Water, Water, Everywhere

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Agenda

- How much water is in there?
- The three forms of water in lubricants
- The effects of water contamination on in-service lubricant performance
- Water separation tests
- How to measure water concentration in oil
- Methods to remove water contamination
- When is water a desirable component of a lubricant?

How Much Water is Typically in Oil?

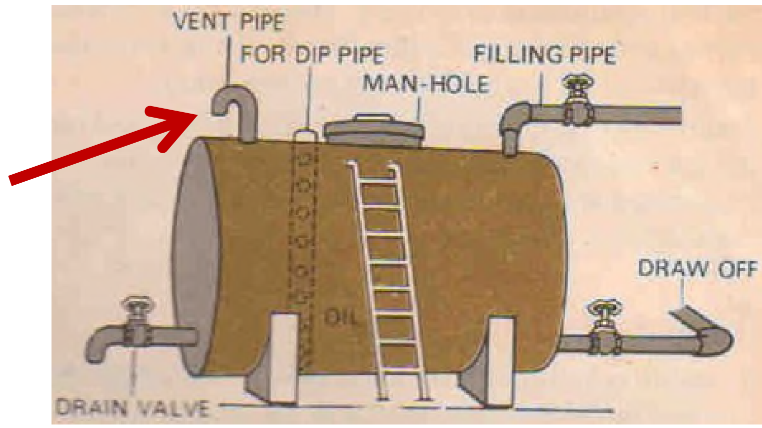
- Most new lubricating oils contain trace amounts of water
    - Typically less than 100 ppm (0.01 %)

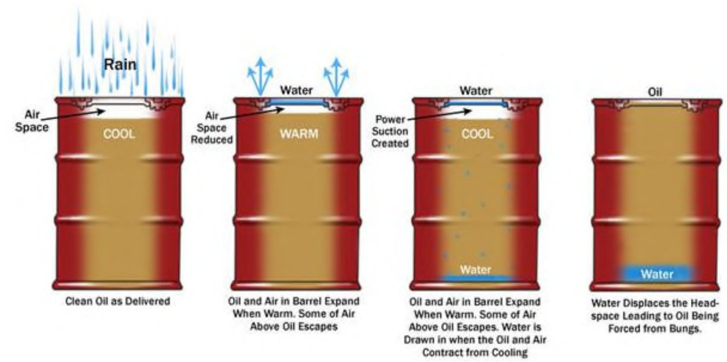
- Transformer oils and high dielectric strength hydraulic oils are specially treated to reduce water concentration (<30 ppm, 0.003 %)

Where Does the Water Come From?

Water can enter a mechanical system in several ways:

- The atmosphere (humidity, precipitation)
- Improper or ineffective vent or breather
- Improper lubricant storage
- Cooling system leaks
- Condensation
- Equipment wash-down





Courtesy: Machinery Lubrication

The Three Forms of Water in Lubricants

- Water in both new and in-service oils is found in three forms:
  - Dissolved water
  - Emulsified water
  - Free water

- New oil should <u>never</u> contain emulsified or free water!

The Three Forms of Water in Lubricants

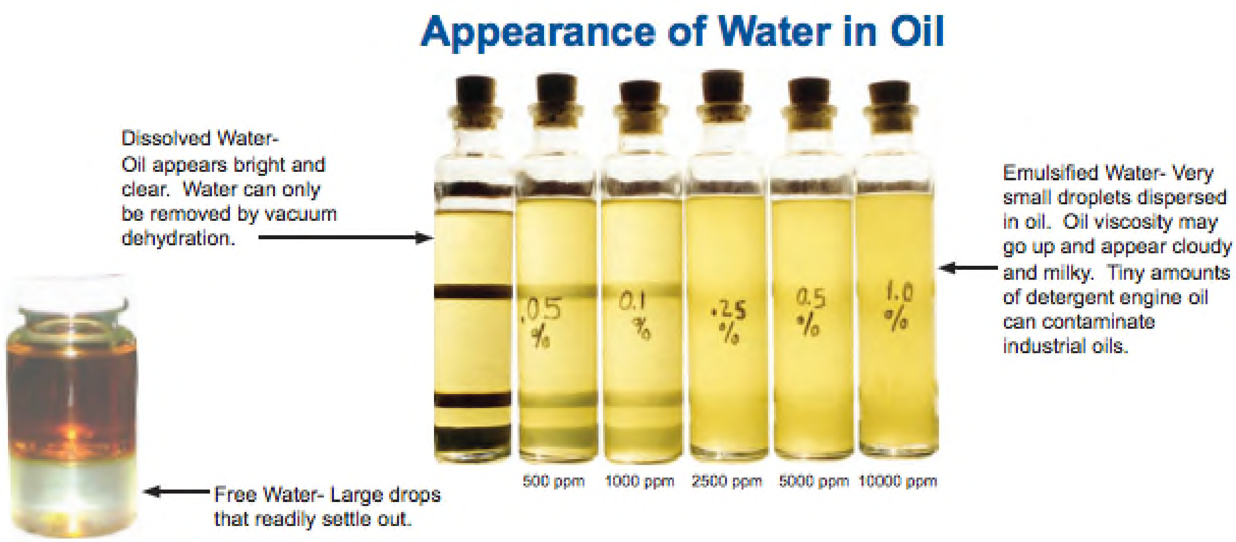
- Dissolved water – a small amount of water dissolves in oil, causing no change in appearance, and no decrease in performance.

- The amount of dissolved water in in-service lubricants varies depending on the type of lubricant, its age, and the temperature. The lubricant typically begins to become hazy at the following water concentrations:

  - Turbine oils, bearing and circulating oils ~100 to 150 ppm
  - Hydraulic oils ~150 to 200 ppm
  - Gear oils ~200 ppm
  - Engine oils ~400 ppm
  - Synthetic fluids
    - PAO ~300 ppm
    - Diester ~2000 ppm
    - PAG ~3000 ppm

The Three Forms of Water in Lubricants

- Emulsified water – When the saturation point of the oil is exceeded, water molecules begin to coalesce in the oil to form tiny droplets – haze. As the oil is churned in service, the water forms a stable emulsion.
    - Additives such as detergents found in engine oils can ruin the water separation properties of industrial oils.
- Free water – Water droplets in the oil merge to form a layer of free water.



Effects of Water on Lubricant Performance

Free and emulsified water contamination in oil can have multiple negative effects on the oil:

- Lubricating film degradation – Loss of hydrodynamic film in journal bearings, flash vaporization leading to erosive wear in rolling element bearings.

- Viscosity increase – The presence of water in oil can cause the viscosity to increase, potentially reducing oil flow or increasing the pressure required to pump the oil. Viscosity increase due to water can mask other issues, such as fuel dilution.

- Oxidation – the rate of oxidation of the oil is increased in the presence of water. The presence of catalytic metals (copper, tin, lead) also contribute to an increase in oxidation rate.

Effects of Water on Lubricant Performance

- Hydrolysis – Certain synthetic fluids (diesters, phosphate esters) can react with water, breaking down in to organic acids and alcohols. Hydrolytic degradation destroys the base fluid in the lubricant, and the formation of the organic acids can cause corrosion on metal surfaces.
- Additive degradation – Certain antiwear, extreme pressure, and oxidation inhibitor additives can also undergo hydrolysis, causing their effect to be diminished or removed completely from the lubricant, and acidic by-products to be formed.
- Additive loss – Other additives, such as detergents, dispersants, rust inhibitors, and demulsifiers, can be dissolved in the water phase, effectively removing them from the lubricant, along with their positive effects on lubricant performance.

Effects of Water on Lubricant Performance

- Hydrogen embrittlement – Water can be decomposed into hydrogen and oxygen; the hydrogen ions then cause metallurgical changes in bearing surfaces that lead to subsurface cracking and eventually pitting and spalling.

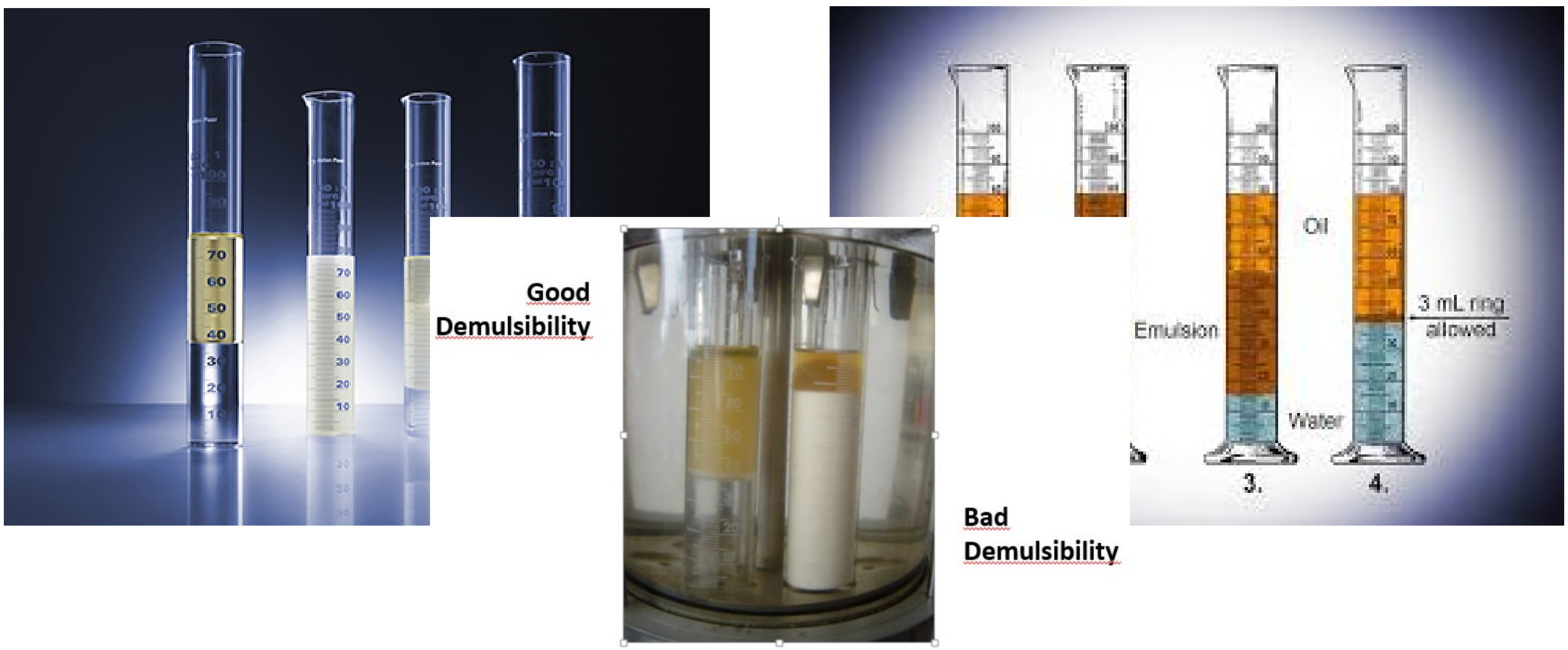
- Filter performance – Water in a lubricant can quickly degrade the performance of filters. In particular, paper (cellulose) filters that perform very well with dry oil can disintegrate when exposed to water and release fibrous material into the oil.

Water Separation Tests

- ASTM D1401 Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids
- ASTM D2711 Standard Test Method for Demulsibility Characteristics of Lubricating Oils

ASTM D1401 Water Separability

This test is for determining how well an oil will separate from water. It is typically run on new oil, but can be used to test the capability of in-service oil to continue to separate water.



ASTM D2711 Demulsibility

ASTM D2711 is another test for measuring how well water separates from oil.

How to Measure the Concentration of Water in Oil

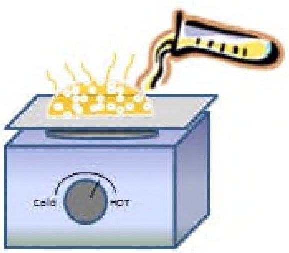
Multiple methods are used to detect water or measure the concentration of water in oil samples:

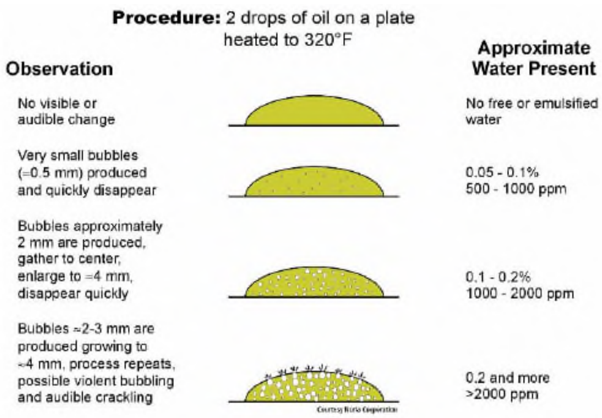
- Crackle Test
- Calcium Hydride Test
- Water by Distillation
- Water by Centrifuge
- Karl Fischer Method
- Fourier Transform Infrared (FTIR) Analysis

Water Measurement – Crackle Test

This test can be run in different ways. The objective is to contact the oil with a hot surface and listen/watch for crackling, spattering, or foaming.

- Hot Plate – Place a small amount of the oil directly on the hot plate surface an observe for crackling, spattering, or foaming.
- Soldering Iron – Place a small amount of the oil in a glass or aluminum dish. Place the tip of a hot soldering iron in the sample. Observe for crackling, spattering, or foaming.





Procedure: 2 drops of oil on a plate heated to 320°F

Observation		Approximate Water Present
No visible or audible change		No free or emulsified water
Very small bubbles (≈0.5 mm) produced and quickly disappear		0.05 - 0.1% 500 - 1000 ppm
Bubbles approximately 2 mm are produced, gather to center, enlarge to ≈4 mm, disappear quickly		0.1 - 0.2% 1000 - 2000 ppm
Bubbles ≈2-3 mm are produced growing to ≈4 mm, process repeats, possible violent bubbling and audible crackling		0.2 and more >2000 ppm

Water Measurement – Calcium Hydride Test

Calcium hydride reacts with water, liberating hydrogen gas.

$$CaH_2 + 2\ H_2O \rightarrow Ca(OH)_2 + 2\ H_2$$

- An oil sample is placed in a pressure cell, calcium hydride is added, and the cell is sealed. Upon agitation, the calcium hydride reacts with the water in the sample to form hydrogen gas. A pressure sensor on the cell detects an increase in pressure, which can be related to the concentration of water in the oil.

- The sensitivity range for this type of test is typically 100 ppm (0.01 %) to greater than 25,000 ppm (2.5 %).

Water Measurement – Water by Distillation

- ASTM D95
- The sample is dissolved in a water-immiscible solvent and heated in a reflux distillation rig.
- Water and solvent are condensed, the water is collected in the graduated receiver.
- The volume of water collected is measured and reported as a percentage of the volume of the initial sample.

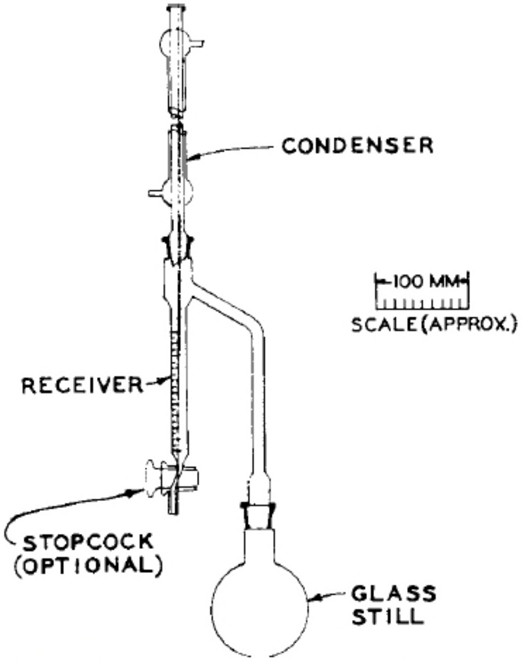


FIG. 1 Typical Assembly with Glass Still

Water Measurement – Water by Centrifuge

- ASTM D1796
- Samples of the oil are placed in two centrifuge tubes and spun at 700G to separate free and emulsified water from the oil.
- The volume % water in the samples is reported.
- Used in D2711 to determine the % water in the oil layer

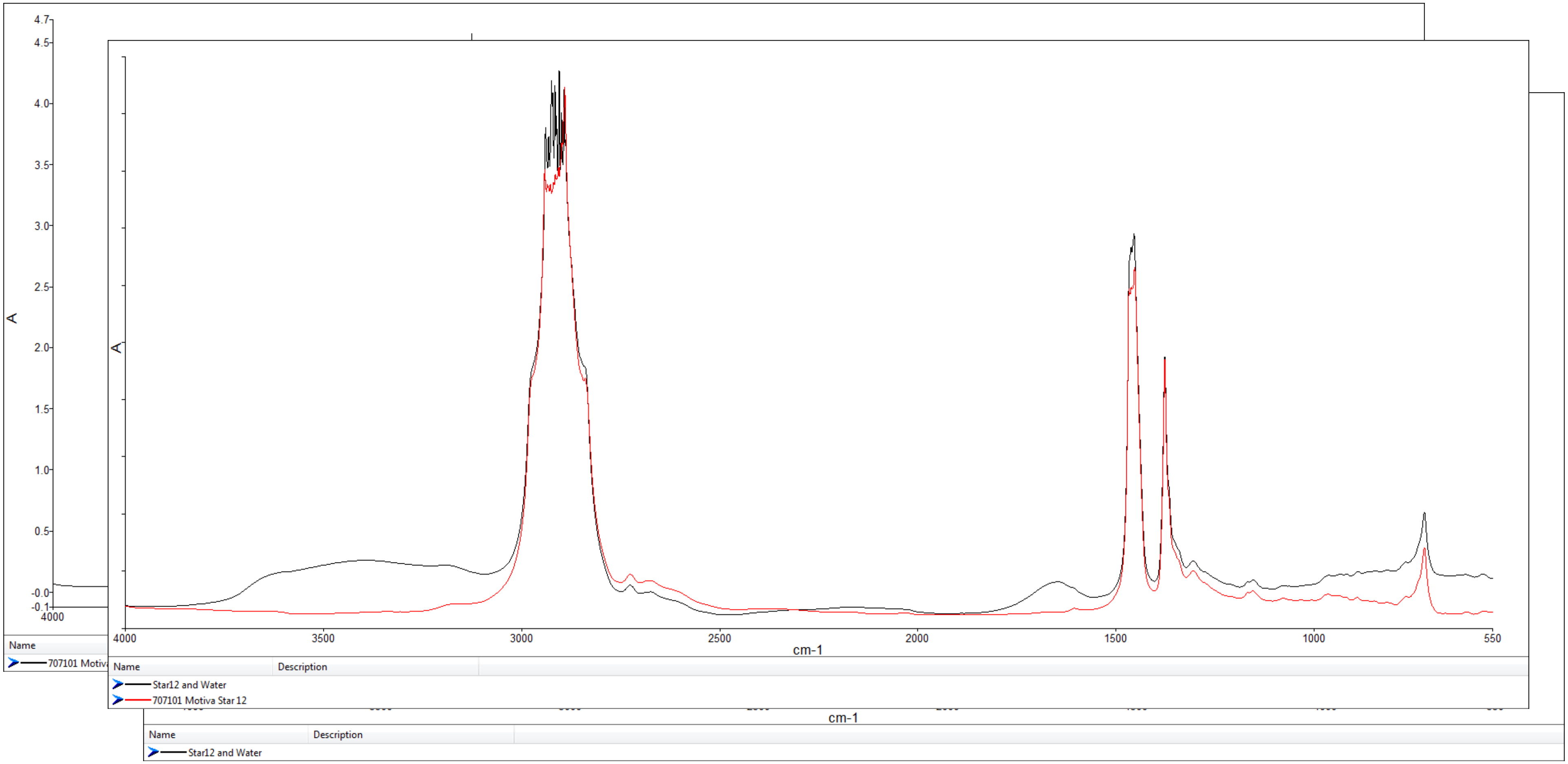
Water Measurement – Karl Fischer Method

- ASTM D6304
- A small sample is injected into the Karl Fischer apparatus and titrated to the endpoint (all water has been reacted).
- The sensitivity range is 10 ppm (0.001%) to 25,000 ppm (2.5%)

Water Measurement – Fourier Transform Infrared

- ASTM E2412
- FTIR analysis produces an absorption plot over a range of wavelengths in the infrared portion of the spectrum, typically 550 to 4000 cm^{-1}.
- Water appears as a relatively broad peak in the 3100 – 3700 cm^{-1} range.
- Following the procedure in E2412, the water concentration in an oil sample can be determined with a high degree of accuracy.
- The sensitivity range of water by FTIR is about 500 to 5000 ppm (0.05 to 0.5 %).

Water Measurement - FTIR



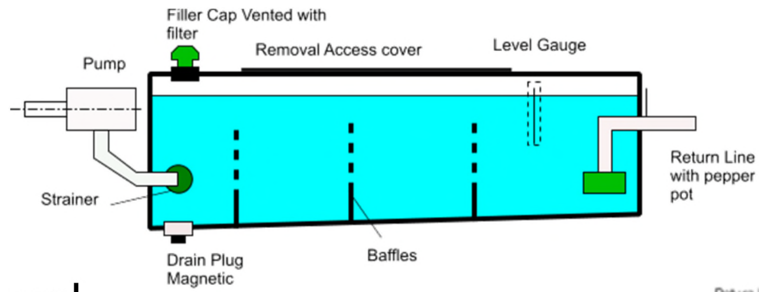
Methods to Remove Water Contamination from Oil

Several technologies have been developed to remove water from in-service lubricants:

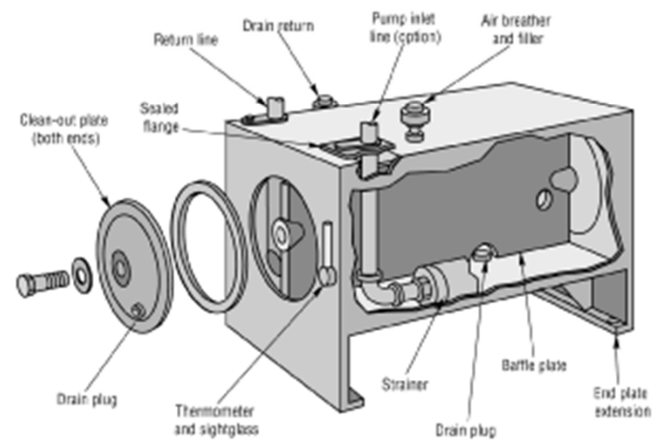
- Gravity Separation – a well-designed reservoir
- Heat
- Centrifuge
- Coalescing filter
- Water-absorbing media
- Air stripping
- Vacuum dehydration
- Headspace dehumidification

Water Removal – Gravity Separation

- The most cost-effective method of removing free water from in-service lubricants is by gravity separation.
- A well-designed reservoir with sufficient residence time will allow free water to settle from the oil, where it can be drained off.
- Atmospheric / Pressurized
- Raised Suction
- Suction Strainer
- Baffle(s)
- Return Line Below Liquid Level
- Desiccant Filter Breather
- Level Indicator
- Temperature Indicator
- Bottom Drain Point
- Access Ports



Hydrostatic system Reservoir

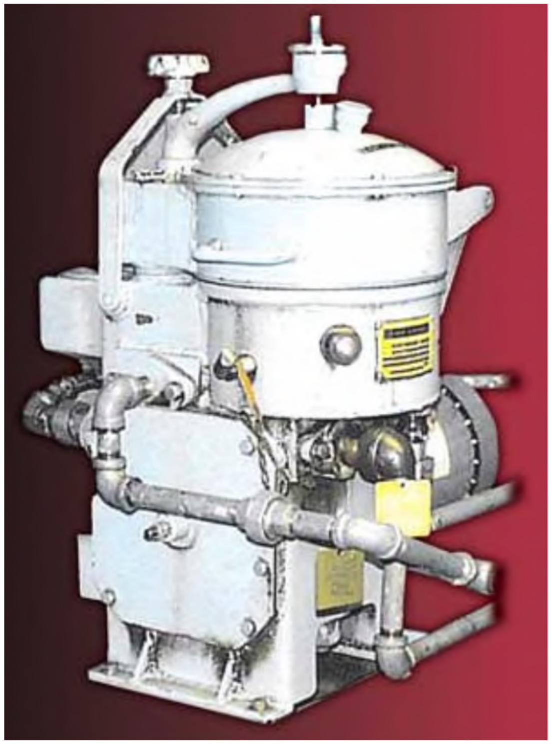


Water Removal - Heat

- Heating oil is typically not a good practice. Oil that is hot enough to cause water to evaporate is likely also hot enough to be thermally degraded.
- Only in limited cases is heating the best way to remove water from oil.
- Heating typically removes only free water.
- Combining heating with other water removal technologies can be helpful.

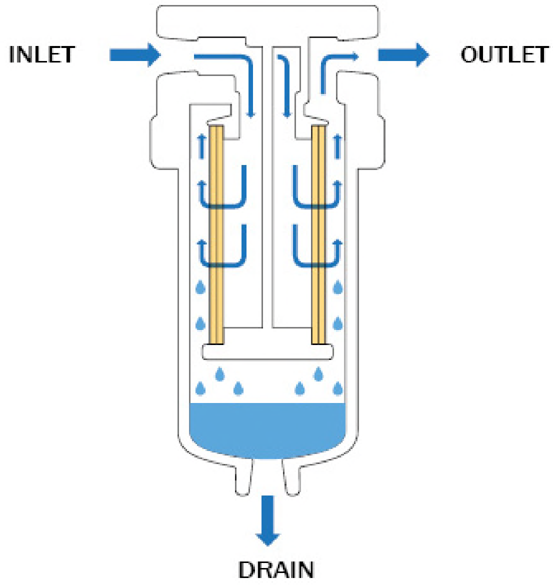
Water Removal - Centrifuge

- Centrifugal separation can remove large volumes of free water and some emulsified water very quickly.
- Centrifugal separation works by separating materials of different density. It is more effective with lower density (lower viscosity) oils than higher density (higher viscosity) oils, since the difference in density compared to water is greater.
- Centrifugal separation can also remove some particulate contamination.
- Centrifugal separation is often part of a used oil reclamation process.



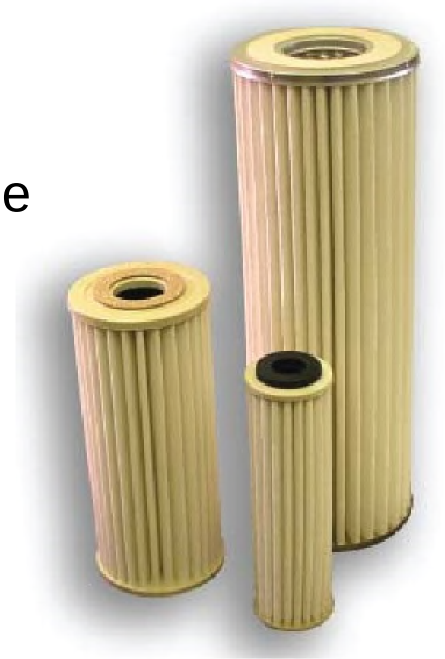
Water Removal – Coalescing Filter

- Coalescing separators work by combining small droplets of water with other droplets to form larger drops of water that separate from the oil more readily.
- Larger drops of water have less surface area in contact with the oil than an equal volume of small droplets.



Water Removal – Water-absorbing Media

- Cellulose (paper) filter elements will absorb some water from oil. Excessive water can cause cellulose filter elements to swell and start to disintegrate.
- Specially designed filter elements are impregnated with super absorbent polymers that trap water. The elements may look just like conventional filter cartridges or spin-on filters.
- The super absorbent polymer can only remove water to the extent that the polymer becomes saturated.
- Water absorbing filters are not suited to removing large volumes of water.
- These filters do not remove dissolved water.



Water Removal – Air Stripping

- Air stripping removes water and gaseous contaminants from the oil.
- Dry air or nitrogen is injected into a stream of heated oil.
- Water and dissolved gases migrate into the air.
- The oil/air mixture is expanded to release the air, which carries the water and gases with it.
- Air stripping removes free, emulsified, and dissolved water.
- The water concentration in the treated oil can be less than 100 ppm.

Water Removal – Vacuum Dehydration

- Vacuum dehydration removes free, emulsified, and dissolved water.
- The oil is heated to about 160°F and passed over media that create a large surface area in a chamber in which a vacuum is pulled.
- The water boils at a lower temperature under vacuum, and vaporizes readily.
- The water is condensed before getting to the vacuum source.
- Vacuum dehydration also removes other volatile contaminants, such as fuels, solvents, refrigerants, and dissolved gases.
- The water concentration in the dehydrated oil can be less than 10 ppm.
- Vacuum dehydration may be used as part of a used oil reclamation process.

Water Removal – Headspace Dehumidification

- The air in the space above the oil in the reservoir is blown through a dehumidifier, which removes the moisture from it.
- The dried air is returned to the reservoir, where moisture in the oil transfers into the air.
- The air then returns to the dehumidifier, where it is removed.
- The oil never comes into contact with the equipment (dehumidifier).
- Headspace dehumidification removes free, emulsified, and dissolved water.
- The reservoir must be well-sealed for headspace dehumidification to be effective.

Products Where Water is a Desirable Component

A few types of products include water as a component:

- Fire-resistant hydraulic fluids (water-glycol)
    - About 40% water

➢ CITGO FR WG-40XD
➢ CITGO Glycol FR-5046HP
➢ Clarion Food Grade FR Fluid

- Metalworking Fluids
    - Soluble (emulsifiable) oils, semi-synthetic, and synthetic metalworking fluids are mixed with water before use.

➢ Trukut GP 205, Trukut HD 220, CITCOOL SS-HD, CITCOOL 33

Questions

- Please post your questions using the Q&A function.

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September 16, 2022	Transmission and Drive Train Lubricants – David Turner