Association of AMMONIA REFRIGERATION

Advantage Ammonia

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Effects of Air and water in Ammonia refrigeration system

by
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Air & Water : Are they good for Ammonia refrigeration plants ?

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Refrigerant Grade Anhydrous Ammonia Specifications-AAR-01

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	33 PPM Max.
Oil (as soluble in petroleum ether)	2 PPM Max.
Salt (calculated as NaCl)	None
Pyridine, Hydrogen Sulfide, Naphthalene	None

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TABLE AMMONIA (R-717) PROPERTIES OF SATURATED LIQUID AND SATURATED VAPOR *

°C	Bar g	PSI g	°C	Bar g	PSI g
-50	-0.59	-8.41	2	3.62	51.55
-40	-0.28	-4.03	4	3.97	56.53
-38	-0.20	-2.89	6	4.35	61.80
-36	-0.12	-1.64	8	4.74	67.38
-34	-0.02	-0.29	10	5.15	73.26
.-33.33b	0.01	0.19	12	5.59	79.46
-32	0.08	1.17	14	6.05	86.00
-30	0.19	2.76	16	6.53	92.88
-28	0.32	4.48	18	7.04	100.12
-26	0.45	6.34	20	7.57	107.74
-24	0.59	8.34	22	8.14	115.73
-22	0.74	10.50	24	8.73	124.12
-20	0.90	12.81	26	9.35	132.92
-18	1.08	15.30	28	9.99	142.13
-16	1.26	17.96	30	10.67	151.79
-14	1.46	20.82	32	11.38	161.89
-12	1.68	23.87	34	12.12	172.44
-10	1.91	27.13	36	12.90	183.48
-8	2.15	30.60	38	13.71	194.99
-6	2.41	34.30	40	14.55	207.01
-4	2.69	38.23	42	15.44	219.54
-2	2.98	42.41	44	16.35	232.59
0	3.29	46.85	46	17.31	246.21
			48	18.31	260.36
			50	19.34	275.08

b = Normal boiling point g = Gauge pressure

* *ASHRAE Fundamentals 2013, page 30.39*

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Two Elements which affect performance of refrigeration plant

1. Water

2. Non-condensables gases

Common Non-condensables
Air
Nitrogen
Hydrogen
Hydrocarbons

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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

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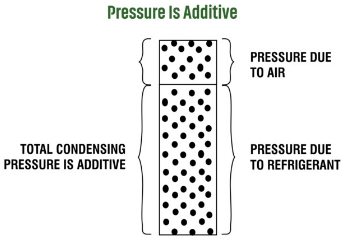
Presence of Air and Other Non-condensables Pressure is additive

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



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Presence of Air and Other Non-condensables

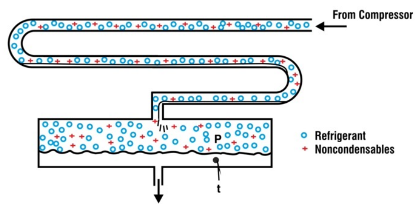
$P_{noncond} = P_{actual} - P_{refrigerant}$

When to Purge ?

If $P > P_t$

P is actual Pressure in receiver

P_t is saturation pressure corresponding to temperature



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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.

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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.

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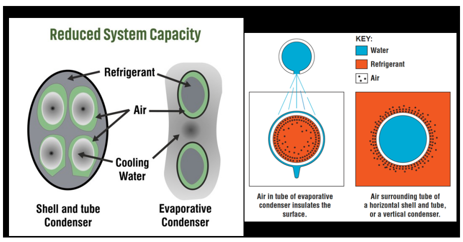
The Presence of Non-condensable Gases



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Air Vs. Power Loss

% of Air by weight	0.5	1.0	2.0	4.0
Air Pressure in PSI	1	1.6	3.2	7
Power %	0.8	1.4	2.8	6.5

for -15°C Evaporating and 38°C Condensing

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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.

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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.

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Remove Non-condensable Gases: Purging

Manual Purging

Automatic Purging

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Advantages Automatic Purging System

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 multi-point purger can continuously 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	

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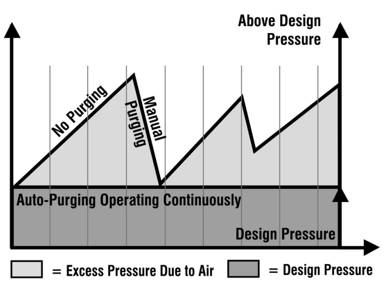
Advantages Automatic Purging System

No Purging Or Non working Purger



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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 non-condensables
3. Condensation of refrigerant using a small evaporator, followed by venting of the air-refrigerant mixture this is now rich in noncondensables

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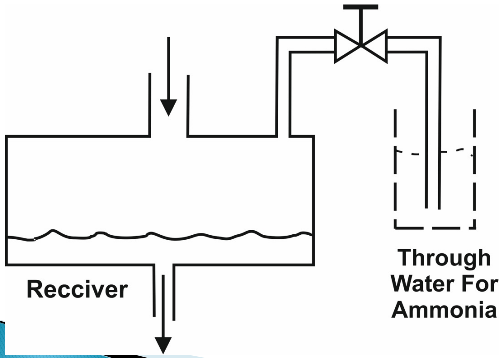
Direct venting: Manual Purging



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Direct Venting: Manual Purging

Manual purging at the condenser or receiver Procedure:

- Always use PPE kit (Mask, gloves, suite)
- Have valve with pipe connection on top of condenser and receiver
- Connect Hose to pipe connection for purge
- Connect weight to other end of hose & deep hose in water bucket
- Pump down refrigerant by shutting liquid valve at outlet liquid receiver, then stop refrigeration plant
- Keep condenser water / fans running for 1 hour
- Slowly open the purge valve
- Check ammonia smell, water colour / foam formation in water for ammonia release
- Close valve immediately if ammonia is released

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Direct Venting: Manual Purging

Manual purging at the condenser or receiver

Problems:

- Takes a lot of valuable time.
- Needs to shut down plant
- Does not totally eliminate air.
- Permits escape of refrigerant gas that may be dangerous and disagreeable to people and the environment, and may also be illegal.
- Is easily neglected until the presence of air in the system causes problems.

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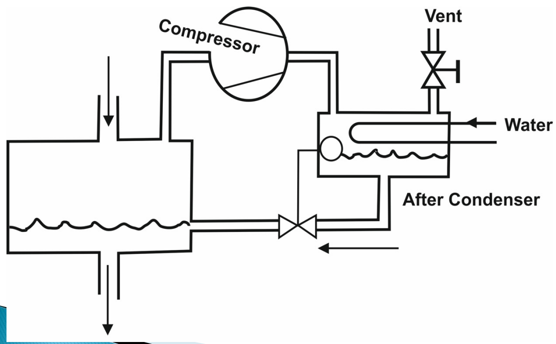
Compression of Mixture



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Compression of Mixture

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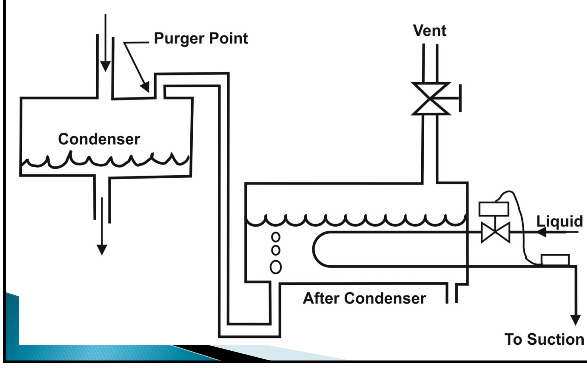
Condensation of refrigerant using a small evaporator



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Automatic Purger Condensation of refrigerant using a small evaporator

- 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 of separate refrigeration system

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Where To Purge Air ?

- Purge point connections must be at places where air will be collected.
- 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 the purge point connection should be made.
- Similarly, the purge point connection at the receiver should be made at a point farthest from the liquid inlet.

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Where To Purge Air ? Receiver or Condenser ?

Air will remain in the condensers when the receiver liquid temperature is higher than condenser liquid temperature. This can happen when:

1. The receiver is in a warm place.
2. Cooling water temperature is falling.
3. Refrigerating load is decreasing.

Conversely, air will migrate to the receiver when the condenser liquid temperature is higher than the receiver temperature. This can happen when:

1. The receiver is in a cold place.
2. The cooling water temperature is rising.
3. The refrigeration load is increasing.

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Purge Points

Evaporative Condenser

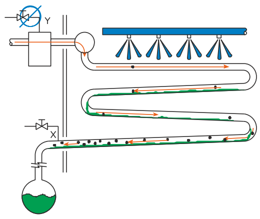

Fig. 1.(left) High velocity of entering refrigerant gas prevents any significant air accumulation upstream from point X. High velocity past point X is impossible because receiver pressure is substantially the same as pressure at point X. **Purge from point X.** Do not try to purge from point Y at the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

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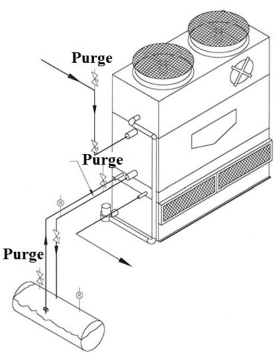
Purge Points



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Purge Points

Purge Connection for Receiver

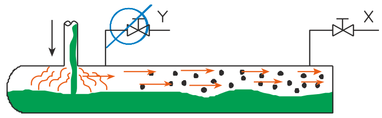

Fig. 5. Purge from Point X farthest away from liquid inlet. “Cloud” of pure gas at inlet will keep air away from point Y.

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Purge Points

Vertical Shell and Tube Condenser

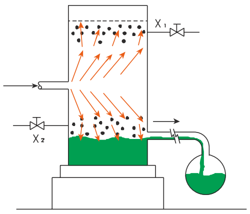

Fig. 4. Low gas velocity will exist at both top and bottom of the condenser. Purge connections desirable at both X_1 and X_2.

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Purge Points

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Purge Points

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Purge Point solenoid valve connection

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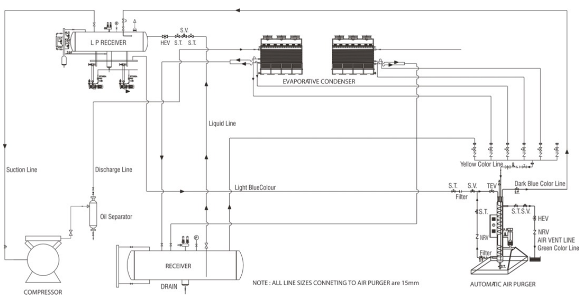
Automatic Purger Installation Liquid Over Feed



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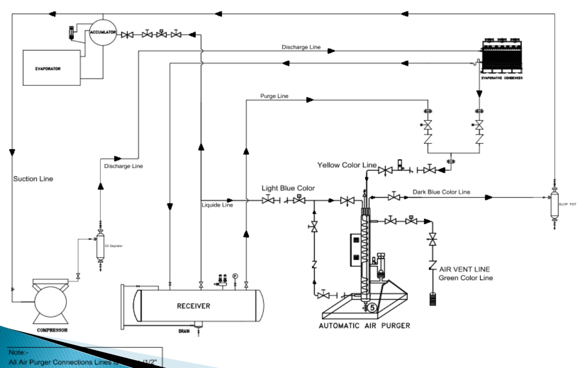
Automatic Purger Installation Gravity Feed



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Automatic Purger



Electrical Power KW for different Condensing Pressure		
	12 kg/sq, cm	16 kg/sq, cm
KC51 2 No.	94	106
KC42 1 No.	45	51
Total Power	139	157
Extra Power	18	
Cost Rs./kW	7.5	
Running Hours in year	6000	
Total Saving due to air purger Rs.	8,10,000	

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Calculation of Increased Power Cost

Plant Details	Freezing Plant	Potato Cold Storage 5000MT
Evaporation Pressure	-40°C	-10°C
Condensing Pressure for 38°C	13.7 kg/cm^2	13.7 kg/cm^2
Refrigeration Capacity	500kW	518kW
Power required by compressor	281kW	148kW
Actual pressure is 1.5 Kg/cm^2 higher	15.2 kg/cm^2	15.2 kg/cm^2
Power required due high pressure	300kW	165kW
Energy Saving	19kW	17 kW
Annual Running Ours	6000 hours	5000 hours
Electricity Cost	Rs. 8/-	Rs. 8/-
Total increase in electricity bill	Rs. 9,12,000/-	Rs. 6,80,000/-

*Other benefits such as reduction in wear & tear of compressor parts, condenser descaling, increase in refrigeration capacity are to be added

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Water Contamination and Removal in Ammonia Refrigeration Systems

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

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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.

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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

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Water Contamination and Removal In Ammonia Refrigeration Systems

Two Sources of Water contamination

1. The contaminated sources in the construction and initial start up phase
2. The contaminated sources after the system has been put into normal operation.

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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.
- while pressure testing with air using system Ammonia compressor
- 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.

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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 that 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.

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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 can create more “free” water in the system.
- Inadequate or no purging

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Water Contamination and Removal in Ammonia Refrigeration Systems

Contamination after the system has been put into normal operation

Inadequate or no purging
Example
Air Purger in a plant removes 5 lit of air per min
Ambient temperature is 35°C, & 75% RH
Hence, water contain is 25 g/kg
5 lit x 1/1000 lit X 25.5 g X 60 min = 7.65 grams of Water per hour
That is 45.9 lit per year considering 6000 hrs per year plant operation
In 10 years, we will have 459 Lit of water in our plant

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Effects of Water Contamination

- Water causes corrosion in the refrigerant cycle
- Accelerates the aging process in oil
- Oil mixes with water and ammonia forms gums
- The compressor oil begins forming organic acids and sludge from a complex chemical reaction
- Increased wear and tear of the compressor and frequent oil changes generate lower plant availability and increase service costs.

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Effects of Water Contamination

- Pressure drops increase through piping
- Pump and evaporator performance are adversely affected
- The system must be operated at a lower suction pressure to maintain the desired temperatures
- Water contamination lowers system efficiency
- Increases electrical costs

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Effects of Water Contamination Compressor

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Effects of Water Contamination Compressor Oil

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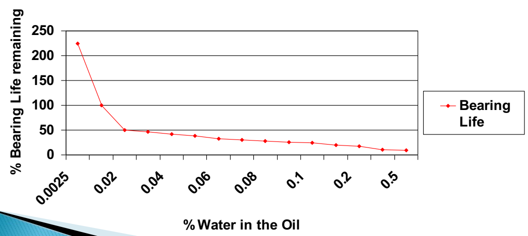
EFFECT OF WATER ON BEARING LIFE

- Water limits are dependent on the fluid's base stock.
- Parafinnic Mineral oils 100 ppm
- Napthenic Mineral oils 150 ppm
- POE's 1000 ppm
- PAG's 2-5%



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Areas Of Highest Water Content

- Recirculation Systems :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.

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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 evaporates in greater proportion than the liquid with the lower vapor pressure, a residue is left containing much more lower vapor pressure liquid when infiltration is not corrected.

Temperature (°C)	Pressure (kPa)	
	Water	Ammonia
0	0.61	329
5	0.87	415
10	1.23	515
15	1.71	629

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Detection of Water Contamination

APPARATUS

The apparatus required for obtaining the sample and making the test consists of:

1. Ammonia evaporation test tube
2. Test tube tongs
3. Sampling converter assembly
4. Vented stopper
5. Water bath maintained at 26° to 32° C
6. Fume hood
7. Rubber gloves
8. Face shield

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Sampling Locations

Suggested locations from which to take samples are:

- Pump Systems - from pump discharge line
- Gas Pressure Systems - from transfer line between transfer drum and controlled pressure receiver
- Flooded Systems - from oil drain valve on liquid leg of surge drum
- DX Systems - from liquid transfer line from accumulator

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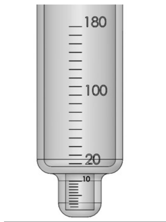
Ammonia Sampler



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Sampling Procedures

1. Wear protective clothing, including face and hand protection.
2. Connect the sampling converter to a liquid outlet of the ammonia tank. Make sure the glass tube is securely attached to the converter outlet. Arrange the vapour hose to discharge downwind.
3. Close the valve at the sampling converter and crack the valve at the tank. Check for leaks
4. Open converter valve one turn. Depending on the length of pipe, upstream of the converter and the temperature, it may take several minutes for the air and vaporized ammonia to pass. Do not assume orifice to be choked, if you do not receive liquid ammonia immediately (wait for at least 5 minutes).

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Sampling Procedures

5. If unit is operating properly, it should take approximately 30-60 seconds to collect 100 ml liquid ammonia. Close the converter valve when the liquid in the glass vessel is approximately 0.5inches below the 100 ml mark to allow for run off. Fill up to the mark by intermittent opening of valve.
6. It is best to discard the first sample to eliminate contaminants from piping. Attach new glass tube and use second sample to determine purity.
7. Place the container on a stand or rack in a safe, ventilated area and allow the ammonia to boil away completely. (for about1-2 hours) Note that, the heat from a hand touching or holding the container can cause the ammonia to boil. If the liquid is boiling violently, a thin steel wire should be put into the sampling container.
8. 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.
9. Compare the quantity of remaining liquid to the chart below. The charts on the reverse of this bulletin show an impact of this water on system performance.
10. Compare the of remaining liquid to the chart below. The charts on the reverse of this quantity bulletin show impact of this water on system performance.

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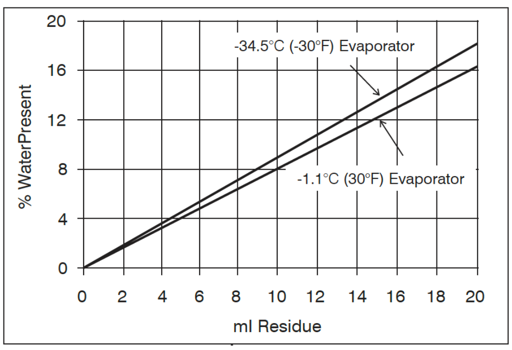
Sampling Procedures



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Ammonia Sampler

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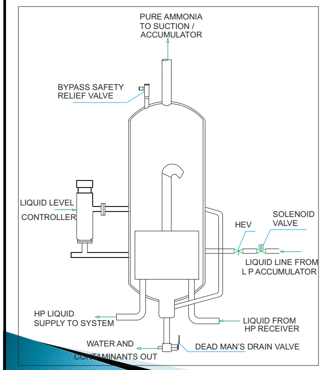
Ammonia Purifier / Dehydrator



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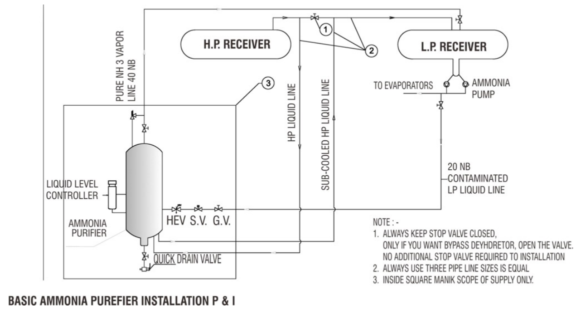
Ammonia Purifier / Dehydrator Installation



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Cost of Water

Parameters	Compressor Type	
	Booster	Two Stage
Compressor Capacity	300 kW	300 kW
Condensing Temperature	-7ºC	40ºC
Evaporating Temperature	-40ºC	-40ºC
Power required	80.1 kW	171 kW
Evaporting Temperaure for 10% Water containination	-42ºC	-42ºC
Corresponding Power required	87.9 kW	181 kW
Extra Power requred	7.8 kW	10 kW
Power Cost	Rs. 8/kW	Rs. 8/kW
Runnuing Hours per year	6000 hours	6000 hours
Total Cost of extra power	Rs. 7,74,400/-	Rs. 4,80,000/-

*Other benefits such as reduction in wear & tear of compressor parts, oil, increase in refrigeration capacity are to be added

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Today's Take Away

Air accumulates at high pressure side of refrigeration system like condenser & receiver

Presence of air

increases discharge pressure,

increases power consumption,

reduces refrigeration capacity,

increases wear & tear of compressor,

increases scaling on condenser

Cost money !

Remove Air online Save Money !!

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Today's Take Away

Water accumulates on low pressure side of refrigeration system like evaporators & pump circulator vessels (LP Vessels)

Ammonia has great affinity with water and makes hydrous ammonia solution

Presence of water

- Water contamination lowers system efficiency
- Increases the electrical costs
- causes corrosion in the refrigerant cycle
- accelerates the aging process in oil
- increases wear and tear
- increase service costs.

Cost money !

Remove water Save Money !!

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Today's Take Away DEMO VIDEO

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Association of
AMMONIA REFRIGERATION

Thank You

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