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GAS-FILLED PANELS: A THERMALLY IMPROVED BUILDING INSULATION

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ABSTRACT

This paper discusses the use of gas-filled panel technology as a high-performance, non-CFC insulation for building applications. Gas-filled panels (GFPs) combine low-emissivity surfaces and multiple, low-conductivity gas-filled cavities to minimize radiation, convection, and conduction. The thermal performance of some GFP designs has been independently tested (ASTM 1989) at a national laboratory. Measurements on first-generation prototypes yielded R-5.2/in. (5.2 h·ft^2·°F/Btu·in. [36 m·K/W]) with an air fill, R-7.1/in. (49.3 m·K/W) with an argon fill, and R-12.5/in. (86.8 m·K/W) with a krypton fill. This paper discusses technical aspects of GFP barrier materials and their gas transmission rate requirements, baffle component characteristics, and potential gas fills. We present examples of potential GFP products for various building applications with cost and performance estimates.

INTRODUCTION

While existing building insulation materials can be very effective, improved materials are desirable because of an increasing emphasis on energy conservation and environmental concerns within the building industry. Improving building energy efficiency typically involves higher levels of thermal performance for envelope insulation; this requires either thicker insulation or higher-performance products. Increasing the thickness of building components to accommodate more insulation can be inconvenient and costly. Insulations with greater R-value per unit thickness can thus avoid changing building techniques and improve energy efficiency. The highest-performance building insulations currently in use are two-part, thermoset polymer foams blown with chlorofluorocarbons (CFCs); these have performance levels around R-7.2/in. (50.0 m·K/W). CFCs are to be phased out by 1996 because of their detrimental effect on the earth's ozone layer. This phase-out will force the use of alternative blowing agents that have higher thermal conductivity, which may result in lower-performance foam products in the future and may not fully solve the ozone depletion problem. The performance of foams blown with alternative agents will decrease anywhere from 0 to 25%, depending on which blowing agents are used and on the success of techniques to decrease radiative heat transport. These high-performance thermoset polymer foams and widely used but lower-performance glass fiber insulations may become problematic for use in buildings because of rising environmental concerns over recyclability and toxicity of building materials. Non-CFC blown thermoplastic foams (such as polystyrene) may avoid environmental problems; however, their performance levels are typically R-5.0/in. (43.7 m·K/W) or less.

Gas-filled panel, or GFP, technology can yield new insulation products that have high performance and are environmentally friendly. GFPs employ a low-emissivity surface baffle structure inside a barrier envelope containing gas at atmospheric pressure. The baffle structure is an assembly of thin sheets whose objective is to produce minimal solid conduction and effectively eliminate radiative and convective heat transfer. High-performance GFPs use gases with thermal conductivities lower than that of air. Gases such as argon or krypton are hermetically sealed within the baffle and retained at atmospheric pressure with the use of high-performance gas barrier materials. Gas-filled panel technology evolved by applying the principles used in high-performance window glazings toward opaque insulation applications (Arasteh et al. 1989, 1990).

Research on and development of gas-filled panels, with a focus on refrigerator/freezer (R/F) applications, are being conducted by a national laboratory. Research focuses on investigating the three components of GFPs (baffle, barrier, and gases) and on fabricating functional prototypes. Approximately 200 to 300 separate baffles, with 75 variations and 150 GFPs, have been produced since research began in late 1989. This paper presents results of GFP research to date that are relevant to the use of GFPs in building applications. GFP designs for buildings are likely to differ from designs for R/F applications because of differences in installation, stiffness requirements, and optimal performance per thickness.

THERMAL PERFORMANCE EVALUATION

Heat Flowmeter Apparatus Testing

The thermal performance of two sets of functional prototypes has been measured by a national laboratory using a heat flowmeter apparatus (ASTM 1989). Note that the testing standard is for homogeneous insulations; GFPs are nonhomogeneous. First-generation random-baffle prototype GFPs were tested in 1990 (Griffith 1991); R-value per thickness results were R-5.2/in. (5.2 h·ft^2·°F/Btu·in [36 m·K/W]) for air-filled panels, R-7.1/in. (49.3 m·K/W) for

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argon-filled panels, and R-12.5/in. (86.8 m·K/W) for krypton-filled panels (McElroy and Graves 1990). A second set of stiffer panels targeting refrigerator/freezer applications was recently tested; R-value per thickness results were R-4.3/in. (30.0 m·K/W) for an air-filled baffle, R-6.3/in. (44.1 m·K/W) for an argon-filled panel, and R-10.1/in. (70.2 m·K/W) for a krypton-filled panel (Graves 1992). The construction and design of the second set of panels differed substantially from panels tested in 1990. The baffle design used in the second set has stiffness, fewer layers, and uniform geometry. The recent test specimens were prepared with nominal 14 in. by 16 in. by 1 in. (0.36 m by 0.41 m by 0.025 m) thick panels and a 1 in. (0.025 m) thick rigid foam perimeter for nominal 24 in. by 24 in. by 1 in. (0.61 m by 0.61 m by 0.025 m) test specimens, whereas earlier specimens used 1 in. (0.025 m) thick panels in a rigid foam "picture frame" mask for 2 in. (0.05 m) thick specimens. For both cases, the test apparatus used a centered, 10 in. by 10 in. heat flux transducer.

Infrared Thermography Testing

Infrared (IR) imaging and temperature measurement equipment is used to examine the relative thermal performance of prototype baffles and GFPs for development. The test typically involves comparing the relative performance of insulators by simultaneously measuring and imaging the warm-side surface temperatures of side-by-side specimens subjected to a temperature difference. Warm-side temperatures correlate directly with thermal resistance: the warmer the room-side surface temperature, the better the insulator. The test apparatus is an infrared scanning radiometer, a computer (for image averaging and data postprocessing), and an environmental chamber. The components of the experimental setup are shown in Figure 1. The IR scanner is an 8- to 12-μm scanning radiometer. The IR system calculates surface temperatures based on measured radiosity, surface emissivity (provided by the user), and background temperature (measured by the system). The environmental chamber produces a temperature difference across a specimen by cooling one face of a vertical 4 ft by 4 ft (1.2 m by 1.2 m) plane while the other face is exposed to ambient room conditions. The environmental chamber can operate at temperatures from -30°F to 120°F (-34°C to 49°C) and at vertical, upward airflow rates of 4 to 14 mph (1.8 to 6.3 m/s). Temperature uniformity inside the environmental chamber is within 0.9°F (0.5°C). There is currently no temperature control for the ambient-side conditions beyond the laboratory's conventional space conditioning. The ambient-side surface temperatures of the test specimen are imaged/measured with the IR system after the chamber-side temperatures have stabilized for an hour or more. Room temperature fluctuations are monitored and attempts made to conduct tests when ambient temperatures are fairly stable.

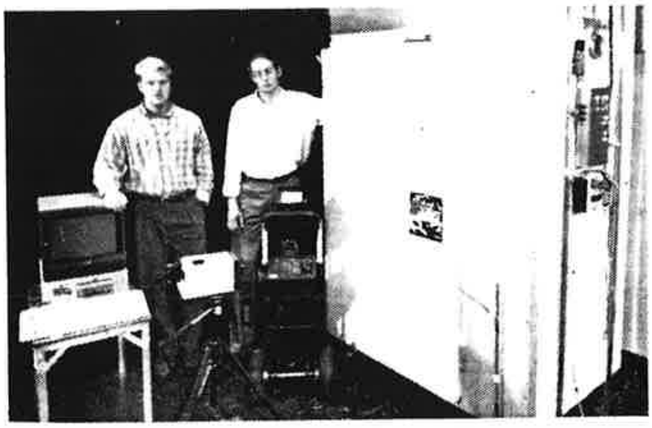

Figure 1 *Photo of infrared thermography test apparatus and setup. The infrared scanner (with control electronics) images/measures the ambient-side temperature distribution of a sample placed between the environmental chamber and ambient. Real-time scanner signals are sent to a computer for image averaging and post-processing.*

PANEL COMPONENTS

Gas-filled panels are composed of three primary components: a baffle, a barrier, and gas fills. The resulting hermetic panel devices can have a variety of thermal, geometrical, and mechanical properties. Each of these three components is discussed and relevant results of current research on panels for R/F applications are presented. Note that for patent and proprietary reasons, specifics of baffle geometries and dimensions are not disclosed.

Baffle Component

A baffle functions to suppress radiation and convection, enabling the performance potential of low-conductivity gases to be realized. "Compartmentalizing" the gas contained within the panel minimizes convective heat transfer. Compartmentalizing is accomplished by constructing the baffle out of solid, thin sheet material assembled into a three-dimensional form, creating multiple layers and cavities. The dimensions of the layers and cavities are selected so that convection is minimized within a cavity or compartment. Low-emissivity cavity surfaces eliminate significant radiative heat transfer. Low-emissivity surfaces are inexpensive and available in the form of roll stock, vacuum-metalized thin polymer films. Such films typically have an aluminum coating 50 to 500 angstroms thick with an emissivity of about 0.04. Solid conduction through the baffle structure can decrease insulating performance; this is minimized by employing solid conduction paths that are long relative to the panel thickness. Baffles can use a variety of different geometries, material types, and thicknesses, resulting in different mechanical properties and thermal performances.

We distinguish between stiff and flexible baffles. Self-supporting and supportive baffles are termed *stiff*, and "inflatable" self-locating baffles are termed *flexible*. Panels with flexible baffles can be lightweight (≈0.4 lb./ft^3 [6.4 kg/m^3]), collapsible, and expandable. Panels with stiff baffles maintain their shape when handled, are heavier (≈2 lb./ft^3 [32.0 kg/m^3]), and require vacuum purging when filled with gas. Research on GFPs for composite applications with rigid foam has focused on stiff baffles in order to help maintain panel geometry during the foaming operation. Research has focused on maximizing baffle stiffness without compromising thermal performance while using only conventional, low-cost materials such as papers and simple thermoplastic films. Baffles with some stiffness and good thermal performance were developed, but we found that GFPs are unlikely to be as stiff as rigid closed-cell polymer foams.

Barrier Component

The barrier component is composed of gas-barrier polymer films that are wrapped or formed to create a hermetic panel of desired size and volume. Effective barrier materials are critical for the long-term thermal performance of GFP insulation. The film must act as an effective barrier to gas diffusion; diffusion is two-way, with air gases driven into the panels and the desired low-conductivity gases driven out of the panels. The film should be a good barrier to moisture permeation, be nondegradable, durable, nonextensible, sealable, flexible or formable, and have low thermal conductivity. The film must also have a relatively low cost and be easily run on fabrication equipment.

Candidate Barrier Films A gas-filled approach to insulation is viable because of recent advancements in polymer barrier film technology within the food packaging industry. A variety of barrier materials and film configurations are commercially available that could be used for GFPs. We distinguish two approaches to gas barriers: vacuum coatings and polymer barrier resins. Vacuum coatings include very thin layers of deposited materials such as aluminum, silicon oxide, and manganese oxide. Polymer barrier resins include ethylene vinyl alcohol (EVOH) and polyvinyl alcohol (PVA or PVOH). Polyvinylidene chloride (PVdC) has potential applications for GFPs as a moisture barrier. Ethylene vinyl alcohol (EVOH) is a copolymer of ethylene and polyvinyl alcohol, so EVOH without ethylene is PVA. EVOH is available with an ethylene content ranging from 26% to 48%; lower ethylene contents provide a greater gas barrier. However, the higher the percentage of ethylene in EVOH, the easier it is to process and the less it is affected by moisture. Both EVOH and PVA can be oriented to increase crystallinity and their barrier performance.

In general, mono-layer films of a single polymer will not be able to meet the demands of GFPs, so combinations of different polymers will be used to create one multilayer film structure that has an adequate gas barrier, is strong, and can be sealed. Multilayer films can be produced by either lamination or coextrusion. For example, an EVOH-based coextruded film may have the structure nylon/adhesive/EVOH/adhesive/EVOH/adhesive/polyethylene. One commercially available PVA-based laminated film has the structure oriented polyester/adhesive/PVdC/oriented PVA/PVdC/adhesive/ polyethylene.

Barrier Material Gas Transmission Rates Performance requirements of GFP barrier materials can be approximated by a first-order analytical analysis. The analysis is based on the equation for mass transport of gas across a membrane (Equation 1) and is facilitated by using constant partial-pressure driving forces at the maximum (initial) level.

$$\frac{\Delta M_{gas}}{\Delta t} = \frac{PA\Delta p}{\ell} \tag{1}$$

where

$\frac{\Delta M_{gas}}{\Delta t}$ = gas transmission rate, cc/24 h;

P = permeability of barrier,

$$\frac{(\text{cc}\cdot\text{mil})}{(100\ \text{in}^2\cdot 24\ \text{h}\cdot\text{atm})},\ \left[\frac{(\text{cc}\cdot\mu\text{m})}{(\text{m}^2\cdot 24\ \text{h}\cdot\text{atm})}\right];$$

ℓ = thickness of barrier material, mil (μm);

Δp = partial pressure difference across barrier, atm;

A = area of barrier material, 100 in.^{2} (m^2).

For our purposes, we assume a gas concentration loss rate of 0.1% per year is acceptable. For a panel initially filled with 100% argon, this rate of gas concentration change would result in concentrations of 98% argon/2% air gases after 20 years and 90% argon/10% air gases after 100 years. The corresponding change in thermal performance can be estimated based on the change in still-gas thermal conductivity, which is roughly the composition-weighted linear sum of the thermal conductivities of the gas mixture components. This corresponds to an R-value change of 1% after 20 years and 5% after 100 years.

We can solve for the value of $\frac{P}{\ell}$ (in Equation 1) required to meet this loss rate condition; the quantity $\frac{P}{\ell}$ is the transmission rate of a particular barrier film and is dependent on the type of gas. The terms O2TR, N2TR, ArTR, and KrTR refer to this quantity for oxygen, nitrogen, argon, and krypton, respectively. Industry uses two different units for these film transmission rates—cc/100 in.^{2}·24 h·atm and cc/m^2·24 h·atm. Experimental data on specific films are typically available for only O2TR. Product literature characterizes the relationship between N2TR and O2TR for EVOH; our analysis assumes N2TR is 10% of O2TR (ECA *Tech. Bul.*). It appears that the relationship between ArTR, KrTR, and O2TR for EVOH has not been characterized experimentally. Theoretical analysis based on the diameter of the gas and its ability to adsorb onto the surface (reflected in its Lenard-Jones potential for solubility) indicates that ArTR is 46% of O2TR and that KrTR is 15% of O2TR (Salame 1986); we assume this relation for analysis. Solving Equation 1 for a panel size of 48 in. by 14.5 in. by 3 in. (1.22 m by 0.37 m by 0.08 m) with the above assumptions leads to the indication of gas transmission rate requirements presented in Table 1.

Barrier Film Performance Capabilities The gas barrier performance requirements indicated in Table 1 are within the capabilities of commercially available materials and existing technologies. A PVA-based film is said to have an O2TR of 0.001 cc/100 in.^{2} · 24 h · atm (0.015 cc/m^2·24 h·atm), which is an order of magnitude better than required for GFPs. EVOH-based materials also appear capable of providing the specified level of performance. Coextruded EVOH films can achieve this performance, although most currently available films have lower performance levels. Aluminum and silicon oxide barrier coated films also appear to be able to meet the required performances (Chahroudi 1991). The performance characteristics of all these barrier films over long periods of time are largely unknown.

Experimental investigations analyzed barrier material performance by measuring the oxygen concentration over time inside sealed, argon-filled panels. A large number of simple panels have been fabricated that measured 8 in. by 10 in. (0.2 m by 0.25 m) inside the seal; these were purged and filled with argon. Our oxygen analyzer employs an electrochemical cell sensor to measure the percentage of oxygen in a small sample of gas taken from the panels; the panels are sealed after the test, closing off the punctured section. O2TRs for the test panels are calculated based on the change in oxygen concentration over time. Minimum measurement resolution of O2TR using this technique is about 0.005 cc/100 in.^{2}·24 h·atm (0.08 cc/m^2·24 h·atm) with uncertainties of around 80% for typical O2TR results. Our results from this testing appear consistent with expectations of film performance. The PVA-based laminate performed very well, but its O2TR could not be quantified using this method; no change in oxygen concentration was detected in one panel after 212 days. We characterized the oxygen permeation of various coextruded EVOH materials and, in general, these materials performed as expected. The dependence of barrier performance on thickness and EVOH ethylene content (as characterized in product literature) was well supported by our testing.

TABLE 1
Barrier Material Gas Transmission Rate Requirements

	cc/100in^2·atm·24h	cc/m^2·atm·24h
O2TR	0.01	0.16
N2TR	0.001	0.016
ArTR	0.005	0.08
KrTR	0.0015	0.02

Gas Fill Component

Thermal conductivity through the gas is the primary mode of heat transfer in a GFP. R-values of GFPs depend strongly on the type of gas fill. Gases with relatively higher molecular weight typically have lower thermal conductivity. Monatomic gases (such as krypton or xenon) have a lower conductivity than polyatomic gases of equal (and typically higher) molecular weight because of the additional rotational and vibrational energies associated with molecules. Although the thermal conductivity of a gas is important, other characteristics of the gas must also be acceptable. Gases cannot be flammable or toxic, nor can they condense at temperatures (at about atmospheric pressure) within ambient temperature ranges. Gases must be stable and cannot react problematically with other components of the panel. The gases should have little or no ozone depletion potential or greenhouse warming potential. The components and processes used to produce a gas should also be relatively benign.

Information on all commercially available gases was compiled to assess which gases could be used for GFPs. Gas vendors' data books were the sources for information about most gases in this search (Braker and Mossman 1980; L'Air Liquide 1976) with the exception of the noble gases (Liley 1968) and the CFC alternatives (Zwolinski et al. 1991). Gases with potential for use in GFPs are listed in Table 2 with their ideal still gas thermal resistivity, projected attainable GFP performance levels, and approximate cost. GFP performance capabilities for the different gases are projected by summing ideal still-gas k-values with a nonideal k-value component intended to account for radiation, convection, and solid conduction. For each gas in Table 2 we used a nonideal k-value of 0.0092 Btu in./h ft^2 °F (0.0013 W/m·K) to estimate the level of performance attainable with a flexible GFP designed for maximum R-value. For air, this corresponds to a performance level of R-5.25/in. (36.4 m·K/W) compared to a measured performance level of R-5.2/in. (36 m·K/W). Because of their environmentally benign nature, argon and krypton are preferred gases, with projected GFP performance capabilities of R-7.6/in. (52.7 m·K/W) and R-13.4/in. (93.0 m·K/W), respectively. Current krypton production capacity is a problem for its use as an alternative for large-scale applications currently using CFC blown foams. However, large quantities of krypton exist in the total atmosphere at a concentration of 1.14 parts per million. Argon is inexpensive and abundant as it is 0.93% of the atmosphere. A number of chlorinated and fluorinated hydrocarbons could be employed in GFP's but their potential for environmental harm is a problem. Note that the relatively good performance of air-filled GFPs makes for a soft failure mode should the barrier component fail.

GFP APPLICATIONS IN BUILDINGS

Gas-filled panel technology can yield a variety of products useful for building envelope insulation applications. Table 3 lists examples of panel configurations and applications as well as performance and cost estimates. Typical panel sizes are given; "L" indicates variable or continuous lengths. GFP configurations are presented in Table 3 to illustrate potential products from gas-filled panel technology; most of these have not been developed or tested as of this writing because research has focused on refrigerator/freezer applications. R-value projections are estimates based on measured GFP performances and still-gas thermal conductivity values. Preliminary cost estimates are the "cost to manufacture" based on material component costs and simple multipliers for added production expenses.

Flexible Expansion GFP Embodiments

Items 1 through 4 in Table 3 are based on a GFP design referred to as a flexible expansion GFP. These panels employ thin baffle materials, resulting in panels that are very lightweight—densities can be around 0.4 lb/ft^3 (6.4 kg/m^3). Performance projections are based on R-5.2/in. (36.1 m·K/W) for air fill and R-7.4/in. (51.4 m·K/W) for argon fill. The added cost of argon panels arises from the use of high-performance gas-barrier materials, not from the cost of argon. The panels can be collapsed and evacuated to aid in shipping, handling, and gas filling. The "batt" GFPs are similar in size to glass-fiber batts, with an interference fit in the width (15 in. width for 14.5 in. cavity). GFP "batts" have flanges for fastening to studs. "Blanket" embodiments could be configured to fit onto joists, centered

TABLE 2
Thermal Performance at 77 °F (25 °C) and Cost Estimates of Gases for GFPs

Gas	Ideal Still Gas Thermal Resistivity		Projected GFP Thermal Resistivity		Approximate Gas Cost	
	h·ft^2·°F/Btu·in.	(m·K/W)	h·ft^2·°F/Btu·in	(m·K/W)	\$/ft^2·in.	(\$/m^3)
Air	5.5	(38.2)	5.25	(36.4)	0.00	(0.00)
Argon	8.1	(56.2)	7.60	(52.7)	0.003	(1.27)
CO2	8.7	(60.4)	8.00	(55.5)	0.01	(4.24)
N2O	8.9	(61.8)	8.20	(56.9)	0.025	(10.60)
CF4	9.0	(62.5)	8.30	(57.6)	0.40	(170.00)
SF6	10.3	(71.5)	9.40	(65.2)	0.15	(63.50)
HFC-134a	10.3	(71.5)	9.40	(65.2)	0.40	(170.00)
HCFC-22	13.1	(90.9)	11.70	(81.2)	0.04	(16.90)
CFC-12	15.3	(106.2)	13.40	(93.0)	0.10	(42.40)
Krypton	15.3	(106.2)	13.40	(93.0)	1.20	(508.00)
Xenon	25.6	(177.7)	20.80	(144.4)	22.40	(9,500.00)

TABLE 3
Potential Applications, Projected Performances, and Cost Estimates for GFPs in Buildings

	GFP Embodiment Designation	Example Application	Typical Panel Size	Projected R-Value	Cost Estimate
			in.(m)	h·ft^2·°F/Btu (m^2·K/W)	\$/ft^2 (\$/m^2)
1	Flexible argon expansion "batt"	Wall cavity, 2×4 Studs	15 × 3 × L (0.38 × 0.08 × L)	22 (3.9)	0.80 (8.60)
2	Flexible argon expansion "blanket"	Attic, floor 2×6 joists	48 × 5.5 × L (1.22 × 0.14 × L)	38 (6.7)	1.05 (11.30)
3	Flexible air expansion "batt"	Wall cavity, 2×4 studs	15 × 3.5 × L (0.38 × 0.09 × L)	18 (3.2)	0.50 (5.40)
4	Flexible air Expansion "blanket"	Attic, Floor 2×8 joists	48 × 7.5 × L (1.22 × 0.19 × L)	38 (6.7)	0.85 (9.10)
5	Stiff air baffle	Wall cavity, 2×4 stud	15 × 3.5 × L (0.38 × 0.09 × L)	18 (3.2)	1.00 (10.80)
6	Stiff argon	Foam composite, foam core panels	15 × 3 × 15 (0.38 × 0.08 × 0.38)	22 (3.9)	1.50 (16.10)
7	Stiff argon	Foam composite, rigid sheathing	15 × 1 × 15 (0.38 × 0.03 × 0.38)	7.4 (1.3)	0.70 (7.50)
8	Stiff krypton	Foam composite, foam core panels	15 × 2 × 15 (0.38 × 0.05 × 0.38)	26 (4.6)	3.30 (35.60)

on common distances. Products could be distributed in collapsed, continuous roll form and subsequently cut and sealed to length. With correct installation, such panels could serve as vapor retarders, eliminating the need for such a component in addition to insulation. Panels are flexible and can deflect around cavity obstructions. Figure 2 is a photo of a prototype flexible expansion GFP (item 1 in Table 3) being placed in stud wall cavity. Figure 3 is a thermagram depicting the thermal performance of a similar argon-filled flexible expansion GFP in comparison to glass fiber insulation.

Stiff Air Baffle

Stiff baffle components (item 5 in Table 3) could be used without a barrier component. Such air-filled insulation material could be produced in a variety of thicknesses and could be cut and installed in the same fashion as conventional insulations. Performance is projected at up to R-5.2/in. (36.1 m·K/W), or about the same as thermoplastic rigid foam insulations. The material would be self-supporting, mildly stiff, and have a density of about 2.0 lb/ft3 (32 kg/m3).

Stiff Argon and Krypton GFPs

Stiff GFPs (items 6, 7, and 8 in Table 3) are currently being developed for refrigerator/freezer appliance applications and may also be useful in conjunction with foam for panelized building systems and rigid foam insulated roofing and sheathing products. Modular panels of convenient

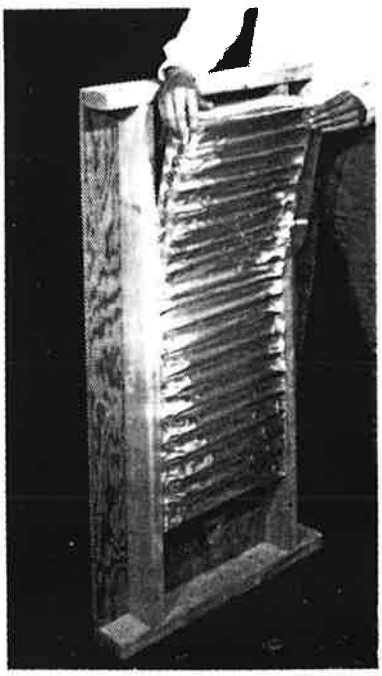

Figure 2 *Flexible expansion GFP.*

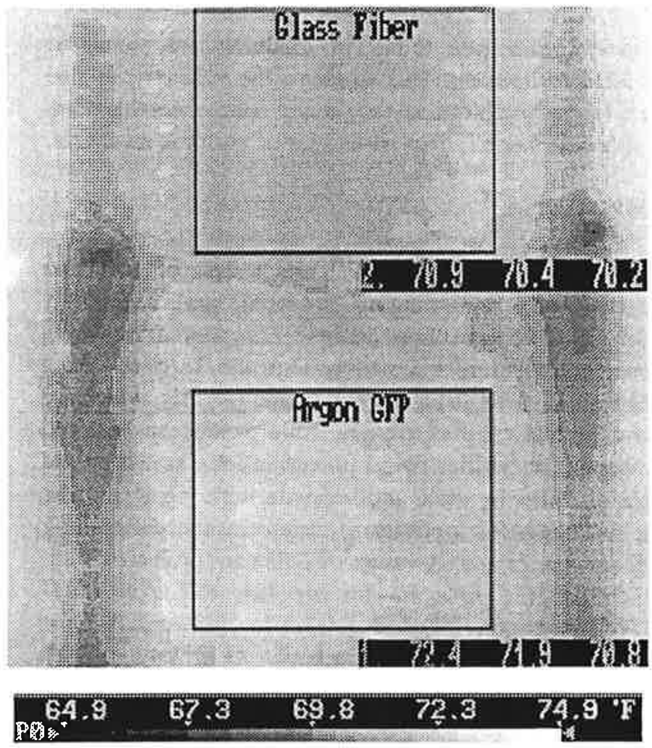

Figure 3 *Infrared image of the warm-side surface of a stud wall cavity test section. The upper portion of the cavity is insulated with R-11 h·ft^2·°F-/Btu (1.9 m^2·K/W) glass fiber insulation and the lower portion with a prototype argon GFP. The wall section is constructed with 0.75-in. (0.019-m) plywood, 0.625-in. (0.016-m) drywall, and standard 16 in. (0.41 m) on center 2-by-4 studs. The back of this assembly faces a cold chamber at -19.9·°F (-28.8°C); ambient temperature is 74.0°F (23.3°C). The warm-side surface temperature of the fiber-glass-insulated section averages 70.4°F (21.-4°C), while the argon GFP-insulated section averages 71.9°F (22.1°C). A corresponding temperature gray scale is shown at the bottom of the figure. Since surface temperatures correspond to heat loss rates, the argon GFP's higher warm-side temperature implies a lower heat loss rate.*

shapes and sizes would be used in composite with non-CFC foam. Foam would serve as the structural element in the GFP/foam composite; GFPs would boost performance and reduce quantities of foam that would otherwise be required.

GFPs for Manufactured Housing

GFPs should be well suited for initial applications in manufactured housing. GFPs by nature are individual hermetic plastic enclosures of discrete shapes and sizes. Products will tend to be uniform and modular, thus lending themselves best to closer tolerance construction and repeated cavity geometries found in modular and panelized manufactured housing. This sector of the industry can also place a higher premium on weight and component thickness and may be faster to adopt new types of building materials.

SUMMARY

Gas-filled panels, or GFPs, are a class of advanced insulation with wide-ranging potential applications for buildings. GFPs have three components: the baffle, which suppresses radiation and convection; the barrier, which holds desired gases inside the panel; and gas fills, which are of low thermal conductivity. Flexible panels can be sized and shaped for cavities found in conventional construction. Panels can also be used in composite with rigid polymer foam insulations for applications such as insulated sheathing and foam core panels. R-values of GFPs are projected at up to R-5.2/in. (36 m·K/W) for air fill, R-7.6/in. (52.7 m·K/W) for argon fill, and R-13.4/in. (93 m·K/W) for krypton fill. The thermal performance of prototype GFPs was measured in 1990 at R-5.2/in. (36 m·K/W) with air fill, R-7.1/in. (49.3 m·K/W) with argon fill, and R-12.5/in. (86.8 m·K/W) with krypton fill.

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