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Pultruded Fiberglass Windows

Pultruded Fiberglass Windows

Presented By: Inline Fiberglass Ltd.
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Description: Provides an overview of pultruded fiberglass window systems and compares them with traditional wood, aluminum, and PVC window systems across a wide variety of performance attributes including: strength and durability, sustainability, condensation resistance, expansion/contraction, fabrication and installation.

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Learning Objectives

At the end of this program, participants will be able to:

- explain the fiberglass pultrusion process and the properties of pultruded fiberglass that make it an ideal product for the fenestration industry
- compare and evaluate the performance characteristics of fiberglass, wood, aluminum, and PVC window systems, and determine their impact on the design goals of a project and the environment
- compare fiberglass window systems to wood, aluminum, and PVC window systems in terms of their "green" characteristics including embodied energy, energy efficiency, toxicity and indoor and outdoor environmental issues, and
- describe the AAMA performance standards, the National Fenestration Council's procedures and ratings, and the ENERGY STAR® program, and use these standards and ratings to specify product type, based on performance level and key performance attributes.

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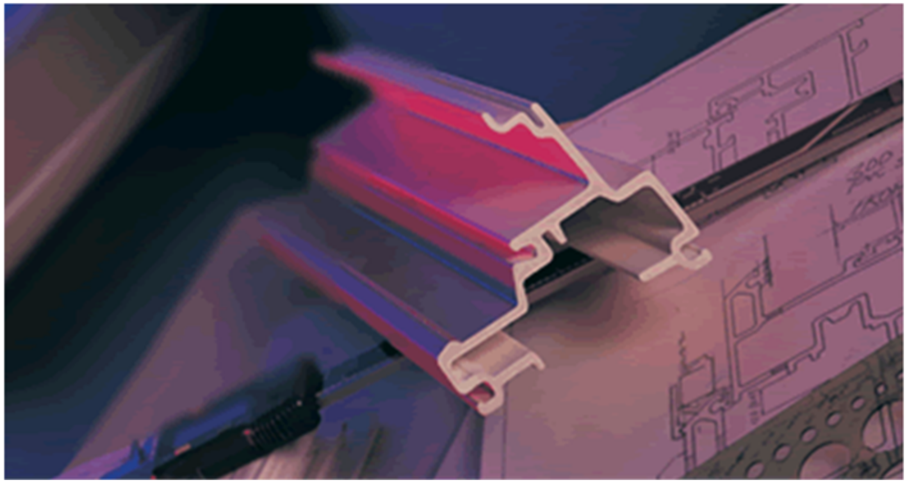
What Is Pultruded Fiberglass?

What Is Pultruded Fiberglass?

Pultrusion is a continuous process for manufacture of composite materials with constant cross section. Fiberglass mat and rovings are pulled through a die; conversely, extrusions are pushed through a die.

Composites are material matrix made up of two or more individual components: glass reinforcing fibers and thermosetting polymer resin, whose combined physical strength exceeds the properties of either of them individually. The fabric provides the strength and the resin acts as a binder distributing the load and provides dimensional stiffness.

FRP is the acronym for fiber reinforced polymer.



Pultrusion History

Fiberglass pultruded profiles are not new. The first patents for pultrusions were issued in 1946 with applications that had heavy walls and did not require specific tolerances (e.g. fiberglass ladders). The entry of fiberglass into the fenestration industry (doors and windows) came about with the ability to maximize the glass content to a minimum of 60%, which increased the physical properties (strength). This allowed engineers and designers to thin down the wall thickness as low as 0.07" (1.78mm), while still maintaining designed strength.

Design potential is limited only by the requirement that the shape be constant over the length of the profile. The high glass content improved many of the properties by stabilizing the resins. Lineal profiles of intricate shapes are achieved with a new inert material with tight tolerances and mechanical properties rivaling metal.

Applications for Fiberglass Products

Applications – Transportation / Aircraft

Fiberglass use ranges from sports cars to large utility construction equipment, truck beds, armored vehicles and tanks, from road signage to highway sound barriers. All applications are exposed to all weather conditions and subject to constant abuse.

The high strength-to-weight ratio of fiberglass is ideal for plane fuselages, propellers and nose cones of high performance jets, and satellites.

Applications – Marine / Recreation

Boats were once completely dominated by wood and aluminum and are now 95% fiberglass, due to its ability to withstand the elements under heat and cold and its resistance to corrosion, from both salt water and atmospheric pollution, while retaining its finish with minimum maintenance.

Equipment that takes a beating under all temperatures includes: golf clubs and carts, snowmobiles, hockey sticks, playground equipment, skis and ski poles, fishing rods, shotgun barrels, travel trailers.

Applications – Construction

Fiberglass is being used to build bridges ("H" and "I" beams) where the bridge span is so wide that if made from steel, it would collapse under its own weight. Fiberglass is replacing steel rebar because it has the strength of steel but resists corrosion. Fiberglass road guard rails and highway signage have proven to be stronger than their steel counterparts. From hydro transmission towers, to street light poles, to street manhole covers; from sea walls and dikes, to offshore oil rigs, fiberglass is used to provide strength and durability, and resist corrosion.

Applications – Household Fixtures / Environment

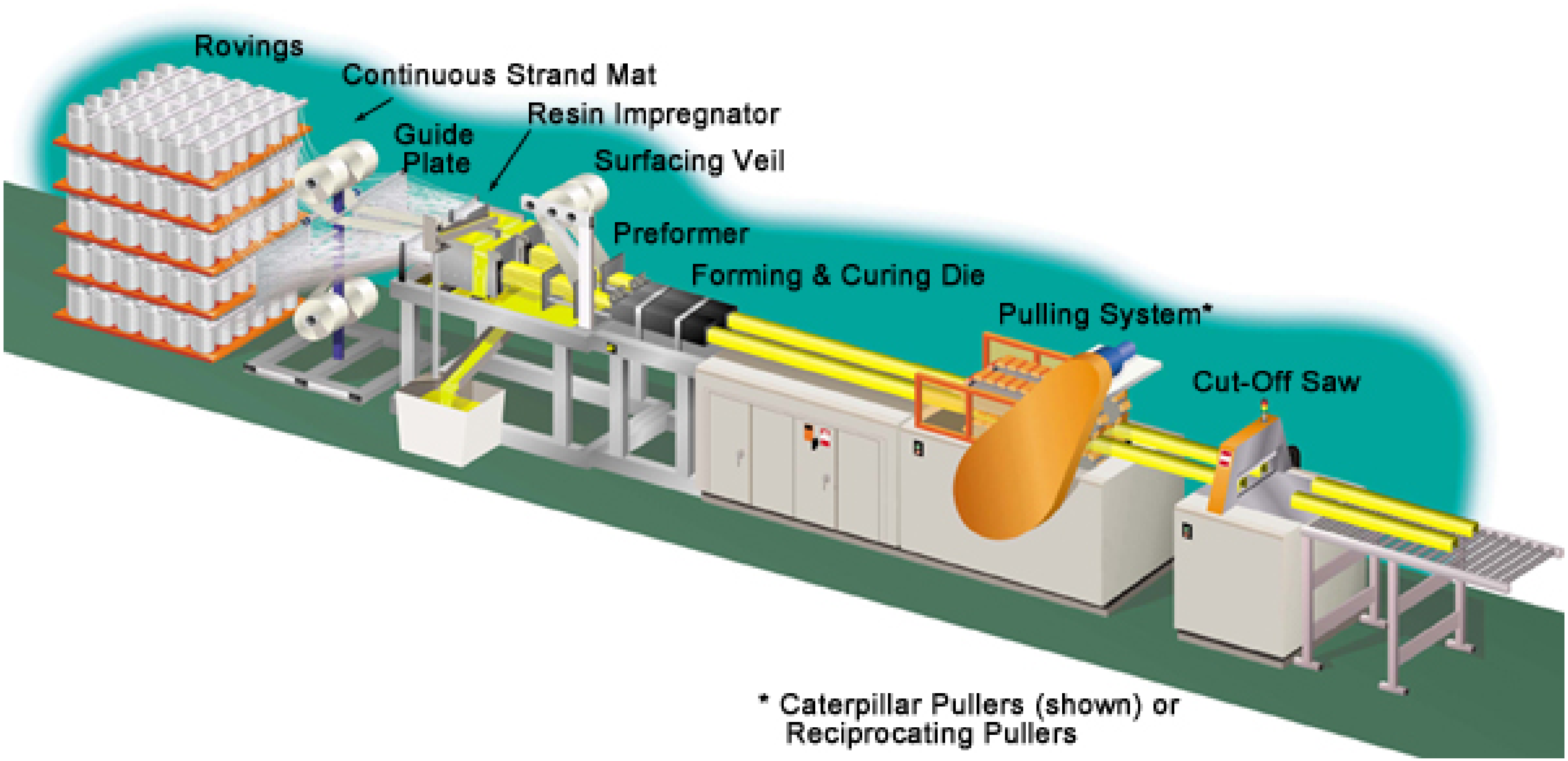
Fiberglass is used in the manufacture of many household items that are taken for granted, including: shower stalls, laundry tubs, hot tubs, and ladders.

In North America, every gas station was required by law to dig up their steel gas storage tanks and replace them with fiberglass tanks, the least likely material to corrode, rot, disintegrate and leak its contents into the ground and water table.

Fiberglass Pultrusion Process

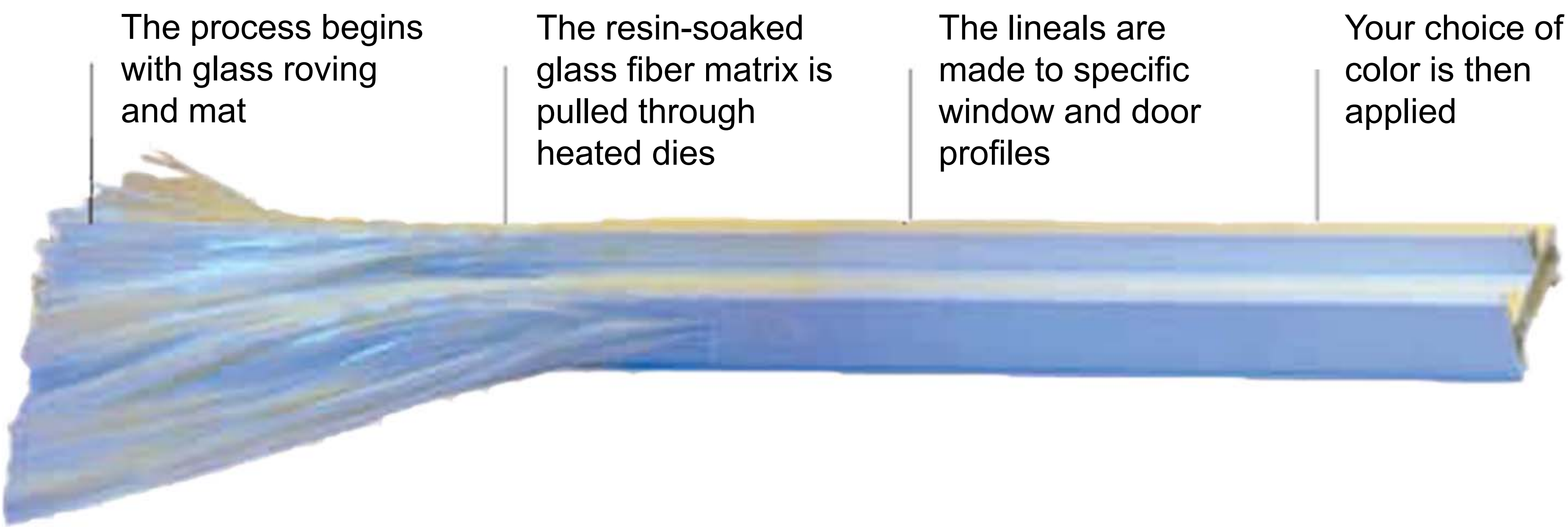
The Fiberglass Pultrusion Process

Continuous fiberglass reinforcements, in the form of roving and glass mat, are fed from a creel to a resin impregnation station, to coat each fiber with a specially formulated polymer thermosetting resin mixture (wet out).



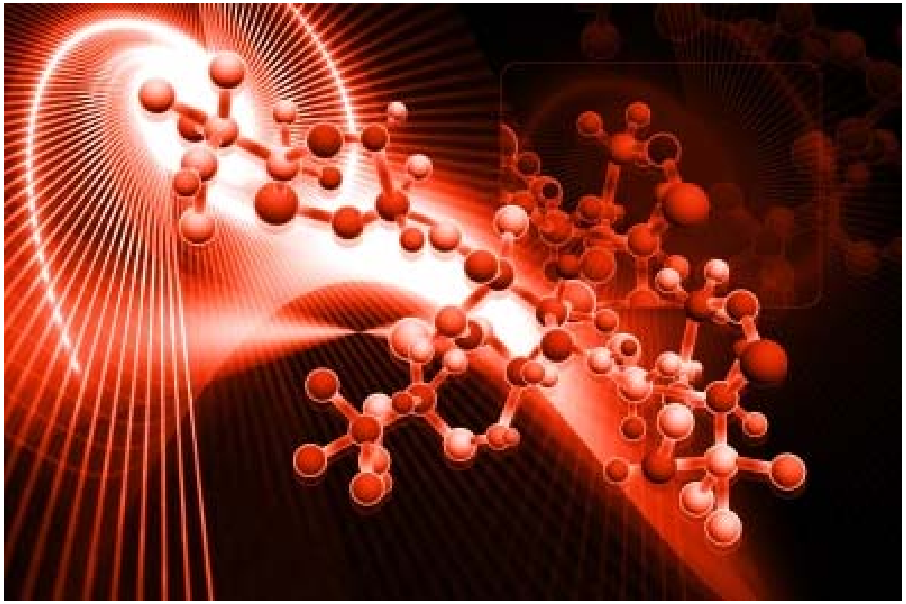
The Fiberglass Pultrusion Process

The coated fibers are assembled by shaping guides into the preformer, which squeezes away excess resin as the product is moving forward and gently shapes the materials prior to entering the forming and curing die, which forms the desired cross section.



The Fiberglass Pultrusion Process

The result is a high strength product, ready to use as it leaves the pultruder. The process is irreversible; its form cannot be changed under heat or pressure, unlike PVC or aluminum that can be remelted and will deform under pressure. In the extrusion process, the aluminum ingot and PVC pellets are heated to a ductile state prior to entering the die. The fiberglass mats, rovings, and resin enter the die at room temperature. Within the die there are several zones of temperature (heating and cooling) throughout its length, which activate the thermosetting reaction (polymerization); under high temperature and pressure, the composite is cured (hardened).



Fiberglass Rovings and Mat

Fiberglass is a man-made fiber, produced from silica, SiO_2 (silicon dioxide), $CaCo_3$ (lime - calcium carbonate), and $NaC0_3$ (sodium carbonate).

The manufacturing process for glass fibers suitable for reinforcement uses large furnaces to gradually melt the sand/chemical mix to liquid form. It is then extruded (pushed) through platinum tipped bushings with small orifices—typically 16 micrometers (.00063 inch) in diameter for E-Glass, 9 micrometers (0.00035 inch) for S-Glass and in other processes, sub-micron openings are used for microfiber.

The individual filaments drawing at speeds of 200 km/hr (125 mph) are bound together into bundles of typically 4,000 separate filaments called rovings. Rovings are then either used directly as glass reinforcement in the pultrusion process or further processed to manufacture fabric mat.

Rovings provides great longitudinal ultimate tensile strength of 200,000 to 300,000 pfsi (pounds force/square inch) (2368 Mpa). Fiberglass multidirectional mat is wrapped on both the interior and exterior of profile to provide transverse strength.

Resins

The resin used in fiberglass pultrusions for windows is almost exclusively unsaturated polyester (95%), although there are exciting future potentials for the use of urethane resins. The formula can vary to meet specific properties. The typical material mix is:

- glass (mat and rovings) - minimum 60%
- polyester resin - minimum 20%

The balance made up of fillers (limestone, clay) and additives (catalyst, lubricants, UV inhibitors, fire retarder).

The physical properties of pultruded fiberglass profiles are far greater than other fiberglass processes, such as molded fiberglass applications (e.g. swimming pools, boats, storage tanks), which have lower glass content (typically 30%) and thus lower strengths.

Fiberglass pultrusion is a fabrication process to produce lineal profiles that brings high performance, space-age composites into the window and door market.

Preface

As we move into a discussion about window systems, where comments are made to specific material (fiberglass, aluminum, vinyl and wood), they are made as general comments applicable to the material.

Where specific material performances are quoted, they have been provided in order to make comparisons. All values quoted are approximate and for general guidance only.

It is important to recognize that each generic material will also vary:

- Wood: Has general properties, but different types of wood—Oak, Pine, Cedar, and Balsa—all perform differently under different criteria.
- PVC: Has many formulas and additives, virgin and regrind, and with or without metal reinforcement.
- Architectural Aluminum: Is constant; the variable is the efficiency of the thermal barrier.

Preface

- Fiberglass: Is an engineered product that can vary with the pultruder's ratio of glass to resins, as well as the resin formula and additives.

Beyond the basic material evaluation is design.

Within each material there are examples of both high and poor quality. Window engineers can either maximize the properties of the material into their designs or, in the interest of economy, create new defects into the product. Unfortunately windows get typecast as either good or bad based on the material from which they are made.

Strength

Strength

A window system is only effective when all components are working together; the basic feature in a window that supports the performance of all the components is the structural strength of the window's framing material.

Tensile Strength (Longitudinal)

Tensile strength is a measurement of the ability of the material to withstand forces that tend to pull it apart and to determine to what extent the material stretches before breaking. Tensile strength equals force (load, lbs.) divided by the cross section area (sq. ft.). Tensile properties of some materials (e.g. PVC) can change rapidly with small changes in temperature.

For an equivalent mass, fiberglass's longitudinal tensile strength @ 60,000 psi is:

- two times stronger than steel
- three times stronger than aluminum, and
- ten times stronger than PVC.

	Fiberglass	Rigid PVC	Wood	6063T5 Aluminum	Steel
psi	60,000	6,500	800	20,000	30,000
MPa (megapascal)	410	45	6	138	207

Modulus of Elasticity

	Fiberglass	Rigid PVC	Wood	6063T5 Aluminum	Steel
psi	3,500,000	350,000	1,300,000	10,000,000	30,000,000
GPa (gigapascal)	24	2.4	0.9	b 69	207

Modulus of elasticity (flexural modulus) is a measurement of the stiffness during the first or initial part of bending.

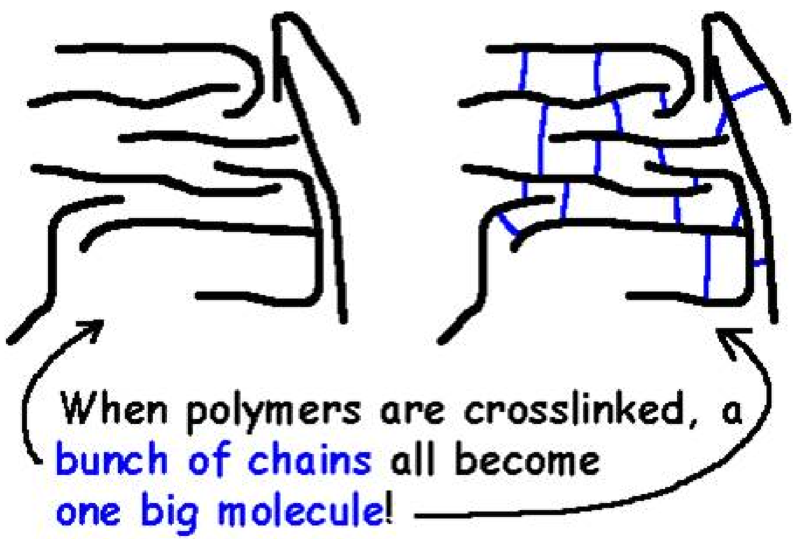
For an equivalent mass, fiberglass has a longitudinal modulus of elasticity that is:

- $\frac{1}{10}$ of steel
- $\frac{1}{3}$ of aluminum, and
- ten times that of PVC.

The polymer resins used to solidify the glass are different from those in PVC. Reinforced fiberglass pultrusions use thermoset resins while PVC uses thermoplastics resins.

Thermoset Cross-linked Fiberglass Profiles

Cross-linking is the process in which large polymer molecules react with each other to form a three-dimensional network. The mechanical and chemical properties of the polymer typically change when this happens.



The drawing on the left shows the difference between lots of single uncross-linked molecular chains and a cross-linked chain.

Cross-linking occurs in the pultrusion forming die at high temperatures, tying all the polymer molecules together. Because they're tied together and locked to a profile, they can't flow (slip) past each other, around each other, or be broken apart from each other.

Thermoset Cross-linked Fiberglass Profiles

Thermoplastics resins (PVC) and aluminum have a linear molecular structure and are not cross-linked.

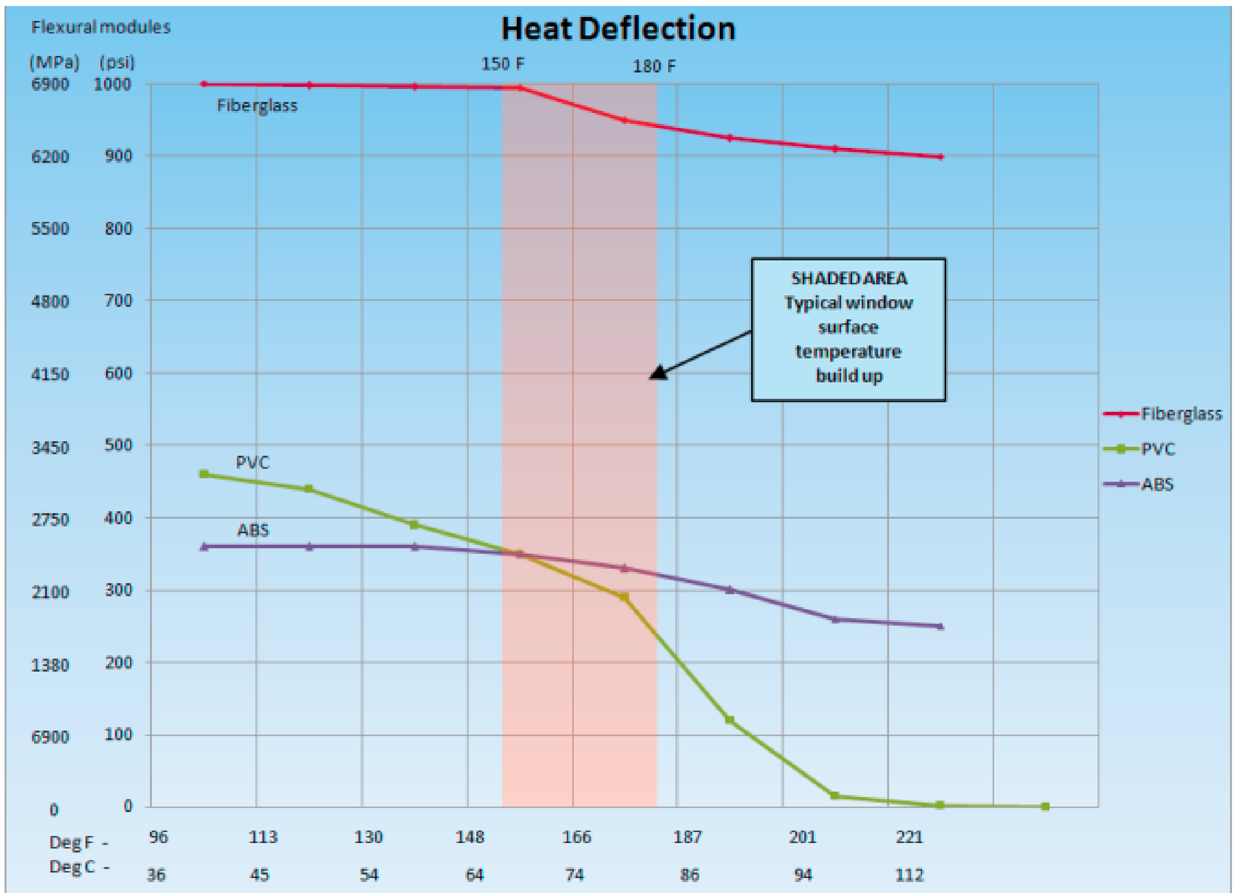
The physical properties of PVC are at their greatest strength around 72˚F (22˚C). PVC, as a thermoplastic resin, is temperature dependent, meaning the tensile strength of PVC will diminish (soften) as the temperature rises above 72˚F, and without additives to the resin can become unstable around 135˚F (57˚C) and will melt around 170˚F (76.6˚C). In cold temperatures, PVC becomes brittle and prone to breakage. The physical properties of PVC are directly related to the air and solar temperature.

The physical properties of fiberglass are relatively constant through the full range of climatic temperatures that a window will be required to perform in.

Heat Deflection at 90˚F Air Temperature

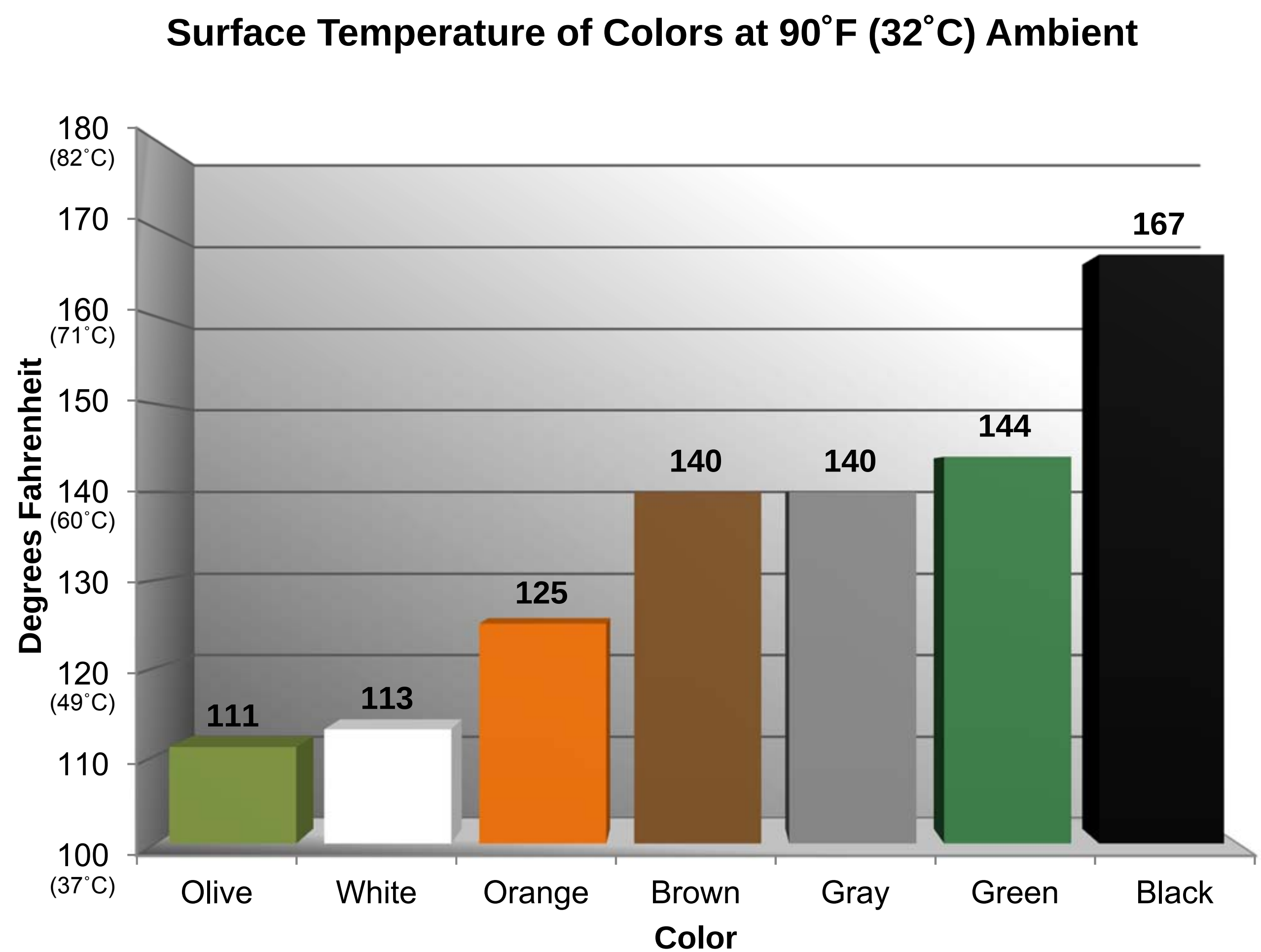
The chart shows how heat reduces the flexural modules of fiberglass and PVC.

The surface area temperature of an object will hold a higher temperature than the air it is exposed to.



Heat Deflection

The chart shows a high temperature of 167˚F (75˚C). This is not extreme. Based on an air temperature of 90˚F (32˚C), thermocouple readings of a medium color painted profile, which will retain heat, could have a surface temperature of 122˚F (50˚C), while a dark color could be 145˚F (63˚C). This is why PVC windows are not normally available in dark colors.



Material Strength

Fiberglass is an inert, stable material:

- It does not out-gas like PVC .
- Its physical properties do not deteriorate over time, and
- It is unaffected by temperatures up to 350˚F (176˚C), or down below 122˚F (50˚C), which is well beyond normal climatic conditions.

Strong window frames:

- allow for slender frame sight lines, equal to metal frames, to maximize glass area
- allow for larger window openings which provide an attractive viewing area, maximize day lighting and provide passive solar collectors, and
- maintain their shape in a square plane and ensure a proper fit into the opening without sagging or bowing, thereby ensuring a smooth operation of sash and maintaining the engineered clearance between the window frame and sash to minimize the potential of air and water leakage.

Material Strength

The strength of fiberglass allows for the use of open-back profiles, similar to aluminum, without compromising the structural performance of the window.

This has the advantage of:

- reducing the thermal conductivity through the frame by 50%, since conduction equals the *coefficient of conduction x the mass* and open-back frames eliminate mass, and
- reducing weight of the window.

PVC windows lack strength. To compensate for this inherent weakness, metal reinforcements are added to meet wind load requirements. However, as the metal reinforcement has a higher conductivity, this reduces vinyl's thermal performance and adds weight.

Fiberglass window and door products are designed with inherent strength, without the extra cost of material and labor to add reinforcements.

Material Strength

Another important property of polymers is their response to the application of a force (wind, operating force or weight of glass/sash).

There are two main types of force behavior: plastic and elastic.

- PVC frames are an example of plastic force, where flow of the molecular structure is occurring, much like viscous liquid. If pressure is applied at an elevated temperature, permanent deformation may take place.
- Fiberglass is an example of elastic force. Deflection (stretch) may occur, but when the pressure is removed, the profile has a memory and will spring back to its normal at-rest position.

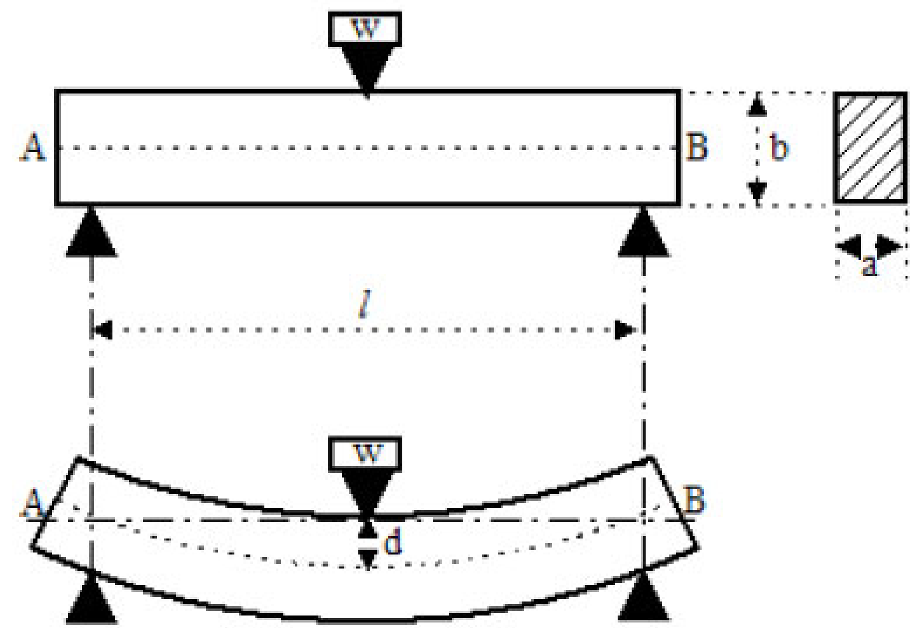


Fig. 2. Deflection of a simple beam.

Image Source: http://blog.cencophysics.com/2009/08/beam-deflection-youngs-modulus/ Accessed January 2012.

Material Strength

Most materials demonstrate a combination of elastic and plastic behavior, showing plastic behavior after the elastic limit has been exceeded.

Fiberglass (glass) is one of the few completely elastic materials while it is below its T_g (glass transition temperature). It will remain elastic until it reaches its breaking point.

The T_g of fiberglass occurs between 950˚F (510˚C) and 1040˚F (560˚C), meaning that in window applications it will remain a solid, yet resist the force, and when the force is removed, will have a memory to return to its original shape.

In comparison, polyvinyl chloride (PVC) has a T_g of only 181.4˚F (83˚C), making it applicable for cold water pipes, but unsuitable for hot water pipes, or a window in a southern exposure where the window is under combined heat and pressure—it will take a permanent set when the force is removed.

Material Strength

Aluminum has an excellent strength-to-weight ratio. It is one of the material's best characteristics, but fiberglass has an even superior strength-to-weight ratio.

Aluminum's strength would perform better if the frame was made from a single profile. But aluminum windows having high thermal conductivity must incorporate a thermal barrier. This produces a three-part component frame (outer frame/thermal barrier/inner frame), which reduces its structural strength as compared to fiberglass as a single profile frame.

As owners and industry standards demand lower U-value performances in a window, aluminum manufacturers are forced to add larger thermal barriers to reduce conductivity, with the trade-offs of weakening the frame and greater expense.

Thermal Performance

Energy Loss

Heat loss may take place as a result of conduction, convection, and radiant transfer. Windows can be “energy robbers,” allowing up to 30% of the total heating/cooling that escapes from buildings. A typical window may lose up to ten times more heat per square foot than the walls around it.

The chart on the right shows the window industry’s improvements over the years to the glazing portion of a window.

Fiberglass windows now offer the first thermal improvement of the frames in over 50 years.

History of Glazing

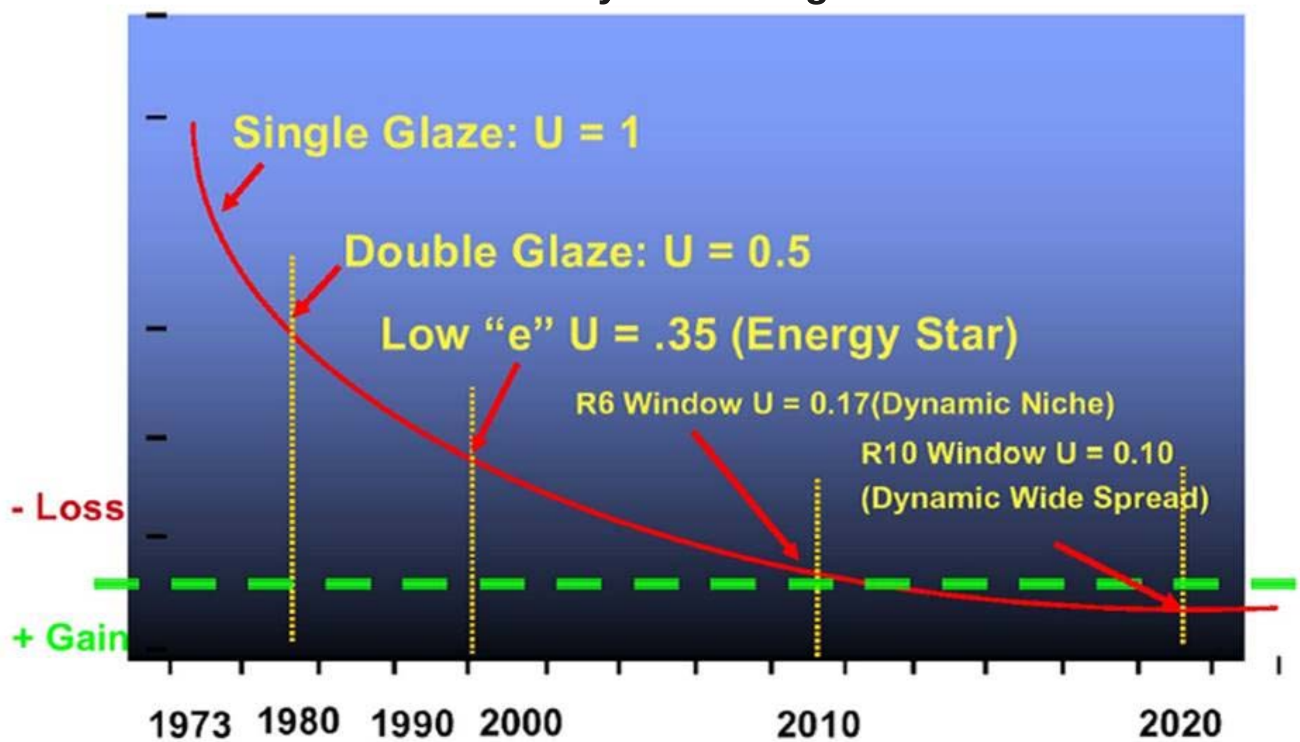


Image Source: U.S. Department of Energy

Thermal Conductivity

Thermal conductivity is defined as the rate of thermal movement through a material, per unit area, per unit thickness, per unit temperature (delta T).

"U" Value (Factor) / (BTU) (British Thermal Unit)

- BTU is used to describe the heat value (energy content) of fuels and the power of heating and cooling systems.
    - BTU per hour, per square foot, per degree Fahrenheit ($h/ft^2/^\circ F$)
    - Watts per hour, per square meter, per degree Centigrade ($h/m^2/^\circ C$)
    - (For metric U-value, multiply the imperial U-value x 5.678)

- BTU is a measurement of the transfer of heat loss or gain, due to the difference between indoor and outdoor air temperature.
- One BTU is the amount of heat required to raise the temperature of 1 lb. (0.454 kg) of liquid water 1˚F (0.556˚C).
- One BTU is approximately the heat produced by burning a single wooden match.
- A window with a U-value of 0.30 will lose half the energy that a window with a U-value of 0.60 will.

Thermal Conductivity

"R" Value (Factor)

- R-value is the resistance to thermal conduction per unit thickness of a material.
- R-value is the inverse of U-value.

The higher the R-value, the more effective or resistant to heat loss the building's insulation will be.

To convert:

"U" = 1/R, "R" = 1/U

The chart provides the R-values and U-values for window materials based on a test sample measuring 1 cubic inch. (1" x 1" x 1")

	R-value	U-value
	Imperial	Imperial
Fiberglass	2.00	5.0
Vinyl (rigid)	1.30	77
Wood	1.00	1.00
Aluminum (6063)	1200	0.0008
Steel (mild)	360	0.0028
Glass (single)	1.00	1.00

The thermal conductivity of fiberglass is <1% of aluminum.

U-values of Window Systems

The U-values of windows are commonly reported as the value based on the center of the sealed unit, which will be an optimum value.

The correct value is the overall value, which must include the poorer performance values of framing and the edge of glass, due to higher conduction of the sealed unit and spacer bar.

The thermal efficiency of a window is composed of the U-value for the:

- Window Frame - Area of frame x frame U-value = ____
- Glazing - Area of glazing x glazing U-value = ____
- Spacer Bar - Area of spacer bar x spacer bar U-value = ____

Total Window U-value = ____

Thermal Efficiency Comparison

Because pultruded profile walls can be made very thin (0.07 inches), they create a narrow heat path or thermal bridge, with minimal mass, resulting in excellent thermal performance. All windows can be glazed with the same high-tech glass. The comparison therefore should be made on the main variable, the U-value of the frame, which may have the poorest thermal efficiency.

Aluminum Window Frames

Aluminum is a high thermal conductor making it excellent for cookware applications, but high conductivity is undesirable for windows.

Aluminum windows must incorporate a thermal barrier separating inner and outer aluminum frames in order to improve thermal efficiency, but the effectiveness of the best thermal barrier will still not perform as well as a wood, PVC, or fiberglass frame.

Wood Window Frames

Wood has the lowest U-value of traditional window framing for a given 1" cube sample. However, wood cannot be fabricated into thin wall cavity profiles like PVC, aluminum, or fiberglass. The thermal efficiency of a high mass wood window times its low U-value is not as efficient as PVC or fiberglass.

Thermal Efficiency Comparison

PVC (Vinyl) Window Frames

PVC has a low U-value for a given 1" cube of material.

The thermal efficiency of the PVC profile requires more mass of material to match the structural strength of an aluminum or fiberglass profile. When PVC's thermal value is multiplied by its mass, it will have a higher window U-value than a fiberglass window.

There are thin PVC windows on the market, making them energy efficient, but thin-walled PVC windows may lack the structural requirements to meet wind load building codes. Most PVC windows must then incorporate metal structural reinforcement, which reduces their overall thermal performance, and is limited to small window openings.

Thermal Efficiency Comparison

Fiberglass Window Frames

Fiberglass is the most energy efficient window framing material, offering resistance to heat loss, reduced heating and cooling costs, and improved occupant comfort.

A simple touch test demonstrates fiberglass's thermal efficiency; in cold climates fiberglass is warm to the touch, in hot climates it's cool to the touch. What is being felt in a fiberglass window is the lack of heat transfer.

Fiberglass windows do not need a thermal barrier within the frame, as required by aluminum windows, as the whole fiberglass frame is a thermal barrier.

Thermal Efficiency Comparison

Typically, architects specify one glass for the entire building. Thought should be given to “Orientation Specific Glazing,” to match the ideal glass type to the elevation.

For northern regions:

- On south walls, install windows with the highest SHGC (Solar Heat Gain Coefficient) to provide for passive solar heating.
- On the east and west walls, use windows with the lowest SHGC.
- On north walls, install windows with the lowest U-value.

Fiberglass windows offer the most energy efficient fenestration framing material available.

This means:

- shorter energy payback analysis for clients
- greater comfort for the occupant, and
- the ability to maintain higher relative humidity without condensation.

Condensation Resistance

Condensation

Relative humidity (RH) is the ratio of the amount of water vapor molecules actually present in the air, as a percentage of the maximum moisture the air can hold at a given temperature. The warmer the air temperature, the lower the percent RH. When warm, moist air meets a cold surface, the air temperature drops, raising the RH until the RH is 100%, where it meets its dew point. Any moisture in the air over 100% is squeezed out and deposited on the closest coldest surface.

The ideal humidity comfort level is a broad range, from 30-50% RH. Below 30%, anyone with asthma or bronchial problems may have difficulty breathing. Building occupants may think they have a perpetual cold, but are suffering from the effects of low humidity. Low humidity dries out nasal passages and aggravates mucus glands, simulating a cold. Cuts and wounds heal more slowly in this environment.

If there is condensation on windows, there is condensation in the walls. If not dealt with, condensation will lead to:

- conditions suitable for mold growth and subsequent health issues for occupants
- the damage of household fabrics and discoloration of paint and wallpaper, and
- the reduction in the effectiveness of insulation, deterioration of drywall, and structural damage.

Design Suggestions

The following are design suggestions to deal with window condensation:

1. The owner must keep the relative humidity in the building below that of the dew point temperature of the windows. Although this may reduce condensation, it is not a good solution, as it is unhealthy for the occupants when the RH is below 30%.

2. Increase the ventilation. This is the reason poor windows with high air leakage may not have condensation. High air leakage allows excessive air changes, where warm moist air is lost and replaced with cold dry air, thus reducing the RH level, keeping the windows clean and dry. This is an expensive solution.

3. Install windows that work as a system. Windows that are tight fitting will minimize the air changes, keeping out the cold, dry air and keeping in the moist, warm air, while reducing heating, cooling, and humidification costs. All window components must have low conduction values. The window frames must have the ability to keep profile surfaces at a temperature that resists meeting their dew point for the relative humidity, yet meets the occupants' lifestyle.

If a window condensates under an acceptable healthy RH, it is a symptom of excessive energy loss or excessive humidity.

Fiberglass frames offer the highest energy efficiency and resistance to condensation.

Expansion / Contraction

Lineal Thermal Expansion

The following materials have known *coefficient of linear expansion* rates:

	Fiberglass	Aluminum	Rigid PVC	Steel
Imperial (in/in/Deg. F.)	**.0000055**	**.000013**	**.000037**	**.000007**
Metric (m/m/Deg. C.)	**.0000031**	**.0000072**	**.000021**	**.0000039**

Expansion and contraction for each degree in temperature (C or F):

- Vinyl is seven times greater than fiberglass.
- Aluminum is three times greater than fiberglass.
- Wood does not expand and contract due to temperature change, but is subject to swelling and shrinkage due to moisture absorption.

Material Comparison

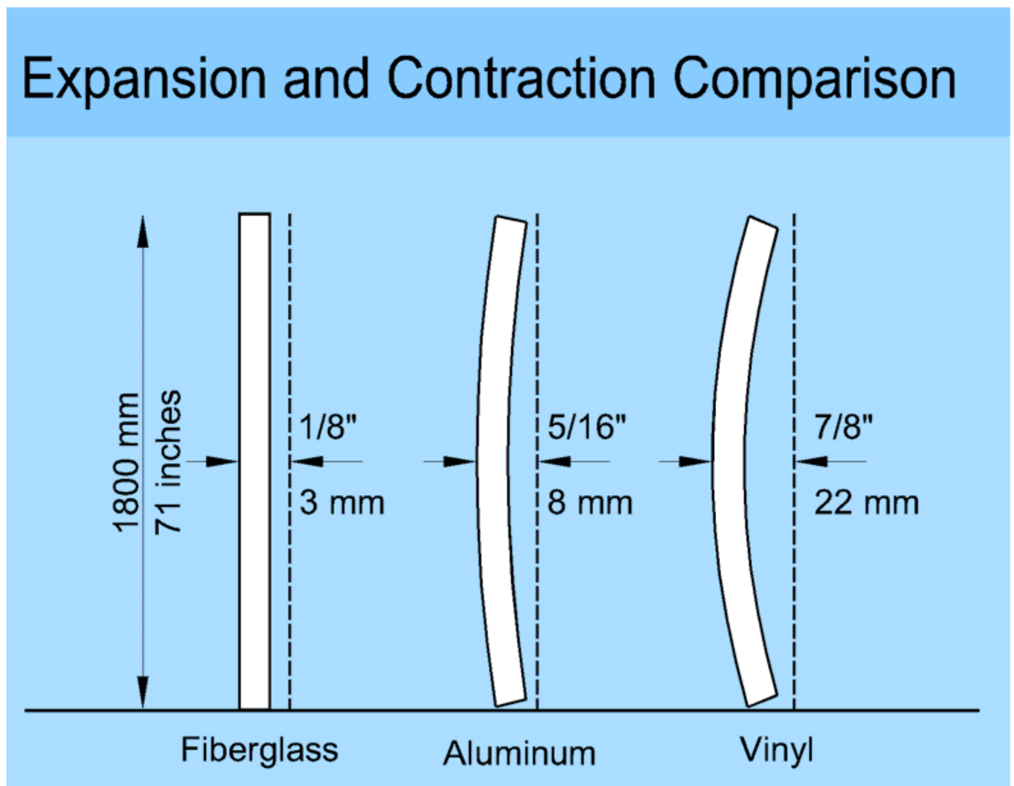
Fiberglass frame profiles have the same low coefficient of thermal expansion as glass, which means both the glazing and the fiberglass frames expand and contract as a single material, resulting in negligible stress between weather seals over the life of the window.

A sash to frame may fit with tight tolerances when fabricated at room temperature, but in the field, the single profile PVC frame will experience contraction on cold surfaces and expansion on the heated surfaces, resulting in warping, twisting, and bowing of the profile.

A large window requires allowance for expansion/contraction. The frame must be smaller than the wall opening and a calculation made to allow for the expansion/contraction of the window. The space between the wall and the window is filled with perimeter sealant, which can be thick and unsightly. With fiberglass, the perimeter clearance can be engineered smaller to minimize unsightly caulking, reducing the potential of perimeter seal failure.

Material Comparison

Windows are lab tested for air leakage at room temperature; this can be misleading compared to testing on-site in extremes of heat and cold. Expansion/contraction distorts framing materials, allowing greater air and water penetration than reported; fiberglass frames will maintain their lab tested air infiltration and water penetration throughout the temperature cycle.



Material Comparison

If sufficient perimeter seal clearance is not provided for expansion/contraction, the constant movement will eventually lead to failures such as:

- sashes not operating smoothly, or not operating at all
- the risk of sealed unit failure
- perimeter caulking failure, and
- increased air and water leakage.

Durability

Characteristics of Window Systems

Fiberglass is not susceptible to the following general negative characteristics of traditional window systems:

Wood Windows

- Wood windows are not dimensionally stable, as they absorb and release moisture.
- When they retain moisture the wood swells, distorting and jamming the operating vents.
- When wood releases moisture the profile will shrink, disengaging the weather-stripping.
- Wood frames that have wet surfaces increase the potential for rot, mildew, and decay.
- Wood is a food source attracting termites, other insects, rodents, or wildlife.
- Applications to resist pest decay can be hazardous.
- Wood frames require greater frequency of painting due to low paint adhesion.
- Wood windows require greater maintenance than other window systems.

Characteristics of Window Systems

PVC (Vinyl) Windows

- PVC’s greatest weakness is its lack of structural strength.
- When exposed to heat or cold, its physical properties are greatly diminished.
- The thermoplastic resins are not stable, allowing out-gassing and ageing.
- High expansion/contraction rate can distort the frame and break down perimeter seals.
- Ultraviolet (UV) radiation can cause PVC to break down and deteriorate.
- PVC has a history of warping, shrinking, and cracking.

Aluminum Windows

- They have the poorest thermal performance.
- They will dent and deform on impact.
- They are susceptible to salt water corrosion and atmospheric pollution.
- Their expansion/contraction rate is threefold that of fiberglass.
- They are difficult to repaint on-site.

Characteristics of Fiberglass Window Systems

Fiberglass Windows

- Fiberglass is known as the "lifetime window"—a strong, dimensionally stable, inert material. None of the normal causes for breakdown or deterioration affect fiberglass.
    - Age or time has no effect on the material.
    - Exposure to heat or cold does not change its physical properties.
    - Wet or dry environments have no effect on the material.
    - It is unaffected by atmospheric pollution, salt or chemical corrosion.
- All of the above can significantly deteriorate the life of a window.
- The glass mat in pultrusion profiles distributes impact load to prevent surface damage.
- Fiberglass windows are easy to repaint by the homeowner.
- They are not susceptible to sweating or frost build-up that can wick moisture from the frame to drywall or masonry walls, causing plaster damage or paint failure.

Characteristics of Fiberglass Window Systems

Longevity

- In terms of performance and durability, fiberglass windows are overkill structurally for residential projects; however, overkill means built-in durability and longevity with minimum maintenance.
- For over 40 years, fiberglass boats, exposed to extreme climates and highly corrosive marine salt water environments, have proven their superiority over all other materials.
- Fiberglass is used for storage containers for acids, chemicals, and salt products and is impervious to environmental corrosive elements.

Acoustics

Acoustical Performance

In today's architectural environment, good acoustical design isn't a luxury—it's a necessity. Acoustics impact everything from employee productivity in office settings to the market value of apartments, condominiums, and single-family homes.

Windows have been classed as the weak acoustical link in a wall.

Glazing can account for a major improvement in sound abatement, which can be applied to any window system. The criteria that separates the various window systems is how the framing material is able to reduce the transmission of unwanted sound.

Sound Vibrations

Sound is vibration resonating through a mass. Aluminum and PVC are homogeneous materials that readily transfer sound through a wall. Fiberglass is made of bundles of glass fibers interspaced with resins and fillers of different densities. As sound waves vibrate alternately through changing densities, the sound vibrations are dampened.

An acoustical window requires larger glazing pockets to accommodate a larger overall sealed unit thickness. Fiberglass windows have the strength to accommodate the weight.

Air Leakage

Sound is a vibration that needs a medium in which to flow, and air is an excellent medium. Air leaks in a window assembly are a sound path for noise.

Laboratory test reports are based on products being tested at labs operating at an ambient temperature, 72˚F (22˚C), the temperature at which the product was cut and fabricated in the window plant. Temperature variances in the field will cause the window frames to expand or contract, creating a bowed profile and an inclusion, allowing for greater air transfer than shown in lab results. Fiberglass is less susceptible to temperature induced movement, and its lower airborne sound transmission will remain constant over its life span.

Where noise is a problem, fiberglass windows will reduce undesirable sound transmission.

Finish

Finish Performance

The factors that determine how well a paint finish performs in the field are the characteristics of the substrate that the finish is applied to.

- Does the material respond to changes in temperature by expanding and contracting?
- Does it respond to changes in moisture content in the air?
- Does it suffer from excessive heat gain?
- What is the effect of out-gassing? What will percolate through the coating?

If these questions are answered with a ‘yes’, there is the potential for the binding agents in the paint to break down, starting the oxidation process that leads to fading, chalking, or peeling of the finish.

A fiberglass substrate does not exhibit any of the above negative features.

Finish Options

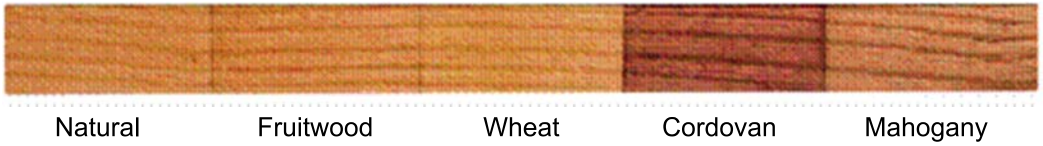
Pultruded fiberglass is factory painted prior to fabrication, normally with a two-part polyurethane enamel, and then oven cured.

Paint film thickness is a minimum of 100 to 200 microns (4 to 8 mils) wet film, which produces a dry film of 50 to 100 microns.

- The finish will have a typical hardness rating of "H".
- The paint has proven not to chip, scale, blister, caulk, or discolor under the most severe weather conditions, with gloss retention and minimal color fading.

Fiberglass manufacturers offer:

- unlimited choice of custom colors
- split finishes; exterior color can be different from the interior
- real wood laminated to a fiberglass substrate, and
- copper and brass foil laminations.



Paint Finishes

Fiberglass does not require a primer to aid adhesion. It is unaffected by the normal stresses that apply to binding agents in paint. This offers the flexibility to change the color of the windows as an easy do-it-yourself project, as the original paint finish acts as a primer once lightly sanded.

Standards for Coatings

To assure full compliance of the finish applied to fiberglass, windows should be tested to window industry finishing standards. AAMA (American Architectural Manufacturers Association), *Voluntary Specifications for Organic Coatings on Fiber-Reinforced Thermoset Profiles:*

- AAMA 623
- AAMA 624
- AAMA 625

These specifications define attributes such as: color and gloss uniformity; hardness; adhesion; direct impact; chemical, moisture, and temperature resistance; exposure, weathering, and aging resistance—with performances akin to paint finishes for the automotive industry which provide durability and longevity.

Organic paint pigments are prepared with natural ingredients and require less maintenance. They are stain resistant and easily washable. They are environmentally friendly and produce less smog and less greenhouse gas emissions than regular non-organic paints.

Finish Applications

Fiberglass's painted finishes, in both bright and dark colors, are specified for extreme project applications:

- in the heat of the desert in Arizona and Egypt
- in the extreme cold of the Arctic and Antarctica, and
- in the extremely corrosive environments of chemical plants and salt mines, and have shown excellent resistance to ultraviolet degradation, fading, discoloration, chalking, blistering or corrosion.

Building "Green"

Building “Green”

According to the U.S. Green Building Council, buildings account for 38% of the carbon dioxide emissions in the United States—more than either the transportation or industrial sectors. Buildings also consume 70% of the nation’s electricity load.

A Habitat for Humanity survey (August 2010) conducted by the NAHB Research Center (a subsidiary of the National Association of Home Builders) polled home builders, as well as consumers, and found the majority of respondents (64 percent) indicated that savings from green home features were sometimes worth the added costs and efforts. This finding was consistent across all income level groups for both renters and homeowners.

Manufacturers across many industries try to promote how green their products are. Fiberglass product manufacturers have no difficulty proving their sustainability claims.

Overview: LEED® Certification

The U.S. Green Building Council (USGBC) is a 501(c)(3) non profit organization composed of leaders from every sector of the building industry working to promote buildings and communities that are environmentally responsible, profitable and healthy places to live and work. USGBC developed the LEED (Leadership in Energy and Environmental Design) green building certification program, the nationally accepted benchmark for the design, construction, and operation of high performance green buildings.

LEED credit requirements cover the performance of materials in aggregate, not the performance of individual products or brands. Therefore, products that meet the LEED performance criteria can only contribute toward earning points needed for LEED certification; they cannot earn points individually toward LEED certification.

For detailed information about the council, their principles and programs, please visit www.usgbc.org.

The following slides outline *some* areas in which window systems can contribute to LEED credits earned on a building project.

LEED Certification

Fiberglass window systems were listed by BuildingGreen® as one of the top ten green products in 2007.

Fiberglass windows were installed in the first building to be awarded LEED® Platinum certification.

Philip Merrill Environmental Center, Annapolis, MD

Passive House

The first certified Passive House in Canada also received a LEED Platinum rating.

If you are not familiar with the Passive House movement, houses are designed and built so that they only use 15 kwh/m^2 of energy for heating and cooling and 120 kwh of electricity per month for lighting, appliances and other household uses.

The typical new home built in Ontario today uses about ten times the energy consumed by a Passive House.

Energy Efficiency

Energy

Buildings account for 40% of all energy used in the U.S. as well as almost 40% of all carbon emissions. Historically, windows and doors have been the poorest energy performers in a building, accounting for 25-30% of the building energy (heating and cooling) loss. Today's energy efficient ENERGY STAR® windows can be an "energy supplier" instead of an "energy loser," thus eliminating a lifetime of heating and cooling costs.

Environment

By selecting fiberglass as the most energy efficient windows, the owner will reduce his total heating and cooling cost. Any savings on energy helps the environment.

Fiberglass glass mats and rovings are made from silica sand, a naturally occurring material which is abundantly available.

ENERGY STAR

ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. ENERGY STAR distinguishes and promotes energy efficient products, above standard lower-efficiency systems, through third-party certification and labeling.

These products will pay back the owner in lower energy bills. When ENERGY STAR certified windows are specified and installed, grants or tax credits are available providing incentives to owners/architects.

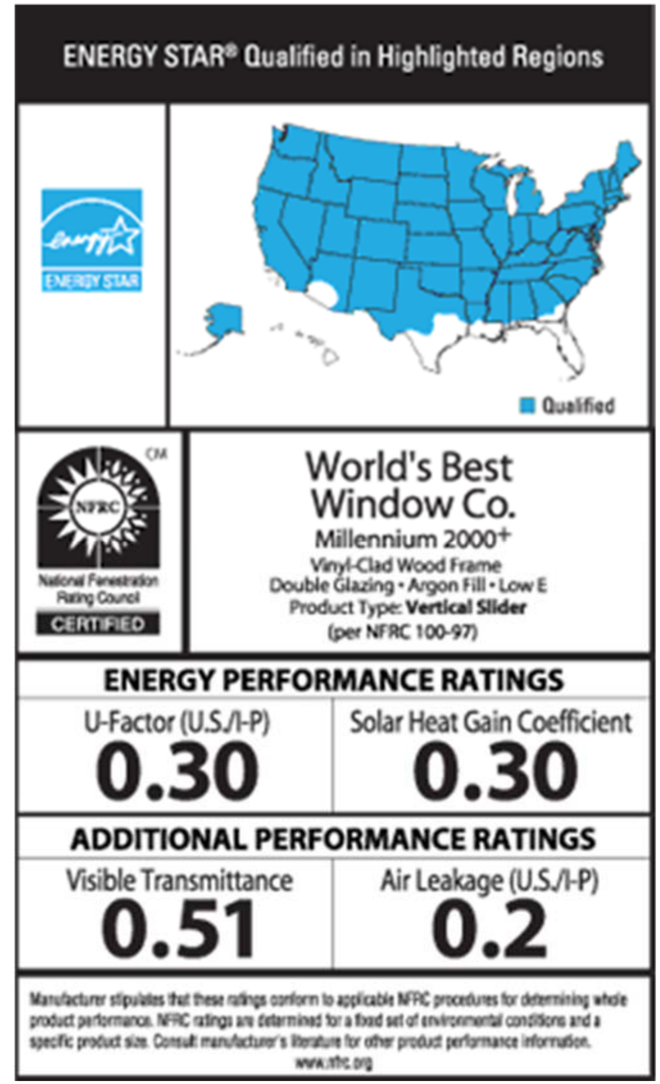
The qualification requirements will be tougher in phase two of the ENERGY STAR program. The goal, in order to obtain tax credits, is to differentiate quality windows by reducing the number of products qualifying to 25% of the current market share. (www.energystar.gov/index.cfm?c=windows_doors.pr_taxcredits)

ENERGY STAR

The ENERGY STAR label signifies improved thermal performance and a “greener environment,” but will also now stand for sustainability.

To qualify as an ENERGY STAR residential window, the product must meet a list of identified criteria, be tested by an authorized third-party testing agency and bear an ENERGY STAR label.

The label includes a map of the United States or Canada, showing the regions of the country and the minimum performance for that specific climate zone.



ENERGY STAR USA

The ENERGY STAR program for the United States divides the nation into four separate climate zones: Northern, North-Central, South-Central, and Southern.

The performance criteria that need to be met in order to be ENERGY STAR compliant in a specific climate zone (effective January 4, 2010) are shown in the chart to the right.

2010 ENERGY STAR Qualification Criteria for Windows

Climate Zones - U.S.	U-Factor	SHGC
Northern**	≤ 0.30	Any
Northern	= 0.31	≥ 0.35
Northern	= 0.32	≥ 0.40
North-Central	≤ 0.32	≤ 0.40
South-Central	≤ 0.35	≤ 0.30
Southern	≤ 0.60	≤ 0.27

**Northern zone windows can meet prescriptive (1^{st} row) or alternative energy performance (2^{nd} & 3^{rd} row) criteria to qualify for ENERGY STAR.

ENERGY STAR Canada

ENERGY STAR Canada has divided the nation into four climate zones.

Products comply for Canada’s ENERGY STAR program based on two paths: either their U-factor total, or their Energy Rating (ER). The Energy Rating (ER) number indicates the window’s thermal performance and the effect on an annual heating bill.

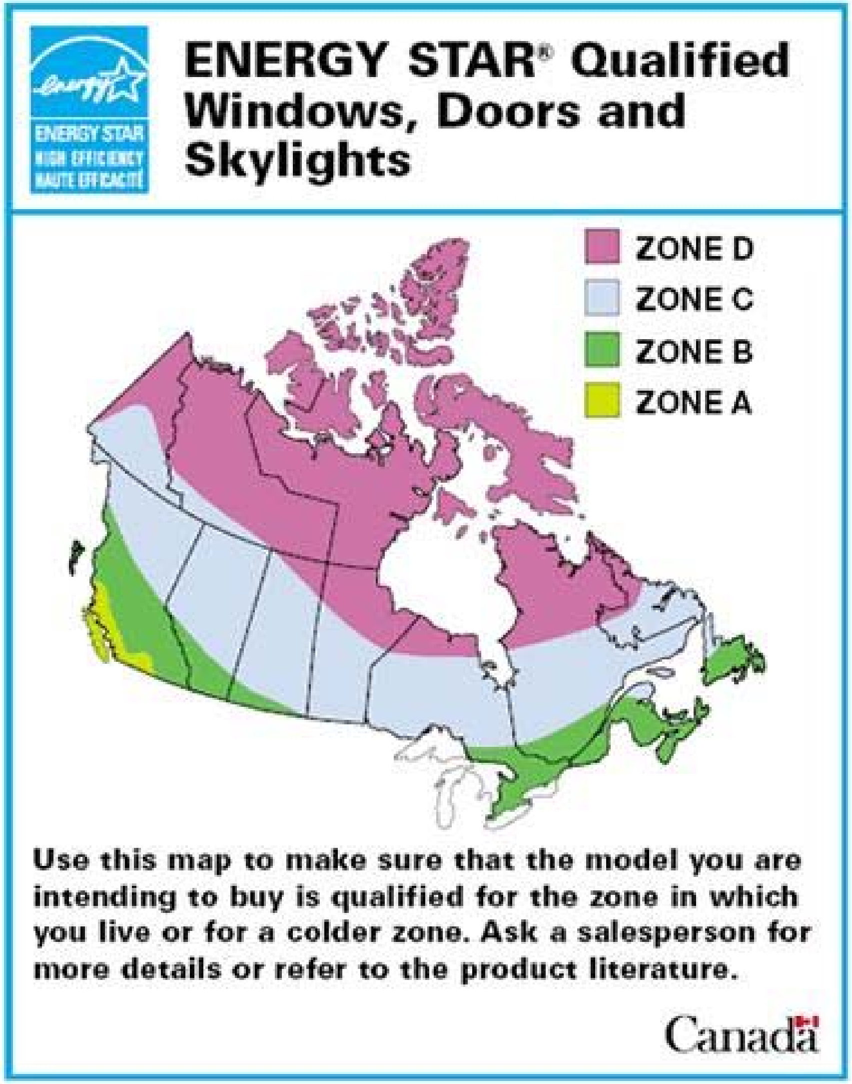
The ER is not a temperature rating; it is a scale of the comparative performance of the windows based on three factors:

- Solar heat gain
- Heat loss through frames, spacers and glass, and
- Air Leakage heat loss.

The lower the number, the more heat is lost and the higher the heating costs.

Fiberglass windows have consistently received the highest ratings of windows under Canada’s ENERGY STAR system, which is tougher than the U.S. ENERGY STAR system.

ENERGY STAR Canada



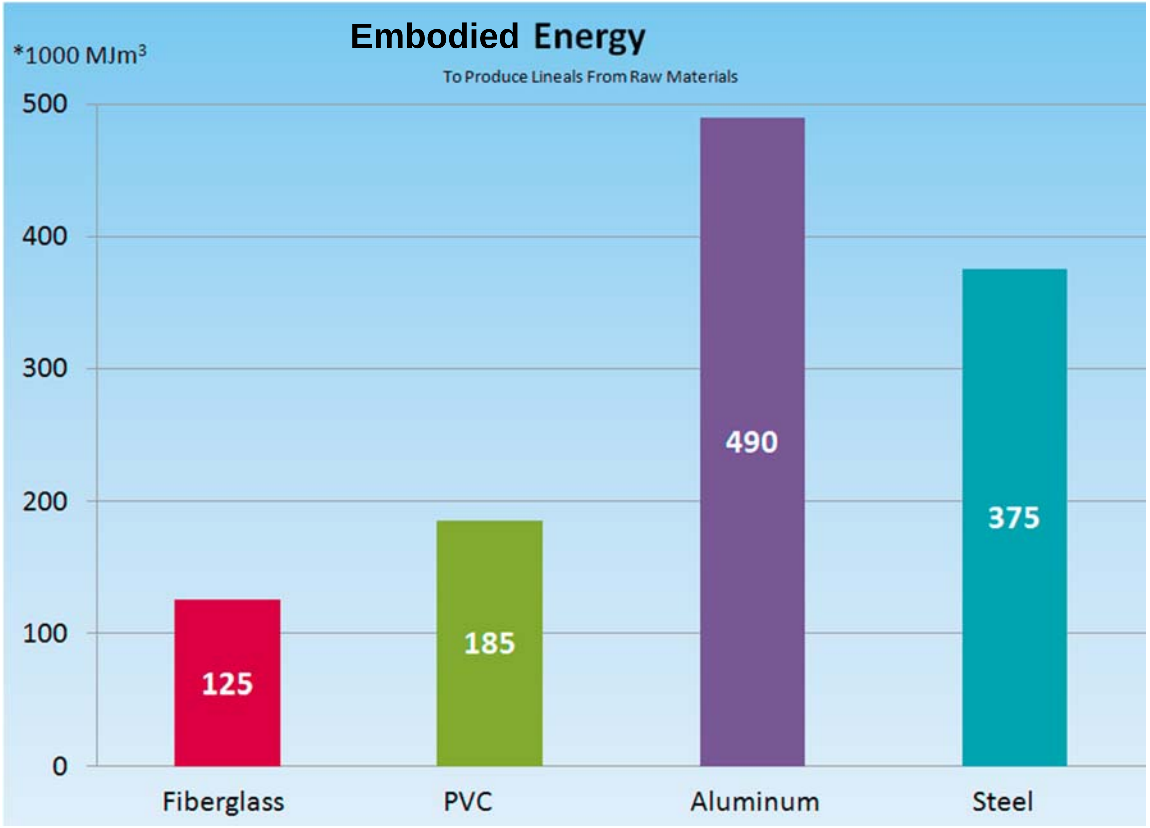
Energy Star – Canada Qualification Criteria

Compliance Paths			
Zone	Minimum Energy Rating		Maximum U-factor
A	21 (Max. U-factor 0.35)	or	< 0.32 (Min. ER = 13)
B	25 (Max. U-factor 0.35)	or	< 0.28 (Min. ER = 13)
C	29 (Max. U-factor 0.35)	or	< 0.25 (Min. ER = 13)
D	34 (Max. U-factor 0.35)	or	< 0.21 (Min. ER = 13)

Source: Natural Resources Canada. "ENERGY STAR® Qualified Windows, Doors and Skylights." http://oee.nrcan.gc.ca/residential/personal/windows-doors/buying.cfm Accessed November, 2011

Embodied Energy

Embodied energy is the non-renewable commercial energy (fossil fuels, etc.) that is used to extract and refine materials, and manufacture and transport the product during processing and use. Fiberglass pultrusions require about 75% less embodied energy than aluminum and 30% less than PVC.



Toxicity Issues

The current belief is that greenhouse gases trapped in the atmosphere are warming our planet. Greenhouse gases are a by-product of fossil fuels, carbon dioxide, and a whole range of gases including the chloride families.

Most of the vinyl chloride produced in North America is used to make polyvinyl chloride PVC, vinyl, and plastic. PVC is composed of chlorine, carbon, and hydrogen and its resin, of which chlorine accounts for 51% by weight. The production of PVC produces many poisonous pollutants such as hydrocarbons, dioxins, vinyl chloride, phthalates, and heavy metals. PVC emits both carbon monoxide and hydrogen chloride, a compound that is twice as toxic.

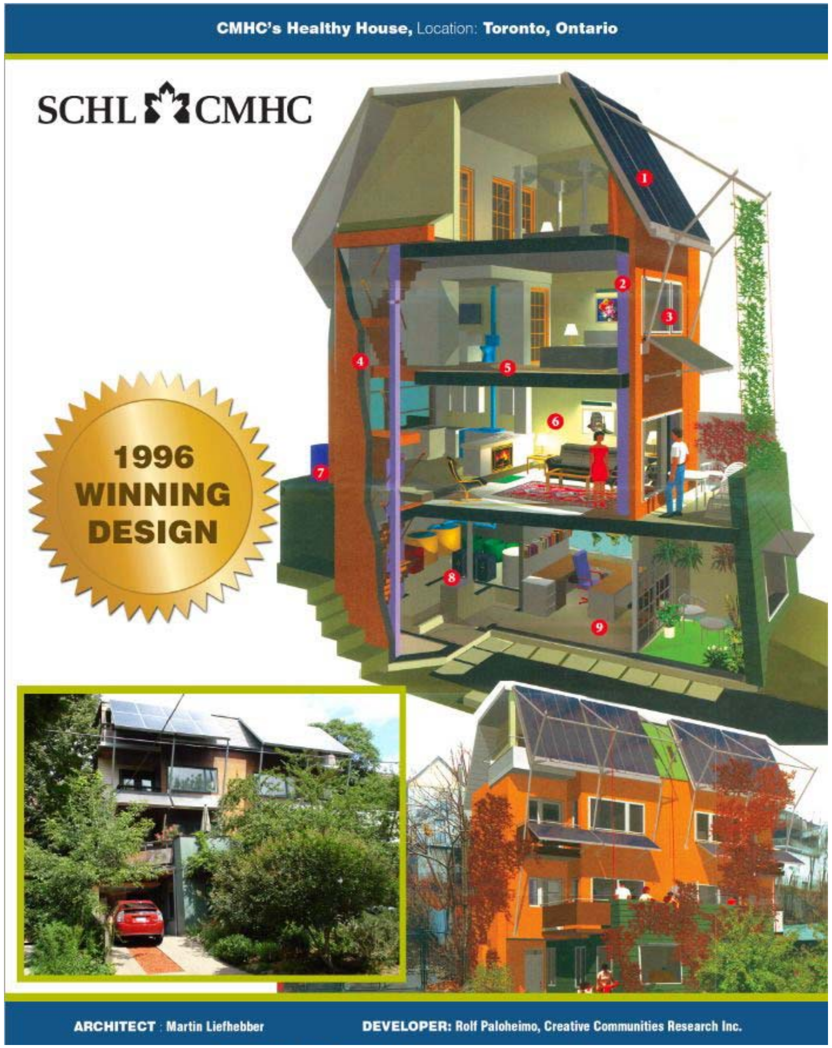
The U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSUR), ranks vinyl chloride as fourth in their list of the top twenty most hazardous substances—Substance Priority List (SPL).

Source: Agency for Toxic Substances and Disease Registry. "Priority List of Hazardous Substances". http://www.atsdr.cdc.gov/spl/ Accessed November, 2011.

Health

Building materials affect the health of occupants. Fiberglass windows were selected by “Healthy House” for occupants who are highly susceptible to or have chronic allergic reactions to materials. Healthy Housing™ projects are designed to promote reduction of chemical emissions and vapors that cause indoor pollution in the home.

Fiberglass was selected under criteria that vinyl and wood could not meet.



Health

There has been a 72% increase in children with asthma and a 62% increase for adults over the last few years. Many things can trigger symptoms, including allergens, pollen, mold, and smoke. Each year about 5,000 people die from the condition in the U.S. alone.

Approximately 10-15% of building occupants react to mold; of that total, 10-15% can have a major reaction. Beyond triggering asthma, it can cause a flu-like feeling, nausea, persistent cough, headaches, and fatigue. Mold is the major cause of chronic sinus infections.

Fiberglass windows will contribute to better indoor air quality:

- Tight fitting windows control air exchanges, reducing entry of pollutants and pollen.
- They provide condensation resistance and water leakage resistance that avoid the potential of mold growth within the walls.

Environmental Issues

Longevity

A product's longevity is an important issue when calculating embodied energy. If the product fails prematurely, it negates any greenhouse gas reductions, with the increased carbon footprint created in the process of making a replacement sash or window, packaging it, and transporting it back to the installation site.

Recycled Fiberglass

Most fiberglass pultruders use raw materials that have recycled content. Currently, there is an insufficient volume of fiberglass scrap to warrant large scale recycling.

The life expectancy of a fiberglass window is estimated at greater than 40 years, which exceeds all the other traditional window materials; this means there are no old fiberglass windows being replaced

Energy Issues

The U.S. Green Building Council (USGBC), American Institute of Architects (AIA), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the U.S. Department of Energy (DOE) have set a goal of making carbon-neutral buildings a reality by 2030. This means no energy consumed from external power grids.

Only recently, windows were the poorest energy efficient component of the exterior of a building. They can NOW be net energy providers, not consumers of energy.

When fiberglass windows are designed and specified into projects, the results are buildings that:

- are energy efficient
- do not have a negative impact upon the environment
- reduce the nation’s energy demand
- provide operating cost savings to the owners, and
- improve the comfort level of occupants.

Fiberglass has the lowest environmental impact of any window framing material.

Fabrication

Designing a Fiberglass Window

- Wall thickness of 0.090" should be used for the sash and frame profiles. For smaller, simpler, non-structural shapes, a 0.070" wall thickness can be used.
- Avoid sharp external radii—minimum radii of 0.030" R to 0.060" R.
- For greater strength, internal radii should be in the range of 0.060" to 0.090".
- Screw bosses should be recessed, not projected.
- Mitered corners with two or three dimensional mechanical corners are desirable. Corners should be designed to give the fiberglass support in two or three directions.
- Backer plates should be considered to spread the load.
- Fiberglass profiles can be open-back with a single wall design providing only one thermal bridge.
- Foam injection, laser cut styrofoam or loose fiberglass insulation can be easily and inexpensively applied to increase thermal values.

Assembly

The fabrication of fiberglass windows is the same as making aluminum windows: sawing, routing, drilling, and punching. The exceptions being:

- Diamond saw blades, router and drill bits must be used to prolong the life of the blades, where carbide tools can be used on aluminum or PVC, and
- Both cutting and routing of fiberglass creates dust. This dust is non-carcinogenic and is considered a nuisance dust. A dust extraction system is required at all stations, similar to a wood fabrication plant.

Assembly

- Fiberglass cannot be welded, but it can be chemically bonded.
- Assembly is by mechanical fasteners with reinforced polymer corner brackets (shear blocks), installed deep within the profile. Prior to fastening the profiles, cut faces are buttered with silicone or other suitable joint sealers and the corners are foam sealed. Screw retention is tested at 400 lb. pull.

Assembly

- Fiberglass profiles are pultruded to considerably tighter tolerances than PVC, and this combined with superior dimensional stability of cross sections, means the profiles fit the fabricator's jigs and fixtures consistently better than PVC, which speeds up processing.
- Compared to an aluminum window which has three components—a thermal barrier plus and inner and outer frame profile—fiberglass window frames consist of a single profile. This means reduced inventory, storage space, handling and process labor to assemble and seal joints against air and water.
- Pultruded fiberglass can be field fabricated using simple carpentry tools.

Fiberglass windows have one single limitation:

- As fiberglass once pultruded is irreversible, in that heat or force will not change its shape, fabricators are unable to reform profiles to produce round top or curved windows. This may be overcome by substituting that profile with a molded fiberglass profile round top.

Installation

Installation Considerations

Fiberglass windows normally are sold as custom ordered specific sizes to within $\frac{1}{16}$". The rumor is that custom sizes are more expensive than standard sizes, but this is not necessarily true:

- Standard sizes have inventory costs that a custom size supplier does not have.
- The advantage of accepting standard sizes is faster delivery lead time.
- Standard sizes may require extra interior and exterior trim to fit a standard size window into a non-standard opening, which increases labor and material costs.

The two main ways to secure the windows into a prepared opening are by:

- factory supplied strap anchors, and
- screwing through the jambs into wood blocking.

A third common option is the use of nailing fins. Although this method offers speed of installation, problems may develop later:

- if insufficient anchorage or blocking is used; then the nailing fin is carrying the total weight of the window, and
- a nailing fin adds an additional seam for potential air and water penetration.

Ease of Installation

Fiberglass windows are quick and easy to install:

- Windows come from the manufacturer pre-glazed and pre-finished, which provides the end-user with the security of a single source warranty.

Fiberglass windows maintain their shape, with solid 90-degree corners, which speeds up installation. A check for level on the sill means the jambs and mullions will also be perpendicular, without bowing at the meeting rail.

Pultruded fiberglass lineal's weight is 0.062 lb./cu inch, which is typically:

- ⅔ the weight of aluminum.
- ½ the weight of vinyl, and.
- ¼ the weight of steel.

Being lightweight, fiberglass is easier to handle and maneuver during erection and installation, with reduced shipping costs.

Ease of Installation

Fiberglass window and door frames are stiff and rigid:

- They do not sag when being installed.
- The corners stay at 90° without racking like PVC windows do.
- The windows and doors are faster and easier to install, thus reducing the installation cost for both the owner and installation contractor.

Fiberglass frames are less susceptible to distortion by over-tightening the fasteners. Fiberglass will resist over-tightening, whereas over-tightening will deform PVC.

Because fiberglass's rate of expansion is so low, the window opening can be designed with smaller clearance allowance for expansion/contraction, resulting in:

- smaller, tighter caulk joints to seal the interface between the window and the wall
- lower potential of critical interface seal deteriorating over the life of the window installation
- the installers applying a small, neat sealing joint with ease, and
- more professional and aesthetically pleasing seals.

Installation Standards

A fiberglass window that's been damaged (shattered or has large holes drilled in it) can be effectively repaired on-site using fiberglass repair kits available from local hardware stores. The damage is sanded, fiberglass patched, sanded again, and repainted. The result is an invisible patch. This cannot be done with aluminum or PVC.

The industry standards which cover the installation of fenestration products into a wall construction and subject the installation systems to a variety of quality performance tests are:

- AAMA 504 - *Voluntary Laboratory Test Method to Qualify Fenestration Installation Procedures*
- AAMA IPBC-08 - *Standard Practice for Installation of Windows and Doors in Commercial Buildings*
- ASTM E2112 - *Standard Practice for Installation of Exterior Windows, Doors and Skylights*
- CSA A440.4 - *Window, Door, and Skylight Installation*

Economics

Material Costs

When fiberglass windows were first introduced, they were considerably more expensive than wood, PVC, or aluminum windows, even though the raw materials, mining and processing, and the embodied energy, were all less expensive than traditional windows.

Slow pultrusion speeds, which produced small yields, made fiberglass windows costly. As with any new technology, there have been considerable improvements which have increased the pultrusion speeds.

Fiberglass windows are now competitively priced, and forecasts predict future cost reductions. Silica sand is abundant and not in great demand, whereas the costs of the traditional window material are expected to increase substantially.

- Wood - The availability of first growth premium wood is becoming scarce.
- PVC - Costs are rising with the price of petroleum.
- Aluminum - Costs will rise with higher energy costs to process bauxite.

Cost Considerations

Windows are the single most expensive item in a new construction home. But greater than the initial capital cost will be the ongoing operating costs over the lifetime of the windows.

Historically, windows and doors have been the poorest energy performers in a building.

By minimizing heat loss through air leakage and conduction, and taking advantage of solar heat gain, windows can have a net energy gain, providing the owner with substantial energy savings.

Where solar heat gain is implemented into a building design, the larger the opening (glass area), the more significant the savings will be. The strength of fiberglass window frames allows for larger openings.

Windows As An Investment

Using fiberglass frames with a lower U-value over traditional materials may allow the designer to use lower performance (lower cost) glass and still meet NFRC's Energy Rating.

The choice of fiberglass windows and doors is a sound investment in personal satisfaction and comfort, as well as proven payback analysis. Dividing the energy savings per year into the incremental cost of the windows shows fiberglass windows provide the shortest payback period.

Consumers are more knowledgeable and will expect more quality when they purchase, focusing on energy (payback period and comfort), durability, longevity, and aesthetics.

Energy efficient windows are an investment for owners upon resale time. *Remodeling* magazine's "Cost vs. Value Report" states that homeowners can expect to recoup 74% of the cost incurred by replacing their windows and doors. When quality windows are installed, the home is more marketable, with a higher return.

Purchasing Criteria

When consumer purchases are based on low price, assume minimum performance and longevity, which means paying a high life cycle cost. Service calls after sale defects are an aggravation to the window manufacturer, dealer/distributor, as well as the end-user.

An important part of the cost equation is the longevity of the window. The life expectancy for fiberglass windows will exceed all other traditional windows.

The purchasing criteria over the last years have prompted window manufacturers to design their products to reduce their costs, by reducing quality. There will always be someone who can produce something cheaper.

But there is a growing niche market among buyers who want quality, performance, aesthetics, and durability, which is fiberglass's niche.

Purchasing Criteria

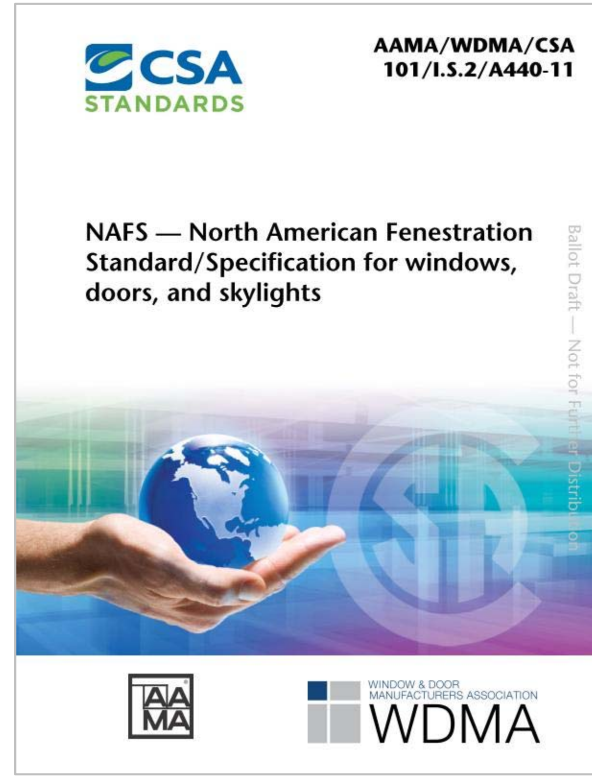
An upfront investment of 2% in green building design, on average, results in life cycle savings of 20% of the total construction costs—more than ten times the initial investment.

Fiberglass windows can easily prove their performance superiority, and they are competitively priced now. Fiberglass manufacturers have a goal to price their product within the price range of low-end residential windows, while providing a product meeting commercial performance levels.

The life cycle cost justifies specifying fiberglass windows. Today's energy efficient, high-tech windows can be "energy suppliers" instead of "energy losers."

Standards, Specifications, Testing

North American Fenestration Standard



All window salesmen will say their products are the best on the market and in most cases, with no supporting documentation.

To counter this, industry standards were developed to quantify and substantiate the minimum requirements and performances.

NAFS (North American Fenestration Standard) is the harmonized USA/Canada/Mexico Standard, produced by:

- American Architectural Manufacturers Association (AAMA)
- Window & Door Manufacturers Association (WDMA)
- Canadian Window & Door Manufacturers Association (CWDMA), and
- Canadian Standards Association (CSA).

This Standard is referenced by building codes, ENERGY STAR, and the National Fenestration Rating Council.

AAMA Industry Standards

- AAMA/WDMA/CSA 101/I.S.2/A440 – *Standard/Specification for Windows, Doors and Skylights:* Covers all requirements of windows: types of windows, classifications, design, performance requirements, test procedures, materials, components.

- AAMA 305 – *Voluntary Specification for Fiber Reinforced Thermoset Profiles:* Covers the design criteria, materials and components, finishing requirements, test requirements, and physical properties.

- AAMA 502 – *Voluntary Specification for Field Testing of Newly Installed Fenestration Products:* Covers the site testing of an installed window to confirm the window was installed to meet project specifications and building code requirements.

Performance Classes

AAMA/WDMA/CSA 101/I.S.2 Performance Classes (U.S.):

Windows are grouped into four categories:

- R - Residential
- LC - Low-rise and mid-rise multi-family dwellings and other buildings where larger sizes and higher loading requirements are expected.
- CW - Similar to "LC" but for applications where heavy use is expected—includes mullion deflection requirements.
- AW - Used in high-rise and mid-rise buildings to meet increased loading requirements.

In Canada:

Windows are grouped into only two categories:

- Residential:
    - for a single-family home
    - not exceeding three floors in building height, and
    - less than 600 square meters (6460 square feet).
- All other buildings

Performance Grades

AAMA Performance Grades (Design Pressure):

The primary performance of a window, from code requirements, is the structural strength or "wind load resistance" that a window must meet to resist the historic climate in which the window will be installed. This is known as the "design pressure" for the building and applies to the total building envelope.

Historic climatic information may be found at:

USA - SEI/ASCE 7-05 - *Minimum Design Loads for Buildings and Other Structures*

Canada - CSA A440.1-00 - *User Selection Guide to CSA Standard A440-00, Windows*

Both reference documents provide historic wind load at 30 ft. (10 meters) for the location of the project and calculations for wind speeds based on the height of building and occupancy.

Minimum Design Load for U.S.

Basic Wind Speeds for Occupancy Category II Buildings and Other Structures

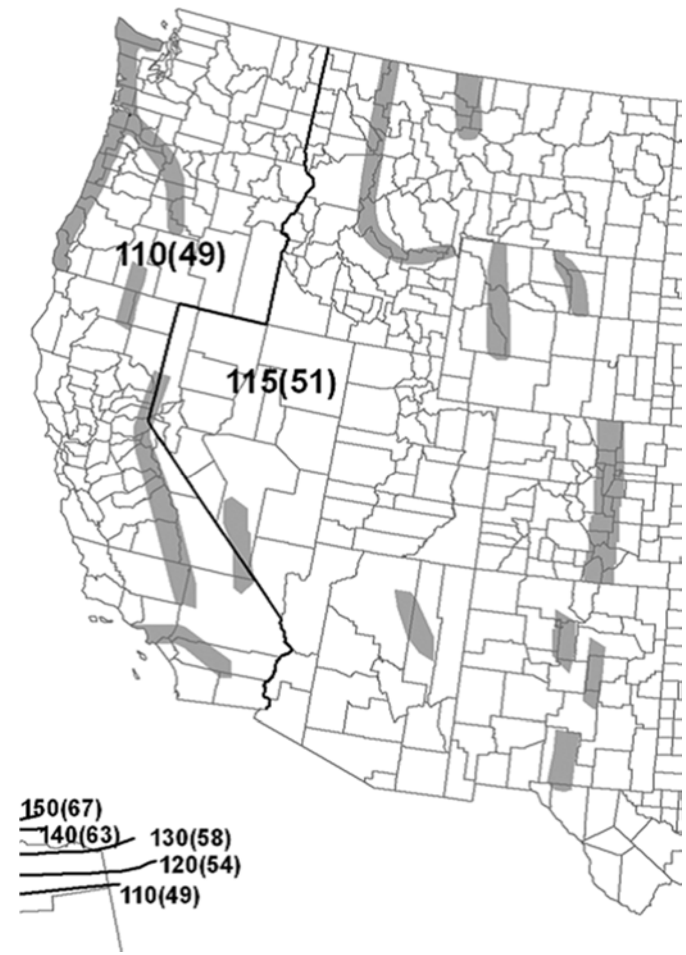
1. Values are nominal design 3-second gust wind speeds in miles per hour at 33 ft. (10 m) above ground for Exposure C category.

2. Linear interpolation between contours is permitted.

3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.

4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

5. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedence Probability = 0.00143, MRI = 700 Years).

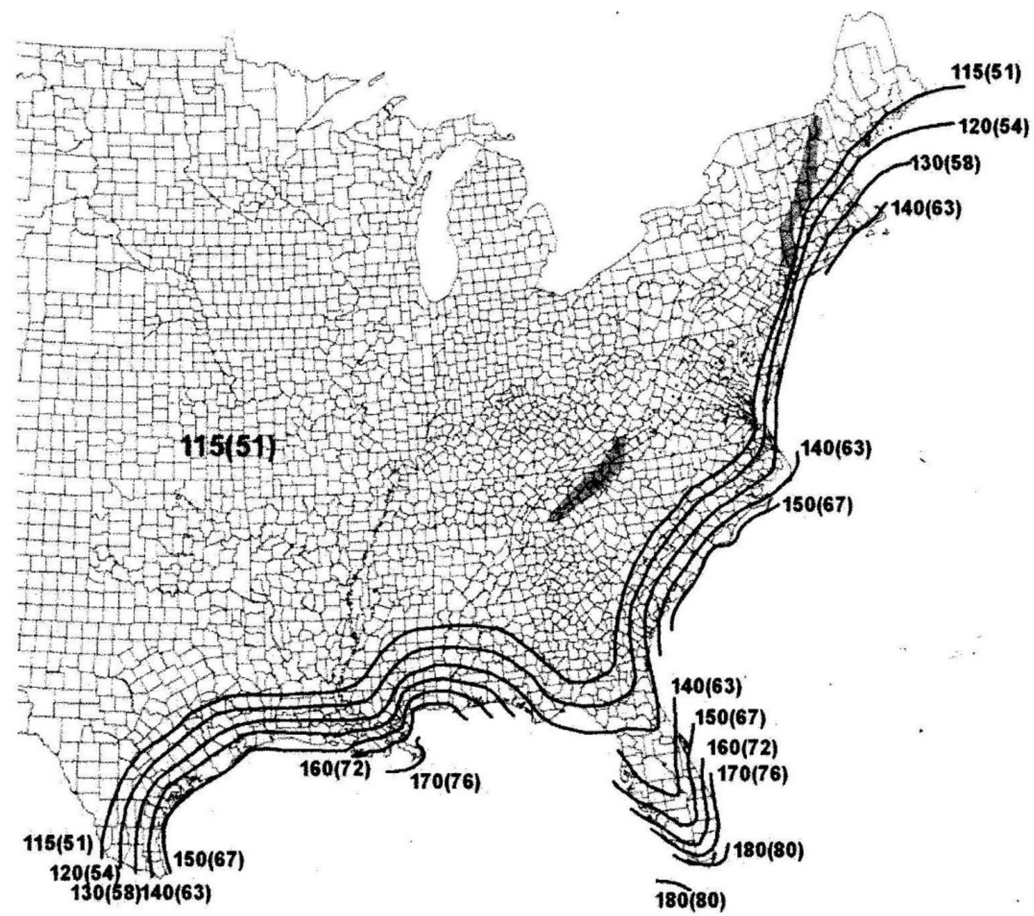


Recommended Performance Levels

It is important that specifiers realize that standards and building codes are not the recommended performance levels, but are written to define the minimum requirements.

It is the responsibility of the architect or owners to assure the performance and requirements are fully specified in the project documents to exceed the minimum resistance to the climate for the location in which the product will be installed.

Due to climate change, with increasing frequency and violence of weather patterns over the last years, historic weather data may be out-of-date and lower than actual conditions.



AAMA Air Leakage Resistance

AAMA Industry Standards require the design and testing of air infiltration only under a positive test pressure. The specifier should also include negative test pressure in project specifications, to simulate air exfiltration. Many windows test well for air infiltration, but test poorly for exfiltration. Exfiltration measures the air leaking out of the building that will require replacement with outside air and the energy to reheat or cool.

Low air leakage has many advantages and selling benefits. Beyond the obvious energy efficiency and comfort:

- air infiltration brings in airborne sound transmission (noisier interiors)
- reduced dust entry from exterior means reduced housekeeping, and
- low air leakage reduces pollen and pollution entry.

AAMA Air Leakage Resistance

Specifiers should be aware that windows are lab tested and reported by manufacturers for air tightness at room temperature on both sides of the window. In reality, when windows are tested on-site there is a temperature difference between interior and exterior. Some windows, although well weather-stripped, exhibited substantial air leakage. This air leakage occurred because the cold outside face of the sash contracted while the interior warm surface expanded, causing the sash to bow at the top and bottom corners—in turn causing the weather-stripped joint between the sash and frame to open and air to enter.

Canadian code requires manufacturers to test both air infiltration and exfiltration. Some window designs test well under positive pressure (air infiltration) but may test poorly for exfiltration (e.g. positive pressure against a casement, awning window blows sash closed, where a negative pressure opens the seal sash to frame).

Fiberglass windows typically show air leakage test reports at < 0.1 cfm (for both infiltration and exfiltration), which is ⅓ the air changes of AAMA Industry Standards.

AAMA Air Leakage Resistance

Heating and cooling specialists base their recommendation for the heating and air conditioning equipment required for a building on the thermal efficiency of the walls, the number of windows, and their estimate of air changes of the windows.

Proper testing is critical to ensure the installation of the proper equipment. Underestimating air changes results in insufficient heating and cooling of the building. Overestimating means over-designing the system with higher capital and operating cost.

AAMA Water Leakage Resistance

Water infiltraton is the number one enemy in construction today. The effects of water penetration include the easily recognizable deterioration of the structure to the harder to detect, and in some cases more critical situation, of mold development.

AAMA Water Resistance Testing requires:

- Classes R, LC, and CW, at 15% of design pressure
- Class AW at 20% of design pressure

AAMA Standards require testing to resist a “tear-drop” of water leakage under test pressure to match the project’s design pressure climatic location, while being pummeled with the equivalent of 8" of water per hour.

The most frequent failure of windows resulting in litigation between window suppliers and owner is water penetration through the window or the perimeter installation, causing deterioration to walls. It is recommended that your project be tested on-site, during or immediately after installation, for both air and water resistance, to protect the owner and building against this common failure.

AAMA Structural Performance (Wind Load Resistance)

There are two structural test requirements to determine suitability to meet climate and anticipated wind.

Uniform Structural Load (Blow-out)

This tests the total window at 150% of design pressure (50% built-in safety factor), and reported at the highest level that the window passed, prior to destruction.

Destruction is any components that fail, disengage or permanently deform, or malfunction.

A pass at this level only defines that this is the failure point of the window or the lowest quality performance to meet building code for a specific building's historic climate, location, and height of building. Since building codes are based on minimum requirements, not the recommended performance, the purchasers must insure that the tested failure point is not a bare pass, but has a safety margin exceeding the lab test.

AAMA Structural Performance (Wind Load Resistance)

Deflection at Design Pressure of Sash and Mullions

Testing is at design pressure, where L is the length of the unsupported span.

U.S. Requirement:

- Mid-rise and high-rise buildings only, require that no member shall:
    - deflect more than L/175 of its span.
    - Permanent deformation shall be limited to:
        - Class R and LC - 4%
        - Class CW - 3%
        - Class AW - 2%

Canadian Requirement:

- Sash members shall not deflect more than 1/125 of their length, and
- Mullions shall not deflect more than L/l75 of their length.

PVC windows normally are unable to meet a deflection limit of L/175 unless the profiles are reinforced.

AAMA Certification Program

The AAMA Certification Program (a volunteer program) is the original third-party window performance verification program and has provided manufacturers with the means to independently demonstrate product performance quality to their customers.

The program requires unannounced random visits to the window manufacturer's plant. The purpose of the visits is to confirm there have been no changes in design, material, or process, as compared to the windows previously submitted for testing, which form the manufacturer's advertised performance claims.

Although currently a volunteer program, it is being specified more frequently in government project documents, which have the tendency to become mandatory if manufacturers wish to be considered for their projects.

★ Please remember the **exam password SOLAR**. You will be required to enter it in order to proceed with the on-line examination.

National Fenestration Council (NFRC)

NFRC provides the procedure for determining, certifying and labeling the following window performances.

U-factor

U-factor measures how well a product prevents heat from escaping.

The lower the U-value, the greater a window's resistance to heat flow and the better its insulating value.

Solar Heat Gain Coefficient (SHGC)

Measures how well a product blocks heat from the sun. The SHGC is the fraction of incident solar radiation admitted through a window (both directly transmitted and absorbed) and subsequently released inward. The lower a window's solar heat gain coefficient, the less solar heat it transmits into the building.

National Fenestration Council (NFRC)

Visible Light Transmission (VLT)

Visible transmittance (VT) measures how much light comes through a product. The visible transmittance is an optical property that indicates the amount of visible light transmitted. The higher the VT, the greater light is transmitted.

Condensation Resistance

Condensation resistance (CR) measures the ability of a product to resist the formation of condensation on the interior surface of that product. The higher the CR rating, the better that product is at resisting condensation formation.

Both AAMA and NFRC Standards can be used as rankings to compare one window against another, under all criteria, backed up through independent testing lab reports.

If one carefully compares all the measurable performances of a window, it is obvious that fiberglass windows outperform vinyl, wood and aluminum window systems.

Summary

Summary

Qualities	Fiberglass	PVC	Wood	Aluminum
Thermal Performance	Excellent	Excellent	Excellent	Poor
Structural Strength	Excellent	Poor	Good	Excellent
Dimensional Stability	Excellent	Poor	Good	Good
Impact Resistance	Excellent	Poor	Poor	Good
Climate Durability	Excellent	Poor	Good	Excellent
Durability	Excellent	Good	Good	Excellent
Longevity	Excellent	Poor	Good	Excellent
Paintable	Excellent	Poor	Good	Excellent
Dark Colors	Excellent	Poor	Good	Excellent
Acoustics	Excellent	Good	Good	Good
Low Maintenance	Excellent	Excellent	Poor	Excellent
Strength-to-Weight Ratio	Excellent	Poor	Good	Excellent
Tolerances	Excellent	Poor	Good	Excellent
Corrosion Resistant	Excellent	Excellent	Excellent	Poor
Condensation Resistant	Excellent	Excellent	Excellent	Poor

Project Photos

Residential

Private Residence, Toronto, ON

Private Residence, Uxbridge, ON

Sportun-Woodbury Project, Haliburton, ON

Private Residence, Toronto, ON

Sustainable

Wilson House, Mono Mills, ON

Private Residence, Lake Ontario, ON

Camp Kawartha Environmental Centre, Peterborough, ON

Sustainable Building by Fleming College, Haliburton, ON

LEED

The Evergreen Brick Works in the Don Valley, Toronto, ON

City of Hamilton Environmental Laboratory, Hamilton, ON

LEED

Sisters of Saint Joseph - New Residence, London, ON

Waterloo North Hydro, Waterloo, ON

Rideau Residences - Passive House Certified, LEED for Homes Platinum Certification, Ottawa, ON

High-Rise

Madison Condo, Hamilton, ON

Toronto Community House, Toronto, ON

Ambleside One, Ottawa, ON

World Trade Center, Toronto, ON

Hotels

Marriot Courtyard, Mississauga, ON

Delta Hotel, Guelph, ON

Schools

St. Christopher Catholic Elementary School, Windsor, ON

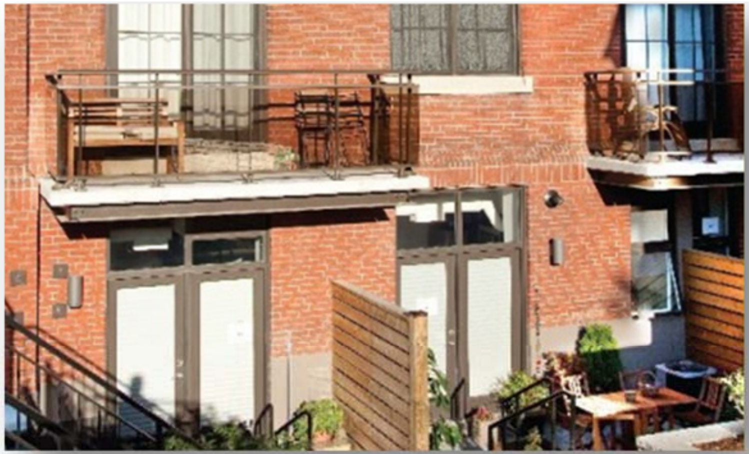
St. Marguerite D'Youville Catholic School, Richmond Hill, ON

Dr. David Suzuki Public School, Windsor, ON

Christ the King Catholic Secondary School, Georgetown, ON

Retrofit / Conversions

Estonia House, Toronto, ON



Victoria Lofts, Toronto, ON

Now House™ Retrofit Project

Green Phoenix, Toronto, ON

Institutional

Tom Taylor Place, Newmarket, ON

Wilfred Laurier University, Brantford, ON

Six Nations Police Building, Ohsweken, ON

Mnjikaning First Nation, Rama, ON

References and Resources

All references were accessed December, 2011.

- AAMA Commercial Installation Reference Manual. http://www.aamanet.org/
- AAMA WSG-11, "Window and Door Selection Guide." http://www.aamanet.org/ (USA)
- Agency for Toxic Substances and Disease Registry. "Priority List of Hazardous Substances." http://www.atsdr.cdc.gov/spl/
- CSA Standards - CSA A440.1, "User Selection Guide." http://shop.csa.ca/ (Canada)
- Dulley, James. "Fiberglass Replacement Windows Are Efficient, Maintenance-free." http://www.dulley.com/docs4/926.htm
- ENERGY STAR. www.energystar.gov/index.cfm?c=windows_doors.pr_taxcredits

References and Resources

- Greenpeace USA. http://www.greenpeaceusa.org
- Hefland, Judith and Daniel Gold. *Blue Vinyl*. Documentary, 2002. www.bluevinyl.org
- My House is Your House. (consumer education and advocacy group) http://myhouseisyourhouse.org
- Natural Resources Canada. "ENERGY STAR® Qualified Windows, Doors and Skylights." http://oee.nrcan.gc.ca/residential/personal/windows-doors/buying.cfm
- U.S. Department of Energy. http://energy.gov/
- U.S. Green Building Council. www.usgbc.org

Conclusion

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