

“R” You Insulated Against the Next Phase (Out)?

By Paul Nastari

In 1987, you could buy gas for about a dollar a gallon and the average home price in the United States was \$127,200. It was also the year the Montreal Protocol was implemented. The Montreal Protocol was enacted to limit use of ozone depleting substances¹.

Twenty years later, gas prices have continued to climb, along with the cost of real estate. However, the use of harmful, ozone depleting substances – CFC’s (chloro-fluorocarbons) and HCFC’s (hydrochlorofluorocarbons) – has actually been declining. One of the many uses of these chemicals is the production of polyurethane foam insulation used in walk-in coolers and freezers².

While the goal of the Montreal Protocol is to reduce the harmful impact of these substances, there may be unintended consequences that are only now being realized. With CFC’s already phased out and a complete HCFC phase out expected by 2010, it is important to understand what impact this action will have on walk-in coolers and freezers.

This article discusses the reduced insulating ability (R-value) of polyurethane insulation as a result of the elimination of CFC’s and HCFC’s, and will also outline design considerations that can help offset these lower R-values.

Global warming and ozone depletion will be reduced with the introduction of these new materials, but diminished R-values will result in higher energy usage (and higher energy cost). Next generation HFC’s will indirectly contribute to global warming because of higher energy use

unless we offset lower R-values with other methods.

It is also important to note that new, environmentally friendly HFC refrigerants used in refrigeration systems powering walk-ins are slightly less efficient than the now obsolete CFC and HCFC refrigerants. This slight degradation in capacity further reduces system efficiency.

Finally, maintaining high quality refrigerated and frozen product is the sole purpose of a walk-in cooler / freezer system. Thus, product quality cannot be sacrificed in system design. Undersized and oversized systems will decrease shelf life of refrigerated and frozen product.

What Is The Value of “R”

R-value is the measure of resistance of a material to heat flow. The higher the R-value the greater the insulating value of the material. Polyurethane insulation, inch for inch, provides the highest R-value available for use in the production of walk-in coolers and freezers. However, with the elimination of CFC’s and HCFC’s in the production of polyurethanes, the R-value has gone down because newer chemicals do not provide the same insulating value per volume measurement.

As manufacturers of walk-ins move to polyurethanes that comply with the Montreal Protocol, insulating efficiencies of walk-ins inevitably go down. It is important to note that polyurethanes that comply with the Protocol continue to be the best choice for insulating walk-ins.

As an example, in the late 1980s and early 90s a 4" thick urethane panel was constructed using gases known as Freon (R11). These gases had low vapor thermal conductivity and provided excellent R-values, inch for inch (R34). But they also contained CFC's, and so had very high global warming potential, contributing to ozone depletion.

Today, the same 4" panel is manufactured using non-CFC, non-global warming gases (HFC - R245fa and HFC - R134a). These gases comply, long term, with the Montreal Protocol, but provide much lower R-values (R28). This equates to an 18% loss in thermal efficiency.

| Refrigerant Blowing Agent Comparison Of R Values | | | | |
|--|------------|---------------|-------------|--------------|
| | CFC R11 | HCFC R141b | HCFC R22 | HFC R134a |
| Coolers | | | | |
| 3.5" | R30 | R27 | R26 | R25 |
| 4" | R34 | R32 | R29 | R28 |
| 5" | R42 | R38 | R37 | R36 |
| 5.5" | R47 | R42 | R40 | R39 |
| Freezers | | | | |
| 3.5" | R31 | R29 | R28 | R27 |
| 4" | R35 | R33 | R32 | R31 |
| 5" | R43 | R41 | R40 | R39 |
| 5.5" | R47 | R45 | R44 | R43 |

CFC R11 was an original polyurethane blowing agent. Because it was a CFC and contributed to ozone depletion it was banned in the early 90's.

HCFC R141b is obsolete. It was the long time preferred replacement for CFC's in the early 90's. R141b had a lower R value than the old CFC (R11, R12). In anticipation of HCFC bans coming by 2010, this blowing agent/refrigerant was put out of production in 2006.

HCFC R22 is currently widely used in foamed in place polyurethane production as well as refrigeration equipment. It is slated for elimination in new product in 2010. Most foamed in place polyurethane manufacturers are phasing out of this product now.

HFC R134a has been in use for well over 10 years in automotive air conditioning. It is environmentally friendly but has lower insulating capabilities than it's predecessors. The industry has held off converting to this blowing agent because of reduced R-values. HFC R245fa is another promising, environmentally friendly blowing agent. Some urethane users may choose to convert to R245fa. Insulating performance is similar to HFC 134a.

Other non-urethane options are clearly not a solution to this reduction in efficiency either. Fiberglass, expanded polystyrene, and extruded polystyrene have far lower R-values than modern urethane systems. Pentane insulation systems (HC's) are excellent, being non-ozone

depleting and non-global warming systems, but they do not have the high R-values of earlier systems and the capital expense necessary to set up HC manufacturing plants is cost prohibitive.

| Extruded Polystyrene vs Polyurethane R-value Comparison | | |
|--|--------------------------|-----------------------------|
| Wall | Extruded Polystyrene* | HFC R134a** Polyurethane |
| 3.5" | R18 | R25 |
| 4" | R20 | R28 |
| 5" | R25 | R36 |
| 5.5" | R28 | R39 |

*Extruded polystyrene provides the highest R-value of any of the polystyrenes.

**We're comparing to current technology HFC R134a, environmentally friendly polyurethane system.

To add to the problem, not only are the insulating values of modern urethane systems lower than past systems, costs for these insulation systems is considerably higher. The end user is confronted with higher initial costs for walk-in coolers and freezers, as well as facing ongoing, higher operating costs. Striking a balance between meeting environmental concerns and keeping costs in check can be tricky business.

BASF is a leading, worldwide, manufacturer of polyurethane foam systems. Michael Krupa, Technical Services Supervisor at BASF says, "At BASF, we are changing blowing agents to conform to the Montreal Protocol. However, these changes will have a negative impact both on costs and insulation value of the (polyurethane) foam."

In the interest of saving energy, state, county and local building departments are cementing higher first costs for end users by requiring minimum R-value standards for walk-in coolers and freezers. As an example, the California Energy Commission Title 20 requirements for minimum R-values in walk-in coolers is R28 or greater, and R36 or greater for freezers. This means that polyurethane coolers, with new foam systems, need to be at least 4" thick and polyurethane freezers, with new foam systems, need to be at least 5" thick. In the past, 4" thick freezers were the norm and 3.5" thick coolers were not uncommon. It is safe to assume that other states will likely set similar guidelines.

So, how can we minimize higher first costs and ongoing operating costs for walk-in coolers and freezers while at the same time, addressing environmental concerns? We need to combine the best attributes of refrigeration systems, polyurethane insulation and ancillary equip-

ment to provide the end user with lowest possible first costs while insuring lowest possible energy usage (ongoing operating expense). Strategic design solutions from a system standpoint will achieve the desired result.

Geography and regional design requirements; product load considerations; and component selection are the key elements in strategic system design. Before we get back to addressing diminished R-values and appropriate efficient component selections, we will explore geography: regional and local design requirements; and product load considerations.

Geography: regional and local design requirements

You might not expect that geography or system location would factor into refrigeration system design, but it does. Altitude/elevation; average outdoor ambient design conditions; and indoor ambient design conditions all play a key role in system design and ultimately system performance. Improper design results in poor product quality because of poor refrigeration control; increased maintenance costs; and

unnecessarily high energy costs. Accurate, detailed knowledge of the end use environment is absolutely essential.

For example, a refrigeration system operating in Denver, CO will be 5% less efficient than the same system operating at sea level. A system in a high mountain ski lodge will lose 10% or more efficiency as compared to the same system operating at sea level. The thinner air and associated lower barometric pressure at higher altitudes are the cause. Further, an application in a high outdoor ambient location such as Tucson, AZ would require a 20% larger refrigeration system than the same application in Portland, OR. A high average humidity, high ambient, sea level location such as Central America would require a larger refrigeration system than a low average humidity, high ambient, sea level location in Southern California.

Outdoor walk-ins require special consideration regarding geographic location for obvious reasons. But not quite so obvious is alignment of walk-ins in outdoor applications from a north to south, east to west standpoint. The fact that southern exposure walls will have far greater heat loads than northern exposure walls is often overlooked. If the application allows, aligning a short wall to the south will lower heat loads. Doors that open to the outside should also be aligned away from the sun to reduce loads. A free standing outdoor walk-in will have a higher load than a walk-in located next to an existing building wall.

Indoor applications need to be examined carefully as well. Walk-in locations next to exterior walls will have higher loads than units installed away from outside walls. Walk-ins with doors opening to loading docks, dish rooms and kitchen equipment such as steam kettles and ovens, will all have higher operating loads than units with doors opening to non-operating areas. Working walk-in coolers and freezers in high-volume kitchens will have much higher loads than storage walk-ins opening to non-operating areas.

Subtle differences in location, such as humidity, will make a difference in energy requirements. Consider a walk-in freezer with a door opening near a dish room. Frost accumulation at the door frame will require more heat to clear the frost than a door opening into a dry storage area. Larger, pallet-size doors contribute to higher infiltration loads as well as requiring more energy to defrost than standard 36" doors. Furthermore, high volume door usage, adds infiltration load to the walk-in.

It's important to note that local, county and state building codes are changing rapidly nationwide. Acceptable practices of the past may not meet new codes.

For years, the industry has opted for 4" nominal size walk-ins with loads selected from quick-pick charts and

Efficient Component Selection

- Replacing 4" thick polyurethane panels with 5" thick panels will offset the diminished R-value of new foam systems. The added cost of the 5" panel will be offset by less than one year payback for freezers. Cooler payback will be several years depending on application.
- Adding positive door closing features such as cam lift and/or spring hinges, door snubbers or positive closing devices will reduce infiltration of warm air. Door open alarms will help staff be aware of doors held open beyond preset times. Powered sliding doors with auto-close features are a very energy efficient approach for larger applications.
- Automatic light off switches will keep cooler/freezer lights off when not needed. Obviously, energy efficient lights are a must.
- Correctly sized anti-frost heaters on freezer door frames will conserve energy. Strip curtains on doors (especially freezer doors) may be deemed inconvenient but can provide measurable energy savings by reducing infiltration loads.
- Refrigerating more or less space than actually needed is not efficient. Careful attention should be given to shelf space requirements. Once cooler or freezer holding requirements are defined, including shelf space layout, the walk-in should be dimensioned to fit the requirements.

**Comparison of Conditions for 40% Energy Usage Difference
(an extreme example)**

| Wall Thickness | Usage | Ambient Temp | Box Load (btuh) | Cost/Year |
|----------------|-------|--------------|-----------------|-----------|
| 4" | heavy | 110F | 17,600 | \$2,633 |
| 5" | light | 90F | 10,900 | \$1,630 |

Based on a 10' x 20' Walk in Cooler, 1 Door, at \$0.75 kwh. Does not consider altitude or humidity impact.

standard packaged refrigeration systems from catalogues. While adequate in years past, this approach falls far short when considering maximum energy efficiency. In comparing extreme examples of all the conditions listed above, one could expect to see as much as 40% difference in energy usage with a resulting rise in monthly energy costs and possible overloading of the system, all of which could lead to a shortened life-span as well as loss of product quality.

Product load considerations

Product load needs to be well understood as part of overall design. Type of product (meat, produce, packaged

frozen goods, bread dough, etc.), volume and weight of product, frequency of loading, as well as entering and holding temperatures of products all need to be well defined in determining an accurate box load.

The type of product determines humidity requirements and pull down loads. Products with high water content, such as red meat and fish, have significantly higher pull down loads than lower water content products such as baked goods. The volume and weight of the product entering the cooler/freezer as well as the frequency of loading the walk-in all significantly impact the product load.

Entering and holding temperatures are the single most important items in determining product load. As an example, meat entering a cooler at +40F off a delivery truck, and being held at +31F has a 50% higher pull down load than meat entering at +35.5F. The same holds true for produce entering at +50F versus +45F. Consider the impact on product load if vats of warm refried beans are placed in a holding cooler!

Freezer applications are even more severe than coolers. Frozen product coming off a +10F delivery truck

Beech Oven

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Product Load Extremes

Example: 100 lbs of Bread

Cooling Capacity Requirements

From refer truck to cooler (+35 to +35F)
 From non-refer truck to cooler (+60 to +35F)
 From oven cooling rack to cooler (+85 to +35F)

Freezing Capacity Requirements

From refer truck to freezer (+35 to -10F)
 From non-refer truck to freezer (+60 to -10F)
 From oven cooling rack to freezer (+85 to -10F)

| | Temp Change >32 | Cooling btu's Required >32* | Change State btu's @32* | Temp Change <32 | Freezing btu's Required >32* | Total btu's Required | | btuh Capacity (over X hours) | |
|--|-----------------|-----------------------------|-------------------------|-----------------|------------------------------|----------------------|-------|------------------------------|---|
| | | | | | | 24 hrs | 4 hrs | | |
| | 0 | 0 | -- | -- | -- | 0 | 0 | 0 | 0 |
| | 25 | 1750 | -- | -- | -- | 1750 | 73 | 438 | |
| | 50 | 3500 | -- | -- | -- | 3500 | 146 | 875 | |
| | 3 | 210 | 5000 | 42 | 1470 | 6680 | 278 | 1670 | |
| | 28 | 1960 | 5000 | 42 | 1470 | 8430 | 351 | 2108 | |
| | 53 | 3710 | 5000 | 42 | 1470 | 10180 | 424 | 2545 | |

*Bread has a moderate btu requirement; fruits, vegetables, meat and fish have a more extreme btu requirement because of their higher water content, and they use even more energy as a result.

Payback Period & Cost Savings For Energy Efficient 5" Urethane vs. Standard 4" Urethane Insulated Panels

| | Cooler | | Freezer | |
|-------------------------|---------------------|-------------|---------------------|-------------|
| | Energy Efficient 5" | Standard 4" | Energy Efficient 5" | Standard 4" |
| kwh/year* | 30,644 | 31,704 | 29,656 | 35,400 |
| btuh usage | 11,939 | 12,352 | 11,554 | 13,792 |
| Energy Savings | 1,060 kwh/yr | | 5,740 kwh/yr | |
| Cost Savings | | | | |
| 5" Urethane | \$75.00/yr | | \$408.00/yr | |
| EC Motors | \$109.00/yr | | \$232.00/yr | |
| Beacon II Controller | --- | | \$170.00/yr | |
| TOTAL SAVINGS/yr | \$184.00/yr | | \$810.00/yr | |
| Additional costs** | \$602.00 | | \$602.00 | |
| Payback Period | 3.27 years | | 0.74 years | |

*Based on btuh usage/3,413 btu/watt x 24 hrs x 365 days/1000, Cooler 18.5x10.5x8.5 feet, Freezer 18.5x11x8.5 feet.

**Based on move from 4" to 5", use of EC motors and Beacon II Controller.

being held at -10F has a negligible product load. The same product, coming in unfrozen and room temp and being pulled down to -10F freezing temp would have a product load 100 times greater. The heat extraction necessary to freeze a product is huge. Extreme examples would be warm baked goods being moved directly into a freezer. If the freezer was sized for holding loads only and a pull down load such as warm baked goods was introduced, it is probable that it would not be able to freeze the product. The time frame required to get a product to freezing temperature also greatly impacts loads. Consider our warm baked goods example. It is obvious that the load would be twice as high if the bread

dough needed to be frozen in eight hours as compared to 16 hours.

For years, the industry has picked product loads off generic load charts with very healthy safety margins built in, so it was likely that the system was oversized for the job at hand. In the unfortunate case where high pull down loads existed, systems were grossly undersized. Knowing the correct product load allows systems to be sized for the specific job at hand.

Energy efficient refrigeration systems, engineered for well defined walk-in and product loads provide significant energy savings and quick payback. Looking in detail at refrigeration systems is beyond the scope of this article. In general, how-

ever, key areas of energy conservation are:

- correctly sized systems
- microprocessor-based controls
- demand versus timed defrost
- floating head pressure controls
- ECM condenser and evaporator fans
- proper piping practices

Keep in mind, the Montreal Protocol also affects the refrigerants available for use in refrigeration systems. Reduction in performance exists with the new, environmentally friendly refrigerants making correct refrigeration system design very important.

Conclusion

There is no turning back. Ozone depletion, global warming, and the Montreal Protocol have created a sense of urgency among chemical companies and equipment manufacturers to embrace the development of environmentally friendly chemicals. Use of these chemicals will achieve desired results from an ozone depletion and global warming perspective but will deliver diminished R-values. Diminished R-values will create higher energy usage and thus higher operating costs. Indirectly, these next-generation chemicals will add to global warming impact via higher energy usage unless we find other methods to offset lower R-values.

Lower R-values provided by these new chemicals are the "hidden cost" of "going green". The industry has typically picked walk-ins and refrigeration from general, quick-pick charts. This generalized approach worked fine in the time of low cost energy and little concern for ozone depletion and global warming.

Now, the designer must look closely at all the elements of walk-in design in developing an energy efficient, en-

vironmentally friendly refrigeration system. Note the word "system". In order to meet these efficiency and environmental goals, walk-ins must now be looked at as complete operating systems, designed for a specific application. Doing so helps the environment, provides lowest operating costs and ultimately insures the highest quality refrigerated product. This approach makes great business sense and is simply the "right thing to do". 🌍

References:

1. Montreal Protocol, see Wikipedia for an overview at http://en.wikipedia.org/wiki/Montreal_Protocol and get a copy of the protocol itself at <http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf> (Adobe PDF document).
2. Fluorocarbons, for general information see Wikipedia at <http://en.wikipedia.org/wiki/Fluorocarbon>

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