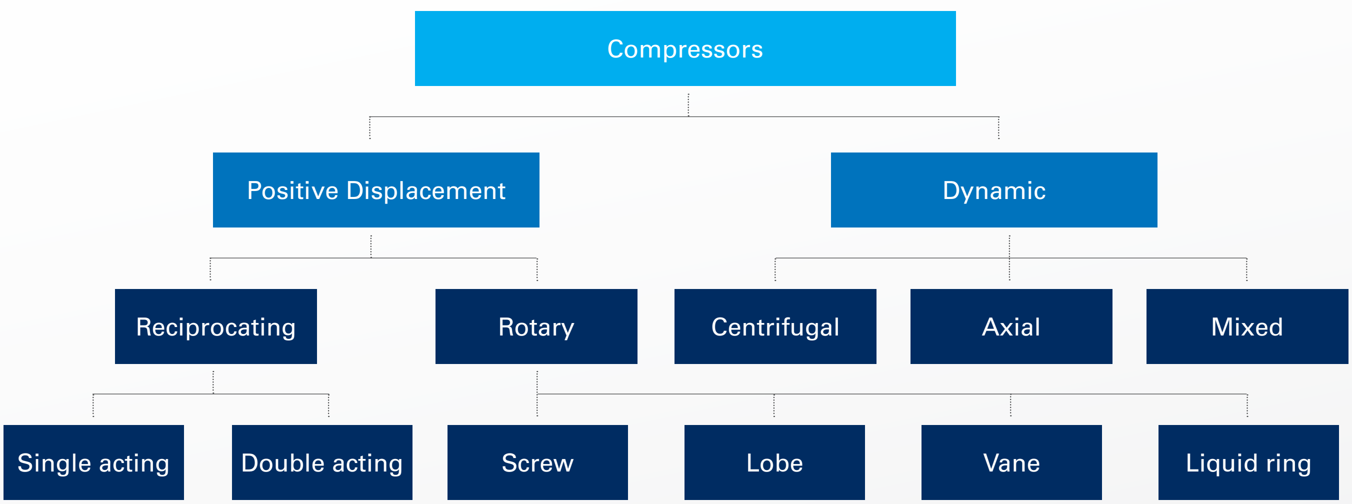
Optimizing compressor performance and equipment life through best lubrication practices

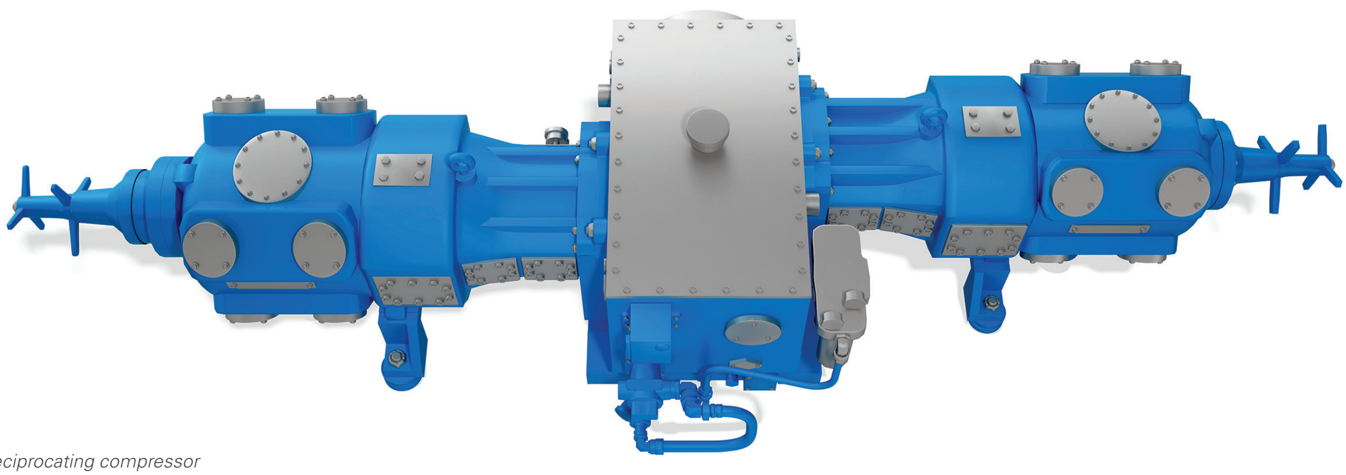
A compressor's basic purpose is to increase the pressure of a gas or a mixture of gases and apply it to a specific use. Most applications involve air compression, however refrigeration and natural gas compression also are very common. While the gases being compressed may vary, the construction and operation of compressors are basically the same. This paper delves into the different types of compressors, the operational challenges they face and best lubrication practices to optimize performance and equipment life.

Compressor types

There are two major types of compressors – positive displacement and dynamic. Positive displacement creates compression by moving a solid boundary, preventing the gas from flowing back toward the pressure gradient. Dynamic compressors increase the velocity of the gas, and the resulting kinetic energy is converted into pressure energy. Compressors can be further classified as follows:



Positive displacement compressors



Reciprocating compressor

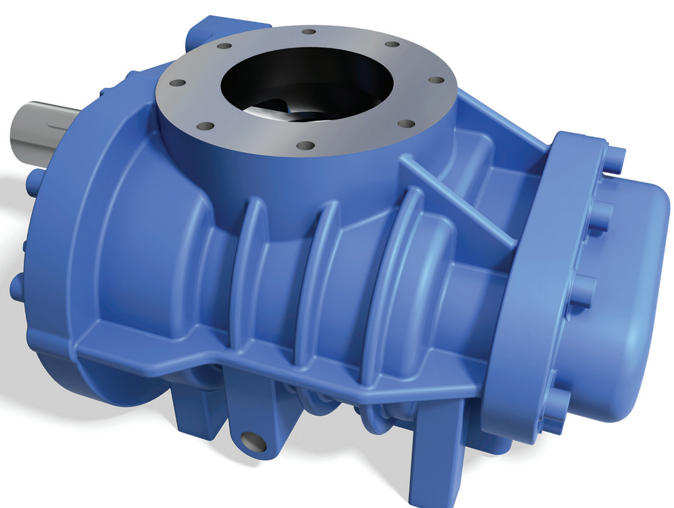
Reciprocating compressors

In these units, gas is compressed and displaced by a piston moving in a reciprocating motion within a cylinder. If compression occurs on only one end of the cylinder (only one of the two piston strokes per crankshaft revolution) it is known as single acting. If compression occurs on both piston strokes per revolution, it is double acting. Reciprocating compressors are typically classified by cylinder arrangement: horizontal, vertical, V, opposed, etc.

In a reciprocating compressor, the cylinders and running gear may be lubricated from the same oil supply or separately. Except where cylinders are open to the crankcase, oil is generally fed directly to cylinder walls at one or more points via a mechanical force-feed lubricator. The cylinders are splash lubricated from the oil reservoir by means of scoops or other projections on the connecting rods or cranks. Since the oil entering the compression chamber invariably ends up in the pipes and discharge passages, the lubricant must be resistant to deposits that can lead to blockage and even explosions in extreme cases. Reciprocating compressors generally use higher viscosity lubricants (ISO VG 68 to as high as ISO VG 460) compared to rotary compressors.

Rotary screw compressors

The rotary screw compressor, also known as helical lobe or spiral lobe, is a two-rotor mechanism that compresses gas between the intermeshing lobes and the rotor chambers of the housing. The male or driven

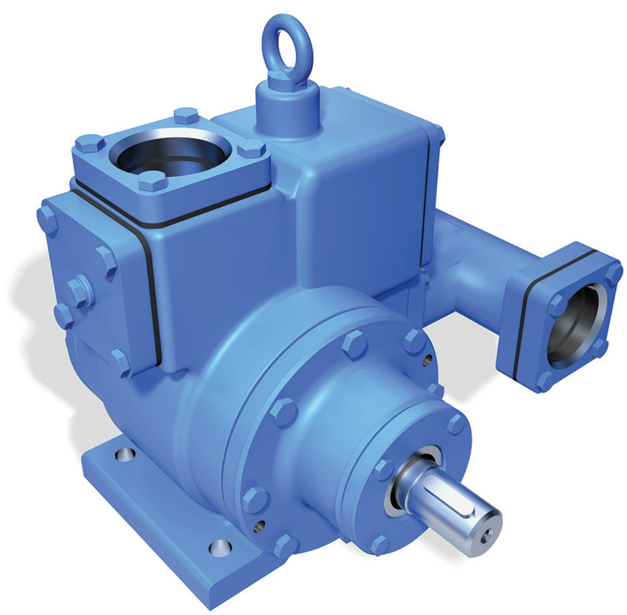


Rotary screw compressor

rotor fits into the pocket of the female or gate rotor. When viewed lengthwise the rotors resemble large screws.

There are two types of rotary screw compressors. One uses timing gears to properly phase the two rotors at all times. These are also known as oil-free or dry screw compressors because the rotors require no lubrication; sealing is achieved by close clearances. The second type floods oil through to lubricate and seal the rotors and cool the compressed gas. Oil-flooded units achieve compression by meshing the rotors in a one-piece cylinder.

In all rotary screw compressors, gears and bearings must be lubricated with premium oils formulated to protect against wear, rust and oxidation.



Sliding vane rotary compressor

Sliding vane rotary compressors

These compressors consist of a cylindrical casing and a slotted rotor assembly fitted with vanes (blades). The rotor is mounted eccentrically within the bore and the vanes slide in and out during each revolution, using centrifugal force to maintain contact with the cylinder wall. Gas entering a suction port is trapped between the blades at their maximum projection and is compressed as the space between the rotor and cylinder decreases. At full compression the blade reaches the discharge ports to release the gas. Since the blades operate in boundary conditions, constantly rubbing in the slots and the casing wall, these compressors require a premium lubricant to minimize friction and wear.

Dynamic compressors

Dynamic compression occurs through the transfer of energy from a set of rotating blades to a gas, in which the rotor changes the momentum and pressure of the gas. The momentum, or kinetic energy, is converted into useful pressure energy by slowing down the gas in a stationary diffuser or another set of blades. Dynamic compressors are classified as centrifugal (the most versatile and widely used), axial or mixed flow, depending on the flow path. Although they differ in design, the same basic aerodynamic theory applies to all three. Dynamic compressors require no internal lubrication and can provide oil-free gas if the inlet gas itself is oil free.

Staging in compressors

Both positive displacement and dynamic compressors share basic elements and have certain limiting operating parameters, such as temperature, pressure, size, etc. When any limitation is reached it becomes necessary to multistage the process, using two or more compression steps. Each step will use at least one basic compressor element designed to operate in series with the other elements of the machine. Most compressors are available in single or multistage designs. When air is compressed, its temperature increases. Multistage compression allows cooling between stages, which saves work in the compression process. Multistage positive displacement compressors nearly always feature an intercooler between stages to take optimal advantage of staging.

Key applications and lubricant considerations

Across the range of compression applications, lubrication requirements vary considerably. Two primary factors go into determining the optimal lubricant – the type of compressor and the gas being compressed. In general, air and gas compressors are mechanically similar. The main difference is the effect of the gas on the lubricant. Generally, gases for compression fall into four categories:

INERT	HYDROCARBON	REFRIGERATION	CHEMICALLY ACTIVE
• Air • Nitrogen • Helium • Argon • Carbon Dioxide • Ammonia	• Natural Gas • Refinery Gas • Propane / Methane • Ethylene • Coke-oven Gas • Coal Gas • Blast-furnace Gas	• CFC (R-12, Freon F-12) • HCFC (R-22, R-31, R-21, R-123) • HFC (R-134a) • HFC (R-32, R-11, R-12, R-23, R-125) • Ammonia (R-717)	• Chlorine • Oxygen • Hydrogen Chloride • Sulfur Dioxide • Hydrogen Sulfide

Inert / Air compression

Air compressors are primarily used in manufacturing and construction. Manufacturing plants use large-capacity stationary units, usually reciprocating, screw or multistage centrifugal, while construction compressors must be self-contained and mobile, usually positive displacement types.

Proper lubrication depends on application and conditions. In humid environments, water condensation in reciprocating compressor cylinders must be properly handled with compounded type compressor oils. For splash lubricated reciprocating compressors, oils meeting DIN 51506 VDL specification with low coking tendency is recommended. In high-pressure compression, a synthetic polyalfaolefin (PAO) or synthetic diester (DE) based compressor oil is recommended to prevent carbon deposits and ensure smooth equipment operation.

Hydrocarbon / Natural Gas compression

The most diverse types and sizes of compressors are found in the chemical and process industries, including a robust market in pipeline compression for natural gas transmission. In process applications boosters are used, which compress gas from an initial pressure above atmospheric to a still higher pressure. Many of the processes require enormous volumes of compressed gas, which is best provided by dynamic compressors. Also, dynamic compressors are preferred due to minimal contact with lubricant.

During hydrocarbon compression, the gas tends to wash lubricant from the cylinder walls and dissolve into the lubricant, reducing the oil's viscosity. This problem that can be counteracted by using higher-viscosity formulations of compounded oils that resist washing.

Another consideration in hydrocarbon compression is miscibility. Lubricants made with mineral oil or certain hydrocarbon-based synthetic base oils tend to be miscible in the gas stream and can cause a condition known as dry cylinder. Left unaddressed, this can damage the cylinders, as they are effectively not being lubricated. One solution is to use a Poly Alkylene Glycol (PAG) synthetic oil, which is not a hydrocarbon derivative and not miscible. Take special care when using a PAG, as it not compatible with hydrocarbon-based oils.

Finally, compressors handling high concentrations of hydrogen sulfide (sour gas) are usually lubricated with oils having a higher Total Base Number (TBN).

Ammonia

In ammonia compression applications special consideration must be given to lubricant formulation, as the ammonia has a tendency to react with certain additives. Also, to address solubility issues, a higher viscosity grade is usually recommended compared to air compression applications.

Refrigeration

Proper refrigeration depends on the reliable compression of refrigerant. Most applications use reciprocating compressors, with rotary vane and screw compressors sometimes used as low-pressure or booster stages. Evaporators in the refrigeration cycle may operate either dry or flooded. In dry evaporators only refrigerant vapor is present, while flooded evaporators contain both liquid and vapor. In many industrial applications ammonia is used a refrigerant. However, due to its toxicity, ammonia was replaced by CFCs, which were later replaced (due to impact on the ozone layer) with HFCs in residential and automotive applications. Lubricant selection depends on the refrigerant being used. Most OEMs have specific requirements that must be followed at all times. Systems using ammonia for normal applications use mineral-based refrigeration oils, however most other refrigerants require specific synthetic lubricants. General lubrication guidelines are listed to the right.

REFRIGERANT	LUBRICATION
CFC (R-12, Freon-12)	Highly refined naphthenic-based refrigeration oil
HCFC (R-22, R-31, R-21, R-123)	Highly refined naphthenic-based oil. Some applications also may use paraffinic base oil. For severe low temperatures (-60°C to -100°C) alkylated benzene-based oils may be used
HFC (R-134a)	Polyol ester-based oils. (Naphthenic or paraffinic oils cannot be used with this specific HFC)
HFC (R-32, R-23, R-125)	Highly refined naphthenic base oils. Polyol ester based oils also may be used in certain applications
R-407A and R-407C	These are a mixture of R-32, R-125 and R-134a, with A indicating a 20:40:40 ratio and C indicating 23:25:52 ratio. Since this mixture has R-134a, a polyol ester-based oil must be used
R-410A	This is a mixture of R-32 and R-125 on 50:50 ratio. These being HFCs, naphthenic or polyol ester refrigerating oil may be used
Ammonia (R-717)	Highly refined naphthenic oils are sufficient in most cases. Some applications also may use paraffinic base oil. Alkylated benzene based oils may be used for severe temperatures and operating conditions
Propane and other hydrocarbon refrigerants	As these are highly soluble in mineral oils, PAG based compressor oils are recommended

Lubricant classifications and standards

ISO 6743-3

- DAA, DAB, DAG to DAJ: Air compressors
- DVA to DVF: Vacuum pumps
- DGA to DGE: Gas compressors
- DRA to DRG: Refrigeration compressors

DIN 51506

- VB, VC: Uninhibited mineral oils
- VBL, VCL: Mineral oil based engine oil
- VDL: Inhibited oils with increased aging resistance

DIN 52503

- KAA: Not miscible with ammonia
- KAB: Miscible with ammonia
- KB: For carbon dioxide (CO2)
- KC: For partly and fully halogenated fluorinated and chlorinated hydrocarbons (CFC, HCFC)
- KD: For partly and fully fluorinated hydrocarbons (HFC, FC)
- KE: For hydrocarbons (e.g. propane, isobutane)

Gas Compressors (including Natural Gas)

PRODUCT	DESCRIPTION	SPECIFICATION / APPROVALS
Cetus PAG	Premium polyalkylene glycol-based oil for hydrocarbon and chemical compressor units	Suitable for use in Burckhardt compressors requiring PAG fluid
HDAX NG (ISO 100)	Premium performance oil for units compressing dry natural gas, or natural gas containing water or sour gases	Suitable for all natural gas screw compressors, including Frick, Howden, FES, Mycom and Ariel
Cylinder Oil W (ISO 220, 460, 680)	Emulsifying oil for lubrication of compressor cylinders, including natural gas units	Meets ANSI/AGMA 9005-E02 for AGMA Lubricant Numbers 5, 7 Compounded, and 8

Refrigeration Compressors

PRODUCT	DESCRIPTION	SPECIFICATION / APPROVALS
Capella® A (ISO 68)	Premium synthetic oil based on PAO for lubrication of ammonia refrigeration units operating at high discharge temperatures in systems with extremely low evaporator temperatures	Meets British Standard BS 2626:1992 and DIN 51503; approved by ABB Stal Refrigeration AB, Broedrene Gram and Sabroe
Capella HFC (ISO 32, 55, 100)	Fully synthetic oil with polyolester technology for refrigeration and AC compressor systems using HFCs, especially R134a	Suitable for units from Bitzer, Bock, Carrier, Century, Daikin, Hi Air Korea, Namirei, Sabroe, Ushio Reinetsu and York
Refrigeration Oil Low Temp (ISO 68)	Premium low-temperature oil based on alkylbenzene designed to offer very low floc point and deliver superior performance in the R22 and R502 evaporator environment	Approved by Bitzer, Bock, Sabroe, Carrier, Thermo King, Dorin, Danfoss, Necchi/ERC and Howden
Capella P (ISO 68)	Premium paraffinic for ammonia systems; also recommended for systems using refrigerant R-22 and R-502 above -30°C; (not for systems using R-12 or R-134a)	
Capella WF (ISO 32, 46, 68)	High-quality, essentially wax-free (naphthenic) oil for refrigeration and AC compressors running refrigerants other than HFCs, such as chlorofluorocarbons (CFCs), ammonia, hydrochlorofluorocarbons (HCFCs), carbon dioxide, sulfur dioxide or ethylene chloride	Meets British Standard BS 2626:1992, Type A Lubricant; suitable for APV-Baker, Bitzer Kühl-maschinenbau, Bock, Carrier, Copeland, Gram, Grasso, Linde, McQuay, Mycom, Sabroe, ABB Stal Refrigeration AB, Sullair, Technofrigo Dell' Osto, York (ISO VG 32, 68)

Run Better Longer

Understanding the many types of lubricants and how they can protect particular compressors is the first step to designing smart lubrication programs that can boost equipment reliability and overall productivity throughout the operation. We can help.

Chevron Industrial Performance group has developed advanced expertise, premium lubricants and targeted programs to help compression operations implement optimal lubrication solutions, so they can extend oil life and get the most out of their equipment. For more information, visit chevronindustrial.com.