GREEN COLD CHAIN

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Abstract

Cold Chain plays a vital role in our lives. This journey of food from farms to consumers includes various processes like collection & handling, transport, precooling, cold storage, C.A storage, freezing & storage, distribution & retail.

All the processes, so important for preservation of perishable foods, are expensive to build & have a bearing on natural resources, environment & energy consumption.

Green technologies use renewable resources; reduce wastes, pollutants, emissions; recover, reuse and recycle; reduce the pressure on natural resources and restore the balance of the ecosystem and biosphere and ultimately help in providing “ecologically sustainable development”. These technologies are, therefore, viable, cost effective, environmentally superior and most suitable to the climatic, economical, geographical, ecological and social conditions of any country.

While there has been a global movement on development of Green buildings, Green homes & now even Green factories, this is perhaps the first attempt to bring in the concept of a Green cold chain in the field of designing, construction & operation of cold chain projects. There are various routes for the variety of food items handled in the cold chain and an effort has been made to bring in the Green concepts in these routes.

Introduction

Cold chain is an integral part of human life in the present day world & and the different routes that constitute a cold chain, for different food items, are shown in Fig.1.

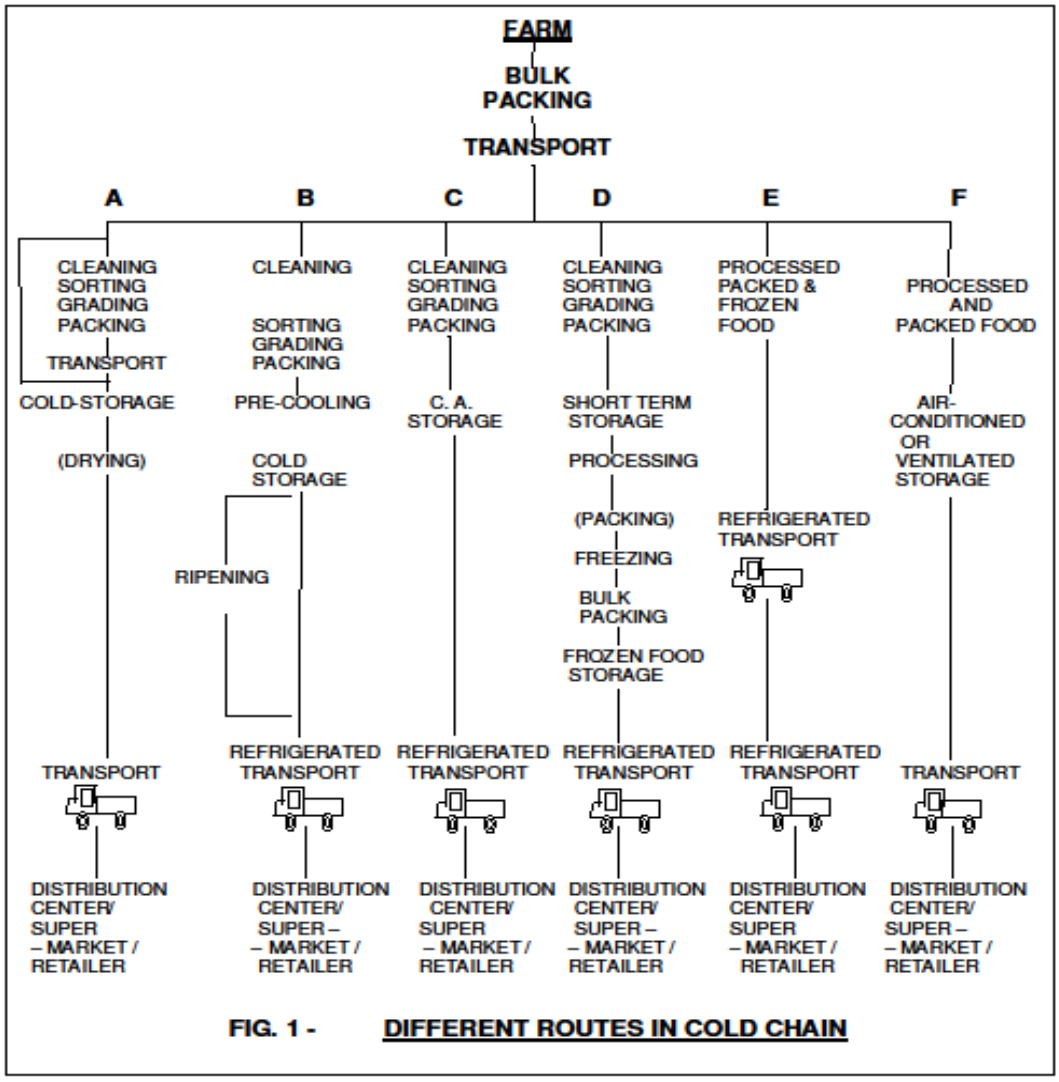

FIG. 1 - DIFFERENT ROUTES IN COLD CHAIN

Types of Cold Chain Processes

A. Direct cold storage of some food items

There are a number of commodities, which after initial sorting, grading and packing are transported to the cold stores either at the producing center or at the consuming center. Such items are, typically, Potato, Apples, Oranges, Tamarind, Red Chilies, Raisins and some other fruits & vegetables. The commodities are stored in bulk cold stores near the producing centers or in multi-product stores mainly located near consuming centers.

B. Grading, packing, pre-cooling and /or ripening and storage of some fresh fruits and vegetables

There are a number of fruits, which are very sensitive to heat and susceptible to moisture loss after harvesting. Such items have to be pre-cooled within a short time after harvesting. The pre-cooling involves faster cooling of product within a

pre-determined period at high RH, generally, over 95%. The pre-cooled products are then loaded into the high RH cold rooms till they are loaded into the reefer containers. The items, which, usually, follow the pre-cooling route, are (a) Grapes, Straw-berries, and Flowers, which require faster cooling, within a short time after harvesting (b) Mangoes, Pomegranates etc. which can be pre-cooled within 24 hours after harvesting.

Some of the products like banana, mango etc also undergo ripening before dispatch to the market.

C. C.A storage for select varieties of Fruits

There are some varieties of fruits like apples, pears can be, successfully, stored for long periods by delaying the natural ripening process. This process is known as Controlled Atmosphere Storage and is used to extend the storage life of seasonal perishable produce when normal cold storage with ambient air environment is not sufficient to retain quality and flavor.

The CA technology requires, apart from refrigeration, gas tight storage construction, equipment to control Oxygen and CO_2 levels, pressure equalization devices, automatic control systems and quality control systems.

D. Processing, Freezing & Storage of foods

There are a large number of fruits, vegetable & other food items, which after some processing, can be frozen and stored in frozen state for a long period of time. The popular items are Green Peas, Corn, Okra, Mixed Vegetables, Tomato Puree, Mango Pulp, Mango Slices and Dices, Pineapple Slices etc. The items need varying type of heat treatment before freezing for instance – blanching for Peas, Corn etc. and pasteurization for Mango Pulp.

The freezing is done in packed or unpacked condition, depending on the type of freezer. The type of freezer used depends on the type and shape of the product and the desired freezing time.

E. Storage of Pre-processed & Frozen products

There are many items such as Ice Creams, Butter, Fisheries, Meat Products and Poultry products which undergo processing and freezing at the main production / processing plants. These items are transported through Reefer Vans to frozen food stores and then to distribution centers / markets

F. AC or Ventilated storage for processed & packed food.

Processed and packed items like Chocolates, Confectionery products, Tobacco, generally, need air-conditioned stores.

Distribution Centers

The distribution centers carry out the function of procurement of large variety of food and other related items, inventory management, processing and freezing for some items, cold storage for others and logistics. These centers play an

important role in the cold chain in distributing food to retail chain sector, hotel & institutional consumers.

Thus, the cold chain broadly involves initial handling and transport, processing, packing, grading, pre-cooling / freezing, cold storage, distribution centers, reefer transport, super markets and retail stores.

Energy and Environment Concerns

Cold Chain projects are a combination of variety of systems including civil works, thermal insulation, refrigeration, electrification & lighting, ventilation, material handling equipment, storage racks, control systems etc. High energy usage & impact on environment are factors associated with cold chain projects & this is where the concept of '**Green Cold Chain**' emerges, on the lines of Green buildings & Green factories.

What constitutes a 'Green Cold Chain'?

Whatever be the path followed in Fig.1 above, a Green Cold Chain project shall incorporate the following features:

1. Location near rail / road terminal
2. Eco-friendly Plant Layout
3. Efficient Building Design using eco-friendly & recycled materials
4. Effective Thermal Insulation
5. Eco-friendly & Energy Efficient Refrigeration / cooling system
6. Waste Heat Recovery System
7. Effective Control Systems & VFDs
8. Energy Efficient Lighting & Electrical systems
9. Natural Ventilation
10. Noise Control
11. Fire Safety
12. Use of renewable energy
13. Minimum Water Consumption and Recycling
14. Rain Water Harvesting
15. Energy saving accessories - Strip / Air Curtains, water saving devices
16. Operational Practices to suit the 'Green' character

A Green building (as a generic term), also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. In this context, Green Cold Stores, can be defined as, structures designed to meet certain objectives such as using energy, water, and other resources more efficiently; and reducing the overall impact on the environment. These and other measures can only be fully realized when they are incorporated right at the conceptual design phase of the projects with the assistance of an integrated team of professionals willing to promote 'Green' concept.

The features of a green cold chain project, indicated above, have been highlighted below:

1. **Location near rail / road terminals**

In order to reduce the transport cost and travel time, locations near highways / rail terminals shall be preferable.

2. Eco-friendly Plant Layout

a) The cold chain project layout would involve an eco-friendly location for the project. It is desirable to use natural landscape to reduce irrigational requirements of the project.
b) Building orientation to achieve minimum solar heat gains. Creating shades by planting tall trees / other shading elements on west, east & even south sides shall be helpful. It is estimated that the shading would reduce the wall heat gain on east & west sides by 30 / 40 W / m^2 and on south by 20 / 30 W / m^2. Doors should be positioned on shady and down wind side of the building to reduce the cooling load due to air infiltration.
c) The location of the machine room shall be selected to ensure minimum lengths of refrigerant & water piping and cabling.
d) The layout should allow a convenient vehicle movement and an efficient material movement plan..
e) The site shall also not be dusty and should not be close to any dust, smoke or other pollutant generating units.

3. Efficient Building Design

a) The cold chain project building houses process halls, precooling and cold chambers, freezers, ante rooms, loading unloading docks, machine rooms, admin areas, toilets etc. The building design shall be such that the ratio of external surface to the volume of building shall be minimum. This means that the cold chambers should have minimum exposed surface area for the given volume of storage.
b) The location of the handling area, ante room and doors shall be selected to achieve minimum possible travel length for men & goods.
c) Most present day cold chain plants are built with insulated panel structure with certain other parts of the building constructed in the conventional manner. However, in some places, in India the entire cold store buildings have RCC frame & brick wall construction. Here the normal bricks could be replaced with fly ash bricks in all conventional construction.
d) Providing reflective coating on the roof would greatly help reduce the heat gains. Considering a solar heat gain in the range of 850 – 1000 W / m^2 on the roofs, a conventional G.S Sheet roof would transmit about 120 W / m^2 to the attic. With reflective coating the heat gain could be reduced to around 65 W / m^2
e) All doors shall be of metal, FRP or reusable plastic construction thus avoiding use of timber.

The various possible features of a Green Cold Store layout & building are shown in Fig.2.

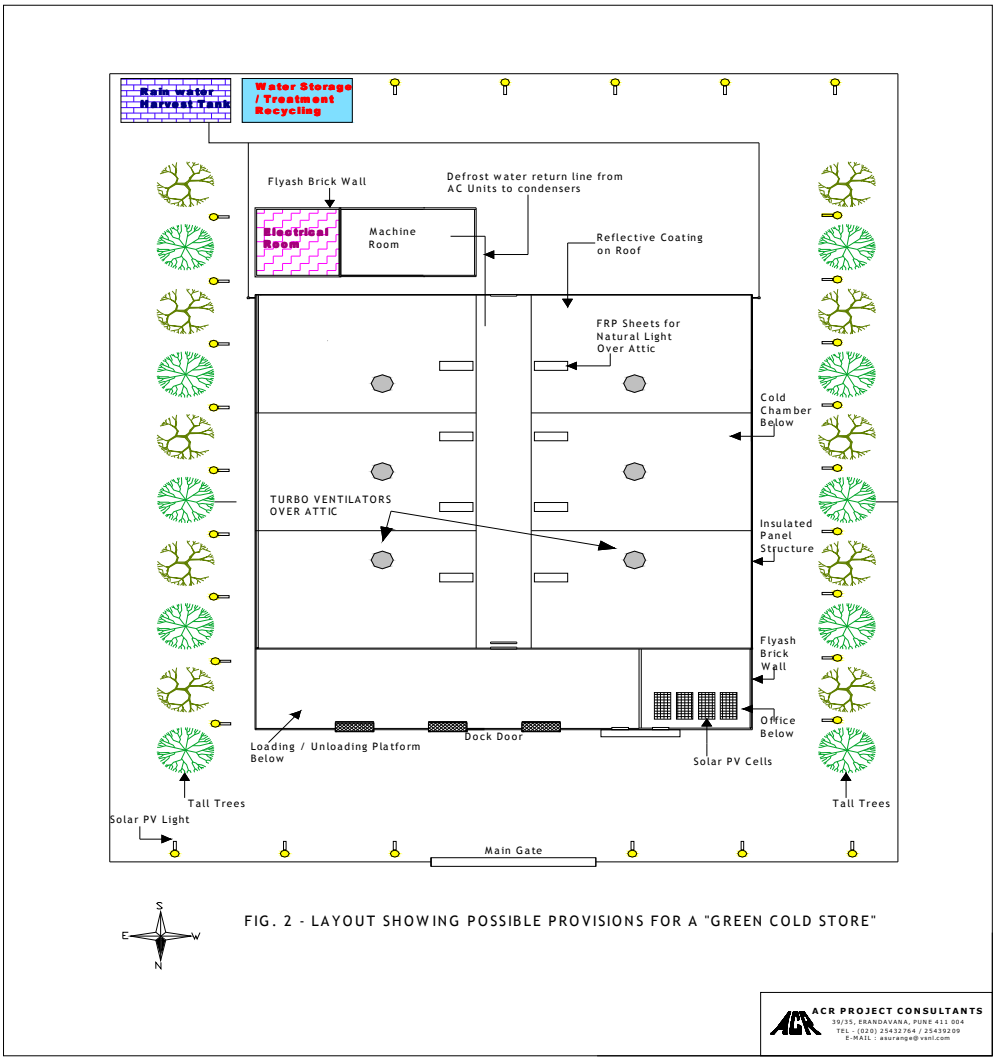

FIG. 2 - LAYOUT SHOWING POSSIBLE PROVISIONS FOR A "GREEN COLD STORE"

Fig 2.

4. Effective Thermal Insulation

a) Well designed thermal insulation system is the most essential feature of a cold store / pre-cooling / freezer / process hall design for achieving minimum possible heat & vapour transmission to cold chambers, piping, low pressure accumulators etc.
b) The insulation material should be eco-friendly i.e the materials like polyurethane foam shall not contain any CFC or such ODSs.
c) Adherence to ASHRAE Stds / ECBC (India) norms is recommended to achieve best possible thermal efficiency of the structures.

5. Eco-friendly & Energy Efficient Refrigeration & Cooling system

a) The essential feature of green cold chain plant would be the plant working on an eco-friendly refrigerant. The natural refrigerants like Ammonia could be the best choice for medium and larger sized stores / pre-cooling / freezer plants. The other refrigerants like HFCs shall have zero or minimum ODP & GWP.
b) CO_2 has also emerged as a refrigerant for low temperature systems and a lot of equipments are available for CO2 application. A cascade with Ammonia & CO_2 refrigerants has also been introduced in the field of industrial refrigeration.
c) The refrigeration system has to be designed to achieve the best possible energy efficiency.
d) The Compressors in larger systems shall have capacity control either stepless or with a number of steps and shall have best possible energy efficiency at part loads.
e) The systems can be air cooled or water cooled depending on the designer's choice, availability of water, size of the system etc. In case of ammonia systems, evaporative condensers are best suited to achieve lower condensing pressures and, thereby, the lower energy consumption. In case air cooled systems are used, it is desirable to use air pre-cooling such as evaporative cooling for the condenser air as this would greatly help in reducing the energy consumption in high ambient temperature regions.
f) In case of systems with water cooled compressor heads / jackets / oil coolers, it is a normal practice to provide cooling towers for cooling of recirculated water. These could be of fanless induced draft type for saving of fan energy.
g) Air cooling unit fans shall be selected on the basis of low motor power requirement and lower noise characteristics.
h) Application of variable frequency drives is recommended for condenser and water pump motors as also the evaporator fans (in cases where loads in pull down period & holding period varies substantially) as also to achieve energy saving during low ambient conditions
i) For larger installations liquid refrigerant pumping system helps achieving efficient performance and better energy efficiency.
j) For collection centers and pre-processing plants, use of evaporative cooling can be considered to have lower temperature and higher RH with much lower energy costs (around 35% as compared to air conditioning).

6. Waste Heat Recovery System

a) In plants where hot water can be gainfully utilized, it is prudent to install waste heat recovery unit which provides "FREE" hot water for possible use in the process / washing, cleaning or pre-heating of water fed to boilers. Generally for a plant capacity of, say 100 KW, about 400 litres of hot water could be generated hourly with a temperature of 50 to 60 deg C
b) One possible use of waste heat can be for the sub-floor heating for sub-zero temperature cold stores.

7. Effective Control Systems and VFDs

a) Appropriate control of temperature with the desired RH levels, proper air circulation are the basic requirements of the cold storage plants. An efficient design would incorporate regulation of the optimum evaporating temperatures, condensing pressures and ensure timely and efficient defrosting (for lower temperature applications). A centralized remote control panel for indication and control of various parameters would be very much desirable. Application of BMS would be an added advantage to monitor various operational parameters and safety systems.

8. Energy Efficient Lighting and Electrical systems

a) Lighting in cold chambers produces heat which acts as a load on the refrigeration system. Efficient light fittings such as CFL and SV Lamps are very effective energy savers as compared to normal tube lights / incandescent bulbs. The use of LED lights can be very beneficial for energy saving. The lighting in cold chambers can be made in different circuits so that the operator could put the lights ON in areas where access is required. Lighting in other areas could also be controlled by occupancy sensors and daylight sensors.
b) Emergency lights and alarms are a must for cold stores and these could work on the solar PV Cell system. Similarly majority of the outside lighting can be done with solar PV Cells.
c) Automatic power factor correction facility must be provided on the electrical system to achieve the best possible PF.
d) In case of attic spaces over the cold chambers, as well as areas like process halls, machine room, the benefit of natural daylight can be availed by using FRP sheets at selected points in the roof structure / walls.

9. Ventilation

a) Certain areas in the cold chain complex do need effective ventilation. The ventilation of large attic spaces can be achieved by providing turbo ventilators which work without electric power thus, saving energy for fans operation. In cold chambers where fresh air supply is required to control CO2 levels, energy recovery systems (ERVs) can be installed to cool the incoming air.

10. Use of Renewable Energy

Solar PV lighting systems can be employed as best as possible. Bio-gas generation for hot water generation is possible from bio-waste collected from processing plants.

11. Noise Control

a) Compressors, Pumps, Condensers, AC Units and D.G.Sets are possible sources of noise on a cold store & allied plants. Selection of low noise equipment, acoustic enclosure for D.G.Sets would be essential to create a quieter environment in the complex.

12. Fire Safety

a) Fire detection sensors, alarms, Dry & Wet fire fighting system shall be essential features of the project. The system shall conform to the local fire safety codes.

13. Water Consumption and Recycling

a) Most medium and large cold store complexes are water cooled and a rough estimate of water consumption per day per 1000 MT cold store capacity would be around 7 to 8 Kl.
b) For water cooled plants water is required as make up for condensers / cooling towers. Evaporative condensers consume minimum quantity of water as compared to other types. In case the evaporator units have water defrosting, it would be worth providing a system to collect this water and feed it to the condenser / cooling tower.
c) Recycling of water is possible on cold store plants which have attached food processing facility where water consumption is substantial. The waste water from the process can be recycled and used for condenser / cooling tower operation.

14. Rain Water Harvesting

a) With large roof surfaces on buildings, it would be possible to take the benefit of rain water harvesting.

15. Energy saving accessories- Strip / Air Curtains, water saving devices

a) Use of Energy Efficient PVC Strip Curtains on cold store doors is an effective way of reducing air exchange that takes place during door openings. Air curtains are also helpful on ante-room entrance doors, process halls entrance doors etc.
b) Use of low flow fixtures on sinks & showers and use of dual flush valves on toilets can reduce water consumption.

16. Operational Practices

a) Energy charges are the major running expenses for cold chain projects and hence it is imperative that an “Energy saving culture” is adopted at every level in the functioning of these units.
b) It is a good practice to load fresh goods coming in at ambient temperature, during early morning hours to take benefit of free natural cooling at nights.
c) The office comfort AC temperatures can be set in the range 24 to 26 deg C in summer and 20 to 22 deg C in winter to effectively reduce energy consumption.

d) The management & the operating staff on cold store units need to be given proper training for efficient operation and maintenance of the various systems to maintain the 'GREEN' character of the units.
e) Environment friendly practices such as 'No Smoking' norms have to be followed in plant premises.
f) Yearly Energy audits on plants would be an essential feature on these projects.

NEXT STEP

In order to formalize the green character of cold chain projects, it would be essential define the bench-marks for each of the above listed features. This would involve the following steps:

1) To prepare ratings for design of green cold stores & other cold chain projects.

2) To institutionalize process of award on the basis of ratings achieved through design & implementation.

3) To offer incentives for implementation of projects with GREEN character.

CONCLUSION

Today, the concept of 'Green Projects' is gaining attention of promoters, designers, engineers and managers all over the world. One should certainly aim at creating the concepts of 'Green Cold Chain' based on sound, safe & eco-friendly technology & high energy efficiency of the plants.

Sincere efforts should be made to think "GREEN" in the whole concept of Cold Chain and industrial refrigeration project construction and operation. A Green Cold Chain project is also about creating / leaving behind a better environment for future generations and conservation of vital resources like water, energy etc.