Dimensional Stability

The dimensional stability of an insulation material is a property that is absolutely necessary for the faultless function of an insulation system. The term implies not only the reversible linear coefficient of expansion, which depends on the temperature, but also irreversible changes of dimensions which can be caused by influences of temperature, water or humidity and also by too-high loads.

Dimensional changes in materials are caused by their thermal expansion coefficients. This is the rate at which materials shrink or expand when they are cooled down or heated. Practically all materials have an expansion coefficient that is dependent on the chemical composition of the material. In general, organic materials have a greater expansion coefficient than inorganic materials. This is the also the case with insulation materials.

Proper insulation performance is greatly dependent upon the dimensional stability of the insulating material, and dimensional stability itself is affected by both the:

- Reversible, temperature-dependent, linear coefficient of expansion.
- Irreversible changes related to temperature, load and humidity/water.

Poor dimensional stability can cause swelling, expansion, shrinkage and buckling of a system's insulation. These actions, in turn, can eventually lead to thermal bridges, coating/waterproofing breaches and unpredictable insulation performance.

PROBLEMS

- *Reversible Changes*

  The thermal expansion coefficient of a material—usually dependent on chemical composition—indicates the rate of reversible, dimensional change seen during heating or cooling. With organic insulations, these coefficients vary with production method, and are usually greater than with inorganics—often up to 10 times greater than cellular glass.

  For example, with one roofing system, the thermal expansion of the extruded polystyrene foam insulation was not sufficiently considered. The resulting expansion and contraction ruined the fully bonded waterproofing system and claims against the manufacturer totaled about $100 million.

- *Irreversible Changes*

  These have various causes, including aging. With plastic foams, especially polyurethane, post-production shrinkage requires that several days pass before cutting is performed. Foamed in-place PUR-insulations can be susceptible to blistering and the outgassing of foaming agent residues in expanded polystyrene may create shrinkage of up to 2%.

  Temperature fluctuation can also cause permanent changes in foamed plastic dimensions. Test on phenolic foams have produced changes of up to 15% by volume, when heated to 266°F (130°C) or higher—which could become critical in case of fire. Even inorganic insulation for high temperature applications over 302°F (150°C) can exhibit changes in dimensional stability. Calcium silicate, for example, will shrink up to 1.5% at 1202°F (650°C).

  In cold systems insulated with low-density polyurethane, in-cell gases can condense, cell walls break down and insulation collapse occurs.

- *Temperature/Humidity Combination*

  During storage, transportation or installation, moisture can enter an insulation. It can then become trapped through encapsulation when waterproofing layers are applied through a faulty or damaged vapor retarder. These occurrences, combined with ambient temperature changes and solar radiation, can cause a remarkable change of insulation dimensions. Polyurethane at 158°F (70°C) and 85% relative humidity (ASTM 2126) shows an irreversible expansion of 3%, or 0.36 in/ft (30mm/m). One manufacturer of this material candidly states that even greater changes are possible under thermal cycling at varying humidities.

Under similar conditions, phenolic foams exhibit shrinkage of up to 2%—depending upon the measurement direction. Unfortunately, some manufacturers provide information for just one condition or periods of 7 days maximum.

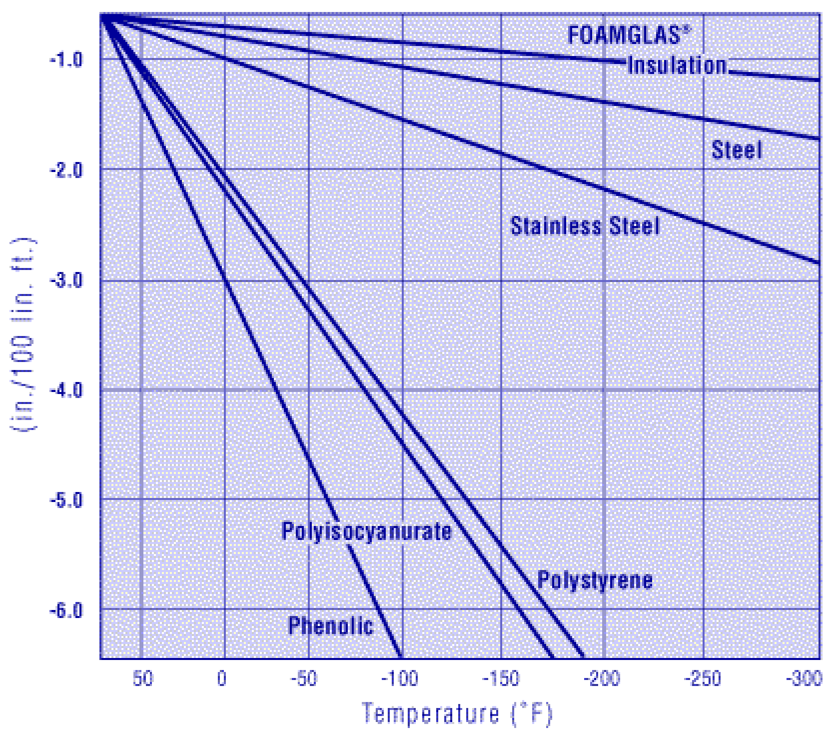
- *Temperature/Loading Combination*

  The influence of load at elevated temperatures must also be considered as a possible source of dimensional change, with potentially severe consequences. As a result, foamed plastic manufacturers publish temperature-related load recommendations to hopefully prevent damage to the insulated structure.

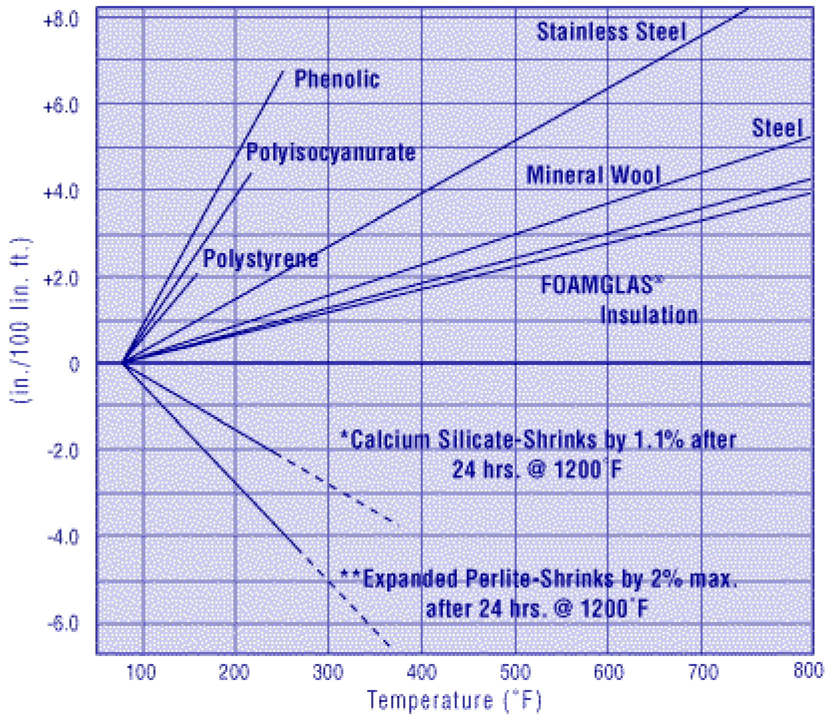
- *Types of Distortion*

  With foamed plastics, severe warping or buckling can occur. If applied at room temperature with tightly butted joints and then exposed to solar radiation, the top surface will heat up and enlarge, while the lower surface remains cooler, resulting in deformation. With in situ sprayed polyurethane foam, blistering shows that dimensional stability can be influenced by personnel, weather and mechanical equipment during application.

Thermal Contraction of Insulations vs. Steel (70°F to -300°F)



Thermal Expansion/Contraction of Insulations versus Steel (70°F to 800°F)



- *Open Joints or Cracks*

  These result from the thermal expansion or shrinkage of certain insulations. On three ships, large cracks developed in the polyurethane insulation of several LNG containment vessels, ending their LNG service.

  At cryogenic temperatures, the joints in polyurethane insulation open substantially. In tests conducted on two-layer urethane systems, the joints were wide enough to permit convection and a substantial increase in heat gain (174% on liquid nitrogen systems). With polystyrene roof insulation, the reduction in thermal efficiency due to open joints is estimated at about 10%.

- *Insulation/Coating Interface Stresses*

  These develop from the varying expansion and contraction of insulation system components coupled with the irreversible dimensional changes in some insulations. These stresses have been examined and predicted by computer models and are quite impressive. The best-known example involved a waterproofed, extruded polystyrene roofing insulation system. In applications around the world, numerous installations developed cracks and leaks due to polystyrene shrinkage—with enormous damage and lawsuits resulting.

The FOAMGLAS® Cellular Glass Insulation Solution

- *Reversible Temperature-Induced Changes*

  Cellular glass exhibits quite minor linear expansion, 0.006in/ft (0.3mm/m), over a temperature difference of 100°F (38°C). Other insulations, especially plastic foams, have an expansion coefficient up to 10 times higher. Because the reversible expansion of cellular glass is so close to that of steel and concrete—the system materials most often being insulated—little or no movement will occur at the insulation joints when temperature changes occur in the system. Such installation contributes to system safety and life.

- *Irreversible Temperature-Induced Changes*

  Years of service performance and testing have shown that there are no irreversible dimensional changes with cellular glass. Even at 752°F (400°C), there is no shrinkage—as seen with other inorganics.

- *Humidity-Induced Changes*

  Again, both service and testing show that cellular glass remains dimensionally stable in extreme humidity. Tests at 68°F (20°C) and 95% relative humidity show no changes in the insulation.

With FOAMGLAS® insulation, all these problems are avoided because this material has a very small coefficient of expansion and also excellent dimensional stability, even under the influences of temperature, humidity and loading conditions.