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Semi-Hermetic Reciprocating Compressors workhorse of the Industry.

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The compressor in a vapour compression refrigeration cycle has mainly two functions. First it removes the refrigerant vapour from the evaporator and reduces the pressure in the evaporator to a pint where the desired evaporating temperature can be maintained. Second, the compressor raises the pressure of the refrigerant vapour to a level high enough so that its saturation temperature is higher than the temperature of the cooling medium available for condensing the refrigerant vapour

In industrial refrigeration three basic types of compressors are used. They are reciprocating, screw and centrifugal. The majority of the compressors used for commercial, and industrial applications are reciprocating type.

This article covers the reciprocating type refrigerant cooled, semi-hermetic compressors, its features and advantages over open drive and screw compressors.

Reciprocating compressors

The design of the reciprocating compressor is somewhat similar to a modern automotive engine, with a piston driven from a crankshaft making alternate suction and compression strokes in a cylinder equipped with suction and discharge valves. Since the reciprocating compressor is a positive displacement pump, it is suitable for small displacement volumes, and is efficient even at high condensing pressures and high compression ratios. Other advantages of a reciprocating compressor are its adaptability to a variety of refrigerants, the fact that liquid refrigerant may be easily run through the connecting piping because of the high pressure developed by the compressor, its durability, basic simplicity of design an relatively low cost.

Accessible hermetic motor compressors

In this type of compressor, both the motor and compressor working parts are sealed within a common enclosure. The motor stator is either pressed or bolted to the compressor body and the rotor is mounted directly on the compressor crankshaft. This type of sealing which is used in open type compressor is highly leak prone and a permanent cause of worry for the user. The hermetic design also eliminates the alignment problems faced with open drive compressors during the installation.

In accessible hermetic motor compressors widely known as semi-hermetic compressors motors are sized specifically for the load to be handled and the resulting design is compact, economical, efficient, and basically maintenance free.

Removable heads, stator cover, bottom plate and housing cover allow access for easy field repairs in the event of compressor damage.

An exploded view of a typical Copelametic semi-hermetic compressor is shown in Figure 1.

Inside view of a Copeland
3D Discus compressor

Advantages of semi-hermetic compressors

Due to the semi-hermetic design such compressors are very compact and occupy less space compared to open type machines thus saving expensive building and plant room costs. The foot print and weight of a semi-hermetic machine is 70% of that of the corresponding open type machine. These compressors are hence easier to handle and do not require heavy foundations like open type machines. The common problem of refrigerant leakage through the shaft seal is not face with the semi-hermetic compressor because the motor is directly mounted on the compressor crankshaft. Semi-hermetic compressors do not require any pulleys and belts and have no alignment problems and no wear and tear problem of the d rive elements. Such compressors are also quieter and produce less vibration compared to the open type. This reason alone makes them the ideal choice for roof-top applications.

Since hermetic motors run cooler than open type motors they are more efficient. Open type motors have a service factor of 1.1 to 1.25 which means that they can only be loaded 10% to 20% above their name plate HP rating. Hermetic motors on the other hand have a wide operating range both due to design and due to refrigerants cooling. In generals, semi-hermetic motors develop more than their nominal HP for most of their operating range Also open drive motors are exposed to the harsh and motor failure. Metal particles can lodge in the winding causing spot burns. Hermetic motors are sealed inside the compressor housing safe from the outsides debris.

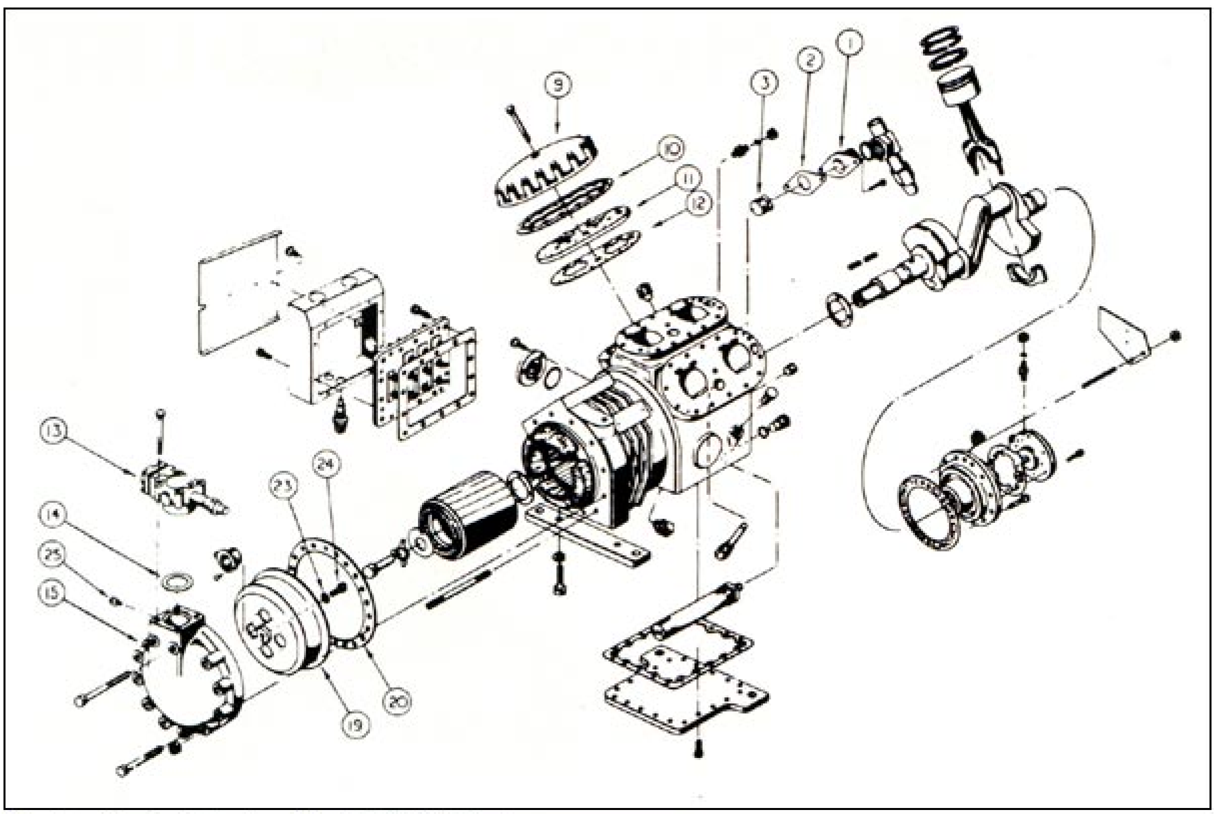

Fig 1 : Exploded view Model “6R” Series compressor

Comparision between open and semi-hermetic compressors

- **Energy Efficiency**

When comparing the published efficiency between open drive and semi-hermetic compressors, open drives are found to have marginally higher efficiency at full speeds and full load conditions. However, when open drive compressors are installed and operated in a system, the efficiency is degraded compared to the efficiency that is achieved under full speed and full load conditions due to drive losses with belt drives and due to decreased motor efficiency at lower that he designed loads. Most compressor efficiency comparisons are made on the basis of full load design value, while most system operation occurs under reduced load and reduced efficiency operation.

If an open drive compressor is operated at reduced speed using belts and pulleys, losses are introduced which detract from the efficiency improvement resulting from slower speed. The causes of these include bearing side loads, belt creep and slippage and flexure of belt and pulley alignment. Leading manufactures of belt and pulleys have stated that a two to three percent loss in power transmitted through the system is typical for a well aligned and properly maintained belt drive system. However they also caution that even slight misalignment can result in significantly higher drive system losses.

Multiple, unequal, non-unloading semi-hermetic compressors always operate at or nears peak motor efficiency. Capacity reduction to meet light load conditions is accomplished by turning the compressor off, not by unloading. Unless these reduced load losses are taken into account for an open drive compressor, the comparison is incomplete and inaccurate.

- **Refrigerant Versatility**

Open drive compressor manufacturers have claimed their products are more versatile in the face of the CFC issue and oil and the speed of the compressor can be varied by changing the pulleys.

All refrigerant and lubricant combinations considered for replacing CFCs and HCFCs are compatible with the materials used in semi-hermetic compressors, manufactured by leading compressor manufacturers.

Because of the lubricity and miscibility issues, conventional mineral oil is not a satisfactory lubricant for use with new refrigerants. However, this is an issue with all compressors to be used with HFCs, whether they are of screw, open-drive, rotary, scroll, and reciprocating design. In every case, some or all of the mineral oil has to be removed and a new lubricant installed. The only advantage one compressor type will have over another is oil volume requirements, since the new lubricants are substantially more expensive than the mineral oil previously used. Some types of compressors such as the screw may have a substantial disadvantage because of he large amount of oil they require for lubrication and cooling.

Most refrigerants presently considered as replacements for CFCs/HCFCs have capacity characteristics similar to the refrigerant they are replacing. Therefore, belt driven open drives and their ability to change speed for capacity reasons provide no advantage.

- **Compressor Discharge Temperatures**

It is widely believed that the discharge temperature of an open type compressor is at least 55°C less than that of a semi-hermetic compressor. The reason given is that the motor heat resulting from the motor inefficiency is conveyed to the suction gas in the semi-hermetic but not in an open drive.

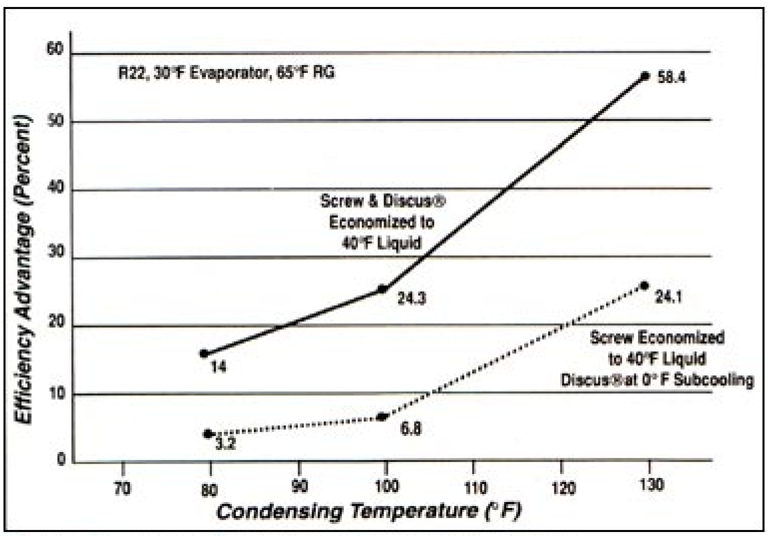

Fig 2 : Efficiency Advantage, Discus® vs. Screw

The Copeland Discus compressors have motors with 90% efficiency levels. Since the higher efficiency motor does not develop as much heat, it does not need as much cooling. As result most of the suction gas bypasses the motor resulting in very little suction gas superheating which helps in reducing the discharge temperature substantially.

Another factor often overlooked is that there is substantial frictional heat generated in the shaft seal of an open type compressor. Thus the discharge temperature is higher for an open drive than would be expected from looking at an isentropic compression efficiency analysis.

- **Cost Effectiveness**

Semi hermetic compressors have a substantial cost advantage over open type compressor. Slow speed, open drive systems have additional operating costs which semi-hermetic systems do not haves. For example, the drive belts must be replaced periodically and must be replaced in sets. Belt tension and alignment must be maintained in order to have the drive system operate with minimal losses. Open drive machines under the best of refrigerant and oil for replenishing the system should not be overlooked.

Copeland Discus semi-hermetic Vs screw compressors for refrigeration.

Drive speed flexibility is no longer a major purchase criterion for refrigeration compressors. Replacement refrigerants which work quite well in reciprocating compressors are now available. The choice between reciprocating and screw compressors has to be done to the basis of operating cost, firs cost, and service.

- **Operating cost**

The primary factor affecting operating cost for refrigeration systems is efficiency. Copeland has performed head to head tests comparing the efficiency of Discus compressors with modern open drive screw compressors. The graph in **Figure 2** shows the efficiency advantage of Discus compressor at different condensing temperatures.

Discus rack systems have an even greater advantage because multiple Discus compressors can be modulated more efficiently than multiple screw compressors

The estimated operating cost advantages with Discus compressors is 10 to 30% less than comparable screw compressor systems.

At first glance a screw system looks small land sample However, after the motor, oil separator, oil cooler, piping and controls are added it is neither small nor simple.

- **Service**

Although screw compressors appear to have an advantage of simplicity and fewer moving parts, actually they are less tolerant to minor problems. A screw compressor is ruined if it is run in the opposite direction. Extra care must be taken to keep the rotor free of debris. Poor maintenance of oil filters will eventually lead to problems. An oil solenoid leak during an off cycle is disastrous. Variable speed drives may require special maintenance and must be done by trained technicians.

Open screws have another disadvantage when compared with Discus systems due to their extensive reliance on oil seals to contain refrigerant leakage. Seals remain intact because they run on a film of lubricant. The lubricant makes an imperfect seal and small amounts of refrigerant are vented to the atmosphere. This contradicts requirements for leak free systems and adds to the operating cost.

Some open-drive, shaft seal materials are not compatible with new refrigerants. Seal failure will cause refrigerant loss and require specialized replacement. Proper motor coupling alignment is also required for long seal life. Semi-hermetic screw compressors avoid many of these problems, but at the cost of other claimed advantages.

Based on the information gathered till date, Discus compressors are equal to or superior to screw compressors in all areas of cost and effectiveness.

Capacity control for semi-hermetic compressors:

Blocked suction internal unloading is used in the Kirloskar Copeland semi-hermetic compressor for capacity control. 6 cylinder model have both single and two stage capacity control options. 4 cylinder compressors come with single stage capacity control. Any standard compressor model can be changed to capacity control model by changing only the cylinder head.

A schematic illustration of the internal valve operation is shown in **Figure 3**.

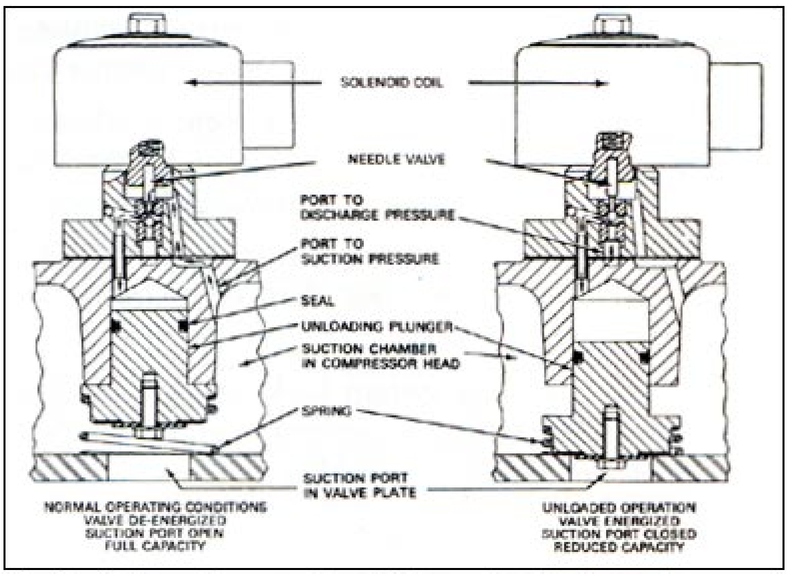

Fig 3 : Schematic operation of internal unloader valve

In the normal (full capacity) operating position with the solenoid valve de-energised, the needle valve is seated on the lower port and the unloading plunger chamber, the gas pressures across the plunger are equalized, and the plunger is held in the open position by the spring.

When the solenoid valve is energized, the needle value is seated on the upper port, and the unloading plunger chamber is exposed to discharge pressure through discharge pressure port. The differential between discharge and suction pressure forces the plunger down, sealing the suction port in the valve plate, thus preventing the entrance of suction vapour into unloaded cylinders.

Demand cooling semi-hermetic compressors

R-22 when used in a properly designed and controlled refrigeration system is a realistic low temperature refrigerant alternative to R-502 which must be phased out due to its high ozone depletion potential. But R-22 can present problems as a low temperature refrigerant because under some conditions the internal compressor discharge temperature exceeds the safe temperature limit for long term stability of refrigerant oil.

To maintain the discharge temperature within safe limits "demand cooling" is employed in semi-hermetic compressors. The "demand cooling module" uses the signal of a discharge gas temperature sensor to monitor discharge gas temperature. If a critical temperature is reached, the module energises a long life injection valve which meters ma controlled amount of saturated refrigerant into the compressor suction cavity to cool the suction gas. This process controls the discharge temperature to a safe level.

If for some reason the discharge temperature rises above a preset maximum level the "demand cooling module" switches the compressor off and actuates its alarm contact. To minimize the refrigerant which must be injected, the suction gas cooling process is performed after the gas has passed around and through the motor See **Figure 4**.

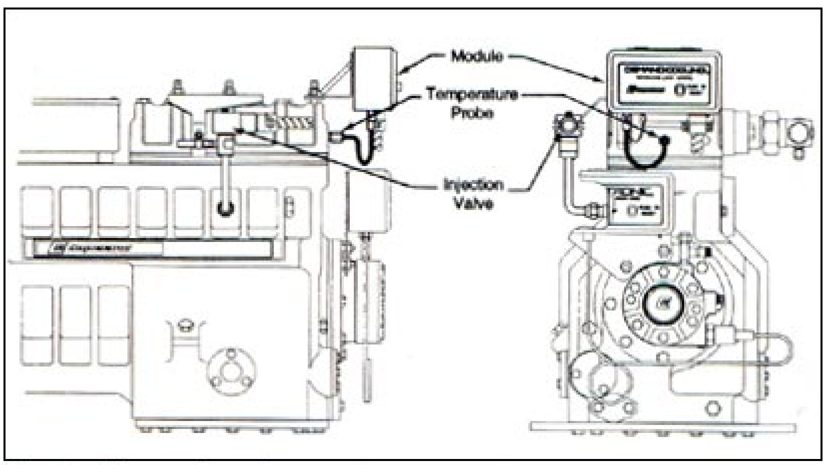

Fig 4 : Demand cooling system

Special features

Semi-hermetic compressors made by Kirloskar Copeland:

- Use an electronic oil pressure controller to safeguard the compressor from lubrication failure. This controller uses a pressure sensor and an electronic module to precisely measure oil pump differential pressure and provides better protection than the age-old mechanical pressure switches. The controller does not require any capillary tubes, bellows and pressure connectors required for mechanical pressure switches which are a known source of refrigerant leakage. The major advantage with this protector is that it comes with a factory set trip point thereby preventing field abuse.

- Use an electronic motor protection device which has the capability of tripping off the compressor if the temperature and or the current drawn by the motor goes above the set values. This module uses PTC sensors embedded in the motor windings to sense the temperature. These sensors can sense even local hot spots and trip the motor thus protecting it from coil burn out.
- Are fitted with DU bearings which can withstand lack of lubrication for a considerable time and hence reduce chances of a bearing seizure.
- Most models haves part winding start facility which reduces the starting current requirement substantially and hence there is no need to use additional staring devices for the compressor.

Conclusion

The modern trend in air conditioning and refrigeration industry is towards more compact, easy to handle and automatic operation units. Semi-hermetic reciprocating compressors are best sited for such needs and give the benefits of both open drive and hermetic compressors.