A New Approach to Improved Efficiency Compressors for Household Refrigerators and Freezers

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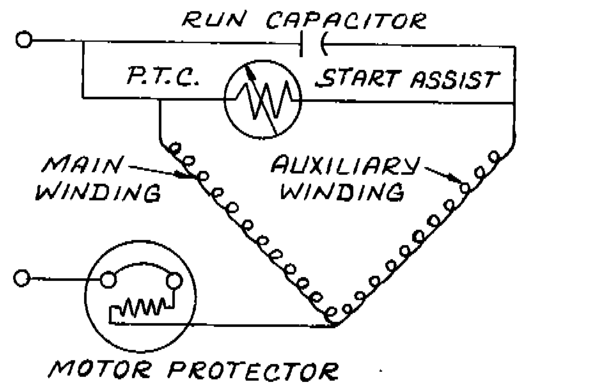
The need for energy conservation in household appliances has become a reality. There are state laws mandating minimum efficiency levels and certain considerations must be made by manufacturers who wish to market products within those states. These considerations usually involve a trade off between additional cost and better performance. Various methods have been suggested to improve the efficiency of household refrigerators and freezers. One such method was to use a permanent split capacitor (PSC) type motor in the hermetic compressor. This method was detailed in a conference paper submitted by G. Schroeder, in 1976[1], and several thousand of such motor-compressors have been produced successfully. A new approach is now necessary to combine a cost effective product with the efficiency needed to produce satisfactory energy conservation.

To provide a brief background into the above PSC method of efficiency improvement, the following summary is provided. A run capacitor is added in series with the auxiliary winding of the compressor motor to raise its efficiency into the area of 80 percent. Having done this, the locked rotor torque of the motor is too low for satisfactory starting performance. To increase the starting torque, a positive temperature coefficient (P.T.C.) relay is added in parallel with the run capacitor. The P.T.C. has very low cold resistance allowing current to bypass the run capacitor and provide normal locked rotor torque equivalent to a resistance start motor. After a brief period of starting current flow, the P.T.C. resistance increases by several orders of magnitude, effectively transferring the current flow back through the capacitor. (Fig. 1).

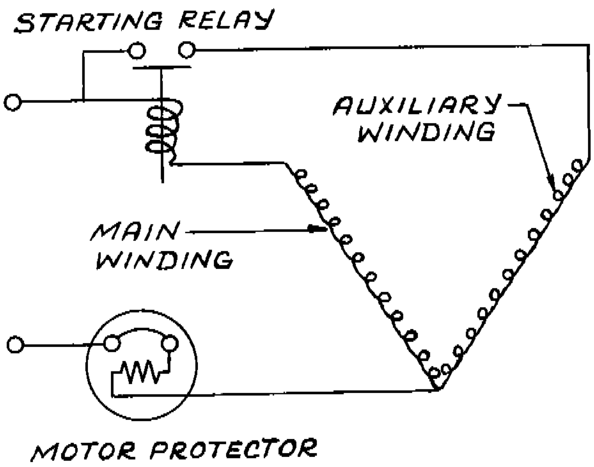


PSC MOTOR WITH PTC START ASSIST
FIG. NO. 1

This method has shown proven improvements in efficiency, in actual applications, of ten to fifteen percent. Even with this considerable improvement in cabinet efficiency, customer acceptance has been lacking. Several reasons surface for the lack of interest in this method, the most significant being the cost premium involved. The motor has been improved and, therefore, contributes to the cost premium. Another problem area involves the expensive run capacitor, with the attendant problems and cost of mounting the capacitor, and the addition of one more link in the chain of reliability.

To alleviate these problems of customer acceptance, we should return to basics and try to improve the compressor efficiency without any additions of extra hardware and a minimum cost increase. We must focus on the compressor motor as before, since this area will yield the largest return in efficiency. Remaining with a resistance start induction run (R.S.I.R.) motor is the key to the solution. By doing this, the expensive run capacitor is eliminated, along with all of the problems associated with that arrangement. This means that it will be necessary to obtain the 80 percent motor efficiency of the PSC design with special R.S.I.R. motor design improvements. (Fig. 2).

[1] G. H. Schroeder, "Improved Efficiency Compressors for Household Refrigerators and Freezers", 1976 I.E.E.E. Appliance Technical Conference No. C76-423-IA.



CONVENTIONAL ELECTRIC SYSTEM

FIG. NO. 2

Since cost is a very important consideration in the motor redesign, only improvements that are cost worthy will be evaluated. The first change will be from aluminum windings to copper windings in order to obtain the optimum conductor material. It is then necessary to fit as much conductor material as possible into the lamination. To accomplish this, it may be necessary and advantageous to redesign the stator lamination to allow better winding distribution. Changing to a slightly lower resistance rotor by revising the rotor lamination, and optimizing the breakdown torque for the stator, will result in an additional increase in motor efficiency. Silicon electrical steel for motor laminations will increase the efficiency about two percent, but the price penalty appears to be too high for the gains achieved. Special "Low Loss Steel" is an alternative to Silicon steels and this approach might be used to offset losses due to laminations that are not optimally designed. Given the proper lamination punching, these steels are generally not worth the cost penalty imposed.

A final improvement is the optimizing of the stator stack height within the compressor design limits. There will be an optimum amount of stator core stacking above which additional amounts will only cause small efficiency improvements. Once this amount of core height is determined, providing it is within the limits of the compressor design, it will provide the most efficiency gain for the least amount of cost increase.

One further gain occurs due to the improvements in the compressor motor efficiency. Because fewer watts are consumed by winding and core losses, there is less heat to be dissipated into the compressor suction gas. This decrease in suction gas heating is reflected in higher output capacity from the compressor with a resulting higher BTU per watt output.

The changes outlined in the preceding paragraphs will provide most of the gains that were attributed to the P.T.C. start capacitor run design at a much lower initial cost. This, plus the absence of the run capacitor and other necessary components, should make this new design very acceptable in the market place. Proven reliability and standard components, with a substantial decrease in power consumption are the attributes of this new compressor design. The slightly higher initial cost of this unit will easily be recovered by the appliance owner within a very reasonable payback period.

The data in the following tables are typical of a third horsepower compressor utilizing the present R.S.I.R. motor, a capacitor run motor, and the new high efficiency R.S.I.R. motor.

MOTOR TYPE (1/3 H.P.):	Present R.S.I.R.	PSC	Improved Eff. R.S.I.R.
Compressor Full Load -			
Motor Efficiency:	73%	80%	77%
Power Factor:	70%	83%	73%
Watts Input:	380	330	350
BTU/Watt:	3.42	4.08	3.86
Capacity (BTU/hr.):	1300	1350	1350
Amperes:	4.8	3.5	4.2
PERFORMANCE IN A TYP. CAB.:			
Ultimate Low Watts:	376	315	340
Ultimate Low Amperes:	4.65	3.45	4.10
Maximum Pulldown Watts:	495	452	460
Maximum Pulldown Amperes:	5.48	4.32	4.90
Percent Wattage Reduction:	-	16%	9.6%

The cabinet used for the above testing was chosen because of the maximized design of the application. When tested on a cabinet with operating characteristics considered more normal, and therefore less demanding, a further reduction in wattage might occur. The improved efficiency R.S.I.R. compressor produces a very favorable reduction in power consumption as indicated in the above tables and although the wattage reduction does not equal that of the compressor with the PSC motor, the gain in efficiency for the reduced added cost makes this new design much more attractive.

It is very imperative for our industry to develop products that will conserve our precious energy resources. If these products will not sell in the market place, we must examine them to determine what problems exist. This new approach, as we have called this compressor design, is only a step in the long progression toward conservation. To educate the consumer that prices will go up to make an appliance more energy efficient is only part of the problem. Keeping these cost increases as low as possible, while saving as much energy as practical, will provide an example that will allow the acceptance of more far reaching designs. Energy prices will continue to rise and this will make costlier, but more efficient designs, acceptable to a consumer who has learned that reasonable increases in cost, to provide better efficiency, will be returned within the life time of the appliance.