Association of AMMONIA REFRIGERATION

Refrigeration Plant Controls

by
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MAKE IN INDIA

Why Automation of Refrigeration plant ?

Observation

- Practically impossible to load unload, start stop compressor manually depending on load variation.
- Operator frequently throttle valves installed at liquid Header (going to cold room) from plant room to avoid liquid stroke to compressor.
- Manually Difficult to close / open each cold room liquid header isolation valve when room temperature is achieved and to reduce load on compressor.
- Manually Difficult, every hour to measure and log each room temperature.
- Measuring and recording energy

Why Automation of Refrigeration plant ?

- To avoid human errors and inefficiency
- Operating plant at designed conditions
- Plant Safety
- Energy efficiency
- Automatic Parameters recording

Why Automation of Refrigeration plant ? Parameters

- Level : Safety & Efficiency
- Pressure : Safety & Efficiency
- Temperature : Product storage life
- Carbon Dioxide CO_2 : Product storage life
- Relative Humidity : Weight Loss

Why Automation of Refrigeration plant ? Energy Efficiency

The energy efficiency of any refrigeration plant is fundamentally influenced by two basic parameters:

- The system mechanical design, including the selection of refrigeration concept, component selection and pipe design.
- The quality of the electronic control system and the control logic utilised.
- Under- or over-sizing of components can reduce efficiencies in many ways. However, even the best designed refrigeration plant can perform poorly if the control system is too basic for the task.
- In many cases, especially where the plant experiences frequent load changes or load combinations, compressors can run inefficiently or even unnecessarily.

Why Automation of Refrigeration plant ? Energy Efficiency

Sector	**Typical percentage of site energy cost spent on refrigeration**
Industrial production of:	
Milk and milk products.	30%
Ice cream	70%
Meat, poultry and fish	50%
Frozen fruit and vegetables.	70%
Chocolate and sugar confectionery	20%
Beer and other brewing	30%
Other sectors:	
Cold storage.	90%
Food supermarkets	50%
Small shops with refrigerated cabinets Pubs and clubs	over 70%

A small percentage reduction in these refrigeration energy costs can represent huge cash savings, leading to increased profits.

Why Automation of Refrigeration plant ? Safety

- Ammonia is a gas with a distinctive pungent odour smell at concentrations as low as 5 parts per million (ppm).
- Acute toxicity of ammonia is a major consideration in the safe design and operation of refrigeration systems
- Can work without discomfort in concentrations of approximately 100ppm. (TWA 25 ppm)
- Concentrations between approximately 150ppm and 200ppm will cause irritation of the mucous membranes and the eyes, but normally with no lasting consequences.
- From approximately 500ppm to 700ppm, the eyes are affected more and more quickly, streaming with tears after 30 seconds or less, but the air is still breathable.
- At approximately 1000ppm, breathing is intolerable and vision is impaired but not lost.
- Ammonia forms a flammable atmosphere at concentrations between 16 and 25% by volume in air.

Data Required for Selection of Controls

- Refrigerant used : Ammonia,
- Type of system i. Gravity feed ii. DX or iii. Pump Recirculation
- Circulation ratio in case of Pump recirculation system
- Evaporating temperature or pressure
- Refrigerant liquid inlet temperature or pressure
- Refrigeration capacity of evaporator
- Condensing temperature or pressure
- Location of the valve i.e. wet suction, dry suction, liquid, discharge, hot gas, condensate return etc.
- Line Size

k_v Factor

What?

The k_v - factor for a given valve is a constant which in a simple way states the valve capacity. The k v - factor is determined by the valve manufacturer by experiments.

"The k_v value is the flow of water in m^3 /hr at a pressure drop across valve of 1 bar, ρ = 1000kg/m^3"

Why?

The k_v - factor is an exact and easily applicable value for use when calculating pressure drops, sizing, and ordering valves.

Use K_v Factor

Q flow in m^3/hr
Δp pressure drop across the valve in bar
ρ density of fluid in kg/m^3
K_v flow factor of Valve in m^3/hr

$$Q = K_v \sqrt{\Delta p / \rho}$$

Q flow in m^3/hr

Δp pressure drop across the valve in bar

ρ density of fluid in kg/m^3

K_v flow factor of Valve in m^3/hr

Various Controls for Refrigeration

- Liquid Level Controllers, Level Transmitters & Float Switches
- Solenoid Valves, Gas Operated Solenoid Valves Single and Two Stage
- Safety Controls Safety valves, Dual Manifold for Safety Valves, Dead Man's Valve
- Automatic Air Purger, Ammonia Purifier
- In Line components Non Return valves, Strainers,
- Controls Valves Flow Regulating Valves, Over Flow Valves, Pressure & Temperature Regulating Valves, Crank case Pressure Regulators

Various Controls for Refrigeration

- Compressor Capacity Controllers, PLCs for Piston and Screw Compressors
- Data Loggers, Temperature, Pressure, Humidity and Gas Indicators / Indicating controllers
- Alarm Annunciators, Defrost Controllers, Ice thickness Controllers
- Ammonia Leak Detectors
- Sensors & Transmitter for temperature, pressure, humidity, CO2, ethylene, Oxygen etc.
- Web-base Monitoring & Control Systems
- Mobile Applications to Monitor plant

Case Study
1. Automation of Cold Storage
2. Automation of Freezing Plant

Automation of Cold Storage

Plant Details

- Factory : Sea Food
- Location : Tuticorin
- Cold storage capacity 350 MT / chamber
- No. of chambers 2
- Chamber temperature Desired -20°C
- Refrigeration System : Liquid Overfeed
- Water defrosting system
- Compressor KC42 @800 RPM
- Motor 100hp
- Condenser Evaporative

Automation of Cold Storage Plant

Problems Observed

- Lowest room temperature achieved -16°C
- Very High Discharge pressure 15 bar
- Oversized Compressor and motor
- Long Running hours 18-20 hour
- Heavy frost formation on cold room coils, floor & ceiling
- Very long defrost time @ 1 hour
- Temperature rises during defrost to-10°C
- Time required to get -16°C after defrosting was @4 hours
- Compressor suction pressure was observed -0.2 bar (-37.6°C)
- Compressor running current 110Amp
- Single Safety valves were with isolation valves
- No warning system for ammonia leakage
- Compromised operation staff safety

Automation of Cold Storage Plant

Solutions

- Replace KC42 compressor +100HP motor by KC31 compressor +75 HP motor
- Installation of Compressor automatic controller
- Installation of Ammonia leak detection system with electrochemical sensors
- Installation of Automatic air purger
- Installation of Ammonia Dehydrator
- Automatic hot gas defrosting for cold room coils
- Dual Manifold with safety valve
- Digital temperature monitoring system

Automation of Cold Storage Plant

Results

- Room Temperature maintained -20°C
- Frosting / icing on coils, floors and ceiling eliminated
- Defrost time reduced to 20 minutes
- Increase in room temperature during defrost limited to 2°C(upto-18°C)
- 2 defrost cycles per day
- Time required to attain -20°C after defrost was 20 min
- Compressor Suction pressure maintained at 0.3 bar
- Compressor Discharge pressure maintained at 12.5 bar
- Compressor running hours reduced to 14-15 hours
- Compressor running current reduced to 75 Amp

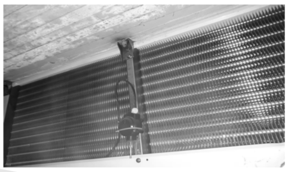
Automation of Cold Storage Plant

Conclusion

- Overall power consumption reduced by 30%.
- New automation system ensured safety & efficiency
- Achieved faster cooling without any fluctuations in temperatures even after defrosting
- Real time based hot gas defrosting eliminated operator interference and operator can concentrate on other activities
- Better monitoring of temperature
- Reduced discharge pressure
- Increased suction pressure
- Ammonia leak detection system was able to deduct leaks at low ppm. Its alarm function ensured safety of people & emergency response was possible on time

Automation of Cold Storage Plant



Automation of Freezing Plant

Plant Details

- Factory : Sea Food
- Location : Taloja
- Blast Freezer capacity 6 MT/Batch 2 No.
- Blast Freezer capacity 3 MT/Batch 1 No.
- Plate Freezer 1MT / bath 1 No.
- Freezer temperature Desired -35ºC
- Refrigeration System : Liquid Overfeed
- Designed freezing capacity 36 MT/day
- Water defrosting system
- Compressor KC31 2 Nos. @800 RPM
- Compressor KC72 1 Nos. @800 RPM
- Evaporating Condenser 2 No.
- High Pressure Receiver 2 No.
- Pump Recirculation (low pressure) vessel 2 No.

Automation of Freezing Plant

Problem observed

- Lowest blast freezer temperature achieved -28ºC
- Very High Discharge pressure 16 bar
- Blast freezer running 14 hours per batch
- Heavy frost formation on freezer coils, floor & ceiling
- Blast freezer coils were starving
- Very long defrost time @ 2 hours
- During defrosting room temperature rises to -12ºC
- Timer required to achieve -28ºC after defrosting was @4 hours
- Plate freezer was required to run 3 hours
- Only one batch per freezer per day and 3 batches of plate freezer was possible
- The maximum freezing capacity achieved 18 Tones per day
- compressor suction pressure was observed @-0.5 bar (-46ºC)
- Single Safety valves with isolation valves closed
- All compressors were running continuously
- No warning system for ammonia leakage
- Oil drain valves were manual and leakage of ammonia was regular occurrence

Automation of Freezing Plant

Solutions

- New compressor KC72 1No. added
- Old compressor KC31 1No. removed
- Plate freezer capacity 1 MT/batch added
- Plant piping and pressure vessel connections changed
- Installation of Compressor automatic controller
- Installation of Ammonia leak detection system with electrochemical sensors.
- Installation of Automatic air purger.
- Installation of Ammonia dehydrator
- Automatic hot gas defrosting for blast freezers, & plat freezers
- Dual Manifold with safety valve
- Digital temperature monitoring system
- Quick Closing oil drain valves for oil drain installed

Automation of Freezing Plant

Results

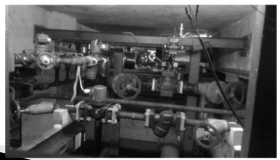
- Blast Freezer Temperature maintained -35ºC
- Frosting / icing on freezer coils, floors and ceiling eliminated
- Defrost time 20 minutes
- Increase in room temperature during defrost limited to 2ºC(upto-33ºC)
- 2 defrost cycles per day
- Time required to attain -35ºC after defrost was 20 min
- Blast freezer running hours 6 hour per batch
- Plate freezer running hour 90 min / batch
- Compressor Suction pressure maintained at -0.3 bar
- Compressor Discharge pressure maintained at 13.5 bar
- Added new Plate freezer 1MT per batch

Automation of Freezing Plant

Conclusion

- Refrigeration system with automation reduced power consumption by 20%.
- Reduction in freezing time helped to get 2 batches from blast Freezer
- Plate freezer cycles increased to 5 batches per day
- Additional plate freezer operating in same system
- Total Freezing Capacity achieved 40MT /day
- New automation system ensured safety & efficiency
- Achieved faster cooling without any fluctuations in temperatures even after defrosting
- Better monitoring of temperature
- Ammonia leak detection system was able to deduct leaks at low ppm. Its alarm function ensured safety of people & emergency response was possible on time.

Automation of Freezing Plant



Automation of Freezing Plant

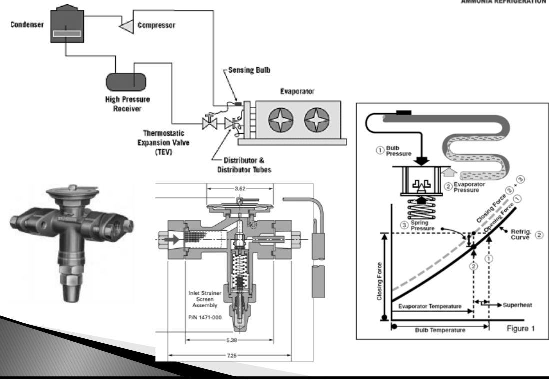
Types of Systems

Direct Expansion

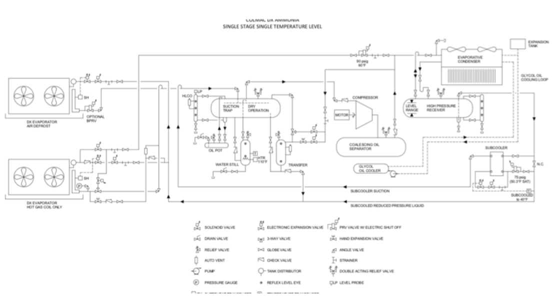
Gravity Feed

Liquid Over feed

Direct Expansion System : Conventional

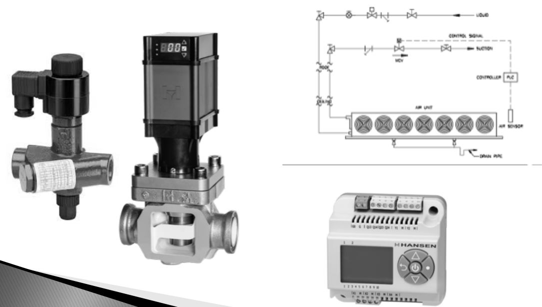


Direct Expansion System : New trend

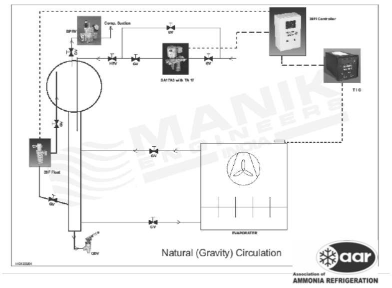


Direct Expansion System : Electronic

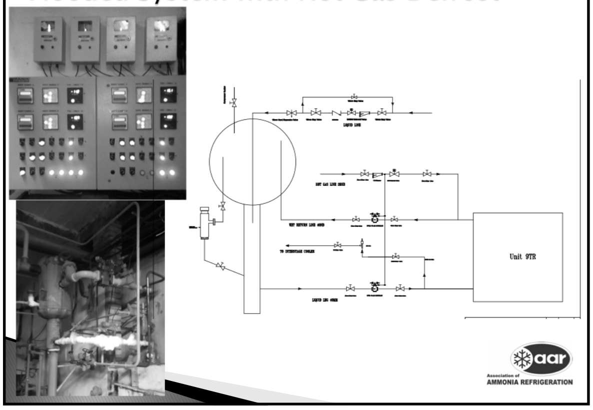
1. Pulse width Modulation Valves
2. Stepper Motor Valves



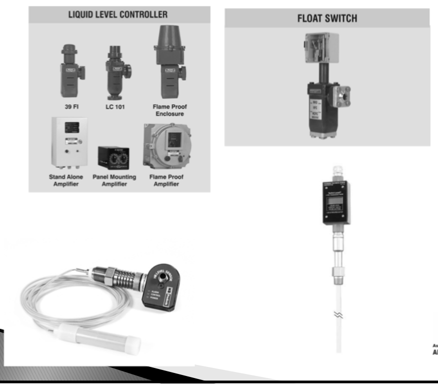
TYPICAL INSTALLATION FLOODED AIR COIL UNIT



Flooded System with Hot Gas Defrost

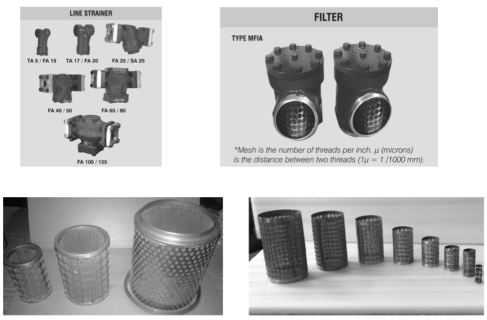


Liquid Level Controller, Transmitters & Float Switch

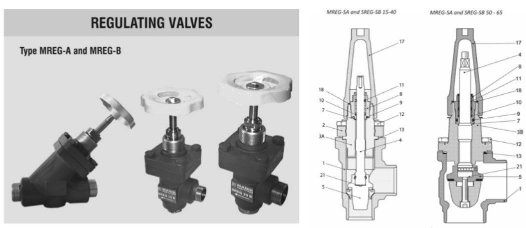


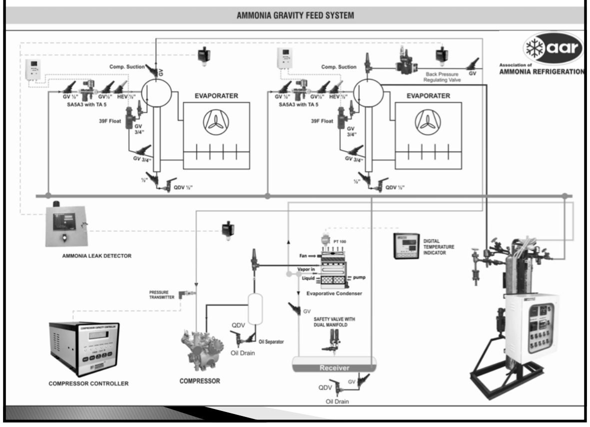
Solenoid Valves

Strainers & Filters

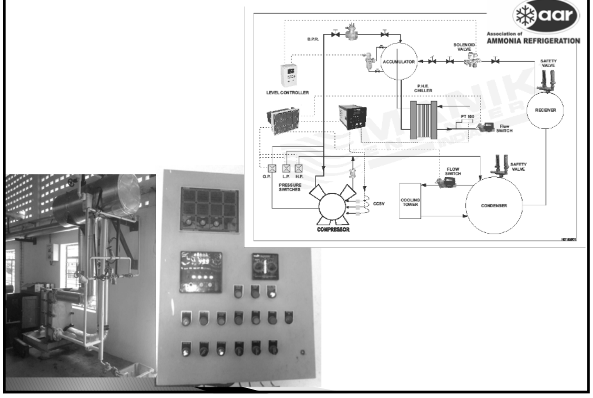


Hand Expansion / Regulating Valve





Typical Controls for Flooded PHE System



MULTI FUNCTION PRESSURE & TEMPERATURE REGULATORS

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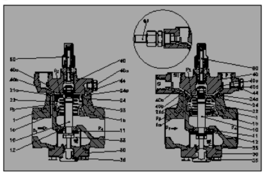
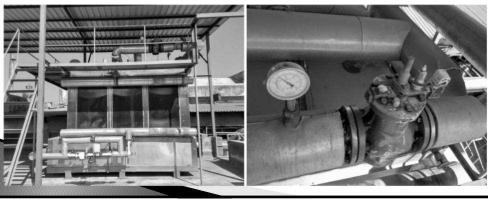
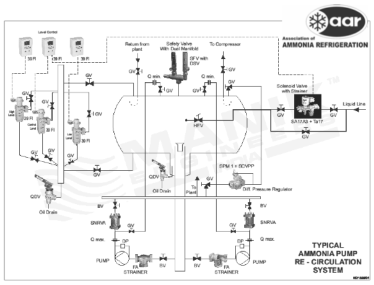
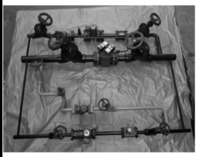


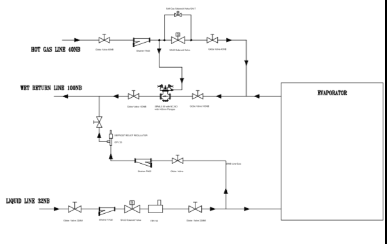


TYPICAL OVER FEED SYSTEM VESSEL



Hot Gas Defrost for Over feed System





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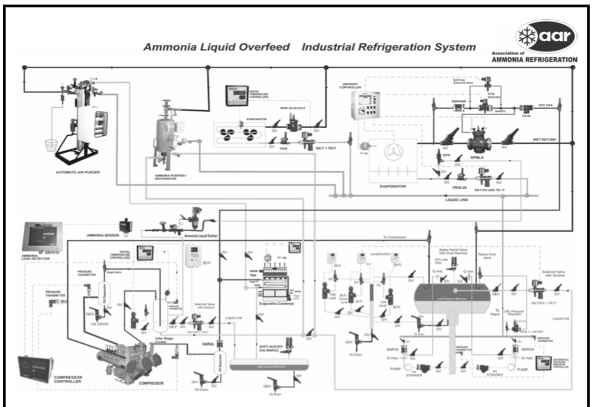
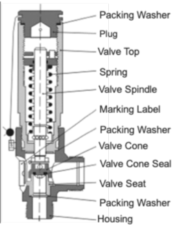
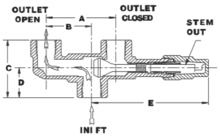


SAFETY VALVES AND DUAL MANIFOLD

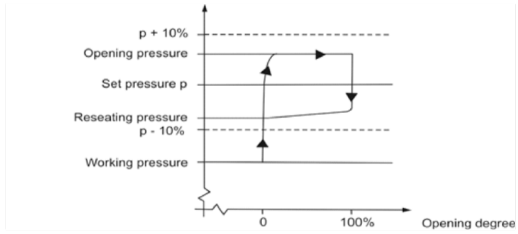




Single Safety Valve or Dual Manifold ?

- Single Pressure Relief Valve for Vessel of internal gross volume more than 3 cu. ft or less than 10 cu. Ft
- Dual Manifold for all pressure vessels with internal gross volume more than 10 cu. Ft.

SAFETY VALVE RELIEF SETTING



SIZING OF SAFETY VALVE

Ammonia Pressure Vessel	IP	SI
General	C = 0.5DL	C = 0.04DL
If combustible materials are used within 20 ft (6.1 m)	C = 1.25DL	C = 0.1DL
For plate heat exchanger or double-pipe condenser	C = 0.5(A/2)	C = 0.04(A/2)

The minimum required rated discharge capacity for a vessel shall be:

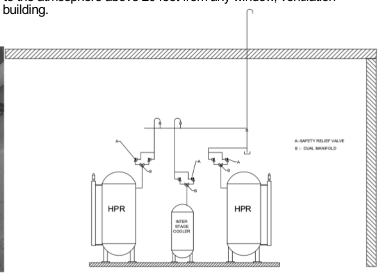
C = F x D x L

where
C = required discharge capacity , lb(air)/min [kg/s]
D = OD of vessel, ft [m]
L = length of vessel, ft [m]
A = Overall external surface, ft2 [m2]

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Safety Valve

- Safety relief System: Safety valve outlet was connected to common header and such that discharge of safety valve to the atmosphere above 20 feet from any window, ventilation opening or exit in nearby building.



AMMONIA LEAK DETECTOR & ALARM

AMMONIA LEAK DETECTOR & ALARM

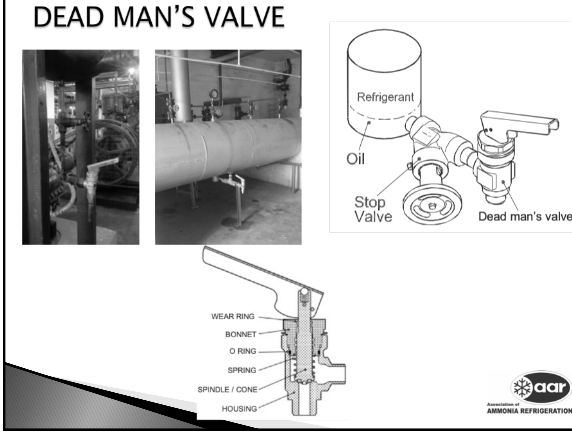
Location of Ammonia Sensors

- The Gas Detectors must be installed at High Level
- At least 1 detector at ceiling level on a grid of 10m to 20m intervals
- Above or to both sides of compressors
- Above Pressure vessels like H P / LP receivers
- Emergency power supply, e.g. battery or UPS for the detection system

AMMONIA LEAK DETECTOR & ALARM

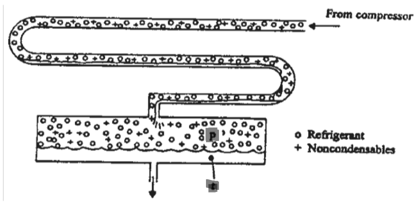
Ammonia Leak Detector Setting		
Alarm	Setting PPM	
	Manned Area	Unmanned Area
First	50	30
Second	150	70
Third	250	100

DEAD MAN'S VALVE



Air and other non-condensables

When to Purge ?
If $P > P_t$
Where,
P is actual Pressure in receiver
P_t is saturation pressure corresponding to temperature t



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. IIAR Paper TP-22

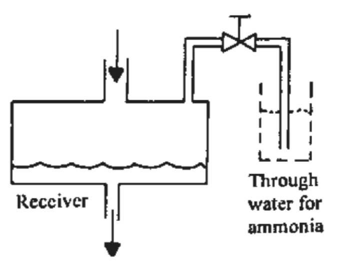
Calculation of increased power cost

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/-**

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



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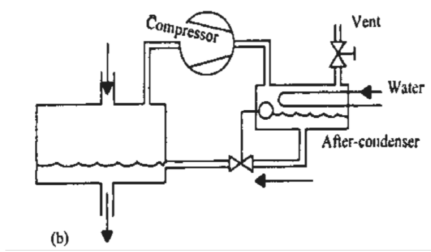
Compression of Mixture



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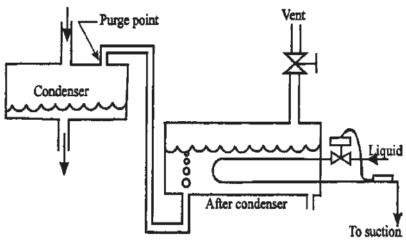
Condensation of refrigerant using a small evaporator



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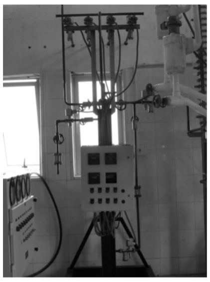
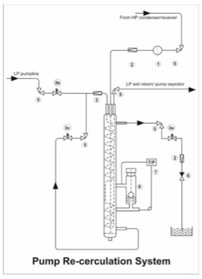
Automatic Purger





Pump Re-cerculation System

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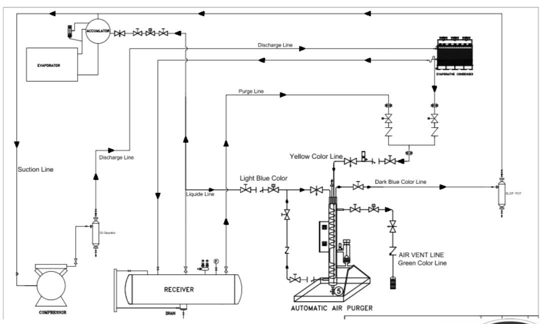
Automatic Purging System



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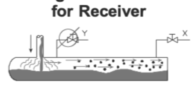
SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Automatic Purging System

Purge Connection for Receiver



Evaporative

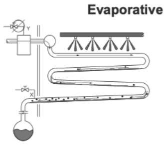


Fig. 5. Purge from Point X farthest away from liquid inlet. "Cloud" of pure gas at inlet will keep air away from point Y.

PHE CONDENSER

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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

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

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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.

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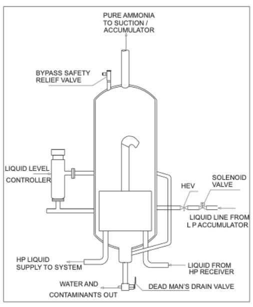
Areas Of Highest Water Content

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 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.

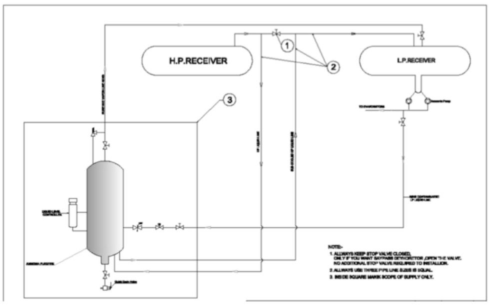
Association of AMMONIA REFRIGERATION

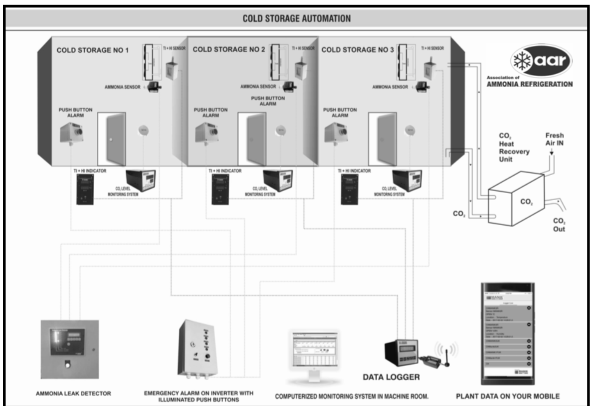
Ammonia Purifier



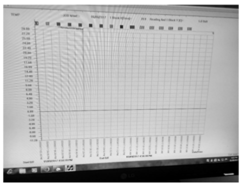
Association of AMMONIA REFRIGERATION

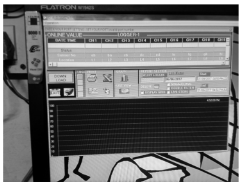
Ammonia Purifier

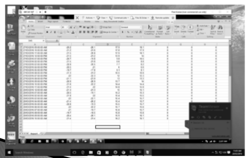




Plant Automation







Plant Automation

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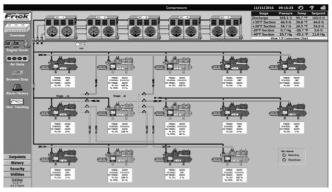

Thank You

www.ammoniaindia.org