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IMPROVED EFFICIENCY COMPRESSORS
FOR AIR CONDITIONING

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INTRODUCTION

Cost of energy has been rising rapidly during the past few years, and this trend is likely to continue in the future. Since energy has a large influence on our way of living, it has become the most talked about subject of our times. Energy conservation efforts being made, as a result of this situation, have a substantial impact on the air conditioning industry. While the awareness of the consumer has improved and energy consumption has become a factor when deciding a purchase, many government regulations have also cropped up. Federal and various state governments have legislated or are in the process of legislating, the minimum efficiency standards for air conditioners. The air conditioning industry has on its own made many product improvements that improve the efficiency, without governmental impetus. But these factors have definitely hastened the pace and acted as catalyst. This has brought into being a new breed of air conditioning compressors. These compressors have been generally known as high performance or improved efficiency compressors.

This paper will discuss reciprocating type improved efficiency compressors in the capacity range of 5,000 to 68,000 Btu/Hr.

DEFINITIONS

Compressor Capacity. This is the cooling capacity in Btu/Hr. at ASHRAE/T conditions. This calorimeter rating condition is 45°F evaporator, 130°F condenser, 95°F suction, 115°F liquid, and 95°F ambient temperatures.

Energy Efficiency Ratio (EER). For the compressor this is the ratio of cooling capacity and watts input to the compressor at ASHRAE/T conditions. The unit for EER is B/W (hr).

Standard and Improved Efficiency. There are no accurate definitions to distinguish between these two efficiencies. Efficiency values given in Table 1 are generally accepted by the industry as a guideline.

COMPRESSOR EFFICIENCY

Following tabulation compares the EER of standard and improved efficiency compressors in different capacity ranges.

Table 1. Compressor Efficiency Comparison

Capacity Range Btu/Hr.	EER Standard Efficiency Compressor	EER Improved Efficiency Compressor
5,000 to 7,500	7.5 - 7.8	9.0 - 9.7
7,500 to 12,000	8.2 - 8.8	9.0 - 9.5
12,000 to 20,000	8.2 - 8.8	9.0 - 9.5
20,000 to 30,000	8.5 - 8.8	9.0 - 9.6
30,000 to 40,000	8.6 - 9.0	9.1 - 9.6
40,000 to 68,000	8.2 - 9.0	9.2 - 9.9

This data is intended to illustrate the efficiency improvements achieved by the new breed of air conditioning compressors. It must be noted here that there are exceptions to these efficiency ranges and that these efficiencies encompass the bulk of compressors available to the industry.

DESIGN CHANGES - MECHANICAL

Suction Gas Superheating. Refrigerant gas returning from the evaporator is considerably colder than the inside of a running compressor. Subsequently this incoming gas picks up heat from the compressor inside ambient, electric motor, and other internal components, before undergoing the compression process. Energy required to compress a pound of refrigerant is dependent on its temperature. As the temperature goes up so will be the energy required to compress it. In the general operating range of air conditioning compressors, a 10°F increase in the temperature of the gas entering the cylinder will increase the energy required for compression by about 1.9%.

Gas handling inside the improved efficiency compressors is designed to reduce the superheating of suction gas. It had been industry practice to have either the suction muffler, the discharge muffler, or both cast as integral part of the crankcase. In some compressor designs, while one muffler is integral with the crankcase, the other muffler is built as an extension of the cylinder head. These design approaches result in compact size and also have cost advantages. But this muffler arrangement reduces the thermal resistance between the suction gas and hotter areas of the compressor. A cast in discharge muffler also provides a larger surface area for heat transfer to the lubricating oil and the inside ambient of the compressor. Improved efficiency designs generally use separate suction and discharge mufflers with minimal thermal contact with each other and with other elements of the compressor. To reduce heat transfer between the returning gas inside the suction muffler and the ambient, these mufflers are made from materials with higher thermal resistance. A 20 to 50°F reduction in suction gas superheating can be attained by this arrangement of mufflers. This will translate into an improvement of .2 to .5 B/W in compressor EER.

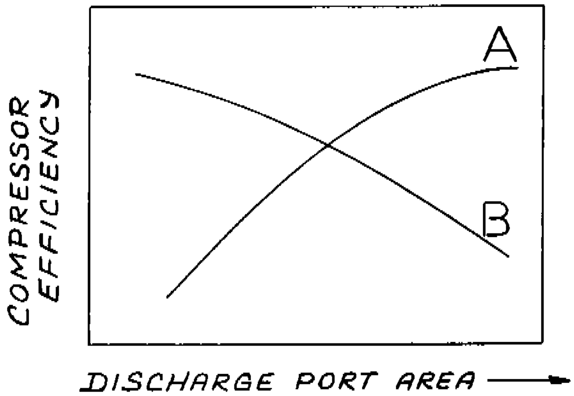
Temperature of the gas inside the compressor shell is influenced by the incoming gas and by the heat generating elements of the machine. This results in a non uniform temperature distribution. Intake orifice of the suction muffler is located such that it will pick up gas with low superheat.

Muffler Design

A very desirable muffler will have two characteristics. First it will not cause excessive flow resistance in the path of refrigerant gas. Second it will have a very broad frequency range of attenuation. This muffler ultimate is not available yet. But with the help of computers and acoustical techniques employed now, advances have been made in this direction. Acoustical requirements of a muffler, in specific compressor design application, are determined first. Mufflers are then designed to fill this requirement. This gives the designer opportunity to employ mufflers with least possible flow resistance.

Valve Plate Design

At the end of every compression stroke, when the piston reaches the top dead center, some gas is always left behind in the cylinder. This high pressure gas is trapped in the discharge ports of the valve plate and in the clearances designed between the piston, valve plate, suction leaf and the cylinder. During the suction stroke, this trapped gas expands to reduce the effective displacement of the pump and also superheats the incoming gas. Net result is a reduction in pump efficiency. Increase in the discharge port size increases this re-expansion volume and thus adversely affect the performance. But it also reduces the gas flow frictional losses and help the performance. Discharge port sizes are chosen to obtain optimum compressor efficiency. Fig. 1 shows the effect of discharge port area on the compressor efficiency.



A. Contribution of flow resistance
B. Contribution of re-expansion volume

Fig. 1 Effect of discharge port area on efficiency

DESIGN CHANGES - ELECTRICAL

Motor Design

Most of the air conditioning compressors, in the 5,000 to 68,000 Btu/Hr. capacity range, use single phase motors. Hence the motor design being discussed here will be limited to single phase motors.

Table 2 compares the efficiencies of motors used in the standard and improved efficiency compressors.

Table 2. Motor Efficiency Comparison

Capacity Range Btu/Hr	Motor Efficiency % Standard Efficiency Compressor	Motor Efficiency % Improved Efficiency Compressor
5,000 - 7,500	70 - 75	78 - 82
7,500 - 12,000	75 - 80	80 - 84
12,000 - 20,000	75 - 82	80 - 84
20,000 - 30,000	80 - 84	83 - 86
30,000 - 40,000	80 - 84	83 - 86
40,000 - 68,000	80 - 84	84 - 86

Permanent split capacitor (PSC) is the most common type of motor used by hermetic air conditioning compressors. The capacitor and the start winding, in a PSC design, stay in the circuit during starting as well as running of the motor. Design of these motors can be optimized for efficiency, while maintaining the necessary starting and maximum torque, by changing the capacitance, rotor resistance, conductor size and turn ratio of start and main windings.

Motor efficiency is also dependent on its stack, electrical conductivity of magnet wire, and the quality of steel. Fig. 2 illustrates the effect of capacitance and motor stack on the efficiency of a 30,000 Btu/Hr. compressor motor.

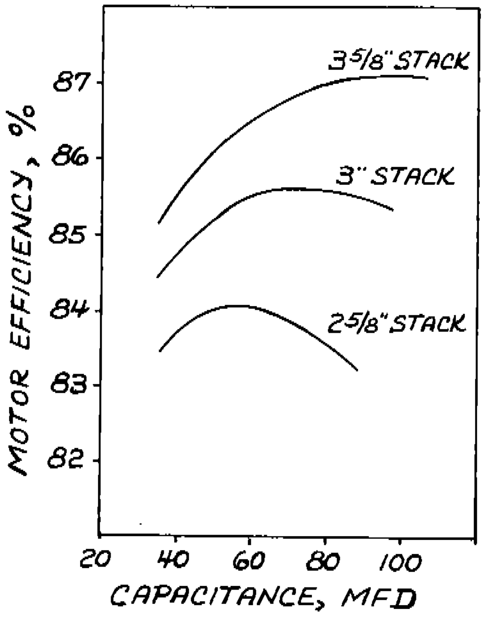


Fig. 2 Effect of capacitance and stack on efficiency

Improved efficiency compressors of today, as compared to standard efficiency models, tend to use motors with higher capacitance, higher stack, and copper conductors. All of these motor design parameters may or may not be fully exploited in a particular compressor design, but this is indicative of the trend.

Better grade of steels will make an additional improvement of 1 to 2% on motor efficiency. These low loss steels are not presently in use due to their extremely high cost.

MOTOR AND COMPRESSOR COMBINATION

In the hermetic compressor application a motor has to meet three basic requirements. First to provide adequate starting capability, second to provide adequate breakdown torque to allow the compressor to run during high load and low voltage conditions, and finally to achieve necessary running performance at ASHRAE/T conditions. Improvements in the starting ability (increase in motor locked rotor torque) and in the ability to run at higher loads (increase in motor maximum torque) adversely affect the motor performance at ASHRAE/T conditions. Motor and compressor combinations can be optimized to reduce the maximum torque demand on the motor and consequently improve the running performance at ASHRAE/T.

In a reciprocating compressor a cyclic load is exerted on the motor. Motor load is high during the compression stroke and in case of a single cylinder pump this will occur once every revolution. Multi cylinder compressors have a more even load on the motor. An increase in the number of cylinders, for a specific compressor capacity, will reduce the max load requirements of the motor because of better load distribution. But it will also mean loss of performance and increase in max torque demand due to higher frictional load. Improved efficiency designs have chosen the number of cylinders to optimize the compressor efficiency. Fig. 3 compares the maximum torque demand on the motor, made by two and three cylinder compressors in the capacity range of 40,000 to 68,000 Btu/Hr.

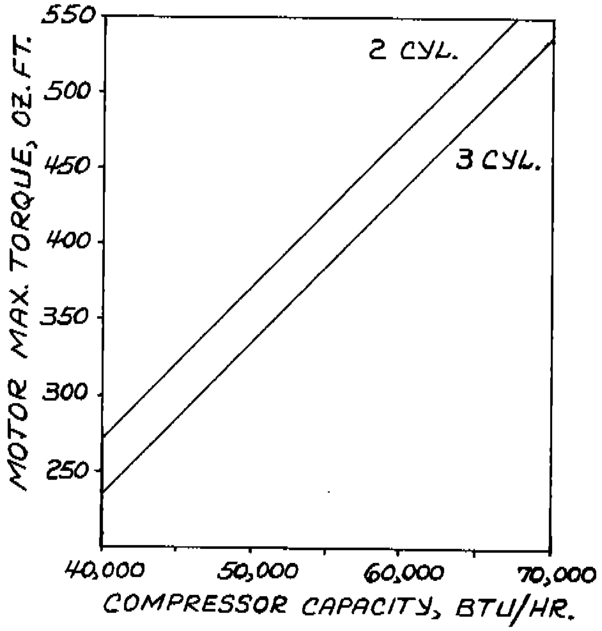


Fig. 3 Max torque requirements of two and three cylinder compressors.

REMARKS

This paper has discussed the design trend in the air conditioning compressors. Further improvements in the efficiency are possible. Use of low loss steel in the motors, capacitor start and run (CSR) design motors, higher values of run capacitance, improved muffling, gas handling and valves are the areas which will be explored. Compressor EER of 10 and better should be commercially practical in the very near future, but at a very high cost.

High performance air conditioners, presently available to the consumer, have made use of improved efficiency compressors as well as better system designs. Changes made to improve the EER have added to the cost of air conditioners. So far cost had been the main factor deciding the practicality of these improved efficiency compressors and air conditioners. Government regulations and soaring energy costs are expected to change this and the trend towards higher and higher EER is likely to continue.