DANGERS OF WATER IN AMMONIA SYSTEMS

Why and how to remove it.
How much water is bad?

- This is a debatable question.
- Refrigerant grade anhydrous ammonia should be 99.95% pure (33 ppm or less).
- 0.2% water may protect against stress corrosion cracking in low pressure vessels by scavenging oxygen.*
- 2% water equals a 1°F rise in suction temperature which equal 2.5% to 3% of lost compressor capacity.

How does water enter a refrigeration system?

- It can enter in relatively small quantities at any time during construction, operation and servicing as humidity in the air.
- A leak in the shell and tube heat exchanger.
- Improperly dried vessels after hydrostatic testing.
- And many other ways...
Water Entry Points

- After service and maintenance if the components are not properly pumped down.
- Through leaks in components and connections in parts of the system operating in a vacuum.
- In new vessels added to the system, but not dried properly after hydrostatic testing.
- Improper procedures when purging non-condensables into a water-filled bucket.
- Improper procedures when draining oil into a water-filled bucket.
- Through leaks in compressor seals.
- Complex chemical reactions between oil, oxygen and ammonia.
- Weld joints that are tacked in place and exposed to the elements during construction.
- Condensation in the piping during construction.
- If the system is not purged with warm, dry nitrogen prior to charging.
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Where does water collect?

Water vapor can only travel with gaseous ammonia in extremely minute quantities.

Nearly always found on the low side of the system where ammonia boils away.

In a mechanically-pumped recirculation system, water will become concentrated in the pump accumulator.
Where does water collect?

- In a gas-pumped system, the water will be transferred through the dump trap (pumper drum) into the controlled pressure receiver. But ultimately it is fed back to the low pressure vessel.

- On a gravity flooded system, the water will accumulate in the evaporator or heat exchanger.
What does water do?

- Causes damage
- Decreases efficiency
- Raises operating costs
Aqueous ammonia will react rapidly with copper, zinc, and many alloys of these metals.

Ammonia mixed with water produces ammonium hydroxide ($\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$).

Iron and steel do not themselves react to aqueous ammonia, the ammonium and hydroxyl ions can cause galvanic corrosion between two different metals near each other.
If water gets into the compressor oil, it will take part in a series of chemical reactions that create nitro compounds (sludge).

Some of these compounds are soluble in ammonia and can escape with ammonia vapor through the oil separator and into the system.

There, they will clog strainers and filters and cause operational problems in valves.
Damage

- Water in the oil means reduced bearing service life.

- Water can lead to system leaks due to embrittlement of gaskets and O-rings.

- Water can cause rust in valves, pipes and compressors.

- Rust can lead to erosion of orifices and expansion valves.
Decreases Efficiency

- Each percent of water in ammonia causes a 1% loss in compressor capacity (Source: IIAR Bulletin 108).
- Other studies indicate power consumption increases 1.5% for each 1% increase in water content.
- For a constant condensing pressure, this means increased power consumption (higher electric bill) and a higher compressor exit temperature (increased wear).
Lost Compressor Capacity Due to Water

![Graph showing the relationship between % Water and % Lost HP Comp Capacity for different evaporator temperatures.]

- 16°F Evaporator
- -28°F Evaporator
- -40°F Evaporator
Sat. Temperature vs. % Water

Aqueous Ammonia

Saturation Temperature (degF) vs. % Water by Weight

- 58 PSIG
- 15.5 PSIG
- 13 PSIG

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Higher Operating Costs

- Aqueous ammonia has a higher saturation temperature than “clean” ammonia.

- The compressor must work harder to develop a lower suction pressure to bring the temperature to where it should be.

- Increased power consumption equals higher electric bill.
Energy Cost Due to Water
(Per 100 TR Per Year)

0 F evaporator and 95 F condenser
The true cost of water

- Higher ammonia saturation temperature.
- Greater use of electricity ($$$$$$).
- Damage to compressor, valves, pipes, etc.
- Can lead to system leaks.
How Much Water is in the System?

The first step in eliminating water from the ammonia is to see how much is already there.

A very precise method for doing this is given in *IIAR Bulletin No. 108.*

Samples of ammonia are taken from the locations in the system where water is likely to be present. The ammonia is allowed to boil away at room temperature and the remaining residue indicates the percentage of water present.
How Much Water is in the System?

- The state of the system at the time the sample is taken should always be considered.

- If, for example, ammonia is taken from the pump discharge when the level in the high pressure receiver is low, the results may indicate a low level of water present. This is because there is more ammonia in the low side of the system.
How Much Water is in the System?

- If the sample is taken at a different time, when the HP receiver level is high, the results would indicate a higher percentage of water.

- In both cases, the actual amount of water present in the accumulator is the same. But reducing the amount of ammonia on the low side of the system increases the percentage of water there.
How Much Water is in the System?

A *quick and dirty* test would be to simply compare the system’s actual operating condition to the ammonia charts.

For example, if your suction pressure is 15 psig, your evaporator coil should be operating at 0°F (assuming, of course, that saturation conditions prevail). If, however, your coil is at 2°F there’s probably 6 or 7% water present.

With this method, the more precise the pressure and temperature measurements the more reliable your conclusions will be.
Phillips Sampling Container

Use with the method in IIAR Bulletin No. 108.
How To Remove The Water

- Replace the entire charge
- Batch cleaning
- Water removal units
- Phillips Anhydrator
Replace Entire Charge

- Shut down the system
- Remove the complete charge of ammonia, then recharge and restart the system.
- This may be practical in a small system.
- However, the combination of down-time and the quantity of ammonia that must be handled often prohibits this approach.
Batch Cleaning

- Sometimes used on larger systems.
- It can take weeks to clean out a large system by the batch method.
- These distillation units need to be carefully adjusted for particular operating conditions, monitored and emptied at unpredictable intervals.
- For these batch-type water removers, a change in the system’s operating conditions can result in sudden and violent boiling inside the distillation vessel. This can cause some of the impurities to be sent back into the system.
Water Removal Units

- Sometimes called *ammonia regenerators*, can be integrated directly into the refrigeration system.
- Typically use hot discharge gas or warm condensed liquid to provide an inexpensive heat source for boiling the cold contaminated liquid ammonia.
- These units can vary in complexity and effectiveness, but generally are capable of operating continuously.
- Intervention is only needed to drain the collected impurities.
Some water removal units use electric heaters to warm the ammonia-water mixture to temperatures above 150ºF.

This is done so that as much ammonia as possible is removed from the water and other contaminants before they are drained.

This approach can lower the ammonia remaining in the effluent to as little as 5%.
Unfortunately, this approach adds the complexity of heaters and thermostats, heating the mixture generates steam – just like a pot of water warming on a stove.

If the temperature is high enough and the pressure is low enough (190°F at -10”Hg), the water will even boil. The resulting steam and water droplets are then sent with the ammonia vapor back into the system.
The Phillips Anhydrator
How It Works

- Cold impure liquid ammonia (typically taken from the pump discharge) is exposed to heat from the high pressure receiver liquid.
- The warm and cold streams do not mix.
- The cold impure liquid ammonia boils, and the resulting pure ammonia vapor is returned to the pump accumulator.
- After giving up some of its heat, the liquid from the high pressure receiver also goes to the pump accumulator.
Because this liquid is now subcooled, the reduction in flash gas at the accumulator roughly balances with the pure ammonia vapor mentioned earlier.

Depending on the system operating point, the liquid collected in the Anhydrator ultimately becomes a mixture of up to about 70% water, 30% ammonia, and other impurities. (It is not practical to remove all the ammonia from the water.)

These impurities are drained from the bottom of the unit and disposed of according to local regulations.
How It Works

- Pure ammonia to suction accumulator
- Ammonia & contaminants from suction accumulator
- Hp liquid supply to system
- Liquid from hp receiver
- Water & contaminants out
- Liquid from hp receiver

Diagram showing the flow of ammonia and contaminants through the system.
Why Use The Phillips Anhydrator?

Lower Installation Cost

Only requires a simple float valve and a few isolation valves (no special electronic devices or controls).

Self-Regulating Operation

The unique design allows it to operate continuously. It easily handles system upsets without re-introducing water and contaminates to the pump separator after they have been removed.
Why Use The Phillips Anhydrator?

- **Shortest Payback Time**

  Thanks to its low initial cost, the Phillips Anhydrator pays for itself in the least amount of time.

- **Energy-Neutral Operation**

  Unlike many other system cleaners, the Anhydrator uses sensible heat from the high pressure liquid to separate the ammonia from water and other contaminants. Instead of being wasted, the resulting flash gas is now doing useful work: cleaning your system.
Why Use The Phillips Anhydrator?

- **Very Low Maintenance**
  
  It is self-regulating. Start it up and let it run. Drain the water and contaminants at your convenience. The unit will hold the water and contaminants indefinitely.

- **No External Power is Required**
What About Air Purgers?

- Conventional air purgers cool and condense the warm ammonia vapor to separate it from non-condensable gases.
- Water vapor is not a non-condensable gas, and therefore cannot be separated from ammonia by cooling it in a purger.
- However, an air purger connected to the high side of the system can be a qualitative indicator of the presence of water.
- Remember that water can leak into a system as humidity in air. If you have a purger that has been removing air from the high side, then there’s water in the low side of your system.
Summary

- Excessive water in the system is not good.
- Water results in higher operating costs and damage to the system components.
- It’s up to you to choose the best course of action to remove it.