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Design of Cold Storage with Process Layout

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***Abstract* - Cold storage plays a vital role in preserving perishable food products, dairy items, and pharmaceuticals by maintaining them at low temperatures and preventing microbial growth. The objective of this project is to design an efficient cold storage system with an optimized process layout for improved performance, safety, and ease of maintenance. The study focuses on understanding the client's existing plant layout and identifying limitations in the placement of compressors, evaporative condensers, and auxiliary components. A modified layout has been developed in AutoCAD, emphasizing minimum piping length, better accessibility, and provisions for future expansion. The design incorporates ammonia (NH_3) as the refrigerant due to its high latent heat and environmental benefits. The modified process layout ensures balanced refrigerant flow, energy efficiency, and adherence to industrial safety norms. The expected outcome of the project is an optimized, safe, and cost-effective cold storage system layout that enhances operational reliability.**

Keywords: Cold storage system, dairy storage, pharmaceutical storage, low temperature control, microbial growth prevention, process layout optimization, plant layout analysis, compressor placement, evaporative condenser, auxiliary components, cost-effective design, system reliability.

I. INTRODUCTION

The preservation of perishable products such as fruits, vegetables, dairy, meat, and pharmaceuticals has become an essential part of modern supply chains. To maintain product quality and extend shelf life, it is necessary to store these items under controlled temperature and humidity conditions. This is achieved through cold storage systems, which utilize mechanical refrigeration to maintain temperatures well below ambient levels.

In recent years, the demand for efficient cold storage facilities has increased significantly in India due to the rapid growth of the food processing industry and pharmaceutical sectors. However, many existing facilities suffer from poor layout planning, long piping runs, and inadequate safety provisions, leading to higher energy consumption and maintenance issues.

This project focuses on the design and process layout of a cold storage plant using ammonia (NH_3) as the refrigerant, which is widely recognized for its excellent thermodynamic properties and zero global warming potential. The objective is to optimize the layout of key components— such as compressors, evaporative condensers, intercoolers, and MCC/PCC panels—within the plant room to improve operational efficiency, safety, and scope for future expansion.

II. METHODOLOGY

The study begins with problem identification, where limitations in the existing client plant layout were analyzed, including improper component placement, long piping runs, and poor maintenance access. Data collection involved gathering site dimensions, ambient temperature conditions, insulation specifications, and product load requirements. Standard design parameters were then assumed for heat load calculations, covering wall, roof, floor conduction, infiltration, lighting, and personnel loads. An ammonia (NH_3)-based two-stage refrigeration cycle was selected due to its superior thermodynamic efficiency and zero global warming potential, making it ideal for industrial cold storage. Equipment such as compressors, evaporative condensers, intercoolers, HPR, and LPR were sized using manufacturer data and standard design charts. A modified plant room layout was developed in AutoCAD to ensure minimum piping length, proper refrigerant flow sequence, and adequate maintenance clearance. A Piping and Instrumentation Diagram (P&ID) was also prepared to map refrigerant flow and instrumentation. Finally, cost estimation and safety provisions including ammonia detectors, ventilation, and PPE requirements were incorporated to ensure industrial compliance and operational reliability.

2.1 Existing Clients Plant Room Layout (Project Study-1)

The existing layout was the client's original plant room design, sized at 14.97 × 7.90 × 5.4 M height. It served as the baseline for analysis and was found to have several engineering and safety shortcomings.

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Key Problems Identified:

1. Component Placement:

- Major refrigeration components — compressors, condensers, receivers (HPR/LPR), intercooler, and control panels — were placed randomly without following a logical refrigerant flow sequence.
- Compressors were placed on the upper/top side of the wall, which caused oil return difficulties, poor lubrication, and mechanical wear.
- The LPR (Low Pressure Receiver) was installed horizontally, occupying excessive floor space and causing poor liquid-vapor separation.
- Condensers were positioned roughly in the center of the layout, placed between compressors and receivers purely out of space convenience, not process logic.
- HPRs (High Pressure Receivers) were placed on the left side due to available floor space, causing longer refrigerant paths and poor accessibility.

2. Piping Issues:

- Interconnecting piping was longer with several sharp bends, causing pressure drops and inefficient refrigerant circulation.
- No clear separation between suction and discharge lines, increasing chances of heat gain and system losses.
- Piping ran unnecessarily long distances between components due to poor spatial arrangement.

3. Maintenance & Safety Issues:

- Clearances between components were insufficient, making maintenance and inspection difficult.
- Some equipment such as condensers and receivers were located too close to walls or each other, restricting airflow and service space.
- Electrical panels (PCC, APFC, MCC) were clustered together without clear labeling or separation.
- No dedicated control panel area was defined near the operator zone.
- Maintenance space was congested throughout the plant room.

4. Airflow & Heat Dissipation:

- Condensers placed centrally blocked proper airflow, causing heat accumulation near compressors and reducing overall system efficiency.

5. Dimensional Accuracy:

- Dimensions were given in approximate meter values, lacking precision for accurate construction and installation.

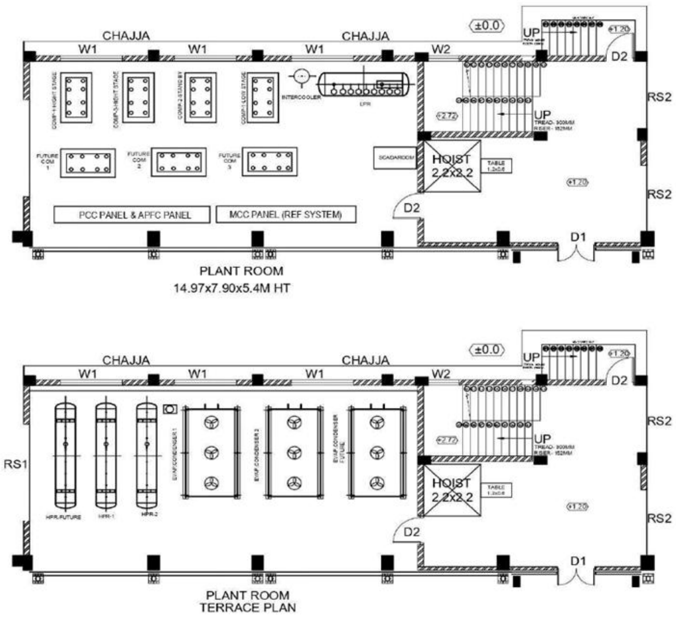

Figure 1: Existing clients plant room layout (Project Study-1)

2.2 Modified Plant Room Layout (Project Study-2)

The modified layout was redesigned in AutoCAD, keeping the same plant room size of 14.97 × 7.90 × 5.4 M height but reorganizing all components based on engineering principles, process flow logic, safety norms, and maintenance requirements.

Key Improvements Made:

1. Compressor Repositioning:

- Compressors were relocated to the ground/lower level of the plant room.
- This ensures smooth suction flow, stable compressor performance, and proper oil return from evaporators.
- The discharge line from the compressor runs upward to the condenser on the terrace, which is thermodynamically ideal as hot gas naturally rises.
- Ground-level placement simplifies installation, vibration control, and maintenance, while reducing structural load on elevated slabs.

2. Refrigerant Flow Sequence:

- The modified layout strictly follows the logical refrigerant cycle sequence: Evaporator → Suction Line

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→ Compressor (ground) → Condenser (terrace) → HPR → LPR → Intercooler → Evaporator

- This gravity-assisted refrigerant flow minimizes bends, fittings, and pressure losses throughout the system.

3. HPR Repositioning:

- HPRs were relocated to the right side, close to the condensers on the terrace.
- This reduced discharge-to-receiver piping length by approximately 20–25%, improving system efficiency.
- An open service corridor was created in front of the HPRs, making all valves, gauges, and safety devices easily accessible.
- HPRs are now isolated from electrical panels and compressors, reducing risks of refrigerant or oil leaks near electrical systems.

4. LPR Orientation Change:

- The LPR was changed from horizontal to vertical orientation.
- This freed up significant floor space, improved liquid-vapor separation, and eliminated vapor carry-over into the liquid line.
- Better maintenance access corridors were created around the LPR.

5. Condenser Repositioning:

- Condensers were shifted to the left side, near an open wall or ventilation area.
- This improved heat rejection efficiency, ventilation, and heat dissipation.
- A shorter, straighter discharge line was achieved, reducing heat influence on compressors.

6. Electrical Panel Separation:

- Electrical panels (PCC Panel, APFC Panel, MCC Panel) were clearly separated and labeled.
- A dedicated Control Panel was added near the operator area for improved plant supervision and troubleshooting.

7. Maintenance & Space Improvements:

- Free floor spacing increased by approximately 15–25%.
- All components became 100% accessible for maintenance and inspection.
- Sufficient clearance was provided all around each piece of equipment.
- The layout became more systematic, following process sequence and safety norms throughout.

8. Dimensional Accuracy:

- All dimensions were updated from approximate meter values to accurate millimeter values, ensuring precise construction and installation.

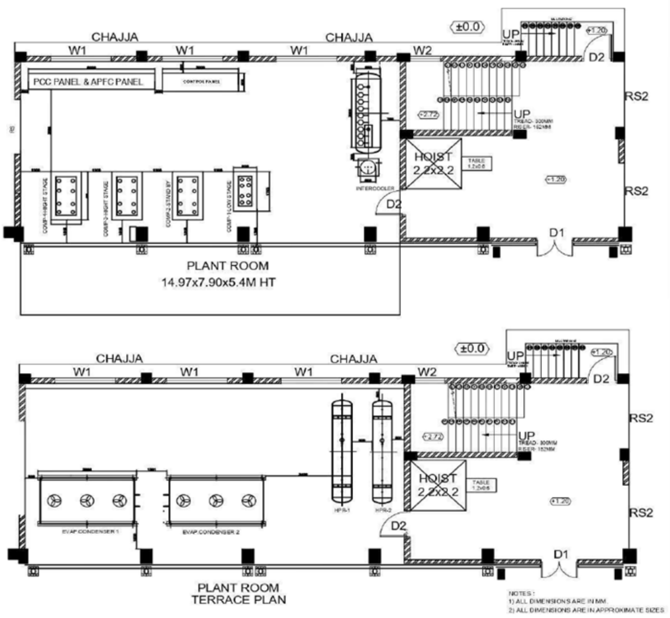

Figure 2: Modified plant room layout (Project Study -2)

2.3 Comparison between existing and modified plant layout

Table 1: Existing Layout vs. Modified Layout Comparison

Aspect	Existing Layout (Project Study-1)	Modified Layout (Project Study-2)
Purpose	Base company layout	Improved industrial layout
Objective	Initial equipment arrangement	Optimized for efficiency & safety
Plant Room Size	14.97 × 7.9 × 5.4 m	14.97 × 7.9 × 5.4 m (unchanged)
Compressor Position	Placed on top side of wall	Relocated to ground level
Compressor Spacing	Compact, less spacing	Reorganized, improved spacing
Refrigerant Flow Sequence	Unsequenced, random	Logical process sequence followed
Piping Length	Long with sharp bends	Reduced by 20–25%
Pressure Drop	High due to long piping	Minimized due to shorter piping
Maintenance Space	Congested, restricted access	Sufficient clearance all around
Future	Multiple future	Only active units

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Equipment	blocks shown	shown
Safety Compliance	Inadequate provisions	Compliant with industrial norms
Operator Safety	Risk due to clustered panels	Improved with separated panels
System Reliability	Lower due to inefficient layout	Higher due to optimized arrangement
Overall Layout Design	Congested, unplanned	Systematic, process-sequence based

III. RESULTS AND DISCUSSIONS

The modified cold storage layout developed using AutoCAD showed a significant improvement in system organization and operational efficiency compared to the existing plant arrangement. The reduction in overall piping length minimized pressure losses and refrigerant leakage chances, resulting in better thermal performance and reduced energy consumption. Proper placement of compressors and evaporative condensers improved heat rejection efficiency and ensured smoother refrigerant circulation throughout the system. The use of Ammonia (NH_3) as a refrigerant enhanced cooling performance due to its high latent heat and excellent thermodynamic properties, while also maintaining environmental safety standards.

The optimized layout provided better accessibility for maintenance activities, reducing downtime and simplifying inspection and repair operations. Improved spacing and arrangement of auxiliary components contributed to safer working conditions and compliance with industrial safety norms. The system also demonstrated balanced refrigerant distribution, avoiding overloading or underutilization of components, which directly increased the reliability and lifespan of the equipment.

From a cost perspective, the reduction in material usage (especially piping) and improved energy efficiency led to lower operational and installation costs. The design also allows flexibility for future expansion without major structural modifications, making it suitable for long-term industrial applications. Overall, the project successfully achieved an efficient, safe, and economical cold storage system layout with enhanced performance and operational stability.

IV. CONCLUSION

The modified cold storage layout provides a more efficient and practical arrangement compared to the existing layout. The optimized layout reduces refrigerant piping length and pressure drop, resulting in better refrigerant circulation. Shifting the condenser to the open terrace improves heat rejection performance and system efficiency. Relocating the compressor to ground level ensures more reliable oil return and easier maintenance. The modified layout also room layout is technically more suitable for efficient cold storage operation.

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