



## Effects of Non Condensables & Water on Ammonia Refrigeration Plant

by

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AIR PURGERS

AMMONIA PURIFIERS

### Two Elements which affect performance of refrigeration plant

Water

Non-condensables gases

Common Non-condensables

Air

Nitrogen

Hydrogen

Hydrocarbons

### Example

Anhydrous Ammonia Gas will change phase from gas to liquid if heat is removed at temperature  $35^{\circ}\text{C}$  and pressure  $13.5 \text{ kg/cm}^2$

At same pressure any Nitrogen present would have be cooled to  $-164^{\circ}\text{C}$  to liquefy.

Hence any nitrogen present in always remain in gaseous state

### 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.

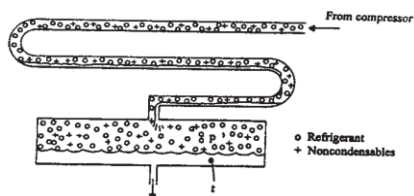
### VARIOUS WAYS IN WHICH NON-CONDENSABLES ENTER THE SYSTEM:

5. Leakage: Systems operating with suction pressure below atmospheric pressure (i.e., working temperatures below  $-33^{\circ}\text{C}$  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



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



## Air and other non-condensables



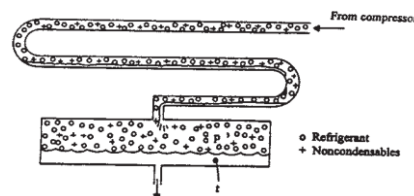
### When to Purge ?

If  $P > P_i$

Where,

P is actual Pressure in receiver

$P_i$  is saturation pressure corresponding to temperature t



### 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.

### The presence of non-condensable gases

- 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.

## AIR VS. POWER LOSS



% 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. IAR Paper TP-22

## Calculation of increased power cost



### Plan Condition :

Evaporation Pressure for -40°C,

Condensing Pressure for 38°C, 13.7 Kg/cm<sup>2</sup>

Refrigeration Capacity 500kW

Power required by compressor 281kW\*

If our actual pressure is 0.5 Kg/cm<sup>2</sup> higher i.e. 14.2 Kg/cm<sup>2</sup>

Then power required would be 285kW

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

If Electricity Cost is Rs. 6 / kW

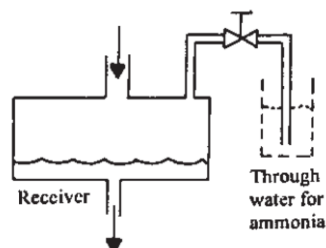
The total increase in electricity bill is **Rs. 1,44,000/-**

## The Three Types of Purging

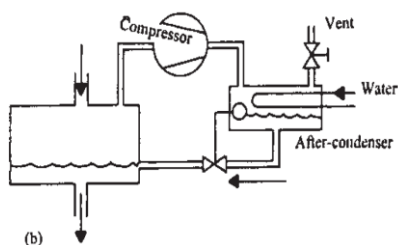


1. Direct venting of the air-refrigerant mixture
2. Compression of the mixture, condensing as much as possible of the refrigerant, and venting the vapor mixture that is now rich in noncondensables
3. Condensation of refrigerant using a small evaporator, followed by venting of the air-refrigerant mixture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

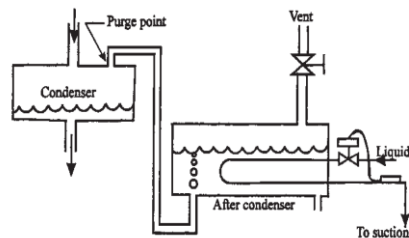
### Direct venting: Manual Purging



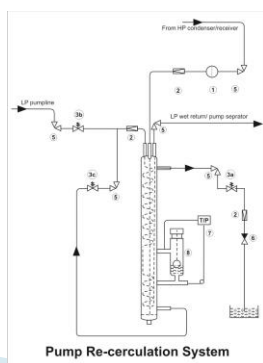
### Compression of Mixture



### Condensation of refrigerant using a small evaporator



## AUTOMATIC PURGER



## AUTOMATIC PURGER



- Fully automatic gas purger for refrigeration plants
- Maintains condensing temperature at nearly optimum operating conditions
- Reduces the concentration of non-condensable gases to a negligible Percentage
- No need separate refrigeration system

## AUTOMATIC GAS/AIR PURGER



## Advantages and Disadvantages of Automatic Air Purger



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

## Air and other non-condensables



Where to Purge air ?

The preferable locations for purging are

- (1) On the high-pressure side of the system,
- (2) Where only vapor exists,
- (3) Where the vapor velocity is low.

## Air and other non-condensables



Where to Purge air ?

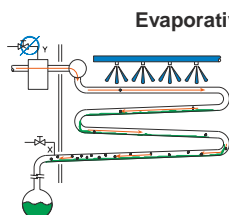
Purge point connections must be at places where air will collect.

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.

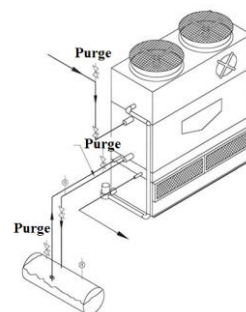
## Purge Points



### 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.

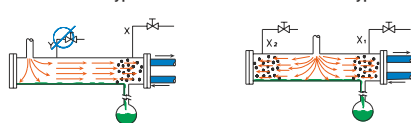
## Purge Points Evaporative condensers



## Purge Points



### Horizontal Shell and Tube Condensers



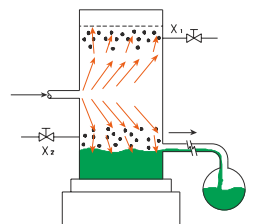
**Fig. 2.** Incoming gas carries air molecules to far end of the condenser near the cooling water inlet as shown. **Purge from point X.** If purge connection is at Y, no air will reach the connection countercurrent to the gas flow until the condenser is more than half of full air.

**Fig. 3.** Incoming refrigerant blows air to each end of the condenser. Air at the left hand end can't buck the flow of incoming gas to escape through the right hand connection at X<sub>1</sub>. **Provide a purge connection** at each end but never purge from both at the same time.

## Purge Points



### Vertical Shell and Tube Condenser

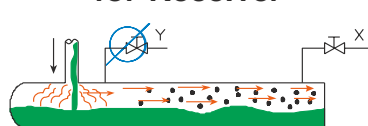


**Fig. 4.** Low gas velocity will exist at both top and bottom of the condenser. Purge connections desirable at both X<sub>1</sub> and X<sub>2</sub>.

## Purge Points



### 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.

## INSTALLATION OF GAS PURGER



The gas purger can be placed where it is most appropriate. In most cases it is placed in the machinery room.

- No Need to Install above Condenser

Pipe Line Connection for Pump Re-circulation

1. Sky Blue: Low Temperature Liquid Line Inlet(A): Lowest Temperature point such as Ammonia Pump Outlet Header
2. Dark Blue(B): Wet suction return line: to be connected to low pressure accumulator
3. Yellow(C): From High temperature line such as condenser outlet, receiver
4. Green: Air vent connection to be immersed in water bucket
5. Red: Safety Relief valve: out let of the valve to be connected LP vessel
6. Black: Provided at the bottom of air purger for drain

## Water Contamination and Removal in Ammonia Refrigeration Systems



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

## Refrigerant Grade Anhydrous Ammonia Specifications-ANSI/IIAR 2

### Purity Requirements

- Ammonia Content 99.95%Min.
- Non-Basic Gas in Vapor Phase 25PPM Max.
- Non-Basic Gas in Liquid Phase 10 PPM Max.
- Water 500 PPM Max.
- Oil (as soluble in petroleum ether) 5 PPM Max.
- Salt (calculated as NaCl) None
- Pyridine, Hydrogen Sulfide, Naphthalene None



## 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 <sup>2</sup> g	0 Kg/ cm <sup>2</sup> g	2.0 Kg/ cm <sup>2</sup> 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

## Water Contamination and Removal in Ammonia Refrigeration Systems



### Two Sources of Water contamination

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



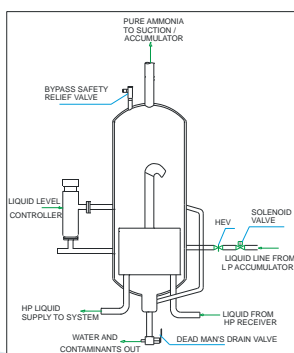
## AREAS OF HIGHEST WATER CONTENT

Reasons :

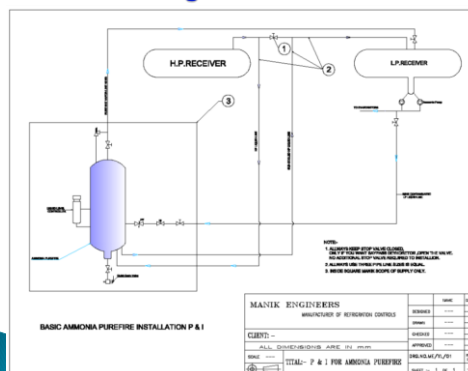
- ▶ Large difference in Vapour Pressure between water and ammonia.
- ▶ For example, at 2°C, the vapor pressure of ammonia is 3.6 Kg/cm<sup>2</sup> as compared to 0.007 Kg/cm<sup>2</sup> for water.
- ▶ Since the liquid with the higher vapor pressure will evaporate in greater proportion than the liquid 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 Regenerator



## Ammonia Regenerator



## Ammonia Regenerator



## Oil Draining Guidelines

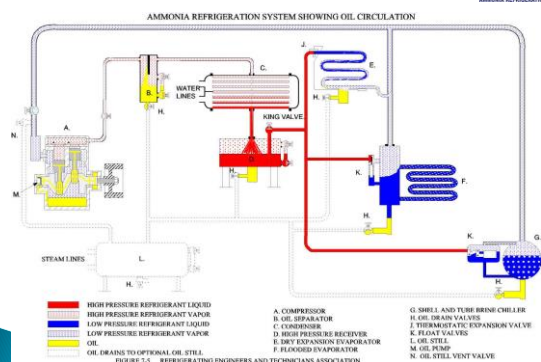


Draining Oil From Ammonia Refrigeration Systems is Potentially Dangerous Process and Should only be done by Properly Trained and Experienced Personnel

Oil Should be drained always from Oil Pot where are drain points are brought

Do not drain oil directly from oil separators or other points when system is in operation

## Oil Draining Guidelines



## Oil Draining Guidelines



Before Draining Oil Ensure Following

1. A Hard hat
2. Chemical Resistant Gloves
3. Chemical Resistant Splash Goggles and Face Shield
4. Clean Bucket To Drain Oil
5. Chemical Resistant Foot ware
6. Chemical Resistant Apron
7. Supplemental Bucket of Water & nearness to eye wash

## Oil Draining Guidelines

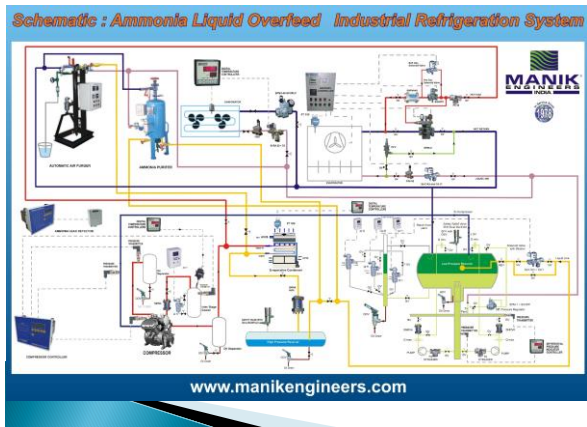


8. Place Clean Bucket under Oil Drain Outlet
9. Check that Ventilation Fans in the area are operating
10. Do not proceed without wearing all Protective Equipment Mentioned
11. Close inlet valve between vessel and Oil Pot
12. Allow ammonia liquid in vessel/line/oil pot to evaporate back in to vessel- Can be observed when frost or ice melts on where oil needs to be drained
13. If system is operating in negative pressure, raise the pressure to a positive value
14. Always drain when system is under positive pressure

## Oil Draining Guide Lines

15. Open Oil Drain Quick Shut off Valve which is self closing Type
16. If there is plug on the drain valve open slowly before removing it –Ammonia may be trapped behind
17. Open the drain valve approximately  $\frac{1}{2}$  Turn and slowly open until flow of oil starts
18. Once oil is drained release tension on valve
19. Close oil drain globe valve
20. Replace plug , re open oil drain inlet and vent valves
21. Measure and log the amount of oil drained
22. Properly dispose the drained oil or give for analysis





Thank You