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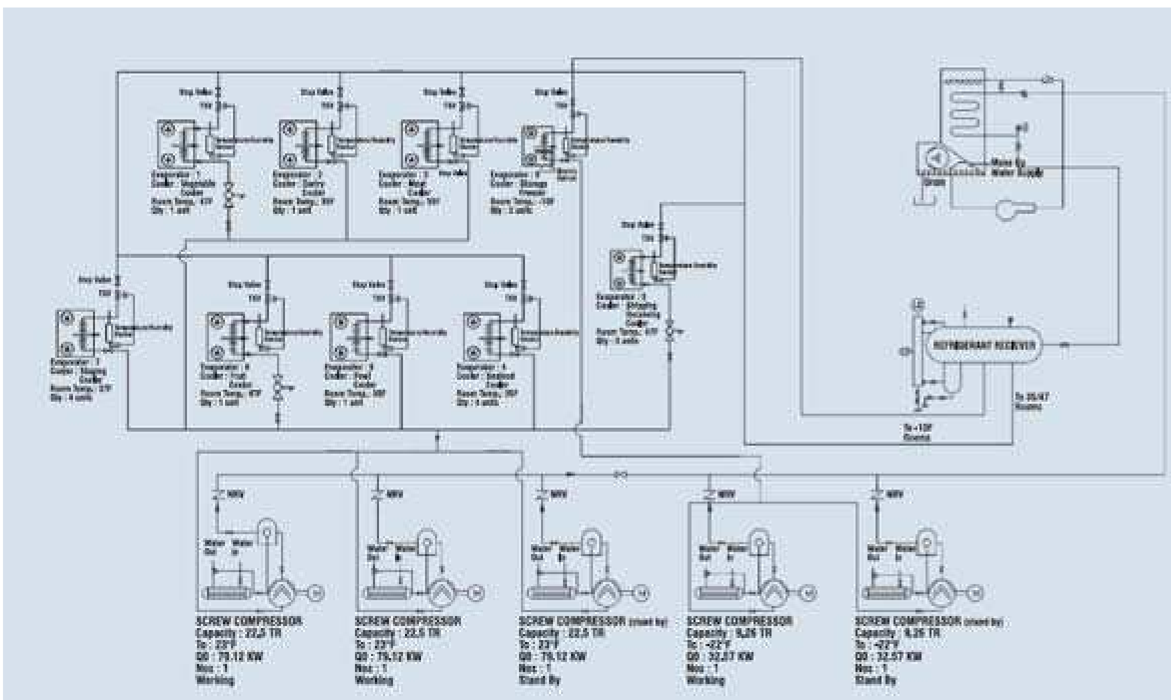

Photo 1 : Rooftop units under installation in the USA.

Designing a Cold Storage and it's Refrigeration System

Humidification for Textile Mills

Describing how a global award winning design was worked out by students of AISSMS's College of Engineering, Pune

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Preamble

ASHRAE USA held a student design competition for the year 2004-05 in three categories:

- Architectural design
- HVAC System Design
- Refrigeration System Design

ASHRAE student branches were eligible for participation and branches all over the world participated. Three awards are given in each category and the award winners are invited to the award presentation ceremony during ASHRAE winter meeting in the USA.

Two students, Gondkar Ashutosh Anand and Amol Anil Khese who were final year B.E. Mech. students from AISSMS Pune college affiliated to Pune University decided to participate with Prof. P.A. Patil acting as project advisor. These students were undergoing training at Thermax Ltd. and the ASHRAE Western India president Mukund Ranade agreed to spare them for devoting time to carry out this activity and also provided them with all required facilities. Ramesh Paranjpey- ASHRAE Fellow member and Arvind Surange, ASHRAE member, agreed to provide technical guidance and it was decided to select the Refrigeration System Design as a subject entry for participation.

A 155 page document was loaded from ASHRAE web site which contained all the rules and procedures to be followed while submitting the project report. The document also contained design specifications and engineering requirements and the KRACK refrigeration manual guide line for load calculations.

The object was to design an industrial refrigeration system and multipurpose cold storage facility located in Portland, Oregon USA for 70,000 pounds of dairy products, fruits, vegetables, meat, fowl and ice cream to be shipped from this cold storage each day. The facility to be housed in an existing building with available space of 100 ft wide by 200 ft long with a bow roof at 30 ft height and a centre height of 40 ft. Temperatures to be maintained in various rooms were 350F, 470F and –100F depending on the products to be stored. The report document was to be limited to 40 pages.

The requirements were to design a refrigeration system using environmentally friendly refrigerants, that would be energy efficient, cost effective and flexible with high reliability and ease of maintenance. The storage should supply products with a minimum weight loss, highest quality, and be accompanied with documents as proof that proper temperature and humidity was maintained during storage.

The dead line for submission was 9th May 2005. Based on these criteria, more than three months efforts were put in and a 44-page report was submitted within the stipulated time period. During my visit to ASHRAE USA during the February 2005 Winter Meeting, when I was invited to accept ASHRAE Fellow award, I had an opportunity to discuss with the students who had won last years awards and were attending the award ceremony, and this helped in properly preparing the submission document. ASHRAE president Ronold Vallort had visited Pune earlier and had given a presentation on cold storage facility designs and some of the valuable inputs from his talk were also used while preparing the project report.

To our pleasant surprise a communication from Ashley M Pruett, manager of student activities was received on 14th July 2005 informing us that our entry from Pune University had won the third prize in the refrigeration category from all the entries received globally. All the regions of ASHRAE had participated and finally 14 entries were shortlisted for selection in the final round.

The first prize in the Refrigeration category was awarded to Chulangkorn University (Thailand) and the second prize to National Taipei University of Technology (Taiwan), whereas all the other awards in the remaining two categories were awarded to universities from the USA.

Now that the award-wining news had been received, we re-looked at our submission and decided to write an article for the benefit of our readers, giving the salient features of our scheme which may have tilted the balance in our favor during the final selection.

The approach adopted was to study the furnished data and to determine whether the basic parameters could be modified so as to make the facility more efficient.

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Building Layout

1. The document contained a suggested layout of the cold storage facility. See **Figure 1**. This layout did not indicate North direction and a clarification was obtained from the organizers, since the building heat load calculations were dependant on which rooms are located on which side.

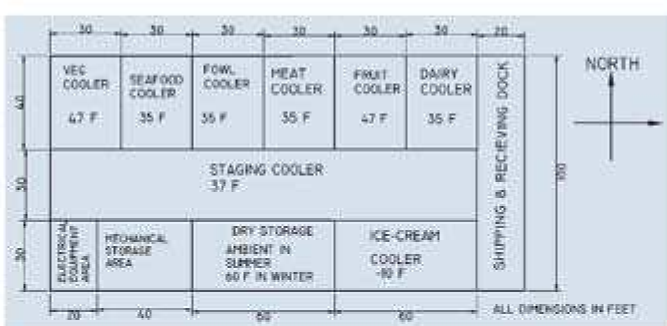

Figure 1 : Original layout block plan.

2. It was decided to rationalize the complete layout by relocating the rooms

and other areas as per **Figure 2**

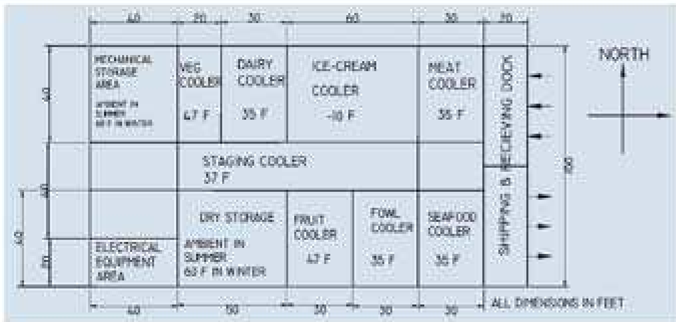

Figure 2 : Modified layout block plan.

3. The machine room and electric room were shifted to one end on the West side since it is a non-air conditioned area and hence it does not matter if the solar load is highest on that side. This helped in shielding the remaining cold rooms from direct exposure to the West side. This also ensured that day-to-day plant operation and maintenance can be carried out without entering the main cold storage facility and thereby disturbing the temperature conditions due to movement of operating staff.
4. Similarly, the shipping and receiving area was maintained on the East side as per the original layout in view of the ease of road transportation facilities available.
5. The low temperature ice cream (–10°F) room was shifted, so that it was sandwiched between two rooms maintained at 35°F. This reduced the conduction load. In the earlier layout this room was at the entrance near the shipping area and would have suffered from constant infiltration of warm air in the staging area.
6. Cold rooms with large turnover were shifted near the loading area to reduce movement of goods.
7. The comparatively higher temperature cold rooms were shifted near the non-conditioned area so that temperature difference across the walls was reduced.
8. In order to avoid inadvertent mixing of received goods and the goods being dispatched, a partition was suggested to avoid confusion.

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Load Calculations

1. Normally air conditioning cooling load estimates are done on an hourly basis and cold storage load calculations are done on a 24-hour basis. The plant sizing is based on 16/18/20 hour operation and depends on the temperature/ humidity to be maintained and the defrosting methods employed.
2. For this project the data sheet indicated that two persons operating fork lifts would work for a maximum duration of four hours in each room and the lighting load to be considered was three Watts/ft^2 The lights would be "on" only when people entered the rooms. Based on this assumption it was decided that the load due to fork lift motors and occupancy as well as lighting load would be taken only for a four-hour duration and not be converted to the 24 hour format as per normal practice and use in software formats available, as it would give incorrect outputs unless corrections are applied.
3. Receiving and shipping dock doors would be opened only while loading/unloading the refrigerated trucks as it was assumed that the truck doors would seal against the dock doors so that outside air infiltration at high temperature (90°F) is minimized.
4. PUF insulation of 4 inches for roof and 3 inches for wall and floor with 0.13 'K' value was considered.
5. Average specific heat was taken for product load calculations since the rooms had a mixed cargo storage ability.
6. Equivalent temperature differences were considered for the conduction load calculation. Since there was no direct solar radiation load, the effect of warming of outside walls was eliminated.
7. Load calculations for individual rooms as well as block loads were calculated so that the plant could be designed for the block load and

individual rooms would have low side equipment to meet individual room loads. This takes into account diversity.

With all these modifications in the room layout and the assumptions made, the conduction load reduced by 23.21% compared to the original layout as per data sheets.

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Refrigeration System Selection

The selection criteria were the refrigerant's environmental impact, its physical and thermal properties, availability and cost.

Three refrigerants were short listed:

- Ammonia
- R 404A
- R-22

Ammonia being the most efficient natural refrigerant was the obvious first choice. After detailed considerations it was rejected on the following grounds:

- The plant is to be located in a thickly populated area
- There is no space on the roof to keep the condensing units
- Semi-hermetic compressors are not available, as on date, for Ammonia
- To make the plant totally safe in case of accidental ammonia leaks would mean high initial costs due to safety measures required as per standards
- The plant capacity was not big enough to justify use of ammonia equipment.

R404A is normally the preferred refrigerant for low temperature applications. In this case the low temperature (–10°F) load was only 10 ton and the high temperature load (35/47°F) was 42 ton. At higher temperatures, R-22 has better efficiency compared to R404A. R404A refrigerant is also a non-azeotropic mixture and in case of leaks, top up is not possible. The refrigerant requires POE lubricants to be used which are highly hygroscopic compared to mineral oils and thus require highly specialized skills in designing piping and its installation as well as for evacuation/dehydration techniques. In view of these considerations R404A was not considered for plant design.

R-22 refrigerant, although it has some environmental impact due to its small ODP, it is still allowed to be used as per Montreal Protocol till the year 2020 and is also being widely used in USA. Skilled manpower for installation and maintenance is readily available and there is greater confidence in operating R-22 plants compared to R404A installations. R-22 refrigerant is also more efficient in the temperature range at which the plant is supposed to operate. In view of these considerations R-22 was selected as the final choice.

A detailed analysis comparing advantages/disadvantages of all three refrigerants was part of the submission document.

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Refrigeration Plant Equipment Selection

The following alternatives were considered keeping in mind flexibility, reliability, available space, and owning / operating costs.

The requirement was estimated as 10 ton for the –10°F room and 43 ton for the 35/47°F rooms.

1. A single plant working at –20°F with a capacity of 53 ton with 100% standby (two compressors, one working and one standby). The high temperature rooms would be provided with back pressure control valves to maintain the higher temperatures.
2. Independent plant of 10 ton capacity for the low temperature room with 100% standby and a separate plant of 43 ton with 100% standby for the high temperature rooms (four compressors in all).
3. Separate plant for the low temperature room of 10 ton with 100% standby and two plants of 22.5 ton, each of 50% capacity, for the high temperature rooms with a common standby compressor to be connected in such a

manner that it can be used with any plant in case the main operating compressor fails. All five compressors are identical giving 22.5 ton capacity at high temperature and 10 ton capacity at low temperature operation. (five compressors in all).

Altents of reliability, lower initial cost as well as running cost and hence it was selected as the final choice.

Compressor Selection. Semi-hermetic reciprocating and screw compressors were considered. Screw compressors being more compact due to their higher speeds were selected. Besides being compact, they are also more reliable with less vibration and require less maintenance.

Condenser Selection. The possibility of using aircooled condensers was the first choice. This was however not considered when the layout was studied. There was no space for installing the condensing units which could reject heat to the atmosphere since the facility was surrounded by adjacent buildings. There was no flat terrace as the roof is dome shaped. For the same reason, watercooled condensers using shell and tube design was not possible as there was no space for locating a cooling tower. The plant room had adequate space for locating an evaporative condenser with a duct outlet for rejecting the hot air. An evaporative condenser also allows lower condensing temperature and lower water consumption. This was therefore the final choice.

Product Coolers. Product coolers with adequate throw, located along the longer side of the wall in each room were selected. Thus the necessity of ducting was eliminated. Blower motors with lower noise levels were selected.

In order to simplify the refrigeration circuit, an electric defrost for the coil and drain pan was provided for coolers operating at 35°F and –10°F. For 47°F no defrost was necessary. Larger rooms were provided with two coolers.

A general piping arrangement scheme as shown in **Figure 3**, was furnished with the report.

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General

- Detailed specifications of each piece of equipment, its performance, initial procurement cost as well as running cost on a yearly basis was calculated and furnished in the report to justify the higher procurement costs but lower running costs. The pay-back period was also worked out and furnished wherever initial costs were higher.
- The organizers had asked for a write-up on how the selected plant would help in improving quality of life. The submitted report furnished a writeup on intrinsic and extrinsic factors indicating how the system impacts on the quality of life, with the conclusion that the selected equipment improves quality of life by reducing cooling loads, controlling noise levels, consuming lower power and using permitted refrigerants, as well as providing quality products stored at correct temperatures and humidity.
- The organizers also wanted a note describing how the selected system could be made suitable for third world countries and what changes would be required. A note was furnished indicating that refrigerant and compressors selected are available readily in all third world countries.

The insulation thickness would have to be increased due to higher ambient conditions and vapor barriers would be needed in places having higher atmospheric humidity conditions.

A water treatment plant may be required in view of the hard water in many places to ensure energy efficient working of evaporative condensers.

Pre-cooling facilities would have to be provided as the product incoming temperatures would normally be high.

Due to erratic availability of power an additional investment in providing a generator set would be needed to prevent product spoilage when the main electric power fails or during planned power shedding schedules.

Conclusion

The entire team put in efforts to ensure that all points were taken care of. No doubt the report submitted was an award winning entry. However, if more time were available a much better presentation could have been made, which could have even fetched the first prize. When one starts working seriously on any assignment, it is always felt that there is a lot of scope for further improvement on the next project and I am sure this award will give confidence and encouragement to students from all India chapters to participate more vigorously in the future.

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