Maintaining Open-drive Chiller to Minimize Leakage

By Jim Parsnow

Introduction

About one-third of the centrifugal water-cooled chillers sold use open-drive motors as opposed to semi-hermetic motors that are sealed and serviceable.

However, these open-drive chillers tend to have the highest leak rates in the industry. Leaking refrigerant not only costs building owners money each year, but also exposes them to liability for environmental contamination, unsafe conditions, and EPA violations.

With careful maintenance, refrigerant leakage can be minimized, and open-drive motors can achieve their average life potential of 10 to 15 years.

There are three important areas to consider for safety, longevity and failure prevention:

1. Refrigerant and oil leakage;
2. Failure modes; and
3. Proper ventilation.

Shaft Seal Leakage

In open-drive centrifugal chillers, refrigerant and oil leakage through the shaft seal can be a cause for concern.

In these systems, the drive shaft from the compressor drive unit is connected to the open motor outside of the compressor housing, so a "rear seal" must be used to ensure minimum leakage of oil and refrigerant.

Open-drive seals are designed to minimize leaks in two modes: during operation of the chiller, when the compressor shaft is rotating; and during a shutdown period, when the shaft is stationary.

As seals are designed to accommodate both conditions, along with normal contact wear on the seal, both oil and refrigerant will leak through the seal. Refrigerant loss increases as the seals dry out during long shutdown periods.

The industry average for refrigerant lost via the oil leaking through the rear seal is 2% of the full chiller refrigerant charge annually.

Oil leakage varies, and can be monitored by collecting it in measured containers connected to shaft seal drains. ASHRAE Guideline 3, *Reducing Emission of Fully Halogenated Chlorofluorocarbon Refrigerants in Refrigeration and Air-Conditioning Equipment and Applications*, provides some understanding and recommendation for rear-seal leaks.

Choose the right seals

To maximize performance and prevent failure, use seals designed to withstand exposure to contaminants found in oil and refrigerants during normal chiller operation.

Double-faced seals and single-carbon seals, with improved features to keep the carbon in a wet state, have been found to be effective and are recommended by ASHRAE Guideline 3.

Lubricate during shutdown and start-up

Lack of lubrication during shutdown periods can cause mating faces of the seal to dry out and adhere together. To avoid this, seals should be lubricated prior to start-up.

It may be necessary to run the oil pump and rotate the shaft periodically during long shutdown periods. If this is not possible, the seals should be inspected and lubricated before starting the system. On large systems, a separate oil pump is recommended to lubricate the seal prior to starting the compressor.

Open reciprocating compressors typically have carbon-face seals that require positive pressure in order to function

Figure 1: Hermetic chiller

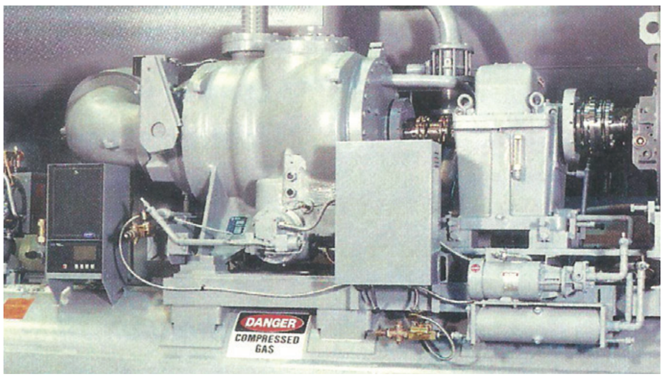

Figure 2: Open-drive chiller

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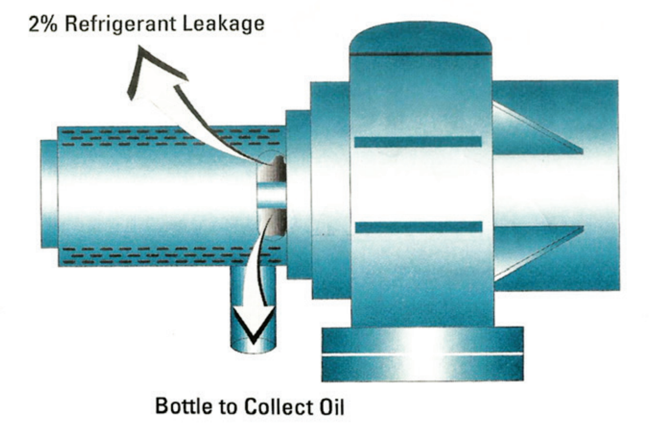

Figure 3: Refrigerant leakage that commonly occurs in open-drive motors.

Leak Rates For Rotary Chillers

	Negative Pressure*		Positive Pressure**	
	Old Installed	New	Old Installed	New
Open Drive	17%	1-2%	10%	1-2%
Hermetic	15%	.5%	8%	.1%

*Operating below atmospheric pressure in cooler
**Operating above atmospheric pressure in cooler

Figure 4: Comparison of refrigerant loss in open-drive vs. hermetic chillers

properly. Since these are not two-way seals, leakage may occur during evacuation.

To prevent leakage, temporary sealing measures (such as shaft caps or clay-like weather stripping) around the protrusion of the shaft should be used.

Motor-compressor alignment is critical in limiting refrigerant leakage, and is affected by the style of the coupling and the speed and horsepower of the motor. Refrigeration machinery requires stringent alignment to accommodate thermal growth over the load and temperature ranges.

Failure Modes

Motor failures in open-drive chillers most often result from misalignment, improper electrical protection, and overheating.

As noted in ASHRAE Guideline 3, motor-compressor alignment is critical in limiting refrigerant leakage. Thermal growth during operation, along with shipment loads, can cause motor-bearing failure along with increased rear-seal leakage.

Proper alignment documentation at the manufacturer's factory should be requested, along with a "hot" or "after run-in" realignment in the final installation. This critical alignment procedure should be included as part of the start-up operation, as well as of any service contract.

Protection at the power supply is also critical in motor protection. Ground fault protection options for motor starters should be used on all installations to ensure full protection. Almost every motor failure that resulted from an electrical

Open-drive vs. Hermetic: What's the Difference?

In a hermetic chiller, the motor is sealed inside the compressor and is efficiently cooled by liquid refrigerant sprayed directly onto the motor windings. The compressor drive shaft is attached to the motor inside the refrigerant atmosphere.

With this configuration, there is no need for the shaft to pass to the outside, thus greatly reducing the chiller's potential for oil and refrigerant leakage.

In open-drive chillers, the motor operates outside the chiller, connected by the compressor drive shaft, which passes through a seal between the inside refrigerant and outside ambient atmospheres. The motor is aircooled and generates more heat than a sealed hermetic motor, necessitating additional mechanical room ventilation and/or cooling.

As sealed systems cooled by refrigerant, hermetic motors have a longer life expectancy – 25 years, as opposed to an average of 10 years for open-drive motors. Hermetic chillers' reliability translates into less concern about downtime and lower service costs. Hermetic chillers also have a track record of lower leak rates (see *Figure 4*).

With all the apparent advantages of hermetic chillers, what's the advantage of an open-drive chiller?

For very large applications requiring chillers over 2,000 tons, open drives are the only type of chiller manufactured. In these large-horsepower applications, quite often the motor will be water- or forced-air-cooled.

Another reason is easy repair. For chillers of all sizes, in the event of burnout, an open-drive motor is more easily replaced with less downtime. The chances for motor failure in a hermetic chiller, however, can be decreased by insisting that ground-fault protection be included in starter equipment or taking steps to prevent premature motor failure.

Regardless of the type, care should be taken to ensure that every chiller is equipped, installed, and operating properly for optimal performance, maximum safety, and the longest useful life possible.

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overload could have been prevented with the proper ground fault protection.

Temperature in the mechanical room can also shorten motor life and lead to failure. One open-drive chiller manufacturer states in its service manual that at full load, motor insulation life is approximately cut in half for each 18° above 40°C ambient.

Proper Ventilation

Open-drive motor chillers generate more ambient heat than hermetic chillers. Proper ventilation can reject this heat during chiller operation, and also helps ensure that any vented refrigerant is removed from the mechanical room. And if the mechanical room is air conditioned, additional cooling equipment can dissipate the motor heat.

If a new, open-drive-motor chiller is installed, the additional heat must be taken into consideration, especially if a hermetic chiller was originally specified. If an open-drive chiller is already in place, the motor ambient temperature limit should be checked. If the mechanical room exceeds or is near this limit, steps need to be taken to augment the ventilation or air conditioning.

For additional protection, a mechanical room thermostat should be installed and set at 40°C, so that if this temperature is exceeded, the chillers will shut down. The control will also send an alarm signal to the central energy management system (ems) display module, prompting the service personnel to diagnose and repair the cause of the over-temperature condition.

Look at the Whole Picture

Since chiller performance is a balance of energy in (heat) versus energy out (cooling), accounting for the open motor heat rejection must also be considered. Any auxiliary ventilation and/or cooling required to maintain the mechanical room conditions will impact the chiller's compliance with its energy efficiency requirement.

Its costs should also be incorporated into the overall required power of the equipment when evaluating and selecting a chiller.

Conclusion

A wide spectrum of factors can affect open-drive system performance. Manufacturers stress that careful maintenance is required for open-drive motors to reach their full 10 to 15 years.

Standards such as ASHRAE Guideline 3 and ASHRAE 15 provide some general direction concerning operational issues of open-drive chillers. However, it is important to work closely with the manufacturer to establish the proper maintenance program for the specific open-drive system installed.