Association of AMMONIA REFRIGERATION

Refrigeration Plant Controls / Automation for Safety & Energy Efficiency

by

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MANIK ENGINEERS INDIA

Made In India for world since 1978

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, $\rho = 1000 kg/m^3$"

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

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

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 :

An Innovative Upgrade To Achieve Energy Savings & High Efficiency For Odisha Ice Cream Making Facility

The Plant: Production capacity of 10 MT of ice-cream

Objective:

1. To upgrade in phases the existing refrigeration plant for higher efficiency and safety , involving reasonable investment with disturbing plant operation

2. ROI period less than a year

3. Achieving minimum 15% energy savings

NOTED PREVAILING PROBLEMS

- The chiller rooms and freezer rooms are not able to achieve desired temperature in spite of long running hours of compressors
- All unit compressors including standby were required to remain in operation in order to meet the required refrigeration capacity .
- The compressors were running full load at all times
- The compressor suction pressure and plant evaporating temperatures did not correlate. The suction pressure was much lower than the corresponding room temperature
- The compressor discharge pressure was high considering the ambient conditions
- Complete plant had to be operated manually.
- The air cooler coils for chiller (cold) rooms and freezer rooms were frosted
- Although the cold room and freezer rooms were designed at -25°C room temperature , however the best temperature achieved would be -14°C

NOTED PREVAILING PROBLEMS

- The defrosting system was manual and was never able to defrost the coils completely
- Plenty of oil was getting accumulated in ACU/ Freezer coils.
- Ammonia leakage during oil draining discouraging operators
- Plant safety management was non-existent.
- The level control system was bypassed and operators were manually throttling the valves on receiver supply line.
- Freezer air cooler coils were starved for liquid supply ,but operators were afraid of liquid surge to compressor.
- Operators were kept occupied by operating various valves and using all efforts to check operation, temperature and liquid level.
- Due to small leakages through flange joints , strong ammonia odor was continuously felt in the machine room.
- The chiller rooms and freezer rooms were located around the plant and many times the loader would be trapped in the room, thus preventing the trapped person to freely communicate with plant operators.

ENERGY-EFFICIENT MEASURES & NOVEL SOLUTIONS

- Installed dual Safety (relief) Valves on all pressure vessels with required pressure ratings.
- Calibrated compressor safety cut out , repaired and re-connected for safety
- Installed (on each compressor) easy to use Automatic Compressor control system with energy monitoring
- Installed fully automatic air purger on condenser and liquid receiver circuit.
- Installed automatic hot gas defrosting system (replacing the existing manual defrost) on all air cooling units in chiller rooms and freezer rooms.
- Installed temperature monitoring and control devices for all cold rooms and freezer rooms.

ENERGY-EFFICIENT MEASURES & NOVEL SOLUTIONS

- The automatic level control system was serviced and put into use.
- Installed the reflex type level gauges and removed the glass tube one.
- Installed an integrated automatic ammonia leak detection system
- All flange type valves were replaced with 40 bar weld in-line valves. The valves were chosen with back seating facility.
- Quick Closing Oil Drain valves installed on evaporators, receiver to facilate ease of oil draining
- The chiller room alarm system with built-in battery back-up was installed on machine room doors for trapped loader and generate alarm in plant room. This unit was incorporated with inbuilt battery backup so that it can work independently in the event of power outage.
- The overall above system improvement is anticipated to provide a Low Life Cycle Analysis (LLCA) and low carbon emissions where the refrigerating system gets greener and the energy savings add to the bottom line footprints.

Results

- The compressor discharge pressure reduced significantly to 160 PSI from 220 PSI
- The automatic operation of compressor units removed operator interference and resulted in smooth loading / unloading of each compressor. Additionally overall energy requirement for compressor was reduced significantly
- The safety valves and release system ensured increased safety at plant and no discharge of ammonia in plant incase safety valve pops up.
- The automatic ammonia leak detection and alarm system increased plant safety meeting OSHA's PSM requirements extending operator flexibility in working around the plant.
- The automatic hot gas defrost system replaced manual defrost operation
- The defrost time was reduced to 15 minutes instead of 45 minutes
- The increase in cold room / freezer room temperature during defrost reduced to 2°C from 10°C
- The cold room / freezer room design temperature of -25°C was sucessfully achieved.

Results

- The time required for freezer operation reduced by 25%
- The number of compressors required reduced. The standby compressor remain as standby, was never required to operate.
- Reducing compressor running hours by 25%
- The automatic level control system made sure that ACU/Freezer coils are flooded thus preventing liquid slop-over to the compressor.
- The automatic level control system avoided operator's interference by throttling valves on receiver supply line.
- Oil accumulation in ACU and freezer units was eliminated
- Frosting on ACU & freezer units eliminated

Results

- The online datalogging and remote monitoring system installed helped customer to monitor the plant on mobile phone while travelling abroad and enjoy his holidays.
- The temperature control system made sure that required temperatures are maintained continuously. No under shooting / overshooting observed. All temperature were maintained within ±2°C
- The weld in lines valves eliminated the leakages through flange joints of the valves .
- The back seating facility in the valve assured operators that now they don't have to pursue in tightening valve glands.

Plant discharge pressure before plant modification

Plant discharge pressure after plant modification

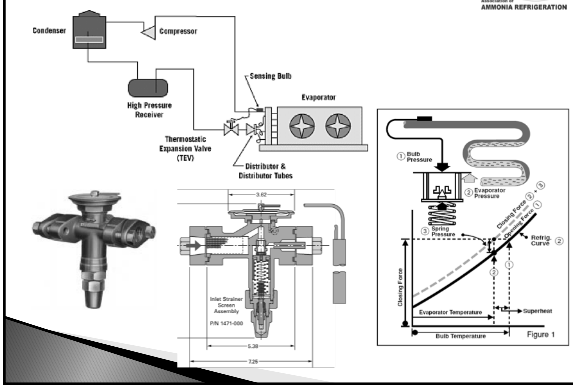
Data monitoring system with webbased operation and mobile application to monitor plant performance online anywhere in world

Easy to use compressor automation system

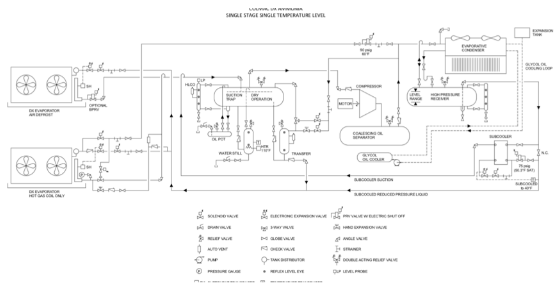
Types of Systems

- Direct Expansion
- Gravity Feed
- Liquid Over feed

Direct Expansion System : Conventional



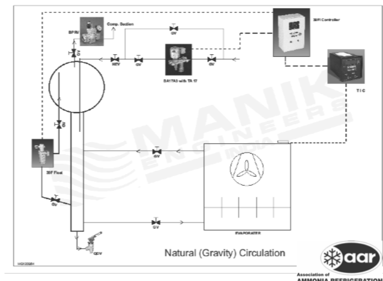
Direct Expansion System



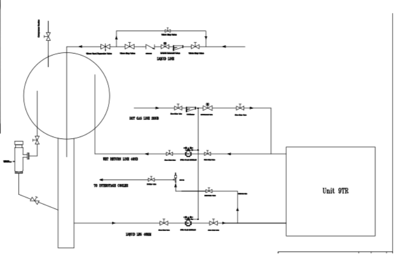
Direct Expansion System : Electronic

1. Pulse width Modulation Valves
2. Stepper Motor Valves

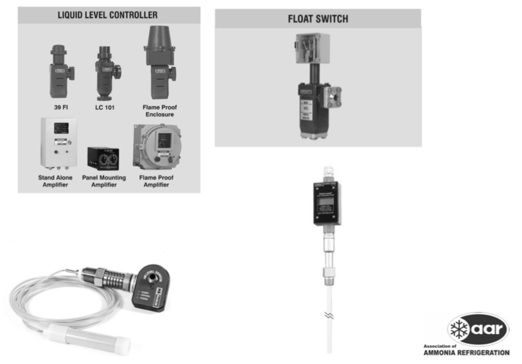
TYPICAL INSTALLATION FLOODED AIR COIL UNIT



Flooded System with Hot Gas Defrost

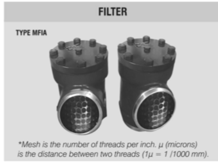


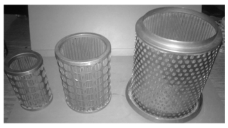
Liquid Level Controller, Transmitters & Float Switch



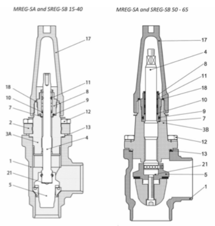
Solenoid Valves

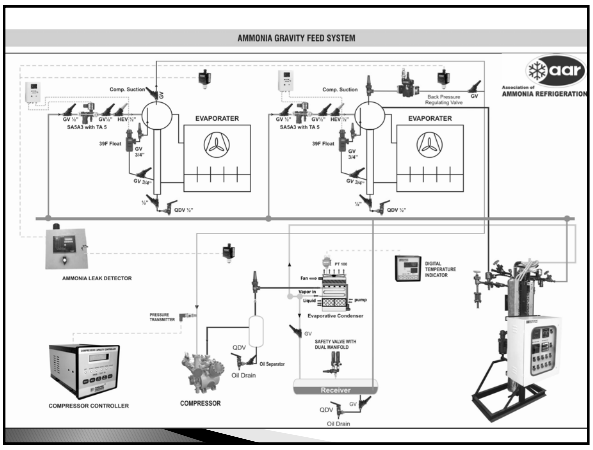
Strainers & Filters



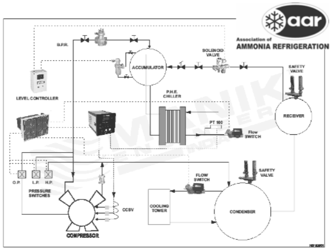


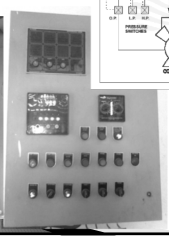
Hand Expansion / Regulating Valve



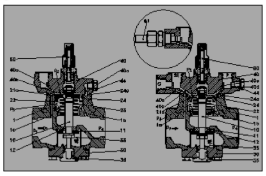


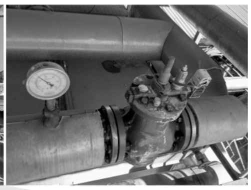
Typical Controls for Flooded PHE System



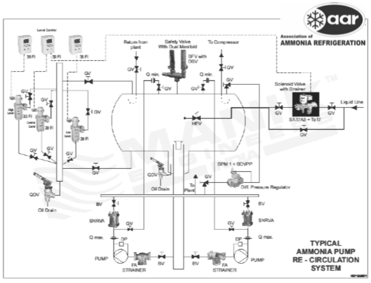


MULTI FUNCTION PRESSURE & TEMPERATURE REGULATORS

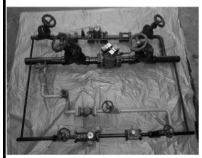


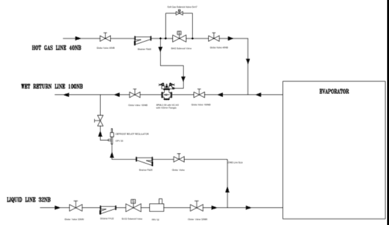


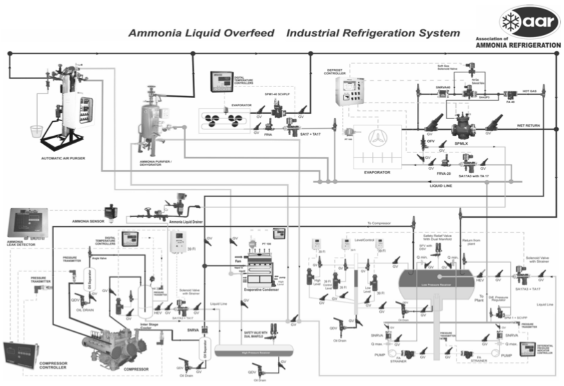
TYPICAL OVER FEED SYSTEM VESSEL



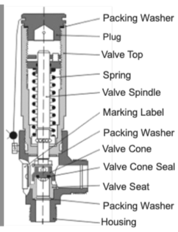
Hot Gas Defrost for Over feed System

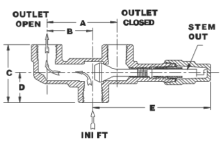






SAFETY VALVES AND DUAL MANIFOLD

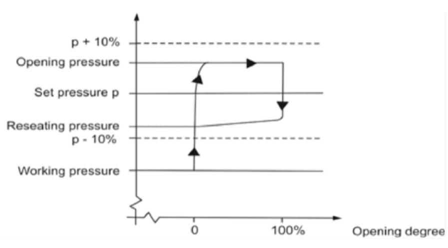




Single Safety Valve or Dual Manifold ?

- 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:

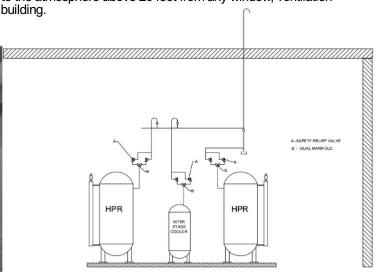
C = F x D x L

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

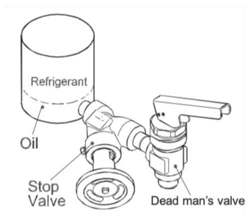
Location of Ammonia Sensors

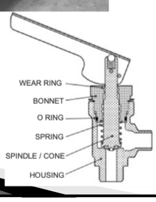
- The Gas Detectors must be installed at High Level
- At least 1 detector at ceiling level on a grid of 10m to 20m intervals
- Above or to both sides of compressors
- Above Pressure vessels like H P / LP receivers
- Emergency power supply, e.g. battery or UPS for the detection system

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

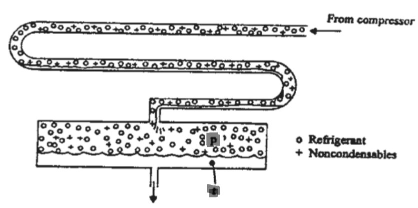
When to Purge ?

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

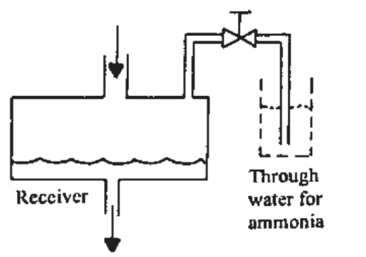
Plan Condition :

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/-**

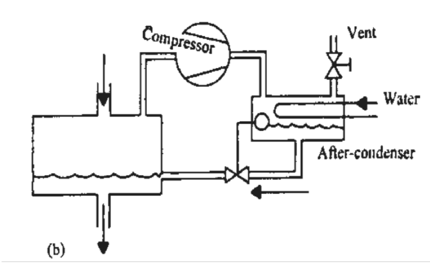
The Three Types of Purging

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

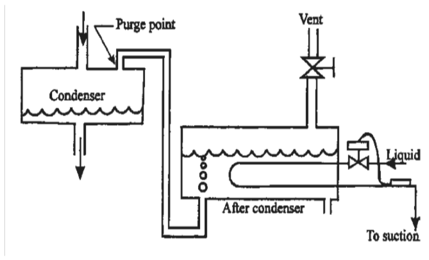
Direct venting: Manual Purging



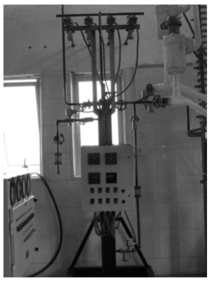
Compression of Mixture

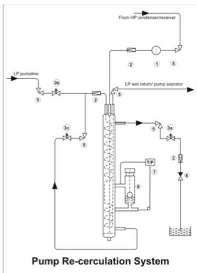


Condensation of refrigerant using a small evaporator

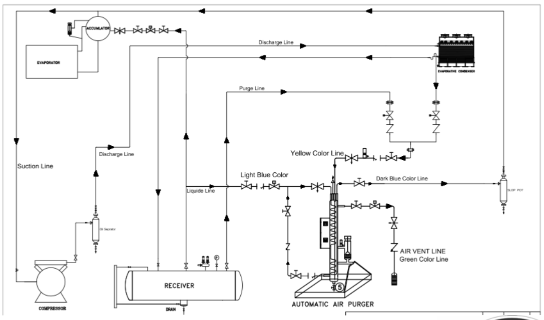


Automatic Purger





Automatic Purging System



SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Automatic Purging System

Purge Connection for Receiver

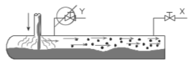
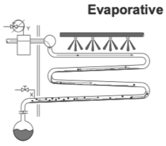


Fig. 5. Purge from Point X farthest away from liquid inlet. "Cloud" of pure gas at inlet will keep air away from point Y.

Evaporative



PHE CONDENSER

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

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

Areas Of Highest Water Content

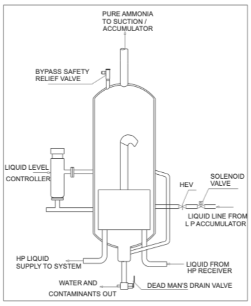
- Recirculation Sysetms :Pump receiver (LPR)
- Flooded systems: evaporator and surge drum.
- DX systems suction accumulator.
- Two-stage systems vessels and evaporators of the low stage portion of the system.

Areas Of Highest Water Content

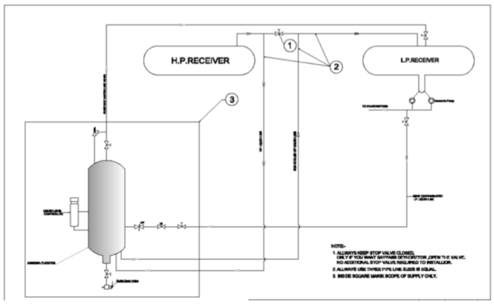
Reasons :

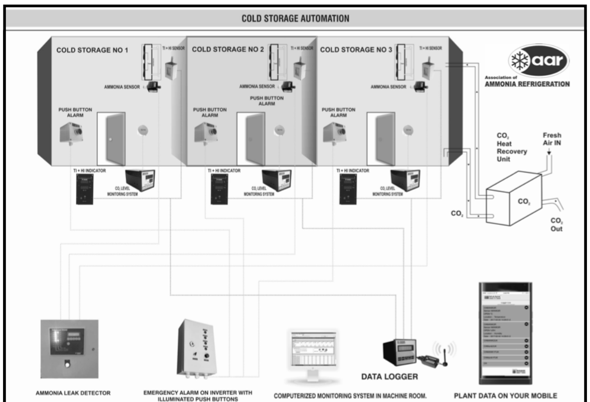
- Large difference in Vapour Pressure between water and ammonia.
- For example, at 2°C, the vapor pressure of ammonia is 3.6 Kg/cm^2 as compared to 0.007 Kg/cm^2 for water.
- Since the liquid with the higher vapor pressure will evaporate in greater proportion than the liquid with the lower vapor pressure,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

Ammonia Purifier

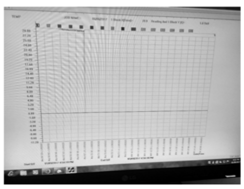


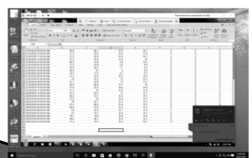
Ammonia Purifier

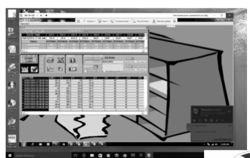




Plant Automation

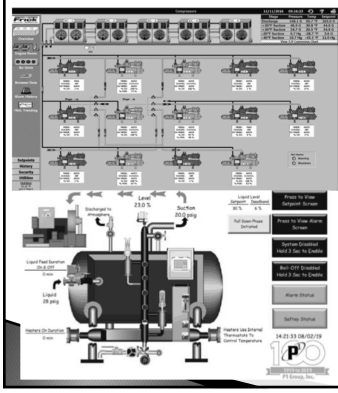






Plant Automation

Plant Automation



Thank You

Association of AMMONIA REFRIGERATION

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