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ENERGY SAVING IN A HERMETIC COMPRESSOR: REDUCING HEAT LOSSES

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ABSTRACT

Energy is becoming dearer. Saving power of domestic appliances is not only for cost benefits but a social obligation and sustaining environment. Hermetic compressor being the heart of an air conditioner, in it's function and also in the power consumption, it is continuously redesigned for increased efficiency, capacity and noise. Two terms get optimised in improving efficiency the capacity delivered and the power consumed. Noise is independently evaluated.

This study helped in identifying root causes of losses and providing corrections to improve the efficiency of fixed and variable frequency compressors to our customer's satisfaction.

INTRODUCTION

The complex analytical solution to the fluid flow and heat transfer model is difficult to arrive at. CFD packages are used, but they need to be validated by experiments and simple analysis, to validate the results. Understanding the thermodynamics of compressor and different losses are explained in detail for a reciprocating compressor [1]. A thermodynamic model of these results is evaluated by a simple thermodynamic model, HPUMP. The model [2] is developed from first law of thermodynamics. Temperatures and pressures at different parts of the compressor's outside and inside the sealed compressor are measured for different load conditions. Motor performance in terms of it's efficiency and losses are separately and individually measured [3].

Hermetically sealed compressor encloses the mechanical compressor parts, the driving electrical motor with the electrical and safety devices, the lubricating oil and the refrigerant. Hermetic sealing is provided by welding the top bottom housings; brazing the suction, discharge & process tubes to the housings and welding electrical terminal to the housing. Hermetic compressor sectional view is shown in Figure 1

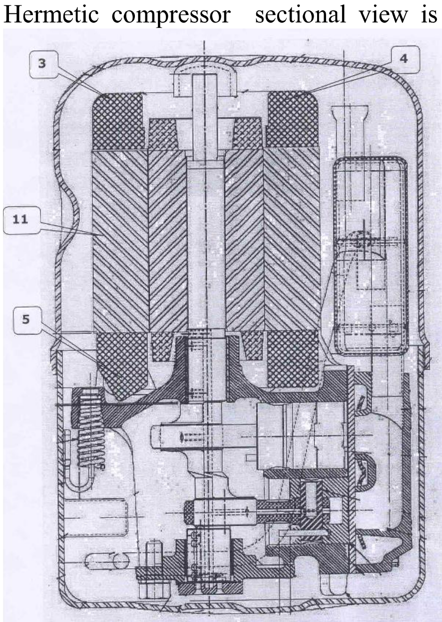

Figure 1 **Sectional View of compressor**

Figure 1, shows the electrical motor. Rotor is shrunk fit to the shaft and the stator is face mounted on to the cylinder block. Thermocouples are tied to the top winding at points 3 &4. Point 11 is the thermocouple to measure the stator core temperature, thermocouple 5 measures the winding bottom temperature. The oil from bottom mixes with refrigerant and moves up vertically cooling the mechanical and electrical parts as it circulates from suction tube to suction muffler through horizontal cylinders through the cylinder head and discharge muffler and the shock loop, end discharges out of compressor.

NOMENCLATURE

1-2-3-4	[-]	Compressor cycle. 1-2 suction, 2-3 compression, 3-4 discharge & 4-1 re expansion.
p	[Psi]	Pressure. Can be measured at different points in a compressor
V	[in^3]	Volume of the cylinder , varies during the thermodynamic cycle.

FABRICATION OF TEST COMPRESSOR

Temperature and pressure measurements inside a hermetic compressor is difficult as in a low side compressor, the suction pressure of 91 Psia, equalised pressure of 135 Psia and the discharge pressure of 314 Psia are to be withstood and also no leakages should occur through these joints. Positions of capillaries, thermocouples, thermistors are shown attached to a mufflers cylinder head assembly in Figures2.

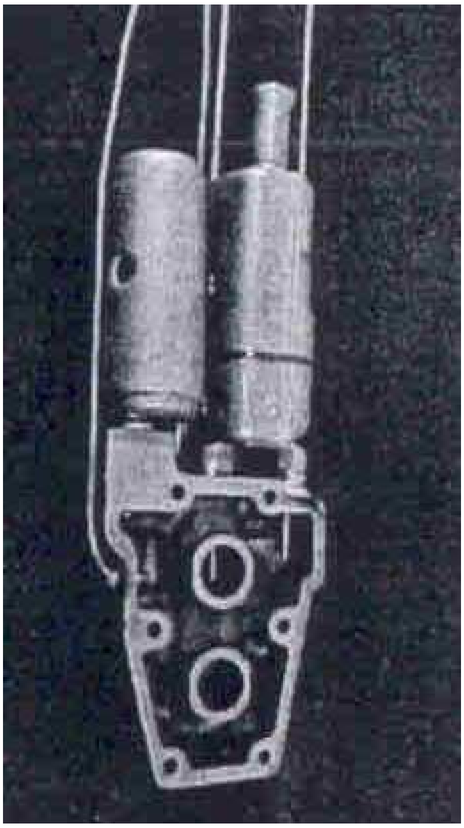

Figure 2 Cylinder head and muffler assembly

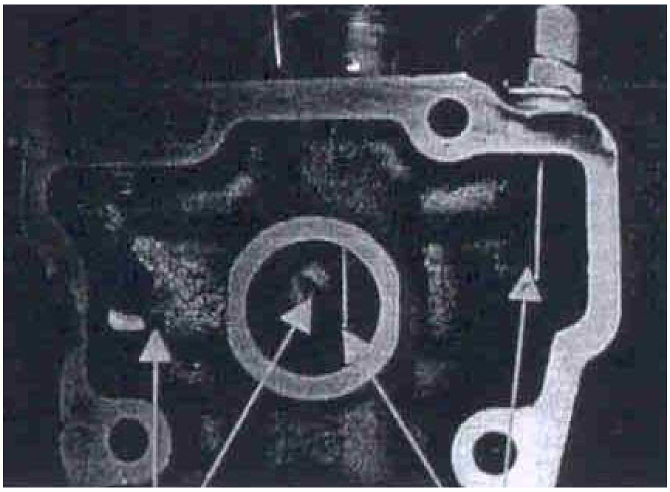

Figure 3 Pressure and temperature sensors at suction inlet and discharge outlet of cylinder head

Figure 3; shows the connections inside the cylinder head. The port opens to the suction valve in valve plate assembly and the plenum in the cylinder head is for discharge gas coming out of the discharge valve of both the cylinders.

Figure 4. shows the special test compressor, the housings of this compressor are not welded but are sealed by bolts with appropriate gasket between the two rings. All the capillaries for pressure measurements are provided with connecting tubes. All the joints are pressure tested for leaks. Electrical parts are tested for resistance and insulation resistance for performance and safety.

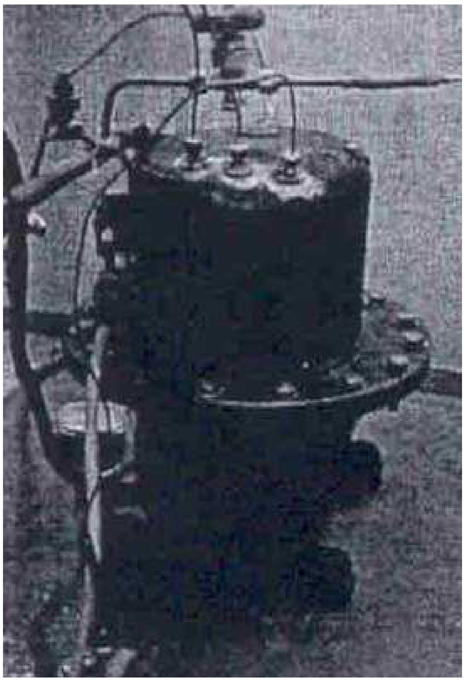

Figure 4 Bolt ring compressor for testing

EXPERIMENTATION

For a 1.5 Ton compressor.

Suction Pressure:	76 Psig
Discharge Pressure:	300 Psig
Evaporator Temperature:	7.2 Deg. C
Super heat Temperature:	27.8 Deg. C
Sub cool Temperature:	9 Deg. C
Suction Temperature:	35 Deg. C
Discharge Temperature:	111.7 Deg. C
Compressor Input:	1859 W
Cooling Capacity:	18602 Btu/hr
EER:	10.1 Btu/hr
Liq. Into expansion valve:	45.5 Deg. C
Vapor out of Cal tank:	35 Deg. C
Ambient Temperature:	35 Deg. C
Motor Speed:	2480 rpm.

Measured Experimental data

Suction plenum Temperature:	60.2 Deg. C
Discharge plenum Temperature:	75.2 Deg. C
Suction plenum Pressure:	130 Psig
Discharge plenum Pressure:	314 Psig

Thermal Audit Analysis

The thermal audit analysis of a compressor is an evaluation of the heat transfer of every part or sub system is equated to the work done.

$$W = \oint pdV = \left(\int pdV\right)_{1-2} + \left(\int pdV\right)_{2-3} + \left(\int pdV\right)_{3-4} + \left(\int pdV\right)_{4-1}$$

$$= \left(\int pdV\right)_{1-2} + p_2(V_3 - V_2) + \left(\int pdV\right)_{3-4} + p_2(V_1 - V_4)$$

=Area of thermodynamic cycle (1-2-3-4)

HPUMP METHOD

The results of the numerical simulation are validated by using an experimental setup for thermal mapping of the compressor with conventional thermocouples to measure pressure. Temperatures and pressures at critical control points are measured in the experiment. These experiment results are used to validate the simulated. Refrigerant data is taken from

Energy Balance

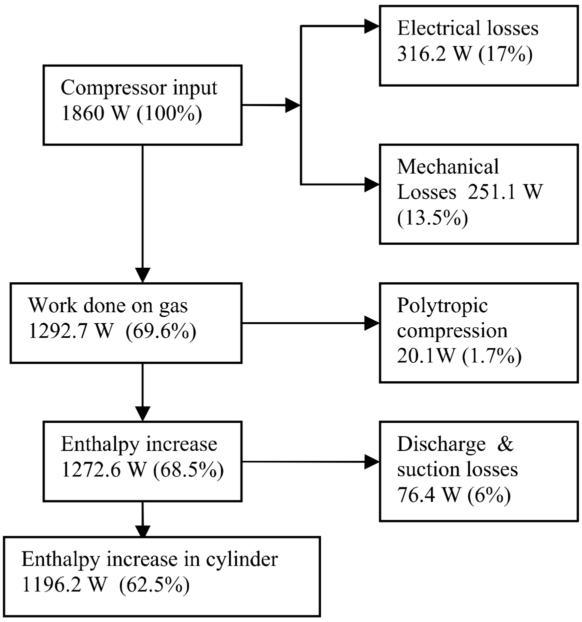

Figure 5 Energy loss distribution in a 1.5 Ton compressor.

Refrigerant data is taken from Refprop of NIST. Electrical measurements of motor were done on a dynamometer independently. Compressor performance is done in a automated calorimeter. The data from these tests are used in HPUMP and the internal losses are calculated from first law of thermodynamics.

TRENDS AND RESULTS

An analytical solution to the fluid flow and heat transfer model is difficult to arrive at., to know the validity of these results a simple thermodynamic model, HPUMP, of calculations from first law of thermodynamics is obtained. Temperatures and pressures at different parts of the compressor external and inside the sealed compressor are measured for different load conditions. Motor performance in terms of it's efficiency and losses are separately and individually measured. From these readings an estimate of the mechanical, thermal & flow losses are made. Optimized, valves, suction muffler, discharge muffler and flow paths were designed to get a 13% improvement in efficiency.

PROCESSING OF RESULTS

From these readings an estimate of the mechanical, thermal & flow losses are made. The distribution of losses are further studied by design evaluation and design of experiments to make necessary improvements to the compressors.

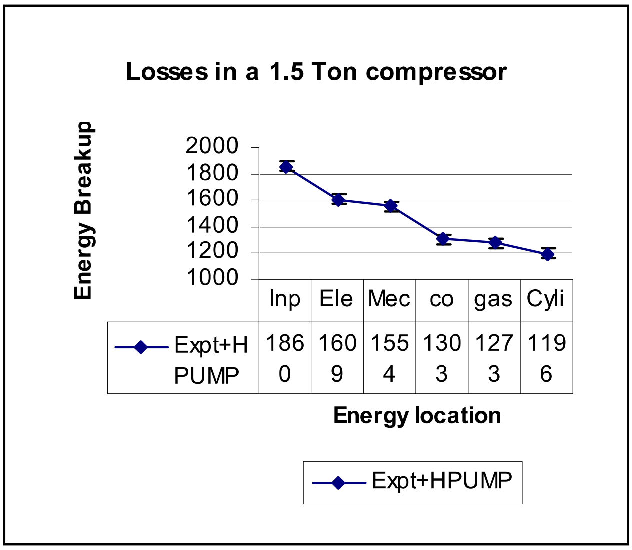

Figure 6 Energy loss break up

From Figure 6 it can be seen that about 62 % of the energy is used in useful work and the balance 38% is distributed as losses. These losses are minimised to design a higher efficiency compressor. This break up of losses is used in performance improvements in compressor. This study helped in reducing time of introduction of new models and in improving performance and quality of existing models.

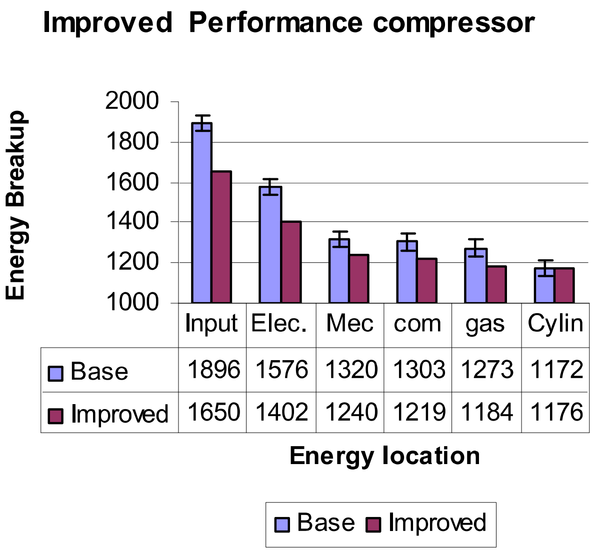

Figure 7 Improved performance Compressor

Improvements were made in compressor by changing motor design, material of core, gas path, mufflers, valve plate and valves, housing and tubes of suction and discharge. Reduction in Input power from 1896 to 1650 is a 13 % improvement in power with the same capacity as shown by the cylinder work of about 1175Watts.

CONCLUSION

This study helped in identifying root causes of losses and providing corrections to improve the efficiency of fixed and variable frequency compressors to our customer's satisfaction.

The simulation model was used to develop variable frequency compressor. Since a basic understanding of the performance and losses is obtained using HPUMP and experiments

CFD packages can be used for further work

ACKNOWLEDGMENTS

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