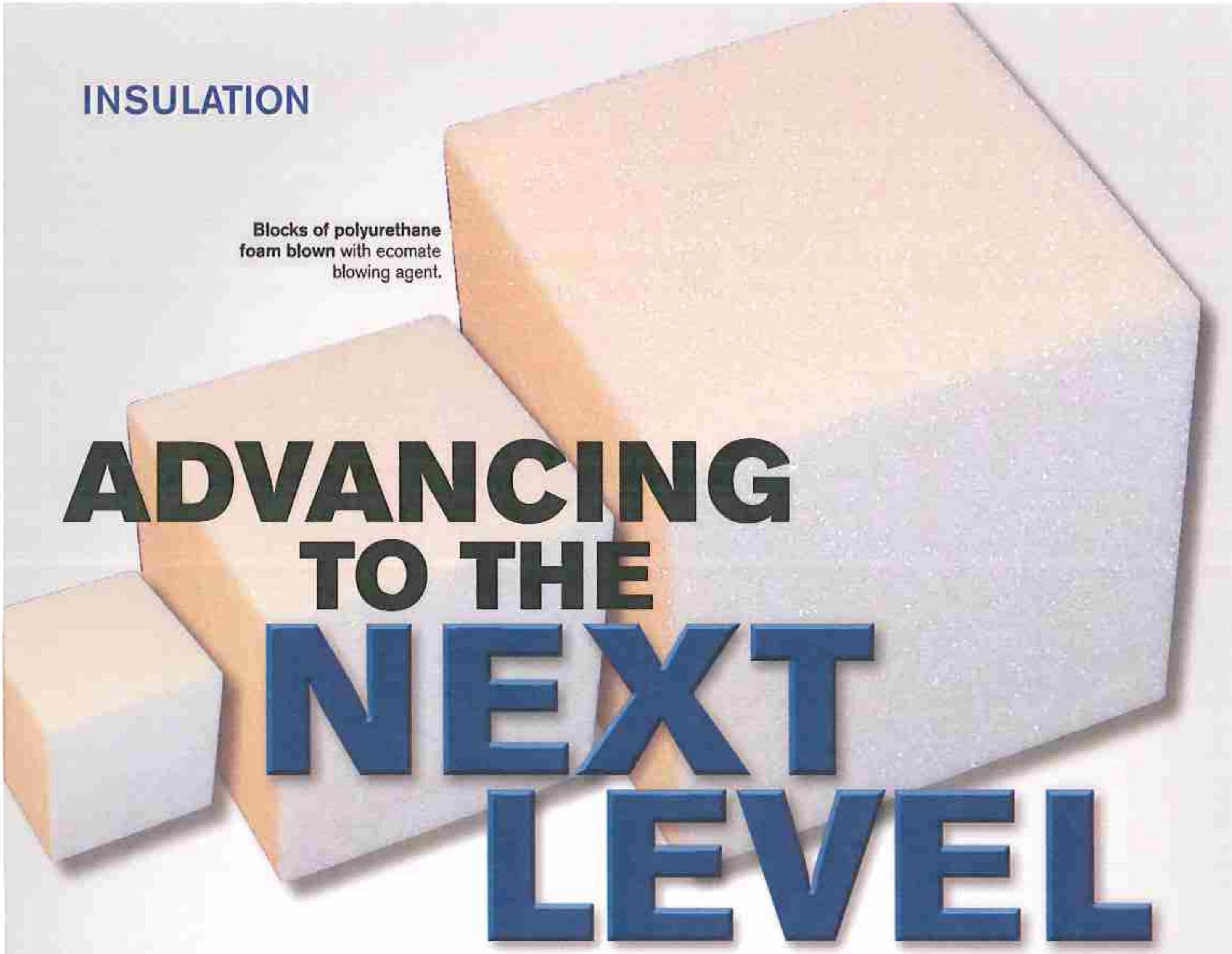
ADVANCING TO THE NEXT LEVEL



Blocks of polyurethane foam blown with ecomate blowing agent.

Alternate blowing agent targets residential appliances.

by john murphy

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With the mandated phase-out of HCFC-141b as a blowing agent for polyurethane insulation, manufacturers of refrigeration appliances were faced with limited choices for alternatives, primarily hydrocarbons or hydrofluorocarbons (HFCs).

Those concerned about the flammability of hydrocarbons steered toward HFC options. But as global warming has risen on the political and public agenda, the high GWP values of the HFCs have raised questions about their long-term future as blowing agents. That concern has spurred development of other low-GWP alternatives such as hydrofluoroethers (HFEs) and hydrofluoroolefins (HFOs).

The HFEs and HFOs present a number of potential issues, chief among them cost. More importantly, they are not yet commercially available for refrigeration insulation applications.

There is, however, another low-GWP alternative blowing agent that is commercially available and already proving itself in the field. The patented methyl formate solution is called ecomate, and was developed by Foam Supplies. In addition to making a refrigeration appliance more environmentally friendly, the ecomate blowing agent is also cost-effective and delivers on other criteria required for such appliances, including good fill properties, good dimensional properties, and good thermal properties.

Hydrocarbons such as pentanes are also being used to blow foam insulation, but this choice brings with it the issue of flammability, along with the various process changes required to deal with it. In addition, this route often requires acceptance of poorer lambda values.

While ecomate (neat) is also flammable, it is far less flammable than hydrocarbons, which has been documented in previous papers. When blended into polyol (or isocyanate), ecomate can be handled in the same way as HCFC-141b. The two have almost identical properties, such as boiling point, solubility, and flammability.

On the commercial refrigeration side, eco-

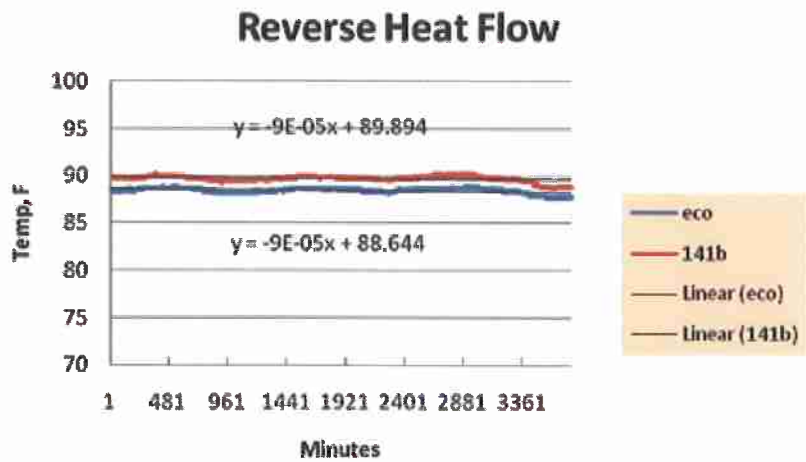

Fig. 1. Reverse Heat Flow of ecomate-blown and HCFC-141b-blown freezer chests at 40 DegF.

mate is already helping appliance manufacturers design improved products. One OEM found that, after switching to ecomate blown foam, its cabinets surpassed Energy Star requirements by 23.7 percent.

A leading manufacturer of beverage dispensers found that ecomate provided superior flow and fill properties to the previously used HFC-134a based system, and the insulation properties were identical as measured by side-by-side ice melt testing.

Another commercial appliance manufacturer who converted to ecomate achieved the same insulation values at the same thicknesses as the original products while using 10 percent less foam.

Inspired by these successes, we asked a maker of residential refrigeration appliances to build a number of units with ecomate blown foam. The unit selected was a 7 cu. ft. freezer chest.

The actual dimensions of the unit are 6.67 cu. ft inside and 13.17 cu. ft. outside. It required 9.5 lbs. of foam at a targeted 2.13 pcf core density. The foam was dispensed in 3.23 seconds through a 40 ppm high-pressure machine. The demold time was 2.5 minutes after shot time.

While the thermal properties of a neat blowing agent give an indication how a specific blowing agent might perform, the industry usually requires that several units be made and tested by a procedure called Reverse Heat Flow Analysis to ascertain its ability to adequately insulate independent of the compressor.

In order to conduct a modified Reverse Heat Flow test, a second unit made by the same supplier was purchased from a local hardware store. Its dimensions were slightly

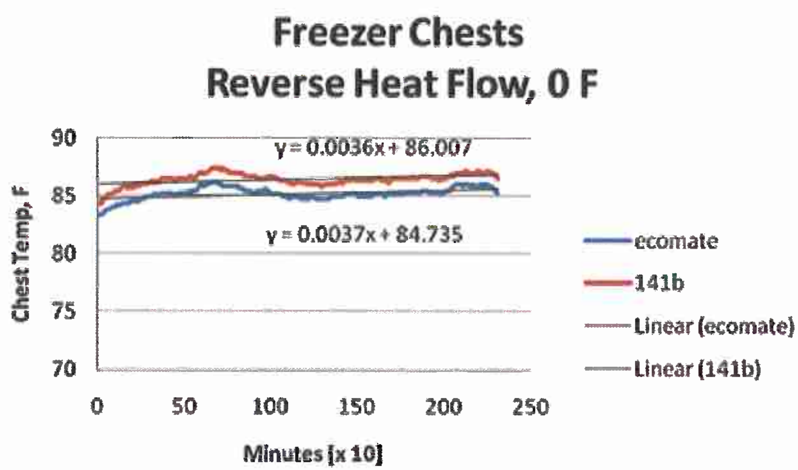

Fig. 2. Reverse Heat Flow of ecomate-blown and HCFC-141b-blown Freezer Chests at 0 DegF.

different, measuring 6.88 cu. ft. inside and 13.77 cu. ft. outside.

The reason for the variance was that the purchased unit was made in China and its foam blown with HCFC-141b. This was not a perfect side-by-side comparison, since no current foam blowing agent can equal the gas lambda of HCFC-141b, which is 10. Gas lambda for ecomate is 10.7.

In the first test, both of the units were placed inside a walk-in refrigerator, maintained at 42 DegF. Heat was generated inside the freezer cabinets by a 40 W light bulb that was transformer controlled to 89.9 V. Temperatures inside both units and inside the walk-in refrigerator were monitored with three Extech RHT10 temperature probes, one for each unit and one for the ambient cooler. The units were monitored once each minute for 70 hours.

There was some variation in the minute-to-minute readings of each box that follows the cyclic variation in the electricity supply during each 24-hour period, which affected the wattage of the bulbs used. Nonetheless, the recorded data showed that both units had the same slope and differed only by the average temperature they held over those 70 hours.

The average temperature for the chest blown with HCFC-141b blown foam was 89.894 DegF. The average temperature for the chest blown with ecomate foam was 88.644 DegF. (A difference of 1.25 DegF.)

We then decided to place the two units in a cold-storage freezer maintained at 0 DegF. The ambient temperature in this freezer averaged -1 DegF. The chests under test were heated in the same manner, this time using 100 W bulbs.

An attempt was made to get the interiors of the freezer chests to 90 DegF, but fell slightly short. The rheostat was set at 75 percent in this trial. With a delta temperature this time of almost 90 DegF, both chests again did remarkably well.

The chest blown with HCFC-141b blown foam averaged 86.007 DegF. The chest blown with ecomate foam averaged 84.735 DegF. (A difference of 1.27 DegF.)

It bears noting that the ecomate foam used in these tests was not optimized for this particular application. In our first effort, our reaction rates were slow, our densities high, and our closed cell content low. This lack of optimization resulted in poorer than expected thermal performance.

The thermal conductivity of urethane foam is affected by both the thermal conductivity of the blowing agent and the polyurethane matrix – the fineness of cells and their orientation. The finer the cells, the better the insulation. And the faster the reaction rate, the finer the cells.

However, faster reactivity may prove to be a challenge in terms of processing, resulting in reduced flow and elongated cells. Our formulation, while finally having the required reactivity, did not have the flow parameters (flow index and core/fill ratio) it needed, nor did it have the desired closed cell content. In spite of these deficits, it did very well in the reverse heat flow tests.

We have recently developed ecomate foam formulations that achieve the desired thermal properties and are optimized for residential refrigeration applications. We are currently putting these new formulations to the test.

In addition to good thermal properties, the residential refrigeration appliance industry also requires that a blowing agent achieve GRAS (Generally Recognized As Safe) status. This is a legal opinion based upon a large amount of testing to determine that, if the blowing agent should leach through the foam and the plastic inner liner of the refrigerator and be absorbed into the food inside, that it would be in low enough concentration, or have low enough toxicity, that it would be of no consequence to humans. We now have GRAS status for ecomate so that it can be used in residential refrigerator/freezer applications.

With the lowest molecular weight of any commercially available blowing agent, and with pricing similar to hydrocarbons, ecomate is expected to be cost effective from a material standpoint. It will also offer economy of production, since no expensive plant conversions will be required for its implementation.

Finally, there is the environmental benefit. For every pound of ecomate used to replace an HFC, more than one metric ton (2,200 lbs.) of CO2 equivalents can be saved. ■

For more information, visit: *www.foamsupplies.com*

Editor's note: This is an abridged version of a paper presented at the Polyurethanes 2009 Technical Conference.