Facts About Rigid Vinyl Window Frames

FIRE PROPERTIES

VINYL WINDOW
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An Introduction to Polyvinyl Chloride as a Building Material

On the following pages, the terms "PVC" and "vinyl" will be used interchangeably with polyvinyl chloride. In the manufacture of those building products enumerated, the rigid (or nonplasticized) state of polyvinyl chloride is the material of choice.

The applications using rigid PVC have grown steadily over the last several years, including such diverse building products as windows, house siding, plumbing pipe, electrical conduit, crown molding, base boards, trim, soffit, rain gutters, and downspouts. This phenomenal growth has occurred because of several unique advantages rigid vinyl offers for the homeowner versus more "traditional" materials. These advantages include:

Low maintenance

Minimal color change; never needs painting

The absence of blistering and peeling

The absence of swelling or shrinking caused by extreme moisture conditions; consequently, vinyl windows will operate smoothly and maintain their weather-tight qualities

The absence of rusting, pitting, corrosion, and attack by insects

Ease of cleaning

Comfortable to the touch in either sub-zero or tropical weather conditions

Facts About the Combustibility of Vinyl Window Frames

Since rigid PVC is widely used as a building material (i.e., windows, house siding, furniture, plumbing pipe, conduit, rain gutters, downspouts, and soffit), there is a great deal of interest as to how it behaves in a fire. The fact is that rigid PVC **will** *burn*, but it will not support its own combustion. What this means is that an article made from rigid PVC will burn **only** if another material is burning, producing a hot and continuous flame in contact with (or very near to) the rigid PVC. Once this supporting flame (or its radiated heat) is removed, the PVC will cease burning.

All organic (carbon-based) materials will burn, and rigid polyvinyl chloride is a carbon-based material. When these organic materials burn, they produce a mixture of combustion products made up of gases, liquids, and solids known as smoke. These combustion products include carbon dioxide, water vapor, carbon monoxide (a very toxic gas), and hydrogen chloride (an irritant gas).

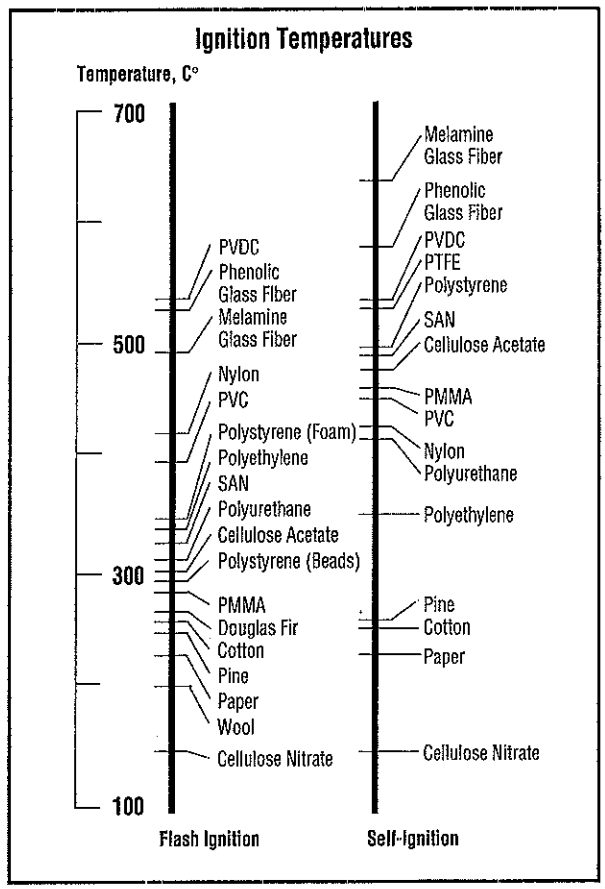
Rigid vinyl windows have been in use for over 30 years. During this period of use, when structure fires have occurred, the presence of rigid vinyl windows has never been reported as a factor causing the fire, as producing an unreasonable fire hazard, or as preventing fire service personnel from effectively fighting the fire.

How Easily Does Rigid Vinyl Ignite?

Rigid PVC, because of the properties presented on the following pages, is relatively difficult to ignite. It will ignite only if other common organic materials such as wood and wood products, fabric, leather, cotton, rubber, and other easily ignitable materials are already burning.

Figure 1, which includes ignition temperatures for rigid polymers, shows that the flash ignition temperature (resulting from the presence of a flame) for PVC is relatively high at 736°F (391°C) when compared to other materials, and its auto-ignition temperature (when no flame is present) is considerably higher, at 849°F (454°C) – ASTM D1921.

Figure 1



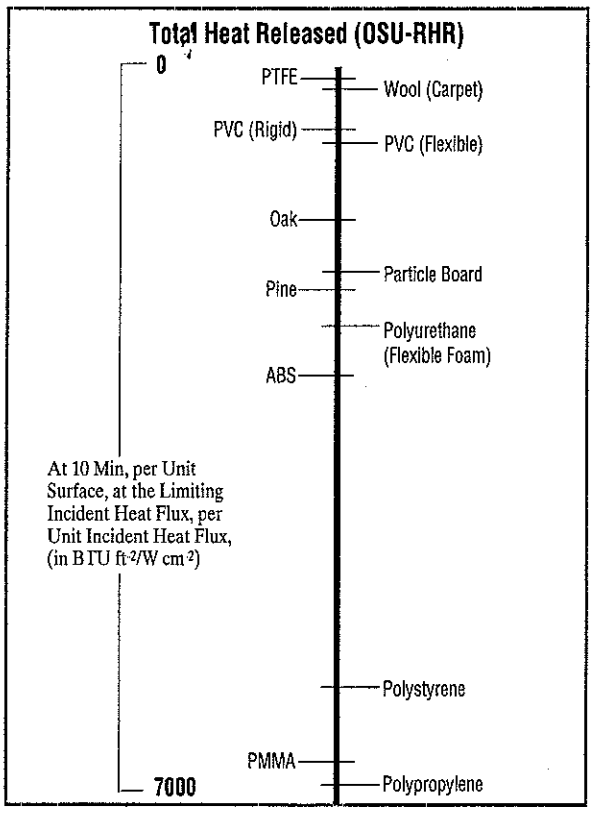
These small-scale laboratory test results are not intended to reflect hazards presented by these or any other materials under actual fire conditions

Other Important Fire Properties of Rigid Polyvinyl Chloride

Many experts consider the most important fire property of a product to be its peak rate of heat release, since this is what will determine the highest intensity of any resulting fire. It is this property that determines the greatest intensity of energy output of any fire. Rigid PVC has a relatively low total heat release value and a low rate of heat release. What this means is that burning rigid PVC liberates less heat energy when it burns than is required to keep itself burning. Thus, it cannot support its own combustion, and when the supporting flame from the other materials (which are easier to ignite) that are burning is removed, the flame of burning rigid PVC will go out.

Figure 2 and Table 1 show the results of ASTM E906 and ASTM E1354 tests run on the Ohio State University calorimeter and the National Bureau of Standards cone calorimeter.

Figure 2



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Heat Release from NBS Cone RHR Calorimeter (Horizontal Exposure[a])

Table 1[1/2/3/]

Material	Maximum Rate Heat Release kW/M²	Smoke Parameter kW kg x 10⁻⁵
1. Polycarbonate	22	0
2. Aircraft panel [b d]	40	–
3. "Low smoke" rigid PVC	89	0 04
4. PVC	91	0 35
5. "Low smoke" FR PVC wire cpd	92	0 15
6. Carpet [b]	100	–
7. PVC (extrusion)	115	0 38
8. Rigid PU foam [b, d]	160	–
9. Particle Board [b, c]	180	–
10. PPO/PS with fiberglass	184	1 66
11. Standard PVC wire cpd	204	2 23
12. FR ABS	250	4 68
13. PPO/Polystyrene alloy	263	4 10
14. FR Polystyrene	315	5 50
15. FR ABS (with PVC)	445	5 84
16. FR Polyurethane TPU	509	3 08
17. PMMA [b, c]	650	–
18. Flexible PU foam [b d]	650	–
19. ABS	746	6 44
20. Polystyrene	859	8 82
21. EPDM/SAN	883	8 97
22. Polyester	1216	5 59
23. Polyethylene	1325	4 46
24. Polypropylene	1335	6 15

[a] Incident Flux: 20 kW/m²; thickness: 0 63 cm
[b] Incident Flux: 25 kW/m²
[c] Thickness: 1 28 cm
[d] Thickness: 2 54 cm

Materials: 1, 6, 8, 9, 17, 18 – Reference 17; 5, 11 – BF Goodrich compounds; others – References 4, 11 Lexan 141-111 polycarbonate; composite with phenolic-polyamide honeycomb and tedlar coating; low smoke PVC sheet extrusion compound; general purpose PVC custom injection moulding compound; PVC fire-retarded flexible wire compound designed for low smoke; wool-nylon carpet with rubberized backing; weatherable PVC extrusion compound; GM31 rigid polyurethane foam[18]; 0 5 inch particle board; Noryl GFN-3-70 PPO/PS with fiberglass; standard flexible PVC wire and cable compound (non-fire-retarded); Cycolac KJT ABS; Noryl N-190 polyphenylene oxide/polystyrene; Huntsman 351 FR polystyrene; ABS fire-retarded with PVC; FR thermoplastic polyurethane; 0 5 inch Rohm and Haas black poly (methyl methacrylate); 0 5-inch low density flexible polyurethane foam; Cycolac CTB ABS; Huntsman 333 polystyrene; Rovel 701 EPDM/SAN copolymer; Celanex 2000-2 polyester; Marlex HXM 50100 polyethylene; Durro 8938 polypropylene

Note: The term 'low smoke' is a manufacturer's designation

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Comparison of the Flammability of Rigid PVC with Other Materials

All combustible materials require oxygen to burn. The Limiting Oxygen Index Test (LOI, ASTM D2863) measures the minimum concentration of oxygen in the atmosphere required for a material to continue burning on its own. The results, Table 2, show that rigid PVC is among the materials with the highest (best) LOI: more oxygen is normally needed to burn PVC than is present in the atmosphere of the earth (21%). Results of the LOI test (which is run on a very small sample) should not be taken out of context: They may not reflect what will happen in a full-scale fire, but give rough indications of flammability, particularly if there are large differences between materials.

Another important fire property is the flame spread rate, which indicates how fast the flame spreads through a material. The results, as measured by the radiant panel test (ASTM E162) show that rigid PVC is one of the materials with the lowest flame spread rating (Table 3).

These results explain why rigid PVC will not burn by itself, unless a flame (or heat source) is kept close by. Once the flame is removed from rigid PVC, it will usually stop burning. On the other hand, many other products, including wood, will usually continue to burn, once they have started burning, even if the flame has been removed.

Table 2[1/4/5]

Limiting Oxygen Indices of Various Materials

Material	LOI	Material	LOI
Polyacetal	14 9	Nylon 6,6	24-29
Polyoxymethylene	15.7	Wool	25 2
Cotton	16-17	Polycarbonate	26-28
Natural rubber	17 2	Neoprene rubber	26 3
PMMA	17 4	Modacrylic	26.8
Polyethylene	17.4	Nomex	28 5
Polypropylene	17.4	Polysulphone	30-32
Polystyrene	17.6-18 3	Leather (FR)	34 8
Polyacrylonitrile	18.0	Polyimide	36.5
SAN	18 0	PVDF	43 7
ABS	18 3-18 8	PVC (rigid)	45-49
Rayon	18 7-18 9	Carbon black rod	59-63
Cellulose	19.0	PVDC	60 0
PET	20 0	Chlorinated PVC	60-70
PVF	22 6	PTFE	95 0

Note: The fire performance for this test improves as the LOI becomes higher

Note: These numerical flame spread ratings are not intended to reflect hazards presented by these or any other materials under actual fire conditions.

Table 3[1/]

Surface Flammability of Some Materials–Flame Spread Index

Material	Thickness (mm)	Flame spread index	Material	Thickness (mm)	Flame spread index
Chlorinated PVC	3	4	Plywood (fir)	6	143
Polyether sulphone	3	5	Hardboard	6	185
PVC	4	10	GRP polyester (21%)	2	239
Polyester	3	30-56	FR acrylic	3	316
FR polystyrene	3	59	Polystyrene	2	355
FR polycarbonate	6	73	Acrylic	6	416
Polycarbonate	3	88	Polyurethane foam (flexible)		1490
Red oak	19	99	Polyurethane foam (rigid)		2220
Phenolic resin	2	114			

Note: The fire performance for this test improves as the flame spread ratings become lower

Note: These numerical flame spread ratings are not intended to reflect hazards presented by these or any other materials under actual fire conditions.

Comparison of Smoke Characteristics of Rigid PVC with Other Materials

When any material burns, it gives off smoke, which will generally result in a loss of visibility. Smoke contains gases, liquids, and solids. The amount of smoke given off by a material is directly related to the amount of material that burns; generally, if more burns, the obscuration is greater. A meaningful way to measure smoke generation so that the results can be used in models to predict full-scale fire behavior is with the National Institute of Standards and Technology (formerly National Bureau of Standards) cone calorimeter.

Table 4 shows that the smoke parameter from the PVC is among the lowest ones measured. It should be stressed that the visible density of smoke (how much it darkens visible light) does **not** give any indication of the toxicity of that smoke.

Table 4[1/2/3/]

Material	Smoke Parameter kW kg x 10^{-5}
3 Low smoke rigid PVC	0 04
4 PVC	0 35
5 Low smoke FR PVC wire cpd	0 15
7 PVC (extrusion)	0 38
10 PPO/PS with fiberglass	1 66
11 Standard PVC wire cpd	2 23
12 FR ABS	4 68
13 PPO/Polystyrene alloy	4 10
14 FR Polystyrene	5 50
15 FR ABS (with PVC)	5 84
16 FR Polyurethane TPU	3 08
17 PMMA b, c	–
18 Flexible PU foam b, d	–
19 ABS	6 44
20 Polystyrene	8 82
21 EPDM/SAN	8 97
22 Polyester	5 59
23 Polyethylene	4 46
24 Polypropylene	6 15

Note: Materials are described in Table 1

ASTM E1354 was used for Table 4

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Combustion Products of Rigid PVC

The major combustion products of PVC are carbon monoxide, carbon dioxide, hydrogen chloride, and water. All of these, with the exception of hydrogen chloride, are also combustion products of all other organic materials, whether natural (like wood) or synthetic (like plastics). In fact, carbon monoxide is, by far, the most important toxicant in all real fires. Hydrogen chloride is an irritant with an easily detectable pungent odor, which can warn people of its presence. While the levels of toxicity of carbon monoxide and hydrogen chloride are very similar, the concentrations of hydrogen chloride required for lethality are rarely reached in real fires.

Toxicity of Smoke

The smoke from all burning materials is toxic. Research shows that the toxicity of the smoke from burning rigid PVC is within the same general range or magnitude as that from all other organic materials. In fact, since rigid PVC window frames are likely to produce a lesser amount of combustion products in a fire than many other products (because of the excellent fire properties of rigid PVC), they will produce less of a toxic hazard.

What Happens to Rigid Vinyl and Vinyl Window Frames in Case of Fire

Rigid vinyl alone will not normally support or spread a fire. It will burn only while a flame or some other source of heat is in direct contact with it.

If a fire is burning very close to a vinyl window, it will cause the vinyl to soften, to sag, and to blister. If the fire is hot enough, it may even cause some burning to occur. However, as soon as the external fire is put out the vinyl window frame will stop burning. Several full-scale fire demonstrations have shown this to be the case.

- Tests, conducted November 1983 by Fire Research Station (UK) and the British Plastics Federation[6], compared the fire performance of vinyl window frames with that of traditional wood window frames. The tests showed that, during a fire, the first thing to happen is the breaking of the glass panes, whatever the framing material. After the glass panes broke open, the wood window frames continued to burn, while the vinyl window frames softened but soon stopped burning. The main toxic hazard was found to be the resulting carbon monoxide, which is a product of all fires. Fires involving wood window frames also generated much higher levels of carbon monoxide than those made of vinyl.

- Other tests were carried out by the Swiss Fire Police, in Zürich[7]. They showed that window frames made of materials in normal use for such applications are unlikely to influence either the course or the intensity of a fire. Again, in all the fire tests the glass panes broke and fell out of the frames before the window lost its stability. Thus, the smoke and fumes streamed out through the window openings rather than contributing to an increased fire hazard inside the building. It was concluded that the window frame material has only minor significance from the point of view of fire prevention and that the use of PVC window frames does not represent an increased fire hazard compared to other materials.

- Burn tests conducted at Lisle-Woodridge (Illinois[8]), showed that the use of a PVC window frame had no adverse effect on the fire conditions. The glass window pane was broken, the aluminum handle melted away, but the window resisted the fire and did not burn. In fact, the window was operational after the fire! The vinyl did not, thus, contribute to flame spread, demonstrating the superior fire performance of PVC.

It can be concluded from all these tests that vinyl window frames display good fire performance and will stand up well to fire conditions.

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