testing Prior To Installation And Then As Random Verification During Installation
- F.1.f Perform Minimum Required Level 2 Commissioning Construction Phase Tasks

F.2 INSTALLATION PRACTICES TO BE AVOIDED

- F.2.a Proceeding With Installation Without Satisfactorily Reviewed Submittals, Mockups, And Successful Field Performance Testing
- F.2.b Out of Sequence Installation Of Fenestration Systems
- F.2.c Puncturing Of Flashing
- F.2.d Field Modification of Prefabricated Sill Flashing Or Receptor Frames
- F.2.e Overlapping Flashings Upstream
- F.2.f Anchorage By Other Than Approved Fenestration Installer
- F.2.g Use Of Fiberglass Insulation As Fire Safing, Air Barrier, Or Vapor Retarder

2.G Energy Efficiency

G.1 ENERGY EFFICIENCY PRACTICES TO BE PROVIDED

- G.1.a Indicate energy efficiency practices to be provided as they relate to fenestration systems:

G.2 ENERGY EFFICIENCY PROGRAMS TO BE CONSIDERED

- G.2.a Indicate what third party energy efficiency programs are to considered or included in the project:

SECTION THREE - REQUIREMENTS COMMENTARY

Introduction

This commentary provides background and support information for the making of more knowledgeable decisions regarding the use of fenestration systems in the building exterior enclosures of state construction projects. Be it new construction, alterations or additions to existing construction, or the maintenance and repair of existing structures, the commentary addresses the place of fenestration in the design and performance of the building. It addresses their design as a system, their selection, their installation, and the proper use of flashing materials and sealants. It explains the need for and use of mockups and testing for the verification of product performance claims, proper detailing, and successful installation.

As outlined in *Section One - Introduction*, the underlying premise of this document is to highlight those performance longevity decisions and practices that either work well and should be included or at least noted, or work poorly and should be avoided and excluded. This commentary on the Requirements for Fenestration in the Building Exterior Enclosure is intended to portray the leading-edge-of-technology knowledge.

All information contained in the requirements, the commentary, and the guidelines will be periodically reviewed and updated as additional facts and industry advances become available.

Definitions

Clerestory: An exterior building assembly, rising above adjacent rooftops either as the upper portion of a façade or as an independent element within the field of a roof, and having vertical glazing with a roof assembly. It is used for the purposes of admitting daylight to the building interior.

Curtain Wall: A multistory exterior building wall framework assembly carrying no floor or roof loads and consisting of metal, glass, and other surfacing materials, and extending continuously *beyond* the outside edges of the floor and roof slabs. The curtain wall can represent a portion of the exterior enclosure of a building, or the entire exterior enclosure of the building itself.

Delegated Design: The transferred design duties and responsibilities from a building Architect/Engineer to the manufacturer of a predesigned and prefabricated complete fenestration system (e.g. windows and doors) or a predesigned component-based fenestration system assembled on or off-site (e.g. storefront and curtain wall systems). While the building Architect/Engineer is responsible for establishing the design and performance criteria and for reviewing the manufacturer's submitted design calculations for conformance with the established criteria, the actual design of the system to those criteria is the duty, responsibility, and liability of the manufacturer.

Entrance Doors: Entrance doors, when part of a fenestration system, are generally incorporated into a Storefront system. Typically consisting of stile and rail glazed doors, they can also include flush doors, balanced doors, sliding or automatic entrance doors, and revolving doors.

Exterior Enclosure: Also known as a building envelope, a building's exterior enclosure consists all the enclosure system between the enclosed interior spaces and the exposed exterior. Typically this includes roof and exposed deck systems, soffitted floor and roof systems, exterior walls, fenestration systems, foundation walls, and foundation slabs. For the purposes of this document, Exterior Enclosure primarily means the exterior walls and the fenestration therein.

Fenestration: Within the extents of this document, 'fenestration' collectively means curtain wall, ribbon window, storefront, window, and window wall.

Fenestration System: Represents the compilation of fenestration, its anchorage, and the associated flashings, sealants, and related materials used for a secure and weather-tight installation. Additional items such as permanently attached exterior screening devices, shading devices, and light shelves are considered part of the fenestration system if they are integrated into and supported by the fenestration system.

Punched Opening: The setting of fenestration within the thickness of a wall assembly and not projecting beyond the plane of either the interior or exterior face of the wall.

Ribbon Window: Also known as a ‘strip’ window, it is generally either a series of windows ganged together or a variation of storefront windows assembled in a ribbon. The ribbon may extend horizontally or vertically in specially framed openings to continue uninterrupted before or behind the wall structure. Because of thermal expansion of metal ribbon windows, and/or the need to accommodate building movement, ribbon windows typically require the use of separate receptor frames or channels set in the framed opening to allow the window assembly to move independently of the wall.

Skylight: An exterior building assembly rising above adjacent rooftops and having sloped or sloped and vertical with glazing and no roof assembly. It is used for the purpose of admitting daylight to the building interior.

Storefront: A glazed exterior building wall assembly typically of metal framing, fixed glass, and other surfacing materials, which forms a continuous glazed area carrying no floor or roof, loads. It is typically located at the ground level (from which it derives its name) and limited to a single vertical span within either a framed opening or between the outside edges of floor and roof slabs.

Window: A pre-manufactured complete individual assembly traditionally of wood, metal, or metal or vinyl clad wood, and glass set in an exterior wall opening to admit light and/or air. The units must be structurally framed around, as the frame of the unit only supports the unit itself and carries no floor or roof loads. Windows may be fixed or operable units, and may be field or factory joined or ‘ganged’ together to form an individual assembly of multiple units. Ganged together units may require additional integral support between ganged mullions, headers, or sills to resist wind loads across the face of the assembly or even the weight of the assembly itself.

Window Wall: A single story exterior building wall framework assembly consisting of wood and or metal, glass, and other surfacing materials an *between* the outside edges of the floor slabs or roof slab. The window wall represents a portion of the exterior façade of a building, but as it extends only between slabs, it usually does not constitute the entire façade itself.

General References

“WBDG Whole Building Design Guide, a Program of the National Institute of Building Sciences,” last accessed August 4, 2015, <https://www.wbdg.org/design/envelope.php>

“Building Science Corporation,” last accessed August 4, 2015, <http://www.buildingscience.com>

NISTIR 2841 *Envelope Design Guidelines for Federal Office Buildings: Thermal Integrity and Airtightness*, National Institute of Standards and Technology, March 1993.
Building Sciences Inc.

3.A Project General Information

Fenestration, as part of a building's exterior enclosure, must be capable of responding to many of the same conditions and fulfilling many of the same requirements as other elements of the building in general and the exterior enclosure in particular. For this reason it is important to gather and know the general project information which will impact the design and selection of fenestration for the project. Provide the following General Project Information where applicable.

3.A.1 BUILDING GENERAL INFORMATION

3.A.1.a Intended Lifespan of Building:

- Long Term (>75 years)
- Mid Term (25-75 years)
- Short Term (<25 years)

Designing and building to meet the intended lifespan of a building requires the building assembly and incorporated products to provide the maximum benefit and return on initial investment for the intended life of the building. It may also justify the raising or lowering of product quality levels as well as the acceptability of costs for the customization of fenestration, finishes, and the glass and glazing techniques used.

3.A.1.b Type Of Project:

- New Construction
- Addition to Existing Construction
- Alteration of Existing Construction
- Existing Construction Maintenance/Repair

With new construction the Architect/Engineer can address the entire assembly and installation. However with existing construction, limitations such as fitting into an existing opening or the existing construction itself may limit the fenestration products under consideration as well as dictate specific installation practices. Attachment design and the flashing and sealing of the fenestration openings may be limited or require ingenuity to find alternative methods to achieve the same goals. Knowing if fenestration must match existing because the project is an addition, historically designated, or partial maintenance replacement requires a different selection and design approach than that of new construction.

3.A.1.c Type(s) Of Construction Per IBC Chapter 6

- Existing construction:
- New construction:

As with type of project, the type of construction will directly impact the selection and detailing of the installation. Placement and attachment methods vary greatly between Type 1A, Type 3, and Type 5 construction. Building movement and long term deformation due to concrete creep, wood shrinkage, or even movement between wall cladding and the backup structure will impact the fenestration systems.

3.A.1.d Project Scale And Magnitude:

- Area:
- Height:
- Number of Floors:
- Area of each Elevation:

Project scale and magnitude affect the economy of the project and help inform the Architect/Engineer as to fenestration cost impact on the budget. They also play a pivotal role in decisions related to the use of multiple fenestration systems, unique sizes, changes in grade/quality, or customizations of systems and their components.

3.A.2 HISTORIC RESOURCE INFORMATION

Projects may involve historic properties - structures or landscapes that have been or may be eligible for historic status. Such listed or eligible to be listed properties are sensitive projects and must be approached with the objective of helping to preserve the property for future generations as part of their continued use or reuse. They are typically required to maintain their historic character and their original or existing construction. Fenestration is an important

element in historic structures. In-kind repairs of original/existing fenestration are heavily encouraged over in-kind replacement. Preservation ordinances and preservation commissions often extensively limit its replacement with new products or construction, even if it has matching trim profiles. Understanding how a building is an historic resource, who has jurisdiction over it, and which of the *Secretary of the Interiors Guidelines for the Treatment of Historic Structures* will direct and inform the design and construction work are pivotal to a smooth and successful project.

Federal law requires each state to establish a Historic Preservation Office and a Historic Preservation Officer (SHPO) for the purposes of coordinating federal preservation laws and programs within each state. Chapter 44 of the Wisconsin Statutes establishes this office and the SHPO and also establishes the state statutes for historic preservation in Wisconsin. In Wisconsin, the SHPO is attached to the Historic Preservation Office of the Wisconsin Historical Society (WHS), attached to the University of Wisconsin, Madison.

To insure that all state agencies and political subdivisions comply with the state preservation statutes, state agencies and political subdivisions (counties, municipalities, etc.) are required to submit all projects affecting State or National Registers of Historic Places listed properties for review by the SHPO. The review is to determine what, if any, adverse affects a project will have on the listed property. The SHPO has authority to negotiate with any state agency or political subdivision for a reduction of a project's determined adverse affects in order to permit the project to proceed.

Additional information about the Historic Preservation Office can be found at: <http://www.wisconsinhistory.org/> and about SHPO Reviews at: <http://www.wisconsinhistory.org/Content.aspx?dsNav=N:1200>

Provide the following information about the project where it involves an historic resource:

3.A.2.a How Project Involves An Historic Resource:

Indicate if the project is a historic property, if it impacts another historic property, or is impacted by a historic property.

3.A.2.b Type(s) Of Historic Resource(s) Involved:

Indicate which of the following types of historic resources are involved in the project:

- Building or Structure
- Designed or Rural Historic Landscape
- Historic Site
- Historic District

3.A.2.c Status Of Resource:

Indicate if the historic resource involved is:

- Listed (on the State and/or National Registers of Historic Places)
- Eligible for Listing (on the State and/or National Registers of Historic Places)
- Contributing (to a Designated or Rural Historic Landscape, Site, or District)
- Non-contributing (to a Designated or Rural Historic Landscape, Site, or District)

3.A.2.d Level(s) Of Listing/Eligibility And Oversight Provider:

Indicate at what level the historic resource designation is managed:

- Local (Zoning Overlay): local Zoning or Historic Preservation Commission
- State Register: Wisconsin Historical Society - State Historic Preservation Officer (SHPO)
- National Register: National Parks Service, SHPO as local intermediary
- National Historic Landmark: National Parks Service, SHPO as local intermediary
- Tribal Historic Resource on State or National Registers or National Historic Landmark – Tribal Historic Preservation Officer (THPO)

3.A.2.e Designate Which of The Secretary of The Interior's Standards for The Treatment of Historic Properties The Project Will Conform To:

To standardize and coordinate the approach to the treatment of historic properties, the Secretary of the Interior issued four distinct standards that are overseen by the National Parks Service (NPS), which is under the direction of the Department of the Interior. As defined by the NPS on their website, the four standards are explained as follows:

1. **Preservation** focuses on the maintenance and repair of existing historic materials and retention of a property's form as it has evolved over time.
2. **Rehabilitation** acknowledges the need to alter or add to a historic property to meet continuing or changing uses while retaining the property's historic character.
3. **Restoration** depicts a property at a particular period of time in its history, while removing evidence of other periods.
4. **Reconstruction** re-creates vanished or non-surviving portions of a property for interpretive purposes.

For each of these standards, the National Parks Service established a corresponding advisory guideline of practices. The selection of which standard and subsequent guideline to follow is an important decision in the life of the project as it provides a conceptual and philosophical framework that will influence the design process and outcome of the project. For this reason it is strongly recommended that a historic preservation consultant be included as part of any team dealing with historic resources. Additional information regarding the standards and guidelines, considerations in selecting the appropriate standard, as well as technical guidelines can be found at:

<http://www.nps.gov/tps/standards.htm>

3.A.2.f Type Of Federal Involvement:

Federal involvement in a project can add an extra layer of investigation and oversight for projects involving historic properties. As mandated by Section 110 of the National Historic Preservation Act, the federal government must integrate historic preservation into all agency programs. As part of this, per the Code of Federal Regulations Title 36 Chapter VIII, Section 106, a review (commonly known as a Section 106 Review) must be performed on all federally funded projects that involve historic properties to identify how the project will impact the historic property and consider the consequence of these impacts. It also allows for commentary on the project by the federal Advisory Council on Historic Preservation. While this review and commentary cannot mandate changes to a project, it does ensure that preservation concerns are factored into the federal government's decision making and ultimately makes the federal government responsible to the public. Failure to perform a required Section 106 Review can result in the shutting down of project and/or the loss of federal funding. Indicate which of the following types of federal involvement are involved in the project:

- 1) Financed in part with federal funds, grants, or loans.
- 2) The property is federally owned or controlled.
- 3) Property is part of tribal lands or will impact a tribal historic property not part of tribal lands.
- 4) Project requires federal permit, license, or approval.
- 5) There is no federal or tribal involvement.

3.A.2.g Indicate If Section 106 Review Is Required Per Appropriate Agency HPO:

As the designated local representative of Department of the Interior's National Park Service, the SHPO or, if involving tribal lands or tribal historic resources, the THPO generally determines the need for the review. For projects with federal involvement, a Section 106 Review may be required. Consult with the appropriate involved agency HPO, in writing, to determine if a Section 106 Review is required for the project.

3.B Exterior Enclosure Criteria

As part of the building's exterior enclosure, the fenestration systems must be compatible and compliant with the various exterior enclosure criteria. In general, exterior enclosure criteria need to be mostly established prior to establishing the fenestration system criteria, but still in progress given that the fenestration criteria is a subset of the exterior enclosure criteria and it may also impact other exterior enclosure criteria. Fenestration systems must be designed to the same wind speeds and loads as the adjacent exterior wall. And while fenestration can not equal the thermal qualities of an R-30 wall, if there is extensive fenestration, the walls may need to be increased to R-35 to compensate.

Provide the following criteria, where applicable, and any additional criteria not listed below:

3.B.1 STRUCTURAL DESIGN CRITERIA

- a) Project established or mandated wind speed:
- b) Importance factor of wind load:
- c) Project exposure category:
- d) Wind loads on frame:
- e) Wind loads on cladding for each tributary area:
- f) Seismic Performance Category and Components Performance Criteria Factor:
- g) Movement limiting design criteria:
- h) Deflection control limits:
- i) Inter-story and total height drift limits:

3.B.2 ENVIRONMENTAL DESIGN CRITERIA

- a) Seasonal interior and exterior Design Temperatures:
- b) Seasonal interior and exterior Relative Humidity levels:

3.B.3 CONTROL LAYER PERFORMANCE AND DESIGN CRITERIA

Control layers are those layers that 'control' specific environmental qualities in the exterior enclosure for the purposes of improved interior environmental control, greater energy efficiency, and the long-term maintenance and performance of the exterior enclosure. Exterior enclosure control layers have corresponding counterparts in the fenestration systems and should be coordinated and connected. For additional information, see the *Control Layer and Drainage Plane Guideline* in *Section Four - Guidelines*. Provide performance and design criteria for the following:

- a) Water Control Layer:
- b) Air Control Layer:
- c) Thermal Control Layer:
- d) Vapor Control Layer:

3.B.4 EXTERIOR ENCLOSURE WALL SYSTEM DESCRIPTIONS

Description of each wall system used in the exterior enclosure:

3.B.4.a Type Of Wall System:

- Mass/storage wall system – one that is able to absorb and gradually release an amount of water that is usually greater than what is normal for local weather events. Thick load bearing masonry walls are one such example.
- Barrier wall system – uses an impermeable cladding or finish to prevent exterior moisture intrusion.
- Drain-screened wall system
 - Diffusion vented – a wall assembly where the inherent construction and construction tolerances permit passive venting between gaps within the water control layer materials as well as between it and the drainage plane.
 - Ventilated – a wall assembly with a designed continuous venting space between the water control layer and the water control layer.
 - Pressure equalized – a wall assembly with a designed continuous venting space between the water control layer and the water control layer that is vented and divided or baffled into individual compartments so as to prevent or minimize pressure differentials between the vented space and the exterior.

3.B.3.b Exterior Enclosure Wall System Materials List

Provide a list of materials used in each type of wall system, including those of the control layers, flashings, and sealants. Do not include fenestration system materials as they will be collected and described separately further below.

3.B.4.c Descriptive Full Height Exterior Enclosure Wall Sections

For the drainage plane and the four control layers to be effective, they must be continuous from roof to foundation. The following tests are important exercises to verify this continuity through all wall conditions prior to the introduction of fenestration. Following the introduction of fenestration, the exercises are repeated to verify that all transitions between the corresponding drainage plane and control layers of the wall and those of the fenestration have been resolved. See the *Control Layer and Drainage Plane Guideline* for additional information.

Provide full height exterior enclosure wall sections through each unique wall condition in large enough scale to illustrate and describe each material in the assembly and to perform the following design verification tests:

- **Control Layer Continuity Test:** For each of the four control layers, starting at the top of the wall and its intersection with the roof, identify in a different contrasting color each of the control layers, uninterrupted down the full height of the wall to the foundation. Provide details for all changes in materials and overlaps along the path of the control layers. Indicate when and where two or more control layers are combined into a single multipurpose control layer and describe the performance of that combined layer to verify it performs all of the functions of each of the individual layers it combines. If details or sections of the control layer planes are not represented, accounted for, or detailed, do so in order to successfully complete the test.
- **Drainage Plane Continuity Test:** Starting at the top of the wall and its intersection with the roof and continuing down to the foundation, identify in a contrasting color the uninterrupted drainage plane, following it down to where it is flashed and wept to the exterior face at various locations. Provide details for all changes in materials and overlaps along the path of the drainage plane. If details or sections of the drainage plane are not represented, accounted for, or detailed, do so in order to successfully complete the test.

3.C Commissioning of Fenestration Systems in the Building Exterior Enclosure

Note: As standards and guidelines are updated periodically, the standards and guidelines listed below should always be verified with their issuing authority to insure the most current version is cited and used.

3.C.1 COMMISSIONING STANDARDS AND GUIDELINES

3.C.1.a Commissioning Standards And Guidelines:

The following serve as guidelines for the commissioning of fenestration systems in building exterior enclosures:

- ASHRAE Guide 0-2013
- ASTM E2947-14 Standard Guide for Building Enclosure Commissioning
- ASTM E2813-12 Standard Practice for Building Enclosure Commissioning

Note: NIBS GL3-2012 Building Enclosure Commissioning Process has been withdrawn following issuance of ASTM E2947-14.

3.C.2 TEST STANDARDS

Commissioning of the building exterior enclosure in general and the commissioning of exterior enclosure fenestration systems are subject to testing for the verification of the manufacturer's product performance claims, for installation conformance with the construction documents, and for conformance to the building environmental design performance. The following is not an all-inclusive list, but represents typical industry standards and tests used for the commissioning of fenestration.

3.C.2.a Fenestration Product Rating Standards/Lab Performance Test Standards:

- AAMA 1503-09 Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazes Wall Sections
- AAMA 1504-97 Voluntary Standard for Thermal Performance of Windows, Doors and Glazed Wall Sections
- ASTM E283-04(2012) Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtin Walls, and Doors Under Specified Pressure Differences Across the Specimen
- ASTM E330/E330M-14 Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference
- ASTM E331-00(2009) Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
- ASTM E1425-14 Standard Practice for Determining the Acoustical Performance of Windows, Doors, Skylight, and Glazed Wall Systems
- ASTM E2319-04(2011) Standard Test Method for Determining Air Flow Through the Face and Sides of Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
- ASTM F1642-12 Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings
- GSA-TS01-2003 – Explosive Testing Standards for Window Systems

3.C.2.b Fenestration Installation Test Standards:

- AAMA 501.2-09 Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Wall, and Sloped Glazing Systems. Fixed joints only.
- AAMA 502-12 Voluntary Specification for Field Testing of Newly Installed Fenestration Products. Window Units only. Air infiltration and water penetration testing.
- AAMA 503-14 Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems. Air infiltration and water penetration testing.
- ASTM E783-02(2010) Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors.
- WK27894 Revision of E1105 – 00(2008) 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 - Note: 1/3 pressure reduction in tests is NOT permitted by DFDM.

3.C.2.c Forensic Testing:

- AAMA 511-08 Voluntary Specification for Forensic Water Penetration Water Testing of Fenestration Products

3.C.2.d Building Envelope Test Standards:

- ASTM E547-00(2007) Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference
- ASTM E779-10 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
- ASTM E783-02(2010) Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
- ASTM E1186-03(2009) Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
- ASTM E1827-11 Standard Test Methods for Determining Air Tightness of Buildings Using an Orifice Blower Door
- ASTM E2128-12 Standard Guide for Evaluating Leakage of Building Walls
- ASTM E2357-11 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies

3.C.3 LEVEL OF COMMISSIONING

3.C.3.a Level OF Commissioning To Be Performed:

Per the DFDM *Policy & Procedure Manual for Architects/Engineers and Consultants*, required project commissioning is performed at one of two levels of intensity:

- Level 1 Commissioning is typically performed by the Architect/Engineer and is provided as basic service on projects of moderate complexity or limited scope under the DFDM *Contract for Professional Services* (DOA 4519P), Articles 2.A.1 and 2. D.9. With regard to commissioning related activities, these articles require that:
 - “The A/E shall review the project program, plans and specifications of record, (to the extent that such documents are reasonably available), and applicable DFDM standards and guides or other written direction by DFDM. The A/E shall establish the limiting parameters of the design as defined by the instructions issued to it by DFDM, to determine if the design concept is achievable within the schedule and budget proposed by DFDM.”
 - “As part of the Substantial Completion verification, the A/E shall perform or witness and document functional testing and review the testing and balance report prepared by others for all plumbing, HVAC, fire protection and electrical systems to verify installation and operation meet the intent of their design. The A/E shall forward the results of the functional testing and provide written recommendations for corrective measures where systems do not meet the intent of their design.”
 - Services beyond the basic Level 1 Commissioning may also be included as part of the project’s request for services issued by DFDM.
- Level 2 Commissioning an elevation level of commissioning often reserved for more complex and larger projects. The commissioning can be performed by the Architect/Engineer, but is typically performed by an independent third party. In addition to all of the Level 1 Commissioning activities, Level 2 Commissioning can also include the commissioning of additional important systems such as life safety, environmental systems, and the building’s exterior enclosure, which by default include the fenestration in that exterior enclosure. Level 2 Commissioning is also more rigorous in its reviews, testing, and documentation. Per the DFDM *Policy & Procedure Manual for Architects/Engineers*, the commissioning provider (CxP) activities and documentation include “CxP review basis of design/design concept, a formal Commissioning Plan and Log, oversight of Agency training, a Substantial Completion review meeting and a Commissioning Report.” The CxP is also responsible for periodically observing construction for conformance with the Construction Verification Checklists included in each specification divisions commissioning section. They also track, review, and comment on the completed checklists submitted by the contractor.

See the DFDM *Policy & Procedure Manual for Architects/Engineers and Consultants* for additional information and the specific requirements of each level of commissioning.

3.C.4 MINIMUM REQUIRED COMMISSIONING ACTIVITIES FOR FENESTRATION SYSTEMS

Proper selection and installation of fenestration in the exterior enclosure of a building is critical to the performance and longevity of the wall system, the exterior enclosure of the building, and the overall performance of the building. Water infiltration can lead to damage and reduced longevity of the enclosure while air infiltration can lead to

inefficient and costly use of HVAC. For this reason, whether the project is subject to Level 2 Commissioning, the Architect/Engineer and DFDM Project Manager shall confer to determine which of the following select Level 2 Commissioning activities are appropriate for the commissioning of the project's fenestration systems:

3.C.4.a Pre-Design Phase Primary Activities:

- 1) Development and Review of Owner's Project Requirements (OPR) based on the Requirements for Fenestration Systems in Building Exterior Enclosures and project specific Owner Requirements.

3.C.4.b Design Phase Primary Activities:

- 1) Review of OPR (or Program if a formal OPR does not exist) with owner, design team, and Building Envelope Commissioning Provider (BECxP) to initiate the start of the Design Phase.
- 2) Development of fenestration system Basis of Design (BOD) by A/E and its review by DFDM, Client Agency, and BECxP.
- 3) Establishment of Fenestration System Design Criteria.
- 4) Preliminary and Final Design Reviews of proposed fenestration systems, products, and construction documents (drawings and specifications) by DFDM, Client Agency, and BECxP.
- 5) Perform Product and Design Concept Testing:
 - a. Product Conformance to AAMA Standards Testing - Lab based testing and certification of manufacturer's standard or modified-standard fenestration product(s) for conformance with AAMA standards and specifications for strength, product classification and grade, thermal performance, air infiltration, water penetration, and finish durability and performance (where applicable).
 - b. Proof of Design Concept Performance Testing – Full-scale installation mockup subjected to functional performance testing to verify validity of design concept. Observation of tests by BECxP, A/E, and DFDM. Recommended for fenestration installations with difficult to resolve design issues or difficult to meet performance requirements.
- 6) Develop submittals and shop drawing lists, requirements, and protocols. Manufacturers should be required to provide product samples, fabrication and installation drawings, and installation instructions following a full review of the Construction Documents. Where appropriate, they should also be reviewing pertinent related submittals and shop drawings of components that will support or interact with their products. Following receipt of the manufacturer's submittals, the installing contractor should review and comment on the submittals, pass them on to the general contractor who will also review and comment on them before assembling of all comments and passing them on to the Architect/Engineer for review.
- 7) Submit exterior finish material samples to sealant manufacturers to determine proper preparation for sealant application and potential for sealant bleeding into materials.
- 8) Establish Construction Phase required mockups and tests for each fenestration system. Required mockups and tests include:
 - a. Aesthetic and Constructability Mockups - performed 'on-ground' and prior to construction to demonstrate contractor's understanding of the installation and identify conflicts between design requirements, installation practices, and field conditions. This is particularly important on historic projects that must conform to the *Secretary of the Interior's Standards for the Treatment of Historic Properties*.
 - b. Functional Performance Test - air infiltration and water penetration testing of the first in-place installation of each fenestration system to verify acceptable construction and correct installation.
 - c. Functional Performance Verification Test - air infiltration and water penetration testing of randomly selected installed fenestration for each fenestration system to verify acceptable construction and correct installation.
- 9) Optional tests:
 - a. Whole Building Air Infiltration Test - air tightness testing of building exterior enclosure to verify construction meets the OPR, design specifications, and LEED or other environmental/energy efficiency organization requirements.
- 10) Establish mockup and testing standards and protocols. Include mockup and testing requirements, rebuilding and retesting requirements, and reconstruction and retesting cost responsibilities per the *DFDM Policy & Procedure Manual for Architects/Engineers and Consultants*.

- a. For every failed random functional performance test specify the number of additional randomly selected installations that shall be tested, at installing contractor's expense. The addition of two new tests for each 'fail' is recommended.
- b. Conduct an onsite test of fenestration system product prior to testing of the installation to avoid test failure due to product failure. Failed products shall be replaced at no cost to the owner.
- c. Required Functional Performance testing minimum sample size:
 - i. Window System: A minimum of two locations of windows in each type of exterior enclosure system is recommended.
 - ii. Ribbon Window System: A minimum of two locations of two bays and their surrounding receivers and frames of each type of ribbon window system in each type of exterior enclosure system is recommended.
 - iii. Storefront System: A minimum of two locations of four lites/panels and their surrounding receivers and frames or an area of 120 square feet, which ever is larger, of each type storefront system in each type of exterior enclosure system is recommended.
 - iv. Curtain Wall System: A minimum of two locations of four lites/panels and their surrounding receivers and frames or an area of 120 square feet, which ever is larger, of curtain wall system in each type of exterior enclosure system is recommended.
- d. For in-place mockup testing, indicate locations on exterior elevation drawings.
- e. For limited random Functional Performance Verification Testing, specify the minimum number of units in separate locations to be tested (a minimum of 2% but not less than two units is recommended) for each type of fenestration system in each type of exterior enclosure system and where access creates special challenges for the installation.
- f. For random in-place quality control testing, indicate roughly where (what floors or heights) tests shall occur without giving exact location.
- g. Determine the number of required additional random Functional Performance Verification Tests to be performed, at installation contractor's expense, for each failure verification test failure. A minimum of two (2) additional locations per failure is recommended.

3.C.4.c Construction Phase Primary Activities:

- 1) Submittal and review of required contractor submittals, including product samples and shop drawings.
- 2) Perform Pre-installation Meeting(s).
- 3) Perform and review of Aesthetic and Constructability Mockups.
- 4) Perform and review Functional Performance Tests.
- 5) Perform and review of limited random Function Performance Verification Tests.
- 6) Perform and review Whole Building Air Infiltration Test, if required.
- 7) Preparation and submittal of Operations and Maintenance (O&M) Manuals which include replacement procedures for glazing, weatherstripping, and hardware along with a list of used materials, including manufacturer, make, style, sizes, and colors where applicable, and copies of all warranties.

3.D Design

INTENT

It is desirable for each element of an exterior enclosure be developed by an expert whose specialty is that area. In reality, such a goal is seldom achieved. With fenestration it is quite common for the A/E to utilize the expertise readily available through most of the major manufacturers in order to develop the basic intended design. However, it is extremely important that the details used are not proprietary nor inhibit reasonable competition. Typically project specifications list acceptable or pre-qualified manufacturers and products or provide a performance specification that permits manufacturers to submit their qualified products for use. It is important to note that the onus of proving a product is qualified and meets the specifications falls upon the manufacturer and not the designer.

Fenestration design information and details in this document are generic and do not address complex configurations. The intention is to illustrate conditions generically and not provide specific design solutions for a specific project. That is the role of the project designer. Details to be considered are not limited to the sill, jamb, head, and horizontal and vertical mullion conditions of the fenestration system, but also how these elements are integrated into the various and variable systems that comprise the exterior enclosure. The lack of adequate design details for these complexities is a common source of performance problems, be they from lack of noting or accommodating the actual conditions, failure to understand appropriate installation sequencing, failure to understand true material thicknesses, flexibilities, and other physical characteristics, or failing to address stresses and movements, usual or not, that occur at these locations. An adequate design must include the full detailing of all standard and variable conditions. Without the provision of these details, the installation at the irregularities is left to the mechanic in the field.

APPLICABLE INDUSTRY ORGANIZATIONS AND STANDARDS

The following is a list of the most commonly referenced or used industry trade and government organizations and their associated standards for fenestration. The most recent date of issuance or revision is indicated in the titles of the standards. Given the non-uniform and unpredictable nature of revisions and new publication releases, the user is encouraged to verify the current standing and relativity of each of the cited standards below in order to use the most recent and valid standards. Also see section 3.C Commissioning of Fenestration Systems in the Building Exterior Enclosure for specific tests and specifications.

AAMA American Architectural Manufacturers Association

- a) Window Systems:
 - o AAMA/WDMA/CAS 101.I.S.2/A440-11 NAFS – North American Fenestration Standard/Specification for Windows, Doors, and Skylights
 - o AAMA WSG-11 – Window and Door Selection Guide
- b) Storefront and Ribbon Window Systems:
 - o AAMA SFM-1-14 – Aluminum Storefront & Entrance Manual
- c) Curtain Wall Systems:
 - o AAMA CW-DG-1-96, rev 5/2005 – Aluminum Curtain Wall Design Guide
 - o AAMA CW-RS-1-12 – The Rain Screen Principle and Pressure Equalized (Curtain) Wall Design - where applicable.
 - o AAMA CWG-1-89 - Installation of Curtain Walls

ASTM International – Formerly the American Society for Testing and Materials

- International test standards used by organizations and professional societies to achieve comparable, reproducible, and documentable results for the testing of materials, products, and installations of products.
- Many AAMA standards are tested using AAMA described tests and/or ASTM test standards. ASTM test standards are often more stringent in a pass/fail sense, while some AAMA standards permit a grey area that would otherwise be considered a fail under ASTM.

DOJ US Department of Justice

- 2010 ADA Standards for Accessible Design

GANA Glass Association of North America

GSA General Services Administration

- a) Blast Resistance Testing of Fenestration Systems:
 - o GSA-TS01-2003 – Explosive Testing Standards for Window Systems

IGMA Insulating Glass Manufacturers Alliance

SMACNA Sheet Metal & Air Conditioning Contractor's National Association

- Architectural Sheet Metal Manual

Revere Copper Products, Inc.

- Copper and Common Sense

3.D.1 FENESTRATION SYSTEM CRITERIA TO BE PROVIDED

Based on the Project General Information, the Exterior Enclosure Criteria, and the Owner's Performance Criteria, provide the Fenestration System Criteria for each type of fenestration system used. Include the following, where applicable:

3.D.1.a Aesthetic Criteria:

Aesthetics are typically the purview of the project designer and the client. In many areas, zoning requirements and restrictions may also impact the design and final aesthetic of the project. In addition to the normal zoning requirements or restrictions of height limitations and build-to or setback lines, material selection, percentage and location of fenestration, types of glazing, and treatment of historic properties may be required through zoning overlays of specific districts.

- 1) Zoning and district aesthetic design requirements:
- 2) Historic Treatment aesthetic and design requirements:

3.D.1.b Fenestration Performance Criteria:

Provide the following performance:

- 1) Structural Adequacy - based on maximum allowable deflection for the required wind loads. Deflection should not be permanent nor damage components or hardware. For window systems, this can be expressed by AAMA/WDMA/CAS 101.I.S.2/A440-11 NAFS window performance class and grade. See *Window Performance Class and Grade Guidelines* for additional information.
- 2) Air Infiltration Criteria - maximum permitted air infiltration for fixed and for operable units.
- 3) Water penetration criteria:
- 4) Thermal performance criteria, including R-value or U-value for frame and center of glass:
- 5) Solar Heat Gain Coefficient (SHGC):
- 6) Condensation control criteria, including Condensation Resistance Factor (CRF):
- 7) Fire resistance:

3.D.1.c Functional Criteria:

Functional criteria deal with other-than environmental performance of a fenestration system. How is the fenestration system required to function/be used as a building enclosure element? Is it just an opening to permit daylighting and view, or is it required to act in other manners, providing access to fresh air, reducing noise infiltration, protecting occupants and building contents from accidental or intended harm? Functional requirements for fenestration to be considered include:

- Operability requirements
- Sound/Acoustic separation or control requirements
- Safety glazing requirements
- Security, forced entry, and vandalism resistance
- Blast resistance per General Services Administration test standards GSA-TS01-2003
- Maintainability – cleaning and repair

3.D.1.d Finish Criteria:

Fenestration performance is not limited to U-factor and maximum allowable air infiltration. Inappropriately or poorly finished fenestration can impact the perception of the building, its success, and maintenance.

- Type of finish or finish options available for the fenestration system
- Environmental durability
- Chalking resistance
- Fading resistance
- Repairable and maintenance requirements
- Custom or multiple color

3.D.1.e Reliability Criteria:

- Manufacturer/fabricator an established firm.

- Fenestration products with a minimum five-year history of successful performance and product support in the US.
- Installer and established firm.

Manufacturer/fabricator qualifications are an important contributor to receiving the expected quality of a product. Fenestration systems should be fabricated by a firm experience in producing systems similar to those indicated in the project bid documents, and whose work has resulted in a record of successful in-service performance during the immediate past three to five years. The fabricator should have sufficient capacity to produce the required components without causing delays in the work.

Installer qualifications are just as important as those of the manufacturer/fabricator. A qualified installer is experienced in the project fenestration systems and the building type of construction, the type of design involved and able to handle they scale of the project within the construction schedule. They should also have a record of successful in-service performance during the immediate past three to five years.

3.D.1.f Delegated Design Criteria:

- Manufacturer/fabricator employs an engineer in good standing who is experienced in the structural design of the fenestration system and its installation, and is licensed to practice and provide those engineering services in the State of Wisconsin.

For predesigned, prefabricated complete or component based fenestration systems, it is important to specify that the design is in fact delegated to the manufacturer and that the manufacturer’s engineer responsible for designing or adapting the fenestration system for its project specific installation, is licensed to practice that type of engineering in the State of Wisconsin.

3.D.2 GENERAL DESIGN TO BE PROVIDED

3.D.2.a Incorporation Of Owner’s Project Requirements (OPR)

Produced as part of a formal Building Enclosure Commissioning (BECx) process or in consultation with the owner as part of the standard project programming.

3.D.2.b Establish Minimum Window Performance Class And Grade

Establish the minimum AAMA/WDMA/CAS 101.I.S.2/A440-11 NAFS window performance class and grade based on project fenestration system design criteria and the OPR. Selected windows should meet or exceed the minimum performance class and grade required for the project. See *Window Performance Class and Grade Guidelines* in *Section Four – Guidelines* for additional information.

3.D.2.c Extension Of Design Requirements To Nontraditional Components Of Fenestration System

When shading, screening, or other devices or design features are integrated into and supported off of a fenestration system, they become part of that system and are subjected to the same design criteria and requirements as the regular fenestration system.

3.D.2.d Fenestration Located And Placed To Readily Accommodate Regular Maintenance

Glass should be periodically cleaned to maintain its psychological benefit and user-friendly environment. Depending on the project, this may involve weekly cleaning of interior glass lites and enclosed glass surfaces in dual glazed units, while exterior glass cleaning can range from a relatively simple operation of opening the window and washing from the room interior, to a very costly procedure using swing-scaffolds or special exterior lifts.

Access for minor repair, such as sealant and seal replacement, and depending on the size and location, glazing replacement, is typically performed using the same access. Based on building type, height, fenestration configuration, usage, etc., consideration should be given to the design of an appropriate method of access for these tasks. A combination of operating units (venting or custodial control) within fixed lite strips allows access to the exterior surface but may substantially add to cost. High-rise buildings or buildings with interior access difficulties may be designed for exterior cleaning using swing-scaffolds. When this procedure is employed, care must be provided to protect the exterior surfaces. Building overhangs, sunscreens, or similar ornamentation may prevent access. Deeply recessed fixed widows may also create difficulty for cleaning. Fenestration may be washed and maintained from the building exterior or interior, and certainly both faces need to be accessed. The

Architect/Engineer's selection of fenestration type and placement within the exterior wall plane will determine the appropriate access method for cleaning and basic maintenance and its related maintenance cost.

3.D.2.e Selection Of Appropriate Fenestration System For Each Application

Each of the numerous fenestration systems types has viable and appropriate applications. The Architect/Engineer is responsible for determining the fenestration system criteria and the selection of the fenestration systems, but not for their design. The fenestration manufacturer is solely responsible for the design of their system, be it a single pre-manufactured window unit or a curtain wall that comprises a major portion of the exterior enclosure. It is the manufacturer who can best recommend the use most appropriate for each of their systems based on the design parameters of each. This becomes all the more critical when the fenestration system begins to comprise more and more of the building enclosure. And while it can be difficult to use only one fenestration system universally, as they all have their own ideal niche, using an over abundance of systems can impact construction and maintenance costs.

Architects/Engineers should meet with fenestration and glass manufacturer representatives, in advance of construction document preparation to discuss the project fenestration criteria for aesthetics, performance, function, finish, and reliability in order to select products appropriate for the application. Additional criteria related to the manufacturer's design and fabrication of the fenestration system, its use in the design of the building, its installation and the detailing of installation should be addressed and coordinated with the building enclosure. Requirements for shop drawing, testing, and design calculation submittals must also be discussed and coordinated. Related products such as hardware and sealants should be discussed. Finally, the required guarantees for each fenestration system, including frame/unit, hardware, glazing, and finishes should be discussed with the manufacturer to ensure their standard and supplemental warranties meet or exceed the project requirements.

3.D.2.f Fenestration System From Manufacturer's Standard Or Modified-Standard Products With Proven Track Record

Minor modifications and alterations to meet job-specific installation conditions are encouraged. Where modifications and alterations are significant or job-specific custom window systems are developed to meet aesthetic or configuration requirements, allow for customization charges, additional production time, and laboratory testing verifying compliance with required design criteria.

3.D.2.g Appropriate Fabrication Techniques Of Fenestration Systems Outlined

See Frame and Frame Elements of section 4.E.2.b Fenestration Components.

3.D.2.h Selection Of Fenestration Systems With Frame Profiles Conducive To Proper Perimeter Sealant Joint Geometry

A frame profiles that captures/supports proper placement of backer rod and sealant between the frame and the prepared flashed opening is critical to providing and maintaining proper long-term protection of the flashed and sealed joint. A frame profile with a 1/4" return is not sufficient if the cavity behind it cannot secure properly sized backer rod in place to support the backside of the sealant. Consider the customization of profiles to improve proper sealant joint geometry when alternate fenestration systems or compatible products are not available, or unique building conditions require it. See detail DT-6 in *Appendix A – Fenestration Control Layer Diagrams*.

3.D.2.i Future Maintenance And Replacement Capacity

Building design and product selection consideration must be given to the fact that fenestration systems are a maintenance item and need to be addressed over the anticipated life of the building. Long term availability or stocking of replacement parts, including framing components, hardware, and weatherstripping is essential. Quality conscious architectural grade fenestration manufacturers use high quality materials that withstand normal usage. Systems should be designed to permit easy field replacement of these items. A major consideration to be addressed in the project specifications is providing some means for on-site custodial use of attic stock on highly abusive projects, such as schools and dormitories. Custom-sized items may or may not be feasible given the number of different sizes, limited number of each size used, and onsite storage availability. Standard hardware subject to high use and/or abuse, such as cam handles, roto operators, or 4-bar hinges, may be stocked for replacement. In all cases the specifications should require that final record drawings, warranties, and spare parts lists be furnished to the Owner's Project Representative and coordinated with a section for fenestration in the O&M manuals.

3.D.2.j Glass Installation And Glazing Methods To Facilitate The Replacement Of Glass

Fenestration installation methods should permit easy glass replacement in the field. When selecting fenestration system options and details, consideration must be given to maintenance of the fenestration system, including the

possibility of glass replacement. Typically window sash may be removed from the inside of the building. Glass in systems such as curtain walls are typically replaced from the exterior due to glass size and interior obstructions, particularly at spandrel locations. Ribbon window and storefront systems can typically be designed for either the exterior or interior glass replacement, but the same considerations such as unobstructed interior access to the fenestration, size of the glazing units, interior door and elevator sizes need to be thoroughly reviewed before committing to interior replacement of glazing.

3.D.2.k Fenestration Systems To Facilitate Replacement Of Sealants

Consider the feasibility of remedial sealant replacement during the selection of fenestration design. Sealants will fail over time, especially if not properly applied and maintained. The replacement of sealant at the perimeter of frames and at joints in the fenestration system becomes all the more difficult if access is limited and additional construction obscures the joint or complicates the joint geometry. As part of the general design process, consideration must be given to maintaining simple, workable geometry for the joints, and sufficient reasonable access to the locations.

3.D.2.l Weatherstripping System To Facilitate The Replacement Of Weatherstripping

Weatherstripping consists of the use of compressible and flexible materials, which by their nature and use wear out or become damaged over time. As a critical component in the sealing off of operable fenestration against air infiltration or loss and water penetration, it is important that weatherstripping in a fenestration product is designed to be readily serviceable and replaceable. Coordinate and verify weatherstripping options for each fenestration system with the fenestration manufacturer. Require the fenestration manufacturer and installer to review replacement procedures with the owner and document replacement parts and procedures in the fenestration section of the required project Operations & Maintenance Manual.

3.D.2.m Verification Of Compatibility Of Fenestration System Materials and Finishes with Building Exterior Enclosure Materials And Finishes

Problems often occur due to the chemical and physical incompatibility of materials, products, and finishes. The potential for problems is often overlooked as it is assumed they work harmoniously together or they would not be on the market. Sealants that do not properly adhere or bleed into substrates, finishes that fail due to adverse chemical reactions to flashings or adjacent finishes; self stick flashing adhesives that run as metal claddings heat up under full sun, flexible flashings and adhered wraps that tear or crack in temperature extremes as they do not share thermal expansion rates of their substrates are all examples of incompatibility. Verify direct contact compatibility, both chemical and physical, between the materials, products, and finishes of the fenestration systems used and the building exterior enclosure.

3.D.2.n Thermal Breaks and Barriers Within Elements

Continuously thermally broken elements are required for the exterior façade of all facilities that are heated or cooled. This is applied to fenestration systems wherever possible. All glazing as well as metal fenestration systems and related elements such as starter sills and receptors are to be thermally broken. Metal clad wood fenestration systems, including frames and sash should be effectively thermally broken whereby the metal cladding does not continue uninterrupted into the interior and become an opportunity for condensation.

3.D.2.o Fenestration System Control Layers and Drainage Plane Identification, Location, And Coordination

Identify and locate the each of the four (4) control layers in the fenestration systems. Identify and locate the drainage plane in each of the fenestration systems and indicate if an air space is required and provided. Identify where and how each control layer and the designated drainage plane will connect to the corresponding layers or plane of the adjacent wall and roof systems of the building exterior enclosure, returning inward or outward as required to maintain continuity and avoid short circuiting the physical or environmental control provided by each layer. Allow for appropriate thickness of layers and plane to maintain system adequacy and performance. Where thermal barriers are reduced in thickness and R-value/U-factor, the reductions in thermal performance must be taken into overall energy calculations and condensation resistance design of the enclosure. See *Control Layer and Drainage Plane Guidelines* for additional information.

3.D.2.p Control Layers And Drainage Plane Continuity Verification

Repeat the Control Layers Test and Drainage Plane Test described in *3.B.4.c Descriptive Full Height Exterior Enclosure Wall Sections* with the introduction of the fenestration openings and fenestration systems. As with the previous tests, verify the continuity of the control layers and the drainage plane along the full height of the wall and across each unique fenestration condition. If details or sections of the control layer planes and drainage plane are

not represented, accounted for, or detailed, do so in order to successfully complete the test. Each of the developed details should be included in the required detailing of the exterior enclosure with regard to the fenestration systems and the exterior wall itself. See *Control Layer and Drainage Plane Guidelines* in Section Four – Guidelines for additional information.

3.D.2.q Coordination Of Required Raceways In Storefront And Curtain Wall Systems

Indicate in the design, on construction drawings, and within the fenestration specifications where raceways for hardware and security system wiring, voice/data, or other systems are to be incorporated into storefront and curtain wall framing. Coordinate with the appropriate specifications and drawings for Hardware, Electrical, Voice/Data, and other systems to be integrated into the fenestration systems.

3.D.2.r Perform Required Level 2 Commissioning Design Phase Activities

See 3.C *Commissioning of Fenestration Systems in the Building Exterior Enclosure* for the list of activities.

3.D.2.s Establish Specification Gateway Requirements For Manufacturers/Products

In the Part 2 - Products section of each fenestration system's technical specification in the Project Manual, provide Gateway Requirements for manufacturers/products.

- Gateway Requirements shall include the criteria developed with the *Requirements Checklist*, and be coordinated with practices as required or to be avoided per the *Design Requirements and Guidelines For Fenestration in Building Exterior Enclosures*.
- Include a list of at least three acceptable manufacturers/products that the Architect/Engineer has reviewed and verified as complying with all Gateway Requirements. Listed manufacturers/products that do not meet all Gateway Requirements can create contradictions in the specifications which can result in the voiding of the Gateway Requirements and unqualified manufacturers and products being allowed to bid.
- Consider the use of a No Substitutions clause.

3.D.2.t Establish Bidding Criteria

For the typical project, bidding criteria is as found in DFDM's Division 01 Specification Requirements, with bidding open only to experienced and qualified Certified Contractors. On occasion, additional requirements may be necessary to ensure contractors and suppliers can provide a well-informed bid. Possible additional bidding criteria that might be considered on special projects are:

- Mandatory Pre-bid Site Visits: For projects involving existing construction or an historic resource, it is often advantageous and strongly recommended to require a mandatory pre-bid site visit where window manufacturers and installing contractors may review existing conditions.
- Exposure of Existing Conditions: For fenestration replacement projects and in conjunction with Mandatory Pre-bid Site Visits, it is recommended that at least a sample of the existing fenestration be removed to permit perspective bidders to observe rough opening conditions as well as the disassembled removed fenestration. Depending on the size of the project, the removal of fenestration at several locations may be warranted to take in differing known conditions or possible hidden random variations in window and wall construction. This may also be of value to the bidders if replacement windows are have matching profiles or be duplicates of the originals.
- Prequalification of Manufacturers: For projects with critical or complicated aesthetic, performance, or installation requirements, or required special customization of fenestration systems or components, the prequalification of manufacturers may be an option. This option is an added extra step normally not found in the bidding process and may be used only upon the DFDM Project Manager's approval. It is a means to provide additional oversight and control over product and project quality in the effort to provide a successful outcome for projects with complex fenestration or intensive performance and appearance requirements. See *Bidding Prequalification Guideline* in Section Four – Guidelines for additional information.

3.D.2.u Establish Requirements for Guarantees From Fenestration System Manufacturers And Installers

The Prime Contractor is to provide written guarantees warranting all fenestration and related work under Contract to be free from defects in materials and workmanship for the extended periods of time as stipulated in the Project Manual. The Prime Contractor's Performance-Payment Bond is not required to apply to any extended guarantee period beyond the time required for all work under contract. This is typically a one or two-year period, and must be called out in the Project Manual by the Architect/Engineer.

The Architect/Engineer must clearly specify in the appropriate technical sections of the Project Manual the Guarantee/Warranty requirements for all products that make up the fenestration systems as well as for their proper installation. The Guarantee/Warranty requirements in the technical section of each particular fenestration system shall be edited to reflect the industry standard Guarantees and Warranties for the products, components, and installation of that particular fenestration system, as well as for any special Guarantees and Warranties required by the project's complexity, uniqueness, or innovative design. The Term of Warranty for fenestration products, related products, and their finishes shall not be less than that offered by the manufacturer of each product. Products include:

- Pre-manufactured and predominantly complete on or offsite installed fenestration
- Component-based fenestration assembled on or offsite
- Glass and glazing units
- Spandrel panels and non-glass infill panels
- Hardware
- Finishes
- Flashing, safin, and sealant products used as part of the installation
- Control Layer products used as part of the installation (e.g. insulation and vapor retarders at non IGU spandrel panels)
- Products integrated into and physically supported by the fenestration (shading and screening devices, etc.)

Edited but unexecuted (unsigned) copies of all Guarantee and Warranty forms are to be included in the list of required submittals and shall be submitted for review as part of the submittal package and not following construction. An executed copy of the reviewed warranty shall be submitted following substantial completion and during project closeout.

Enforcement of contract document quality and performance requirements is essential to a successful project, rather than relying solely on a guarantee.

3.D.3 DESIGN DETAILS TO BE PROVIDED, WHERE APPLICABLE

3.D.3.a Structural Calculations

Structural calculations, for fenestration systems and their anchorage, signed and sealed by a qualified structural engineer licensed to practice in the State of Wisconsin. The calculations should indicate wind load on horizontal and vertical mullions, dead and live loads, shear, torsion, and tension loads on structural members and anchorage.

3.D.3.b Anchorage Materials And Methods With Avoidance Of Anchorage Penetrations Through Sill And Sill Pan Flashing

The fenestration manufacturer should provide the proper clips or anchors necessary for perimeter attachment, which adequately transfer loads to the structural supports. See details DT-1 thru DT-5 in *Appendix A – Fenestration Control Layer Diagrams*.

Wherever possible, jamb anchorage of fenestration is preferred over sill anchorage in order to avoid penetrating sill or sill pan flashing. Anchor bolts used at curtain wall anchors should be double-nutted, fastened with self-locking fasteners, or the threads should be deformed to prevent loosening (the least preferred method).

3.D.3.c Provision For Differential Movement Between Building And Fenestration

Joints for movement should be a minimum of 3/8" wide and having a high-range movement capability (plus or minus 50%). Joints should be appropriately designed so their width can sufficiently accommodate anticipated movement (tensile, shear, etc.) relative to the performance capabilities of the sealants specified. The coefficient of thermal expansion for aluminum is 12.9×10^{-6} inches/inch/degree F, which is far greater than other common building materials utilized in construction.

3.D.3.d Permanent Closing And Sealing Of Wall Cavity Openings Along With Proper Termination Of Control Layers At Openings And Prior To Fenestration System Installation

In exterior walls that are to receive fenestration, the cross sections of any cavities within the openings for fenestration are to be sealed with closed cell insulation or foam and sealant, as appropriate, prior to fenestration installation. The purpose of the seal is to prevent the transfer of moisture-laden air from, to, or between the interior, the wall cavity, and the exterior. It is also intended to prevent wall cavity air from escaping at the perimeter of the

opening in order to retain the integrity of vented or pressure equalized drain screen walls. In addition, without airtight insulated perimeters, the thermal control layer of the fenestration system could be bypassed.

The thermal break in fenestration frames and receptor frames are typically much narrower than the cross section of any wall cavity that they span. Without filling the full cross section of the wall cavity to create an airtight insulated perimeter, the frame or receptor on “interior” side of the thermal break will still be exposed to same temperatures on the “exterior” side of the thermal break. The thermal break within the fenestration frame or receptor frame only stops the direct thermal transfer between the different sides of the frame. If the interior and exterior sides of these frames are exposed to same environment, the thermal breaks serve no purpose. Thermal breaks must be continuous through the wall and into the fenestration system in order to work. Specifications should require the wall cavity closure to be completed before window installation is started. See detail DT-5 in *Appendix A – Fenestration Control Layer Diagrams*.

Jamb, head, and sill closures at frame cross-sections are to provide proper support for perimeter sealant backer rod. The means for achieving this should be specifically detailed and called out. A possible suitable alternative method for creating closures may be use of self-adhere silicone closures sheets, depending on the specific condition and minimal to no expected movement. See details DT-1, thru DT-5 in *Appendix A – Fenestration Control Layer Diagrams*.

3.D.3.e Detail the Continuity Of Building Exterior Enclosure Control Layers Between Wall Systems And Fenestration Systems

Per 3.D.2.n *Fenestration System Control Layers and Drainage Plane*, provide details showing how the various adjacent wall control layers return inward or outward as required by the location of the fenestration system and its corresponding control layers:

- 1) At inboard set fenestration (see DT-3 in *Appendix A – Fenestration Control Layer Diagrams*):
 - a. Detail the return inward of the adjacent exterior wall control layers and designated drainage plane back toward the recessed corresponding layers of the fenestration system.
 - b. Exterior sills at recessed fenestration should not cross or interrupt the control layers. Return control layers below sills and back to fenestration.
 - c. If the thermal layer is reduced in thickness and thermal value as it returns back to meet the recessed fenestration, verify that the reduce thermal value will not create thermal bridges and promote condensation formation within the confines of the wall or on interior or exterior finished faces.
 - d. Compartmentalize drainage planes such that at the heads of openings with recessed fenestration, flash and drain the drainage plane to the exterior face, while providing a separate compartmentalized drainage plane for the soffit of the recess. Do not direct the gathered water of the drainage plane above the opening back into a recessed opening.
 - e. Provide adequate anchorage and structural support for the recessed fenestration and coordinate with location of adjacent wall or building structure. Avoid penetrating control layers and flashing with anchorage where possible and at sills in particular.
 - f. See *Control Layer and Drainage Plane Guidelines* for explanatory conceptual diagrams.
- 2) At outboard set fenestration (see DT-4 in *Appendix A – Fenestration Control Layer Diagrams*):
 - a. Detail the return outward of the adjacent exterior wall control layers and designated drainage plane out toward the corresponding control layers and drainage plane of the projecting fenestration.
 - b. Interior sills at projecting fenestration should not cross or interrupt the control layers. Return outward the control layers below sills and to fenestration.
 - c. If the thermal layer is reduced in thickness and thermal value as it returns outward to meet the projecting fenestration, verify that the reduce thermal value will not create thermal bridges and promote condensation formation within the confines of the wall or on interior or exterior finished faces.
 - d. Compartmentalize drainage planes such that at the sills of projecting fenestration are flashed and drained to the exterior and not part of the drainage plane returning back to the adjacent wall drainage plane. Provide a separate compartmentalized drainage plane for the soffit of the underside of the projecting fenestration. Do not direct the gathered water of the sill flashing into the soffit below the projecting window.
 - e. Provide adequate anchorage and structural support for the projecting fenestration and coordinate with location of adjacent wall or building structure. Avoid penetrating control layers and flashing with anchorage where possible and at sills in particular.

f. See *Control Layer and Drainage Plane Guidelines* for explanatory conceptual diagrams.

3.D.3.f Head, Jamb, Mullion, And Sill Details

For each fenestration system, provide head, jamb, and sill details, including receptor frames where applicable. Provide mullion details of field ganged or mulled fenestration as well. Show terminations of control layers and flashing of fenestration openings.

3.D.3.g Sequential Details Of Flashing Of Fenestration Drainage Plane Into Exterior Wall Drainage Plane

Properly flash fenestration drainage plan into drainage plane of exterior wall, paying attention to proper sequencing of flashing with upstream flashings overlapping downstream flashings and avoiding skyward facing seams. Per *4.D.2.o Control Layers and Drainage Plane Continuity*, follow drainage plane to ensure water is collected and directed downward and directing it outward to the face of the exterior enclosure. Provide sequential detailing to illustrate proper sequence and overlapping of flashings.

3.D.3.h Provide Properly Sloped And Terminated Through-Wall Flashing At Window Heads And Sills

All flexible flashing must transition to metal flashing when terminating at the exterior face of the building exterior enclosure. No flexible flashing to be exposed or permitted within 3/4" of exterior face of building exterior enclosure. All through-wall head and sill flashing to terminate with 3/4" cut and neatly hemmed metal drips extending out beyond the face of the exterior enclosure and uniformly bent down at a 45-degree angle per SMACNA Architectural Sheet Metal Manual.

Where upstream flashings overlap downstream flashings, and where flexible flashings transition to metal flashings, provide a minimum of 2" of overlap. Metal flashing to extend from the drip back into the wall, across any horizontal bed and terminate with a 1" minimum upturned leg to serve as a continuous support and back up for flexible flashings. Set the horizontal bed portion of all through-wall flashings to slope down and outward to aid in expelling water. Back-sloped flashing pools water on the flashing and can funnel it back into the wall opening. End dam all flashing to avoid water flowing laterally into the wall opening. Seal all seams.

3.D.3.i Proper Insulation Of Curtain Wall Spandrel Panels

Provide mechanical attachment of curtain wall insulation to fenestration frame and vapor retarders or back-pans of like metal impermeably sealed to frame.

3.D.3.j Isolation Of Fenestration Systems From Parapet And Roofing Systems

Parapets and roofing materials should be isolated from fenestration systems, particularly curtain wall components, to permit independent movement of each and avoid thermal short circuits.

3.D.3.k Isolation Of Fenestration Systems From Interior Wall And Ceiling Materials

Interior wall and ceiling materials should be isolated from the fenestration system to accommodate expected movement of the system and eliminate drywall problems. For example, curtain wall systems can have an integral drywall trim pocket member at the sill while a simple sealant filled control joint may suffice at a windowsill. See detail DT-1 in *Appendix A – Fenestration Control Layer Diagrams*.

3.D.3.l Sealant Geometry And Detail Review and Verification

To verify the feasibility of easy remedial sealant replacement as outlined during in *3.D.2 General Design To Be Provided*, review sealant geometry conditions at fenestration to verify sealant is readily accessible and that the geometry does not require blind installation or is impeded by adjacent/subsequent construction.

3.D.3.m Glass Installation Review And Verification

Review feasibility of easy glass installation and replacement at each fenestration opening to ensure that building elements or other construction do not impede the selected interior or exterior replacement of glazing.

3.D.3.n Glazing Materials And Replacement Procedures Provided In The Project O&M Manuals

Require that O&M manuals include for each fenestration system a complete list of glazing and fenestration products used, and including finishes, coatings, manufacturers names, and product numbers.

3.D.3.o Hardware Options With Respect To Entrance Doors

See *3.E.1.e Hardware*.

3.D.3.p Hardware Requirements for Operating Sash and Vents Within Fenestration Systems

When selecting hardware for operating vents, it is important to acknowledge the application of the installed product. The selection of locks, hinges, and operation mode will affect the overall function of the operating sash or vent. Architects/Engineers are encouraged to meet with the fenestration manufacturer to ensure that the hardware selection will meet the expectations of the end user of the product. Special consideration must be given to ANSI A117.1 requirements and psychiatric/detention applications. Applicable building codes may also dictate the type of sash or ventilation hardware needed for the type of building being constructed. Smoke evacuation, egress, ingress, access, security, and safety are some examples of other things to consider when selecting hardware. For further information, refer to AAMA WSG.1.

3.D.3.q Proper Fabrication And Installation Of Receptor Frames Where Used

Properly flash rough opening prior to placement of receptors. Use only receptor frames that have successfully performance-tested with windows in-place for air infiltration, water penetration, and for thermal performance. End dam and seal head channels and sub/starter sills where no jamb receptors are required by manufacturer and installation condition. Where jamb receptors are included, corners are to be mitered, screw-fastened, sealed, and back sealed to head channels and sub/starter sills.

Provide expansion joints, equally spaced, when lengths are greater than 20' per manufacturer's recommendations. Properly seal and flash expansion joints per manufacturer's recommendations. At splices, properly seal and reinforce all splices with metal plates per manufacturer's recommendations. Allow for proper thermal movement of receptors in the rough opening.

3.D.3.r Detailing For Miscellaneous Non-Typical Fenestration Conditions

Non-typical situations require detailing to communicate how to address the non-typical conditions. For example, thermal storefront framing systems can be provided with field-installed, snap cover thermal plate or rigid extruded installation around fenestration unit perimeter for sealant back rod. However this must be specified and detailed. Foam installation is expensive and causes undue pressure on the fenestration unit that may result in deflection or damage to the fenestration. Also, as a blind application, one cannot ensure that all voids are being filled.

3.D.4 DESIGN CONDITIONS AND DETAILS TO BE AVOIDED

3.D.4.a Exterior Fenestration Sills Projecting Into The Interior Air Space Or Bridging Control Barriers Of The Exterior Enclosure Systems.

See 4.D.3.e *Detail the Continuity Of Building Exterior Enclosure Control Layers Between Wall Systems And Fenestration Systems.*

3.D.4.b Single Lines Of Sealants As The Sole Means Of Preventing Water Penetration

Sealant materials have a finite life and must eventually be replaced. It is not a question of "If," but "When." Location, exposure, joint design, material used, joint preparation, and application may result in drastic time differences before joint failure (water penetration) results. When sealant is required to serve as a skin, any breaks in the sealant or separation from the materials it seals to creates the potential for instant water penetration. This is highly undesirable. Options should be considered when developing details for the exterior envelope. A second recessed line of sealant or screen walls should be used to protect the primary seal from direct exposure to rain and UV degradation. Movement of water by capillary action can readily be controlled by use of drips, gaps, and membranes.

3.D.4.c Noncontinuous Water, Air, Vapor, And Thermal Control Layers

Failure to properly connect and seal the control layers of the building enclosure's wall and roof systems to the corresponding layers of the fenestration system will negate the purpose and function of the control layers. Air and vapor infiltration, water penetration, and loss of thermal protection leave the construction at risk for significant damage and deterioration, which can reduce the use and lifespan of the building. See *Control Layers and Drainage Plane Guidelines* in *Section Four - Guidelines*.

3.D.4.d Noncontinuous Thermal Break In Fenestration Systems

Thermal slot systems, which are common to storefront systems, are used to reduce thermal mass and transfer in and effort to improve thermal performance. All framing systems having slotted holes require investigation of thermal integrity and structural integrity for torsion or twist of vertical mullions. Sealing the slotted system in the horizontal position may be difficult. Specifying a 56 or higher CRF precludes the use of thermal slot framing. Skip de-

bridging and/or use of metal fire clips also change the system from broken to thermally enhance system, which are not allowed.

3.D.4.e Thermally Unbroken Through-Wall Metal Flashing Exposed To The Interior

When thermally unbroken metal flashing is exposed on both the interior and the exterior of the exterior wall system, substantial head transfer by conduction will occur and condensation can be expected. During extremely cold weather, the temperature of the interior side of the metal flashing maybe such that the vapor will condense as ice in the form of hoarfrost. Such buildup may be appreciable. As rapid melting of the buildup occurs, the extensive water formed may stain and damage interior finishes, or enter the exterior wall system and cause damage. Even if the flashing is hidden and terminates on the warm side of the wall, condensation may still occur unseen within the wall unless the flashing is thermally broken.

3.D.4.f Exposed Splices And Joints In Receptor Framing Elements

Exposed splices and joints in receptor frame elements are weak points that offer water an opportunity to enter the wall assembly. See subsection *4.D.3.r Proper Fabrication And Installation Of Receptor Frames Where Used*.

3.D.4.g Concealed Overhead Closers For Doors

Concealed overhead door closers do not function well at low temperatures.

3.D.4.h Single Pane Glazing And Glass Spandrel Panels

Desired U-factors and high CRF values to prevent condensation preclude the use of such glass in typical applications.

3.D.4.i Four-Sided Field Structural Glazing

Four-sided structural glazing involves securing materials to a perimeter support system with a high-grade structural silicone glazing sealant. To retain the glazing infill material, four-sided systems rely completely on the integrity of the silicone's adhesive/cohesive characteristics and the quality of the methods used during its application. Systems utilizing four-sided applications must have the initial glazing and reglazing operations performed in an environmentally controlled shop. Four-sided structural glazing framing support systems must be removable and replaceable for reglazing purposes. For further information, refer to *AAMA Aluminum Curtain Wall CW 13-85*.

Limit field structural silicone glazing to two parallel sides, with the other two parallel sides supported within the glazing pockets of the frame to provide physical mechanical support and connection.

3.D.4.j Blind Seals

Blind glazing is the application of sealant without being able to observe placement of the bead and should not be used.

3.D.4.k Glazing Without Weeps

Glazing systems without weeps do not permit water that has penetrated the glazing pocket. Weeps are a planned redundancy that recognize that sealants, glazing systems, and even frames are not perfect and do not remain in a perfect condition over time.

3.D.4.l Dissimilar Metals In Direct Contact Or In Contact Formed By Standing Water

Galvanic action between dissimilar metals prematurely oxidizes and corrodes metals to the point of failure. Contact between dissimilar metals, either direct or formed when in standing water, should be avoided. Paint and anodized finishes are not acceptable barriers between dissimilar metals in direct contact.

3.D.4.m More Noble/Cathodic Metals Upstream Of Or Able To Splash On Less Noble/More Anodic Metals

Ions from oxidizing metals are carried in runoff water. When dissimilar metals are placed in the same drainage or runoff path, the more noble/Cathodic metals upstream can shed ions in runoff water and prematurely oxidize and corrode less noble/more anodic metals downstream. Although the corrosion is not as intense or quick as that of dissimilar metals in direct or standing water contact, damage can still occur. Runoff from copper wall panels above aluminum windows can damage window frames and trim. Anodized finishes are not acceptable protection of aluminum downstream of oxidizing copper.

3.D.4.n Glazing Sills Less Than 18” Above Grade

Glazing sills are to be not less than 18” above grade. This removes glazing from the greatest impact zone, be it stones or objects inadvertently kicked, projected by site maintenance equipment, or impact with interior or exterior site maintenance equipment. It also raises sills above typical water runoff levels and typical snow levels.

3.D.4.o Specified Acceptable Manufacturers/Products Not Compatible With Gateway Requirements

Do not list manufacturers/products that have not been verified to meet all specification Gateway Requirements. The listing of manufacturers/products that do not meet the specification Gateway Requirements creates contradictions in the specifications and can void the Gateway Requirements, thereby opening bidding to unqualified manufacturers and products. Verify that all listed manufacturers and products meet the Gateway Requirements.

3.E Materials

3.E.1 FENESTRATION COMPONENTS

Indicate and give consideration to the fenestration components comprising each fenestration system used:

3.E.1.a Receptor Frames, where applicable:

Receptor frames, also known as sub-sills, are used on aluminum fenestration systems, such as ribbon windows, curtain walls, and storefront systems. They permit rough openings to be leveled, overcome otherwise challenging rough opening construction tolerances, and floor slabs and building construction in general to deflect or move independently of the fenestration. They help with water management by collecting and channeling water that may have gotten into the fenestration assembly. Receptor frames should be thermally broken and have been tested with the fenestration system it will receive.

3.E.1.b Frame Type, Material, Construction:

The type of framing construction to be used is directly related to the performance and appearance of the installed product. Typically, windows are prefabricated while curtain wall systems can be assembled and installed in several ways. Curtain wall systems range from finished stock lengths to pre-glazed unitized modules. The level of quality control will vary with the amount of factory fabrication and assembly performed. Experienced personnel in a controlled factory environment typically best accomplish alignment of framing members and the application of critical frame seals. Proper anchorage of the frame to the adjacent building construction requires careful analysis of the independent materials. Acknowledging thermal expansion/contraction, dynamic building movement, the load imposed on the superstructure by the fenestration system, and the location and need for impenetrability of control layers and the drainage plane are all vital to successful product installation. Architects/Engineers are encouraged to meet with the fenestration manufacturer to ensure that the overall design will meet the requirements of the Contract Documents.

3.E.1.c Finishes:

PVDF-type finishes (polyvinylidene fluoride), consisting of coating systems using either Kynar 500 or Hylar 5000 resins, are more versatile for architectural finishes than anodizing. PVDF is more resistant to building wash, lime leaching, acids, etc. Warranties on PVDF finishes are typical (5-year manufacturer and 10-year applicator warranties) depending upon who is providing the warranty. The term of the warranty must be specified. PVDF finishes are not recommended for use at entrances without abrasion-resistant protection topcoats because they are softer finishes than anodized or epoxy/urethane finishes and are less resistant to abrasion from hand contact. Specifying a precise color as early as possible (e.g., referencing a manufacturer's paint chip number) is helpful in reducing lead times and ensuring competitive bids.

Anodized finishes have excellent solvent, abrasion, and UV resistance. It is recommended that Architects/Engineers meet with fenestration manufacturers, well in advance, to discuss fenestration performance, glass, and hardware, in order to select a product appropriate for the application.

No mill-finished aluminum is to be allowed to exposed exterior applications because of the oxidation of aluminum and the likelihood of resulting staining.

For hardware finishes, see *4.E.1.e Hardware*.

3.E.1.d Glass and Glazing:

The Architect/Engineer should be familiar with the various glazing types, methods of fabrication, and inherent properties of each with respect to their specific end-use requirements and configurations. The more common glazing types include: Float glass

- Insulating glass
- Reflective glass
- Heat-treated glass
- Spandrel glass
- Fritted glass
- Laminated glass
- One-way glass
- Bullet resistant/security glass

- One-way bullet resistant/security glass

Performing a lifecycle cost analysis for the various types of glass in a given project is a recommended means to determine the best choices available with regard to cost effectiveness, energy savings, etc.

Glazing seals vary widely in their use, composition, and performance. They provide a weather-tight seal between the glass and frame. The basic components are organized into three groups:

- Wet glazing sealants – sealants
- Dry glazing sealants – glazing tapes, expanding foam gaskets, and preformed gaskets
- Wet/dry glazing sealants - a combination of all of the above

Glass can be factory or field glazed, and often depends on the type of fenestration system being used and whether it is typically factory or field assembled. Factory glazing is generally more cost effective and provides more consistent quality and workmanship under controlled environmental conditions. It can, however, conceal nonconforming-glazing work. For major projects, the Architect/Engineer should periodically review the manufacturer's assembly process during fabrication with emphasis on early work. Glazing stops should be removed randomly to check glazing components such as setting blocks, jamb blocks, insulating glass unit edge seals, and the location and size of weep holes when the units are delivered to the site to ensure that the factory glazing was performed in accordance with the Contract Documents.

A glazing system consisting of butyl tape with silicone sealant cap bead on the weather-side of the glass and wedge-type or foam gaskets on the interior-side of the glass provide a durable and reasonably reliable glass-to-metal seal. The recessed cap bead seal provides parallel bonding surfaces for optimum sealant geometry, and the sloped design for the sealant helps shed water away from the glass. Butyl tape provides a solid backup for the sealant in the joint and a reliable buffer to cushion the glass from contact with the metal frame. The adhesive quality of the tape and cap bead also reduces the tendency for the glass to 'walk' laterally; but this does not eliminate the potential need for anti-walk blocks.

Low-Emissivity (Low-E) glass has an invisible to the naked eye metal or metallic-oxide coating that reflects the long wave infrared portion of the heat spectrum. Insulating glass units (IGUs) with Low-E coatings applied to either the second or third glass surface can achieve a 0.30 U-Factor. Adding a third pane of glass and/or filling the air space between the panes of glass with Argon gas can further improve the U-Factor.

Colored spacers are available and should be specified if applicable to design requirements or to the system used.

Size and weight of the glass units should be reviewed to determine glazing feasibility. Protect units during delivery and installation to prevent racking and slippage.

Spandrel Glazing is available in two forms:

- With a ceramic coating, which is normally applied to the third or fourth surface of the insulated glass units;
- With an opacifier layer, which normally matches the coating selected for the vision glass both in color and applied surface.

Monolithic glazing is discouraged because of condensation potential in winter months. To reduce these problems if a monolithic glazing is desired for a project, use of a vapor retarder on all interior edges and surfaces with all joints and holes forming the shadow box taped so moisture is effectively prevented from condensing on the back of the spandrel glass. There is also concern that volatiles in the insulation and other materials of the shadow box will form deposits on the spandrel glass, consequently damaging the coating as well as degrading the appearance.

3.E.1.e Hardware:

1) Fenestration Hardware:

Window and fenestration hardware should be fabricated using aluminum, stainless steel, or other noncorrosive metals compatible with aluminum or other metal from which fenestration framing may be manufactured. Latching hardware and strikes should generally be made of stainless steel to avoid short-term replacement due to wear.

2) Entry and Door Hardware:

Aluminum is the preferred material for entrance doors and frames because of the many finishing options and the ability to match other materials where continuity is desired. Aluminum is also well suited to the climate in the region of the Upper Great Lakes.

Basic considerations when detailing and specifying entrance door hardware include security, life safety, durability, maintenance, and compatibility with and integration into the entrance system. Not unlike the hardware selection process for wood or hollow metal doors, hardware items fall into the following categories:

- Operating Hardware: Hinges, pivots, closers, balanced door mechanisms, revolving doors, and automatic operators for swing, slide, and revolving applications.
- Securing Hardware: Locks, latches, security devices (e.g. card readers, combination locks, magnetic locks, and monitor switches), exit devices, flushbolts, and cylinders.
- Accessory Hardware: Stops, holders, push/pulls thresholds, and protective plates.

The Architect/Engineer can contact aluminum door manufacturers, hardware manufacturers, and hardware consultants for assistance in specifying and detailing aluminum door hardware. Entrance door hardware should be coordinated with hardware used in other parts of the project. Entrance door hardware normally is specified in the technical section for storefront fenestration/entry systems. The project specifications should include a detailed list of hardware for aluminum doors while the drawings typically include a door schedule indicating which door receives which hardware package. The hardware supplier, in turn, must prepare a detailed hardware schedule for submittal that closely corresponds to the specification's detailed list of hardware and is coordinated with the shop drawing submittal for the entrance doors and the fenestration entrance system they fit into.

Since factory automated equipment produces a stronger and better finished aluminum door and frame, preparation for hardware must be performed at the door factory. The hardware supplier should furnish dimensionally accurate templates to the door manufacturer in a timely manner.

Hinges: Butt hinges support the door in its frame and provide single-acting swing action. Pivots, either center or offset-hung, are preferred over hinges to swing large and/or heavy doors. Double-acting doors must always utilize center-hung pivots.

Closers: All types of closer may be used on hinged or pivoted entrance doors; however, concealed overhead closers do not perform well at low temperatures and require more maintenance. Floor closers are suitable for high traffic entrances and heavy/large doors. Their sealed installation in the slab renders them vandal-proof and weatherproof. The use of special hydraulic oil (cold weather fluid) maintains its viscosity at low temperatures. Coordination with related hardware, including pivots and overhead stops, is required. Regarding ANSI A117.1 compliance, at 90 degrees opening, a floor closer's closing force is 100% more efficient than that of a surface mounted closer. When using floor closers, closely coordinate the placement of the related cement case with the concrete trade. Bottom pivots and floor closers should only be considered for use when they can be kept relatively free of de-icing salts, dirt, and other deleterious matter.

Balanced Door Hardware: A swing door that rotates around a rolling pivot provides a balance of wind pressure on the door leaves. This facilitates operation under high wind or stack pressure conditions and provides the widest possible opening with the smallest wing arc.

Automatic Operators: Various types of available for ANSI A117.1 compliance include electro-hydraulic, electro-pneumatic, and electro-magnetic (all electric). Factors to consider when selecting an automatic door operator include: door size and weight, wind conditions (pressure), stack action, frequency of use, location of power unit, and electrical requirements.

Hardware Metals and Finishes: Corrosion-resistant, non-ferrous base metals and finishes are required. Dull stainless steel (US 32D-BMHA 630), dull chrome-plated brass (US 26D-BMHA 626), dark bronze, oil rubbed (US 10B-BHMA 613), and satin bronze clear coated (US10-BHMA 6512) are the most common finishes for entrance door hardware.

For more detailed information on entrance door hardware, see manufacturers' literature, DHI literature, AAMA Aluminum Storefront and Entrance Manual SFM-1-14, and NAAMM Metal Finishes Manual.

3.E.2 FLASHING SYSTEMS

3.E.2.a Flashing Systems (Flashing Material and Additional Installation Materials):

Flashing systems can range from a simple single component system to seal window flanges to a drainage plane, to the use of multi-component systems comprised of flexible flashings that transition to metal or incorporate metal flashings and drips. Flashing material requirements can also vary with the required quality and expected life of a building. It is important is to consider using the most durable materials with the appropriate qualities for each of the flashing tasks that constitute the flashing system. Their ability to interact and work together to form a comprehensive watertight flashing system is critical. Considerations include building movement and movement between fenestration and the wall, thermal movement of the wall, material compatibility with fenestration and exterior enclosure materials, damage due to UV or temperature extremes, and susceptibility to installation damage during the installation of subsequent or adjacent exterior enclosure components. Mason's trowels like metal wall panels can be sharp, and both are capable of puncturing flexible flashing. Types of flashing and flashing components used include:

- Flexible Membranes
 - Flexible Self Adhered Sheet Membranes
 - Flexible Self Adhered Tape
 - Mechanical Fasteners
 - Liquid Applied Membrane Flashing
 - Roller Applied Membrane Flashing
 - Spray Applied Membrane Flashing
 - Reinforcing Mesh or Tape
- Sheet Metal
 - Sheet Metals
 - Fasteners
 - Solder

See *4.D.3.h Provide Properly Sloped And Terminated Through-Wall Flashing At Window Heads And Sills* for additional information and detailing concerns about proper sloping and termination of through-wall flashing.

3.E.3 SEALANTS

3.E.3.a Types Of Joints, Widths, And Movement:

Silicones or polyurethanes have been the preferred materials for sealing perimeter joints, although with the continued development of non-staining, non-soiling silicones, polyurethanes are falling out of favor in this application given their limited life expectancy and the difficulty in removing them after they have hardened and cracked. Joints should typically be 3/8" to 3/4" wide and have high-range movement capability and be UV resistant to maintain color and flexibility. When designing joint widths, consideration should be given to applicable fabrication and erection tolerances, and open unobstructed access to the joint for proper placement and tooling.

3.E.3.b Material Compatibility And Testing:

Establish the compatibility of sealants with adjoining materials and other sealants. Soiling of sealants and resultant staining runoff onto adjacent surfaces is a concern and should be addressed with the manufacturer prior to specifying. Bleeding into porous materials such as brick and stone masonry is an additional concern as it can change the appearance of the porous material and create wet appearing stains. Explore the ramifications of using more than one generic type of sealant (e.g. silicone and polyurethane). Always require material compatibility testing, including bleeding into porous materials, during the design phase of the project. This allows enough time for testing and testing of alternate selections if required.

3.E.3.c Sealant Systems (Sealants And Additional Materials):

Sealants systems consist of multiple materials and not just the sealant. Materials include:

- Surface Preparation Materials: Cleaners, degreasers, and primer coatings to create optimal adhesion conditions for the application of the sealant.

- Closed Cell Backer Rod: Of various diameters to flexibly support the blind side of the sealant while not permitting it to seal to a fixed surface. Sealant should only adhere to two fixed surfaces – either side of a joint – to maintain flexibility of the sealant and avoid tears from being stressed in three directions.
- Sealants: Manufactured in a variety of chemical compositions for different uses and flexibility. Sealants come available in standard colors but usually can be custom colored for an additional charge and a specified minimum order size.

3.E.3.d Surface Preparation And Field Adhesion Testing:

Always require field-adhesion and compatibility tests to determine proper preparation of substrate for cleaning and if a primer is required for contact with non-porous materials.

3.F Installation

3.F.1 INSTALLATION PRACTICES TO BE PROVIDED

Too often, many fenestration problems encountered in the field can be traced back to improper installation. The shop drawings/installation instructions furnished by the manufacturer should provide complete detail, including all the accessories needed for anchorage/fastening of the elements in to the exterior wall. It is vitally important that samples of the products to be installed are provided to insure understanding and compliance with the Contract Documents, the reviewed shop drawings, and the manufacturer's written installation requirements. This should be accomplished by means of a constructability mockup to view and issue a review of the proposed means, methods, and end results as appropriate before installation work begins in earnest.

3.F.1.a Roles Of Fenestration Manufacturer And Approved Installer Defined

Poor installation practices can undo the effects and efforts of well prepared Contract Documents, fully reviewed submittals and shop drawings, and quality control measures undertaken by the manufacturer in the factory. Close collaboration between the manufacturer and the installer is essential to the successful project, each understanding their prospective role in the process.

3.F.1.b Reference Manufacturer Installation Instructions, Industry Training, And Installation Programs (ASTM E2112, AAMA InstallationMasters, AAMA Commercial Training Manual)

Practices should follow industry standards, manufacturers' recommendations, required training, and quality control. Manufacturers' representatives should observe initial installation and provide periodic follow-up to ensure installation is meeting their standards and their warranty requirements.

3.F.1.c Rough Opening Preparation

Rough openings must be prepared to receive control layers, flashing, fenestration, and fenestration anchorage. Openings should be sound, smoothly finished, neat and clean, free of debris, standing water, and moisture.

3.F.1.d Proper Preparation or Termination of Flashing and Control Layers

Proper sequencing of construction is critical to the proper weathertight installation and performance of fenestration. In particular, the proper sequencing and termination of flashing and control layers in anticipation of the fenestration installation allows not only for proper installation, but any subsequent joining or sealing of the control layers to the fenestration system. Out of sequence work can lead to unintended air infiltration and water penetration that negates the careful design and detailing of the fenestration and jeopardizes the construction of the building exterior enclosure. See *3.F.2 Practices To Be Avoided* for additional concerns regarding improper preparation and sequencing of installation.

3.F.1.e Perform Sealant Pull Testing Prior To Installation And Then As Random Verification During Installation

Through the use of pull tests, verify that the specified sealant for each application does in fact adhere to the intended substrates, and that any surface preparation is appropriate and beneficial to the adherence of the sealant to the substrates.

3.F.1.f Perform Minimum Required Level 2 Commissioning Construction Phase Tasks:

Based upon the discussions between the Architect/Engineer and the DFDM Project Manager in section *3.C.4 Minimum Required Commission Activities for Fenestration Systems*, provide only those of the following Level 2 Construction Phase activities that are to be performed:

- Submittal and review of required contractor submittals, including product samples and shop drawings.
- Perform Pre-installation Meeting(s).
- Perform and review of Aesthetic and Constructability Mockups.
- Perform and review Functional Performance Tests.
- Perform and review of limited random Function Performance Verification Tests.
- Perform and review Whole Building Air Infiltration Test, if elected.
- Preparation and submittal of Operations and Maintenance (O&M) Manuals

3.F.2 INSTALLATION PRACTICES TO BE AVOIDED

3.F.2.a Proceeding With Installation Without Satisfactorily Reviewed Submittals, Mockups, And Successful Field Performance Testing

Proceeding without proper review of submittals, mockups, and successful field performance testing opens the project to extensive risk of failure due to misinterpretation of the construction documents, lack of understanding of expected field conditions, inadequate, inappropriate, and inconsistent construction practices, and no verification that the installation performs correctly for the construction documents. Contactors who offer to take the responsibility of proceeding without the satisfactory completion of these checks also endanger the project schedule (and may incur contract mandated liquidated damages) should remedial work be required.

3.F.2.b Out Of Sequence Fenestration Installation

Proper installation of fenestration systems requires the proper sequencing of opening preparation and system installation to ensure a sound, weather-tight and waterproof installation. When a project is improperly scheduled or the project is behind schedule, contractors often resort to changing the sequence of construction to keep a project moving. In the case of fenestration installation, such a change in sequencing can impact the weather-tightness and waterproofness of the construction in general and the window installation in particular. Often the window installer may be asked or pressured to accept an incomplete or improperly prepared opening for the sake of maintaining the overall project schedule. Warranty and legal issues can arise out of this as additional liability may have been transferred to the installer by their acceptance of the situation.

Proper flashing and sealing of an out of sequence installed fenestration system often cannot be achieved short of a costly and destructive removal and reinstallation of the fenestration. Resulting leaks and failures, whether occurring within or outside the one or two year limit for which the general contractor and installer are bonded, can be costly and litigious affairs, particularly if the failure is determined to be the result of the installer accepting incomplete or improperly prepared openings. Out of sequence fenestration installation is not be permitted, and should be so noted in the appropriate installation sections of the fenestration specifications.

3.F.2.c Puncturing Of Flashing

Care and coordination must be provided to ensure secure perimeter fastening of the fenestration system, without damaging the integrity of the surrounding flashing, particularly at sills and lintels. It is recommended that fenestration anchorage avoid sills and lintel where possible. It is recommended that the placement and shape of formed flashing be reviewed with the fenestration manufacturer to prevent penetrations.

3.F.2.d Field Modification of Pre-manufactured Sill Pan Flashing and Receptor Frames

With the exception of preapproved shop drawing noted modifications to the length of sill pan flashing and receptor frames, no field modifications of sill pan flashing or receptor frames shall be made without written preapproval and photographic field documentation of the field modifications.

3.F.2.e Overlapping Flashings Upstream

Overlapping flashing upstream or against the drainage path risk of directing water into the assembly should the joints or seals fail. Overlapping flashing like lap siding on a wall or shingles on a roof directs water down and away from the joints and seals. If the lapping is reversed, water is force up and between the layers. Even in a sealed overlap condition it takes only a small gap or bird-mouth to offers a means for water to infiltrate the assembly and negate the purpose of the flashing.

3.F.2.f Anchorage By Other Than Approved Fenestration Installer

It is recommended that the fenestration installer assume full responsibility for installing anchor connections to the building structure. Other trades who may perform this work may not completely understand the connection's purpose or the need to precisely position anchors due to lack of familiarity with the fenestration system.

3.F.2.g Use Of Fiberglass Insulation As Fire Safing, Air Barrier, Or Vapor Retarder

Water vapor is carried from one place to another in a current of air or by diffusion. Of these two mechanisms, vastly more moisture may be moved in air currents allowed by the air leakage. Conventional fiberglass insulation is neither an air barrier nor a vapor retarder, but rather the same material in furnaces as air filters. In addition, fiberglass is not appropriate for use as spandrel panel insulation, fire containment/safing, and smoke containment. It is subject to damage and loss of effective performance when wet with condensation, and its low melting point and permeability preclude it from use as fire safing or smoke containment.

3.G Energy Efficiency

3.G.1 ENERGY EFFICIENCY PRACTICES TO BE PROVIDED

The challenge is to maximize energy efficiency without creating a detrimental impact to occupant comfort and use of the building. The use of fixed and operable windows, once anathema to environmental engineers now is recognized as a reasonable means take advantage of good weather and lower building operations energy costs for heating and cooling by not needing to constantly use them. Use of fenestration and shading systems is also an excellent means to take advantage of daylighting, reduced glare, and lowered building operations energy costs for lighting, heating, and cooling. Subsequently, by lowering the demand on heating and cooling equipment, the units themselves can be downsized or ‘right-sized’ for the application, and thus perform at their peak efficiency.

3.G.2 ENERGY EFFICIENCY PROGRAMS TO BE CONSIDERED

Use of LEED, Green Globes, Energy Star, or other governmental or independent third party environmental standards and practices program to minimize the environmental impact and energy costs of the construction and operation of the building is encouraged.

SECTION FOUR - GUIDELINES

4.A Control Layer and Drainage Plane Guideline

4.A.1 Purpose

As construction has moved away from simple mass walls, it has become more complex and less forgiving with the use of multi-component based enclosure systems. These component materials have certain higher properties but in a more narrowly defined role, requiring the use of additional components to make the entire assembly. In these cases, the proper design, selection, detailing, and installation practices and sequencing have become exponentially more critical to the success of the wall.

The purpose of Control Layers and Drainage Planes is to not only help separate interior environmental conditions from exterior environmental conditions, but to do so in a manner that does not deteriorate or adversely affect the materials of building exterior enclosure separating the two conditions or detract from the desired interior conditioned environment. In Wisconsin, this typically means keeping interior spaces warm and slightly humidified in winter, cool and dry in summer, have enough leeway in the design to deal with the variables of spring and autumn, and able to direct water vapor or liquid down and out of the building exterior enclosure.

4.A.2 Control Layers Overview

The ‘Water Control Layer’ is a physical barrier that keeps exterior sourced liquid water out of a wall. It may be vapor permeable or impermeable. It may be the cladding system on the exterior face of a wall, however most cladding systems really do not qualify as true Water Control Layers as while they may keep the vast majority of exterior sourced liquid water out of the wall, they do not keep all of it out. Brick veneer and wood lap siding are two examples of cladding systems that are not a true water control layer as they absorb water which can then saturate the material to the point that liquid water is conveyed through the material. Claddings typically act as more of a screen than a true barrier. Asphalt impregnated building felts, properly shingle lapped, have been used for most of the 20th century as the water control layer behind claddings. Today, the water control layer is often combined with the air control layer in the form of a single layer that is both water and airtight.

The ‘Air Control Layer’ stops air infiltration and exfiltration through the building’s exterior enclosure. Stopping the airflow through the exterior enclosure stops heat gain or loss due to convection (untempered air entering a building or tempered air escaping it). It also stops air pressure from actively forcing air through seams or leaks in the vapor control layer. This is important in Wisconsin winters when the interior air is much warmer and more humid than the exterior environment. If the moist warm air is pulled into an exterior wall, as it moves through the insulation towards the outer face, and the temperature in the wall drops, the moisture can condensate and freeze in the wall rather than escape. Frozen condensation continues to build up in the wall until spring, when it thaws and saturates the building materials and results in deteriorated materials through rot, corrosion, mold growth, and staining. Air control layers typically consist of a sheet goods product or as a liquid applied layer to the exterior, but other options and variations exist. They may be vapor permeable or impermeable, be combined with the water control layer to act as the drainage plane, or even combined with the vapor control layer when the thermal control layer is moved outboard of the air control layer.

The ‘Thermal Control Layer’ is the insulating layer that seeks to control heat loss or gain and thereby make the building more energy efficient and environmentally stable. Thermal control layers may be located on the outside face of the wall, within the wall, or on the inside face of the wall depending on the wall type.

The ‘Vapor Control Layer,’ often referred to as a vapor retarder, manages the ability of the wall to block water vapor from entering a wall assembly where if climatic conditions and building construction are not coordinated, vapor laden air can drop below the dew point and the vapor condenses into water within the exterior envelope assembly and lead to cosmetic and structural damage, mold growth, and loss of insulating value of some forms of insulation. Vapor control layers may be located on the exterior or interior face of the exterior enclosure depending on the location and type of thermal barrier used. In Wisconsin, vapor control layers are placed on the warm (interior facing) side of the insulation except in special cases, e.g. cold storage facilities.

4.A.3 Drainage Plane Overview

A drainage plane is a moisture resistant layer or barrier used to stop the infiltration of water into a building. More than just a water barrier, the term “drainage plane” also implies the use of a field or path to collect and direct moisture somewhere away. Depending on the type of wall and the materials that comprise the components and

control layers of the wall, the drainage plane may be face of the wall, as with barrier walls (membrane coated or clad concrete wall), or it may be buried in the cross section of the wall. In the latter case, the plane could be as shallow as gap between two layered materials as found in a diffusion vented wall system (clapboard siding over building wrap), a purposely separated material with weeps and vents out of the wall as in a vented system (face brick with a clear cavity separation from the backup wall), or purposely separated and subdivided vented cavities as in a pressure equalized system (metal panel rainscreen system).

The drainage plane also typically doubles as one of the Control Layers, such as building wrap air barriers or joint sealed closed cell rigid insulation. And like these layers, the drainage plane material may also be vapor permeable. This is an advantage in Wisconsin's cold climate as it lets vapor out of the wall rather than trapping it where it may condensate and do damage. When a drainage plane doubles as one of the Control Layers, it should be noted on drawings as both, but first and foremost as the Drainage Plane.

The important point of a drainage plane is that it halts the penetration of exterior moisture, collects it, and gives it a path out of the wall. The amount of moisture let through the water control layer determines what means of moisture removal is required. Where only minimal moisture is admitted, venting via diffusion through nominally loose joints of typical lap cladding may be acceptable. In instances where more moisture can be expected, physical removal of the majority of the moisture through the use of a formal cavity in the construction, and gravity, flashings, and weeps is required. Proper design of the drainage plane depends on an understanding of the environmental conditions the building exterior enclosure will be subject to and the properties and capabilities of the water control layer that will clad that wall.

Wicking and capillary action can also affect the design of drainage planes. Materials have different absorption ratings as well as capacities for holding that moisture. Masonry and wood are more absorptive than metal and have differing capacities for holding the moisture and naturally releasing it over a long period of time. Wicking and absorption can work against the drying out of the wall. The additional step of venting the wall may be required to dry out the wall in addition to draining it. Capillary action occurs between the surfaces of two materials resting close enough to each other for the surface tension of water to pull the water up into the cavity, against gravity, and drop over the flashing where it can wick into unprotect materials behind the drainage plane. While sufficient overlap of materials may prevent this from happening under normal conditions, wind pressure may drive the water even further into the gaps. Pressure equalized ventilated systems (rain screens) were designed to address these conditions.

4.A.4 Control Layer and Drainage Plane Applications and Coordination

While it is important to understand the duties, properties, and limitations of each of the control layers, their coordination with each other, and how and when they become the drainage plane, it is also important to understand how these layers are coordinated with fenestration. Fenestration starts with a hole in the building exterior enclosure, so the proper coordination and installation of the wall's Control Layers and the Drainage Plane and their joining to those of the installed fenestration is critical to long term proper functioning of the building exterior enclosure as a whole. Misaligned thermal control layers can result in condensation on interior surfaces or even within the profile of the wall. Improperly terminated or sealed drainage planes can funnel runoff water into the wall and building interior. Failure to join and seal the vapor control layer correctly to the fenestration can result in heat lose through air leaks and vapor being introduced into the wall where it may condensate and deteriorate materials or support mold growth. Two excellent resources for understanding the proper detailing and coordination of Control Layers and the Drainage Plane are the National Building Institute's online Whole Building Design Guide <http://www.wbdg.org/design/envelope.php> and Building Science Corporation's website <http://www.buildingscience.com>. Both of these sites have been instrumental in the updating the design requirements and guidelines.

4.B Window Performance Classification and Grade Guideline

4.B.1 Purpose

A joint effort between the American Architectural Manufacturers Association (AAMA), the Window and Door Manufacturers Association (WDMA), and the Canadian Standards Association (CSA), AAMA/WDMA/CSA 101/I.S.2/A440-11-the North American Fenestration Standard (NAFS) is voluntary set of standards and specifications established to more uniformly define and measure performance, durability, and quality of windows, skylights, and doors for the fenestration industry. One of the purposes of this is to aid the A/E in specifying the correct windows for a project. NAFS continues to evolve in response to new technology and market demand and was last reissued in 2011, thus the '-11' suffix in the formal document title. For the purposes of this guideline, only the window portion of NAFS will be discussed.

4.B.2 Understanding

The key to understanding NAFS is to understand how it categorizes windows and what those categories mean. NAFS categorizes windows first into one of four Performance Classes, and then within each class it further categorizes windows by Performance Grade. Understanding the meaning and use of Performance Classifications and Performance Grades is important as they signify two different things and are not interchangeable. In addition, with the continued evolution of NAFS, these terms have been refined, and in the case of Performance Classes, the number of classes has been reduced. Originally created with five classes, as of the 2008 edition these were reduced to four. Classes C and HC were discontinued and replaced with the newly formed Class CW. Failure to understand these changes and/or grasping the meanings of Performance Classification and Performance Grade can lead to confusion and misinterpretation, and result in less than optimal or product selections.

Performance Classification

NAFS Performance Classifications, or Classes, divide the range of environmental exposure, available maximum window size, and level of use into separate predetermined classes. Each of these different classes have their own established specifications and standards that windows must meet and be tested against to be included in that Performance Classification. Originally these classifications corresponded to specific project types, but the reality is project type is nothing more than a starting point for narrowing down the appropriate Performance Class for a project. In the current NAFS 2011 edition, the Performance Classes, in order of least to most severe exposure rating, are explained as follows:

- Class R: commonly used in one and two family dwellings.
- Class LC: commonly used in low-rise and mid-rise multi-family dwellings and other buildings where larger sizes and higher loading requirements are expected.
- Class WC: commonly used in low-rise and mid-rise buildings where larger sizes, higher loading requirements, limits on deflection, and heavy use are expected.
- Class AW: commonly used in high-rise and mid-rise buildings to meet increased loading requirements and limits on deflection, and in buildings where frequent and extreme use of the fenestration products is expected.

The emphasis is on 'higher loading requirements,' 'larger window sizes,' 'limits on deflection,' 'frequent and extreme use' and not the building type. It must be reiterated that the listed 'common uses' are just the starting point for determining an appropriate Performance Classification for each project. Project specific environmental requirements such as actual exposure, wind speeds, temperature ranges and fluctuations are more critical than generic statements of common use on a project type. As the State of Wisconsin often builds for the long term, and buildings are seen as the physical representation of an institution, the use of higher performance classes is required to meet the longer terms of service expected from a window, especially if the windows are operable and/or within a human contact or impact zone. Location and limited access to the window for maintenance may also warrant the use of a higher performance class than normal as well.

Performance Grade

As previously mentioned, windows must be able to successfully perform under the specific environmental and use conditions encountered. Performance Grade essentially represents the design pressure, the positive and negative force of pressure the wind exerts at a specific speed perpendicularly to a surface, that a window is designed for and tested against. Thus a window successfully tested to a 50 psf design pressure will be awarded a PG50 performance grade. Please note that while loading and deflection may be tested at the full design pressure, this does not mean

that it is used for all tests of that Performance Grade. Water penetration resistance, for instance, is tested at 15% or 20% the design pressure, depending on the Performance Grade.

Because each Performance Category addresses a different part of the environmental exposure spectrum, they each have a different minimum or 'gateway' Performance Grade. In addition to the gateway Performance Grades, NAFS permits additional optional Performance Grades in 5 psf minimum design pressure increments up to PG100 in Performance Classes R through CW. For Class AW, the most severe exposure class, there is no upper limit. Thus it is possible for two or more Performance Classifications to have similar Performance Grades, but because of the differing Performance Classification specifications, they are not equal.

4.B.3 Window Size and Type

Window size also has an effect on the both Performance Classification and Grade. The larger the window, the stronger it must be to handle the same standards and design pressures of a smaller window. Each Performance Class requires a different minimum size window for testing. In what at first may appear going against common sense, the more severe the Performance Class, the larger the minimum window size is required by the tests. For the most part this is due to the fact that larger windows are often demanded in the taller buildings. It also does not mean smaller windows in that Performance Class and Grade are not available. Typically a manufacturer tests the largest window in their line for the desired Performance Class and is then able to enter all smaller sizes without testing. They then may test the increasingly smaller windows for the purposes of achieving a higher optional Performance Grade within that Performance Class that the larger windows do not achieve.

Window type will also have an effect on Performance Class and Grade due to the additional impact of the function. The action, mechanism, and means for casements/awnings, single/double hung and slider windows to function may limit the ability of a window to respond to deflection, air leakage and water infiltration that is not present in a picture window. As a result, not all types of windows at all the same sizes of picture windows should be expected in each of the Performance Classes and Grades.

4.B.4 Application

First and foremost, the minimum Performance Class and Grade required for windows on a state project must not be less than what is required by each project's fenestration design criteria, particularly the structural and energy efficiency criteria. From there, based on additional criteria, including the proposed building longevity and the owner's project requirements, a higher Performance Class and Grade may be specified as the minimum for the project. While this direction will increase initial cost, given the increased reliability, durability, and quality, the full building life cycle costs may be less, as future maintenance could be less intensive.

4.C Prequalification of Fenestration Systems Guideline

4.C.1 Purpose

The proper design, fabrication, and installation of fenestration systems are crucial to the successful performance and longevity of the building exterior. Prequalification is not a baseline practice, but rather an additional step that can be applied, when warranted and approved by the DFDM Project Manager, to projects. For these limited special or critical projects, taking the extra step of prequalifying the fenestration system manufacturers and their specific products can be crucial to ensuring conformance with design intent, specification requirements, and project details to achieve a successful outcome on the project. Prequalification of manufacturers and their products should not be confused with the certification of contractors. Certification of contractors is to ensure that the contractor is reputable and experienced, financially secure, properly bonded and insured, and has the equipment and workers to undertake state projects. Prequalification of manufacturers and one or more of their specific products is done on a project by project basis and addresses directly the specific design and performance requirements of that project. Essentially, prequalification incorporates an early construction quality control review into the project timeline during the formal bidding process. It affords the Architect/Engineer and DFDM a level of security in that it reduces the potential for grey areas in a selected and bid product critical to the project, it confirms that a manufacturer can fabricate or customize the required product as intended. Also it allows the prime general contractor to cull out unqualified bidders and products and thereby avoiding much of the post-bid question and verification of just what exactly was being bid.

4.C.2 Application

During the design phase, the Architect/Engineer identifies specific fenestration design and performance criteria, materials, and customization requirements that may or may not be standard or typical to the normal full range of fenestration manufacturers. The Architect/Engineer will then seek to identify relevant fenestration manufacturers and products. This is initially done through the Architect/Engineer's product research and preliminary discussions with manufacturers to verify that the criteria and requirements are feasible, albeit perhaps custom or beyond normal scope of product offering.

Bid documents are then assembled using 'Basis of Design' whereby a specific fenestration manufacturer's product, with or without custom modifications, becomes the basis for the design and specification. At least two additional potential fenestration manufacturers and products are also listed in the specification. Through the DFDM and as part of the general invitation to bid, a formal notice of invitation to submit for prequalification is issued to fenestration manufacturers.

For the fenestration manufacturers this creates a two-stage bid process similar to DFDM's process for identifying low bid MEP contractors who are then incorporated into the project team of all bidding general contractors. However, in the case of the fenestration manufacturers, the idea is to identify prequalified manufacturers and products and not the low bidder. Simply put, manufacturers are invited to submit product samples, documentation, and statements indicating they can meet or exceed the project criteria and requirements. It should be noted that as a public project, all manufacturers are invited to submit product and documentation, but it is strictly the manufacturer's responsibility to prove to the satisfaction of the Architect/Engineer and DFDM that submitted products meet the project criteria and requirements. Following a review by the Architect/Engineer and DFDM of all manufacturer and product submittals, a list of approved prequalified manufacturers and products is then issued and incorporated in the bid documents by formal addenda. General contractors must then select from this list as the use of non-prequalified fenestration manufacturers and products is not permitted and will result in a rejection of the bid submittal.

4.C.3 Incorporation

The Prequalification process and requirements are typically incorporated into and coordinated in three locations:

- Invitation to Bidders
- Instructions to Bidders
- Construction Drawings
- Technical Specifications

Notice of Special Bid Submittal

Notice of a prequalification of manufacturers and specific products is first announced in the project's Invitation to Bid. A statement is provided indicating that a 'Special Bid Submittal' for the prequalification of fenestration

manufacturers and preapproval of specific fenestration products is required and that only base bids submitted with the required prequalified manufacturers and their preapproved products will be accepted; base bids submitted without the required prequalified manufacturer and preapproved products will be rejected.

The notice must then indicate that following review of manufacturers' submittals, an official list of prequalified manufacturers and their preapproved products will be issued as a formal addendum by DFDM no later than two weeks before the set bid date. The addenda formally incorporates the list into the bid documents and per state requirements must be issued no later than two weeks before the set bid date or the bid date will need to be revised.

Prequalification Criteria

Within the Instructions to Bidders portion of the Invitation to Bid, bidders must be directed to the specific criteria for preapproved manufacturers and products in both the project specifications and drawings. In the specifications, the criteria is located in the fenestration systems' technical specifications Part 1 – General section, under the Performance Requirements, the System Description, and the Warranty subsections, and in the Part 2 – Products section under the Manufacturers, Materials, Fabrication, and Finishes subsections. The specific details and any custom profiles required by the specifications are located in the construction drawings to which bidders must also be directed as they are also part of the prequalification criteria.

Special Bid Submittal Requirements

Bidders must also be informed of the requirements of preapproval process. This occurs with a Quality Assurance subsection inserted into the Part 1 – General section of the technical specifications. All requirements, such as submittal of samples materials and the fenestration product itself (with or without the customizations, depending on the lead time, contract cost, and complexity of customizations), written descriptions of fabrication processes, testing documentation, complete product specifications, and whatever else requirements might be pertinent to the process and the project.

SECTION FIVE - WAIVERS

5.A Waiver Requests

The design process is a process of discovery. On occasion, such discovery may bring into question the validity of a checklist-required criteria or practice for a specific project. Other times, creativity or innovation on a specific project may be inadvertently stifled due to a criteria or practice requirement that may not have anticipated certain innovation or a suitable alternate practice. When one of these conditions occurs on a project and it is believed that the requirement in question is no longer valid, warranted, or is detrimental to the project, a Waiver Request may be submitted to DFDM to ask that compliance with the requirement or practice in question be waived for that specific project.

5.B Waiver Request Limitations

Waiver Requests have a very narrow application and a limited timeframe in which they may be submitted. The *Design Requirements and Guidelines* serve an important purpose and the waiving of one of them for a project is a rare exception rather than a matter of standard practice. Waiver requests are a means solely for the Architect/Engineer as designer, the Client Agency as end user, and the DFDM Project Manager to formally petition for the waiving of a requirement or practice as a result of discovery, exploration, or research during the design phase of a project. It is a way for DFDM to formally document and track that rare exception when one of its design requirements for fenestration may not be appropriate for the project at hand. It is not a means to receive additional explanation about criteria and guidelines or relieve the Architect/Engineer of a design burden. It is not to be used as a means to reduce project costs or quality levels or be broadly applied to the requirements and guidelines in general to reduce their impact on a project. It is also not a means for a manufacturer or product supplier to get their product included in a list of acceptable products when they do not meet all of the established criteria.

Valid use of the Waiver Request is limited as follows:

- In general, separately questioned criteria require separate Waiver Requests.
- Only the Architect/ Engineer, the Client Agency, or the DFDM Project Manager may submit a Waiver Request, and then only on their own behalf. Contractors, Manufacturers, and Product Suppliers can not submit a Waiver Request.
- All Waiver Requests are to be submitted to the DFDM Project Manager who will in turn submit the request to the appropriate DFDM staff in a timely fashion.
- The request must be made prior to or in conjunction with the 35% Submittal Review.
- Supporting documentation and/or product examples must be submitted with the fully completed Waiver Request form.

Following the submittal of a Waiver Request, DFDM will review the request and make a formal determination to be indicated on a copy of the submitted Waiver Request and returned to the applicant through the DFDM Project Manager in a timely fashion. DFDM may approve, approve with conditions, or reject the request. The DFDM Project Manager will keep a copy of all in process of review and all reviewed Waiver Requests.

5.C Situation Examples for Waiver Requests

The following are example situations in which a Waiver Request may be warranted:

- A new state park shower and restroom facility has been commissioned, and separately the Wisconsin DNR has learned of a new self-operating window system, promoted for school and hotel swimming facilities, that includes interior/exterior humidity and temperature monitors, and can open and close windows using battery power from a photovoltaic system. The product has been on the market for two years and the DNR would like to use this new facility to test the product as they prepare for retrofitting several other existing sites over the next few years that have had deterioration issues due to humidity buildup. The DNR, as a client agency, could submit a waiver request from requirement D.1.e Reliability Criteria, which requires the use of fenestration products with a minimum five-year history of successful performance.
- A roof deck greenhouse is included as part of a new academic building, but the Checklist as edited, makes no distinction between greenhouse and the rest of the building in regards to requirement D.2.m Thermal Breaks and Barriers Within Elements, which requires fenestration systems to be thermally broken. The greenhouse, while heated in the winter and open to the outdoors in warmer seasons, is meant to be nothing

more than a greenhouse, which is typically not constructed of insulated glazing units and thermally broken framing. The Architect/Engineer could submit a Waiver Request asking to allow the greenhouse to be exempt from this requirement as is standard industry practice.

5.D Waiver Request Submittal

A Waiver Request may be made by submitting the following information, on the submitter's corporate or agency letterhead, to the DFDM Project Manager for DFDM consideration:

1. The following project information:
 - a. DFDM Project Number
 - b. Date of Request
 - c. Building Name
 - d. User Agency/Location
 - e. DFDM Project Manager
2. The following submitter information:
 - a. Signature
 - b. Name/Title
 - c. Firm/Agency
 - d. Address
 - e. Telephone
 - f. Email
3. The requirement/practice to be provided or avoided:
 - a. List the checklist number and title for the requirement/practice in question.
 - b. Fully explain the reason for requesting the waiver and how the granting of it will be of a benefit to the project.
 - c. Indicate what, if anything, is in lieu of the requirement/practice to be waived.
 - d. Provide a statement indicating how, if approved, the waiving of the requirement or guideline in question will not result in a reduction of the project's quality, building longevity, building performance, or building maintainability, or result in the failure to meet the owner's project requirements.
 - e. Provide a list of all submitted supporting documentation and/or product examples.
4. Submit the request to the DFDM Project Manager for DFDM review. In their official response to the waiver, DFDM will indicate if the request is on hold pending receipt of additional requested information, rejected, granted, or granted with conditions.

APPENDIX A – FENESTRATION CONTROL LAYER DIAGRAMS

The Fenestration Control Layer Diagrams illustrate concepts and practices presented in the *Design Requirements And Guidelines For Fenestration In Building Exterior Enclosures*. These diagrams are not construction details, but several important issues regarding the placement of fenestration within openings, and the location and continuity of control layers in the walls and fenestration of building exterior enclosures. Not all fenestration types, wall types, or placement locations are presented. Those that are, are the most common. The wall types used in each diagram are not exclusive to that example, but are used to present common situations.

The diagrams are meant to start a discussion/exploration with the designing Architect/Engineer by reminding them of the issues they must consider and resolve in order to properly design a weather tight, long lasting, and maintainable installation. These diagrams are just that, diagrams. Not all systems and components are shown, and those that are, are illustrated in a simplified manner for the purposes of presentation and discussion. The actual design and detailing of the installation must be performed by the Architect/Engineer to address the specific criteria, requirements, and conditions of the project at hand.

Five examples of four fenestration placement concepts are presented:

- DT-1 Inline Set Fenestration Example - illustrating an installation whereby the fenestration system is set “inline” with the control layers of the exterior enclosure
- DT-2 Inline Set Fenestration Example – a variation of the first example that illustrates the use of an alternate wall type for the exterior enclosure.
- DT-3 Inboard Set Fenestration Example – illustrates some of the issues encountered when the fenestration is pulled inboard of the exterior enclosure control layers.
- DT-4 Outboard Set Fenestration Example – illustrates some of the issues of setting the fenestration outboard of the exterior enclosure control layers.

An example of retrofitting existing construction with new fenestration is also presented:

- DT-5 Retrofit Fenestration Opening Example – illustrates issues commonly encountered in the retrofit of older masonry buildings.

Finally, an example of a common detailing/constructability challenge is reviewed:

- DT-6 Engagement of Perimeter Seals – explores the need to properly engage backer rod & sealant within the perimeter joint between the prepared opening and the fenestration.

COMBINED AIR-WATER-VAPOR CONTROL LAYER

COMBINING THESE LAYERS INTO ONE LAYER REQUIRES THE USE OF INSULATION ON THE OUTBOARD SIDE ALLOWING ANY CONDENSATION AND ICE THAT MIGHT FORM TO BE OUTSIDE THE SEALED PORTION OF THE EXTERIOR ENCLOSURE

THERMAL CONTROL LAYER

WHEN LOCATED OUTSIDE THE WEATHER AND VAPOR CONTROL LAYERS, WATER & ICE RESISTANT INSULATION IS REQUIRED

CLADDING LAYER

NOT A CONTROL LAYER IN THIS EXAMPLE, THE CLADDING PROTECTS THE CONTROL LAYERS FROM THE DIRECT IMPACTS OF WEATHER AND UV LIGHT

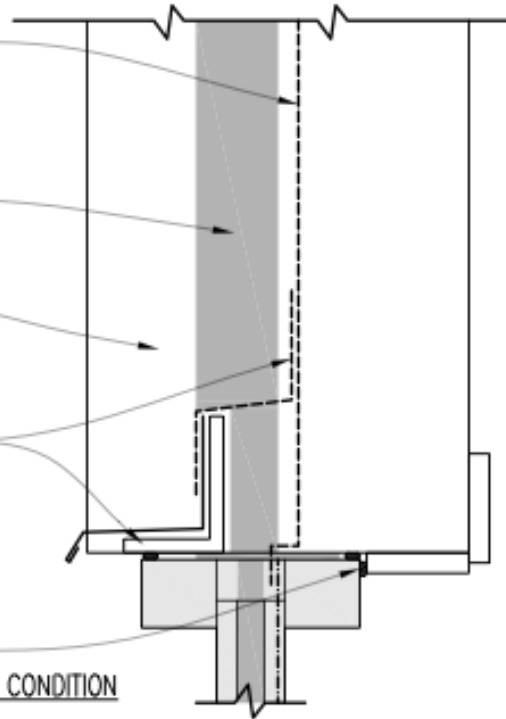
DRAINAGE PLANE & WEEPS

THE COMBINED CONTROL LAYERS ARE THE DRAINAGE PLAN FOR THIS EXAMPLE. FLASHINGS MUST BE SEALED TO THE DRAINAGE PLANE AND, AT CRITICAL JUNCTURES, DIRECT WATER OUT THROUGH PLANNED WEEPS, OFTEN AROUND ELEMENTS OF THE CLADDING, SUCH AS THE STEEL LINTEL, OR THE FENESTRATION FRAME ITSELF.

FENESTRATION FRAME - INTERIOR FINISHES SEPARATION

A COMPRESSIBLE SEAL, SUCH AS BACKER ROD & SEALANT, PERMITS MOVEMENT BETWEEN FRAMES AND INTERIOR FINISHES WITHOUT DAMAGE

HEAD CONDITION



FENESTRATION COMBINED AIR-WATER-VAPOR CONTROL LAYER

THE INTERIOR SIDE OF THE THERMALLY BROKEN FRAME AND INTERIOR PANE OF GLASS IN AN IGU OFTEN FORM THE COMBINED AIR-WATER-VAPOR CONTROL LAYER IN FENESTRATION, ALLOWING GLAZING POCKETS AND THE WEATHER SIDE OF THE FRAMES TO BE WEPT TO THE EXTERIOR WITHOUT COMPROMISING THE SEPARATION

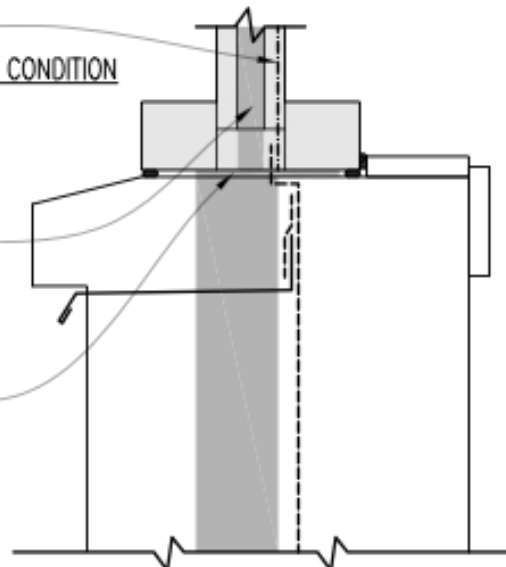
SILL CONDITION

FENESTRATION THERMAL CONTROL LAYER

THE THERMAL BREAKS INCLUDED IN THE FRAME AND IN THE INSULATED GLAZING UNIT (IGU) FORM THE FENESTRATION THERMAL CONTROL LAYER

THERMAL CONTROL LAYER AT SHIM SPACES

TO MAINTAIN A CONTINUOUS THERMAL CONTROL LAYER, SHIM SPACES MAY BE FILLED WITH MINERAL WOOL OR EXPANDING CLOSED CELL FOAM. CARE MUST BE PRACTICED TO AVOID DEFORMING FRAMES WHEN USING EXPANDING CLOSED CELL FOAM.



DT-1

INLINE SET FENESTRATION EXAMPLE: USING A MASONRY CAVITY WALL IN DIAGRAMMATIC FORM AS AN EXAMPLE, THE FENESTRATION SYSTEM IS LOCATED SUCH THAT ITS CONTROL LAYERS ALIGN WITH THOSE OF THE WALL. THIS EXAMPLE ALSO ILLUSTRATES THE COMBINED AIR-WATER-VAPOR CONTROL LAYER BEING PHYSICALLY CAPTURED BY THE FENESTRATION FRAME, AS IS POSSIBLE WITH CURTAIN WALL AND SOME STOREFRONT FENESTRATION SYSTEMS.

COMBINED AIR-WATER CONTROL LAYER

WHEN THE AIR-WATER CONTROL LAYER IS OUTBOARD OF THE THERMAL CONTROL LAYER, CONSIDER IF THE AIR-WATER CONTROL LAYER SHOULD BE VAPOR PERMEABLE

THERMAL CONTROL LAYER

A TWO PART THERMAL CONTROL LAYER IS ILLUSTRATED: INSULATED STUD CAVITY WITH A LAYER OF CONTINUOUS EXTERIOR INSULATION OVER THE COMBINED AIR-WATER CONTROL LAYER BUT BEHIND THE CLADDING. WHEN LOCATED OUTSIDE THE WEATHER AND VAPOR CONTROL LAYERS, WATER & ICE RESISTANT INSULATION IS REQUIRED.

VAPOR CONTROL LAYER

OVERLAPPING AND SEALING THE COMBINED AIR-WATER CONTROL LAYER TO THE VAPOR CONTROL LAYER COMPLETELY ENCLOSES AND PROTECTS THE STUD CAVITY THERMAL CONTROL LAYER FROM WATER VAPOR AND CONDENSATION

CLADDING LAYER

NOT A CONTROL LAYER IN THIS EXAMPLE, THE CLADDING PROTECTS THE CONTROL LAYERS FROM THE DIRECT IMPACTS OF WEATHER AND UV LIGHT

HEAD CONDITION

PERIMETER SEALS

IN INSTANCES WHERE THE AIR-WATER, AND VAPOR CONTROL LAYERS CAN NOT BE PHYSICALLY ENGAGED BY THE FENESTRATION FRAME, PROPERLY INSTALLED SEALANT OVER BACKER ROD AND/OR SELF ADHERED SILICONE SHEETS CAN ACT AS THE SEAL BETWEEN THE AIR-WATER OR VAPOR CONTROL LAYERS OF THE WALL, AND THOSE OF THE FENESTRATION. FENESTRATION FRAMES MUST HAVE LEG RETURNS OR ACCEPT PVC INSERT CAPS TO PROPERLY ENGAGE THE SEALANT AND BACKER ROD. SEE DT-6.

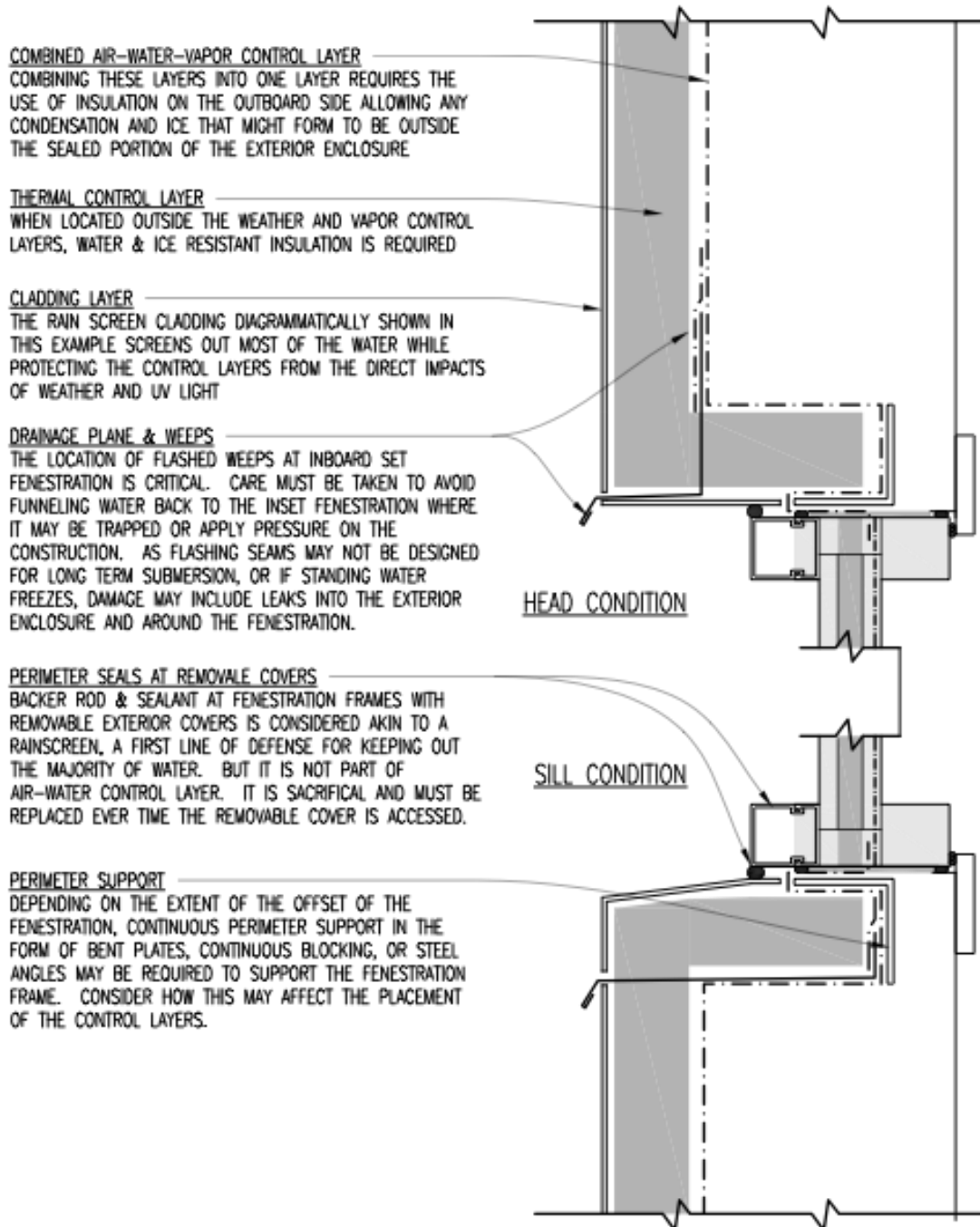
SILL CONDITION

METAL CLAD SILL/SILL FLASHING

DEPENDING ON THE CLADDING MATERIAL AND THICKNESS USED, METAL PAN FLASHING FOR THE SILL MAY ALSO SERVE AS FLASHING OVER THE TOP OF THE CLADDING AT THE SILL LINE. CONSIDERATION MUST BE GIVEN TO THE FLASHING MATERIALS AND DESIGN IF THE PAN CROSSES THE THERMAL CONTROL LAYER AND INTERIOR CONDENSATION IS A POSSIBILITY.

DT-2

INLINE SET FENESTRATION EXAMPLE: THIS DIAGRAM USES A CLAD, INSULATED STUD CAVITY WALL WITH CONTINUOUS EXTERIOR INSULATION TO ILLUSTRATE HOW CONSIDERATION MUST BE GIVEN TO THE PROPER TERMINATION AND SEALING OF THE WALL CONTROL LAYERS WHILE STILL CONNECTING TO THE APPROPRIATE FENESTRATION CONTROL LAYERS. GAPS SHOWN ARE FOR CLARITY PURPOSES ONLY WHEN ILLUSTRATING MULTIPLE CONTROL LAYERS.



DT-3

INBOARD SET FENESTRATION EXAMPLE: ILLUSTRATED WITH A RAIN SCREEN CLADDING EXAMPLE, THE WALL CONTROL LAYERS MUST MOVE INWARD TO ALIGN WITH THOSE OF THE INBOARD SET FENESTRATION SYSTEM. THEIR CAREFUL COORDINATION WITH THE STRUCTURAL SUPPORT FOR FENESTRATION IS REQUIRED TO AVOID SHORT CIRCUITING THE THERMAL CONTROL LAYER OR INTERRUPTING THE COMBINED AIR-WATER-VAPOR CONTROL LAYER.

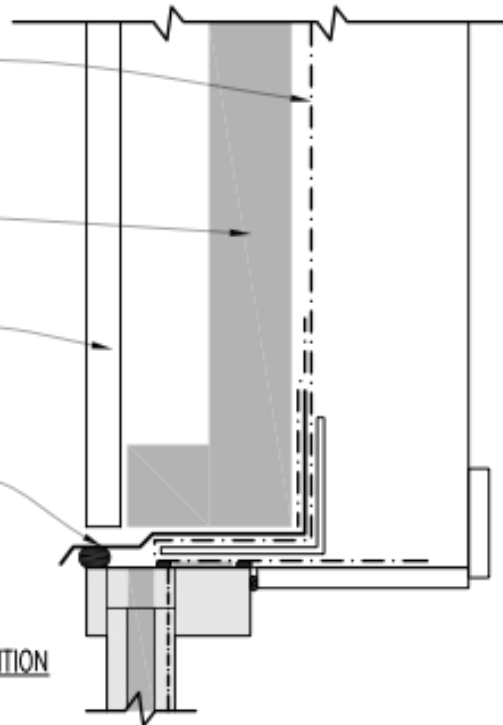
COMBINED AIR-WATER-VAPOR CONTROL LAYER
 COMBINING THESE LAYERS INTO ONE LAYER REQUIRES THE USE OF INSULATION ON THE OUTBOARD SIDE ALLOWING ANY CONDENSATION AND ICE THAT MIGHT FORM TO BE OUTSIDE THE SEALED PORTION OF THE EXTERIOR ENCLOSURE

THERMAL CONTROL LAYER
 WHEN LOCATED OUTSIDE THE WEATHER AND VAPOR CONTROL LAYERS, WATER & ICE RESISTANT INSULATION IS REQUIRED

CLADDING LAYER
 NOT A CONTROL LAYER IN THIS EXAMPLE, THE RAIN SCREEN CLADDING IS INTENDED TO SCREEN OUT MOST OF THE WATER WHILE PROTECTING THE CONTROL LAYERS FROM THE DIRECT IMPACTS OF WEATHER AND UV LIGHT

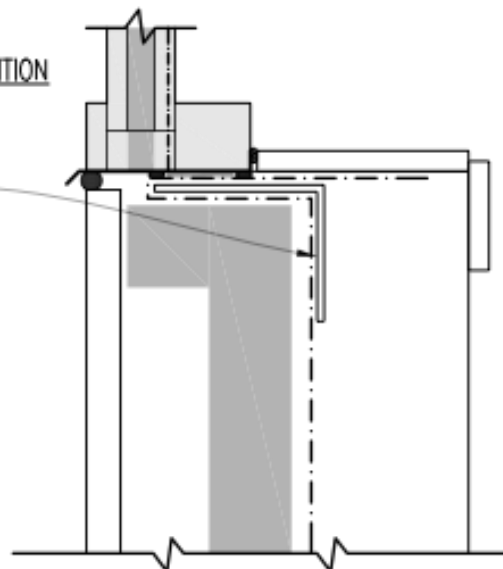
DRAINAGE PLANE & WEEPS
 BECAUSE OF THE OUTBOARD SETTING OF THE FENESTRATION FRAME AND THE USE OF A RAINSCREEN CLADDING, THE USE OF A HEAVIER FLASHING RIGID FLASHING MATERIAL IS REQUIRED TO CREATE AN OUTER SLEEVE TO WHICH THE FRAME MAY BE SEALED AT THE CLADDING LAYER

HEAD CONDITION



SILL CONDITION

PERIMETER SUPPORT
 DEPENDING ON THE EXTENT OF THE OFFSET OF THE FENESTRATION, CONTINUOUS PERIMETER SUPPORT IN THE FORM OF BENT PLATES, CONTINUOUS BLOCKING, OR STEEL ANGLES MAY BE REQUIRED TO SUPPORT THE FENESTRATION FRAME. CONSIDER HOW THIS MAY AFFECT THE PLACEMENT OF THE CONTROL LAYERS.



DT-4 **OUTBOARD SET FENESTRATION EXAMPLE:** ILLUSTRATED WITH A RAIN SCREEN CLADDING EXAMPLE, THE WALL CONTROL LAYERS MUST MOVE OUTWARD TO ALIGN WITH THOSE OF THE OUTBOARD SET FENESTRATION SYSTEM. SIMILAR TO INBOARD SET FENESTRATION, THE CAREFUL COORDINATION OF THE CONTROL LAYERS WITH THE STRUCTURAL SUPPORT FOR FENESTRATION IS REQUIRED TO AVOID SHORT CIRCUITING THE THERMAL CONTROL LAYER OR INTERRUPTING THE COMBINED AIR-WATER-VAPOR CONTROL LAYER.

AIR-WATER CONTROL LAYER

IN EARLY MASONRY CONSTRUCTION, IF A CAVITY IS PROVIDED, A SIMPLE CEMENT PARING OVER THE MASONRY OR BOOK TILE BACKUP WALL MAY BE THE CLOSEST THE EXTERIOR ENCLOSURE COMES TO AN AIR OR WATER CONTROL LAYER. THOUGH INEFFECTIVE BY TODAY'S STANDARDS, THOUGH MUST BE GIVEN ON HOW IT MIGHT BE INTEGRATED WITH THAT OF THE RETROFIT FENESTRATION

THERMAL CONTROL LAYER

IN EARLY MASONRY CONSTRUCTION, THE THERMAL CONTROL LAYER IS OFTEN NOTHING MORE THAN THE MASS OF THE MASONRY WALL AND AN AIR CAVITY IF PROVIDED. THIS IS RUDIMENTARY AT BEST, BUT NOT AN EXCUSE FOR MAKING THE THERMAL BRIDGING WORSE Y NOT USING BEST PRACTICES.

DRAINAGE PLANE & WEEPS

IF A CAVITY EXISTS, CONSIDER THE COST VS. BENEFITS OF INSTALLING HEAD FLASHING. EXISTING CONSTRUCTION WOULD NEED TO BE OPENED TO ACCESS THE CAVITY. OBSERVED WATER DAMAGE AND CORRODING LINTELS INDICATE A WATER CONTROL PROBLEM THAT NEEDS TO BE ADDRESS.

PERIMETER SEALS

WITH THE LACK OF TRUE AIR-WATER, AND VAPOR CONTROL LAYERS IN AN XISTING WALL, SEALANT AND BACKER ROD ARE THE ONLY MEANS OF SEALING THE FENESTRATION CONTROL LAYERS TO THE EXISTING CONSTRUCTION

HEAD CONDITION

FENESTRATION THERMAL CONTROL LAYER

FENESTRATION AIR-WATER CONTROL LAYER

SILL CONDITION

METAL CLAD SILL/SILL FLASHING

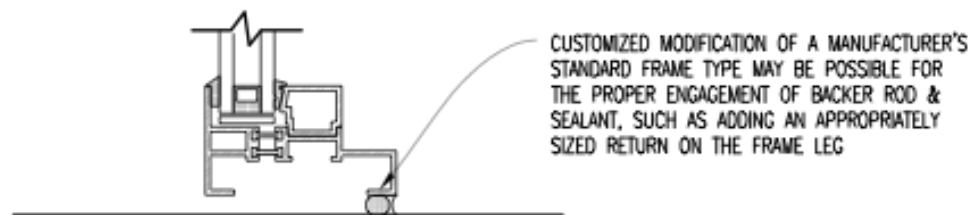
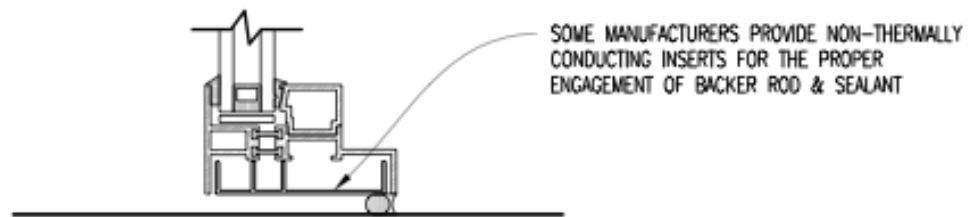
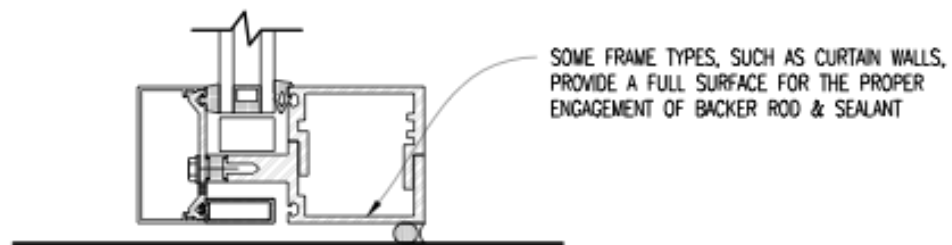
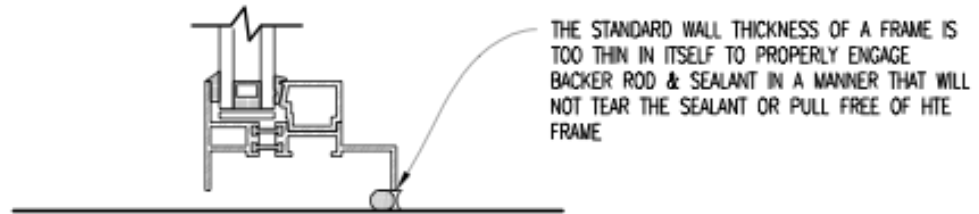
EXISTING SILLS MAY BE A SOURCE OF WATER INFILTRATION DUE TO A PREPODERANCE OF HEAD JOINTS IN A BRICK ROWLOCK SILL, CRACKS IN THE MATERIAL, OR THE USE OF HIGHLY ABSORBANT MATERIAL. A RETROFIT APPLIED ALUMINUM SILL WITH DRIP OVER THRU-WALL FLASHING MAY REDUCE WATER PENETRATION AT THESE LOCATIONS. SILL ENDS SHOULD HAVE A DOWNTURNED LEG TO ALLOW FOR PROPER SEALING OF THE SILL TO THE EXISTING OPENING JAMB.

FULL CROSS SECTION CAVITY SEAL

ANY WALL CAVITY IN EXISTING CONSTRUCTION MUST BE SEALED AGAINST AIR, WATER, VAPOR, ACROSS ITS FULL CROSS SECTION JUST AS WITH MODERN CONSTRUCTION. WHILE CONTROL LAYERS MAY NOT BE PRESENT IN A FORM AS EFFECTIVE AS IN NEW CONSTRUCTION, IT IS ALL THE MORE IMPORTANT TO NOT DISRUPT OR SHORT CIRCUIT EVEN THE MOST RUDIMENTARY EXISTING CONTROL LAYERS.

DT-5

RETROFIT FENESTRATION OPENING EXAMPLE: THERE ARE MANY CHALLENGES WHEN REPLACING FENESTRATION SYSTEMS IN EXISTING OPENINGS: DEPENDING ON THE ERA IN WHICH THE BUILDING WAS DESIGNED AND CONSTRUCTED, IT LIKELY DOES NOT HAVE CONTROL LAYERS AS WE KNOW THEM; ONE OR MORE CONTROL AYERS MAY NOT EXIST; AND THE SURROUNDING CONSTRUCTION IS NOT OR CAN NOT BE OPENED TO PERMIT PROPER TERMINATION OF CONTROL LAYERS.



DT-6 ENGAGEMENT OF PERIMETER SEALS: THE USE OF SEALANT & BACKER ROD AS A PERIMETER SEAL REQUIRES THE MEANS FOR THE FENESTRATION FRAME TO FULLY ENGAGE THE SEALANT & BACKER ROD. ILLUSTRATED ABOVE ARE A FEW COMMON METHODS.