
 AMMONIA REFRIGERATION

Importance of Oil in Refrigeration Plants

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 AMMONIA REFRIGERATION

Importance of Oil


Ensuring Efficiency, Reliability, and Longevity of Industrial Systems

Agenda

- ▶ The Mechanical Heart: Compressors and Lubrication.
- ▶ The Paradox of Refrigeration Oil.
- ▶ The Four Primary Functions of Oil.
- ▶ Mechanical Lubrication vs. Gas Sealing.
- ▶ Heat Dissipation in High-Pressure Systems.
- ▶ System Cleaning and Contaminant Transport.
- ▶ Types of Oils: Mineral, AB, POE, and PAG/PAO.
- ▶ Essential Properties: Viscosity, Pour Point, and Floc Point.
- ▶ Oil circulation in Refrigeration Systems
- ▶ The "Oil Loop" and System Dynamics.
- ▶ The Threat of Oil Migration and Evaporator Logging.
- ▶ Need for Oil Separator and its working Principle
- ▶ Advanced Separation Technology and Benchmarks.

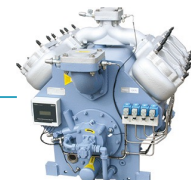
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 AMMONIA REFRIGERATION

The Mechanical Heart

Oil = Lifeblood of the Compressor
Lubricates, cools, and protects.



Refrigerant = Blood
Carries heat through the system.

HEART OF REFRIGERATION SYSTEM

Refrigeration oil is the compressor's lifeline. It lubricates moving components, minimizes friction, removes heat, and prevents premature wear. Without adequate oil, compressor failure can occur rapidly due to overheating and severe mechanical damage.

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The Paradox of Oil

✓ **Inside the Compressor**
 Oil is an absolute necessity. It prevents wear, seals gases, and cools rotors. It ensures volumetric efficiency.

✗ **Outside the Compressor**

Once oil enters the heat exchangers (condensers and evaporators), it becomes an unwanted contaminant that drastically kills efficiency.

📌 **Effective oil management is one of the most important factors in refrigeration system performance and reliability.**

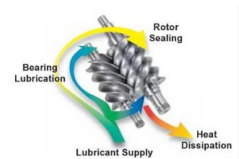
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The Four Primary Functions

Core Functions Overview

1. **Mechanical Lubrication:** Preventing metal-to-metal contact.
2. **Gas Sealing:** Maintaining pressure differentials.
3. **Heat Dissipation:** Absorbing compression heat.
4. **System Cleaning:** Transporting wear debris to filters.



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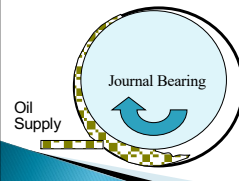
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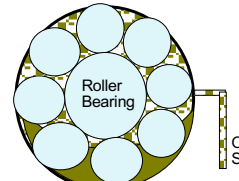
1. Mechanical Lubrication

The oil forms a hydrodynamic film between moving parts. This film must be strong enough to withstand the load of the rotating crankshaft and pistons without breaking.

The Risk of Failure:

If this microscopic film breaks (due to low viscosity or oil starvation), direct metal-to-metal contact occurs. This results in galling, bearing failure, and catastrophic compressor destruction.





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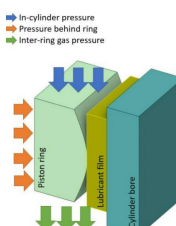
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2. Gas Sealing

Viscosity is critical for creating a microscopic fluid seal between the high-pressure (discharge) and low-pressure (suction) sides.

Reciprocating: Seals the gap between piston rings and the cylinder wall.

Screw Compressors: Seals the gap between the meshing male and female rotors. Without oil, the high-pressure gas simply "blows by" back to suction.



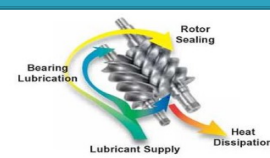
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3. Heat Dissipation

Compressing refrigerant generates intense heat. Refrigerant vapor removes part of this heat, but compressor oil plays the critical role of cooling and protecting internal mechanical components.

If oil flow is restricted, discharge temperatures will instantly spike. High discharge temperatures lead to oil carbonization (cooking) on the exhaust valves.



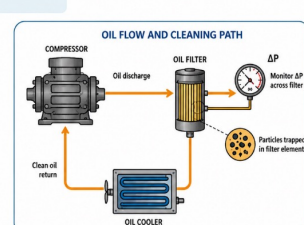
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4. System Cleaning

A closed-loop system generates microscopic wear debris over time (metal shavings, silica, etc.). Proper oil circulation and filtration keep the system clean and reliable.

- Oil suspends these fine particulates.** The oil film captures and holds wear debris in suspension.
- Transport and Protection** Oil transports the contaminants safely away from critical bearing surfaces and precision components.
- Filtration** Contaminants are deposited into the primary oil filters, keeping the oil clean and effective.



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Types of Oils & Evolution

Mineral Oils (MO)

The traditional standard, refined from crude petroleum. Categorized mainly as Naphthenic (preferred due to low wax) and Paraffinic.

Applications: Ammonia (R-717) and older HCFCs.

Miscibility with Ammonia: *Immiscible.* They do not mix. This separation requires special arrangement (oil pots) to manage safely.

Cost: Highly cost-effective but has limited thermal stability. Approximately Rs. 500.00 to 600.00 per liter in India.

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Types of Oils & Evolution

Alkylbenzenes (AB)

The first step into synthetic lubricants. Formed by chemical reaction rather than distillation.

Advantages over Mineral Oil

- Superior thermal stability at high discharge temperatures.
- Excellent low-temperature fluidity (very low pour point).
- Does not contain waxes that plug expansion valves.

Cost: Costlier than the mineral oil as this oil is semi-synthetic oil has good thermal stability. Approximately Rs. 1000.00 to 1500.00 per liter in India.

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Types of Oils & Evolution

Polyol Esters (POE)

The required synthetic standard for modern HFC refrigerants (R-134a, R-404A) and CO₂.

- Miscibility:** Highly miscible with HFCs, ensuring smooth return from evaporators.
- Hygroscopicity:** Rapidly absorbs moisture from the atmosphere.
- Hydrolysis:** Moisture causes POE to break down into acids and alcohols, leading to motor burnout and copper plating.
- Cost:** Higher cost due to fully synthetic oil & has very good thermal stability. Approximately Rs. 2200.00 to 2300.00 per liter in India.

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Types of Oils & Evolution PAG & PAO Synthetics

PAG (Polyalkylene Glycol)
Used in automotive AC and specialized CO2.
Extremely hygroscopic.
Incompatible with POE oils (creates sludge).

PAO (Polyalphaolefin)
Premium synthetic alternative for Ammonia.
Exceptional thermal and chemical stability.
Longer service life in severe industrial applications.

Cost: Higher cost due to fully synthetic oil & has very good thermal stability.
Approximately Rs. 2200.00 to 2600.00 per liter in India.

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Lubricant Comparison Matrix

Type	Primary Refrigerants	Miscibility	Moisture Sensitivity
Mineral (MO)	Ammonia, HCFCs	Low (Immiscible)	Low
Alkylbenzene (AB)	Ammonia, HCFCs	Medium	Low
Polyol Ester (POE)	HFCs, CO2	High (Miscible)	Very High
PAO	Ammonia	Low	Low

No lubricant is universally superior. The best choice depends on refrigerant compatibility, oil return requirements, and moisture control strategy.

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The Hidden Costs of Cheap, Low-Grade Oils

Frequent Oil Changes: Cheap oils oxidize rapidly, requiring 2x to 3x more changes per year.

High Volatility: Higher carry-over rates, increasing the load on your separators.

Sludge Formation: Deposits require manual teardowns and chemical cleaning of heat exchangers.

Energy Overhead: A 1% drop in heat transfer due to oil fouling can increase annual electricity costs by lakhs of rupees.

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Essential Properties

Property 1: Viscosity

The measure of a fluid's resistance to flow. It is the single most important property.

Too Low (Thin): The oil film breaks under load, causing wear and loss of gas seal.

Too High (Thick): Excessive friction, heat generation, and poor flow return from the cold evaporator.

Viscosity Index (VI) measures how much viscosity changes with temperature. High VI = highly stable.

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Essential Properties

Property 2: Pour Point & Floc Point

Pour Point
The lowest temperature at which the oil will still flow under gravity. If evaporator temp drops below pour point, oil freezes into solid sludge.

Floc Point (Cloud Point)
The temperature at which wax crystals begin to precipitate out. Wax crystals instantly plug expansion valves (TXV) and pilot controls.

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Essential Properties

Property 3: Chemical Stability

Thermal Stability: Resisting carbonization (coking) at the discharge valves (>120°C).

Oxidation Resistance: Resisting breakdown when exposed to oxygen.

Acid Number (TAN): A measure of degradation. High TAN indicates acids are forming, which will corrode internal copper pipes and motor windings.

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Oil Circulation in Refrigeration Systems

What Happens?

During operation, a small amount of oil is entrained by the high-velocity refrigerant vapor at the compressor discharge. This oil circulates with refrigerant through the system and may accumulate in the condenser and evaporator. As a result, less oil returns to the compressor, causing poor lubrication and reduced efficiency.

Problems caused by oil circulations:

- Poor lubrication – wear and overheating
- Oil accumulation in evaporator
- Inc. Pressure drop in coils and lines
- Higher Power consumption
- Possible liquid slugging and compressor failure.

SOLUTION

- ✓ Oil Separator removes oil from the discharge vapor and returns it to the compressor.
- ✓ Oil Cooler maintains oil at the right temperature and viscosity before it enters the compressor.

Oil Separator improves oil return and system efficiency. Oil Cooler maintains proper oil temperature and viscosity for reliable lubrication.

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System Dynamics & Loop

How oil moves through, and escapes, the primary circuit.

The "Oil Loop" Explained

While refrigerant travels the entire plant, the primary oil loop should ideally be isolated to the compressor package.

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Reciprocating Dynamics

Oil sits in a crankcase sump. An internal oil pump forces it through the crankshaft to rod bearings.

Main Bearing & Connecting rods: Requires continuous hydrodynamic oil film.

Wrist Pins: Experience pivoting friction; heavily dependent on splash or forced lubrication.

Oil Level glass: Essential visual checkpoint for mechanical safety.

Piston Rings: Require oil to glide smoothly against the cylinder liner.

Friction Reduction: Prevents scoring and micro-welding of metal surfaces under high heat.

Heat Dissipation: Cools the cylinder walls during the violent compression stroke.

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Rotary Screw Compressors Dynamics

Rotor Interlocking Profile: Rotors mesh together at incredibly high RPMs.

Oil Injection: Liquid oil is injected directly into the moving rotors.

Cushioning Effect: The oil film absorbs shock loads and reduces mechanical chatter.

Wear Prevention: Ensures the driving rotor does not erode the driven rotor.

Capacity Control: Provides infinitely variable capacity modulation (e.g., 10% to 100%).

The Shaft Seal: The only boundary preventing refrigerant gas from leaking into the room. Maintains microscopic liquid seal between stationary & rotary seals. Prevents cracking of seals due to frictional heat.

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Oil carried over to the system

Crankcase Starvation & Mechanical Failure

The Mechanics of Aerosolization: A very high discharge temperatures break down oil into microscopic vapor and creates fine oil mist.

Loss of Oil: If oil leaves the compressor faster than it returns, the oil level drops. Oil pressure will drop and compressor will trip on low oil pressure or low oil level.

Boundary Lubrication: Metal-on-metal contact begins as the fluid film collapses.

Catastrophic Seizure: Bearings overheat, melt, and snap the connecting rods.

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Condenser Fouling – The First Stop

The oil aerosol enters the condenser alongside hot, high-pressure gas.

As the refrigerant cools and condenses into a liquid, the oil separates.

Oil coats the internal copper or steel walls of the condenser coils.

Reduces the effective surface area available for subcooling the refrigerant.

An oil-coated condenser cannot reject heat efficiently.

Consequence: Head pressure (discharge pressure) climbs significantly.

Motor Strain: The compressor motor must draw more electrical current to pump against higher head pressure.

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Evaporator Fouling in Ammonia Systems

- Oil is significantly heavier than liquid ammonia.
- Escaped oil sinks directly to the absolute bottom of evaporators and surge drums.
- Forms a stagnant, thick insulating blanket on the inside of cold tubes.

Result: Drastic loss of heat transfer, forcing lower suction pressures and wasting power. You end up burning electricity to cool a layer of oil, rather than cooling your product.

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Recognizing Logging Symptoms

Symptom Observed	System Impact
Frequent adding of oil	Compressor sump remains empty; oil is hiding in coils.
Inability to reach setpoint	Massive loss of heat transfer capacity in air units.
Sluggish expansion valve	High-viscosity oil causing drag on TXV needles.
Sudden oil return on defrost	Hot gas thaws the frozen oil, slugging the compressor.

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The Physics of Oil Logging in Heat Exchangers

The Evaporator Crisis - Understanding Insulating Layers in the evaporator.

Viscosity Behaviour at Low Temperatures:
Refrigeration oils are designed to flow. Inside the evaporator (-10°C to -40°C), oil changes from a thin fluid to a thick, like sludge. The oil settles at the bottom of the evaporator tubes, creating stagnant pools.

The Thermal Insulation Effect:
An oil film of just 0.1 mm acts as an effective thermal blanket inside the tube. Prevents the boiling refrigerant from absorbing heat from the process fluid or air.

Suction Pressure Drop & Capacity Loss:
To force the heat across that insulating oil layer, the system naturally drops its suction pressure. This lower pressure means less dense gas, lower mass flow, and a severe drop in total plant cooling tonnage.

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The Physics of Oil Logging in Heat Exchangers

The Evaporator Crisis - Understanding Insulating Layers in the evaporator.

Dangerous Refrigerant Liquid Slugging:
Periodically, a massive surge of trapped oil and unevaporated liquid refrigerant enters the compressor and make loud hammering sound. It happened during starting of every cycle. Liquids are completely incompressible. When the slug hits the compressor cylinders, it breaks valves, cracks pistons, and destroys bearings.

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Need For Oil Separator and its Working Principle

Oil separators:

- Return oil to compressor crankcase
- Prevent oil accumulation in evaporator
- Improve heat transfer
- Reduce compressor wear
- Increase system efficiency
- Essential in low-temperature and multi-compressor systems

Working Principle

- High-pressure refrigerant-oil mixture enters separator.
- Velocity decreases.
- Centrifugal/impingement action separates oil droplets.
- Oil collects at bottom.
- Float valve returns oil to compressor.
- Refrigerant vapor exits to condenser.

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Hardware & Adv. Separation

Engineering solutions to control and filter oil.

Infrastructure Overview

```

    graph LR
      A[Separation  
Catching the oil at the discharge line.] --> B[Cooling  
Restoring safe viscosity levels.]
      B --> C[Recovery  
Bringing back what escaped.]
      C --> A
    
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Effective oil management requires a holistic approach; a failure in one component compromises the entire loop.

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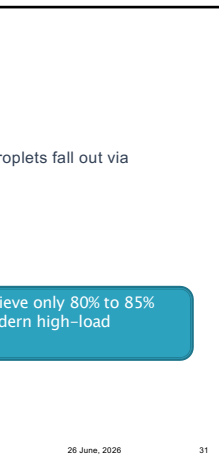
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Traditional Separation

Velocity Drop (Impingement):
Rapidly slowing the gas velocity so heavy oil droplets fall out via gravity.

Demister Pads:
Wire mesh pads that catch fine mist droplets.

Limitation: Traditional demisters generally achieve only 80% to 85% efficiency, which is no longer sufficient for modern high-load industrial plants.



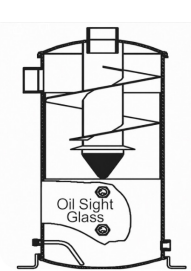
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Helical Flow Principles

Modern high-efficiency designs utilize centrifugal force.

- The gas/oil mixture is forced into a spinning helical path.
- Centrifugal force throws the heavier oil droplets to the outer walls.
- Reduces pressure drop (ΔP) significantly compared to forcing gas through thick mesh filters.



Helical Oil Separator

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Advanced Coalescing Technology

To catch microscopic aerosols (below 10 microns), coalescing elements are required.

Fiber Matrix: Borosilicate glass microfibers capture sub-micron aerosols.

Merging: Fine aerosols are forced together, merging into larger, heavier droplets.

Drainage: An outer drainage layer allows the liquid oil to fall by gravity into the sump.



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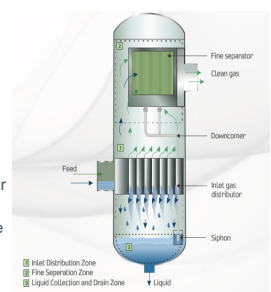
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Multi-Stage Design Benchmarks

Combining helical flow with high-grade coalescing elements represents the current pinnacle of separation technology.

Target Efficiency

The engineering goal is to reduce oil carryover to less than 5 PPM (Parts Per Million). This translates directly to massive energy savings by keeping the evaporator surfaces clean over the plant's lifespan.



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Benefits of Oil Separator and factors affecting its Performance

Without Separator	With Separator
Oil in evaporator	Clean heat transfer surface
Reduced capacity	Improved cooling capacity
Poor lubrication	Proper compressor lubrication
High power consumption	Lower energy usage
Frequent maintenance	Increased reliability

Factors Affecting Separator Performance

- Gas velocity and Oil viscosity
- Refrigerant type
- Operating temperature
- Pressure difference
- Separator design

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Case Study: High-Efficiency Performance

Analyzing the internal construction of high-performance units reveals why they outperform standard catalog models.

- Dual-chamber design for turbulence reduction.
- Integrated oil-return ports for automated recovery.

Good Quality Coalescing oil separators Efficiency

99.98%
Maximum separation efficiency under full compressor load, securing evaporator heat transfer.

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Case Study: Yearly cost of oil top up Mineral Oil

For reciprocating & Screw compressor with standard available Oil separator approx. oil carryover and oil top up charges for Mineral oil @ 350 INR.

➤ Reciprocating Compressor:

With Standard available oil separator – 7 ltrs X 12 = 29400 INR
With High Efficiency Oil separator – 0.5 ltrs X 12 = 2100 INR

➤ Screw Compressor :

With Standard oil Oil Separator – 12 ltrs X 12 = 50400 INR
With High Efficiency Oil Separator – 0.5 ltrs X 12 = 2100 INR

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Case Study: Yearly cost of oil top up Synthetic

For reciprocating & Screw compressor with standard available Oil separator approx. oil carryover and oil top up charges for Synthetic oil @ 1950 INR.

➤ Reciprocating Compressor:

With Standard available oil separator – 7 ltrs X 12 = 163800 INR
With High Efficiency Oil separator – 0.5 ltrs X 12 = 11700 INR

➤ Screw Compressor :

With Standard oil Oil Separator – 12 ltrs X 12 = 280800 INR
With High Efficiency Oil Separator – 0.5 ltrs X 12 = 11700 INR

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The Golden Rule

⚠ Never Mix Oils!

Mixing incompatible oils can cause:

- Sludge formation
- Separator blockage
- Compressor failure
- System downtime

Before Changing Oil Type

- ✓ Verify compatibility with refrigerant and compressor manufacturer
- ✓ Completely drain existing oil
- ✓ Flush the system if required
- ✓ Replace oil filters and separators as recommended
- ✓ Confirm residual oil contamination is within acceptable limits

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THANK YOU

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