Cold Storage automation for Safety & Energy Efficiency

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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

Which Parameters ? Why ?

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

Energy Efficiency

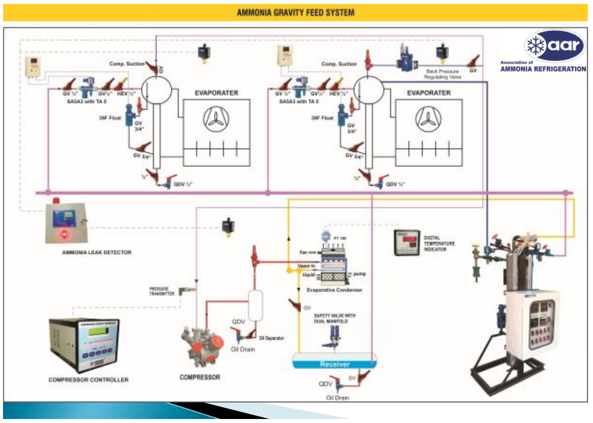
The energy efficiency of any refrigeration plant is fundamentally influenced by two basic parameters:

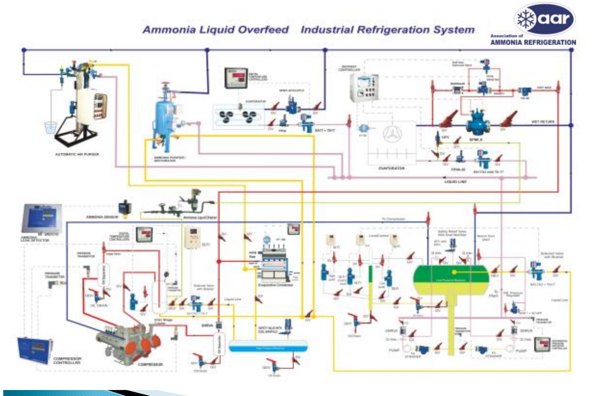
- The system mechanical design, including the selection of refrigeration concept, component selection and pipe design.
- The quality of the electronic control system and the control logic utilised.
- Under- or over-sizing of components can reduce efficiencies in many ways. However, even the best designed 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.

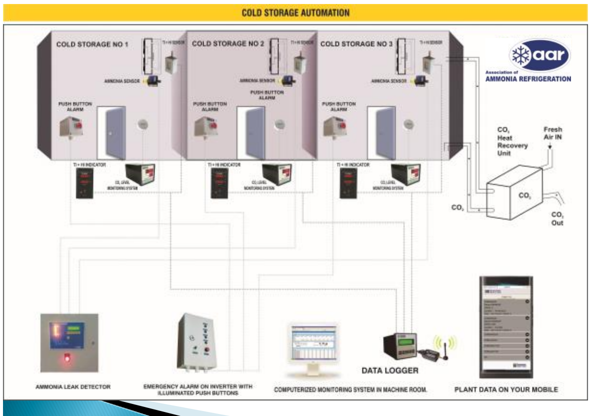
Types of Systems

Gravity Feed

Liquid Over feed







Case Study

An Innovative Upgrade to Achieve Energy Savings & High Efficiency For Odisha Ice Cream making Facility

Why Automation of Refrigeration plant ?

Sector

Industrial production of:	**Typical percentage of site energy cost spent on refrigeration**
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%
Milk and milk products	30%

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

Ice Cream Plant

Production capacity 10 MT of ice-cream per day

Refrigerant : Ammonia NH3

Compressor : Piston Two Stage
KC51 1 No. Working 1 No. Standby
KC21 1 No.
KC42 1 No.

System : Gravity

Objective

- To study plant operation and suggest suitable upgrade in phases for existing refrigeration plant
- Implement plant upgrading without disturbing plant operation
- Achieving minimum 20% energy savings
- Improving Plant Safety
- ROI period less than a year
- All equipment must be easy to operate and maintain

Standards followed

AAR Standard AAR01-2016

ASHRAE Standard 15 -2013

IIAR Standard 2A-2014

ISO 5149-1993

EN/BS 378

NOTED PREVAILING PROBLEMS

Compressor

- 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
- Manual operation of Compressors
- Ammonia Liquid stroke to compressor
- Safety cutout such as suction pressure, discharge pressure and differential oil pressure were bypassed

NOTED PREVAILING PROBLEMS

Compressor

The compressor discharge pressure was high considering ambient conditions

Discharge pressure :16 kg/cm^2 ambient temperature 34^{o}C

NOTED PREVAILING PROBLEMS

Chiller and Freezer Rooms :Temperature ?

- The chiller rooms and freezer rooms are not able to achieve desired temperature in spite of long running hours of compressors
- Although the cold room and freezer rooms were designed at -25°C room temperature , however the best temperature achieved would be -14°C
- The hot gas defrosting system was manual and was never able to defrost the coils completely, typically 1 to 1 ½ hour required for defrosting and requires lot of valve operation manually
- Room Temperature rises by 10°C during defrosting

NOTED PREVAILING PROBLEMS

Chiller and Freezer Rooms :Temperature ?

- The air cooler coils for chiller (cold) rooms and freezer rooms were heavily frosted
- Increase in Humidity in Chiller and freezer room

NOTED PREVAILING PROBLEMS

Chiller and Freezer Room : ACU

- Plenty of oil was getting accumulated in ACU/ Freezer coils.
- Ammonia leakage during oil draining discouraging operators

NOTED PREVAILING PROBLEMS

Chiller and Freezer Room : ACU

- The level control system was bypassed and operators were manually throttling the valves on receiver supply line.
- Liquid Line Solenoid valves and filters were clogged
- Freezer air cooler coils were starved for liquid supply

NOTED PREVAILING PROBLEMS

Plant Operation

- The compressor suction pressure, evaporating temperature and plant evaporating temperatures did not correlate.
  Compressor Suction pressure (-)0.1 kg/ cm² (-35ºC)
  Room Temperature (-)14º C
- Operators were kept occupied by operating various valves and using all efforts to check compressor operation, temperature and liquid feeding to evaporator.
- Operators were reluctant for air purging because of need of plant shut down and manual operation of valves at condenser and receiver
- Removing of oil from Oil separators and evaporators was difficult due to operation of valve and possibility of ammonia leakage
- Glass tubes were used for level monitoring on high pressure receiver
- 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.

NOTED PREVAILING PROBLEMS

Plant Operation

- Operators were kept occupied by operating various valves and using all efforts to check compressor operation, temperature and liquid feeding to evaporator.

- Due to small leakages through flange joints , strong ammonia odor was continuously felt in the machine room.
- Single Safety valves were installed on pressure vessels were not working

SAFETY, ENERGY-EFFICIENT MEASURES SOLUTIONS

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

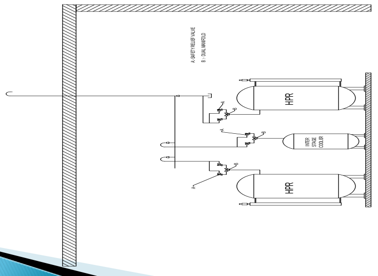
Safety Valve

- Dual Safety (relief) Valves were on all pressure vessels (pressure settings 20kg/cm^2)
- All Stop valve before safety valve were replaced by Dual Manifold

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.



SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

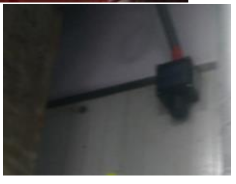
Oil Draining

Quick Closing Oil Drain valves installed on Oil Separators, Evaporators, receiver to facilitate ease of oil draining

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Ammonia Leak Detection System

Centralized Ammonia leak detection system installed to monitor ammonia leakage. Sensors were install in chiller room, freezer room, plant room



SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Ammonia Leak Detection System

Limits of Toxicity of Ammonia

Minimum Detectable Concentration	10 ppmv
TWA Value	30 ppmv
Serious Irritation Level	250 ppmv
Limit to Tolerable Breathing	500 ppmv

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Ammonia Leak Detection System

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

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Cold Room Person Trap Alarm

The chiller room alarm system was installed in machine room with self illuminated push button system near doors in chiller and freezer rooms for trapped loader. This unit was incorporated with inbuilt battery backup so that it can work independently in the event of power outage.

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Safety

- Compressor safety cutouts were repaired, calibrated and re-connected
- All flange type valves were replaced with 40 bar weld in-line valves. The valves were chosen Teflon seat and Teflon back seat facility.
- Reflex type level gauges were installed instead of glass tube

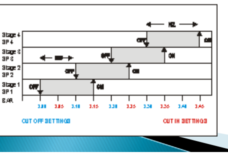
SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

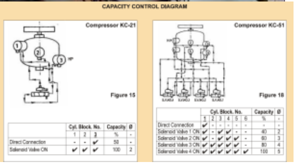
Compressor Automation

Easy to use Automatic Compressor control system with energy monitoring was Installed on each compressor

Typical application

PRCC-04 unit stage control:
Set Point 2.00 bar
Neutral Zone 0.15 bar
Inter-Stage Differential 0.10 bar





SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Automatic Purging System

Installed fully automatic online air purger on condenser and liquid receiver circuit.

Plant discharge pressure after plant modification

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Automatic Purging System

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

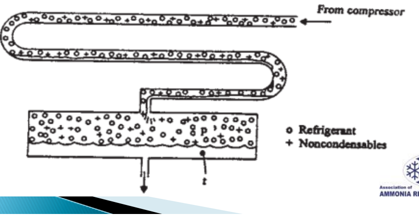
When to Purge ?

If $P > P_t$

Where,

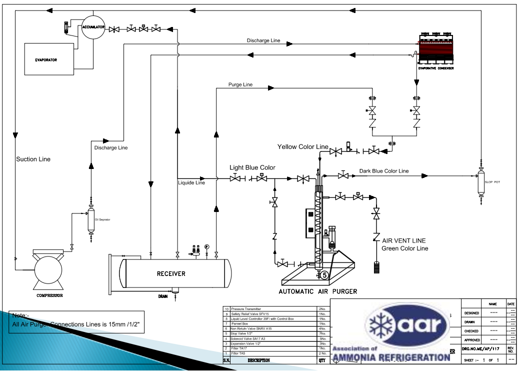
P is actual Pressure in receiver

P_t is saturation pressure corresponding to temperature t



SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Automatic Purging System



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Automatic Purging System

Purge Connection for Receiver

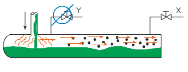
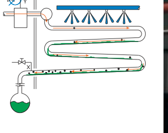


Fig. 5. Purge from Point X farthest away from liquid inlet. "Cloud" of pure gas at inlet will keep air away from point Y.

Evaporative



PHE CONDENSER

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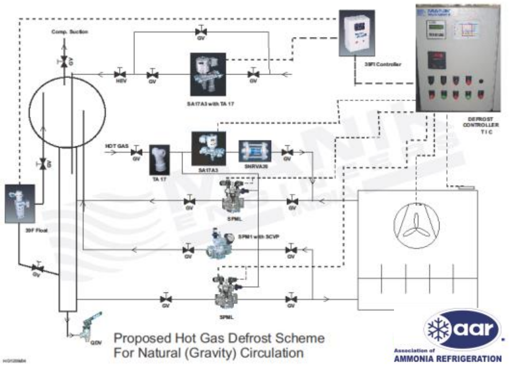
Liquid Level Control & Hot Gas Defrosting System

The existing automatic level control system consisting of electronic level controller and solenoid was serviced and put into use

Automatic hot gas defrosting system for gravity feed installed on all air cooling units in chiller rooms and freezer rooms replacing the existing manual defrost.

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Liquid Level Control & Hot Gas Defrosting System



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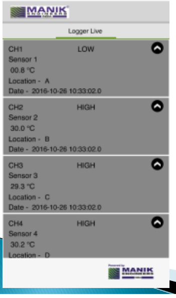
Plant Automation and Monitoring

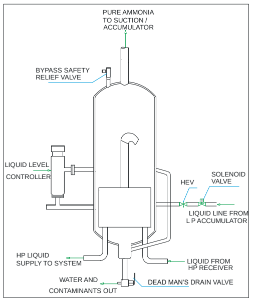
Centralized data logging and web-based monitoring system with mobile application installed.

Temperature Control system installed for individual rooms



SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Ammonia Dehydrator



SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Ammonia Dehydrator

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.

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Ammonia Dehydrator

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

SAFETY, ENERGY-EFFICIENT MEASURES SOLUTIONS

RESULTS

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Results

- compressor discharge pressure reduced significantly to 12 kg/cm² from 16 kg/cm² after installation of Online automatic purging system
- Due to removal of water from Ammonia compressor suction pressure and room evaporating temperature were corelated to room temperature.
  Room temperature -25ºC
  Evaporating Temperature -30ºC
  Compressor Suction pressure increased from -0.1 kg/cm² to 0.2 kg/cm²
  Increase in suction pressure saved power with compressor
- 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 number of compressors required reduced. The standby compressor remain as standby, was never required to operate.
- Reducing compressor running hours by 25%

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Results

- The safety valves and release system ensured increased safety at plant and no discharge of ammonia in plant incase safety valve pops up.
- Chiller room safety trap alarm increased safety of people working in plant
- Safety relief system ensured no harm to nearby buildings and plant operators.
- 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.

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Results

- The automatic hot gas defrost system replaced manual defrost operation
- The defrost time was reduced to 15 minutes instead of 90 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 successfully achieved.
- Significant reduction in Room humidity

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Results

- The time required for freezer operation reduced 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

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

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 automatic ammonia leak detection and alarm system increased plant safety meeting OSHA's PSM requirements extending operator flexibility in working around the plant.

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Automatic Purging System

Energy saving Calculation

Evaporation Temperature -30°C,
Condensing Temperature / Pressure for 34°C, 12 kg/cm^2
Refrigeration Capacity 200kW
Rated Power required by compressor 102kW
Actual pressure was 16.5 Kg/cm^2
Actual power consumed 116kW
The excess power of 14 kW per hour
6000 hours of operation in one year total excess power 84000kW
Electricity Cost Rs. 8/- per kW
Saving in a year **Rs. 6,72,000/-**

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Implementation, Investment & payback

The project was implemented in 2 stages

1st Stage Safety system (safety valves, ammonia leak detection system, compressor safety), automatic purging system, level control system

2nd Stage Hot Gas Defrosting system, Temperature monitoring and Control system, Oil drain & Ammonia Dehydrator

Total investment 31,55,000/-

Payback period 6 months

SAFETY, ENERGY-EFFICIENT MEASURES & SOLUTIONS

Conclusion

Refrigeration systems affect the environment in two ways: indirectly through the energy they consume, and directly through the effect of refrigerants if they leak to atmosphere. Making your plant as energy efficient as possible will minimise its environmental impact.

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.

Thank You

Association of AMMONIA REFRIGERATION

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