

Inverter Compressors: Improving the Efficiency of Refrigerators & Freezers

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As the “heart” of the refrigeration system, the compressor is the workhorse behind the stable operation of the refrigerator or freezer. Most home-use refrigerators and freezers today utilize single speed compressors which are either “on” or “off” and can only operate at one speed. This type of performance does not allow flexible operation to adapt to the different usage conditions such appliances experience during the day, nor does it efficiently utilize electric power once the unit is at a steady state.

In 1996, Panasonic began to utilize inverter compressors in its refrigerators as a solution for providing more flexible operation of the compressor, thereby significantly increasing the overall appliance efficiency. Compared to the traditional single speed compressor, the inverter compressor can run at a number of desired speeds, depending on how the refrigerator is being used by the consumer. This provides options for quick pull down or freezing, or to run at a very low speed once the cabinet is at a steady state, thereby significantly reducing energy consumption.

Panasonic has recently introduced its ENI and EFI inverter compressors to the North American market. These compressors make use of the same inverter basic inverter technology that Panasonic introduced over 10 years ago, however it offers this performance in a smaller package and with better efficiency than the products from last decade.



When applying an inverter compressor in a refrigeration system, one must take a number of factors into account. The cooling load requirement of the cabinet must be considered. In addition, in order to maintain the durability and reliability of the compressor, one needs to make sure of the pressures and temperatures of the compressor, particularly at low speeds.

Generally refrigerators are designed to secure their specific cooling performance when the load is highest (i.e. Summer). Therefore it is necessary to select a compressor with the freezing capacity equivalent to the maximum cooling load of the static cooling load plus the “door open-shut” load (see Figure 1). Historically then refrigerators were being designed with compressors to accommodate the maximum freezing capacity that the refrigeration system would require. In reality, however, the actual load on the refrigerator is not this large at all times. In fact, the load seen by the unit for most of the year is actually much smaller. But the freezing capacity of the compressor is constant irrespective of the actual load, so it will be excessive under the usual or more normal cooling operation (see Figure 1). This results in a great loss of efficiency due to the high compression ratio. It's wasted energy.

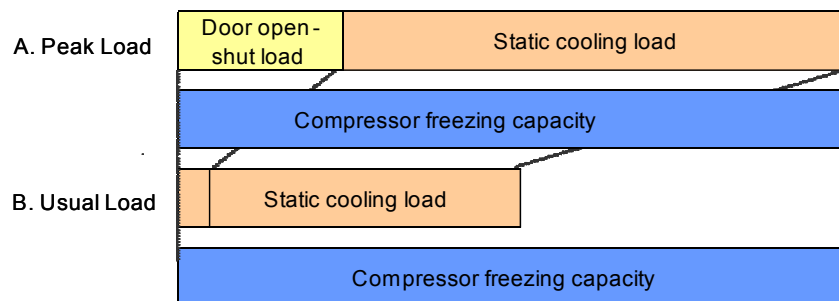


Fig. 1 Conventional Design

In order to maximize on the efficiency of the refrigerator, the ideal solution would be to reduce the standard static cooling load of the refrigerator. Careful consideration of the design can accomplish this, including the adoption of better insulation as well as vacuum insulation panels. By reducing the static load requirement, the cylinder volume of the compressor can be reduced as less capacity will be required, even at peak load conditions. Aside from this downsizing, under usual load conditions, less freezing capacity is

required. A normal single speed compressor can only operate at one speed with one capacity. By varying the speed of the inverter compressor, to a lower speed so as to match the cooling load that is required, you maximize on efficiency (see Figure 2).

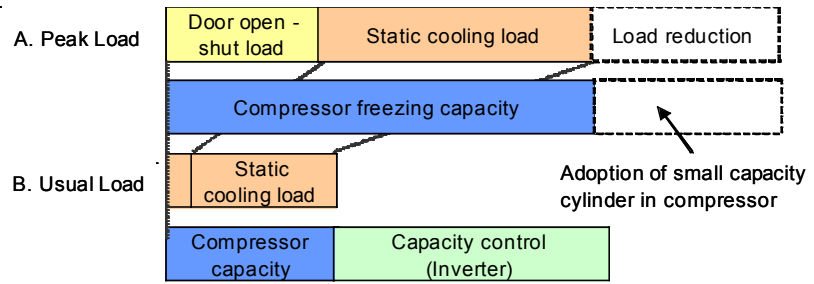


Fig. 2 Approach to energy -saving

Even in cases where the cylinder volume or displacement size of the compressor can not be reduced due to design limitations in reducing the static load, the benefit of employing an inverter compressor can be realized (see Figure 3).

Figure 3 illustrates a comparison of a conventional single speed compressor versus an inverter compressor where you can vary the speed. A single speed compressor must cycle on and off based on the cooling capacity needs of the refrigeration system. Regardless of the time of day or the cooling capacity required, the compressor can only rotate at one speed. So during the daytime, when there is more activity and more cooling capacity is required, the compressor can only run at one speed and deliver a set cooling capacity.

By varying the speed of the inverter compressor, the cooling capacity can be tailored to the cabinet's need at that time. For example, if the door is left open for a period of time due to loading of the cabinet, the compressor can run at a high speed to provide maximum cooling, in some cases possibly more than what the conventional single speed compressor could deliver. Likewise the compressor can

Controlling Compressor Rotation

Comparison of Compressor Rotation

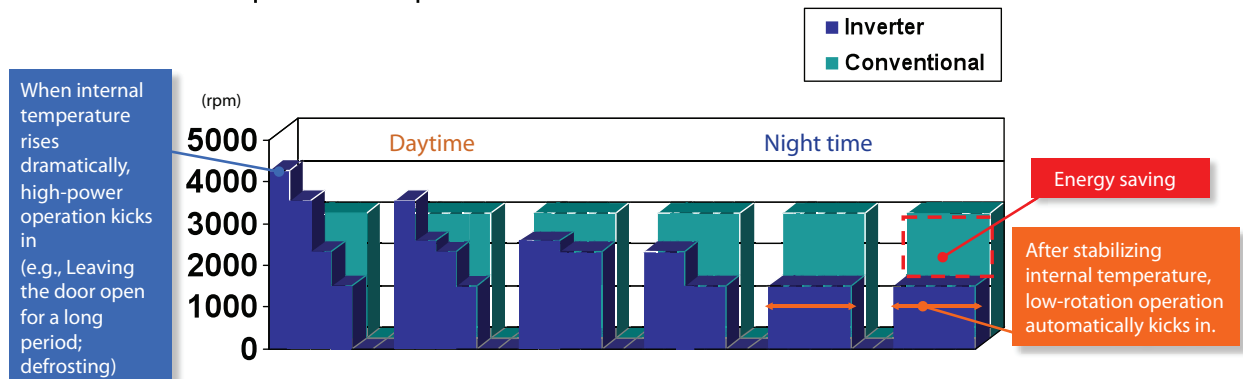


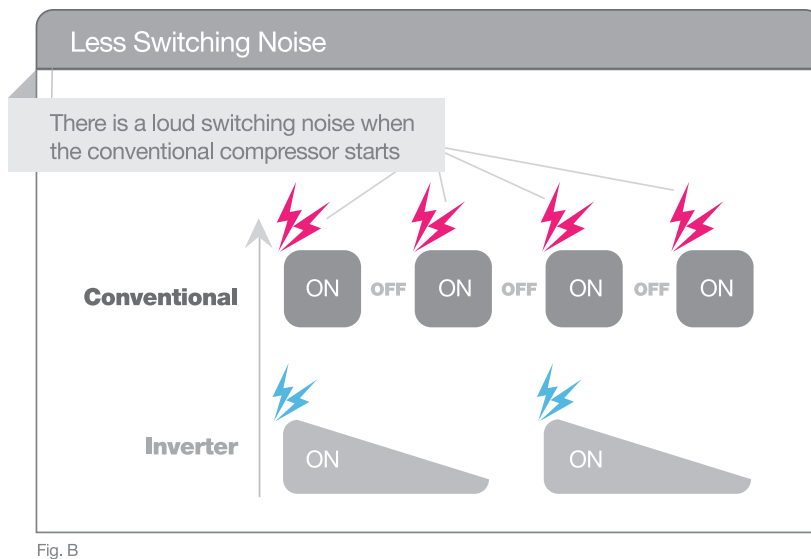
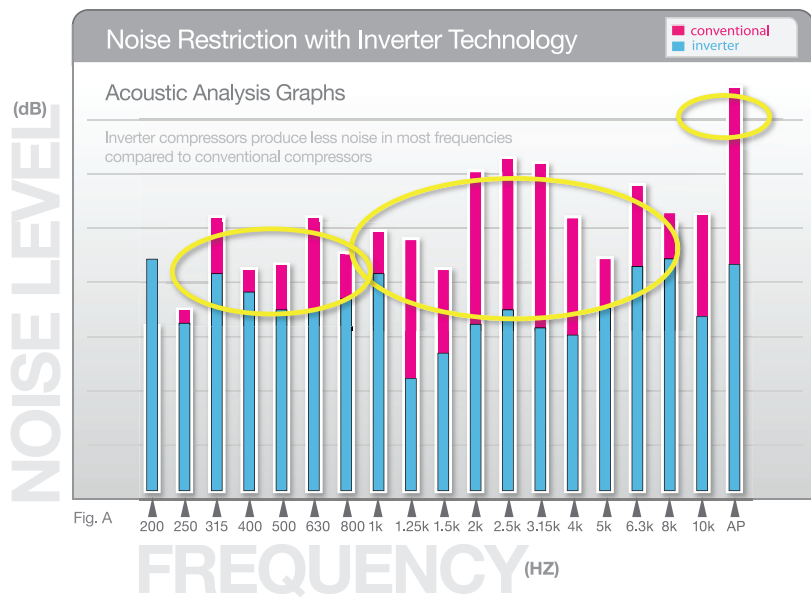
Fig. 3

run at gradually lower speeds as the need for cooling capacity diminishes. Since the conventional compressor can only operate at one speed, it is during these periods that there is a significant benefit in terms of energy efficiency. At night when there is little activity, a conventional single speed compressor would still have to cycle on and off, again at a constant cooling capacity, when the freezer/refrigerator compartment temperature goes below a certain level. The inverter compressor can operate at a very low speed during this time, providing just enough cooling capacity to maintain the cabinet's temperature. It is during these periods where the maximum energy efficiency benefit can be realized (see figure 3).

All compressors will cycle on and off based on the temperature level in the cabinet and the cooling capacity required. An inverter compressor, by running at a low speed, can actually be run for a longer period of time, but the result would still be reduced energy consumption as the input watts required for the lower speed operation are much lower. With the on and off cycling of the compressor, and with only one large cooling capacity available, the temperature fluctuates quite a bit. The temperature can be kept much more stable by employing an inverter compressor which can be run at a much lower speed and for longer cycle times.

This combination of low speed operation and longer cycle times also improves the overall noise levels of the refrigerator. Single speed compressors typically produce noticeable start-up noise as they cycle from off to full speed operation and again from full speed to off at the end of the cycle. The inverter compressor starts up at low speed so the transition noise is minimal. The long cycle times at low speed produce obvious noise advantages compared to the high speed operation of the single speed compressor. (see Figures 4A & 4B)

In designing the inverter compressor, it was clear that operation at low rotational speeds could provide many benefits. However it is at these low rotation speeds that stresses can act upon the compressor, resulting in wear due to a shortage of oil supply. Therefore it was critical to design the inverter compressor in such a way to allow for proper lubrication, even at lower speeds. Great care was taken in designing the oil pick up system as well as the pathway for distribution of the oil over all critical parts. For each type and size of inverter compressor, there are clear specifications for the condensing, and evaporating pressures, as well as the Motor winding and discharge 2" temperatures, for each speed range of the compressor. As the oil circulation is greater at higher speeds, the pressures and temperatures the compressor can withstand are greater. As the compressor speed slows, correspondingly the maximum allowable pressures and temperatures decrease. The refrigeration design must account for these specifications to insure reliability of the compressor.



If one takes these design specifications into account, it is possible to design a very effective and efficient refrigeration system using an inverter compressor. Being able to vary the speed, and thereby the capacity, to accommodate only the cooling load that is necessary provides for much better temperature performance in the cabinet, and much lower energy usage. Further design enhancements which could allow for lowering the static load requirements of the system would also provide for employment of smaller displacement compressors, further reducing energy consumption. This combined with utilization of superior insulation technology such as vacuum insulation panels and installation of variable speed fan motors can lead to ultra high efficiency refrigeration systems.

References

- (1) *"High Efficiency Refrigerator Cooling System Using an Inverter Compressor"*, S. Kanaoka, T. Noda, H. Hamano, Y. Kubota.
- (2) *Panasonic Corporation Refrigeration Devices Business Unit, Technical Bulletin No. D-B16Ef12-E, Dec. 25, 2009.*