Effects of Air & Water on Ammonia Refrigeration

by
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Elements which affect performance of refrigeration plant

1. Non-condensables gases
   - Air
   - Nitrogen
   - Hydrogen
   - Hydrocarbons
2. Water
3. Oil

Example

Anhydrous Ammonia Gas will change phase from gas to liquid if heat is removed at temperature 35°C and pressure 13.5 kg/cm^2

At same pressure any Nitrogen present would have be cooled to -164°C to liquefy.

Hence any nitrogen present in always remain in gaseous state

Symptoms of Presence of Non Condensable

1. Loosing capacity over the years
2. Capacity problems during the summer
3. Increased power consumption
4. Higher service/maintenance costs
5. Oil decomposing
6. Unexplained behavior…

VARIOUS WAYS IN WHICH NON-CONDENSABLES ENTER THE SYSTEM:

1. The refrigerant, when delivered, may contain non-condensable gases upto 15%.
2. Inadequate evacuation before commissioning the refrigeration plant
3. For service and maintenance certain parts of the refrigeration plant are frequently opened, causing air to penetrate into the system.
4. Oil changing and recharging with refrigerant have the same effect.

VARIOUS WAYS IN WHICH NON-CONDENSABLES ENTER THE SYSTEM:

5. Leakage: Systems operating with suction pressure below atmospheric pressure (i.e., working temperatures below -33°C for ammonia system) can have small leaks (from system piping, valves, vessels valve stem packing, bonnet gaskets, compressor shaft seals, non-welded connections, and control transducers etc.) allowing air to penetrate into the system.
6. Decomposition of the refrigerant or the lubricating oil can occur due to catalytic action of the various metals in the installation and due to high discharge temperatures. Ammonia for instance decomposes into Nitrogen and Hydrogen.

Air and other non-condensables

$P_{actual} = P_{refrigerant} + P_{noncond}$

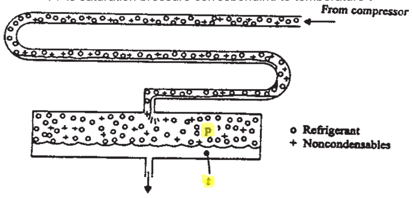
When to Purge ?

If $P > P_t$

Where,

P is actual Pressure in receiver

P_t is saturation pressure corresponding to temperature t



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The presence of non-condensable gases

- Increases electrical power demand
- Decreases Refrigeration system capacity
- Decreases system efficiency
- Excess head pressure puts more strain on bearing and drive motors. Belt life is shortened and gasket seals are ruptured.
- Occupies condenser surface= higher condensing pressures
- Blocking drainage of liquid

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The presence of non-condensable gases

- Chemical reactions take place = oxidation of oil and metals
- Control problems due to air pockets
- Increased pressure leads to increased temperature, which shortens the life of compressor valves and promotes the breakdown of lubricating oil.
- Increases condenser scaling which increases maintenance cost and reduces life of condenser
- Increase in discharge temperature leads to “Ammonia explosions” and it breaks down into Nitrogen and Hydrogen. Which means further addition to non-condensable gases.

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AIR VS. POWER LOSS

A 1°C increase in condensing pressure means approx…

- 1% lower cooling capacity
- 3% Lower COP
- 3.1% Higher Power Consumption (for a given capacity)

% of Air by weight	0.5	1.0	2.0	4.0
Air Pressure in PSI	0.7	1.3	2.7	5.5
Power %	0.6	1.2	2.5	5

for -15°C Evaporating and 30°C Condensing Ref. IIAR Paper TP-22

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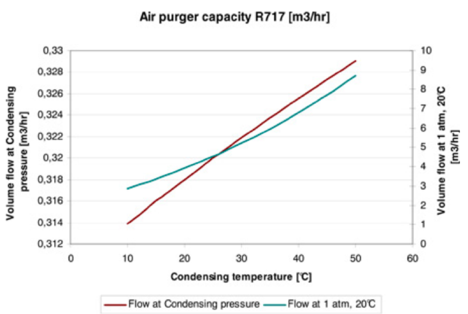
AIR VS. POWER LOSS



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Calculation of increased power cost

Plan Condition :

Evaporation Pressure for -40°C,

Condensing Pressure for 38°C, 13.7 kg/cm^2

Refrigeration Capacity 500kW

Power required by compressor 281kW*

If our actual pressure is 0.5 Kg/cm^2 higher i.e. 14.2 kg/cm^2

Then power required would be 285kW

The 4 kW per hour for 6000 hours of operation is 24000kW

If Electricity Cost is Rs. 8/- per kW

The total increase in electricity bill is **Rs. 1,92,000/-**

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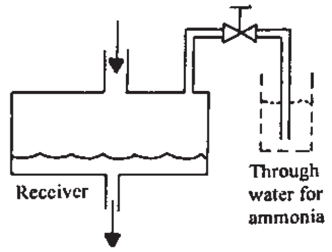
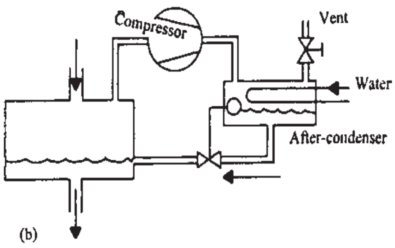
The Three Types of Purging

1. Direct venting of the air-refrigerant mixture
2. Compression of the mixture, condensing as much as possible of the refrigerant, and venting the vapor mixture that is now rich in noncondensables
3. Condensation of refrigerant using a small evaporator, followed by venting of the air-refrigerant mixture this is now rich in noncondensables

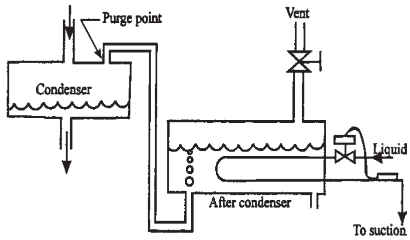
Direct venting: Manual Purging



Compression of Mixture



Condensation of refrigerant using a small evaporator



Advantages and Disadvantages of Automatic Air Purger

Advantages	Disadvantages
Safety: Automatic Purgers eliminate the need for refrigeration staff to manually "open the system" on frequent basis	**Capital cost:** The cost is high because of purger unit, piping, solenoid valves and other controls
Effectiveness: A properly installed and operated multipoint purger can continually function to scavenge and remove NCG from System	**Maintenance Cost:** For the purger unit, accompanying solenoid valves and transducers required for purge control
Labour: Eliminates the labour associated with personnel regularly removing NCG by manual operation	

Where to Purge air in Automatic Purging System ?

- Purge point connections must be at places where air will collect.
- Refrigerant gas enters a condenser at high velocity. By the time the gas reaches the far (and cool) end of the condenser, its velocity is practically zero.
- This is where the air accumulates and where the purge point connection should be made.
- Similarly, the purge point connection at the receiver should be made at a point furthest from the liquid inlet.

Purge Points

Evaporative Condenser

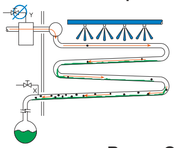


Fig. 1.(left) High velocity of entering refrigerant gas prevents any significant air accumulation upstream from point X. High velocity past point X is impossible because receiver pressure is substantially the same as pressure at point X.**Purge from point X.** Do not try to purge from point Y at the top of the oil separator because no air can accumulate here when the compressor is running.

Purge Connection for Receiver

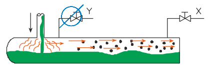
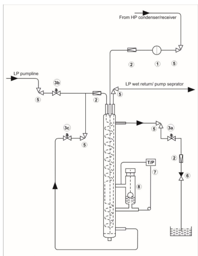


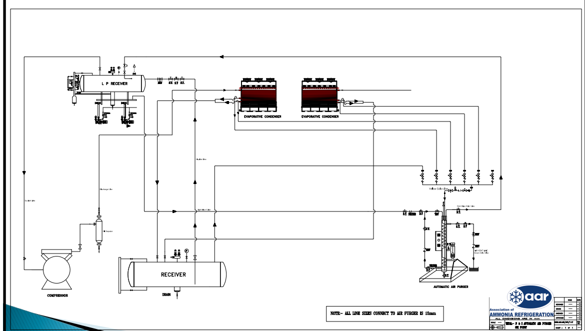
Fig. 5. Purge from Point X farthest away from liquid inlet. "Cloud" of pure gas at inlet will keep air away from point Y.

Automatic Purger



Pump Re-cerculation System

Automatic Purger



Water Contamination and Removal in Ammonia Refrigeration Systems

Water Contamination is very Commonly observed due to Solubility of Ammonia in Water

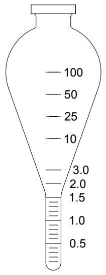
Ammonia-water Relationship

- Ammonia and water have a great affinity for each other.
- For example, at atmospheric pressure and a temperature of 30°C., a saturated solution of ammonia and water will contain approximately 30 percent ammonia by weight. As the temperature of the solution is lowered, the ability to absorb ammonia increases.
- At 0° C. the wt. percentage increases to 46.5 percent;
- At -33°C. the percentage increases to 100 percent ammonia by wt.

Ammonia-water Relationship
Solubility Of Ammonia With Water

% Dilution	Saturated Suction Temperature at		
	-0.3 Kg/ cm^2 g	0 Kg/ cm^2 g	2.0 Kg/ cm^2 g
0	-40.2°C	-33.3°C	-8.9°C
10	-38.6°C	-31.6°C	-7°C
20	-36.4°C	-28.9°C	-3.9°C
30	-32.2°C	-24.4°C	2.3°C

How to measure Water in Ammonia



- A stand or rack on which to place the sampling container while the ammonia evaporates
- Thin steel wire (approx 8")
- Face shield
- Protective gloves

How to measure Water in Ammonia

PROCEDURE

Wear protective clothing, including face and hand protection.

SLOWLY draw a 100 ml ammonia sample from al location on the cold side of the system such as the pump discharge1 into the sampling container.

Place the container on a stand or rack in a safe, ventilated area and allow the ammonia to boil away completely. (1-2 hours) Note that heat from a hand touching or holding the container could cause the ammonia to boil-over. If the liquid is boiling violently, a thin steel wire should be put into the sampling container.

After boiling has ceased, note the volume of residual liquid at the bottom of the sampling container. This residue is water (about 70% by weight), ammonia, oil, and other impurities.

Compare the quantity of remaining liquid to the chart below. The charts on the reverse of this bulletin show impact of this water on system performance.

For example: If 14 ml of liquid remained after boiling the ammonia drawn from a -33°C system, this indicates the ammonia contains about 12% water. As shown on the chart on the reverse of this page, the system is losing nearly 10% of its compressor capacity.

Water Contamination and Removal in Ammonia Refrigeration Systems

Two Sources of Water contamination

1. The contamination sources in the construction and initial start up phase

2. The contamination sources after the system has been put into normal operation.

Water Contamination and Removal in Ammonia Refrigeration Systems

Contamination During construction and at initial start up

- Water remaining in new vessels, which are not properly drained after Hydro pressure test.
- During construction, water may enter through open piping or weld joints, which are only tacked in place when either are exposed to the elements.
- Condensation, which may occur in the piping during construction.
- Condensation, which may occur when air has been used as the medium for the final system pressure testing.
- Water, which remains in the system as a result of inadequate evacuation procedures on start up.
- The use of non-anhydrous ammonia when charging the system.

Water Contamination and Removal in Ammonia Refrigeration Systems

Contamination after the system has been put into normal operation

- Rupture of tubes on the low-pressure side of the system, especially in Shell & Tube Heat Exchangers such as chillers or oil coolers
- Improper procedures, when draining oil or refrigerant from vessels or pipes in vacuum range into water filled containers.
- In systems, which are operating below atmospheric pressure or which are making pump down so the pressure goes into a vacuum range: Leaks in valve stem packing, flexible hoses, screwed and flanged piping joints, threaded and cutting ring connections, pump and compressor seals, and leaks in the coils of evaporator units.

Water Contamination and Removal in Ammonia Refrigeration Systems

Contamination after the system has been put into normal operation

- Improper procedures when evacuating the system or parts of the system, while service and maintenance work is carried out.
- Complex chemical reactions in the system between the ammonia, oxygen, water, oils and sludge's can create more "free" water in the system.
- Lack of adequate or no purging

Water Contamination and Removal in Ammonia Refrigeration Systems

Contamination after the system has been put into normal operation

- Lack of adequate or no purging

Example

Air Purger in a plant removes 5 Ltr of air per min

The ambient temperature is 35°C, with 75% RH

Hence water contain is 25 g/kg

5 Ltr x 1/1000 ltr X 25.5 g X 60 min = 7.65 grams of Water per hour

That is 45.9 Ltr per year considering 6000 hrs per year plant operation

In 10 years we will have 459 Ltrs of water in our plant

Effects Of Water Contamination

- Water contamination lowers system efficiency
- Increases the electrical costs
- In addition, water also causes corrosion in the refrigerant cycle and
- accelerates the aging process in oil
- Increased wear and more frequent oil changes generate lower plant availability and increase service costs.

Areas Of Highest Water Content

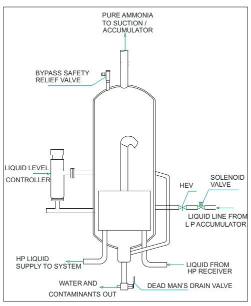
- Recirculation Sysetms :Pump receiver (LPR)
- Flooded systems: evaporator and surge drum.
- DX systems suction accumulator.
- Two-stage systems vessels and evaporators of the low stage portion of the system.

Areas Of Highest Water Content

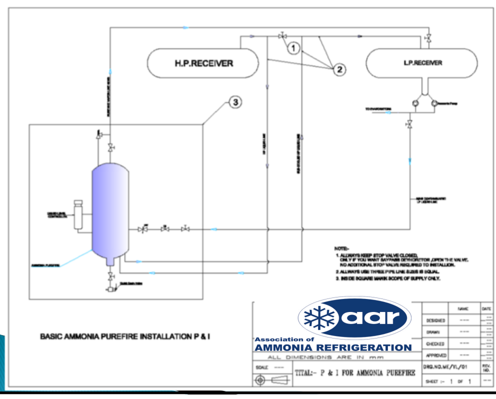
Reasons :

- Large difference in Vapour Pressure between water and ammonia.
- For example, at 2°C, the vapor pressure of ammonia is 3.6 Kg/cm^2 as compared to 0.007 Kg/cm^2 for water.
- Since the liquid with the higher vapor pressure will evaporate in greater proportion than the liquid with the lower vapor pressure, a residue is left containing more and more of the lower vapor pressure liquid if infiltration is not corrected.

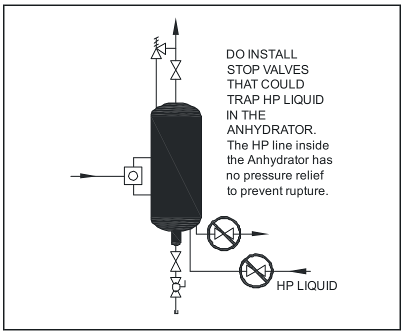
Ammonia Purifier



Ammonia Purifier



Ammonia Regenerator



Never Trap HP Liquid

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Thank You

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