Proper Use And Application Of Flexible Closed-Cell Insulation

By Roger Schmidt

Flexible closed-cell insulation materials were first introduced over 50 years ago.

Over this time period, this group of insulation materials has grown considerably in the types of product offered. They have been successful in preventing condensation and energy loss (heat transfer) in refrigeration, air conditioning and chilled water applications. They have also been used in applications ranging from domestic hot water to original equipment manufacturer (OEM) applications such as water coolers, chillers, and air handling equipment. A secondary effect to saving energy and natural resources is the reduction of greenhouse gases when energy is wasted.

Closed-cell insulation is defined as insulation composed of small individual cells separated from each other. Closed-cell products may be based on elastomeric polymers, glass or foamed plastics such as polyolefin, polystyrene, or polyurethane. The term, flexible closed-cell insulation materials, further defines the range of products which can be classified under this description. Combining the inherent performance features of a closed-cell structure with a flexible material that is easy to install provides the end user a product that is well suited for many applications.

Flexible closed-cell insulation materials fall into two categories: elastomeric and polyolefin based. Elastomeric products as a classification will be discussed first.

GENERAL DESCRIPTION OF ELASTOMERIC-BASED INSULATION

Elastomeric products are commonly based on a blend of poly vinyl chloride (PVC) and nitrile butadiene rubber (NBR) using a chemical blowing agent. The basic processing steps in manufacturing the product are mixing, extrusion, or shaping and heating. During the heating step, the elastomeric portion of the product is crosslinked, or vulcanized, and the chemical blowing agent decomposes to produce primarily nitrogen gas.

The first product of this type -sheet form - to be used as an insulation material was produced in the 1930s. In the late 1940s, sheet materials similar to what are being used today, except those manufactured via a press-molded process, were commercialized for use by the military for insulation and padding applications.

The first continuous tubing product was manufactured in the 1950s. Continuous sheet products were first made by splitting a large tube but are now also extruded flat. Sheet products are offered up to two inches thick and seventy two inches wide. Tubular products are offered with inside diameters up to eight inches and thicknesses through one inch walls.

The vast majority of elastomeric products sold to date have been based on a PVC/NBR rubber polymeric blend. The standard elastomeric products contain PVC as well as other halogen containing ingredients, which enhance the flammability characteristics of the product. A new class of elastomeric products has been introduced recently. This new class of materials is not based on PVC but on other polymeric blends and contains no halogens. These blends eliminate the potential problems associated with halogen containing products such as corrosive smoke generated when the product is burned. However, the current non-halogen products on the market do not meet a 50 rating on the smoke developed index in standard thickness when tested according to the American Society for Testing and Materials (ASTM) E-84 (a requirement commonly required for commercial insulation applications.)

Elastomeric products offer excellent flexibility, low water vapor transmission (WVT of 0.1 perm in. or less), thermal conductivity (k) similar to other insulation materials (0.30 BTU-in./hr.-sq. ft. F or less at 75ºF mean temperature) and flammability properties which meet the requirements of model building codes. Other attributes which are generally derived from this polymeric blend are good oil and ozone resistance and excellent adhesive/coating receptiveness. Typical use temperature ranges listed are -70ºF (-57ºC) to 220ºF (105ºC). Although all closed-cell elastomeric products are going to share many similar physical properties, a wide range of additives (fillers, plasticizers, aging and flame inhibitors) can be incorporated to enhance the product's physical properties.

Elastomeric insulation products have been used to prevent condensation on refrigeration and heating, venting, air conditioning (HVAC) applications. Within its stated temperature range, there are few restrictions which would prohibit the use of this product with proper installation techniques. It can be used on plumbing (hot and cold water), burial applications, duct insulation and hot water heating systems.

GENERAL DESCRIPTION OF POLYOLEFIN-BASED INSULATION

A Japanese based company, Sekisui, first introduced flexible closed-cell polyolefin materials in the 1960s. The first polyolefin tubular products were produced by thermoforming cross-linked polyolefin sheet into a tubular form. This process is still used in some parts of the world. However, the predominantly used product in North America today is based on a non-crosslinked polyolefin/physical blowing agent process (direct extrusion) which was introduced in the 1970s.

Poylolefin-based insulation materials employ an entirely different manufacturing technology than the elastomeric materials; relying on the thermoplastic nature (sharp melting point) of the polyolefin base resin to form a structure around a physical blowing agent (gas) which has been mixed into the polymeric matrix. The ingredients are fed (metered) directly into the extruder. The extruder blends and melts the ingredients while they are being conveyed forward. The physical blowing agent is added to this mix under high pressure. Physical blowing agents are gases or combination of gases such as hydrochlorofluorocarbons (HCFC), hydrofluorocarbons (HFC) or hydrocarbons (e.g. Isobutane).

Chlorofluorocarbons (CFCs) are no longer allowed to be used in the manufacture of polyolefin insulation products as legislated by Congress. As the mix exits the extruder through a high-pressure sizing die, a cellular profile is formed and cooled by the expanding foaming agent.

The product is further cooled to ambient temperature and cut to length. This process allows the product to be manufactured at 2-pcf density or less. Polyolefin-based tubular products are manufactured in sizes with up to six inch inner diameters through one inch wall thicknesses. Sheet product is generally manufactured in thinner thickness - one half inch - and heat laminated for thicker thickness. Polyolefins is a broad polymer family including polyethylene, polybutylene and ethylene vinyl acetate (EVA). Most polyolefin-based insulation materials contain minor amounts of additives for improved ultraviolet (UV) protection, added flexibility, or limited flame retardant. Polyolefins offer general physical properties such as excellent low temperature flexibility, low water vapor transmittance (WVT generally less than 0.1 perm in.), thermal conductivity (k) similar to other insulation materials (less than 0.30 BTU - in./hr. sq. ft. F at 75°F.) and excellent chemical resistance to acids. Typical use temperature ranges listed in published literature are -150°F to 180°F.

Polyolefin insulation materials are being recommended for, but not limited to, applications such as plumbing (hot and cold water), underground burial and low temperature applications.

COMPARISON OF ELASTOMERIC AND POLYOLEFIN PRODUCTS

Though manufactured by two different processes, elastomeric and polyolefin insulation products share many physical properties as a result of their closed-cell structure. Both products are non-fibrous, non-dusting and non-toxic. Neither product uses CFCs in manufacturing processes. These products do not contain any latex or formaldehyde based raw materials. Because of their closed-cell structure, both products possess excellent thermal and water vapor transmittance properties. Resistance to compression or compaction is also a result of the closed-cell structure. Closed-cell products do not readily trap dirt or moisture, which eliminates some of the concerns associated with mold and bacteria growth. These products would meet the requirements of standard fungal and bacteria tests (ASTM G-21 and ASTM G-22). The surface of the material is not susceptible to air erosion and is durable enough to be cleaned.

Differences in the products exist in the effects of high and low temperatures, elasticity and burning characteristics. These differences arise from the polymers of which the products are based and the processes used to manufacture them. Elastomeric insulation is crosslinked (thermoset) whereas polyolefin insulation products are thermoplastic. When exposed to very high temperatures, elastomeric insulation will not melt but undergoes gradual continued crosslinking resulting in hardening of the product. However, the product continues to have the same thermal conductivity properties as it hardens - it only loses flexibility which, after installation, is not generally a major concern.

Polyolefin pipe insulations have precise temperature transitions that restrict their allowable temperature-use range. Polyolefin pipe insulations are thermoplastic and as a result, when they are exposed to elevated temperatures (above 200°F) they will soften and deform. At 220° F or above for even a short period of time, such as during a temperature spike, they will melt, resulting in a catastrophic failure.

Because of this risk, polyolefin insulation should not be used on any system where there is the possibility of the system approaching the melting point of the insulation. An example of such a system is hot water heating lines.

Published literature on polyolefin insulation would indicate it would have better low temperature flexibility properties than the elastomeric blends currently used. This may have some importance for insulating a flexible line that will see sustained periods of low temperature service and be flexed while at that temperature. Most elastomeric insulation materials used in the commercial insulation market generally begin to stiffen around 30° F and have a cold crack or brittle point of -40° F. However, although they lose flexibility at sub-freezing temperatures, this does not adversely affect their thermal conductivity properties.

Elastomeric insulation products are more flexible (have a lower modulus) than polyolefin materials at 75ºF. This flexibility or modulus issue has two application implications: first for slide-on applications and second, in the stresses induced on the seams of the product in applications which cycle from hot to cold and can cause expansion and contraction of the insulation up to ten percent.

Standard elastomeric and polyolefin insulation materials used for commercial insulation applications have a Fire Hazard Classification Rating of 25/50 for one inch thickness and below when tested according to ASTM E-84 (Standard Method of Test for Surface Burning Characteristics of Building Materials). However, their burning characteristics are considerably different and may be a consideration in choosing a product for a particular application. Elastomeric insulation products are designed to form a char and reduce the amount of oxygen available to the fire. Polyolefin insulation products do not react in this same manner, rather they melt away from the flame front, causing the insulation to lose continuity with the flame front. ASTM cautions users of any of their standards that the test method may not be indicative of actual fire situations. ASTM E-84 is the most commonly referred to specification in the industrial and commercial construction markets. It is often referred to even when the model building code does not require it. Other small scale test methods that are sometimes referred to are ASTM E162 (Radiant Panel Test) and ASTM E-662 (NBS Smoke Density Test). These are more commonly referred to for mass transit and flooring applications. UL 94 can be required for appliance enclosures and equipment applications.

Limited oxygen index (LOI) can also be specified. There are a host of other flammability test methods which have been developed but have not yet reached the general acceptance of the ASTM E-84 test method. An example of this type of test would be the Cone Calorimeter. This test provides alternate data such as rate of heat release which can provide a better picture of how the material will react in a real fire situation. Full scale burn tests have been conducted but are expensive. Each of the test methods provides the user with different information. Conformance to one test does not imply conformance to another.

The overall hazard of the product should be assessed using a combination of tests that would be appropriate for the end-use application.

STANDARDS AND TEST METHODS

ASTM C-534 (Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form) is the standard most widely used to specify material properties of elastomeric insulation. It details test methods and requirements for the properties that affect the insulation performance.

These include thermal conductivity (k), water vapor transmittance (WVT), water absorption, flexibility and dimensional stability. The standard provides a minimum base line of requirements and a basic set of test methods for comparing common materials. ASTM C 534-94 is in the process of being reviewed and a revision of the standard should be completed in 1999.

There is no current ASTM standard for polyolefin-based insulation materials. ASTM C-16.22 Sub-Committee is currently developing a standard for polyolefin insulation.

The ASTM C-16.22 Sub-Committee has formed a task group to develop a standard for flexible closed-cell foam sheet insulation used as a liner to insulate HVAC equipment and duct systems. The task group is in the sub-committee ballot stages of the standard development process.

INSTALLATION OF FLEXIBLE INSULATION

Proper installation is critical to the insulation system's performance. The saying that "the system is only as good as its weakest link" definitely pertains to installing insulation materials, particularly in applications concerning condensation control. The insulation must be sized properly and the entire system must be closed to outside air penetration for proper performance. Using simple installation techniques, it is easy to seal the entire system, which is critical for condensation control applications. All butt and longitudinal seams should be sealed by use of either a solvent-based contact adhesive, factory applied pressure sensitive adhesive (PSA) or other method recommended by the manufacturer. The use of electrical or duct tape is not recommended. When using a contact adhesive, the adhesive should be applied to both surfaces (thin coating preferred), allowed to tack dry and pressed firmly together. The insulation must also be sealed around all tees, 90s, fittings, valves and at the end of the pipe runs to prevent ambient air from entering the system.

This can be easily done by applying a thin coating of adhesive to the pipe and the inner diameter (ID) of the insulation. If the system is not sealed properly, condensation will form between the pipe and the ID of the insulation, generally accumulating water in the lowest place along the pipe run. If condensation forms on the outer surface of the insulation, then additional insulation thickness was required for the operating parameters.

When installing the product, it is important not to stretch the insulation. It should be pushed rather than pulled. Stretching results in two problems: first, reduction in thickness and second, it can result in stress on the insulation. All joints or butts should be fitted under compression to ensure good sealing. Insulation should only be applied to systems that are unheated at the time of installation for this same reason.

Flexible closed-cell insulation is easy to cut and fabricate. No special fittings or mechanical clips are needed. These products are non-abrasive and no special installation precautions are required. Flexible closed-cell products are very uniform and consistent.

Sliding around 90 degree bends is a common practice for ¾" wall thickness and below, particularly on refrigeration applications. This practice eliminates a longitudinal seam and speeds up installation, which are benefits to this type of application. However, for optimum insulation performance, 90-degree bends and tight radiuses such as P Traps, particularly on thicknesses above three quarters of an inch, should be mitred.

By sliding the insulation around the 90 degree bend, the insulation is stretched as it goes around the outer bend, causing the insulation to lose thickness at that point. Depending on the wall thickness, the loss can reach up to 40 percent. This causes it to lose insulation value, which may allow condensation formation. In addition, because the insulation is stressed at that point, the stresses may cause it to age prematurely and crack.

Sheet insulation installed on ductwork should be fabricated, not wrapped for the same reasons. The insulation should be adhered to the entire surface of the duct. When installing insulation on the outside of a duct, it is recommended to fabricate the product such that a water shield is formed on the edges. This is accomplished by cutting the top section such that it overlaps the side section and the side section overlaps the bottom section. This protects the edges from abuse and potential water seepage between the insulation and the duct.

Outdoor weathering of any insulation material that will be subject to the harmful effects of ultraviolet radiation, ozone and oxidation is a concern. Elastomeric- and polyolefin-based insulation products have been used outdoors where exposure to sunlight is limited without any added protection from the effects of UV rays. An example of this exposure is when insulation is applied to the refrigerant lines from a heat pump to the house. In this application, UV exposure is limited and the product meets the customer's expectations. However, for optimum outdoor performance or applications where UV exposure is severe (e.g. roof top applications), these products must be protected from light degradation with a UV resistant coating, mastic or jacketing depending on the environment and the application. Elastomeric products will become stiff, harden and crack when exposed to UV. Polyolefin products will break down to a powder when exposed to UV. Excellent adhesion can be achieved between elastomeric insulation and typical coatings on the market. Coatings should be applied to a clean, dry surface. Generally two coats are required. Water-based coatings should be applied and allowed to dry at temperatures above 50°F .

Closed-cell insulation materials are resistant to water absorption. However, special precautions must be taken for applications where the product will be exposed to sustained periods of water contact, particularly if the water is under a hydrostatic pressure such as burial applications below the water table. Water will gradually be absorbed by the product, causing it to lose its thermal properties. Ground water infiltration or seepage may also carry corrosive contaminants which may be damaging to steel and copper pipes. In applications where this is a concern, insulated pipes can be encased in a sealed conduit made of PVC pipe which will protect it from water infiltration as well as compression. For burial applications above the water table, the use of clean fill such as sand (3"- 5" layer) to provide good drainage and care in backfilling to avoid compaction has been successfully used. It is extremely important that all seams and butts be sealed completely to prevent water infiltration between the insulation and the pipe.

Because the material is flexible by definition, precautions should be made not to compress the insulation which will cause it to lose thickness. Compensation for that loss or special fabrication techniques should be employed. An example is on pipe hangers where the insulation would be under compression unless special fabrication techniques are used. In this situation, it is recommended that a metal shield be used to spread the load in conjunction with support devices. Support devices are typically short lengths of wood dowels or blocks which are the same thickness as the insulation and inserted in the insulation.

The holes cut into the insulation for the supporting devices should be undersized to ensure a tight fit. The support devices should be coated with contact adhesive prior to insertion in the holes. They should be inserted while the adhesive is still wet, then the outer surface should be coated with adhesive to form a vapor seal. The supporting devices rest on the metal shield which is installed between the insulation and surface and the pipe hanger. Larger pipes will require wood blocks approximately 1" x 3" by the insulation thickness. Contouring the blocks to the shape of the pipe will provide even support. It may be necessary to use additional support devices (dowels) placed along the curvature of the insulation (four and eight o'clock positions) to maintain proper positioning of the pipe.

APPLICATIONS

The primary markets for these products are refrigeration, HVAC and plumbing, applications for the purposes of condensation prevention, energy savings, improved equipment performance, water savings, freeze prevention, noise reduction and personal protection. Energy savings can improve the operating efficiency of the equipment and can even go so far as to reduce the cost of the original unit by allowing the use of smaller equipment to perform the same function as a larger unit that is not as well insulated. When these products are used on hot water plumbing lines, water savings are accomplished and can be significant in areas such as the southwest.

Flexible closed-cell insulation products are ideal for preventing condensation (maintaining the outer surface of the insulation above the dew point). The closed-cell structure of the product provides an inherent moisture vapor retarder (0.1 perm-in. per ASTM E-96 or better) and an excellent thermal barrier. In most applications, there is no need for an additional moisture vapor barrier layer/jacketing which can be torn, punctured or otherwise penetrated. For applications that may be subjected to long periods of high humidity and below ambient operating temperatures (above 90 percent relative humidity (RH) and 90°F ambient temperatures) an additional water vapor barrier may be required to maintain proper performance of the insulation. The temperature/humidity range over which the majority of condensation control applications occur do not require the use of an additional vapor barrier with these products.

Key factors in determining the proper insulation thickness to prevent condensation are pipe size, operating temperature, ambient temperature, wind speed, emissivity (heat reflective properties of the insulation) and relative humidity.

Jacketing and protective coatings can also affect the insulation thickness required. Examples of how these parameters affect the insulation thickness recommendation are given in Table 1 on the previous page.

Emissivity (the ability to emit or reflect heat by radiation) may be a factor in determining insulation thickness to prevent condensation, particularly for outdoor applications. Emissivity theoretically can range from 0 to 1 but would generally range from 0.25 for insulation with a white protective jacketing or wrap applied to 0.85 for the black insulation. Most recommendations provided in the published literature conservatively use a value close to zero as the emissivity factor. For condensation control applications, the intent is to maintain the surface temperature of the insulation above the dew point. In this situation, the black color provides an advantage.

Elastomeric insulation products are well suited for HVAC and refrigeration applications because of their flexibility which allows for low stress on the butt and longitudinal seams during the expansion and contraction of the system when it cycles from hot to cold. The ability to seal the system from outside air intrusion is another main reason these products are used in this area. Elastomeric insulation has been successfully used on hot water heating systems as well.

Polyolefin insulation is well suited for applications which do not cycle between hot and cold such as plumbing applications. The low cost of the product and ease of installation are reasons it is widely used in the "do-it-yourself" market.

Flexible closed-cell insulation products are used to prevent pipes from freezing. In this application it is important to note that insulation will prolong the period of time prior to freezing. However, where there is no liquid flow and when the temperatures are cold enough for a long enough period of time, freezing will occur. The use of commercial heat tapes is acceptable with elastomeric and polyolefin based products subject to the heat tape manufacturer's specific recommendations.

Flexible closed-cell insulation products are available in a wide range of sizes to fit most tubular applications. Large diameter tubing can be insulated with sheet. In these situations, the sheet should be cut to the proper width to fit the pipe diameter. Never stretch the sheet to fit the pipe. The sheet should be adhered along the seam and butts only, not to the pipe itself. In certain applications, the recommended wall thickness may exceed 1". In these cases, the product can be sleeved or a layer of sheet insulation can be used to obtain the recommended thickness. Failure to seal the system properly will result in condensation on the pipe between the insulation and the pipe. Failure to use the correct wall thickness for the application conditions will result in condensation on the outer surface of the insulation. Use of fans to create air movement will assist in drying out the insulation if problems occur.

THERMAL CONDUCTIVITY VALUES

Temperature affects the thermal conductivity properties of closed-cell materials. Thermoconductivity values (k factors) may vary from .30 BTU - hr./in. sq. ft. F at 100°F to .16 BTU - hr./in. sq. ft. F at -100°F. Many applications for these products are below ambient temperature, thus benefiting from this effect.

In determining thermal conductivity of a closed-cell material, the samples should be properly aged to allow normalization of the gases in the cell with the atmosphere. The time for this process to occur varies with each of the materials discussed in this paper. If the samples are not allowed to age properly, erroneous k values can be obtained. The supplier should check with the material vendor to verify the aged k factor of the product.

AVAILABLE INFORMATION

Manufacturers of flexible closed-cell insulation have installation guides available. The National Insulation Association (NIA) has a video on the topic. Information on the determination of the recommended thicknesses to prevent condensation for specific applications is available in many formats from published guidelines to PC-formatted disks. Technical Bulletins on special application situations are available from the manufacturers as well. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) also provides guidelines for use of insulation products. Specific application requirements can be found in the model building code, state and local building codes and through the National Fire Protection Association (NFPA).

PRODUCT FORMS OFFERED

Flexible closed-cell tubular insulation is offered for use in the following three forms: unslit, slit, and slit with PSA on the longitudinal seam for easy installation. The product is available in standard forms of six foot lengths. In addition, three foot lengths and continuous coiled product are also available.

Flexible closed-cell sheet insulation is offered with or without PSA in rolls or sheets. Standard rolls are 48" wide x 50' long but widths up to 72" and lengths of 200' rolls are also offered. Standard sheets are 36" x 48" for easy handling.

The use of products supplied with pre-applied PSA in either tubular or sheet form has grown rapidly in the past five years. The use of such products greatly reduces the need for solvent-based contact adhesives and provides a consistency that is difficult to match in the field. The added cost is offset by greater ease and efficiency of installation.

SUMMARY

Flexible closed-cell insulation products, both elastomeric- and polyolefin-based, offer the insulation market a product that is easy to use and very effective in preventing condensation and energy loss in a wide range of applications. The combination of flexibility with a closed-cell structure makes them well suited for many applications.

Introduction of these product forms such as PSA/self-seal products increases installation efficiency and consistency of the job. The marketplace is looking for products that offer a consistent high level of performance but are easy to use.

As the number of products in this insulation category increase, care must be taken to select the correct product for the specific application and install it properly. The price of the insulation is only one factor in the overall cost of a job; labor, installation tools required, material damage or scrap during installation/fabrication, and time to complete the job are all significant factors to consider. There is no price that can be put on the peace of mind that comes from knowing a job was done right and will perform for many years. After determining your specification needs, selection of the correct product is key to a first class job and will ensure long term success of your project.

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