How To Design & Build Efficient Cold Store With minimum Heat Gain and minimum Moisture penetration?

BY

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PART-1

GENERAL CONSIDERATIONS

(There is separatePart-11 for machine room construction)

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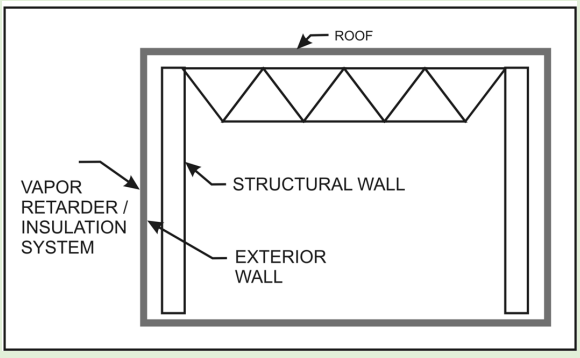
MODERN PRE ENGINEERED BUILDING STRUCTURES-LATEST CONSTRUCTION METHOD





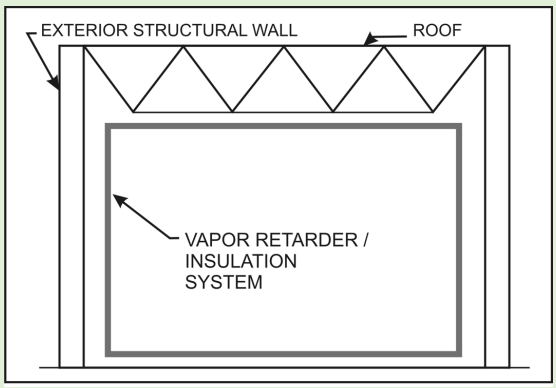
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BOX OUT DESIGN



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BOX IN DESIGN



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PRE ENGINEERED STRUCTURE WITH PUF PANELS



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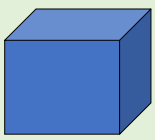
EXTERIOR BUILDING VIEW

- Tilt-up Construction at the dock Level
- Insulated Panels

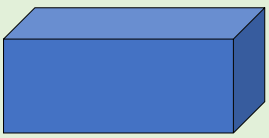


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SIZE AND SHAPE MATTERS



Dimension 1m*1m*1m
Surface Area : 6 m^2
Floor Area 1 m^2
Aspect Ratio 6



Dimension 0.5m*2m*1m
Surface Area :7.0 m^2
Floor Area 1 m^2
Aspect Ratio 7

Aspect Ratio = Surface Area / Floor Area

CUBICLE SHAPE PREFERRED

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THE BUILDING LAYOUT PLANNING

1. Ceiling With Ventilated Attic Space
2. Planning Layout With Ante Room To Ensure Outside Air And Cold Room Has In-between Barrier To Reduce Both Heat & Moisture Gain
3. Office Location Near Goods Entrance
4. Room For Expansion Of Cold Storage Area And Space For Additional Rooms
5. Separate Entrances For Cold Rooms, Machine Room, Offices?
6. Fire Protection Devices Installed At The Right Places
7. Docks Tilt Up Design To Ensure Trucks/Trailers-no Air Leakage
8. Site – Parking Area Provision
9. Space For Vehicle Turn Around Movement
10. Waste Material Disposal Area
11. Number, Type And Size Of Doors,

9

BUILDING FEATURES

1. Minimize columns
2. High ceilings
3. Avoid Condensation
4. Provide Racking arrangement
5. Equipment/machinery-separate room
6. Minimize painting-use pre coated panels
7. Minimize flat edges and corners to avoid turbulence inside the cold room
8. Trees/Shading on the East and West side walls

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HEAT GAIN FACTORS

1. **Sensible Heat Gain-** transmission heat gain- Through walls due to temperature difference between ambient temperature and cold room inside temperature-**ΔT**

This load is termed as sensible heat gain

2. **Latent Heat gain due to moisture-ΔP** –vapour pressure difference between ambient vapour pressure and the inside cold room vapour pressure

Since temperature is a easily measurable parameter -load calculations are easy, with PUF/PIR panels moisture proof panels- no need to consider latent load

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MOISTURE-X

Moisture is the greatest enemy

Temperature can be measured

Moisture in the air is invisible

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PROBLEMS –MOISTURE PENETRATION

Ice formation, fogging, condensation on walls, ceiling, ice around the doors, frequent defrosting

REASONS

1. Leakages- through doors, cracks, pipe/cable openings
2. No proper vapour barriers or seals on walls, roof, flooring
3. Use of incorrect insulation material
5. Doors remaining open too long during loading
6, No ante room provision-Air lock
7. No air curtains on the cold room doors

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LATENT HEAT V/S SENSIBLE HEAT

- To Cool one kg of dry air requires 1.006 kJ/kg_{da}.K energy (0.24 Btu/lb)
- To condense one kg of Vapor requires 2500.77 kJ/kg_{da}.k energy (1076Btu/lb.)
- To condense one lb. of air requires 970Btu/lb. whereas to cool one lb. air one requires only 0.24Btu/lb.(970÷o.24= 4041times more energy required to condense water)

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RELATIVE HUMIDITY IS A MISNOMER

Always measure absolute Humidity or g/kg_{da} of air

- Relative Humidity indicates only the ability of air to absorb additional moisture
- High Relative Humidity does not mean high moisture content

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SPECIFIC HUMIDITY OR MOISTURE CONTENT G/KG- MORE IMPORTANT THAN R.H.

Sr. No.	Degree C	R.H. %	Moisture content g/Kg.da
1	5	90	0.6
2	15	90	1.2(Twice the amount of moisture compared to sr.no.1)

Sr.No.	Temperature	Moisture content-g/kgda	R.H.%
1	5-degree C	0.6	90
2	30-degree C	0.6	20

HIGHER R. H. DOES NOT MEAN HIGHER MOISTURE CONTENT

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PROPERTIES OF AIR

Temperature °C	Relative Humidity %	Absolute Humidity- g/kg of dry air	Partial pressure of water vapour-Pa
40	25	11.59	**13.86**
5	85	4.6	**5.56**
-20	95	0.6	**0.73**
-40	**95**	**0.075**	**0.019**

Higher R.H. does not mean more moisture content-

1. 5°C & 85% R.H. has less moisture content 4.6 g/kg_{da} as against
2. 40°C & 25%. R.H.-11.59g/kg_{da} indicating that higher R.H. air has lower moisture content than air having lower R.H.

2. R.H is not correct indicator, find out g/kg for inside and outside conditions-or vapour pressure difference which is a driving force for moisture

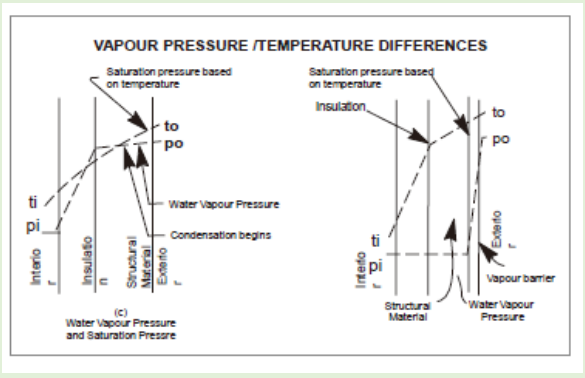
3.The vapour pressure difference(13.86-5.56) is the driving force for moisture to enter the cold storage .

4. **Lower the temperature of cold room more is (vapour pressure difference) the driving force for moisture penetration**

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IMPORTANCE OF VAPOUR BARRIER

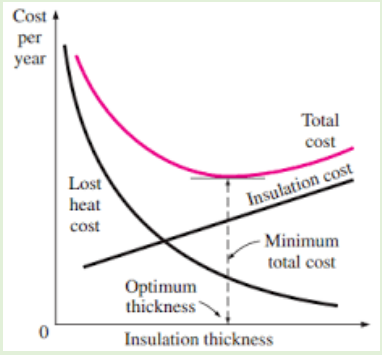
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Providing Vapour Barrier on Warm side drastically reduces vapour pressure below condensation temperature/pressure

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Optimum insulation Thickness



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Construct a vapour Tight moisture proof cold storage and not an ice factory-provide proper vapour barriers in Flooring,Walls and Roof

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DEFROST LOADS-LATENT LOADS-BTU/0.7LB FROM COIL

		kWh
1	To produce Frost	0.21 kWh
2	To Defrost Frost	0.09 kWh
3	To remove Defrost Heat	0.16 kWh
4	Total power	0.46 kWh
6	Power required to remove 1 lb of ice	0.46/0.7= 0.66 kWh
7	Power required to remove 1 kg of ice	1.45kWh

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TYPES OF VAPOUR RETARDERS

Plastic coatings or thin fluids

- Examples of materials of this category are asphalt, bituminous emulsions and polymer resins. These types of vapour retarders are applied on the exterior surface of insulation, usually before the insulation is installed.

1. Sealing sheets

The examples in this category include asphalt paper, plastic sheets, and metal films.

Metal films like aluminum foil is inexpensive and excellent vapour barrier but is difficult to install and it is impossible to make a fool proof seal without considerable punctures occurring. Also, if applied to walls directly there is possibility of corrosion as well.

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VAPOUR BARRIER—POLYETHYLENE SHEETS

Polyethylene installation becomes comparatively easier due to reduced number of joints and overlapping and bonding wherever required.

Also, polyethylene is quite stretchable before fracture occurs unlike metal foil. This characteristic is highly desirable in a cold storage vapour barrier in order to absorb building movement without rupture.

It should be also noted that two thin layers of film are not as good as one thick layer since there are twice as many chances of failure of the vapour barrier and it would require double the labour, seals, and joint overlaps.

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Typical Permeance Values for selected Material (IARW 1995)
IARW-International Association of Refrigerated Warehouses

Material	Perm value
Concrete block 8" thick	2.4
Exterior grade plywood ¼" thick	0.7
Hot melt asphalt 2 oz/sq.ft.	0.5
Reinforced concrete slab 8" thick	0.4
Polyethylene film 0.20 mm thick	0.04
Polyethylene film 0.25 mm	0.03
Metal foil –aluminum	0.0

Recommended-Polyethylene film 0.25 mm

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TRENDS IN THERMAL INSULATION PRACTICES

- **Old Units**
  - Rice husk used as Thermal Insulation
  - Cheap but necessitated large thickness
  - Lot of maintenance problems
  - Walls and Ceiling finished with AC sheets
  - Many units had cork as insulation
  - Lot of moisture penetration
- **Last Three decades**
  - Expanded Polystyrene, Fiber glass on walls and ceilings with sand and cement plaster or Sheet metal cladding using Aluminum sheet or Pre coated G.S. sheet. Floor with EPS.
- **Latest or current practices**
  - Prefab Insulated Panel Structure (also called Sandwich Panel)
    - EPS Panels with EPS bonded to sheet metal skins using special glue
    - PUF/PIR Panels using Polyurethane/Polyisocyanurate as insulation material foamed between two metal skins

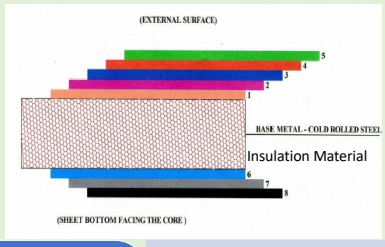
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INSULATED PANELS

Applications
- Application right from small walk-ins to very large Cold Stores
- Used also for processing plants, prefabricated houses, ware houses etc.
- Also for doors for cold stores –light and simple construction

Highlights
- Greater flexibility and faster construction
- Better isolation and better thermal insulation & vapour barrier
- Brick Walls eliminated and therefore C.S. volume increases on a given floor area
- Modular construction feasible and offers advantage of addition / expansion as per requirement
- Now being regularly used in most of the cold chain projects.

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PANEL CONSTRUCTION

A pre-coated galvanised iron (PCGI) laminated panel has the following layers:

1. Zinc coat and passive layer
2. Primer coating
3. First topcoat: silicon mould polyester
4. Second topcoat: silicon mould polyester
5. Peel off guard film
6. Zinc coating
7. Corrosion inhibitive primer
8. Back coat

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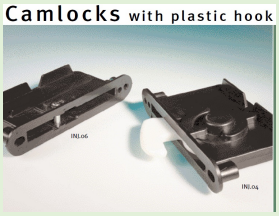
INSULATION-RECOMMENDED

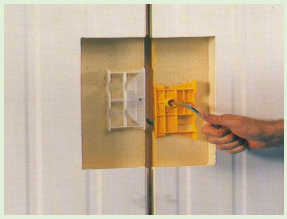
- Floor Insulation
  - Extruded polystyrene(EPS)
- Wall panels
  - Polyurethane(PUF)
- Roof Insulation
  - Polyisocyanurate(PIR)



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CAM LOCK PANELS-FOR BLAST FREEZERS

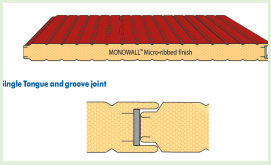


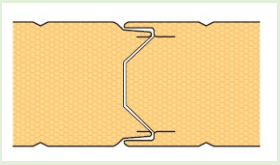




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PUR/PIR PANELS

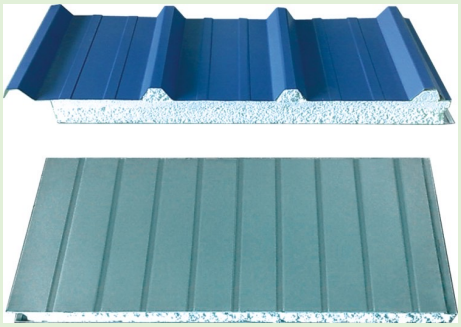




TONGUE AND GROOVE JOINTS

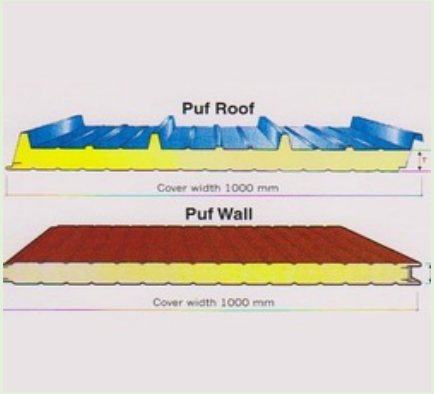
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EPS PANELS



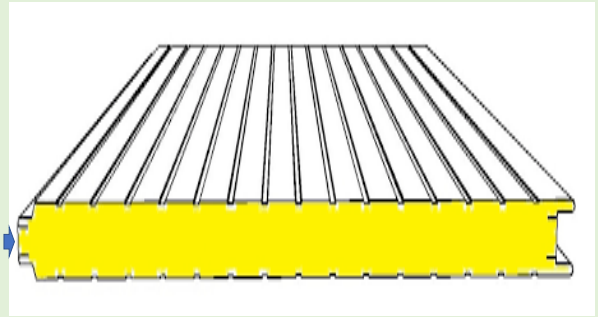
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PUF PANELS



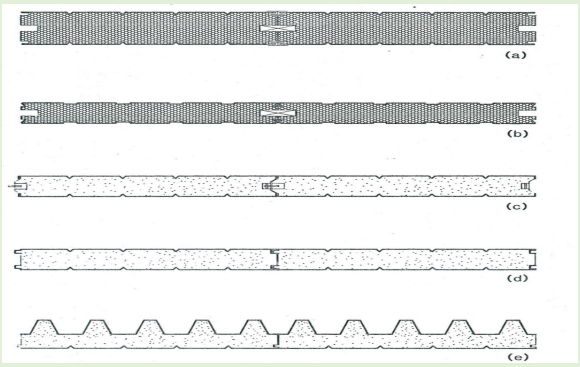
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CONTINEOUS PANELS



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DIFFERENT TYPES OF INTERLOCKING FOR COLD ROOM PANELS



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MORE INSULATION MEANS LESS ENERGY AND MORE SAVINGS

	Q= U x A x TD=Ux2(21x16+21x13.7+16x13.7)x(45-3)	
80mm	U=0.023/0.080=0.2875	Q= 20.356 kW
100 mm	U=0.023/0.1=0.23	Q= 16.284 kW
120mm	U= 0.023/0.12=0.1976	Q=13.57 kW
Savings	120mm instead 80 mm	20.356-13.57=6.786 kW/Room
Savings -4 Rooms-NHB	6.786 x4 =27.1 kW or 7.71 TR @ 1.1kW/TR=8.481 kW	
	8.481 kW x 8Rs/kW x 20 hrs/day x300 days = Rs. 4,07,088	

K' Values for Various Material – (Btu/hr/sq.ft/Deg F /in OR W/m.k)
Polyisocyanurate Cellular Foam (R-141b expanded) Slabs – 0.16 / 0.027
Polyurethane Board Panels (R11-expanded) – 0.18 / 0.023 to 0.026
Polystyrene Extruded (R141b) – 0.24 / 0.035
Fiberglass – 0.24 / 0.035
Polystyrene Expanded (R141b) – 0.26 / 0.037
(Reference ASHRAE Refrigeration Volume 2014)

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RECOMMENDED INSULATION THICKNESS-

Ref: (ASHRAE)

Outside Temp Deg C / Deg F	Inside Temp Deg C / Deg F	Difference Deg C / Deg F	PUF/PIR Thickness (mm)	Polystyrene / Fiberglass
38 / 100.4	0 / 32	38 / 60.4	50	75
40 / 104	0 / 32	40 / 72	60	100
45 / 113	0 / 32	45 / 81	75	100
38 / 100.4	-23 / -9.4	61 / 91	150	200
40 / 104	-23 / -9.4	63 / 94.6	150	200
45 / 113	-23 / -9.4	68 / 104.6	150	200

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PART-II
CONSTRUCTION DETAILS

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HOW TO CONSTRUCT WALLS/PARTITION

WALLS, CEILING & FLOORING

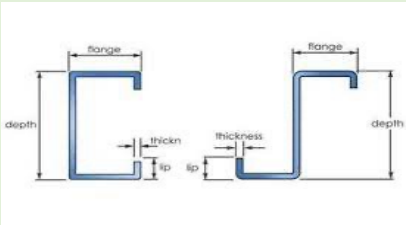
SO THAT IT BECOMES MOISTURE PROOF BUILDING & WITH MINIMUM HEAT GAIN

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WALLS CONSTRUCTION

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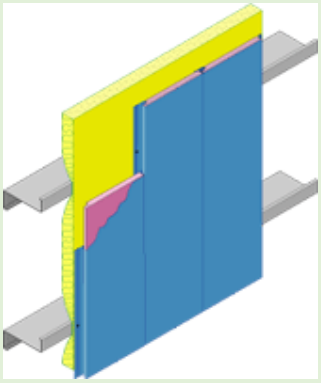
‘C’ or ‘Z’ Purlins For Wall to PEB Structure



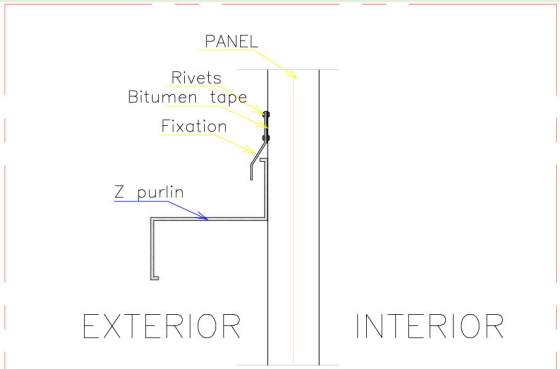
- **Z Purlins are extremely strong and can support heavy structures although, C purlins have relatively less strength**. Therefore, in buildings with a bigger roofing or loading capacity, Z purlins would be a better choice. They are commonly used in agricultural and industrial buildings.

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FIXING PANEL TO PEB STRUCTURE WITH “Z’ SECTION

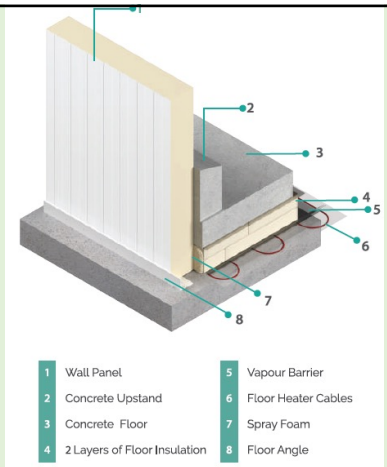


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ALLOW PANEL TO MOVE DURING COOLING AND AT AMBIENT TEMPERATURE

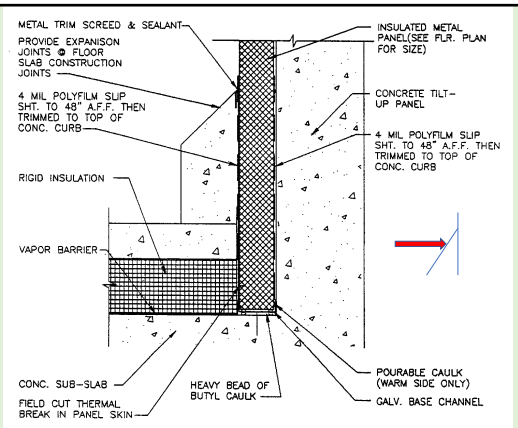
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WALL TO FLOOR JOINT

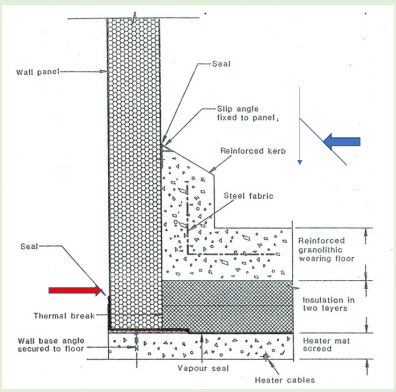
1. **Wall Panel**
2. **Concrete protection wall**
3. **Concrete Floor**
4. **Two staggered layers of Floor insulation**
5. **Vapour barrier0.3 mm Polyethylene film**
6. **Floor heating cable to avoid cracking**
7. **Spray Foam Sealing**
8. **Panel support Floor angle**

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EXTERIOR WALL AT FREEZERS

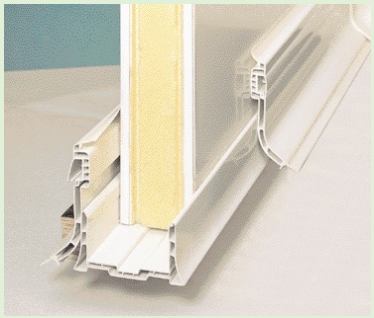
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VAPOUR SEALING FOR WALL TO FLOOR

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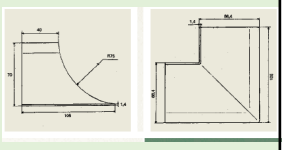
'U' CHANNEL PROFILE FOR WALL TO FLOOR JOINT



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AVOID CORNERS AND SHARP EDGES IN FLOOR AND CEILING JOINTS

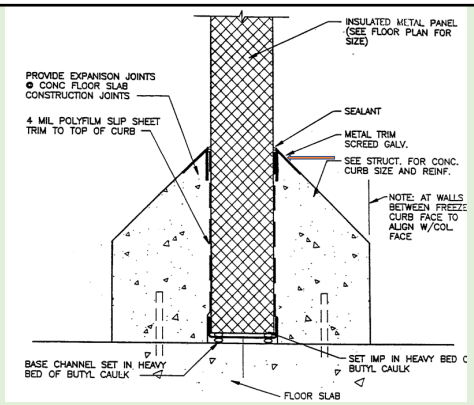




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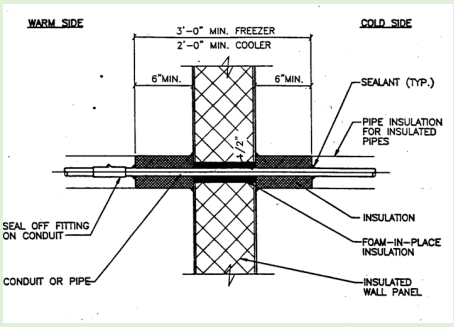


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INTERIOR WALL WITH CURBS

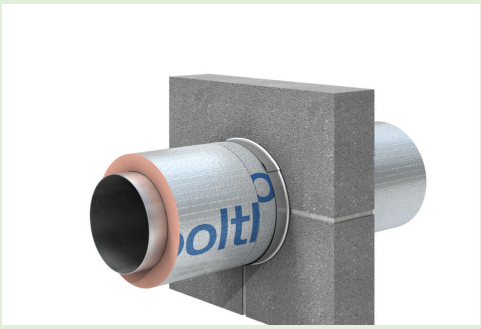
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INSULATED METAL PANEL
WALL PENETRATION DETAIL

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WALL PENETRATION OF PIPE FITTING



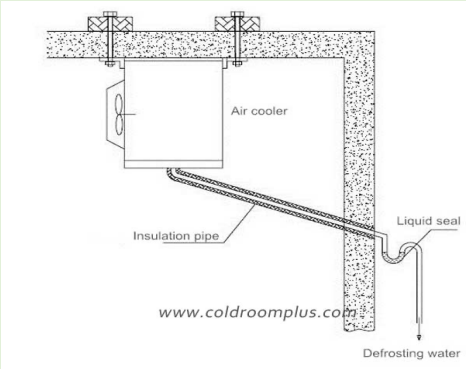
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WALL PENETRATION OF PIPE FITTING



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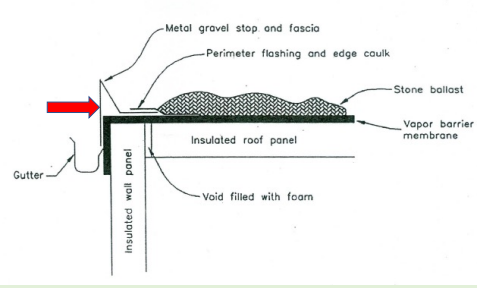
AIR COOLER DRAIN PIPING WITH LIQUID SEAL



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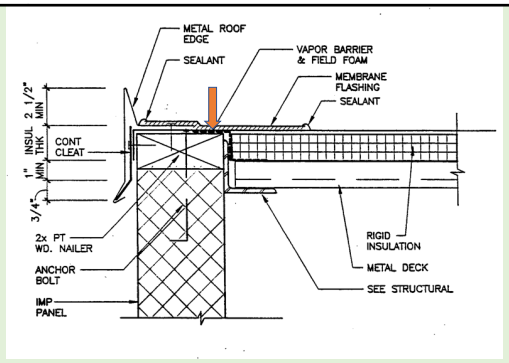
ROOF CONSTRUCTION

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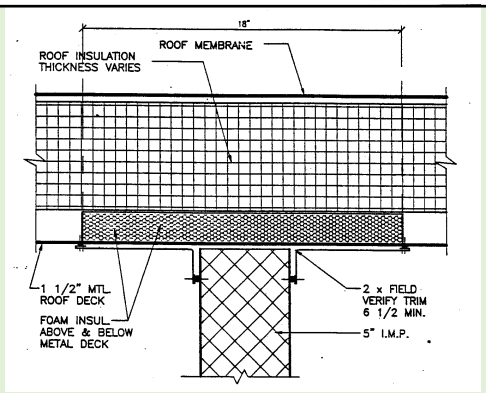
VAPOUR SEALING FOR ROOF

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FLASHING AT EXTERIOR INSULATED METAL PANEL WALL

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IMP PERPENDICULAR TO ROOF DECKING

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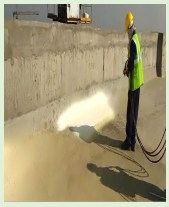


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SPRAY INSULATION


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WALL PENETRATIONS (NOT ROOF)

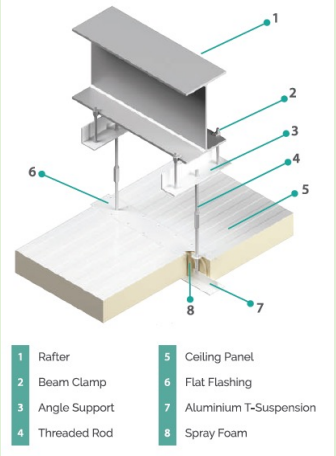


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AIR COOLER PIPING OUTSIDE THE BUILDING ON TERRACE



67

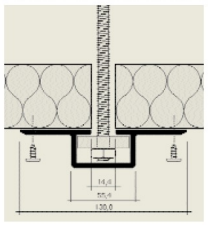


CEILING SUSPENSION

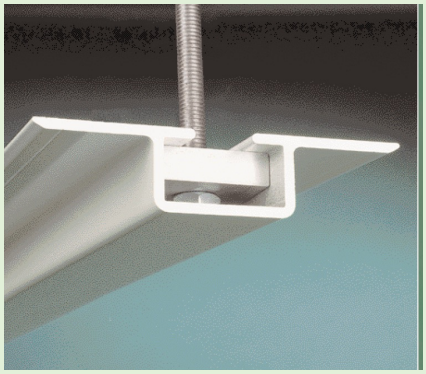
68

1. Insulated panel
2. PUL.11 OMEGA polyester (GFK) profile
3. Galvanized metal threaded rod
4. A.95 G. Steel Nut 40 x 40 x 12 mm
5. Self tapping screws

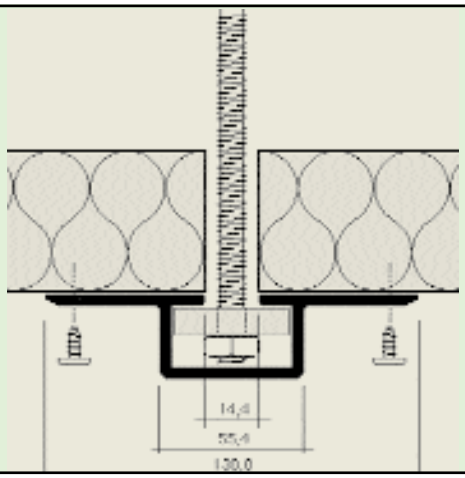
Note
There are holes for the screws every 30 cm. on both sides



69

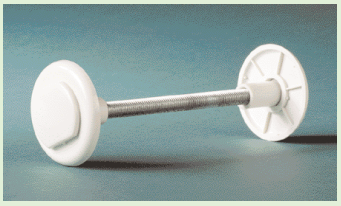


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SCREW FOR FASTINING ,CELINGS,DOOR FRAMSES,AND INSULATED PANELS-RESISTANCE-350Kg.Sizes M8.M10,M12



The screw prevent any formation of condensation

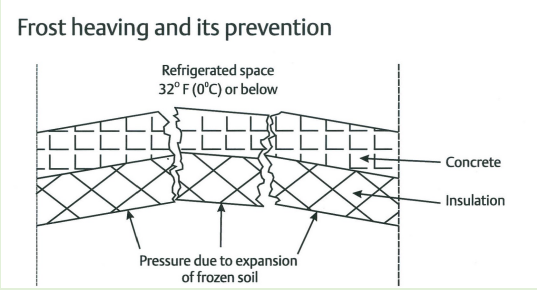
- Galvanized steel treaded rod can be used

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FLOOR CONSTRUCTION

73

IMPROPER PROPER FLOOR CONSTRUCTION & ITS VAPOUR CEILING AS WELL AS ITS INSULATION



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FLOOR CONSTRUCTION

- Floors
  - Type of finish
  - Slope (1/8 in. – ¼ in.)
  - Drains 1/400 s.f.
- Floor insulation
- Vapor barrier

75

FLOOR CONSTRUCTION

Most Common Approach -

1. Under Floor Heat System –
2. Concrete Sub Slab
3. 10 mill Poly Vapor Barrier –
4. 2 Layers of Extruded Polystyrene(5”-6”-7”) –
5. 6 mill Poly Slip Sheet –
6. Concrete Finish Floor(5”-8”)

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FLOOR WARMING

Any moisture in the sub soil freezes and causes floor frost heaving.

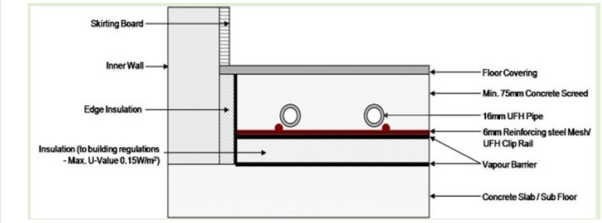




- There are methods to avoid these such as

1. under floor tubes vented to atmospheric air
2. Artificial heating by air circulated through under floor ducts
3. Glycol circulated through plastic pipes
4. Electric heating cables

77



1. Underfloor Heating System –
2. Concrete Sub Slab
3. 10 mil thick Poly Vapor Barrier –
4. 2 Layers of Extruded Polystyrene (5”-6”-7”) –
5. 6 mill Poly Slip Sheet –
6. Concrete Finish Floor (5”-8”)
7. Slope (1/8 in. – ¼ in.)
8. Drains 1/400 square feet

78

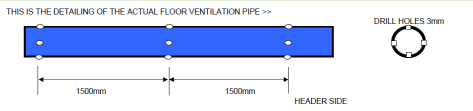
Air Vent Pipes- Frost heave prevention using underfloor ventilation (100 to 150mm dia. PVC pipes)

According with some paper you should estimate between 2-3btu/ft2 h the heat entering to the cold room through floor .

1. The air pipe should be PVC reinforced.
2. They should be installed between 1.2 to 1.6 m wide
3. The pipe should be 4" ,6" or 8" diameter according the length
4. It will be better located the pipe in the shorter distance
5. the pipes should be pitch 0,5 to 1% down
6. Each pipe should be independent .
7. The inlet should be protect against rain water and animals getting in.
8. The outlets should drain freely and protect it against animals

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USE 100MM DIA PVC SCH80 with PIPES AND DRILL 3 MM HOLES AT A FREQUENCY OF 1.5M OR SO



The general construction of flooring should be as under

1.first layer of sand

2. Second layer of boulders, stones, rubble in which air vent pipes are embedded

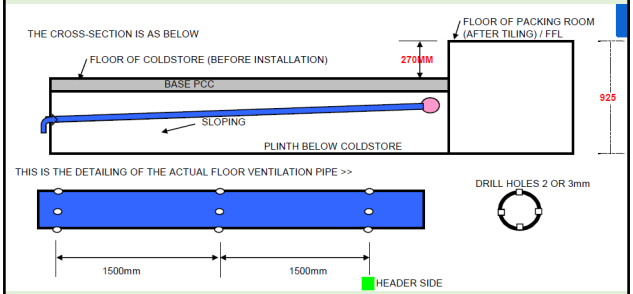
3.Third layer of plain cement concrete

4. Fourth layer of vapour barrier of 10mm thick plastic sheets in two-layer overlap of minimum 2ft.

5. 5th layer of 150mm trimix concrete dewatering type

The air vent pipes could be 4” diameter PVC placed at 1 to 1,5 m apart over the entire width of flooring

80



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Air Vent Pipe Outlets

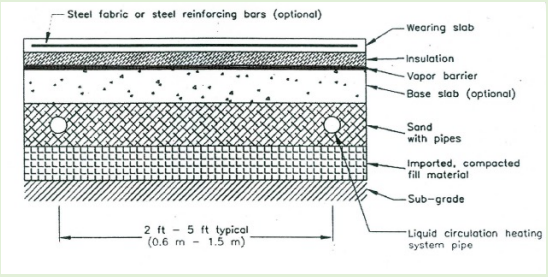


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Air Vent Pipe Outlets



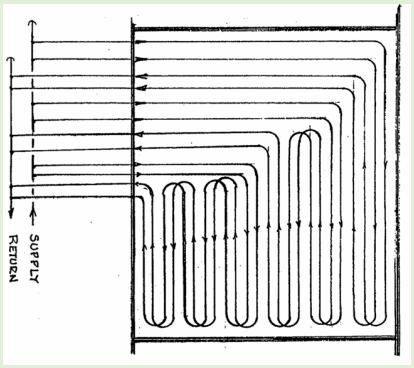
83



Vapour sealing & Glycol circulation system for Floor warming

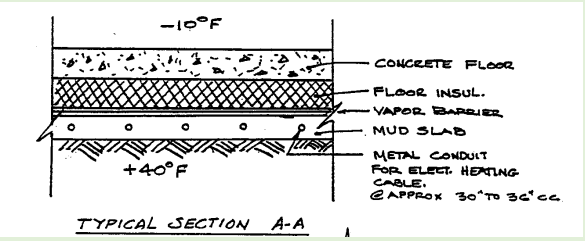
84

GLYCOL FLOOR WARMING SYSTEM



1000 ft maximum length
No joints permitted under floor

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ELECTRIC UNDERFLOOR WARMING SYSTEM

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Electrical cable warming under the floor



87

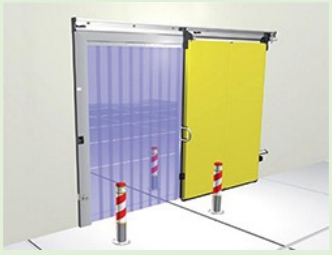
SLIDING DOORS WITH ELECTRONIC SENSORS TO ENSURE THE DOOR OPENING TIME IS KEPT MINIMUM, HELPS IN SAVING ENERGY TO LARGE EXTEND



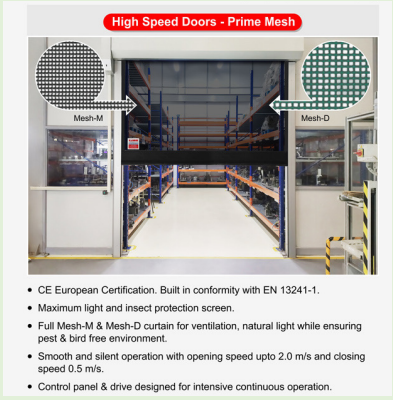
88

PVC DOOR CURTAINS

PVC 2mm thick, strip curtains are often used in cold storages. They are preferred to prevent the cold air escaping from the room when the door is opened. Because the most heat loss is experienced when the doors remain open. In addition to cold storage, PVC curtains are also preferred for the outside doors of factory and hangars.

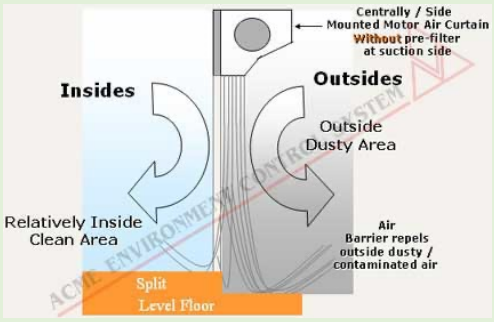


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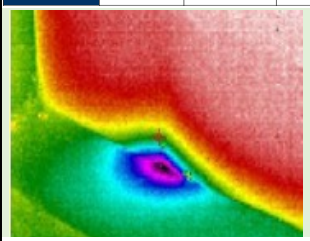
AIR CURTAINS



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SITE AND MEASURING PARAMETERS

OBJECT PARAMETER	LOCATION	DISTANCE	CONDITIONED PREMISE TEMP.	OUTSIDE AMBIENT TEMP.	EMISSIVITY
Value	Outdoor	05 FT	-21 C	23 C	0.95



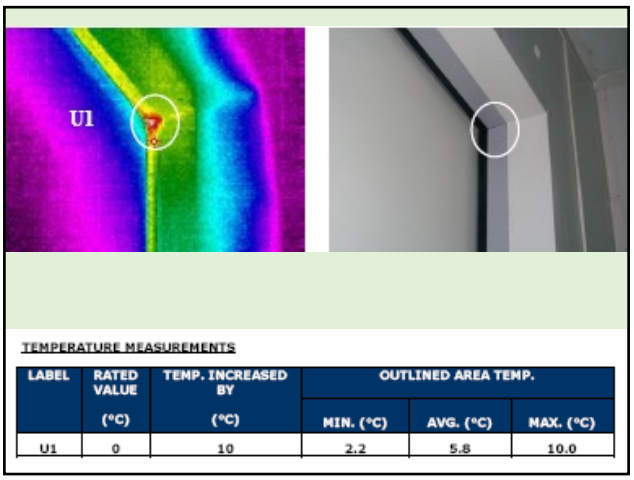


TEMPERATURE MEASUREMENTS

LABEL	RATED VALUE (°C)	TEMP. DECREASED BY (AS PER MIN) (°C)	OUTLINED AREA TEMP. MIN. (°C)	AVG. (°C)	MAX. (°C)
U1	23	9.7	13.3	17.1	21.8

Recommended Action:
Temperature at highlighted area in the real image is 9 C less than the ambient outside temperature. A panel joint at bottom has not been done properly. By injecting silicon sealant at mentioned area will maintained the temperature.

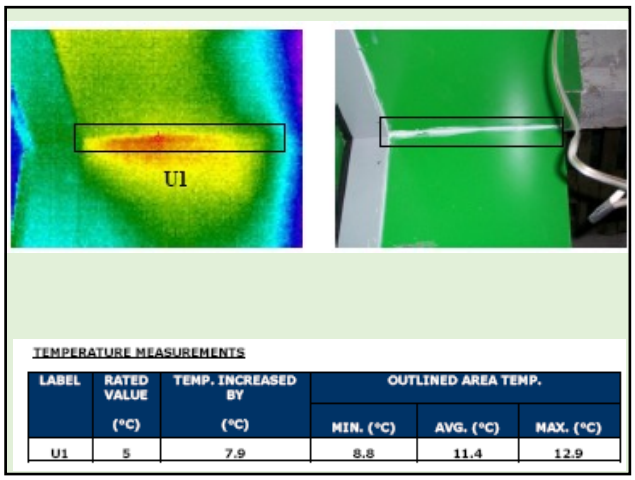
92



TEMPERATURE MEASUREMENTS

LABEL	RATED VALUE (°C)	TEMP. INCREASED BY (°C)	OUTLINED AREA TEMP.		
			MIN. (°C)	AVG. (°C)	MAX. (°C)
U1	0	10	2.2	5.8	10.0

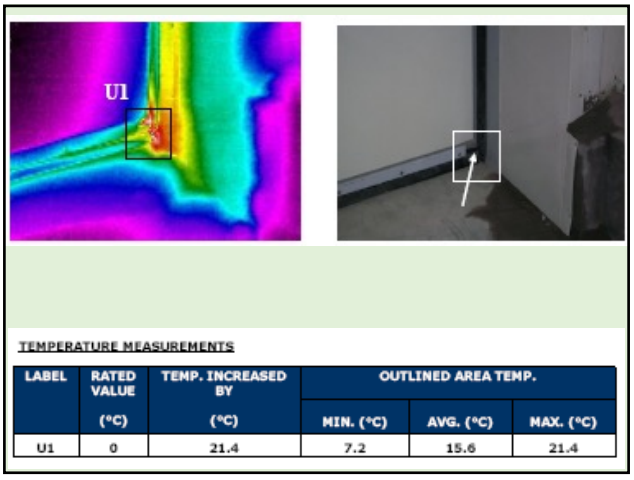
93



TEMPERATURE MEASUREMENTS

LABEL	RATED VALUE (°C)	TEMP. INCREASED BY (°C)	OUTLINED AREA TEMP.		
			MIN. (°C)	AVG. (°C)	MAX. (°C)
U1	5	7.9	8.8	11.4	12.9

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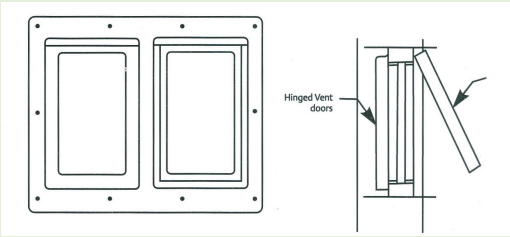
TEMPERATURE MEASUREMENTS

LABEL	RATED VALUE (°C)	TEMP. INCREASED BY (°C)	OUTLINED AREA TEMP.		
			MIN. (°C)	AVG. (°C)	MAX. (°C)
U1	0	21.4	7.2	15.6	21.4

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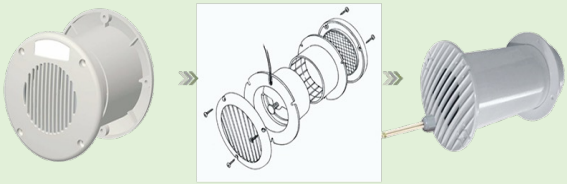
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PRESSURE EQUALIZATION VENT FLAPS

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PRESSURE EQUALIZING VALVES

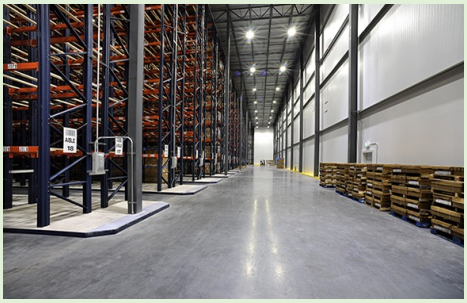


When air is cooled, its density increases and internal pressure reduces, if no equalizing valves are provided, the panels distort or collapse.

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LED LIGHTING INSIDE COLD STORAGE

- Programmable Logic Controller Systems
- Lighting Levels
  - Inspection
  - Processing
  - General
  - Storage



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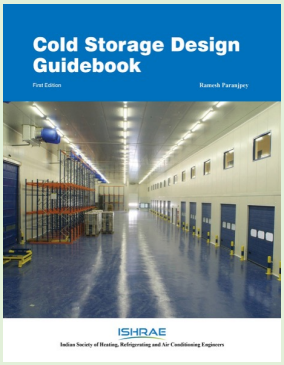
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ELECTRICAL-CONTROL PANEL

- Switch Gear
- MCC Panels



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Published on 8th December at Ahmedabad during REFCOLD
Contains Following Chapters

1. Introduction
2. Heat load contributing factors
3. Commodity storage requirements
4. Construction of efficient and moisture proof cold storage
5. Load calculations for positive temperature applications
6. Load calculations for negative temperature applications
7. Energy efficient equipment selection
8. Refrigerant piping material & selection
9. Controls for cold storage plant
10. Operation & Maintenance practices for cold storage equipment
11. Hazard and operability study
12. Troubleshooting

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WELL DESIGNED MACHINE ROOM



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THANK YOU
Questions?

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Web: http://ramesh-paranjpey.com

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