with vacuum panels would increase by about 50 pounds.

"• Polyurethane foam averages about 15 cents per board foot. Powder-filled panels are $2.50 to $3.50 per board foot and fiber-filled panels range from $5.00 to $7.50 per board foot. An average refrigerator-freezer has about 114 board feet of surface area, of which approximately 35 board feet would be vacuum panels.

"• Worldwide production capability for all types of vacuum panels is between 3 to 5 million board feet per year. Full implementation of vacuum panels in the U.S. alone would require more than 400 million board feet of panels.

"• Product-life performance characteristics (15 to 20 years) are being observed, but industry continues to work toward a vacuum panel product that maintains reliability over the life of the refrigerator.'' (Joint Comments, No. 49 at 7–8).

The Environmental Protection Agency sponsored a study to estimate the cost of producing vacuum panels at a new plant designed to produce enough vacuum insulation panels for 300,000 refrigerator-freezers per year. It determined that the variable cost for a 21 cubic foot refrigerator-freezer is about $1.40 per board foot, and the investment cost is about $0.55 per board foot. (EPA, No. 34, Appendix 5 at 54–58). After feasibility is established and funding is obtained, it would take about 2 ½ years to begin production. (EPA, No. 34, Appendix 5 at 56–59). The energy savings estimated by simulation analyses averaged about 16 percent for top-mounted refrigerator-freezers. (EPA, No. 34, Appendix 5 at 73).

Based on the information cited above, the Department has concluded that production capability will be insufficient in 1998 for vacuum panel insulation to be considered as a design option for all classes of refrigerator products. However, the Department believes that for some classes of refrigerator products, vacuum panels may be the most attractive option available to meet the proposed standards.

Gas-Filled Panels. Whirlpool stated there is a low probability that this technology will be viable for use on products built in 1998. It is not aware of any situation in which gas-filled panels have been successfully demonstrated in a refrigerator. A major problem with application in a refrigerator is the lack of sufficient structural integrity of the resulting product. Whirlpool recommended that this option not be considered. (Whirlpool, No. 36 at 5). U-Line commented that gas-filled panels are not a feasible technology. (U-Line, No. 11 at 3).

General Electric Appliances stated that the gas-filled panels developed at the LBL are even less promising than vacuum insulation panels. Insulation values are only about R13/inch even with the most insulating gas, krypton. This is only about 60 percent of the value of powder vacuum panels. At the same time, gas panels are projected to exceed vacuum panels in cost. Even if gas panels had comparable performance and cost characteristics, they would require enormous investment expenditures to be incorporated into current refrigerator designs. At present, virtually all mass-produced refrigerators are designed using the liner, foam insulation, and exterior metal case as integrated elements of the cabinet structure. General Electric Appliances also stated that gas panels have absolutely no structural capability and would require the development of a fundamentally different cabinet design concept to achieve adequate structural integrity. Unlike other design options, where the option is designed to fit the refrigerator, gas panels would require the refrigerator to be completely redesigned to accommodate this option. Finally, the cost to the industry would be enormous and, given the comparatively unattractive efficiencies offered, unjustified. (GEA, No. 39 at 6).

The Department concurs that gas-filled panels lack structural integrity and have low resistivity compared to evacuated panels and therefore has not considered them in this NOPR.

Improved Gaskets. Whirlpool stated that much work has been done in attempting to improve the performance characteristics of refrigerator door gaskets. However, there is a tradeoff between the thermal performance of a gasket and the forces required to open or close the door. This makes it extremely difficult to improve on current designs. While savings on the order of 1 percent may be achieved on some models, Whirlpool stated this design option may not be available for all products, and, therefore, should not be recommended as a viable design option. (Whirlpool, No. 36 at 5). U-Line stated that because many manufacturers redesigned gaskets prior to 1993, any additional enhancements would provide diminished returns. (U-Line, No. 11 at 3).

The Environmental Protection Agency submitted a report, ''Finite Element Analysis of Heat Transfer Through the Gasket Region of Refrigerators-Freezers,'' evaluating means of improving a 1991 model refrigerator, that described theoretical modeling and experimental research on gasket heat loads. (EPA, No. 34, Appendix 6). The report concluded that replacing about half of either the metal door flange or cabinet flange with plastic can reduce the heat flow through the gasket region by 25 percent. (EPA, No.34, Appendix 6 at 28). The report concluded that for one refrigerator-freezer, a 30 percent heat flux reduction for the gasket region led to a measured 7 to 8 percent energy use reduction, whereas for a second refrigerator-freezer, a 22 percent heat flux reduction led to a measured 4 to 5 percent energy use reduction. (EPA, No. 34, Appendix 6 at 26–28).

AHAM provided the Department with estimates of energy savings and the costs of improved gaskets from a number of its member manufacturers. These values ranged from less than 1 percent to nearly 3 percent energy savings depending on the size and configuration of the refrigerator product.

The Department has decided to use the industry supplied data in the engineering analysis for each class of refrigerator. (See TSD, Chapter 3.) The higher EPA energy savings estimates were based on a refrigerator that met the 1990 standards whereas the Department's analysis is based on models which meet the 1991 standards.

Double Door Gaskets. Whirlpool stated that this option involves the same tradeoff between thermal performance and door opening and closing forces discussed under ''improved gaskets,'' see above. The company does not recommend this as a viable design option. (Whirlpool, No. 36 at 5). General Electric Appliances agreed with Whirlpool's comments. (GEA, No. 39 at 6–7). U-Line stated that cabinet icing and other potential field service-related issues have precluded their application to compact refrigerators and freezers. (U-Line, No 11 at 3).

The Department's analysis indicates that a significant amount of heat leakage (from the outside) into a refrigerator occurs across the door gasket. Decreasing this leakage could result in significant energy savings. This could be achieved by either improving the gaskets or using double-door gaskets. The cost of a double-door gasket is more than the cost to improve the single gasket to achieve the same amount of savings. The Department has, therefore, decided not to consider this option but instead to consider improved gaskets, as discussed, *supra.*

Reduced Heat Load for Through-the-Door Features. Whirlpool stated that there is some potential for energy savings in this area through improvements in insulation around the