MODERN ENERGY EFFICIENT COLD STORAGE CONSTRUCTION & INSULATION SYSTEM

K.K. MITRA – VICE PRESIDENT (MKTG. & TECH.)
LLOYD INSULATIONS (INDIA) LIMITED

PREFACE

India has a wide variety of Horticulture Crops harvested through out the year and spread all over the country. There are altogether seven varieties out of which vegetables have 58.93 percent share followed by fruits of 31.74 percent, plantation crops of 6.09 percent, spices of 2.76 percent and 0.48 percent others.

In vegetables sector, Potato has the maximum share of 28 percent and in fruits sector Banana has 31.86 percent, Mango 21.34 percent and citrus 10.82 percent. But out of huge production done a major chunk gets wasted in the field or transportation or due to improper storage. India is a tropical country and major parts experience higher day temperatures which has an impact on the farm produces deterioration. An ambient of 40 deg.C can cause 25 percent loss of agriculture produce per day. So there is an urgent necessity for protection at different levels for the fresh produce :-

HARVEST :

- Protection of the product from direct sun.
- Quick transportation to the packinghouse.

COOLING :

- Minimize delays before cooling.
- Thorough cooling of the product as soon as possible.

TEMPORARY STORAGE :

- Keeping the product at optimum temperature.
- Ship to the market as soon as possible.

TRANSPORT TO MARKET

- Use refrigerated truck.
- Cool truck before loading.
- Load pallets towards the centre of the truck.
- Avoid delays during transport.
- Monitor product temperature during transport.

HANDLING AT DESTINATION

- Use of refrigerated unloading area.
- Measurement of product temperature.
- Quick movement of product to proper storage area.

HANDLING AT HOME OR FOOD SERVICE OUTLET

- Transport to retail market in refrigerated trucks.
- Display of temperature range.
- Use product as soon as possible.

But unfortunately existing system does not take care of the above factors, not even 40 percent. What we have, is inefficient Cold Chain practices at every level. The produce is voluminous but what the ultimate customer gets is awful and limited. The fresh produce should be treated as a living human being which breathes, releases heat, looses moisture and can get sick and even die. So there is an urgent need for protection at different levels for fresh produce like :

- **POST HARVEST MANAGEMENT**
  - Collection centers
  - Pack houses.
  - High humidity cold stores associated with pack houses.
- **COLD CHAIN MANAGEMENT**
  - Single/ dual commodity cold stores.
  - Multi commodity cold stores with modified atmosphere control system.
  - CA Cold stores

THERMAL INSULATION SYSTEM IN COLD CHAIN MANAGEMENT

DEFINITION OF A COLD STORE

A cold storage is a building or a group of buildings with Thermal Insulation and a Refrigeration System in which perishable food stuffs can be stored for various lengths of times in set conditions of temperature, humidity and appropriate environment to slow down deterioration and spoilage, which would occur in a natural environment. In some countries cold stores are known as refrigerated warehouses. A cold store may also be defined as a sealed structure, the internal volume of which is maintained at a temperature generally below ambient and other conditions and used for the storage of goods of all types, mainly foods.

Thermal Insulation System is a combination of material, ancillaries for application and application methodology which resists the flow of environment heat to inside of a building or enclosure which is supposed to maintain a much lower temperature than outside (a typical Indian situation mostly where ambient temperatures are higher during most period of a year). Thermal Insulation will resist the flow of heat by acting as a barrier. The most effective insulation will provide maximum resistance and will be defined by a particular 'R' value which will depend upon its thermal conductivity value and thickness. Lower the thermal conductivity of an insulation material the more effective it will be. Further mass of the insulation material is also important defined as adequate density of the material to be selected. A slighter higher density will increase the heat capacity of the material and result into a lower thermal diffusivity value. A material having lower diffusivity value will be able to maintain a constant temperature or slow rise in temperature inside a building in a situation when internal cooling is not working.

In a cold store operation Refrigeration system brings down the temperature initially during start-up but Thermal Insulation maintains the temperature later-on continuously.

The basic terms related to insulation and some of the materials are mentioned below :-

ROLE OF THERMAL INSULATION

FACTORS	Relationships	ABBREVIATIONS	UNIT	RELATIONSHIP TO INSULATING VALUE
"K"	L/R	Conductivity	W/mK	Lower is better.
"U"	K/L	Conductance	W/m2K	Lower is better.
"R"	L/K	Resistance	m2K/W	Higher is better.
"D"	K/CP x density	Diffusivity	m2/sec.	Lower is better.

THERMAL INSULATION MATERIALS CHARACTERISTICS USED IN COLD STORES

INSULATION MATERIAL	DENSITY (KG/M3)	"K" VALUE (W/mK) AT 10^0C MEAN TEMP.	AVAILABILITY
Mineralwool (Rockwool / Glasswool) Slabs	24-48	0.028	Indigenous
Expanded polystyrene	32	0.036	Indigenous
Polyurethane Slabs	36±2	0.021	Indigenous
Polyisocyanurate Slabs	32±2	0.021	Indigenous
Polyurethane Panels with Sprayed In-situ Polyurethane	40±2	0.023	Indigenous

Thermal Insulation is not material alone, it is the complete system which includes how it is applied and finally finished or the cladding / covering arrangement which provides protection. Proper application technique is equally crucial to its success.

In case of cold stores where a lower temperature is maintained insulation has a major role to play. Insulation will resist flow of heat from outside. If insulation does not perform effectively cold loss from inside will take place and load on refrigeration will increase.

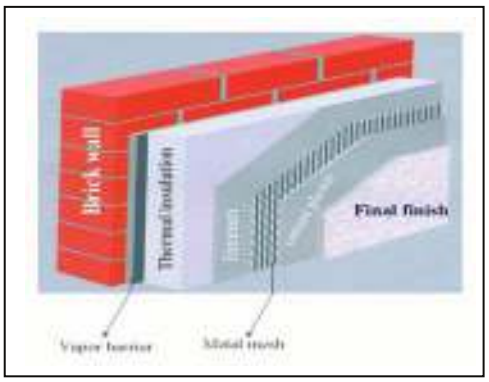
Now let us look into the functioning of cold storage and how insulation failure can be identified and what are the causes. Cold Store is a situation under cold insulation chapter. Cold Insulation is also defined as anti condensation insulation. Wherever there is a situation of a cold body and there is humidity present all around heavy condensation deposition on the cold body will take place which will make the entire area moist. An even severe situation can be icing formation. Now even if insulation is done over the cold body, condensation will still take place as water vapour will make passage through the insulation joints. So a term called vapour barrier is used, which is a solid impervious membrane applied over the insulation on the warm side which avoids the water vapour or humidity to go through the insulation. Vapour barrier is very important in cold insulation. Together with vapour barrier is proper adhesive and fixing of insulation within a holding framework so that it remains in place for a longer period and perform effectively.

❑ EXISTING COLD STORAGE SITUATION

INTRODUCTION

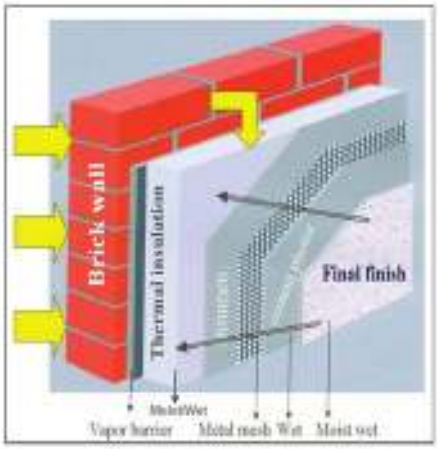
Cold Storage primarily meant for Potato Storage is an industry in existence since independence. These cold storages usually running from capacities 2000 tons to 6000 tons are in the co-operative sectors and Private Sector. The usual height on an average is 40-50 ft. and base is like a square of various dimensions, depending upon the capacity. The main construction methodology involves erection of RCC columns on the periphery, thick brick walls, asbestos sheet roofing fixed over a steel structure or RCC roofing and a false ceiling.

The inside construction activities involves:



1. Erection of steel or RCC columns / beams structural network for creating storage spaces of rectangular boxes. The vertical beams are erected first and then the cross horizontal beams which are carried up to the walls forming 4 to 6 tiers. Wooden planks are placed over the horizontal beams forming racks for holding the storage bags. In between the wooden planks gaps are maintained for air circulation. Each rectangular box holds approx. 42 bags. of 50 kg. capacity.
2. Thermal Insulation of usually Expanded Polystyrene or Mineralwool / Glasswool Slabs in 100mm is fixed over the walls with wooden battens, vapour barriers (over the plastered brick surface) and finally plastered. Floor is insulated with Expanded Polystyrene Slabs having concrete or stone slab finish. There is a false ceiling of rigid board and insulation is placed over false ceiling, is usually Rice husk spread uniformly. Mineralwool / Glasswool slabs placed inside polythene bags are also used.
3. Refrigeration system is usually hung on the top or sides. The temperature desired for potato storage is 2-5 deg.C.
4. Usually a single chamber with no partition walls in between.
5. Staircase is running inside usually at the centre and placed in front of the door.

Offlate these conventional cold storages have become ineffective and inefficient because of failure of Insulation and Refrigeration system mainly. The insulation has given away because of continuous moisture ingress through the plastered surface, leading to the surface becoming wet, loose and chipping off. This exposes the insulation and the wooden battens, which then is attacked by the moisture and gradually destabilizing the system making it ineffective and inefficient. In cold storage's mouse is very common which eats up the Expanded Polystyrene. In case of Mineralwool moisture gets trapped between the fibres making them heavier & ineffective. The vapour barrier which is on the warmer side of insulation and fixed over the plastered brick wall, slowly & gradually gets exposed to the moisture ingress and gets dislodged from its place.



1% Moisture Ingress = 5% Reduction in 'R' Value

This results into the inside cold environment coming in direct contact with the outside brick wall. This situation leads to moisture deposition from outside environment to the wall due to cold spots formation. So finally the insulation is under attack both from inside and outside. This slowly & gradually makes the insulation wet rendering it ineffective with passage of time. **One percent moisture ingress reduces insulation value by five percent**. So at a point of time insulation looses its resistance property and outside heat ingress increases. This leads to more running of refrigeration compressor and load on the refrigeration machinery, which in turn increases electricity consumption. With prolonged power cuts situation cold storage inside situation becomes warmer and that leads to product deterioration. So it is a cyclic effect starting from construction methodology or system to improper running and finally attack on product storage life and losses.

Usually most of the conventional cold stores have single large chambers. So even when storage is half-filled entire refrigeration machinery has to be in function making the cold storage operating cost higher and making it a loosing venture.

Insulation is supposed to maintain a desired temperature for sometime even when the Refrigeration compressor is not functioning. That is it should not allow heat from outside to penetrate through the walls & ceiling in to the cold storage, playing a role for energy conservation. So slower the heat passage through the walls & ceiling slower would be the gain in temp. inside the cold storage when compressor is not running. Consequently in case of power failure the inside temp. will remain congenial for a longer period of time. Otherwise the moment power goes off temp. rises fast and the products inside start decaying.

Insulation also helps in the running cycles of compressor. The compressor can be switched off after reaching a lower or stable temperature and depending upon the temperature rise switched on. The time gap between this “Off & ON” function will depend upon the efficiency of insulation system.

In present situation almost all the old cold storages in India have faced or are facing inefficient insulation function leading to Refrigeration system failure. The insulation system had been found to have sagged or have fallen down partially with the plaster or water soaked making it ineffective. This leads to formation of cold spots on the walls. A continuous moisture presence leads to Algae formation making inside atmosphere filthy leading to faster deterioration of products. So product decays, higher energy costs, failure of refrigeration system has lead to many cold storages being closed down.

NEW INSULATION SYSTEM

A thorough analysis was done of the existing cold storage problem in India and it was found that the insulation system needs a complete change over. The present insulation materials like Expanded Polystyrene & Glasswool / Mineralwool which are of open cell structure, which allows moisture ingress & deposition. The most appropriate modern insulation for cold services is a closed cell material like Polyurethane Foam. In Indian condition both in terms of techno-commercial factors and availability Polyurethane Foam has much better insulation properties and higher thermal efficiency in comparison to those being used presently mostly (Expanded Polystyrene / Mineralwool / Glasswool). Further it has a density almost double that of Expanded Polystyrene. Because of its lower thermal conductivity value the thickness required for Polyurethane Foam will be less thus allowing more storing space inside. Moreover PUF is not eaten by rats & insects. Another alternative is Polyisocyanurate Foam, which is an advanced fire safe insulation material. These two are also closed cell insulation material with lower conductivity values and higher densities.

While selecting insulation for cold storage one should differentiate it from an air conditioned building. A building is a situation where the various occupants like human beings and electronic gadgets generate continuous heat. Further there are windows and doors through which heat or cold comes in. So the design has to take care all these effect and has an effect on insulation material & thickness whereas in a cold storage no. of openings are limited and mostly closed and the products once stored will release humidity (whereas human beings & electronic gadgets in an office building release only heat). Further the product once cooled will act as a cold body emitting cold.

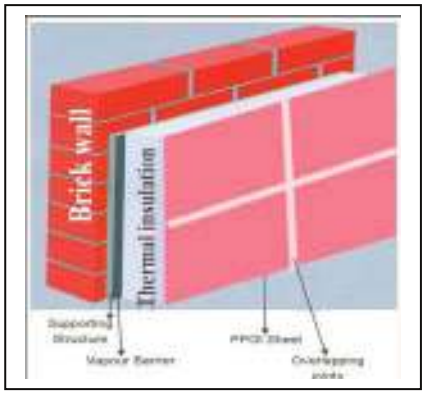
The problem faced with conventional insulation system was not only the material but also the application procedure. Cold storage insulation is different from building insulation concept. In normal insulation system vapour barrier is applied on warmer side of insulation. But in case of cold stores vapour pressure is from both sides, that is outside environment as well as from inside the storage whereas vapour barrier on warmer side prevents vapour from outside environment, there is no system in place to stop the moisture ingress from inside. Since inside cover or finish over insulation is plaster which is again a porous material will allow moisture deposition and absorption. So we need an insulation application where the insulation should be covered with an impervious cover or membrane from both sides. This cover should be non-porous and mechanically stronger.

Another problem was the insulation form. Insulation is applied in slab form allowing numerous joints which has to be properly covered with adhesive. Multiple layers with adhered joints all to be sealed properly. Even the vapour barrier to be properly sealed. Now all these are highly labour oriented and any lapse at any step will result into leakage and cold spots formation. Finally while applying plaster, above a reinforcement of wire netting is required, which has every chance of puncturing the insulation. Plaster is porous and moisture from inside slowly gradually is absorbed by the plaster. So from inside the moisture slowly gradually kills the insulation system.

Insulation thickness is an important tool to its effective performance. If thickness is inadequate, there will be heat ingress continuously. In thickness calculation humidity is an input. One should take care of considering the maximum RH happening in that area or remaining in sometime during rainy season. Say if average taken is 70% then during peak monsoon period when RH remains 85-90% there will be cold spots formation. So it is advisable to follow at least 85% during design.

Existing insulation system is highly labour oriented, cumbersome and a basic draw back in terms of application methodology. Continuous supervision during construction is required.

Next comes the basic insulation material which has a defined property with respect to the water / moisture ingress. An open cell structure material like a fibrous material or steamed compressed beads filled insulation like Expanded Polystyrene will have the tendency to absorb moisture and retain it through out. So once moisture will go into the material it will remain there, reducing its efficiency. Ultimately ice formation also takes place.



Now let us analyze which are the possible controllable factors. These are material, design and procedure. Now material can be changed to closed cell materials like Polyurethane Foam, Polyisocyanurate Foam, Extruded Polystyrene Foam. By opting for RH 85% adequate thickness can be followed.

In terms of vapour barrier the same can be applied on both sides. Insulation can be laminated on the facing side,

similarly vapour barrier application on the wall. First layer will be applied on top of brick wall and then insulation laminated with aluminium foil on one side to act as vapour barrier on product storage side. Finally apply colour coated galvanized steel sheet (1m wide and any length) fixed vertically or horizontally on to the supporting structure and sealing the joints with sealants and 75mm wide tape.

The most efficient and latest technology application will be fixing of closed cell insulation slabs with special cement based adhesive on to the walls and then applying polymerized plaster 4mm thick in 2 layers with synthetic reinforcement superimposed between the 2 layers. The plaster after drying will have a natural finish (white colour). Alternatively applying 2 coats of proper grade painting. These walls can be cleaned / washed.

Proper application procedure can be formulated, but how much control is there practically during construction. The application procedure remains labour intensive requiring lots of supervision and control. But it has to be seen how properly the application is done. So by changing or shifting to an efficient system is not the final solution – it is a partial solution. The total construction time for a typical 5000 tons cold storage will remain to be around 9-10 months. So if harvesting time is February construction has to start around May-June the previous year with monsoon in between.

So basic system needs a correction.

RECOMMENDED OVERALL HEAT TRANSMISSION COEFFICIENT FOR COLD STORAGE STRUCTURE (IS : 661-2000 – Revised / Proposed)

Storage Temp. range (^{0}C)	Max. U value, W/m^{2}K			
	Exposed Walls	Intermediate Walls / Ceilings	Roofs	Floors
-30 to -20	0.17	0.47	0.14	0.20
-20 to -15	0.21	0.47	0.17	0.23
-15 to -4	0.23	0.47	0.21	0.27
-4 to 2	0.27	0.58	0.24	0.29
2 to 10	0.35	0.93	0.29	0.47
10 to 16	0.47	0.93	0.29	0.64
16 & above	1.28	1.47	1.05	1.63

Note : Surface coefficient values can be taken as per IS : 3792 (Guide for Heat Insulation of non-industrial buildings)

INSULATION THICKNESS SELECTION IN COLD STORAGE AS PER IS 661:2000 (REVISED / PROPOSED)

THICKNESS FOR EXPOSED WALL

Storage Temp. Range	Insulation thickness for different materials (in mm)					
(Deg. C)	PUF/PIR	Phenolic Foam	EPS	Rock wool	Glass wool	PUF/PIR Panel
-30 to -20	120	140	200	180	180	130
-20 to -15	100	110	160	150	150	100
-15 to -4	90	100	150	130	130	90
-4 to +2	80	90	120	110	110	80
+ 2 to 10	60	60	90	80	80	60
10 to 16	40	50	70	60	60	50
16 and above	10*	10*	10*	10*	10*	10*

THICKNESS FOR INTERMEDIATE WALL

Storage Temp. Range	Insulation thickness for different materials (in mm)					
(Deg. C)	PUF/PIR	Phenolic foam	EPS	Rock wool	Glass wool	PUF/PIR Panel
-30 to -20	50	50	70	60	60	50
-20 to -15	50	50	70	60	60	50
-15 to -4	50	50	70	60	60	50
-4 to +2	40	40	60	50	50	40
+ 2 to 10	20	20	30	30	30	20*
10 to 16	20	20	30	30	30	20*
16 and above	10*	10*	20*	20*	20*	10*

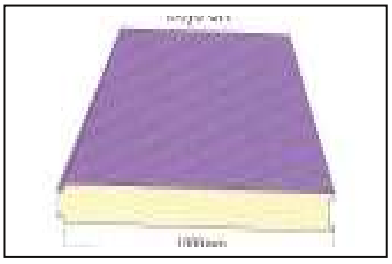
THICKNESS FOR ROOF

Storage Temp. Range	Insulation thickness for different materials (in mm)					
(Deg C)	PUF/PIR	Phenolic foam	EPS	Rock wool	Glass wool	PUF/PIR Panel
-30 to -20	160	180	260	230	230	160
-20 to -15	130	140	210	190	190	130
-15 to -4	110	120	170	150	150	100
-4 to +2	90	100	150	130	130	90
+ 2 to 10	80	90	120	110	110	80
10 to 16	80	90	120	110	110	80
16 and above	20*	20*	30	30	30	20*

THICKNESS FOR FLOOR

Storage Temp. Range	Insulation thickness for different materials (in mm)					
(Deg C)	PUF/PIR	Phenolic foam	EPS	Rock wool	Glass wool	PUF/PIR Panel
-30 to -20	110	130	180	160	160	110
-20 to -15	100	110	150	140	140	100
-15 to -4	80	90	130	120	120	80
-4 to +2	80	90	120	110	110	80
+ 2 to 10	50	50	70	60	60	50
10 to 16	30	40	50	50	50	30
16 and above	10*	10*	20*	20*	20*	10*

*** For manufacturing & commercial viability, Insulation materials are available in the thickness of 25mm in increment of 5mm & PUF/PIR Panels in 30mm (Min.)**



MODERN CONSTRUCTION TECHNOLOGY

Then comes the decision to opt for a new Modern Technology Concept where a complete study of existing construction system is done starting from basic civil infrastructure to insulation system, which can take care of existing problems. The massive civil construction involving RCC & brick works also needs to be given a thought. Suppose the brick wall & insulation system is replaced by a system which will serve the purpose of a permanent wall & insulation as a composite system then it becomes very convenient. This is exactly where modern technology comes. Now we have prefabricated panels which can serve as permanent walls & insulation and also can be used for roofs. These panels have closed cell insulation (PUF) and faced on both sides with colour coated steel. These panels since faced on both sides with metal sheet act as vapour barrier and resist flow of moisture from both sides. Being steel faced provides mechanical strength and sturdiness to environment attacks. The panel does not have any thermal bridge in between to allow heat conduction.

PANEL CONSTRUCTION

The panel system consists of basic pre-fabricated panels made to very tight specification and the full range of accessories required, including insulated doors, pressure relief valves, sealants, mastics, PVC and aluminium profiles, ceiling suspensions and plastic components.

The inner and outer surface of each pre-fabricated panel is made of a 0.5 / 0.6mm thick hot dipped galvanized steel sheet and sandwiched between them is a 40±2 kg/m3 layer of rigid CFC free close cell & also HCFC free and zero ODP polyurethane foam. Each panel is complete with a tongue and groove joint and optionally is provided with camlocks jointing arrangements to ensure rigid interlocking between panels.

Each panel is supplied pre-painted with a colour coating of 20-25 microns of architectural polyester on a minimum 175 gms/m2 base of zinc coating. PVC and plastisol coatings of 200 micron thickness are also available as an option. The standard colour is off-white and the surface of the steel sheets have light-cutting grooves both to enhance their strength as well as to provide an aesthetic appearance. Plain panels are also available. Panels are usually approx. 1M wide and transportable length upto max. 12 mtr.

Built into the pre-fabricated panel is a large choice of doors, hatches and viewing glasses. Doors can be hinged or sliding, manually operated or mechanized. Standard mechanized doors are 1300 x 2300mm and come complete with electrical heat tracers to prevent freezing of gaskets. Manual sliding doors are 2200mm x 3000mm in size and normal hinged door of 1220mm x 2010mm.

These panels are manufactured in a semi automated or fully automated continuous machines with total quality control. The panels are indigenously manufactured and easily available in the country (approx. mfg. capacity 20 million sqm. per annum).

PANEL FIXING

These panels can be directly bolted to the RCC columns with suitable fastening arrangements. There can be two type of fixing arrangement. In one method after fixing the panels horizontally the joints on the column is covered by a flashing. In other type the panels are fixed with a hidden fastening arrangement, which makes an absolute flushed finish. In both case, panels are fixed horizontally and the columns are inside visible only. Outside an absolute smooth wall will be noticed.

The RCC columns can further be replaced by steel columns, rafters & purlins. This technology of steel is also termed as Pre-engineered Building concept. The entire RCC framework is replaced by structural steel components (vertical-columns, horizontal – rafters). The columns are usually placed at 4-5 meters. These steel structures are lighter than conventional steel structure. The steel columns and rafters are tapered reducing steel consumption. Secondary steel purlins (C or Z sections) are used wherever required and usually spaced at 1.5m on roof. Wall panels are fixed vertically to these purlins. Wall panels can be upto 12m length maximum. Here horizontal purlins will be on top and bottom, fixed to the columns. In case of above 12m, 2 panels will be used. The entire steel fabrication is done at the factory and brought to site in knock-down condition, thereby reducing any welding function at site. This makes construction faster. Since no site welding is involved, site is clean of debris.

The roofing arrangement here is a 2-tier system. A false ceiling with prefab PUF panels is hung from the roof structure. An insulated 'T' arrangement is done, on to which panels are placed. Over the steel structure, profile colour coated steel sheet is provided, which stops direct heat or rain to come in contact with the panels below. Exhaust fans are provided to blow out the heat accumulated in between the roof & panels. Chilled water pipes can be carried in this space.

For a typical 5000 tons cold storage with steel PEB structure and panels construction time will be around 90 days. Since time period is short, construction can be taken up 2-3 months before the harvesting time and save interest period.

Main features of the Panel system are :

- A high strength to weight ratio, with significant savings in steel work and load bearing foundations, allowing large spans to be constructed with no intermediate columns.
- Dimensional stability.
- Maintenance-free surface.
- High thermal efficiency ensures low heat transmission, resulting in lower refrigeration load.
- No deterioration of thermal efficiency over time.
- Panels can be furnished in single jointless height / Length upto 12 mtrs. Partition wall can be easily erected as the panels are self supporting.
- Panel system incorporates special "L" shaped single piece panels for CORNERS. This avoids wall to wall direct jointing - provides additional stability, strength, aesthetical appearance, easy house keeping etc.
- To arrest thermal leakage, joints are finished in tongue and groove configuration which in combination with CAMLOCKS (optional) ensures a foam to foam joint rather than a metal to metal joint.
- For additional reinforcement "U/L" shaped flashing are provided at wall to ceiling joints.

THERMAL AND LOAD CHARACTERISTICS							
THICKNESS	**MM**	**60**	**80**	**100**	**120**	**150**	**200**
'U' VALUES	**W/M^{2}C**	0.36	0.26	0.21	0.19	0.14	0.11
PANEL WEIGHT	**KG/M2**	11.25	12.05	12.85	13.65	14.85	16.85

POLYURETHANE FOAM INSULATION CHARACTERISTICS

INSULATION PROPERTIES	CFC Free Rigid Polyurethane Foam (PUF) as per IS : 12436
Foam Overall Density	40±2 kg/m3
Foam Thermal Conductivity (K-value) at 10^0C mean temp.	0.023 W/mK
Compressive Strength @10%	2.5 kg/sq.cm.
Deformation	3.0 kg/sq.cm.
Tensile Strength	2.5 kg/sq.cm.
Flextural / Bending Strength	90-95%
Shear Strength	125mm (Extent of Burn) – Max.
Closed Cell Contents	Fire Retardent, Self Extinguishing
Horizontal Burning Characteristics	Quality Foam
Water Absorption	0.2% volume at 100% RH – Max.
Water Vapour Permeability	0.12 ng/pasm at 88% RH & 38^0C-Max.
Dimensional Stability at -25^0C Cold Temp. 70^0C Hot Temp.	 ±2% ±2%
Green Rating Points	5

CFC, HCFC Free & Zero ODP continuous technology panels are also available

BASIC ADVANTAGES OF MODULAR CONSTRUCTION OF COLD STORAGE

1. The foremost advantages is that this type of construction provides the best possible Thermal Insulation value achieveable.
2. Overall construction period is reduced to a great extent.
3. With Modern Cold Storage Construction with PU Panels, the inside atmosphere becomes complete hygienic and resistant to attack by fungus and rats. According to available data, this accounts to 30 percent savings of stored products.
4. The deposition of any kind of impurities over the panels or holes being created by rats is completely ruled out.
5. Cleaning and washing of the panels is also very easy. The panels are completely maintenance free.
6. Such systems are in use in the country for more than ten years now.

ENERGY SAVINGS ASPECT

CASE STUDY (For Potato Storage) CONVENTIONAL COLD STORAGE DESIGN Vs. MODERN COLD STORAGE DESIGN

POTATO COLD STORE - CONVENTIONAL

CASE STUDY

Storage Capacity : 6000 MT

Size : 105' (32M) x 105'(32M) x 60'(18M) (H)

Wall Design :

Brick Wall : 225mm (9")

Cement Plaster : 12 mm (both sides), Bituminous primer.

Al-Foil (vapor barrier) : 0.05mm.

(U-nails and Wooden Runners and Battens for fixing Insulation)

Expanded Polystyrene : 100mm or 4" (in two layers).

The final finish is a rendering of plaster ½" or 12mm.

Total Wall Thickness : 360 mm.

Ceiling Design

Ceiling is made up in a similar manner, with EPS being 100 mm or 4" in thickness (in case of RCC Slab as roof).

Floor Design

Floor is insulated with 60mm EPS, after tar felting and finished with Lean Concrete (PCC) 3" (75mm).

THEORETICAL HEAT GAIN FOR CONVENTIONAL CONSTRUCTION

Considering the Thermal Conductivity value for Polystyrene Foam (EPS) as 0.036 W/mK in order to allow for aging and imperfections during application for an ambient of 40-45 deg.C and operation at 4 to 6 deg.C.

Thermal Transmission Values

Q Wall = 12.26 W/m2

Q Ceiling = 8.98 W/m2

Considering a 6000MT Potato Cold Store

Dimension 105' (32M) x 105'(32M) x 60'(18M) (H)

Total Area

Wall – 1152 m2, Ceiling -1024m2, Floor – 1024 m2.

Thermal Transmission Value

Q Total (Theoretical) = 24 KW

PRE-FAB PANELS

Wall insulation is an 80mm thick Rigid Polyurethane Foam Panel, with 0.5mm thick Colour Coated and Galvanized Sheet on both sides, with Tongue & Groove jointing detail and cam-lock arrangement.

Ceiling Panels are 100mm thick.

Floor is 60mm EPS or 50mm Polyurethane Slabs

For this system, the thermal characteristics, based on design Thermal Conductivity Value of 0.023 W/mk (For PUF), a similar calculation as in the case of Conventional will result in

Thermal Transmission

Q wall = 11.00 W/m2
Q ceiling = 8.57 W/m2.
Considering total area as above, Q total = 21 KW

A reduction of 12-15% in heat gain over conventional method at the initial stage.

Energy savings approx. Rs.13000/ month or Rs.1.60 Lacs per annum@ Rs.6/KW at the initial stage.

But gradually with insulation system failing in conventional system, it is found the efficiency reduces by at least 30% from 2nd season and then the difference in electricity saving will be Rs.43000 per month or Rs. 5-6 Lacs per annum.

The cost of the modern technology cold storage construction will be approximately 20-25% more than conventional construction methodology which is compensated by the electricity bills savings and pay back period ranges between 2 to 4 seasons depending upon the capacity. The life of compressor will increase as running time will get reduced because PU Panels shall maintain a stable temperature and slow rise in temperature inside the cold storage. The environment inside will be totally hygienic. The problems of rats can also be over come with this system. Storage space also increases. Because of better cooling and no loss of cooling to outside through walls and ceiling the products stored themselves absorbs cooling and increases its shelf life. This also leads to energy conservation further. In case of electricity failure temperature rise inside will be slow due to higher insulation value of PUF. Compressor running time also decreases.

CONCEPT OF MULTI PRODUCT MULTI CHAMBERED COLD STORAGE CONSTRUCTION

- This modern technology Modular Cold Storage is further modified to form multi chambers with partition walls & ceilings.
- A center door opens to a corridor
- On the corridor small independent chambers are constructed with Polyurethane Foam panels.
- Ceilings are also with Polyurethane Panels.

The concept involves making an insulated corridor in the middle, on the ground floor in front of the main entrance door and on both sides of the corridor insulated cabins are made maintaining different temperatures. The upper floors' stair cases are through these individual chambers. Normally 6-8 chambers are constructed on the ground floor (for a large cold storage) with provision of stair case inside 3-4 chambers only. The upper floors may have small number of chambers. Temperature indicators are installed outside each chamber on the corridor. Such cold stores in limited numbers are in operation for the past 5 years.

CA STORES & POST HARVEST MANAGEMENT

CA Cold Stores can also be similarly constructed with pre-fab panels. But in case of CA stores the panels are fixed from inside the structure and the structure is visible outside. In fact for Post Harvest Management which also consists of Sorting Grading, De-sapping, Washing, Drying, Packing / Crating, Pre-cooling, Ripening, Final Packing & Cold Storage – a complete infrastructure building can be made of Pre-engineered building technology. Inside this super structure individual above activities can be arranged conveniently and systematically one after another. The Cold Stores and CA Stores individual chambers depending upon the capacity can be erected. Now for such independent cold stores if the dimensions are upto 6M wide then the panels can be individually joined to each other by camlocking (wall to wall, Wall to ceiling). The walls will be fixed to the floor with 'U' clips. There will be separate corner panels for convenience. This makes an unique combination of a complete system within a short span of time.

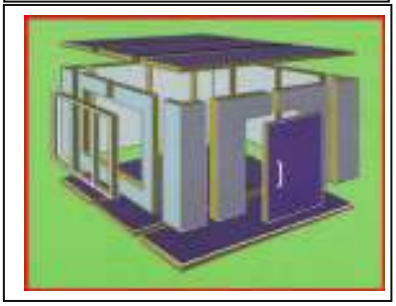
Ripening chambers can be conveniently constructed (usually of smaller size) with pre-fab panels anywhere inside a building. The panels can be camlocked and a chamber constructed. Together with the panels will be an insulated door with glass peep window to see the product.

COLLECT CENTRE STORES

Such panel constructed small stores at collection centres near the field can be useful to store products during the day time or it will protect it from day sun heat.

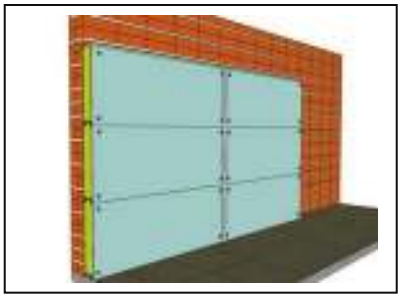
These panels do not get affected from sunrays or rain fall. Further there will be a temperature gradient difference of 5-7 degrees from outside to inside even without any cooling arrangement. Only an exhaust fan can be installed.

These stores are to be erected over a raised civil foundation. For protection against windage corner panels and may be some wall panels will be provided with tie-rods fixed to floor and roof panels. An additional rain guard roofing can be provided or the ceiling panels can be provided in a slanting fashion.



REVAMPING OF COLD STORES WITH PANELS

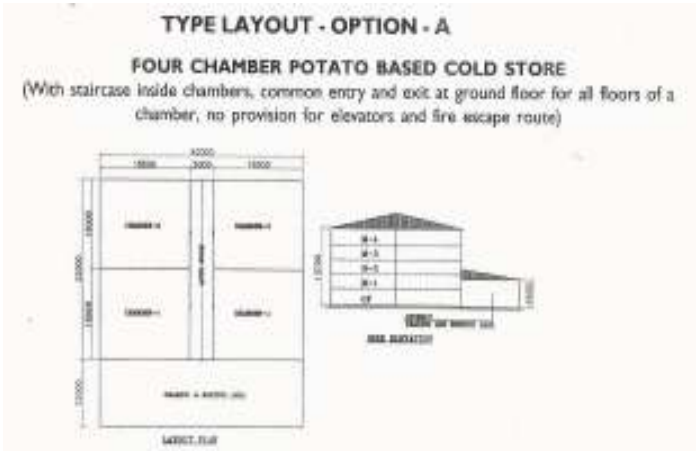
Existing cold stores with sound civil construction and damaged insulation can be revamped using prefab polyurethane panels. First the existing insulation will be removed including all supporting structure, surface cleaned and plastered. Thereafter fixing prefab panels on to the walls with fasteners. These panels will be slightly different comprising of metal sheet finish on cold storage side and thick paper or aluminium foil on wall side. This will make panels economic. The panels can be fixed horizontally or vertically. These panels can be upto 12m length & 1m wide and usually 50-80mm thickness.



FINANCIAL ASSISTANCE COVERAGE – NHB STANDARD

These panels constructed Cold Stores and even PEB structures are covered under financial subsidiaries and loans from Banks. These specifications are also included in NHB standards specifications titled **Technical Standards and Protocols for the Cold Chain in India**, Technical Standard No. NHB - Cold Storage – Type 01-2009 for Multi Commodity Cold Storage, National Horticulture Board, Dept. of Agriculture & Cooperation, Ministry of Agriculture, Govt. of India' which now is a published document.

This novel standard covers the insulation specifications of a cold store. Some of the salient features are –



Super Structure Foundation : As per BIS Standard

Cold Chamber :

Walls - 1. 230mm brick wall with plaster on both sides, vapour barrier insulation and profiled pre-coated GS sheet

2. Pre-fab steel structural frame work with insulated panel boards

Roof - 1. RCC slab with waterproofing, proper sloping and mosaic finish.
2. Truss roof with pre-coated GS sheet with FRP sheet provision for natural lighting and turbo ventilators or alternatively insulated roofing panels. There should be provision for fixing insulated panels from the trusses to act as False Ceiling.

Floor - Base concrete with insulation & RCC finish.

Procedure - As per IS : 661

Materials :

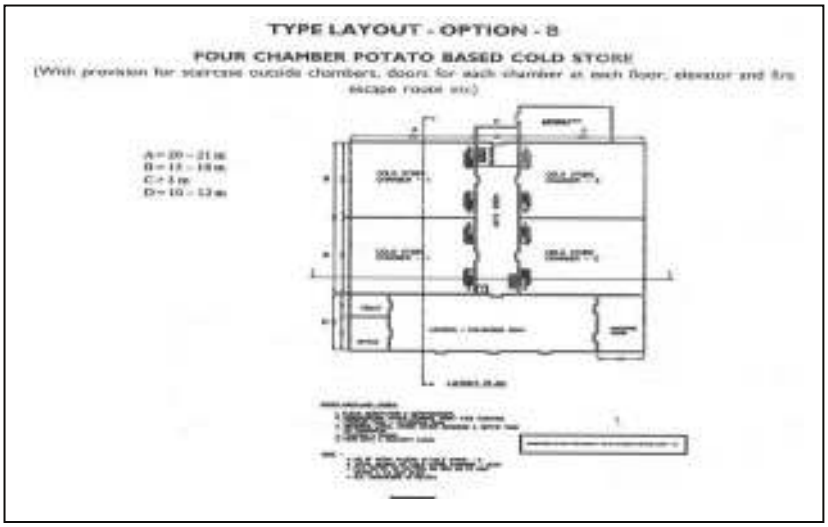
a) Expanded Polystyrene

b) Rigid Polyurethane Foam

c) Rigid Phenolic Foam

d) Mineralwool / Glasswool

e) Extruded Polystyrene



Thermal Insulation for Refrigerated Piping :
EPS, PUF, Nitrile Rubber

Vapour Barrier : Aluminium Foil, Polythene Sheet

Bitumen Cold Adhesive Mastic for insulated panel structure.

Pre-fabricated panels with cam lock or Tongue & Groove joints.

MINIMUM INSULATION THICKNESS FOR VARIOUS INSULATION MATERIALS BASED ON RECOMMENDED 'U' VALUES FOR -4 TO +2^0 COLD STORAGE

Type of Insulation	Material		Wall		Ceiling / Roof U Value = 0.24 W/m^{2}K	Floor U Value = 0.29 W/m^{2}K
			External U Value = 0.27 W/m^{2}K	Partition U Value = 0.58 W/m^{2}K		
	p Density Kg/m3	K (at 10^{0}C) W/mK	Thickness mm	Thickness mm	Thickness mm	Thickness mm
EPS	15	0.036	150	75	150	125
PUF	32	0.023	100	50	100	100
XPS##	30-35	0.025	100	50	100	100
Phenolic Foam***	50	0.026	100	50	125	100
Mineralwool***	48	0.033	125	50	125	100
Bonded Fibre Glass / Glasswool ***	32	0.033	125	50	125	100
Panel	40±2	0.023	80	60	80	80

***Recommended only with vapour barrier and metal or FRP cladding min. 0.5mm TCT
##Recommended in conformance to ISO/FDIS 4898:2008(E) for properties of XPS used for thermal insulation of buildings, Categories-II, III & IV only.

NHB latest standard covers both Conventional & Modern Insulation Panel System.

IS - 661 : Thermal Insulation of Cold Storage – Code of Practice

This IS: 661 Code which is exclusively on Cold Stores, is under revision. The new revision will include properties of insulation materials, application procedure, insulation thickness, energy conservation aspect etc. The new standard includes panels. The new standard will be a guide for proper construction of cold stores.

For further details please contact

LLOYD INSULATIONS (INDIA) LIMITED
Post Box No.4321, Punj Star Premises
Kalkaji Industrial Area
New Delhi-110019
Phone : 011- 30882874/ 30882900 - 06
Fax : 011 – 30882894 / 30882895
E-mail : kk.mitra@lloydinsulation.com /
lloyd@del2.vsnl.net.in