Design and Performance of an “Inertia” Reciprocating Compressor

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DESIGN AND PERFORMANCE OF AN 'INERTIA' RECIPROCATING COMPRESSOR

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ABSTRACT

High performance efficiency is one of the major goals of compressor design. An advanced compressor (Inertia™) has three special features. The passage of suction gas through side ports on crankcase and piston into cylinder tremendously reduces heat transfer from high side gas resulting in high volumetric efficiency. The piston mounted suction valve provides a large escape area. The discharge valve nests in the valve plate allows large escape areas for discharge gas to pass through. Opening and closing of the suction valve is controlled not only by pressure differential but also by inertia forces. The suction valve is freely floting between the piston and a retainer, therefore avoiding the spring force normally associated with reed and ring type suction valves.

The 'Inertia' compressor is 7 to 9% higher in mechanical and thermal efficiency than a conventional reciprocating compressors. With the addition of a high efficiency motor, the 'Inertia' compressor is 12 to 15% more efficient than conventional reciprocating compressor at the ARI test conditions with R-22 (45/130 20 SH 15 SC). One of the most desirable attributes of the 'Inertia' compressor is its high efficiency over a wide range of compression ratios which contributes to higher SEER ratings on unitary air conditiong and heat pump application.

This paper will present some of the design criteria which were used to develop an 'Inertia' reciprocating compressor from 2-1/5 to 5 ton capacity range.

INTRODUCTION

In order to provide a high efficiency compressor for air conditioning and heat pump application so Unitary Manufacturers can meet the new Federal Energy Standard, the high performance efficiency become a goal of compressor design. Over the years the reciprocating compressors have developed an excellent reputation for efficiency, reliability, wide range of application, and low cost of manufacture.

With unique design features, proven reliability and low cost to manufacture, the reciprocating compressor will continue to be the compressor of the nineties.

DESIGN FEATURES

The 'Inertia' compressor design incorportes several special features that achieve significant performance.

Valve Arrangement

There are four basic valve arrangements on the valve system design of reciprocating compressor: laterally in cylinder cover, parallel in cylinder cover, inclined in cylinder cover, and in piston and cylinder cover. The last valve arrangement design provides for large usable areas for suction and discharge gases to pass through. The disc type design of suction and discharge valves could be the best optimization for this in piston and cylinder cover arrangement valve system.

Gases Passage

The suction gas through side ports on the cranckcase and piston into the cylinder tremendously reduces heat transfer from high side gas. This results in better volumetric efficiency.

Disc Type Discharge Valve

The conventional ring or reed type discharge valve always result in clearance volume at discharge ports thru the valve plate. The disc type design of discharge valve seat on the valve plate and retained by the spring between valve and cylinder head. With the piston at the top dead center, the minimum clearance volume can be obtained. The 'Inertia' compressor offers 30% to 60 % reduction of clearance volume.

Inertia Suction Valve

The suction valve is freely floating between the piston and retainer which is mounted on the piston. Opening and closing of the suction valve is controlled not only by pressure differential but also by inertia force developed in the valve when the piston changes direction. This also provides a special feature of avoiding the spring force normally associated with tranditional reed and ring type suction valves. From pressure/time trace in actual test, the suction valve opened about 2 to 5 degrees earlier than the tranditional valve at ARI test condition with R-22 (45/130 20 SH 15 SC).

DESIGN CRITERIA

Several key dimensions of major components such as crankcase, piston, housing, etc. must be determined during the early design stage. These components need to have longer tooling lead time, also the outline of configuration has to be provided for unit system designer.

Stroke Range

Overall stroke range is deterimned after runing of concept compressor. Based on the test of concept compressor and theoritical net suction volume, the rough stroke range could be decided.

$$V_{ns} := \left[V_c + V_s\right] - V_c \cdot \left[\frac{P_d}{P_s}\right]^{\frac{1}{k}}$$

V_{ns} :=	Theoretical Net Suction Volume
V_c :=	Clearance Volume
V_s :=	Piston Swept Volume
P_d :=	Discharge Presure
P_s :=	Suction Pressure
k :=	The Ratio of Specific Heats of Refrigerant

The restriction of running mechanism also is to be considered. In this particular series, the two factors dictate the stroke range optimization, they are the minimum distance between wrist pin location and piston skirt end and minimum running clearance between piston skirt and counter weight. From the above guide lines, the stroke range is designed to be .480 to 1.050 inches which is able to meet the 2-1/2 to 5 ton target also provides 5 % margin.

Length of Crankcase Deck and Piston

The suction ports on the piston would reduce contact surface length between piston and cylinder. This creates a greater possibility of blowby between high and low side gas. The oil seals on the piston are necessary to avoid blowby effect. The longer pistons are needed due to the ports and seal groove on them. Three different lengths of pistons were decided that meet the above two govern factors and to provide the above stroke range.

The over all deck length of crankcase is the most critical dimension on reciprocation compressor design. The deck length is optimized according the criteria as follows:

1. Suction valve/piston above the deck at TDC
2. Suction valve lift

3. Cylinder bore relief

4. Bore relief to seal groove on piston at TDC

5. Seal groove to suction port of crankcase at BDC

6. Minimum gap between piston and connection rod

7. The length of connection rod

8. Maximum/minimum stroke

Gas Passage Area of Valve System

In order to increase the gas passage area between piston and valve, the projection of valve seat diameter on piston seat would be kept greater than the diameter of piston seat. The areas for suction gas to enter the cylinder and discharge gas to escape to cylinder head are governed by the valve lift and diameter of valve seat.

$$\text{Area} := \pi \cdot L \cdot \cos\theta \cdot \left[\frac{D_{vs}}{2} + \left[\frac{D_{vs}}{2} + (L \cdot \cos\theta \cdot \sin\theta)\right]\right]$$

$$\left[D_{vs} + 2 \cdot L \cdot \cos\theta \cdot \sin\theta\right] > D_{ps}$$

$\theta :=$ Valve Angle

$D_{vs} :=$ Diameter of Valve at Seat

$D_{ps} :=$ Diameter of Piston at Seat

$L :=$ Valve Lift

Miscellaneous

The following items must be mentioned on this advanced 'Inertia' compressor design:

1. Wire size of mounting spring and gage of mounting brackets are designed for higher running torque generated by high efficiency motors.

2. Two different housing heights are decided by using existing motor caps with various motor stack heights without new tooling.

3. Three different lengthes of piston casting and three different shaft forgings provide target capacity with most economic combination.

4. High performance engineering plastic materiais selected for both suction and discharge valves.

5. High temperature plastic was selected for the intake manifold and assembled on crankcase with proper sized O-rings.

6. PTCR selection for the single phase motors and the protectors selection for high effiency motors.

PERFORMANCE

The 'Inertia' compressor is 7 to 9% higher in mechanical and thermal efficiency than a conventional reciprocating compressors. With the addition of high efficiency motor, the 'Inertia' compressor possesses a 12 to 15% efficiency advange over conventional reciprocating compressor at ARI condition. One of the most desirable attributes of the 'Inertia' compressor is its high efficiency over a wide range of compression ratios which contributes to higher SEER ratings on unitary air conditioning and heat pump application.

CONCLUSION

The features and significant performance have been discussed for the new 'Inertia' compressors. Within a limited time from concept to agency approval and mass production, we do believe the modification on the innovative feature of suction gas passage from crankcase to piston/valve into cylinder will provide better performance in the near future.

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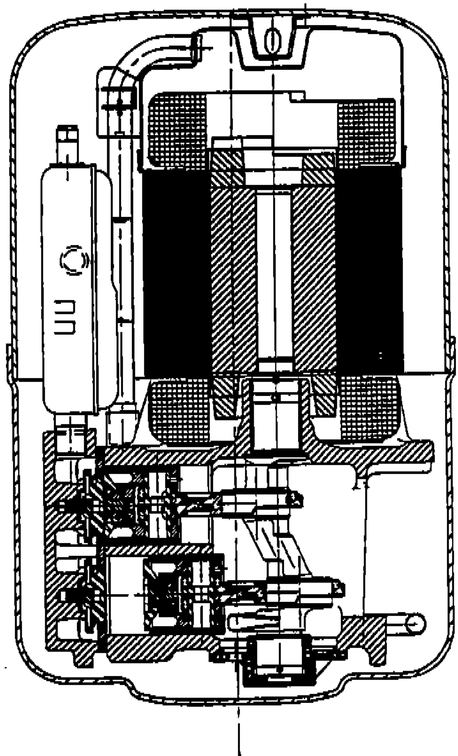

Fig. 1

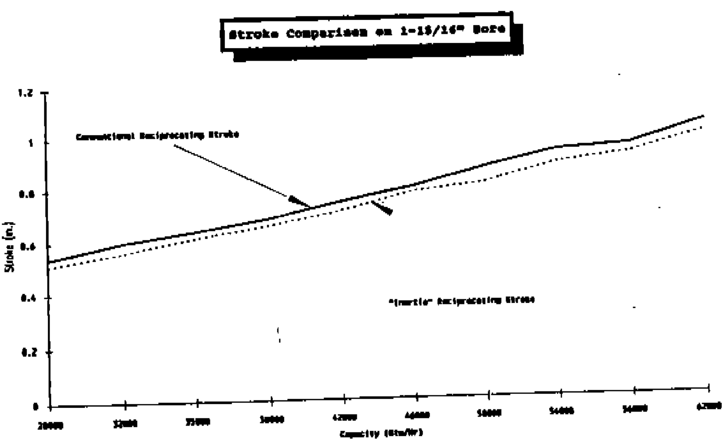
Stroke Comparison on 1-15/16" Bore
1.2
1
0.8
0.6
0.4
0.2
0
Stroke (in.)
Conventional Reciprocating Stroke
"Inertia" Reciprocating Stroke
Capacity (Btu/Hr)

Fig. 2

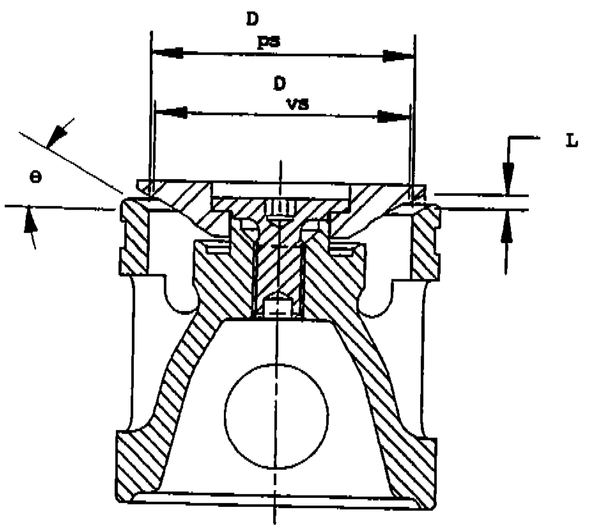

Fig. 3