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December 23, 2022

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RE: NFPA 285 Compliant Exterior Wall Constructions incorporating 4¼-inch Thick DuPont™ Thermax™ and Spray Polyurethane Foam (SPF) with Non-Combustible Claddings
JENSEN HUGHES Project No. 1JJB05306.011

To Whom It May Concern:

Jensen Hughes has completed our engineering analysis of exterior wall assemblies compliant with NFPA 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components*, constructed using the Thermax™ Brand Rigid Insulation and a closed cell (CC), nominal 2.0 lb/ft^3 density, spray polyurethane foam (SPF) insulation material.

Use of these combustible materials in an exterior wall assembly requires compliance with NFPA 285 by the applicable building code requirements to ensure excessive vertical and lateral exterior flame spread will not occur during a fire event. Specifically, Section 2603.5.5 of the International Building Code (2000 through 2021 Editions) require exterior wall systems incorporating foam plastic insulation materials to meet the requirements of NFPA 285. Similarly, Section 1403.5 of the IBC (2000 through 2015 Editions) and Section 1402.5 of the IBC (2018 and 2021 Editions) requires exterior wall assemblies on buildings of Types I, II, III, or IV construction that are greater than 40-feet above grade plane to comply with NFPA 285 if they incorporate a combustible water-resistive barrier (WRB) material.

DuPont has conducted numerous NFPA 285 fire tests of exterior wall assemblies that have incorporated the Thermax™ Brand Rigid insulation and various CC SPF insulation materials. The NFPA 285 test reports used as the bases for developing the NFPA 285 compliance tables within this letter are listed in the “references” section at the end of this letter.

Based on the results of these NFPA 285 tests, additional testing of water-resistive barriers (WRB) materials per ASTM E1354, and our experience with the NFPA 285 fire test, it is our opinion that the various configurations of exterior walls described in Tables 1 through 3 will meet the performance requirements of NFPA 285. Additionally, special opening header details shown in Figure 1.

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Table 1 – NFPA 285 Complying Wall Construction with Max 4¼-inch Thick Thermax™ Sheathing and Non-Combustible Cladding

Wall Component	Materials
Base Wall System – Use either 1, 2, 3, 4, or 5	1) Concrete wall 2) Concrete Masonry Unit (CMU) wall 3) Standard clay brick wall (nominal 3⅝-thick brick) 4) Wood studs: nominal 2-inch × 4-inch or greater FRTW wood studs spaced at a maximum of 24-inch OC. One layer of ⅝-inch thick Type X gypsum wallboard installed on interior face of wood studs. One layer of ⅝-inch thick Type X exterior gypsum sheathing installed on exterior face of wood studs. Minimum two top plates at floorlines. As an option, any thickness of plywood or OSB may be installed on exterior face of wood studs under exterior gypsum sheathing. 5) Steel studs: minimum 3⅝-inch depth, minimum 20-gauge at a maximum spacing of 24-inch OC with lateral bracing every 4 ft. vertically. One layer of ⅝-inch thick Type X gypsum wallboard on interior face of studs. Gypsum wallboard joints shall receive at a minimum a Level 2 finish with all fasteners covered with joint compound.
Floor Line Firestopping Required in curtain-wall construction	4 lb./cu ft. mineral wool in each stud cavity and at each floor line
Interior Vapor/Moisture barrier	1) None 2) Any 6-mil thick polyethylene film
Cavity Insulation – Use either 1, 2, or 3 Or combination of 2 and 4 Or combination of 3 and 4	1) None – Screw end of fasteners that protrude into the stud cavity can be covered with a maximum of 1½-inch diameter plug of DuPont™ Froth-Pak Class A rated per ASTM E 84 2) Minimum 1¾-inch thickness of BASF Walltite Plus (covered in Intertek CCRR-0374) applied using sheathing or insulation as substrate and covering the width of the cavity and inside the stud flange. Window header protection as shown in Figure 1. 3) Minimum 1¾-inch thickness of Huntsman Building Solutions Heatlok HFO Pro (covered in IAPMO UES Evaluation Report No. ER-565) applied using sheathing or insulation as substrate and covering the width of the cavity and inside the stud flange. Window header protection as shown in Figure 1. 4) Fiberglass blown-in or batt insulation (faced or unfaced) or mineral wool blown-in or batt insulation (faced or unfaced)
Exterior Sheathing – Use either 1, 2, or 3 OR	1) None 2) ½-inch thick, exterior gypsum sheathing 3) ⅝-inch thick, Type X exterior gypsum sheathing **Note:** Exterior sheathing is not required for ***Base Wall Systems 1 through 3***.
Multi-Function Sheathing & WRB Products	1) USG Securock® ExoAir® 430 System **Note:** This item replaces the exterior sheathings above. When this item is used the exterior sheathings are not required and additional WRBs shall not be used.
WRB Materials Applied to ***Exterior Sheathing Items 2 or 3***	1) None 2) Any shown in Table 2 **Note:** Any WRB material shown in Table 2 can be applied over ***Base Wall Systems 1 through 4*** above, where able.

Wall Component	Materials
Exterior Insulation – Use either 1 or 2	1) None - If no exterior insulation is used, Exterior Sheathing Items 2 or 3 must be used for ***Base Wall Systems 4 or 5***. 2) DuPont™ Thermax™ Brand Rigid Insulation - Total thickness to be a minimum of ⅝-inch to maximum of 4¼-inches.
Exterior Insulation Joint Flashing – Use either 1 or 2	1) None – Only when a water-resistive barrier is applied to ***Exterior Sheathing Items 2 or 3*** or when a water-resistive barrier is applied to ***Exterior Insulation Item 2***. 2) Flash all exterior insulation joints and veneer tie penetrations with one of the following: a. DuPont™ LiquidArmor™ - CM Flashing and Sealant – max. 50-mil wet thickness, max. 4-inch width b. DuPont™ LiquidArmor™ - LT Flashing and Sealant – max. 35-mil wet thickness, max. 4-inch width. c. DuPont™ LiquidArmor™ - QS Flashing and Sealant – max. 50-mil wet thickness, max. 4-inch width d. DuPont™ Tyvek® Fluid Applied Flashing & Joint Compound+ – max. 25-mil wet thickness, max. 3-inch width e. Asphalt, acrylic, or butyl-based flashing tape – max. 4-inch width f. DuPont™ Great Stuff Pro™ - Use on joints that are ≤ ¼-inch, vertical joints must be staggered & remove significant excess from the face of the Thermax™ **Note:** With either e) or f), a small amount of spray primer may be used to aid in adhesion; maximum 4-inch width.
WRB Materials Applied Over ***Exterior Insulation Item 2*** – Use either 1 or 2	1) None 2) Any shown in Table 3 **Note:** Any WRB material shown in Table 3 can be applied over ***Base Wall Systems 1 through 3***, where able.
Drainage Mat – Use either 1 or 2	1) None 2) DuPont™ Tyvek® DrainVent™ Rainscreen – For use with any listed exterior veneer only when no air gap is present between the veneer and the DrainVent™. May be used in conjunction with any WRB shown in Table 3, but not with WRBs from Table 2.

Wall Component	***Materials***
Exterior Veneer – Use either 1, 2, 3, 4, 5, or 6	1) Brick - Standard nominal 4-inch thick, clay brick with standard type brick veneer anchors, installed maximum 24-inches OC vertically on each stud. Air gap between exterior insulation and brick to be a maximum of 2-inches. WRB from Table 2 can be used over the exterior insulation. 2) Stucco – Minimum ¾-inch thick, exterior cement plaster and lath. A secondary water-resistive barrier can be installed between the exterior insulation and the lath. The secondary water-resistive barrier can be 1 or 2 layers of asphalt building paper but shall not be full-coverage asphalt or butyl-based self-adhered membranes. WRB from Table 2 can be used as the secondary water-resistive barrier. 3) Minimum 2-inch thick limestone or natural stone veneer or minimum 1½-inch thick cast artificial stone veneer. Any standard non-open-joint installation technique such as ship-lap, etc., can be used. 4) Terracotta cladding – Use any terracotta cladding system in which terracotta is minimum 1¼-inch thick. Any non-open-joint installation technique such as ship-lap, etc. can be used. 5) Concrete or precast concrete panels – Minimum 1½-inch thick panel, with a 2-inch maximum air gap between exterior insulation and concrete panel. Any standard non-open-joint installation technique such as ship-lap, etc. can be used 6) Concrete Masonry Units - Minimum 4-inch thick panel with a 2-inch maximum air gap between exterior insulation and the interior face of the exterior CMU. Any standard non-open-joint installation technique can be used
Flashing of Windows, Doors, and Other Exterior Wall Penetrations.	As an option, flash window, door and other exterior penetrations with either: 1) DuPont™ LiquidArmor™ – CM Flashing and Sealant – max. 50-mil wet thickness, max. 4-inch width. 2) DuPont™ LiquidArmor™ – LT Flashing and Sealant – max. 35-mil wet thickness, max. 4-inch width. 3) DuPont™ LiquidArmor™ – QS Flashing and Sealant – max. 50-mil wet thickness, max. 4-inch width. 4) DuPont™ Tyvek® Fluid Applied Flashing & Joint Compound+ – max. 25-mil wet thickness, max. 3-inch width 5) Limited amounts of acrylic, asphalt or butyl-based flashing tape – max. 12-inch width. 6) DuPont™ DuraGard™ CM Transition Flashing – max. 12-inch width **Note:** Flashing tape used in wall openings may extend the wall width plus extend up to a maximum of 4-inches onto the exterior face of the sheathing. Flashing tape may be used on sheathing exterior corners where the flashing tape may extend a maximum of 4-inches onto the sheathing face on either side of the corner.
Mortar Net	As an option, non-full wall coverage mortar drop and drainage nets and meshes can be installed at base of wall and at shelf angles to permit water drainage. Maximum 12-inch high.

Table 2 – Allowed Water-Resistive Barrier Applied Over Exterior Sheathing and Under Exterior Insulation

Weather Resistive Barrier Manufacturer/Product
3M™ • 3M™ Self-Adhered Air and Vapor Barrier 3015
Carlisle • CCW-705FR w/ Primers • Barritech™ VP
Dörken Systems • Delta®-Foxx • Delta®-Foxx Plus • Delta®-Fassade S • Delta®-Vent S/Plus • Delta®-Maxx Plus
DOWSIL™ • DefendAir 200 • DefendAir 200C
Dryvit • Backstop® NT
DuPont (See Figures 4, 5, and 6) • DuPont™ Tyvek® CommercialWrap® • DuPont™ Tyvek® CommercialWrap® D • DuPont™ Tyvek® ThermaWrap™ • DuPont™ Tyvek® Fluid Applied WB+ – nominal 25 wet mil thickness • WeatherMate™ • WeatherMate™ Plus
GCP Applied Technologies • Perm-A-Barrier® Aluminum Wall Membrane • Perm-A-Barrier® VPL • Perm-A-Barrier® VPL LT • Perm-A-Barrier® VPS
Henry Company • Air-Bloc® 17MR • Air-Bloc® 31MR • Air-Bloc® 33MR • Air-Bloc® 21 FR

Weather Resistive Barrier Manufacturer/Product
• Air-Block® All Weather STPE • BlueskinVP™ 160 • Metal Clad™ • Foilskin®
Hohmann & Barnard • Enviro-Barrier™ VP
JX Nippon ANCI, Inc. • JX ALTA™ Commercial Wrap • JX ALTA™ HP Wrap • JX ALTA™ LP Wrap
Kingspan • Kingspan® GreenGuard® Max™ Building Wrap • Kingspan® GreenGuard® Classic Building Wrap • Kingspan® GreenGuard® C2000 Building Wrap • Kingspan® GreenGuard® Raindrop® 3D Building Wrap • Kingspan® GreenGuard® HPW™ Building Wrap
Momentive Performance Materials • GE SEC2500 SilShield* AWB • GE SEC2600 SilShield* AWB • GE SEC2600-R SilShield* AWB
Sto Corp • Sto Gold Coat® with StoGuard Fabric • Sto Emerald Coat® with StoGuard Fabric • Sto ExtraSeal™ w StoGuard Mesh
STS, Inc. • Wall Guardian™ FW-100A
Tremco • ExoAir 230 • ExoAir 430
VaproShield • WallShield® • WrapShield® • RevealShield™ • RevealShield SA™ • PanelShield SA™
W.R. Meadows • Air-Shield™ LMP (Gray)

Weather Resistive Barrier Manufacturer/Product
• Air-Shield™ LMP (Black) • Air-Shield™ TMP • Air-Shield™ LSR • Air-Shield Aluminum

Table 3 – Allowed Water-Resistive Barrier Applied Over Exterior Insulation

Weather Resistive Barrier Manufacturer/Product
DuPont (See Figures 4, 5, and 6) • DuPont™ Tyvek® CommercialWrap® • DuPont™ Tyvek® CommercialWrap® D • DuPont™ Tyvek® ThermaWrap™ • WeatherMate™ • WeatherMate™ Plus
Kingspan • Kingspan® GreenGuard® Max™ Building Wrap • Kingspan® GreenGuard® C500 Building Wrap • Kingspan® GreenGuard® Raindrop® 3D Building Wrap
VaproShield • RevealShield™ • RevealShield SA™ • PanelShield SA™

Engineering Analysis

DuPont has performed a successful NFPA 285 fire test on an exterior wall assembly constructed as follows (interior to exterior):

1. Nominal ⅜-inch thick layer of Monokote Z-3306 thermal barrier material applied over nominal 1½-inc thick layer of DuPont™ STYROFOAM Brand Spray Polyurethane Foam CM 2045 sprayed into all stud cavities.
2. 6-inch deep, 20 gauge steel studs spaced 24-inches on center
3. 4-inch thickness of the Thermax™ Brand Rigid Insulation polyisocyanurate foam plastic insulation board. All board joints covered with a 4-inch thickness of the Dow WEATHERMATE Straight Flashing tape.
4. Standard 4-inch thick clay brick veneer with a 2-inch air gap.
5. Wall opening header, sill, and jambs were finished with 0.080-inch thick aluminum flashing.

A complete description of the tested wall constructions, the test observations, and the test results are provided in Southwest Research Institute Test Report No. 01-15822.01.001, dated September 9, 2010 [1]. This successful NFPA 285 test was used as the basis for qualifying the use of 4-inches of the Thermax™ Brand

Rigid Insulation material in an exterior wall assembly. A previous engineering analysis conducted by Jensen Hughes used this test report, along with other test reports included in the References Section of this engineering analysis report, to increase the maximum allowable Thermax™ Brand Rigid Insulation material to 4¼-inches. This analysis and the conclusion were based on the good fire performance of the wall assembly and limiting the exterior veneer materials to non-combustible materials which will provide the greatest thermal protection to the Thermax™ Brand Rigid Insulation material.

The other successful NFPA 285 tests were constructed as follows (interior to exterior):

6. One layer of ⅝-inch thick Type X gypsum wallboard installed continuously over the interior surface of the wall assembly.
7. 3⅝-inch deep, 18 gauge steel studs spaced 16-inches on center
8. Stud cavities filled with minimum 1¾-inch depth of SPF applied to the Thermax™ sheathing as the substrate. SPF may be either the BASF WALLTITE Plus or the Huntsman Heatlok HFO PRO closed cell (CC) SPF products
9. 3-inch thickness of the Thermax™ polyisocyanurate foam plastic insulation board. All board joints covered with a 3-inch thickness of the DuPont™ LiquidArmor™ CM Flashing and Sealant applied at 50 mils wet.
10. DuPont™ Tyvek® CommercialWrap® WRB
11. 8¼-inch wide, 5/16-inch thick James Hardie Hardie® Plank Lap Siding installed horizontally over ⅞-inch deep, 18-gauge steel hat channels installed vertically, 24-inches on center.
12. Wall opening framed with one layer of ⅝-inch thick Type X exterior gypsum sheathing on header and jambs. Header, jambs, and sill finished with 18-gauge “L” shaped steel flashing and the header was additionally covered with aluminum drip cap. 5/4-inch × 4-inch Hardie window trim was fastened around the window perimeter

A complete description of the tested wall constructions, the test observations, and the test results are provided in Intertek Building & Construction Test Report No. N4815.01-121-24, dated June 9, 2022 [2] and ICC-NTA Test Report No. DDPS082422-45, dated August 24, 2022 [3].

These three successful NFPA 285 tests supported the use of a maximum 4¼-inches of the Thermax™ Brand Rigid Insulation material and a CC SPF sprayed into the wall stud cavities, applied to the interior surface of the Thermax™ insulation.

The analysis which follows provides the technical substantiation for modifications to the tested wall assemblies for the following wall construction features:

1. Alternate base wall assembly construction
2. Stud cavity insulation materials
3. Exterior sheathing materials
4. Alternate WRB materials
5. Alternate exterior cladding materials
6. Alternate miscellaneous wall materials

ALTERNATE BASE WALL ASSEMBLY CONSTRUCTION

Concrete and CMU Block Walls

Additional base wall assemblies listed in Table 1 include a concrete wall and a concrete masonry wall. In an NFPA 285 test, a concrete or concrete masonry base wall will provide improved protection to the wall assembly from the burn room fire exposure based on its increased rigidity, significantly higher thermal mass, and increased level of fire performance. Table 1 of the National Concrete Masonry Association (NCMA) TEK Guide

7-1C, *Fire Resistance Rating of Concrete Masonry Assemblies* [11], provides minimum concrete thicknesses for various hourly fire-resistance ratings. A normal calcareous or siliceous gravel concrete wall with a minimum thickness of 2-inches will provide a 30-minute fire-resistance rating; a rating equal to the duration of the NFPA 285 test. Any exterior wall assembly will typically require a concrete wall thickness greater than 2-inches for structural reasons, and concrete block is typically much thicker than 2-inches, again for structural reasons. Based on the documented fire performance of concrete construction, a concrete or concrete block base wall assembly will provide the same or better fire performance than the tested steel stud and gypsum base wall assembly.

Standard Clay Brick Wall

Standard clay bricks have overall nominal dimensions of 3⅝ × 2¼ × 8-inch (D×H×L), and typically have hollow cores within them. Table 3 of the NCMA TEK 7-1C document [11], the equivalent thickness of hollow brick or tile or clay tile needed to achieve a 1-hour fire-resistance rating is 2.3-inches. The equivalent thickness of typical hollow core commercial masonry brick that has an overall thickness of 3⅝ inches is approximately this thickness. Therefore, a standard clay brick wall will provide approximately a 1-hour fire-resistance rating. This is very close to the amount of fire protection a steel stud wall assembly with interior/exterior ⅝-inch thick Type X gypsum wallboard will provide. Therefore, a standard clay brick wall is an acceptable substitute for a steel stud and gypsum wallboard base wall assembly. This performance comparison does not take into account the improved structural performance of the wall assembly. This structural performance must be considered when performing a material installation over an existing clay brick wall assembly.

Wood Stud-Framed Walls

Table 1 allows for the use of minimum 2×4-inch dimensional fire-retardant treated wood (FRTW) lumber studs, spaced at maximum 24-inches on center. Through Jensen Hughes' experience from conducting and witnessing NFPA 285 tests, we have observed that when wood studs are used within a base wall assembly that has ⅝-inch thick, Type X interior and exterior gypsum coverings, minimum char damage is sustained by the wood studs throughout an NFPA 285 test. Since the wood studs only experience minimal char damage during an NFPA 285 test, vertical and lateral flame propagation does not occur from the compartment of fire origin such that failure criteria are observed. Based on this observed test assembly performance, it is Jensen Hughes' opinion that FRTW wood studs can be used as the framing for the base wall assembly as long as one layer of ⅝-inch thick, Type X gypsum is used on both the interior and exterior faces of the assembly.

All NFPA 285 compliant assemblies in Table 1 (Except for the concrete and masonry Base Wall Systems 1, 2, and 3) require a layer of ⅝-inch thick, Type X gypsum installed continuously over the entire interior face of the exterior wall assembly. However, when FRTW wood studs are used to frame an exterior wall, the exterior gypsum wallboard is also required to be ⅝-inch thick Type X gypsum wallboard, as reflected in Table 1. This will ensure sufficient protection is afforded to the FRTW wood stud framing from both the interior and the exterior face.

Base Wall System 4 also allows for plywood or OSB to be installed on the exterior face of the wood studs and under the exterior gypsum sheathing. When located behind the exterior gypsum sheathing, and in the wall stud cavity, the additional layer of plywood or OSB will not adversely impact the compliance of the wall assembly with NFPA 285 as it will be protected by the interior and exterior layers of gypsum wallboard. The optional use of plywood in fire-resistance rated wall assemblies is includes in a number of UL fire resistance design listings (e.g., UL Designs U302, V419, and V423). Wall assemblies tested to the more severe ASTM E119 fire resistance test standard has determined that this added combustible layer does not adversely impact the overall wall fire performance. In an NFPA 285 wall assembly incorporating wood studs, the plywood is protected in a manner similar to the wood studs with gypsum wallboard on the interior and exterior sides of the base wall assembly, shielding the plywood or OSB from direct flame impingement during the 30 minute NFPA 285 test.

Steel Stud Wall Assemblies

The successfully tested NFPA 285 wall assembly which formed the basis for this engineering evaluation letter utilized 3⅝-inch deep, 18-gauge steel stud spaced at 16-inches on center. The interior surface of the stud framing was covered with a single layer of ⅝-inch thick Type X gypsum wallboard. Several of the referenced test assemblies [4, 5, 6, and 9] had a base wall consisting of a 3⅝-inch deep, 20-gauge steel stud spaced at 24-inches on center. Through Jensen Hughes' experience from conducting and witnessing NFPA 285 tests, we have observed that wall assemblies framed with 3⅝-inch deep, 20-gauge steel stud spaced at 24-inches on center do not adversely impact the overall wall fire performance.

A steel stud/gypsum wallboard base wall assembly incorporating heavier gauge studs, decreased stud spacing, and/or deeper studs will provide improved fire performance of the wall assembly. Commentary in the front of the UL Fire Resistance Directory as well as Section 12.5 of ASTM E2032, *Standard Guide for Extension of Data from Fire Endurance Tests*, supports this conclusion. Therefore, Table 1 allows for minimum 3⅝-inch studs, of minimum 20-gauge, and at a maximum spacing of 24 inches on center.

STUD CAVITY INSULATION MATERIALS

CC SPF Insulations

One of the successfully tested NFPA 285 wall assemblies which formed the basis for this engineering evaluation letter [2] incorporated the BASF Walltite Plus SPF applied in all stud cavities, applied to the interior side of the DuPont™ Thermax™ Rigid Brand insulation at a nominal thickness of 1¾-inches. This successful NFPA 285 test supports the use of the BASF Walltite Plus SPF in an exterior wall assembly with the Thermax™ insulation material and non-combustible exterior cladding materials.

The second successfully tested NFPA 285 wall assembly which formed the basis for this engineering evaluation letter [3] incorporated the Huntsman Building Solutions' Heatlok HFO PRO SPF applied in all stud cavities, applied to the interior side of the DuPont™ Thermax™ Rigid Brand insulation at a nominal thickness of 1¾-inches. This successful NFPA 285 test supports the use of the Huntsman Heatlok HFO PRO SPF in an exterior wall assembly with the Thermax™ insulation material and non-combustible exterior cladding materials.

Fiberglass, Mineral Wool, or other Non-Combustible Batt Insulation Materials

The referenced NFPA 285 wall assemblies for this analysis [1,2,3] contained the combustible CC SPF spray applied into all wall stud cavities. Based on the fire performance of this tested assembly and the experience of Jensen Hughes personnel in conducting and witnessing NFPA 285 tests, the inclusion of any fiberglass, mineral wool, or other non-combustible insulation, will not adversely impact compliance of the wall assembly with NFPA 285. Rather, the inclusion of fiberglass, mineral wool, or other non-combustible insulation in the stud cavity of a wall assembly typically improves the overall wall fire performance. When compared to an empty stud cavity, the inclusion of fiberglass or mineral wool insulation will increase the amount of insulation and thermal protection that the stud wall provides to the exterior combustible components; especially when the Thermax™ Rigid Brand sheathing is installed directly to studs and does not have exterior sheathing separating it from the stud cavity. When compared to foam plastic insulation, fiberglass and mineral wool do not have the heat content that foam plastic insulation does and therefore will reduce the overall combustible load within the wall assembly and will not contribute to a fire that reaches the stud cavity.

This is further supported by many fire-resistance rated wall designs from the UL Online Fire Resistance Directory. Many wall design listings describe wall assemblies, tested to the more severe ASTM E119 fire exposure conditions, where the inclusion of fiberglass or mineral wool insulation is an optional item in the assembly. The optional inclusion of the stud cavity insulations indicates that their inclusion will not adversely impact the fire-resistance rating of the assembly. An increase in the fire resistance performance of a wall assembly will result in the base wall assembly providing a greater degree of thermal protection to the exterior combustible components from an interior fire exposure.

The fiberglass or mineral wool insulation can be faced or unfaced. The minimal amount of fuel loading added to the assembly by these facer materials is very low and the facers are protected on both sides by the interior gypsum wallboard or the exterior gypsum sheathing.

EXTERIOR SHEATHING MATERIALS

Exterior Grade Gypsum Sheathing

The referenced test assemblies [1,2,3] had no exterior gypsum sheathing and Thermax™ Rigid Brand sheathing was installed directly to the studs. When a wall assembly is compared to the tested assembly that had the Thermax™ Rigid Brand sheathing direct to the studs, it is the opinion of Jensen Hughes that the installation of gypsum sheathing underneath the Thermax™ is a more conservative installation scenario. Exterior gypsum sheathing will provide thermal separation between the Thermax™ Rigid Brand sheathing and the potential spray foam insulation installed in the stud cavity and will also provide greater protection to the Thermax™ Rigid Brand sheathing from an interior fire source. It is acknowledged that the use of exterior gypsum sheathing may warrant the use of a combustible WRB material, but any WRB materials used over the exterior sheathing are approved based (per Table 2 above) on comparative flammability evaluations based on WRB materials included in NFPA 285 tests. Based on this rationale, it is the opinion of Jensen Hughes that the wall assemblies approved under Table 1 may use Thermax™ Rigid Brand sheathing direct to the studs, or the Thermax™ Rigid Brand sheathing installed over ½- or ⅝-inch thick exterior gypsum sheathing.

Securock ExoAir 430 Panel

The Securock ExoAir 430 panel is an exterior grade gypsum sheathing product with a factory applied fluid applied weather barrier to it. Specifically, Tremco's ExoAir 430 WRB is applied to United States Gypsum's Securock sheathing. Based on the fluid applied WRB material used in referenced test [4,5] and WRB materials installed behind Thermax™ Rigid Brand sheathing in other tests Jensen Hughes has witnessed, it is the opinion of Jensen Hughes that the flammability of the ExoAir 430 compares favorably and is an acceptable material to be installed under the Thermax™ Rigid Brand sheathing.

ALTERNATE WRB MATERIALS

WRB Materials Installed Over Exterior Gypsum Sheathing and Under Exterior Insulation

In the referenced test [4,5], the DuPont™ Tyvek® Fluid Applied WRB was installed over the exterior gypsum sheathing and under the Thermax™ Rigid Brand sheathing. Alternate sheet good WRB products having similar or better flammability properties as the tested WRB are approved in Table 2 for installation over exterior sheathing and under the Thermax™ sheathing. Comparative fire performance properties were either developed by testing conducted by Jensen Hughes on these materials in accordance with ASTM E1354 (Cone Calorimeter apparatus) or by ASTM E1354 test reports provided to Jensen Hughes from various WRB manufacturers who performed testing at accredited third-party laboratories. Given that these alternate materials would be expected to perform similarly based on comparative fire performance properties, it is our engineering opinion that the materials listed in Table 2 will not adversely impact the overall wall fire performance and will maintain compliance with NFPA 285.

WRB Materials Installed Over Exterior Insulation

Referenced tests [2,3,8] incorporated DuPont™ Tyvek® CommercialWrap® over the continuous Thermax™ sheathing exterior insulation. Therefore, alternate sheet good WRB products having similar flammability properties as the tested WRB are included in Table 3 for use over Thermax™ sheathing in NFPA 285 compliant exterior wall assemblies. Comparative fire performance properties were developed by testing conducted by Jensen Hughes on these materials in accordance with ASTM E1354 (Cone Calorimeter apparatus). Given that these alternate materials would be expected to perform similarly based on comparative fire performance properties, it is our engineering opinion that the materials listed in Table 3 will not adversely impact the overall wall fire performance and will maintain compliance with NFPA 285.

EXTERIOR CLADDING MATERIALS

Brick

Common clay brick is a typical material used in NFPA 285 tests to evaluate the ability of wall systems to comply with NFPA 285 when heavy masonry claddings are installed over the exterior face of the wall assembly. Numerous referenced DuPont test assemblies [1,6,7,8,9,10,11] used exterior clay brick veneers as the exterior wall covering materials in the test. Therefore, common clay brick is an acceptable material for use as the exterior wall covering.

Stucco

Table 8 of the NCMA TEK 7-1C [12] indicates that a ¾-inch thickness of Portland cement-sand plaster will provide 20 minutes of fire-resistance. A nominal 20 minutes of fire-resistance means that the unexposed side of the ¾-inch thickness of Portland cement-sand plaster membrane would not exceed a maximum individual temperature rise of 325°F (181°C) above ambient during an ASTM E119 fire exposure test.

The fire exposure conditions to the exposed side of a wall assembly tested in accordance with ASTM E119 are significantly more severe than the fire exposure conditions experienced by the exterior wall covering material in an NFPA 285 test. In an ASTM E119 test, the test sample is mounted onto the front of the test furnace and subjected to the fire exposure conditions generated within the furnace over the entire exposed wall surface. In an NFPA 285 test, only the exterior portion of the wall assembly directly over the window opening is subjected to full fire exposure conditions from the room burner and the window burner employed in this test method.

The temperature and heat flux produced by the burn room and window burner (as indicated in Table 8.1.6 of NFPA 285 for the calibration test) are significantly lower than a what is produced by the test furnace in an ASTM E119 test. The time-temperature curve within the test furnace during an ASTM E119 fire exposure is 1,000°F (538°C) at 5 minutes, 1,300°F (704°C) at 10 minutes, and 1,550°F (843°C) at 30 minutes. In an NFPA 285 test, the average centerline temperatures measured 1-ft above the window opening are required to be 602°F (317°C) during the first 5 minutes, 870°F (466°C) between 5 and 10 minutes, 992°F (533°C) between 15 and 20 minutes, and 1,078°F (581°C) between 25 and 30 minutes into the test. The heat flux developed within the test furnace during an ASTM E119 fire exposure has been measured to be approximately 20 kW/m^2 at 5 minutes, 65 kW/m^2 at 15 minutes, and 88 kW/m^2 at 30 minutes [13]. Comparatively, the exposed surface heat fluxes generated during an NFPA 285 test 2-ft above the window opening are 9 to 19 kW/m^2 during the first 10 minutes of the test, 25 to 29 kW/m^2 during the middle 10 minutes of the test, and 34 to 38 kW/m^2 during the last 10 minutes of the test.

Thus, the thermal exposure conditions developed within an ASTM E119 test furnace are significantly more severe than the conditions developed on the exterior wall surface during an NFPA 285 test. Therefore, a material which provides a nominal 20 minutes of fire-resistance when subjected to the fire exposure conditions specified in ASTM E119 will demonstrate better fire-resistance performance in terms of remaining in-place, restricting heat passage to the unexposed surface, and preventing pyrolysis and ignition of materials on the unexposed surface during an NFPA 285 test. Additionally, during the NFPA 285 test, the exterior wall cladding is only subjected to the fire exposure conditions from the window burner for 25 minutes.

In a Portland cement-sand plaster (stucco) on metal lath wall system, no air gap would exist between the stucco and the insulation board. In DuPont's NFPA 285 tests incorporating brick veneers over the Thermax™ sheathing, a nominal 2-inch air gap existed between the insulation board and the brick. This gap remained open as the aluminum window flashing melted and hot gases and flame from the first-floor burn room flowed into this air cavity. Even with this air gap, the Thermax™ sheathing complied with the NFPA 285 acceptance criteria. Thus, if the gap does not exist (as in a typical stucco exterior wall covering system), the insulation will exhibit less fire spread/damage.

Based on the above analysis, it was concluded that a minimum ¾-inch thickness of Portland cement-sand plaster (stucco) could be used in lieu of the tested 4-inch common clay brick and still meet the test conditions of acceptance described in NFPA 285.

Natural Stone Materials

Several UL Design Listings allow minimum 2-inch thick natural stone as an optional exterior wall covering material. Stone such as granite, limestone, marble, and sandstone are naturally occurring and provide fire-resistance based on their thickness, density, and composition.

One means to assess the thermal performance of a material is to develop a thermal inertia value. The thermal inertia is the product of the thermal conductivity, k (W/m·K), density, ρ (kg/m3), and specific heat capacity, c_p (kJ/kg·K). A material which has a higher thermal inertia will absorb more heat and transfer the heat at a slower rate than a material with a lower thermal inertia. In order to provide the technical justification for the substitution of the minimum 2-inch thickness of natural stone materials in lieu of the tested 4-inch standard clay brick, the thermal inertia values for the materials were calculated.

Published literature values for the thermal conductivity, specific heat capacity, and density for standard clay brick and limestone are provided below in Table 4 [14]. Table 4 also includes the calculated thermal inertia ($k\rho c_p$) for each material.

Table 4 – Thermal Properties for Brick, Various Natural Stone Materials, and Select Metals

Material	Thermal Conductivity (W/m·K)	Density (kg/m³)	Specific Heat Capacity (kJ/kg·K)	Thermal Inertia (W²·s/m⁴·K²)
Clay brick	0.69	1600	0.84	927
Limestone	1.26 – 1.33	2500	0.9	2,835 – 2,933
Granite	1.73 – 3.98	2640	0.82	3,745 – 8,616
Sandstone	1.83	2160 – 2300	0.71	2,806 – 2,988
Marble	2.07 – 2.94	2500 – 2700	0.80	4,140 – 6,350

The thermal inertia values for the natural stones range from more than double to more than nine times greater than standard clay brick. Therefore, a minimum 2-inch thickness of natural stone would be expected to provide improved thermal protection to the Thermax™ sheathing when compared to the tested standard clay brick.

Natural stone can also be applied such that either no air gap or a very limited gap would exist between the stone and the Thermax™ sheathing. In the NFPA 285 test using the Thermax™ sheathing a nominal 2-inch wide air gap existed between the Thermax™ sheathing and the brick and the assembly still passed the NFPA 285 test.

Natural stone can also be applied such that either no air gap or a very limited gap would exist between the stone and the Thermax™ sheathing. In the NFPA 285 test using the Thermax™ sheathing, a nominal 2-inch wide air gap existed between the Thermax™ sheathing and the brick and the assembly still passed the NFPA 285 test.

The natural stone must be installed as a solid veneer without open joints (vertical or horizontal) as was with the brick veneer. The occurrence of open gaps, separations, etc. will provide a potential path for the fire to enter the wall cavity and spread within it.

Therefore, it is the opinion of Jensen Hughes that a non-open jointed, minimum 2-inch thickness of natural stone (limestone, granite, sandstone, and marble) may be used in lieu of the tested 4-inch clay brick and still meet the test acceptance criteria specified in NFPA 285; as reflected in Table 1.

Terracotta Cladding

Terracotta is included in Table 1 based on the successful testing documented in DuPont's referenced test report [1], which included 4-inches of Thermax™ sheathing and BASF Spraytite® SPF insulation in the stud cavity of the wall assembly. DuPont also conducted a successful NFPA 285 test of an exterior wall assembly consisting of an ACM panel cladding system. A CC SPF was also sprayed into the wall stud cavities, against the interior side of the Thermax™ Brans Rigid Insulation material [15]. It can be seen from photographic documentation provided in referenced report that the ACM panel located directly above the window opening in the test melted and allowed the insulation underneath to be exposed to direct exterior flames and combust, leading to further elevated temperatures on the exterior face of the wall. This is typical performance of ACM panel systems in NFPA 285 tests, where approximately 20 to 25 minutes into the test the exterior cladding is compromised, allowing combustible materials beneath the cladding to burn and potentially contribute to exterior flame spread over the assembly.

Terra Cotta is a clay-based material similar to the clay brick. According to Table 3 of the NCMA TEK 7-1C guide [12] a solid 1¼-inch thickness of non-open jointed Terra Cotta would be expected to provide nominally 28 minutes of fire-resistance (in accordance with ASTM E119) by interpolating the information in Table 3. In an NFPA 285 test, the Terra Cotta exterior veneer would be required to provide only 25 minutes of protection as the window burner is not ignited until 5 minutes into the test. Based on the data in Table 3 of the NCMA TEK 7-1C guide, a minimum 1¼-inch thickness of Terra Cotta would be expected to provide more than 25 minutes of fire-resistance when subjected to the fire conditions described in ASTM E119.

Based on this technical rationale, it is expected that 1¼-inch thick Terra Cotta cladding would perform superior to the ACM panel cladding used in the DuPont referenced test report [15]. As noted in the referenced test report, the ACM panel melted and exposed the insulation underneath to fire, while the Terra Cotta is a masonry type material that would not melt in an NFPA 285 test. Therefore, the Terra Cotta is included in Table 1 for use with maximum 4¼-inch thick Thermax™ sheathing insulation.

Concrete, Precast Panels, and Concrete Masonry Units

The fire-resistance provided by concrete can be calculated per Table 1 of the NCMA TEK 7-1C [12]. As detailed previously in the Stucco technical discussion section, fire-resistance ratings in accordance with ASTM E119 are developed based on significantly more severe exposure conditions than the NFPA 285 test. Therefore, a material that provides a fire-resistance rating equal to or greater than the duration of the NFPA 285 test will provide sufficient protection to underlying combustible when it is used as the exterior covering material over an exterior wall needing to comply with NFPA 285.

Assuming siliceous concrete, a minimum 2-inch thickness will provide approximately 30 minutes of fire-resistance. Thus, based on the 25-minute exterior fire exposure to the exterior wall covering in the NFPA 285 test, the 2-inch thickness of concrete will protect the Thermax™ sheathing and can be used in lieu of the tested brick veneer.

The fire-resistance provided by concrete masonry units (CMU) can also be calculated per Table 1 of the NCMA TEK 7-1C [12]. Assuming siliceous concrete, a minimum 2-inch equivalent thickness calculated using a 4-inch thick CMU will provide approximately 30 minutes of fire-resistance. Thus, based on the 25-minute exterior fire exposure to the exterior wall covering in the NFPA 285 test, the 2-inch equivalent thickness of CMU will protect the Thermax™ sheathing and can be used in lieu of the tested brick veneer.

The concrete or the CMU can be applied such that either no air gap or a very limited gap would exist between the concrete or CMU and the Thermax™ sheathing, as a nominal 2-inch wide air gap existed between the Thermax™ sheathing and the brick veneer in DuPont's NFPA 285 tested assemblies. The concrete or CMU must be installed as a solid veneer without open joints (vertical or horizontal) as was with the tested brick veneer. The occurrence of open gaps, separations, etc. will provide a potential path for the fire to enter the wall cavity and spread within it.

Based on this analysis, it is concluded that a minimum 2-inch thickness of concrete or a 4-inch thick concrete masonry unit with a maximum 2-inch air gap between it and the Thermax™ sheathing may be used in lieu of the tested 4-inch clay brick and still meet the test conditions specified in NFPA 285.

MISCELLANEOUS MATERIALS

Exterior Insulation Joint Flashing

Referenced test [15] used DuPont™ LiquidArmor™ flashing over the board joints at a 50 mil thickness and 4-inch wide strip. Based on ASTM E1354 test data, various LiquidArmor flashing products are approved for use over the board joints at maximum installed thicknesses and widths that are equal to or less than the tested condition.

Additionally, the IBC specifically states that flashing materials are not to be considered part of the water-resistive barrier product when assessing compliance of products in an exterior wall assembly. Through our extensive testing experience, we have never seen flashing products applied in small quantities over the face of the exterior wall assembly contribute to excessive vertical and/or lateral flame spread. Flashing materials are simply not applied in sufficient quantities and do not contain excessively high amounts of heat energy when applied over the board joints to contribute significantly to increasing the overall wall combustibility, especially when applied over foam plastic materials which, due to their nature, contain high amounts of heat energy. Knowing that flashing products do not contribute to excessive burning and do not support flame spread in a wall assembly, it is our opinion that the wall flashing materials, in the limits specified in the report, will not adversely impact the compliance with NFPA 285.

Drainage Mat

The Tyvek® DrainVent™ Rainscreen product was included in DuPont's FRTW wall test [16] and demonstrated that when located directly behind the exterior cladding material (Hardi Lap Siding), no significant vertical or lateral flame spread occurred. Subsequent cone calorimeter testing was conducted on the same DrainVent™ product tested in the FRTW wall assembly and the flammability properties were mid-range of WRB materials Jensen Hughes has evaluated when tested in accordance with ASTM E1354.

Mortar Net

Mortar net products are similar in construction to the Tyvek® DrainVent™ product and are placed at the bottom of the wall and along brick shelf angles to maintain open water drainage. Similar to flashing materials, these products are not used as full wall coverage and are placed in strips within the air cavity of the wall assembly, behind a masonry veneer. There are not adequate quantities of material to support vertical and lateral flame propagation within a masonry clad exterior wall assembly.

Jensen Hughes has conducted proprietary cone calorimeter testing on various mortar net type products and the flammability properties of these products are less than the Tyvek® DrainVent™ product tested in the FRTW wall assembly. In the FRTW wall assembly, the Tyvek® DrainVent™ was installed full wall coverage. The mortar net products are limited to a maximum 12-inch high strip of material located at the base of the wall and at brick shelf angles (which are typically installed every 3 floors). Given the relatively small amounts of mortar net material installed in a wall assembly, it is Jensen Hughes' opinion that the use of these products will not adversely impact the overall wall fire performance.

CONCLUSION

DuPont has conducted successful NFPA 285 tests on exterior wall assemblies incorporating SPF products installed in the wall cavities and sprayed against the back of the Thermax™ sheathing material. Successful NFPA 285 test were conducted on wall assemblies incorporating the Thermax™ Rigid Board insulation covered by non-combustible brick and Fiber Cement siding as well as combustible ACM panel systems. Based on these successful tests, alternative wall constructions were developed as detailed in Table 1 of this letter. The additional wall construction features will result in wall assemblies which will still meet NFPA 285 and provide a comparable level of fire performance as the tested wall assemblies. The technical justification for the use of additional wall system components is provided above to support their use in an exterior wall assembly which will continue to meet the conditions of acceptance of NFPA 285.

REFERENCES

These NFPA 285 compliance tables are generated based on the following test reports:

DuPont has conducted numerous NFPA 285 tests of exterior wall assemblies incorporating the Thermax™ Brand Rigid insulation, SPF insulation materials, and various exterior cladding systems. These tests include:

1. Brick exterior wall construction - Reported in Southwest Research Institute Final Report No. 01.15822.01.001, dated September 9, 2010.
2. Fiber Cement Board exterior wall construction – Reported in Intertek Testing Final Report No. N4815.01-121-24, dated June 9, 2022.
3. Fiber Cement Board exterior wall construction – Reported in ICC-NTA Testing Final Report No, DDPS082422-4, dated August 24, 2022.

4. Aluminum Composite Material (ACM) Panel exterior wall construction – Reported in Intertek Testing Final Report No. G101240263SAT-001, dated August, 29, 2013.
5. Aluminum Composite Material (ACM) Panel exterior wall construction – Reported in Southwest Research Institute Final Report No. 16046.01.610b, dated November, 30 2012.
6. Brick exterior wall construction – Reported in Southwest Research Institute Final Report No. 01.05805.01.001, dated November 2002.
7. Brick exterior wall construction – Reported in Southwest Research Institute Final Report No. 01.13104.01.001c, dated September 5, 2008.
8. Brick exterior wall construction – Reported in Southwest Research Institute Final Report No. 01.15210.01.607a, dated May 24, 2010.
9. Brick exterior wall construction – Reported in Southwest Research Institute Final Report No. 01.05805.01.001, dated November 2002.
10. Brick exterior wall construction – Reported in Southwest Research Institute Final Report No. 01.13104.01.001c, dated September 5, 2008.
11. Brick exterior wall construction - Reported in Southwest Research Institute Final Report No. 01.15822.01.001, dated September 9, 2010.
12. National Concrete Masonry Association (NCMA) TEK 7-1C, "Fire Resistance Rating of Concrete Masonry Assemblies," Herndon, VA, 2009.
13. Sultan, M.A., "Fire Resistance Furnace Temperature Measurements: Plate Thermometer vs. Shielded Thermocouples," *Fire Technology*, 42, pp 253-267, 2006.
14. National Fire Protection Association, Appendix B, *The SFPE Handbook of Fire Protection Engineering*, Fourth Edition, DiNenno, P.J. (ed.), National Fire Protection Association, Quincy, MA, 2008, pp. A-32 to A-33.
15. Aluminum Composite Material (ACM) Panel exterior wall construction – Reported in Intertek Testing Final Report No. J0651.01-121-24-R0, dated April 24, 2019.
16. Fiber Cement Board exterior wall construction – Reported in Intertek Building and Construction Final Report No. M4492.03-121-24-R0, dated December 15, 2021

This analysis is based on the specific construction materials installed in the manner described in the referenced test report(s). Changes or modifications to the construction and/or materials used in the tested assembly may result in a different fire performance and may change this analysis.

This analysis does not address performance characteristics such as weatherability, durability, or structural issues.

We trust this engineering analysis will be of use to DuPont. Should you have any questions regarding our analysis, please contact us at 443-313-9891 or at **aparker@jensenhughes.com**.

Sincerely,

Daniel A. Martin, PE, CFEI, CVFI
Fire Protection Engineer

Arthur J. Parker, P.E.
Sr. Fire Protection Engineer

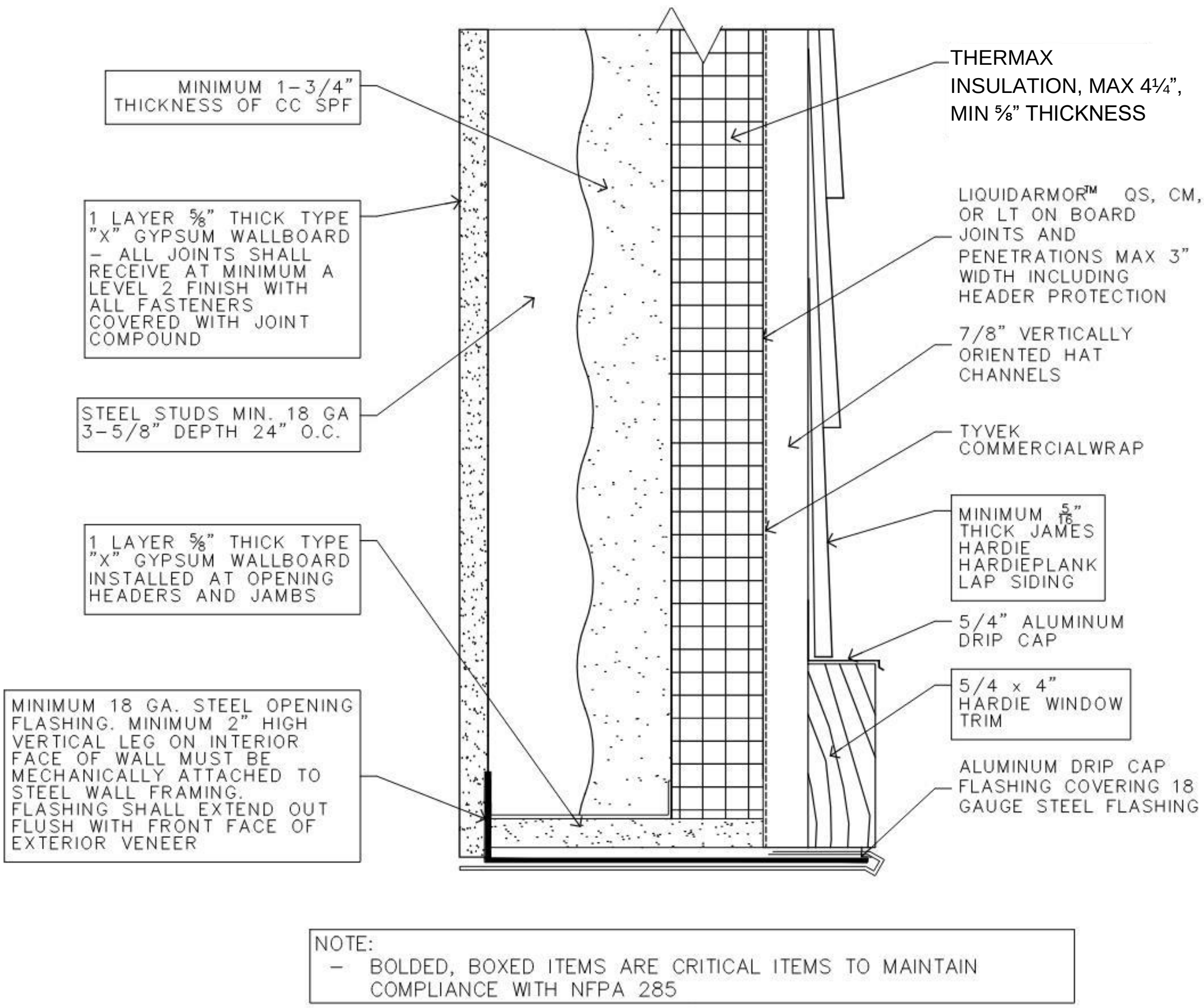

Figure 1. Exterior Wall Construction – Thermax and CC SPF Spray Foam