National Fenestration Rating Council Incorporated

NFRC 101-2010[E3A20]

Procedure for Determining Thermophysical Properties of Materials For Use in NFRC-Approved Software Programs

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FOREWORD

The National Fenestration Rating Council, Incorporated (NFRC) develops and operates a uniform rating system for energy and energy-related performance of fenestration and fenestration attachment products. The Rating System determines the U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT) of a product, which are mandatory ratings for labeling NFRC-certified products, and are mandatory ratings for inclusion on label certificates, and are supplemented by procedures for voluntary ratings of products for Air Leakage (AL) and Condensation Resistance. Together these rating procedures, as set forth in documents published by NFRC, are known as the NFRC Rating System.

The NFRC Rating System employs computer simulation and physical testing by NFRC-accredited laboratories to establish energy and related performance ratings for fenestration and fenestration attachment product types. The NFRC Rating System is reinforced by a certification program under which NFRC-licensed responsible parties claiming NFRC product certification shall label and certify fenestration and fenestration attachment products to indicate those energy and related performance ratings, provided the ratings are authorized for certification by an NFRC-licensed Certification and Inspection Agency (IA).

The requirements of the rating, certification, and labeling programs (Certification Programs) are set forth in the most recent versions of the following as amended, updated, or interpreted from time to time:

- NFRC 700 Product Certification Program (PCP)
- NFRC 705 Component Modeling Approach (CMA) Product Certification Program (CMA-PCP)

and through the Certification Programs and the most recent versions of its companion programs as amended, updated, or interpreted from time to time:

- The laboratory accreditation program (Accreditation Program), as set forth in the NFRC 701 Laboratory Accreditation Program (LAP)
- The IA licensing program (IA Program), as set forth in NFRC 702 Certification Agency Program (CAP)
- The CMA Approved Calculation Entity (ACE) licensing program (ACE Program) as set forth in the NFRC 708 Calculation Entity Approval Program (CEAP)

NFRC intends to ensure the integrity and uniformity of NFRC ratings, certification, and

labeling by ensuring that responsible parties, testing and simulation laboratories, and IAs adhere to strict NFRC requirements.

In order to participate in the Certification Programs, a Manufacturer/Responsible Party shall rate a product whose energy and energy-related performance characteristics are to be certified in accordance with mandatory NFRC rating procedures. At present, a Manufacturer/Responsible Party may elect to rate products for U-factor, SHGC, VT, AL, condensation resistance, or any other procedure adopted by NFRC, and to include those ratings on the NFRC temporary label affixed to its products or on the NFRC Label Certificate. U-factor, SHGC and VT, AL, and condensation resistance rating reports shall be obtained from a laboratory that has been accredited by NFRC in accordance with the requirements of the NFRC 701.

The rating shall then be reviewed by an IA that has been licensed by NFRC in accordance with the requirements of the NFRC 702. NFRC-licensed IAs review label format and content, conduct in-plant inspections for quality assurance in accordance with the requirements of the NFRC 702, and issue a product Certification Authorization Report (CAR) and may approve for issuance an NFRC Label Certificate for site-built or CMA products and attachment products. The IA is also responsible for the investigation of potential violations (prohibited activities) as set forth in the NFRC 707 Compliance and Monitoring Program (CAMP).

Products that are labeled with the NFRC Temporary and Permanent Label, or products that are listed on an NFRC Label Certificate in accordance with NFRC requirements, are considered to be NFRC-certified. NFRC maintains a Certified Products Directory (CPD), listing product lines and individual products selected by the Manufacturer/Responsible Party for which certification authorization has been granted.

NFRC manages the Rating System and regulates the PCP, LAP, and CAP in accordance with the NFRC 700 (PCP), the NFRC 701 (LAP), the NFRC 702 (CAP), the NFRC 705 (CMA-PCP), and the NFRC 708 (CEAP) procedures, and conducts compliance activities under all these programs as well as the NFRC 707 (CAMP). NFRC continues to develop the Rating System and each of the programs.

NFRC owns all rights in and to each of the NFRC 700, NFRC 701, NFRC 702, NFRC 705, NFRC 707, NFRC 708 and each procedure, which is a component of the Rating System, as well as each of its registration marks, trade names, and other intellectual property.

The structure of the NFRC programs and relationships among participants are shown in Figure 1, Figure 2, and Figure 3. For additional information on the roles of the IAs and laboratories and operation of the IA Program and Accreditation Program, see the NFRC 700 (PCP), NFRC 701 (LAP), and NFRC 702 (CAP) respectively.

Figure 1

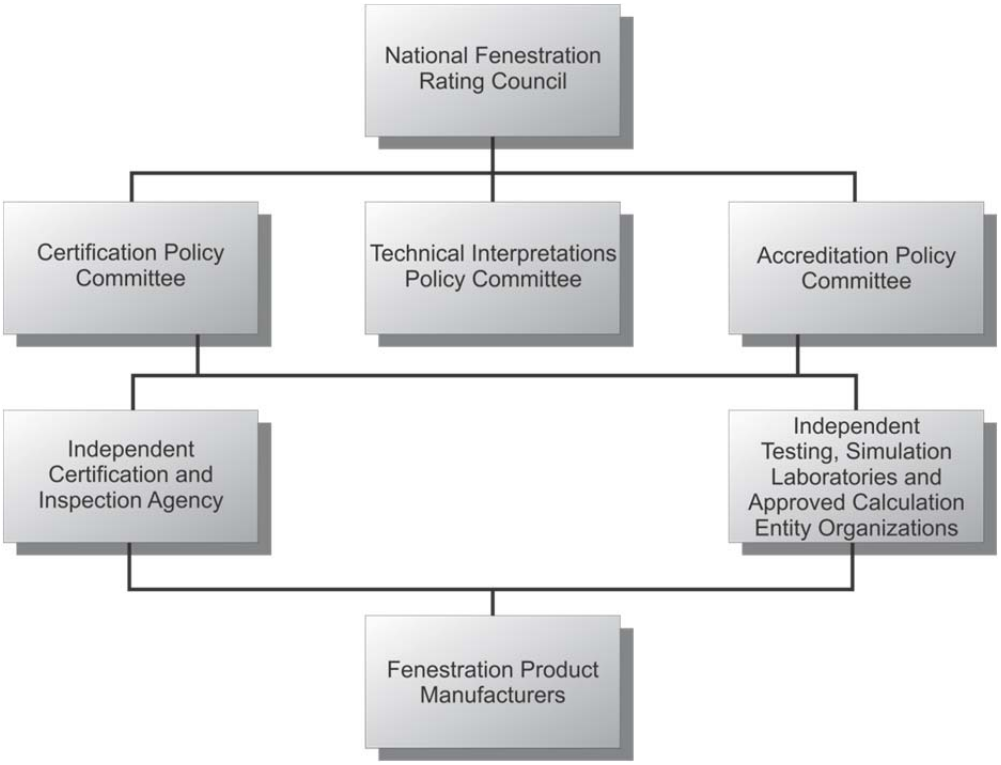


Figure 2

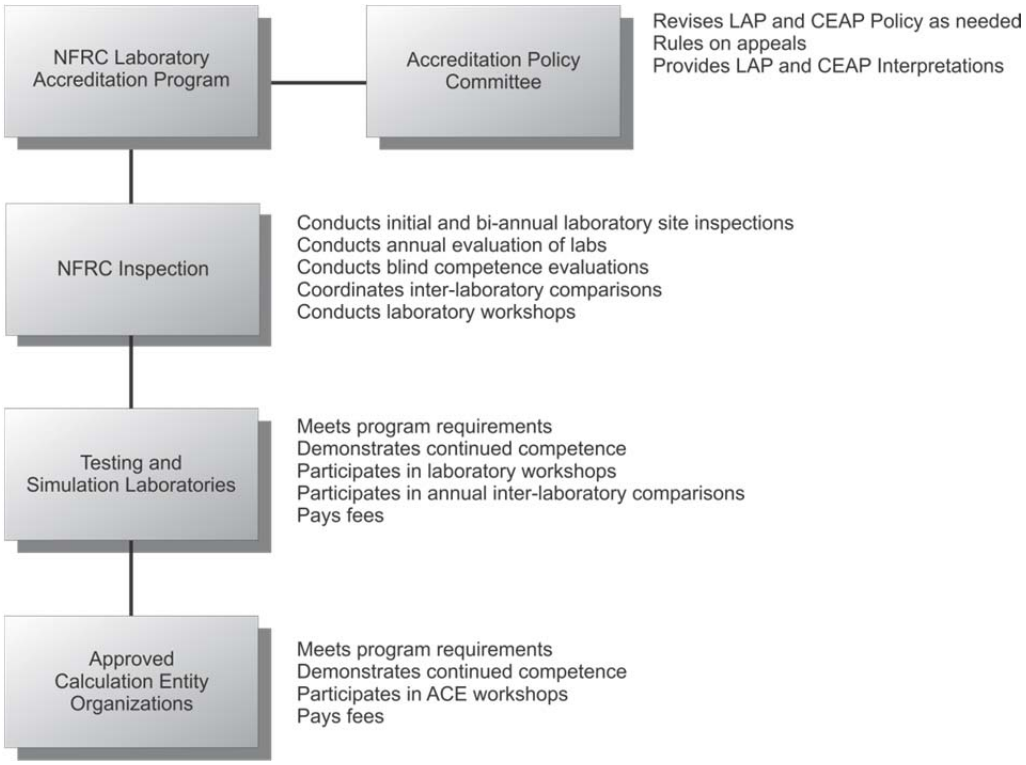
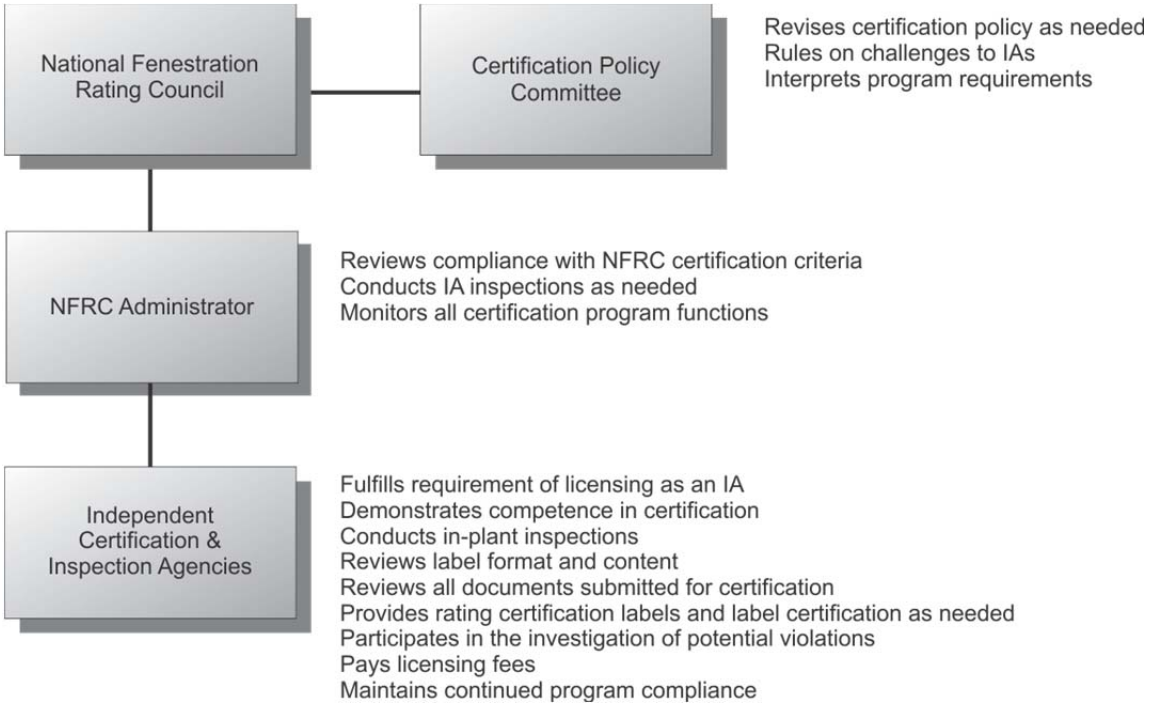


Figure 3



Questions on the use of this procedure should be addressed to:

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DISCLAIMER

NFRC certification is the authorized act of a Manufacturer/Responsible Party in: (a) labeling a fenestration or related attachment product with an NFRC Permanent Label and NFRC Temporary Label, or (b) generating a site built or CMA label certificate, either of which bears one or more energy-related performance ratings reported by NFRC-accredited simulation and testing laboratories and authorized for certification by an NFRC-licensed IA. Each of these participants acts independently to report, authorize certification, and certify the energy-related ratings of fenestration and related attachment products.

NFRC does not certify a product and certification does not constitute a warranty of NFRC regarding any characteristic of a fenestration or fenestration-related attachment product. Certification is not an endorsement of or recommendation for any product or product line or any attribute of a product or product line. NFRC is not a merchant in the business of selling fenestration products or fenestration-related products, and therefore cannot warrant products as to their merchantability or fitness for a particular use.

NFRC THEREFORE DISCLAIMS ANY AND ALL LIABILITY THAT MAY ARISE FROM OR IN CONNECTION WITH SERVICES PROVIDED BY, DECISIONS MADE BY OR REPORTS OR CERTIFICATIONS ISSUED OR GRANTED BY ANY NFRC-ACCREDITED LABORATORY, NFRC-LICENSED IA OR ANY PRODUCT MANUFACTURER/ RESPONSIBLE PARTY; RELIANCE ON ANY NFRC PRODUCT DESCRIPTION, SPECIFICATION, RATING, TEST OR CERTIFICATION, WHETHER APPEARING IN A REPORT, A PRODUCT CERTIFICATION AUTHORIZATION OR A PRINTED OR ELECTRONIC DIRECTORY, OR ON A LABEL, OR ON A LABEL CERTIFICATE; OR THE SALE OR USE OF ANY NFRC-RATED OR CERTIFIED PRODUCT OR PRODUCT LINE; INCLUDING BUT NOT LIMITED TO DAMAGES FOR PERSONAL OR OTHER INJURY, LOST PROFITS, LOST SAVINGS OR OTHER CONSEQUENTIAL OR INCIDENTAL DAMAGES.

NFRC program participants are required to indemnify NFRC from and against such liability.

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1. INTRODUCTION

The National Fenestration Rating Council (NFRC)has developed a uniform national rating system for fenestration product energy performance.

A product certification program reinforces the rating system by requiring ratings are determined by NFRC accredited laboratories and then reviewed and authorized by NFRC licensed independent certification and inspection agencies (IAs) and conform to NFRC requirements.

This procedure has been developed to provide uniform and credible tables (libraries) of thermophysical properties of materials used in the construction and manufacture of fenestration products in approved software tool(s). The following thermophysical properties, currently considered, are: thermal conductivity, long-wave surface emissivity, and solar surface absorptivity hereafter referred to as thermophysical properties**.**

In this procedure, a table of generic materials and their associated thermophysical properties is provided, as well as a process of introducing custom materials or new, manufacturer-specific materials. This procedure should improve the credibility of the values used in simulating thermal performance indices of fenestration systems.

This procedure may involve hazardous materials, operations, and equipment. This procedure does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate health and safety practices and to determine the applicability of any regulatory limitations prior to use.

The values stated in metric (SI) units shall be regarded as the standard. The inch-pound (IP) units shown in parenthesis shall be for reference only.

2. PURPOSE AND SCOPE

2.1 Purpose

The purpose of this procedure shall be to provide a uniform method for determining the thermophysical properties of glazing (thermal conductivity only), framing, and other opaque materials used in the construction and manufacture of fenestration products. These thermophysical properties shall be used in NFRC approved software for the simulation of thermal performance indices of fenestration products.

2.2 Scope

2.2.1 Materials Covered By This Document

- All frame materials, either single component or composite
- All glazing materials, thermal conductivity only
- All sealants and adhesives

- Weather-stripping materials
- Thermal barrier materials
- Cladding materials
- Spacer materials
- Desiccant materials

2.2.2 Materials and/or Properties Not Covered By This Document

- Thermal conductivity of finishes
- Glass coatings
- Solar-optical properties of glazing and other transparent materials. (See NFRC 300 and NFRC solar-optical database)

3. TERMINOLOGY

Absorptance: The ratio of the absorbed radiant energy to the total incident radiant energy.

Accreditation: Official authorization, approval, or recognition accorded by NFRC to a laboratory based upon specific NFRC qualifications.

Accreditation Program: The NFRC program administering the Laboratory Accreditation Program (LAP) as set forth in NFRC 701.

Air Leakage (AL): The volume of air flowing per unit time per unit area through a fenestration system due to air pressure or temperature difference between the outdoor and indoor environment.

Ambient Temperature: Temperature at a given set of environmental conditions.

Angle of Incidence: The angle between the solar beam and the normal (perpendicular) to the plane on which it is incident. (The plane of incidence may be the aperture plane, the glazing plane, or any other plane of interest.)

Areas, A:

Center-of-Glazing Area (A_c): All glazing areas except those within 63.5 mm (2.5 in) of any part of a primary sash and/or frame and/or divider; or any part of a primary door and/or frame and/or divider.

Total Fenestration Product Area (A): The area of the total fenestration product that includes all frame, divider, edge-of-glazing, edge-of-divider, and center-of-glazing areas.

Attachment: See “Dynamic Attachment” or “Fenestration Attachment.”

Blackbody: A perfect emitter and absorber of thermal radiation. A blackbody emits radiant energy at each wavelength at the maximum rate possible as a consequence of its temperature and absorbs all incident radiant flux.

Center-of-Glazing: Referring to thermal or optical properties of a glazing system in that area of the system which is not influenced by the frame, glazing bars, mullions, or other opaque or conducting members of the fenestration product.

Certification: The affixing by a licensed Responsible Party of an NFRC label on a fenestration product, or on a box/packaging containing an attachment product, or the distribution of an NFRC Label Certificate, for which Certification Authorization has been granted.

Certification Agency Program (CAP): Set of rules and procedures by which an independent certification and inspection agency becomes licensed and operates.

Certification Authorization Report (CAR): Certificate listing performance values of NFRC-rated products that is issued by an NFRC-Licensed IA granting the licensee the authority to affix NFRC Labels on a fenestration product or on the box/packaging containing an attachment product, or to obtain an NFRC Label Certificate, upon PCP compliance by the licensee.

Certification Program: A term often used for the Product Certification Program (PCP or CMA PCP).

Certified Simulator: Any individual that has attended at least one NFRC-sanctioned Simulation Training Workshop, completed and satisfactorily passed all necessary examinations, participated in NFRC simulation round robins, and is approved by NFRC to use at least one NFRC-approved simulation software tool.

Cladding: An applied rigid or semi-rigid roll-formed or extruded covering that is placed over or is attached to and follows the contour of the interior or exterior framing member for the primary purpose of protection from environmental elements and/or aesthetics. Cladding adds no structural integrity to the framing member.

Compliance and Monitoring Program: A program that establishes activities that are prohibited by law and/or contract, and fines associated with such activities.

Computer Simulation: The process by which a product is analyzed for energy performance characteristics utilizing NFRC-approved computer software and manufacturer supplied product specifications and drawings, in accordance with the requirements of the NFRC Rating System.

Condensation Resistance: A relative indicator of a fenestration product's ability to resist the formation of condensation at a specific set of environmental conditions. The higher the Condensation Resistance value the greater the resistance to the formation of condensation.

Product Condensation Resistance: The lower of CR_f, CR_c, and CR_e.

Curtain Wall, Curtain Wall System: An external non-load bearing wall that consists of any combination of framing materials, fixed glazing, opaque glazing, operable windows, or other in-fill materials. See “Storefront,” “Window Wall.”

Diffuse (adj.): Referring to radiometric quantities: indicates that flux propagates in many directions, as opposed to a direct beam, which refers to quasi-collimated flux from the sun, whose angular diameter is approximately 0.5 degree. When referring to reflectance, it is the directional hemispherical reflectance less the specular reflectance. Diffuse has been used in the past to refer to hemispherical collection (including the specular component). This use is deprecated in favor of the more precise term hemispherical.

Divider: Any bar used to separate glazing into multiple lites or placed in the gap between sheets of glazing. Dividers may be external or internal, may be removable or non-removable, and may be real (true) or simulated. Dividers may also be called grids, grilles, or muntins.

Dynamic Attachment: Any Fenestration Attachment that incorporates Dynamic Glazing.

Emissivity (ε): The relative ability of a surface to reflect or emit heat by radiation. Emissivity ranges from 0.00 to 1.00. (Blackbody emissivity is 1.0)

Fenestration: Products that fill openings in a building envelope, such as windows, doors, skylights, curtain walls, etc., designed to permit or limit the passage of air, light, vehicles, or people.

Fenestration Attachment: A device (such as, but not limited to, shades, films, or blinds) designed to be physically attached to, incorporated with, or covering a fenestration product.

Fenestration System: a fenestration is a glazed aperture in a building for the controlled admission of solar radiant heat and light. A fenestration system is a system of usually planar (but sometimes curved) transparent or translucent glazings, frames holding the glazing, mullions, muntin bars, dividers, and other attachments and/or shading devices that form the fenestration system. The glazing can include glass or plastic sheets that are patterned, corrugated, or otherwise distorted, so long as some visible light can pass through them. The fenestration system is often referred to as the test specimen in this document.

Finish: The final treatment or coating of a surface.

Frame: The enclosing structure of a window, door or skylight which fits into the wall or roof opening and receives either, glazing, sash or vents.

Glass: An inorganic, amorphous substance, usually transparent, composed of silica (sand), soda (sodium carbonate) and lime (calcium carbonate) with small quantities of other materials.

Glazing: The act of installing the glazing system/glazing in-fill. n, The transparent or semi-transparent infill material in a glazing system.

Glazing System/Glazing In-fill: A generic term used to describe an infill material, such as glass, plastic or other transparent or translucent material, or assembly of glazing material, spacer and desiccant, used to enclose openings in a building created by a specific framing system.

Heat Flux (q): The heat flow rate through a surface of unit area perpendicular to the direction of heat flow in units of energy per unit time and per unit area.

Individual Product: Any one specific fenestration product within a product line, specific to weather seals, glazing method, hardware, opening/non-opening configurations, ventilators, weep systems, and sills.

Insulating Glass Unit (IGU), Sealed Insulating Glass Unit: A preassembled unit comprising lites of glass, which are sealed at the edges and separated by dehydrated space(s). The unit is normally used for windows, window walls, picture windows, sliding doors, patio doors, or other types of fenestration.

Integrating Sphere: An optical device used to either collect flux reflected or transmitted from a sample into a hemispherical solid angle or to provide isotropic irradiation of a sample from a complete hemispherical solid angle. It consists of a cavity that is approximately spherical in shape with apertures for admitting and detecting flux and usually having additional apertures over which the sample and reference specimens are placed.

Interlayer: A layer of material acting as an adhesive between layers of glazing.

Irradiance: A radiometric term for the radiant flux in any or all directions in a hemispherical solid angle that is incident upon, passing through, or leaving a surface.

Label: Permanent and/or temporary marker or device applied to a fenestration product, listing rating information and indicating compliance with certification requirements.

Label Certificate: A document used in lieu of an NFRC Temporary Label specific to certain products that have received certification authorization (see NFRC 705).

Laboratory Accreditation Program (LAP): Set of rules and procedures by which a laboratory becomes accredited and operates.

Licensee: Any entity entering into an NFRC License Agreement and meeting the NFRC PCP requirements.

Opaque (adj.): Not allowing visible light to pass through.

Product Certification Authorization: The authority granted by an NFRC-Licensed IA to an NFRC Licensee to affix NFRC Labels, or obtain an NFRC Label Certificate, evidenced by a Certification Authorization Report (CAR) or Label Certificate issued by the IA.

Product Certification Program (PCP): The NFRC program for granting of authorization to licensees to label products under the NFRC energy rating system.

Radiant Flux: The time rate of flow of energy in the form of electromagnetic waves or photons.

Radiation: The transfer of heat in the form of electromagnetic waves or photons from one body to another.

Rating: Performance values obtained using NFRC-approved procedures used for comparative purposes only (i.e., U-factor, SHGC, VT, etc.).

Rating System: A system that consists of NFRC simulation and test procedures for determining comparative fenestration product energy performance characteristics, as supported by the Certification Program.

Reflectance: The ratio of the reflected radiant flux to the incident radiant flux.

Responsible Party: The entity (manufacturer, fabricator, lineal supplier, building owner, architect, door distributor, or other party) that signs an NFRC License Agreement. The responsible party agrees to comply with all applicable program requirements.

Sash: The portion of a fenestration assembly that is installed in a frame and includes the glazing, stiles, and rails. A sash may be operable or fixed.

Simulation Software: Any computer software used for Computer Simulation.

Slab: Part of a hinged door system, glazed or unglazed, surrounded by a frame. Slabs may be fixed or operable.

Solar (adj): (1) Referring to radiometric quantities, indicating that the radiant flux involved has the sun as its source or has the relative spectral distribution of solar flux; (2) referring to an optical property, having as its weighting function a standard solar spectral irradiance distribution.

Solar Heat Gain (SHG): The quantity of incident solar energy passing through a fenestration system. Included are both directly transmitted solar radiation as well as solar energy absorbed by the fenestration system and re-transmitted into the inside space.

Solar Heat Gain Coefficient (SHGC): The ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation. NFRC rates SHGC at normal incidence.

Solar Radiation: Electromagnetic radiation covering the spectral range from 300 to 4000 nm, coming from either natural direct beam solar radiation or from an artificial radiation source having a similar spectral distribution.

Spacer: The component that separates and maintains the space between the glazing surfaces of an insulating glass unit (IGU), excluding any sealants.

Spectral (adj): Indicating that the property or quantity was evaluated at a specific wavelength (λ), within a small wavelength interval ($\Delta\lambda$ about λ). Usually indicated by placing the wavelength symbol λ, as a subscript following the symbol for the quantity, as with E_λ, thereby indicating that the flux-related quantity is a concentration of flux at the indicated wavelength, or it may be placed inside parentheses following the symbol for the material property, as with $\alpha(\lambda)$. It is permissible to indicate the wavelength dependence of a flux quantity as follows: $E_\lambda(\lambda)$.

Specular (adj.): Indicating that the flux leaves a surface or medium at an angle of reflection or transmission numerically equal to the angle of incidence.

Thermal Break, Thermal Barrier: A component made of material of relatively low thermal conductivity, which is inserted between two components having high thermal conductivity, in order to reduce heat transfer.

Thermal Bridge: A path of high thermal conductance from the exterior to interior surfaces of a system that has lower thermal conductance in all other areas. An example would be metal fasteners penetrating an insulating wall or thermally broken frame.

Thermal Conductivity, k: Heat transfer property of materials expressed in units of energy per time per length per degree temperature difference.

Total Fenestration Product Area, A: the area of the total fenestration product that includes all frame, divider, edge-of-glazing, edge-of-divider and center-of-glazing areas.

Translucent (adj.): Permitting light to pass through but with differing degrees of obscuration and diffusion.

Transmittance: the ratio of the transmitted radiant flux to the incident radiant flux.

Transparent (adj.): Permitting light to pass through with clear vision.

Visible Transmittance, VT: The ratio of visible radiation entering the space through the fenestration product to the incident visible radiation, determined as the spectral transmittance of the total fenestration system, weighted by the photopic response of the eye and integrated into a single dimensionless value. Weighted by a standard solar spectrum.

Weather Strip: A flexible component used to reduce air leakage or water penetration or both between the sash or panels and/or sash or panels and frame.

Window: An assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air to an enclosure.

4. REPRESENTATIVE THERMOPHYSICAL PROPERTIES

All materials used in the design and fabrication of a fenestration product shall have either generic thermophysical properties assigned from the list in Appendices A or B, or a manufacturer shall supply thermophysical properties determined by an approved test procedure(s) (see Section 5) and shall be listed in Appendix C.

4.1 Generic Thermophysical Properties

Those materials determined by NFRC to be generic in nature shall be identified and listed in Appendix A (Basic Set of Generic Materials) or Appendix B (Extended Set of Generic Materials). NFRC may add or remove materials as needed.

4.1.1

All simulators shall use Appendix A, unless the simulator's client requests the use of Appendix B or the material is not represented in Appendix A. If the simulator's client requests the use of material properties from Appendix B, then the client shall provide the simulator with appropriate product drawings and/or material specifications verifying that the requested material properties are representative of the material(s) specified. If such documentation is not provided to the simulator, then the simulator shall use the applicable material property value(s) from Appendix A.

4.1.2

If a wood component's cross-sectional material properties vary randomly along the length of the component, and the client wishes to use material property values from Appendix B, then for purposes of simulation, the cross-section shall be assigned the highest conductivity of all the materials used in that component.

> For example, consider a wood frame member composed of multiple individual pieces of wood finger-jointed together along the length of the frame member. Some of the wood pieces are Sugar Pine (k=0.099 W/m•K), some are Ponderosa Pine (k=0.122 W/m•K), and some are Radiata Pine (k=0.128 W/m•K). The cross-section for this frame member would be assigned a conductivity of 0.128 W/m•K. See Figure 1.

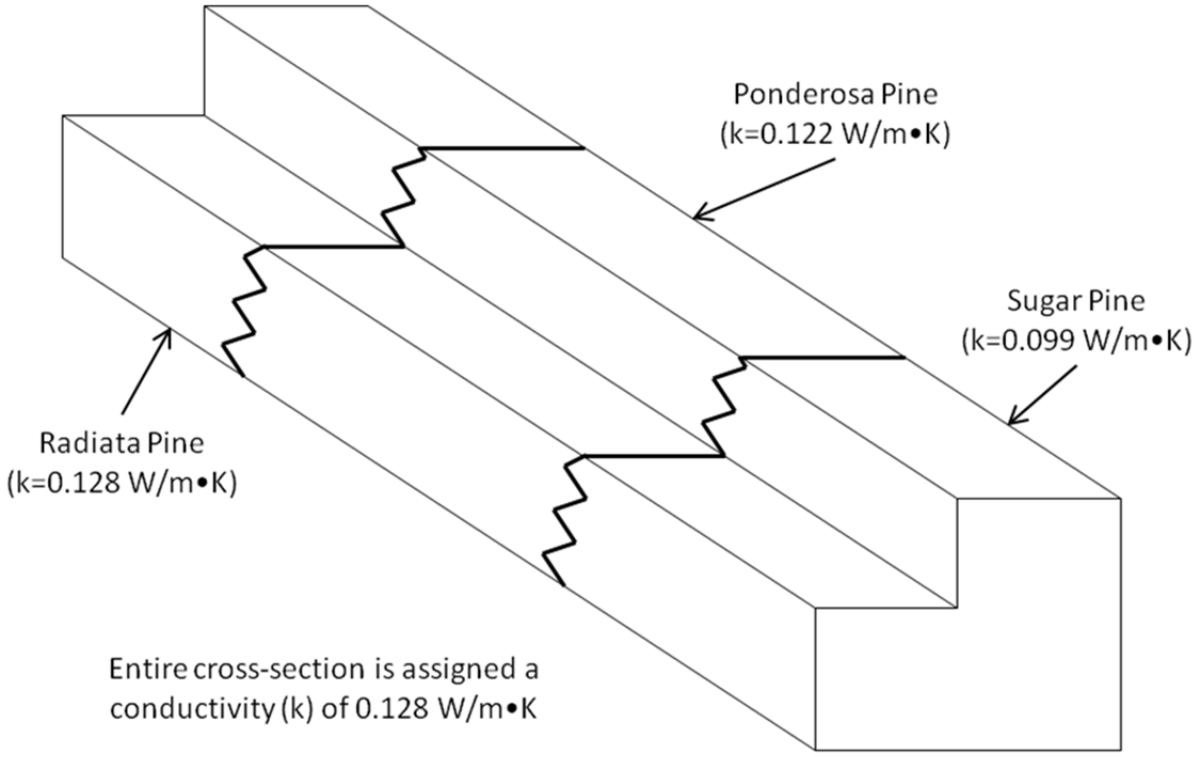

Figure 1

[***Note***: If a product is simulated using material properties from Appendix B, then additional requirements will apply during annual inspections of Product Certification Program licensees. See NFRC 700 for details.]

4.1.3

The NFRC Thermophysical Properties Subcommittee shall review the list of generic materials and update the thermophysical properties as necessary. Each update shall be announced and promptly posted on the NFRC website for easy retrieval by NFRC-accredited simulation laboratories, NFRC-certified simulators, NFRC IAs, and other interested parties. The update shall have its version number clearly identified and NFRC shall post the date when this new material library becomes effective. Upon the effective date of the new material property file as posted by NFRC, old versions of the material library are deemed obsolete.

If the material data are not in the generic material library, and an interested party believes that the material in question is generic, the interested party may request in writing that NFRC include said material in Appendix A or Appendix B. Such requests shall be handled as outlined in NFRC 103 Sections 2.4 through 2.6. If the interested party disagrees with a published Generic Thermophysical Property, the interested party may request, in writing, testing of representative samples to determine a corrected thermophysical property. In such a case, a minimum of three different samples of the same generic material, preferably supplied by three different manufacturers, its thermophysical properties shall be determined in accordance with Section 5. The average of the measured thermophysical properties shall be compared to the currently-used generic thermophysical property. If the difference is less than 10% or 0.003 W/(m•K) (0.02 Btu•in./(hr•ft^2•°F)), whichever is greater, the current thermophysical property shall be considered valid. If the average of the three individual thermophysical property values is more than 10%, or 0.003 W/(m•K) (0.02 Btu•in./(hr•ft^2•°F)), whichever is greater, different from the current generic thermophysical property, this new thermophysical property shall be peer-reviewed, and upon acceptance, shall become the new thermophysical property of that generic material and be included in the updated material database.

4.2 Manufacturer Specific Thermophysical Properties

If the material is not considered generic and is not part of the generic material library, its thermophysical properties shall be determined in accordance with Section 5. The manufacturer is responsible for providing typical samples for testing.

The Manufacturer may use its own equipment or hire a third party laboratory to determine thermophysical properties and submit test data to the NFRC Thermophysical Properties Subcommittee for verification. The testing shall be done according to the procedure(s) outlined in Section 5. In addition, the testing laboratory shall retain the three original test samples for the duration of the peer review challenge period and so that they may be sent to NFRC for verification according to NFRC 103.

Emissivity and solar absorptance of materials is not required to be determined if the manufacturer accepts default values of 0.9 for emissivity and NFRC default values for solar absorptance.

5. THERMOPHYSICAL PROPERTIES TEST METHODS

Thermophysical properties shall be determined according to appropriate ASTM standards, as indicated in Sections 5.1, 5.2, and 5.3. A minimum of three samples shall be measured and the mean value reported. If the difference between any individual sample value and the average value of all samples is more than 10% or 0.003 W/(m•K) (0.02 Btu•in./(hr•ft^2•°F)), whichever is greater,

of the average value, the materials shall not be considered to be the same, and the reasons for outlier(s) shall be determined.

5.1 Thermal Conductivity

For the determination of thermal conductivity, the test shall be done according to ASTM C177, C518, C1114, E1225, E1530, E1461 or E1952, as applicable for the specific material. The test equipment shall be calibrated at least once each year as per the recommendations in the appropriate ASTM document(s).

> [***Note***: The specimen conductance should be less than 16 W/m^2•K (thermal resistance greater than 0.0625 m^2•K/W) if the test is done using C177. C518 may be used for a specimen with thermal conductance less than 10 W/m^2•K (thermal resistance greater than 0.10 m^2•K/W). For either of these tests, the temperature difference across the specimen shall not be less than 10 K. C1114 is applicable to a low-conductance specimen only and the specimen shall be thermally homogeneous. Apparatus of the type covered by C1114 apply to the study of thermal properties of specimens containing moisture because of the use of small temperature differences and the low thermal capacity of the heat source. E1530 is similar in concept to C518 and is especially useful for materials in sheet and similar forms having a thermal resistance in the range from 20 x10-4 to 400x10-4 m^2•K/W over the approximate temperature range from 150 to 600 K. Reduced accuracy will be achieved for thicker specimens and for thermal conductivities up to 10 W/m•K. E1225 uses a steady state technique for the determination of thermal conductivity of homogeneous, opaque solids with effective conductivities in the approximate range of 0.2 to 200 W/m•K over the approximate temperature range between 90 and 1300 K. E1952 covers the determination of thermal conductivity of homogeneous, non-porous solid materials in the range of 0.10 to 1.0 W/m•K by modulated temperature differential scanning calorimeter. ASTM E1461 is a flash diffusivity method used for thin gauge highly-conductive materials such as sheet metals. Use of ASTM E1461 for NFRC thermophysical properties requires following specific heat capacity measurement and thermal conductivity measurement per ASTM E1461's Appendix X2.]

Test method information is summarized in Table 1.

Table 5-1 --Summary of Thermal Conductivity Standards and Their Applicability

ASTM Standard	Conductivity Range (W/m•K)	Conductance Range (W/m^2•K)	Min ∆T (K)	Remarks
C177		< 16	10	Thermally homogeneous
C518		< 10	10	Thermally homogeneous
C1114			None	Thermally homogeneous, for specimens with moisture
E1225	0.2-200		90-1300	Thermally homogeneous, Opaque
E1530		25-500	150-600	Thermally homogeneous
E1952	0.1-1.0		None	Thermally homogeneous
E1461	NA	NA	NA	Primarily homogeneous isotropic solid materials. Thermal diffusivity values ranging from 10^{-7} to 10^{-3} m^2/s; temperature range: 75 to 2800 K (appendix X2 use mandatory)

5.1.1 Mean Temperatures

The test shall be conducted at a mean temperature of 2±1ºC (35±2ºF) unless otherwise specified by the applicable ASTM test method. ASTM E1461 is conducted at 25±1°C (77±2°F).

5.1.2 Specimen Thickness

The thickness of the specimen shall be chosen based on the standard procedure selected. With ASTM E1530, the thickness of the specimen is required to be less than 12mm (.47 in). ASTM C177 and ASTM C1114 recommend that maximum specimen thickness depends on several parameters, including the size of the apparatus, thermal resistance of the specimen, and the accuracy desired. ASTM E1461 specimen thickness ranges from 1.0 mm to 6 mm (.04 in to .24 in). For more specific quantitative information on thickness limitation see References 1 - 4.

5.1.3 Non-homogeneous Specimens

Non-homogeneities normal to the heat flux direction, such as layered structures, can be evaluated using ASTM C177. However, for testing specimens with non-homogeneities in the heat flux direction, such as an insulation system with thermal bridges, see test method ASTM C1363 for

guidance. To use ASTM E1225 for composites or heterogeneous systems consisting of slabs of plates bonded together, the specimen shall be more than 20 units wide and 20 units thick, respectively, where a unit is the thickness of the thickest slab or plate.

5.2 Emissivity

For the determination of long wave surface emissivity, the test shall be done according to ASTM E1933 or ASTM C1371. ASTM E1933 requires the specimen to be at a temperature at least 10K warmer or cooler than the ambient temperature while ASTM C1371 provides a comparative means of quantifying the emittance of opaque, highly thermally-conductive materials near room temperature. The long-wave range is considered from 2.5 μm to 40 μm.

Emissivity for non-metallic materials is defaulted to 0.90 without actual measurements.

5.2.1 Cleanness of the Surface

ASTM C1371 recommends that the procedure used should ensure minimum alteration of the specimen surface. For example, if the emittance of a dust-covered specimen is desired, the dust shall not be removed. However, if the surface is intended to be clean and free of any residue, it shall be visually inspected for signs of contamination prior to the measurement and, if necessary, cleaned with the appropriate solution and dried.

5.2.2 Finishes

For painted or finished specimens, the paint or finish shall be fully cured and in good contact with the substrate (i.e., no bubbles, peeling, or scratches). For further instructions, see ASTM D3359.

5.3 Solar Absorptivity

For the determination of surface solar absorptivity, the test shall be done according to ASTM E903 or ASTM C1549.

Solar absorptance of all frame materials is defaulted to 0.50 for commercial products and to 0.30 for residential products without actual measurements.

5.3.1 Finishes

The painted or finished surfaces shall be treated as in the case of emissivity measurement. See Section 5.2.2.

5.3.2 Specularity

This test method has been found practical both for materials having specular and diffuse optical properties.

5.3.3 Cleanness of the Surface

Surfaces that are measured shall be clean and free of any residue.

5.4 Density

The density of the material shall be determined by dividing its weight by its volume. Table 2 describes allowable density measurement methods for various materials.

Table 5-2 --Density Standards and Their Applicability

Material	Procedure
Polymer or plastic based materials	ASTM D792, ASTM D1505, ASTM D4883, ISO 1183-1, ISO 1183-2, or ISO 1183-3
Timber based	ASTM D2395
Fine aggregates	ASTM C128
Any other	Must report density measurement standard used

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APPENDIX A BASIC SET OF GENERIC THERMOPHYSICAL PROPERTY VALUES OF MATERIALS

Table A.1: Thermophysical Properties of Solid Materials[1]

Name	Density ρ	Conductivity *k*			Source[2]	Emissivity ε
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•^{o}F	-	-
Rubbers						
Butadiene	980	0.250	0.144	1.733	1	0.9
Butyl rubber (isobutene, solid/hot melt)		0.240	0.139	1.664	1,6,11	0.9
Expanded rubber (rigid)	72	0.032	0.018	0.222	2	0.9
Ethylene propylene diene monomer (EPDM)	1150	0.250	0.144	1.733	1	0.9
Foam Rubber	60-80	0.060	0.035	0.416	1	0.9
Neoprene (polychloroprene)	1,240	0.230	0.133	1.595	1	0.9
Polyisobutylene (PIB)	930	0.200	0.116	1.387	1	0.9
Polysulphide	1,700	0.400	0.231	2.773	1	0.9
Polymers						
PVB		0.221	0.128	1.536	21	0.9
Polycarbonate	1,200	0.200	0.116	1.387	1	0.9
Polyethylene/polythene HD (high density)	980	0.500	0.289	3.467	1	0.9
Polyethylene/polythene LD (low density)	920	0.330	0.191	2.288	1,6	0.9
Polypropylene	910	0.22	0.127	1.525	1	0.9
Polystyrene	1,050	0.160	0.092	1.109	1	0.9
Polytetrafluoroethylene(PTFE)	2,200	0.250	0.144	1.733	1	0.9
Polyurethane	1,200	0.250	0.144	1.733	1	0.9
Polyurethane foam	70	0.050	0.029	0.347	1	0.9
Polyvinylchloride (PVC) flexible, with 40% softener	1,200	0.140	0.081	0.971	1	0.9
PVC/Vinyl (rigid)	1,390	0.170	0.098	1.179	6,11	0.9
Silicone		0.350	0.202	2.427	1	0.9
Silicone foam		0.170	0.098	1.179	6,11	0.9
Silicone, filled		0.500	0.289	3.467	1	0.9
Urethane-thermal break		0.121	0.070	0.839	13	0.9
Urethane/polyurethane		0.210	0.121	1.456	1	0.9
Composites						
Fiberglass		0.300	0.173	2.080	6,11	0.9
Polyamide 6.6 with 25% glass fiber		0.300	0.173	2.080	1	0.9
Timbers						
Coniferous woods (Softwoods)		0.140	0.081	0.971	6,11	0.9
Deciduous woods (Hardwoods)		0.160	0.092	1.109	6,8,11	0.9

Name	Density ρ	Conductivity *k*			Source[2]	Emissivity ε
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•^{o}F	-	-
Wood based panels						
Hardboard (medium density)	800	0.110	0.064	0.763	11	0.9
Particleboard, Plywood (low density)	300	0.100	0.058	0.693	1	0.9
Particleboard, Plywood (medium density)	700	0.170	0.098	1.179	1	0.9
Particleboard, Plywood (high density)	1,000	0.240	0.139	1.664	1	0.9
Metals						
Aluminum (oxidized, mill finish)		237.000	136.936	1643.235	8	0.2
Aluminum alloys (oxidized, mill finish)	2,800	160.000	92.446	1109.357	1,6,11	0.2
Aluminum (anodized)		237.000	136.936	1643.235	8	0.8
Aluminum alloys (anodized)	2,800	160.000	92.446	1109.357	1,6,11	0.8
Aluminum alloys (painted)		160.000	92.446	1109.357	1,6,11	0.9
Steel (oxidized)	7,800	50.000	28.890	346.674	1	0.8
Steel (rolled, ground)	7,800	50.000	28.890	346.674	1	0.6
Steel Stainless (oxidized)	7,900	17.000	9.822	117.869	1	0.8
Steel Stainless (buffed)	7,900	17.000	9.822	117.869	1	0.2
Steel- galvanized sheet (0.14%C)		62.000	35.823	429.876	11	0.2
Glazing Materials						
Glass (Plate or Float)		1.000	0.578	6.933	1,6,11	0.84
Glass mosaic	2,000	1.200	0.693	8.320	1	0.84
Glass-Flint (lead), Pyrex	4,280	1.400	0.809	9.707	5	0.84
Glass-Quartz		1.400	0.809	9.707	1	0.90
Plexiglass (PMMA) / Lucite		0.200	0.116	1.387	11	0.90
Insulating Materials						
Cellulosic fiber, Cotton fiber	56	0.042	0.023	0.277	11	0.9
Expanded perlite, organic bonded	16	0.052	0.030	0.361	2	0.9
Polystyrene-expanded	15	0.038	0.022	0.263	11,1	0.9
Extruded polystyrene (XPS) with CFC and HCFC	25-65	0.029	0.017	0.201	11, 1	0.9
Extruded polystyrene (XPS) with CO2	30-50	0.034	0.020	0.236	1	0.9
Felt	330	0.050	0.029	0.347	5	0.9
Glass fiber (semi-rigid) Sheathing		0.034	0.020	0.236	11	0.9
Glass fiber (spray applied)		0.039	0.023	0.270	11	0.9
Glass fiber (rigid) Roof insulation		0.047	0.027	0.326	11	0.9
Glass wool	52	0.038	0.022	0.263	5	0.9
Insulation Fiberboard (Ceiling Tile, Lay-in Panel)		0.061	0.035	0.423	11	0.9
Insulation Fiberboard (Roof Board)		0.055	0.032	0.381	11	0.9
Insulation Fiberboard		0.050	0.029	0.347	11	0.9
Mineral fiber-low density (rock, slag, glass)		0.042	0.024	0.291	11	0.9

Name	Density ρ	Conductivity *k*			Source[2]	Emissivity ε
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•^{o}F	-	-
Mineral fiber-loose fill (rock, slag, glass)		0.050	0.029	0.347	11	0.9
Perlite		0.053	0.031	0.367	11	0.9
Polyester fibre	15	0.040	0.023	0.279	1	0.9
Polyisocyanurate/polyurethane-Unfaced Board		0.020	0.012	0.139	11	0.9
Polyisocyanurate/Polyurethane-Faced Sheathing		0.024	0.014	0.166	11	0.9
Polyurethane Foam Insulation (Spray Applied)		0.024	0.014	0.166	11	0.9
Ureaformaldehydefoam	11--26	0.040	0.023	0.277	2	0.9
Vermiculite	179	0.077	0.044	0.534	10	0.9
Miscellaneous						
Foam glass		0.040	0.023	0.277	1,12	0.9
Mohair		0.140	0.081	0.971	6,11	0.9
Desiccant-desiccated matrix	-	0.290	0.168	2.011	24	-
desiccant–loose fill	-	0.030	0.017	0.208	6,11,24	0.9
Silicone Foam		0.170	0.098	1.179	11	0.9
Foam weather stripping		0.030	0.017	0.208	6,11	0.9
Paints		N/A	N/A	N/A	-	0.9

[1] These values are typically included in the THERM Materials Library

[2] Numbers listed in this column refer to documents listed in Section 6.2

Table A.2: Thermophysical Properties of Gases

	Conductivity $k = a + bT+cT^2$ [W/m•K]			Dynamic Viscosity $\mu = a + bT+cT^2$ [kg/m•s]		
Gas	**Coefficient a** [W/m•K]	**Coefficient b** [W/m•K^2]	**Coefficient c** [W/m•K^3]	**Coefficient a** [kg/m•s]	**Coefficient b** [kg/m•s•K]	**Coefficient c** [kg/m•s•K^2]
Air*	$2.873x10^{-3}$	$7.760x10^{-5}$	0	$3.723x10^{-6}$	$4.94x10^{-8}$	0
Argon	$2.285x10^{-3}$	$5.149x10^{-5}$	0	$3.379x10^{-6}$	$6.451x10^{-8}$	0
Krypton	$9.443x10^{-4}$	$2.826x10^{-5}$	0	$2.213x10^{-6}$	$7.777x10^{-8}$	0
Xenon	$4.538x10^{-4}$	$1.723x10^{-5}$	0	$1.069x10^{-6}$	$7.414x10^{-8}$	0
CO_2	$-5.8181x10^{-3}$	$7.4714x10^{-5}$	0	$8.5571x10^{-7}$	$4.7143x10^{-8}$	0
Octaflouropropane	$-1.576x10^{-3}$	$1.804x10^{-5}$	$9.830x10^{-8}$	$-2.009x10^{-6}$	$5.475x10^{-8}$	$-2.054x10^{-11}$

*Note: Nitrogen shall be treated as air.

	Specific Heat $Cp = a + bT + cT^2$ [J/kg•K] -				Molecular Masses
Gas	**Coefficient a** [J/kg•K]	**Coefficient b** [J/kg•K^2]	**Coefficient c** [J/kg•K^3]		Mass [kg/kmol]
Air*	1.00274×10^{3}	1.2324×10^{-2}	0		28.97
Argon	5.21929×10^{2}	0	0		39.948
Krypton	2.48091×10^{2}	0	0		83.80
Xenon	1.58340×10^{2}	0	0		131.30
CO_2	5.76903×10^{2}	9.18088×10^{-1}	0		44.01
Octaflouropropane	6.332×10^{2}	-3.805×10^{-1}	3.119×10^{-3}		188.02

*Note: Nitrogen shall be treated as air.

APPENDIX B EXTENDED SET OF GENERIC THERMOPHYSICAL PROPERTY VALUES OF MATERIALS

Table B.1: Thermophysical Properties of Solid Materials[3]

Name	Density ρ	Conductivity *k*			Source[4]	Emissivity ε
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•°F	-	-
Rubbers						
Neoprene(polychloroprene)	146	0.036	0.021	0.246	10	0.9
Neoprene(polychloroprene)	1290	0.237	0.137	1.643	10	0.9
Polymers						
Polyurethane foam	24-40	0.026	0.015	0.180		0.9
ABS	1,020-1,210	0.190			Web	0.9
Timbers						
Redwood(California)	392-448	0.118	0.068	0.818	2	0.9
Cedars (western, red)	247-502	0.130	0.075	0.901	2	0.9
Cypress (southern)	502-514	0.132	0.076	0.915	2	0.9
Elm (soft)	521	0.131	0.076	0.909	7	0.9
Fir (white)	430	0.120	0.069	0.832	5	0.9
Fir(Douglas)	529	0.111	0.064	0.769	7	0.9
Hemlock (eastern)	457	0.115	0.067	0.799	7	0.9
Larch (western)	625	0.143	0.082	0.988	7	0.9
Mahogany	550	0.130	0.075	0.901	5	0.9
Maple (sugar)	720	0.187	0.108	1.297	5	0.9
Oak (red)	721	0.173	0.1	1.198	7	0.9
Oak (white)	745-750	0.176	0.102	1.218	5,7	0.9
Pine (sugar)	409	0.099	0.057	0.689	7	0.9
Pine (white)	430	0.110	0.064	0.763	5	0.9
Pine (Norway)	441	0.120	0.069	0.829	7	0.9
Pine (northern white)	481	0.121	0.070	0.839	7	0.9
Pine (ponderosa)	489	0.122	0.071	0.849	7	0.9
Pine (Radiata)	504	0.128	0.074	0.887	10	0.9
Pine (longleaf)	609	0.138	0.080	0.958	7	0.9
Pine (shortleaf)	545	0.141	0.082	0.978	7	0.9
Pine (southern, yellow)	659	0.161	0.093	1.116	2	0.9
Alder(Red)	440	0.114	0.066	0.791	10	0.9
Spruce (Sitka)	425	0.098	0.057	0.679	7	0.9
Wood based panels						
Particleboard, Plywood	500	0.130	0.075	0.901	1	0.9

Name	Density ρ	Conductivity *k*			Source[4]	Emissivity ε
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•°F	-	-
Particleboard, Plywood	600	0.140	0.081	0.971	1	0.9
Insulating Materials						
Cellulose	48	0.039	0.023	0.273	10	0.9
Cellulose	54	0.057	0.033	0.395	5	0.9
Cellulosic fiber	96	0.049	0.028	0.340	1	0.9
Polystyrene expanded (EPS)	50-60	0.031	0.018	0.218	1	0.9
Polystyrene expanded (EPS)	35-45	0.032	0.019	0.223	1	0.9
Polystyrene expanded (EPS)	30	0.033	0.019	0.227	1	0.9
Polystyrene expanded (EPS)	25	0.034	0.020	0.236	1	0.9
Polystyrene expanded (EPS)	20	0.035	0.020	0.243	1	0.9
Polystyrene expanded (EPS)	10	0.043	0.025	0.300	1	0.9
Polystyrene expanded, molded beads	16	0.037	0.021	0.257	1	0.9
Polystyrene expanded, molded beads	24	0.035	0.020	0.243	1	0.9
Polystyrene expanded, molded beads	32	0.033	0.019	0.229	1	0.9
Extruded polystyrene(XPS) CO2	30-50	0.034	0.020	0.236	1	0.9
Mineral fiber with resin binder		0.042	0.024	0.291	2	0.9
Polyester fiber	25	0.035	0.020	0.243	1	0.9
Polyester fiber	35	0.033	0.019	0.230	1	0.9
Polyester fiber	45	0.032	0.019	0.225	1	0.9
SilicaAerogel	73	0.024	0.014	0.166	10	0.9
Polyurethane foam, HCFC blown		0.021	0.012	0.146	11	0.9
Masonry Materials						
Concrete – medium density	1,800	1.15	0.66	7.97		0.90
Concrete – high density	2,400	2.00	1.16	13.87		0.90
Concrete – reinforced (2% steel)	2,400	2.50	1.44	17.33		0.90
Brick, Fired clay – high density	2,400	1.47	0.85	10.19		0.90
Brick, Fired clay – medium density	1,600	0.74	0.43	5.13		0.90
Brick, Fired clay – low density	1,120	0.45	0.26	3.12		0.90
Gypsum plasterboard	900	0.25	0.14	1.73		0.90
Metals						
Bronze	8,700	65	37.56	450	1,9	0.20
Brass	8,400	120	69.34	832	1,9	0.20
Copper	8,900	380	219.56	2634	1,9	0.80
Gold	19,290	310	179.12	2149	9	0.50
Iron, cast	7,500	50	28.89	346	1,9	0.80
Lead	11,300	35	20.22	242	1,9	0.30
Nickel	8,800	93	53.74	644	9	0.40

[3]These properties are not typically included in the THERM Materials Library

[4] Numbers listed in this column refer to documents listed in Section 6.2

APPENDIX C MANUFACTURER SPECIFIC THERMOPHYSICAL PROPERTY VALUES OF MATERIALS

Table C.1: Thermophysical Properties of Solid Materials

Name	Density ρ	Conductivity k			Emissivity ε[1]
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•^{o}F	-
Aspen Aerogel-IM-Green-100F (4mm)	124.94	0.012	0.007	0.085	-
Aspen Aerogel-IM-Green-100P (3mm)	123.34	0.011	0.006	0.011	-
Aspen Aerogel-Spaceloft	137.1	0.015	0.009	0.103	-
ADCO PIB-8 HSNB Gray	1,060	0.155	0.089	1.073	-
ADCO Kömmerling - TPS Material	1,243	0.245	0.141	1.70	0.9
Advanced Environmental Recycling Technologies-Moisture Shield	1,000	0.198	0.114	1.373	0.9
Aurora Plastics-AP 3344 Foam Board	673	0.061	0.035	0.424	-
Aurora Plastics-AP 3345 Foam Board	602	0.061	0.035	0.425	-
BASF Neopor EPS Foam w/ Graphite	19.7	0.029	0.017	0.200	-
Bayer Material Science-Glass-Reinforced Polyurethane Pultrusion	2,127	0.219	0.127	1.522	-
Boshert Dokana – Insulating foam one	78.7	0.034	0.020	0.236	-
Boshert Dokana – Insulating foam two	244	0.047	0.027	0.326	-
Boshert Dokana – Tecniplast CV51	519	0.060	0.035	0.418	-
Cabot Nanogel Translucent Aerogel	81.4	0.019	0.011	0.134	0.9
Cardinal Stainless Steel	7,808	14.187	8.197	98.37	-
Chelsea Building Products-composite PVC	1,698	0.292	0.169	2.023	-
Chelsea Building Products-PVC Adapter	702	0.092	0.053	0.639	-
Colonial Warmetal-SST	7,688	12.933	7.473	89.673	-
Colonial Metal-tin plated steel	7,660	50.2	29.05	348.6	-
CW Ohio-Wood Flour Polystyrene Material	587.9	0.077	0.044	0.533	0.9
Deceuninck-DNA Thermal Reinforcement	1,649	0.341	0.198	2.370	-
Eagle Window and Doors-Eagle Composite	1,349	0.190	0.110	1.317	-
Edgetech-Silicone foam spacer, S1	968	0.159	0.092	1.104	-
Edgetech-Silicone foam spacer, S2	690	0.102	0.059	0.704	-
Edgetech-Super Spacer Material nXt	740	0.114	0.066	0.789	-
Edgetech-Super Spacer Standard (EPDM)	820	0.127	0.074	0.883	-
Edgetech-Tri-Seal Premium Plus, S2	776	0.117	0.067	0.809	-
Edgetech-Tri-Seal Premium, S2	767	0.130	0.075	0.899	-
Efco-Acetal copolymer	360	0.189	0.109	1.313	-
Ensinger, Inc.- Insulbar Material	1,292	0.251	0.145	1.74	0.9
Fibrex EB-vinyl coated composite material	1,389	0.199	0.115	1.38	0.9
Futura Coatings-ITW Foamseal E-Z Fill Foam	51.9	0.03	0.018	0.211	-
Futura Coatings-ITW Foamseal E-Z Fill Plus Foam	41.7	0.030	0.018	0.212	-
GED-Intercept Ultra Stainless Steel	7,473	13.63	7.877	94.52	-
Glasscraft-CelukaFoamed PVC	628	0.066	0.038	0.455	-

Name	Density ρ	Conductivity k			Emissivity ε[1]
	kg/m^3	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft^2•^{o}F	-
Glasscraft-Extira Brand Composite Panel	730	0.106	0.061	0.732	-
Glasscraft-Houston Polyurethane from Houston Foam	35.24	0.024	0.014	0.166	-
Glasslam- Air-Tight EPDM foam spacer	826	0.143	0.083	0.995	-
Glasslam- Air-Tight silicone foam spacer	1,009	0.125	0.072	0.867	-
Gossen Cellular PVC	653	0.066	0.038	0.459	-
ICT, Inc. - Cellulosic Thermoplastic Composite	1,057	0.244	0.141	1.693	0.71
Interlayer Solutions-Evasafe Interlayer	935	0.207	0.120	1.435	-
Jeld-Wen-LFI Door Skin sample-30% CaCO3	1,353	0.134	0.077	0.929	-
Jeld-Wen-LFI Door Skin sample-no CaCO3	1,464	0.170	0.098	1.18	-
Jeld-Wen EPS Door Core Material	18.58	0.033	0.019	0.229	-
Jeld-Wen Fiberlast Door Skin Material	878	0.107	0.062	0.742	-
Jeld-Wen Sunpro Lambdapor Premium Expanded Polystyrene	21.5	0.029	0.017	0.199	-
Kalwall Insulation A	4.54	0.115	0.066	0.794	-
J-M Manufacturing- Plastpro-Cellular PVC Material	597	0.067	.039	.462	-
J-M Manufacturing- Plastpro PF Wood Plastic Composite Material	698	.084	.049	.583	-
Kalwall Insulation B	4.06	0.093	0.054	0.648	-
Kalwall Insulation C	12.82	0.047	0.027	0.327	-
Kalwall Insulation D	38.98	0.032	0.019	0.222	-
Kalwall Insulation E	8.0	0.04	0.023	0.277	0.9
Lakeside Radiant SST	7,461	14.1	8.16	97.9	-
Leading Edge SST coil	7,720	13.467	7.781	93.370	-
Leading Edge – TS tin plated steel	7,147	51.6	29.8	358	-
Major Industries - Translucent Thermal Insulation 15	6.94	0.079	0.046	0.549	0.9
Major Industries - Translucent Thermal Insulation 24	4.31	0.098	0.057	0.680	0.9
Major Industries - Ultimate Series FRP	1,236	0.143	0.083	0.993	0.9
Major Industries-10 Light Transmitting Insulation	9.58	0.07	0.041	0.487	-
Major Industries-15 Light Transmitting Insulation	5.89	0.061	0.035	0.422	-
Major Industries-IMG 125 Light Transmitting Insulation	6.92 (@ 1.25“)	0.037	0.021	0.258	-
Midwest Manufacturing-Elastopor® P 15860R RESIN/ELASTOPOR® P1001U ISOCYANATE RIGID POLYURETHANE FOAM SYSTEM	25.63	0.022	0.013	0.154	-
Midwest Manufacturing-Elastocool® P18731/P1001U Iso RIGID URETHANE FOAM SYSTEM	19.22	0.017	0.010	0.120	-
Mikron-EnergyCore Fusion Insulated System	134	0.032	0.019	0.225	-

Name	Density ρ	Conductivity k			Emissivity ε[1]
	kg/m³	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-
Mikron XTD composite (updated, 2009)	493	0.052	0.030	0.362	-
Milgard Polyethylene	38.9	0.053	0.031	0.366	-
Milgard Polystyrene foam	25.9	0.032	0.018	0.220	-
Milgard Polyurethane w/ fly ash	753	0.124	0.072	0.862	-
Nan Ya Plastics-Neuma Door-foam PVC	999	0.082	0.048	0.570	-
Nan Ya Plastics-Neuma Door-phenolic foam	740	0.029	0.017	0.201	-
Novatech-Foamed PVC	303	0.047	0.027	0.324	-
Plast Pro-cellular PVC framing material	999	0.096	0.055	0.665	-
Ply Gem Windows-Ply Gem G-Force	916	0.093	0.054	0.646	-
Royal Moldings- cellular PVC	635	0.066	0.038	0.456	-
Saint-Gobain-Norseal V730 Foam	85.86	0.025	0.015	0.177	-
Saint-Gobain-SAN 35% Glass Fiber	1216	0.142	0.082	0.986	-
Serious Materials-Ultem 2300	1,522	0.223	0.129	1.549	-
Trinity Glass International - Wood Flour Resin	45.80	0.081	0.047	0.559	0.9
TrueSeal Technologies - Butyl 761-71X		0.231	0.133	1.603	0.9
Unilux-Compressed PU-Foam	451	0.064	0.037	0.443	-
Veka-cellular PVC	775	0.065	0.037	0.449	-

1 **EMISSIVITY FOR NON-METALLIC MATERIALS IS DEFAULTED TO 0.90 WITHOUT ACTUAL MEASUREMENTS**

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