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Thermal Transmission Properties of EPS

I. HEAT TRANSFER

Heat Transfer is the process in physics by which energy in the form of heat is exchanged between bodies or parts of the same body at different temperatures. Heat is generally transferred by convection, radiation, or conduction. Although these three processes can occur simultaneously, it is not unusual for one mechanism to overshadow the other two.

A. CONVECTION

Convection transfers heat through the exchange of hot and cold molecules. This is the process through which water in a kettle becomes uniformly hot, even though only the bottom of the kettle contacts the flame. Convection is classified as either free convection or a forced convection.

Free convection is the movement of a fluid (e.g. air) by natural imbalances caused by a thermal process. The more excited molecules with the fluid move more rapidly than the less excited molecules. These faster molecules move further apart, and this portion of the fluid becomes warmer, expands, and rises. All heat, however, does not rise. The majority of heat will rise in still air spaces and still liquids. All heat transfer is subject to temperature differences. The direction of motion is toward the cold side.

Forced convection is the movement of a fluid (e.g. air) by a fan or pump.
Air is composed of molecules, which are relatively far apart. The less dense the air, the fewer molecules it has per cubic unit and the slower is the rate of heat transfer. When air is compressed by force, its molecules are closer together and its heat transfer rate increases. This is easily observed when wind blows on the outside of a structure. The air film next to the structure is compressed, the density of molecules in the air film increases and so does the heat transfer rate. If the wall is colder than the air or wind, the transfer of heat will be from the wind into and through the wall. The reverse is true if the wind is colder than the wall. Convective heat transfer of air is consequently dependent upon the conductive thermal resistance of the film.

B. RADIATION

Radiation is the transfer of heat via electromagnetic (usually infrared) radiation; this is the principal mechanism through which a fireplace warms a room. Radiation is the emission of energy from a body or object. This energy travels at the speed of light. This process is fundamentally different from both conduction and convection in that the substances exchanging heat need not be in contact with each other.

C. CONDUCTION

Conduction is the transfer of heat along a solid object. It is this process that makes the handle of a poker hot, even if only the tip is in the fireplace. The rate of heat transfer is a function of the density of the solid and its molecular makeup. Because of low thermal resistance (R), the rate of heat transfer through one inch of concrete is much faster than it is through one inch of wood, glass or insulating materials. The rate of heat transfer depends not only on thermal barriers, but also on temperature differences. Heat transfer is also a function of time and the direction is from the warm side to the cold side.

II. HEAT TRANSFER THROUGH EXPANDED POLYSTYRENE

Heat transfer through EPS occurs from all three modes: radiation, convection, and conduction. A large portion of heat transfer occurs from radiation of heat from the cell wall. At extremely low densities the cell walls begin to lose their ability to radiate heat and the overall R-value decreases. The ability of heat to transfer through (liquid) air via convection is dependent upon the cell size and its ability to inhibit the air molecules from becoming excited and vibrate. As the density of the EPS increases above about 2 lb/ft^3, the convection of heat increases while the R-value decreases. Conduction of heat through the polystyrene is the third mode of heat transfer. Polystyrene in itself is not a good insulator and transmits heat easily. As the density or mass of EPS increases, the R-value decreases. Thus, the most effective use of expanded polystyrene as an insulator is generally within the range of about 0.9 to 2.0 pcf.

III. MEASUREMENT OF HEAT TRANSFER

For the purpose of measuring heat transfer, insulating materials such as molded expanded polystyrene are considered solids and the mode of transfer is by conduction. The standard test method for measuring heat conduction is by use of ASTM C518 "Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter". Definitions of thermal terminology can be found in ASTM C 168 "Standard Terminology Relating to Thermal Insulating Materials". Some of the more important terms and mathematical relationships are herein provided.

k-value Thermal conductance (C), the quantity of heat (Btu) which will flow through a one-square foot section of a 1-inch thick homogenous material, during one hour when there is a 1°F difference in the hot to cold side of the sample being tested. Thermal Conductance and Thermal Resistance are the reciprocals of one another.

Thus: **C** = Btu / (h • ft^2 • °F)

C = W / m² °K

R-value Thermal resistance is an index of a material's resistance to the flow of heat. The higher the R-value, the better the resistance to the flow of heat (Btu's) and the better the insulation. R-values are usually reported for 1-inch (25.4

mm) of thickness and are not necessarily per inch of thickness. Thermal Resistance and Thermal Conductance are the reciprocals of one another.

Thus: R = **1/C or** (F • ft^2 • h) /Btu
= **(°** K • m^2**)** / W

The Federal Trade Commission Trade Regulation Rule (16 CFR Part 460), 1978 requires that the R-value of all insulation used in residential construction must be reported at 75°F (23.9°C).

REFERENCES

ASHRAE HANDBOOK - FUNDAMENTALS, I-P Edition. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA

ASTM C-168, Standard Terminology Relating to Thermal Insulating Materials

ASTM C-518, Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat-Flow Meter Apparatus

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