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Project Summary

Advanced Insulations for Refrigerator/Freezers: The Potential for New Shell Designs Incorporating Polymer Barrier Construction

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Current efforts to design and build domestic refrigerator/freezers (R/Fs) with high performance insulation technology are directed at using vacuum panels in a composite with polymer foam to improve performance. However, certain restrictions generally enable only relatively small improvement in thermal resistance using these techniques. This report examines design alternatives which may offer greater increase in thermal performance than is possible with panel/foam composites. These design alternatives involve basic redesign of the R/F and use of alternative materials of construction. One design alternative includes use of a polymer outer shell material component that incorporates in its construction an advanced insulation technology that reduces thermal bridging and edge losses. Computer modeling of a R/F door incorporating this concept shows a doubling of effective thermal resistance over conventional R/F designs. The report also addresses materials and manufacturing technologies needed to fabricate polymer barrier advanced insulation components for R/Fs.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Overview

The impending phaseout of chlorofluorocarbons (CFCs) used to expand foam insulation, combined with requirements for increased energy efficiency, make the use of non-CFC-based high performance insulation technologies increasingly attractive. The majority of current efforts are directed at using advanced insulations in the form of thin, flat, low-conductivity gas-filled or evacuated orthogonal panels, which we referred to as Advanced Insulation Panels (AIPs). AIPs can be used in composite with blown polymer foams to improve insulation performance in refrigerator/freezers (R/Fs) of conventional design and manufacture. This AIP/foam composite approach is appealing because it appears to be a feasible, near-term method for incorporating advanced insulations into R/Fs without substantial redesign or retooling. However, the requirements for an adequate flow of foam during the foam-in-place operation impose limitations on the allowable thickness and coverage area of AIPs. This restriction, combined with thermal bridging effects associated with elements such as steel outer shells and surrounding foam, generally allows only relatively small improvements in overall thermal resistance as a result of incorporating AIP/foam composite insulation into conventional foam core R/Fs.

This report examines design alternatives which may offer a greater increase in overall thermal resistance than is possible with the use of AIP/foam composites in current R/F design. These design alternatives generally involve a basic redesign of the R/F, taking into account the unique requirements of advanced insulations and the importance of minimizing thermal bridging with high thermal resistance insulations. The focus here is on R/F doors because they are relatively simple and independent R/F components and are therefore good candidates for development of alternative designs. R/F doors have significant thermal bridging problems due to the steel outer shell construction. A three-dimensional finite-difference computer modeling exercise of a R/F door geometry was used to compare the overall levels of thermal resistance (R-value) for various design configurations.

One design alternative involves substituting polymer shell materials for conventional steel to reduce thermal bridging and edge losses. The computer modeling of a simplified R/F door geometry indicated that the percentage of improvement in overall R-values from the use of a polymer outer shell could be 13% for foam insulation, 15% for gas-filled AIP/foam insulation, and 18% for evacuated powder AIP/foam insulation.

Another design alternative includes the use of polymer outer shell materials but discards foam-in-place insulation in favor of a more comprehensive use of advanced insulation technologies. In this case we distinguish between AIPs and Advanced Insulation Components (AICs). Where an AIP is an insulating panel made for the inside cavity of a component, an AIC is an entire functional component of a product that incorporates an advanced insulation technology. An AIC is thus a thin-walled, hermetic, barrier part with a modified internal atmosphere and an insert consisting of advanced insulation filler material. In the case of R/Fs, an AIC could be an entire door with accessories attached to it. The barrier envelope, or outer surface, of an AIC would typically be a formed (or molded) polymer part that includes layers of gas and moisture barrier material in a multilayer structure. A gas-filled AIC would have an insert consisting of a multilayer reflective baffle and polymer stiffeners as needed. An evacuated powder AIC would, for example, have an insert consisting of compressed and formed powder. AICs would typically not employ blown polymer foam insulations.

The polymer barrier AIC approach offers some significant advantages over using AIP/foam composite in conventional R/F design. One of the most important advantages is better resistance to heat transfer resulting from greater thickness and coverage area of the advanced insulation. The polymer outer shell, in addition to causing less thermal bridging than steel, can offer other advantages such as design freedom, parts reduction, weight reduction, scrap recyclability, and process consolidation. Polymer barrier AICs could be designed for disassembly giving them an advantage in terms of post consumer recyclability over conventional foam core R/Fs because adhesive polyurethane foams make it difficult to disassemble conventional R/Fs.

Computer modeling of a simplified geometry (representing a 2 in. (0.05 m) thick refrigerator door) produced overall R-values for various configurations of insulation and shell materials as shown in Table 1.

The individual materials and manufacturing technologies needed to fabricate polymer barrier AICs are generally well developed; however, it appears that there have been no efforts to apply them directly to the production of AICs. Technologies such as coextrusion and lamination could be used to produce thermoplastic multilayer polymer structures with the necessary stiffness and barrier properties. Processes such as twin-sheet thermoforming and coextrusion blow molding could be used to fabricate shaped barrier parts for AICs. Thermal and solvent welding could be used to hermetically join the barrier parts.

The major conclusions of the study are

(1) AICs could be mass produced with existing polymer technologies,

(2) AIC R/F components can offer higher levels of thermal resistance than conventional assemblies insulated with foam or AIP/foam composites that have the same thickness, and

(3) a considerable amount of development is required to assess the energy efficiency improvements, economics, manufacturing, and reliability of AICs for R/F applications.

Table I. *R-Values for Various Configurations of Insulation and Shell Materials*

R/F door configuration	*Overall Effective R-value* hr·ft^2·°F/Btu (m^2· K/W)
CFC blown foam w/conventional steel outer shell	*9.03 (1.59)*
evacuated AIP/foam composite w/conventional steel shell	*11.14 (1.96)*
gas filled AIP/foam composite w/conventional steel shell	*9.71 (1.71)*
evacuated AIP/foam composite w/polymer outer shell	*13.09 (2.31)*
gas-filled AIP/foam composite w/polymer outer shell	*11.15 (1.96)*
evacuated-powder polymer barrier AIC	*18.80 (3.31)*
gas-filled polymer barrier AIC	*13.50 (2.38)*

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The complete report, entitled "Advanced Insulations for Refrigerator/Freezers: The Potential for New Shell Designs Incorporating Polymer Barrier Construction," (Order No. PB93-146991; Cost: $17.50; subject to change) will be available only from

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