WHITE PAPER

Fire Safety of Insulated Metal Wall Panels

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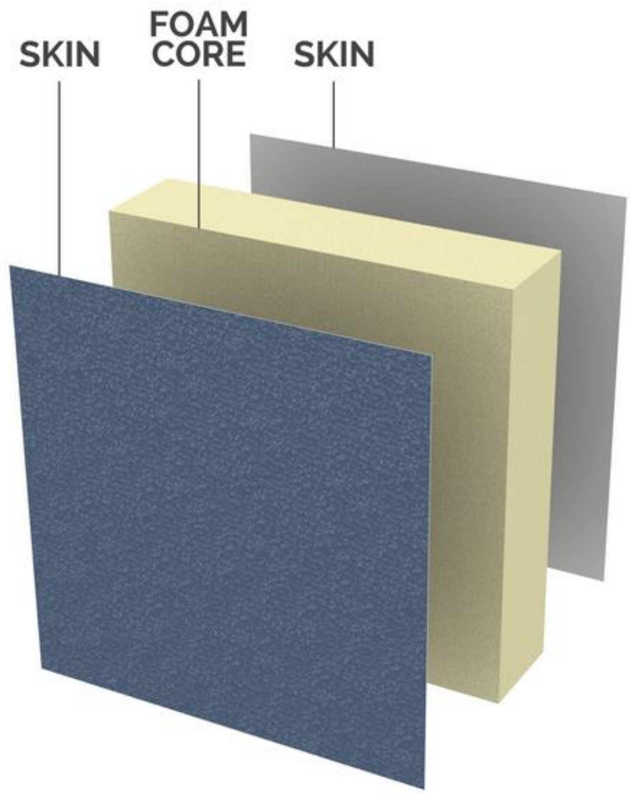
Introduction



Insulated Metal Panels (IMPs) are lightweight composite exterior wall and roof panels with two layers of coated thin sheet metal (typically steel or aluminum) wrapped around a rigid foam core to form a stiff composite. They are molded in a variety of styles and sizes depending on the application. The foam plastic core gives these panels superior insulating properties, helping to provide increased energy efficiency. Also, the metal surfaces offer various design capabilities (for interior or exterior applications) as well as a sustainable barrier to weather. They can be used for exterior and interior design but are typically used in exterior walls. They have both semi-gloss and matte finishes, are available in a variety of colors and can be shaped and formed into many different textures, widths, profiles and finishes, enabling virtually any aesthetic desired for walls and roofs. Depending on how they are employed, IMPs also act as a rain screen and water barrier, preventing water from entering a building from the outside, and from spreading from room to room in the interior. Since fire safety is a key issue in construction, the presence of metal walls can act as a barrier to fire to help keep an active fire from spreading. Fire safety will be the focus of the remainder of this document.

IMP, an acronym for Insulated Metal Panel, Sandwich panels is a designation that strictly represents self-supporting double skin metal-faced insulating panels, with an insulating foam core. The core materials can be rigid polyurethane (including polyisocyanurate), expanded polystyrene, extruded polystyrene foam, phenolic foam, cellular glass and mineral wool. However, the term sandwich panel has been used quite vaguely to describe many different products, including IMPs SIPs (Structural Insulated Panels), MCMs (metal composite materials) and ACMs (aluminum composite materials).

Insulated metal panels are different from metal composite materials (MCMs) and from aluminum composite materials (ACMs), themselves a subset of MCMs. MCMs are described as metal skins bonded to both faces of a solid plastic core (meaning that the core is not a foam plastic, in contrast to IMPs with a foam core). Insulated metal panels are different than Structural Insulated Panels (SIPs) which consist of a light-weight foam plastic core securely laminated between two thin, rigid wood structural panel facings. Typically, codes and standards do not specifically reference IMPs, but such references do exist for MCMs, ACMs and some other types of sandwich panels. Thus, regulations deal with IMPs in the same way that they deal with any product, for exterior or interior use, that includes combustible components.

IMPs generally use a foamed-in-place or laminated, polyisocyanurate foam plastic insulation (at thicknesses of 2-4 inches). This type of material can provide a thermal resistance value (R-value) of nominally 7 per inch (compared to values of 2-4 for fiberglass or mineral wool). Their high R-values are one reason that explains the popularity of foam plastic insulation materials. The metal facers are typically coated steel and they provide a barrier to water and vapor migration through the wall and typical thicknesses are 26 gauge (0.01875 inches) on the interior side and 22 gauge (0.03125) on the exterior side. When used in exterior walls, the IMPs are intended to act as the exterior cladding of the wall assembly as well as providing insulation, air, water and vapor barrier capabilities. The panels are installed vertically or horizontally over the exterior wall framing system. They can also be a back-up panel covered by another exterior veneer system. They are attached in different ways to the exterior of the building, depending on other requirements.

Effectiveness of Insulation Value

The following are the most common insulation materials for buildings: foam plastics (including, typically, expanded polystyrene (EPS), extruded polystyrene (XPS), rigid polyurethane (PUR), spray polyurethane (SPF), polyisocyanurate (PIR), polyimide, phenolic, melamine, polyolefin, and others), cellulose loose-fill, fiberglass, mineral wool, reflective, straw bale, cementitious foam and recycled denim. Some of these insulation materials do not typically need flame retardants to meet code requirements (for example fiberglass, mineral wool or polyimide foam) but many others do.

The primary reason foam plastic insulation materials are extensively used in building construction is that they tend to provide better insulation than many other materials (see Table 1). The effectiveness of insulation is assessed by an R value, which is a measure of the temperature difference across an insulator per unit heat flux. The typical practical units for R values are degrees Fahrenheit square feet hours per Btu, (°F. $ft^2 \cdot h/Btu$) and it is usually expressed as the thickness of the material normalized to the thermal conductivity. The R value depends on the material's resistance to conductive heat transfer and accounts for convective and radiative heat transfer.

Table 1 – Nominal R values (per inch) of typical insulation materials

Foam Plastic Insulation		Non- Foam Plastic Insulation	
Expanded Polystyrene Foam	≈ 4	Fiberglass Batt	3.1 – 3.7
Extruded Polystyrene Foam	≈ 5	Fiberglass Blown	2.2 – 4.3
Polyurethane Spray Foam (Closed Cell)	5.8 – 6.4	Cellulose Loose Fill	3.0 – 3.3
Rigid Polyurethane Foam Panel	5.5 – 8	Mineral Wool Batt	4.0 – 4.4
Polyisocyanurate Foam	5 - 7	Mineral Wool Blown	3.3 – 3.8
Urea Formaldehyde Foam	5 - 6	Straw Bale	0.9 – 1.5
Phenolic Foam	4.8 – 7	Recycled Denim	3.7 – 4.0

The use of efficient insulation materials is an essential part of modern building construction as it is the most effective way of lowering energy use and providing environmentally-friendly buildings. When buildings are better insulated they need less heating in winter and less cooling in summer. In fact, energy conservation codes are continually requiring higher and higher insulating values, in order to provide energy efficiency and lower the environmental impact of building construction.

Fire Safety Requirements in the US

In the US, regulations (issued by government agencies) reference codes (such as a building code), which in turn reference fire test methods and acceptance criteria. Fire safety is regulated by a combination of active and passive fire protection measures. Passive fire protection involves the use of products that are unlikely to generate a serious fire under their expected use. Active fire protection involves the use of methods to reduce or prevent the spread and effects of fire, heat or smoke by means of detection and/or suppression of the fire.

The basis for passive fire protection in fire safety regulation, particularly in US codes, is that all products used in construction must comply with some appropriate fire test suitable for the application. This recognizes that the key means to ensure fire safety is to assess the way in which a product performs in a fire situation rather than to use requirements based on composition, particularly composition of product components (such as non-combustibility). US codes also tend to require that the fire tests incorporate every one of the components of composite products, with the same layout as the product to be used in the field, instead of testing individual components only. Experience indicates that individual components of complex products can adversely affect the fire performance of the complete product so that, in some cases, each component can get good fire test results but the assembly burns vigorously, and vice versa. This is a key concept for understanding both the rationale for the fire test requirements that apply to insulated metal panels and the reason that requirements based exclusively on the fire performance of components is not a good approach to effective fire safety.

Therefore, US codes typically require that composite assemblies be fire tested both as a complete assembly and that the individual combustible components also be tested. In particular, US codes place special emphasis on ensuring the fire safety of foam plastic insulation materials on their own.

In the US, foam plastic insulation materials used in construction (including those used as components of assemblies) must comply with the fire safety requirements contained in chapter 26 of the International Building Code (IBC)[1] or chapter 48 of the NFPA Building Construction and Safety Code (NFPA 5000)[2]. The requirements in both codes are quite similar to each other.

The foam plastic insulation materials themselves must be listed and labeled. Listing of a product involves two issues: the conduction of appropriate fire test results and the assurance that the products are manufactured consistently to continue complying with the requirement In order for foam plastic insulation materials to be listed for US construction use, the materials must have complied with a flame spread index of not more than 75 and a smoke-developed index of not more than 450 (i.e. a Class B) where tested in the maximum thickness intended for use in accordance with ASTM E84[3] (known frequently as the Steiner tunnel test), or UL 723[4] (which is an equivalent fire test method). Listed materials are included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products, that maintains periodic inspection of production of listed materials and whose listing states that the material meets appropriate designated standards or has been tested and found suitable for a specified purpose. The listing/assurance is provided by a nationally recognized testing laboratory (NRTL).

Although US codes include exceptions to the flame spread requirements above for some applications of foam plastic materials, none of these exceptions apply when the foam plastic insulation materials are contained within IMP panels. Typical foam plastic insulation materials (including polyisocyanurate foam plastic insulation) require the incorporation of flame retardants into the foam in order to meet these fire test requirements.

When foam plastic insulation materials are used in US buildings, they not only must meet the fire test requirements indicated above; they must also be separated from the interior of the building (or the habitable areas) by a thermal barrier or the foam plastic must meet requirements based on a full-scale room corner test, typically NFPA 286[5]. The figure below shows flames in the NFPA 286 fire test. That test assesses whether the material causes sufficiently low heat release, smoke release and flame spread and whether it is likely that flashover will occur. Typically, the requirements will not be met by common foam plastic materials, which is why the thermal barriers ensure fire safety.

NFPA 286 Fire Test Flame, at 160 kW

A thermal barrier is typically made of ½ inch gypsum board but it can be made of any material that complies with the NFPA 275[6] fire test. In order for a material to comply with the requirements of a thermal barrier (via NFPA 275) it needs to meet two fire tests. One test is a fire resistance test that is intended to demonstrate that the material itself resists the penetration of fire through the thermal barrier for a certain period of time (15 minutes). The other test is a reaction-to-fire test, most commonly NFPA 286. The thermal barrier material, when tested in conjunction with the foam plastic of interest, must comply with all the requirements that ensure low flame spread and low release of both heat and smoke, including no flashover in the test room. The thermal barrier must be approved by the authority having jurisdiction (typically the local code official).

The ASTM E84 fire test for the core material is, of course, just the basic requirement for materials to be able to be considered for use as the core in IMPs or other assemblies. The complete assembly must also be fire tested using NFPA 285[7] when used as or on exterior walls of Type I, II, III, or IV construction, which are at least 40 ft. in height. The building code describes 5 types of building construction, as shown below. The purpose of these designations is to allow the code to apply specific requirements and use limits for each referenced type.

- Types I and II construction require that all building elements be made of non-combustible materials. The code actually allows a significant number of specific exceptions of permitted combustible materials in designated applications.
- Type III construction requires that only the exterior walls be made of non-combustible materials. It also allows fire-retardant-treated wood framing to be used in exterior wall assemblies of a 2-hour fire resistance rating or less.
- Type IV construction (also known as Heavy Timber or HT construction) requires that the exterior walls be made of non-combustible materials and the interior building elements be made of solid or laminated wood without concealed spaces.
- Type V construction allows all building elements to be made of any material (including any type of combustible material) permitted for use in the code.

That means that assemblies, including IMPs, used in any construction that requires the use of some non-combustible building elements must be tested to NFPA 285, if they are at least 40 ft. in height.

The NFPA 285 fire test evaluates the vertical and lateral flame-propagation potential of any wall system that contains combustible components, typically foam plastic insulation. The wall systems evaluated are non-load-bearing assemblies, such as exterior curtain wall construction. The NFPA 285 test exposes an exterior wall assembly to a “typical” fire scenario. The fire scenario is one in which a fire occurs inside a room, the fire vents through a window opening and the exterior wall is exposed both from the interior fire and to a flame plume exiting the window.

Therefore, the fire test involves a two-story structure with a height of 15 ft. 8 in, with a test room on each story and a window opening. The test rooms have inside dimensions of 10 ft. × 10 ft. by 7 ft. high. The window opening is 78 inches wide by 30 inches high and it is located 30 inches above the ground floor. There are two burners: one burner is placed inside the ground floor test room, and the other burner is placed outside, near the top of the window opening (see Figure below).

The test wall assembly specimen must be at least 17.5 ft. high by 13.3 ft. wide.

The 30-minute fire test measures the following parameters:

- Vertical and lateral flame propagation over the exterior face of the wall assembly (as determined by either visual observation of flames or temperature measurements),
- Vertical and lateral flame propagation within all combustible components, including the combustible core (as determined by temperature measurements),
- Lateral flame propagation from the compartment of fire origin to adjacent compartments (as determined by either visual observation of flames or temperature measurements),
- Vertical flame penetration into the second story (as determined by either visual observation of flames or temperature measurements),
- The temperature is not allowed to exceed 1000°F on the exterior face of the test specimen or in any wall cavity air spaces,
- The temperature is not allowed to increase more than 750°F within any combustible component of the test specimen,
- The temperature is not allowed to increase more than 500°F anywhere in the second story,

The above acceptance criteria mean that some very limited flame propagation is allowed, but that flame propagation is severely limited both on and within the test wall assembly.

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NFPA 285 requires that the complete wall assembly, with its associated means of attachment, be evaluated. In terms of IMPs there are many variables to assess, including the following:

- Foam plastic core insulation: Each different foam plastic core must be evaluated, at the maximum density and thickness intended for use. Lower thicknesses would be allowed because experience indicates that a lower amount of combustible material of the same type would not make the assembly have worse fire performance.
- Facings: Each different metal facing must be evaluated, at the minimum thickness intended for use. Larger thicknesses would be allowed.
- Panel size: The IMP panel is tested such that it is either the full height or full width of the test wall assembly.
- Panel orientation: If IMP panels can be installed both vertically and horizontally, both orientations must be evaluated since the attachment systems will likely be different.
- Joints: Joints must be evaluated as intended for use.
- Thermal barriers: If the IMP panel is to be separated by a thermal barrier, it must be included in the evaluation.
- Attachments: The IMP panel must be evaluated using the attachment methods intended for use.
- When the IMP panel is part of a more complex wall assembly, everything must be tested together.

The NFPA 285 test is based on the performance of the entire wall assembly, meaning that the complete wall assembly must be tested, including every single combustible component that could contribute to the fire performance of the overall assembly. This, of course, includes the foam plastic insulation cores but also some thin materials, such as combustible vapor barriers or air barriers. *It is also critical that the results of fire tests to NFPA 285 is only valid for the specific assembly that was tested and no material substitutions or changes in product design are allowed without retesting. Each NFPA 285 test is applicable only to the exact assembly tested.* Product design involves both the materials used (at their corresponding thicknesses) and the layout of the materials within the assembly. It is not acceptable to conduct individual fire tests (to NFPA 285 or any other test) of specific components of an assembly and expect those test results (even if they show compliance with NFPA 285) to be indicative that the assembly of all those components will meet the requirements of NFPA 285. For example, if two products, such as an exterior cladding, such as a sandwich panel, and a combustible insulation are each fire tested independently and both meet the criteria needed to pass the NFPA 285 test, the combination of these two products may well fail the fire test requirements. It is only when the actual complete wall assembly is tested as intended for use that compliance is assured.

The above manner of testing full assemblies, and the potential interactions between components of an assembly, is a key reason why the replacement of one (or more) components of an assembly by non-combustible materials will not provide certainty of fire test compliance.

US codes do allow means to demonstrate (to the satisfaction of the approving code official) that a system that is not identical to the actual system tested is still suitable when changes are made that could affect fire test performance. This is included in an IBC code section entitled “Alternative materials, design and methods of construction and equipment” (104.11) which states as follows:

“*The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety. …*”

The use of this approach could be needed when (a) one component is replaced by another one or (b) the wall assembly design or geometry are changed (such as adding cavities or changing material thicknesses). Such substitutions must be evaluated by either a new fire test or an appropriate fire hazard analysis under the concept of “alternative materials, design and methods of constructions and equipment” section of the code. This approach typically requires that the analysis be conducted by a professional who must demonstrate that the alternative product (meaning the alternative design) is, for the purpose intended, not less than the equivalent of that prescribed in the code in “quality, strength, effectiveness, fire resistance, durability and safety”, something which provides a difficult threshold. Sometimes, documentation provided to demonstrate alternate compliance for a specific application is called an “Engineering Judgement”.

Fire Safety Requirements in Some Other Countries

Table 2 below shows fire safety requirements for exterior wall assemblies in some countries.

Table 2 – Fire Tests for Exterior Claddings

Country	Test Method	Test Scale - Issue
US	NFPA 285 + ASTM E84	Full
Canada	ULC S134	Full
France	Lepir II	Full
Germany	Draft DIN 4102 Part 20	Full
Sweden	SP Fire 105	Full
UK	BS 8414-1	Full
Australia	ISO 1182 (as AS1530.1)	Small (non-combustibility)
New Zealand (option 1)	NFPA 285 or others	Full
New Zealand (option 2)	ISO 5660 (ASTM E1354)	Small (component) (heat release)
Singapore (option 1)	BS 476 Part 4	Small (non-combustibility)
Singapore (option 2)	BS 476 Part 11 (ISO 1182)	Small (non-combustibility)
Singapore (option 3)	BS 476 Parts 6 & 7	Intermediate (flame spread)
Singapore (option 4)	EN 13823	Intermediate (heat release)
Singapore (option 5)	NFPA 285	Full
Singapore (additional)	Components	Non-combustibility or low combustibility

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EU	EN 13823	Intermediate (heat release)
ISO	ISO 13785-1	Full
ISO	ISO 13784-1	Intermediate (small room)
ISO	ISO 13784-2	Full/intermediate (larger room)
US	FM 4880 (25 ft. & 50 ft.)	Full (heat release/flame spread)
US	FM 4880 (parallel panel)	Full (heat release/flame spread)

As the table above shows, exterior wall assemblies (sometimes known as façades) are tested for fire safety in various countries in a variety of ways. The basic concept associated with the tests shown for Canada, France, Germany, Sweden and UK are similar: limited flame spread upwards and limited increase in temperature within the composite. In the US, the FM 4880 tests (at 25 or 50 ft.) do not involve compartments and they are used primarily by FM Global for facilities of their clients. The more recent FM 4880 parallel panel test is intended as a newer replacement for the earlier versions of FM 4880, which are no longer used often. The Canadian ULC S134 has been proposed for standardization in the US, at ASTM. CEN (European Committee for Normalization) standard (EN 13823) is a part of the European Union harmonized reaction-to-fire set of tests but is not used in all member states. The ISO (International Organization for Standardization) tests have been standardized but there is no indication that they are used as part of the requirements in any specific country.

If the systems meet the requirements it is expected that they will not spread flame vertically, but the severity of the tests and the details vary. Tests shown for some other countries indicate that the appropriate fire safety of exterior wall assemblies is being taken seriously throughout the developed world and that the concept of ensuring that the assemblies are safe, irrespective of their detailed composition remains the correct approach. Experience on the effectiveness of the fire safety requirements on fire losses is most carefully monitored in the US, by the National Fire Protection Association (NFPA).

Fire Loss Experience

An NFPA Fire Protection Research Foundation study, based on NFPA fire statistics and NFIRS (US Fire Administration's National Fire Incident Reporting System) data for the 2007-2011 period investigated exterior wall fires[8]. This includes all fires where the exterior wall is the area of origin or is the item first ignited or where external fuel loads are located against external walls or where the external walls are exposed to fires from adjacent buildings where the fire spreads to the interior of the building but the external wall does not play a significant role in the fire spread. These fires represented 3% of all structure fires in the US and 3% of all fire fatalities. Of those fires, well over half occurred in residential structures, which is also where all fire fatalities occurred.

The use of NFPA 285 as the large-scale fire test for exterior assemblies containing combustible materials is mostly restricted to the US, where it was introduced in the 1980's. In the years since the requirements were introduced there have been no fatal fires involving combustible exterior cladding assemblies that had been tested successfully to NFPA 285 (or to its predecessors, UBC 17-6, UBC 26-4 and UBC 26-9). Four US high-rise building fires have been identified where exterior cladding was a key contributor[8]. One of these incidents involved an MCM system but none involved IMPs.

- El Dorado Hotel (Reno, NV, 1997; "hard-coat polyurethane over expanded polystyrene (EPS)", soon extinguished, no fatalities, no NFPA 285 compliance),
- Palace Station Hotel (Las Vegas, NV, 1998, "polyurethane foam and urethane-coated EPS", façade only burned, soon extinguished, no fatalities, no NFPA 285 compliance),
- Water Club Tower, Borgata Hotel[9, 10] (Atlantic City, NJ, 2007, building under construction, MCM: aluminum composite panel with solid polyethylene core covered by polystyrene, soon extinguished, no fatalities, no NFPA 285 compliance),
- Monte Carlo Casino[9, 11] (Las Vegas, NV, 2008, EIFS: exterior insulation and finish system and non-compliant polystyrene insulation, no fatalities, no NFPA 285 compliance).

On the other hand, there have been multiple examples of tragic high-rise building fires associated with combustible exterior cladding assemblies outside of the US and none of them involved systems that complied with NFPA 285, but several involved products described as sandwich panels, typically in food processing plants, cold storage buildings or factory buildings. There is no evidence that any of these fires involved insulated metal panels.

One of the most publicized, and tragic, fires involving combustible exterior cladding systems occurred on June 14th, 2017 at the 24-storey Grenfell Tower block of public housing flats in London, UK. It caused an estimated 80 fire fatalities and multiple injuries and it completely destroyed the building. The exterior cladding system appears to have consisted of an aluminum composite material with a solid core of polyethylene (non-fire retarded) backed by polyisocyanurate foam insulation. The system involved was not an insulated metal panel and it is likely that it would not have met the criteria associated with the British Standard BS 8414-1[12] and probably not those associated with US code fire test requirements (NFPA 285). The only reason this incident is referenced here is that the cladding used might be confused with an IMP.

Summary

A number of reports from various organizations are being circulated claiming that the use of non-combustible materials is always preferred to the use of foam plastic materials in exterior claddings. That concept is very misleading for two reasons:

(1) The use of cladding products containing non-combustible insulating materials is typically associated with lower insulating efficiency and that is not a desirable feature in modern construction, and

(2) The use of Insulated Metal Panels containing foam plastic insulating materials, when they comply with the appropriate fire test requirements for both the components individually and the assembly, for example as used in the US, have been shown to exhibit excellent fire performance and have not been involved in any significant number (if any) of tragic fires.

Insulated Metal Panels can be used safely in exterior claddings and should continue to be a significant part of building construction.

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