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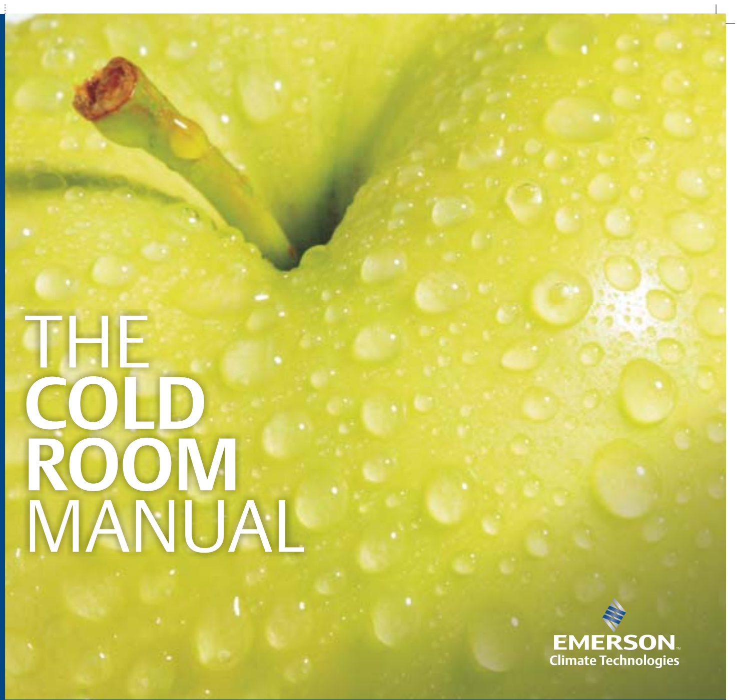
The **Cold Room** Manual



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Preface

This booklet has been prepared to include some basic information pertaining to design, construction & selection of equipment for cold rooms. This information is taken from the series of Technical seminars conducted in India jointly by Emerson Climate Technologies with Mr. Ramesh Paranjpey, the well known consultant.

The information is based on various suggestions/queries that emerged during the seminar interactions and therefore contains most of the information needed by the customers/dealers in getting preliminary knowledge needed for selecting proper equipment. The booklet contains information on product storage requirements, insulation and vapour barrier importance and addresses other major issues which need to be taken into account before venturing in cold room business.

Effort has been made to present the information in simple step by step manner and we are sure this booklet would serve as a reference document for those who deal in cold rooms.

Those who wish to get further detailed information can refer to ASHRAE volumes, Emerson Refrigeration Manual and/or other published material. You can also contact Emerson Climate representatives/dealers in your area who would be delighted to provide such details.

So here is the logic, here are the facts and now, you have the choice to build the cold room that you want. It gives us immense satisfaction in bringing you this easy to use manual after understanding your requirements because, at Emerson, we foresee your needs.

Acknowledgement

Emerson Climate Technologies wish to thank Mr. Ramesh Paranjpey, who helped in conducting the technical seminars and compiled this manual. His efforts to address the various queries and suggestions raised during the seminar interactions are deeply appreciated.

Mr. Ramesh Paranjpey is a Fellow Life Member of ASHRAE and Institution of Engineers India. He was President, ISHRAE, Pune and President, ASHRAE Western India Chapter. He holds an M.Tech degree in Refrigeration from IIT Mumbai. He has conducted corporate training on national and international level for various corporations in India, Singapore, China and the USA and ISHRAE and ASHRAE forums. His professional experience includes 27 years as the Vice President of AC&R Division at Kirloskar Pneumatics Ltd, Pune, 4½ years as the Managing Director of Carrier Refrigeration Ltd in Bangalore and Singapore and 6 years as the Chief Executive Officer at Voltas Air International Ltd, Pune.

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Introduction to a Cold Room

Introduction
to a **Cold Room**

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CHAPTER 1

INTRODUCTION TO A **COLD ROOM**
Applications

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Introducing the cold room

Cold rooms can be termed as large size walk-in coolers for short term storage of perishables like fruits, vegetables, meat and fish, dairy products or special products like medicines, chemicals etc.

Cold storage and cold room

Cold storages are run as independent industrial units & sizes range from 1000 Ton storage capacity to 20000 Ton or even more in multi- room/multi temperature/multi product configuration with individual room sizes as large as 75' x 40' x 50'. Products are stored in multi level racking arrangement & for loading/unloading, mechanical devices like forklifts are generally used. Frozen or chilled products can be stored in different rooms. The grading, packing, pre-cooling, blanching and other operations are also carried out in processing halls within the same complex.

As against this, the cold rooms are generally single rooms or units comprising of many small rooms of sizes having maximum height of 10-12 ft. The intention is that the person operating this facility should be able to load/unload the products without using forklifts or any other mechanical/electrical equipment. Products needing similar storage conditions are generally stored together in the cold room.

Applications

Cold rooms are used for storing various products either at positive temperatures or at negative temperatures. This booklet covers requirement of both, indicating temperature and humidity requirements as well as shelf life. Generally speaking, as the temperature is lowered the shelf life extends.

Two temperature ranges required are:

a. Positive temperature
   32°F to 50°F (0°C to 10°C)

Dairy products
Fruits and vegetables
Pharmaceutical products
Hotels and kitchens
Blood storage
Floriculture
Fresh meat and fish
Miscellaneous

b. Negative Temperature Products
   0°F to -20°F (-18°C to -30°C approx.)

Frozen meat and fish
Ice cream

Once the required temperature, humidity range for a particular commodity is known, the design of the cold room will have to take into account, the following aspects as well.

I Compatibility of food items

a. Different shelf lives:

Bread cannot be stored for more than 72 hours, while under the same storage conditions, apples can last for up to around 3 months. So they make for incompatible commodities on the basis of their respective shelf lives.

b. Different humidity requirements:

Many commodities which have a similar temperature requirement cannot be clubbed together because they demand different humidity levels. Eg. Onions (require only 65% humidity) and mushrooms (95%).

c. Different temperature requirements:

Apples, lemons and oranges require temperature to be maintained around 36^{0}F, while bananas and mangoes lose their appearance or flavour if stored below 54^{0}F.

Note: Most fresh products are susceptible to chilling/freezing injuries if temperature is lowered below the threshold level. Though shelf-life can be increased by lowering the temperature, the right shelf life-temperature balance has to be reached.

II Avoiding cross contamination

Some products despite requiring similar conditions of storage should still not be stored together. Dairy products and garlic, fish and flowers are few such combinations as this would affect the smell of either of the products making them unacceptable.

Storage Requirements of The Products

Chilled Products

Products	Storage Temperature °F	Relative Humidity RH%	Approx. Storage Life
Apples-depend on variety	30 -39	90-95	1 to 6 months
Pears	34	90-95	4 to 6 months
Asparagus	36-41	95-100	2-3 weeks
Banana	55-59	90-95	1-4 weeks
Strawberry	32	90-95	7 -10 days
Cabbage	32	98-100	3-6 weeks
Carrot	32	98-100	3-6 months
Cauliflower	32	95-98	3-4 weeks
Celery	32	98-100	1-2 months
Broccoli	32	95-100	10-14 days
Lemons	50-55	85-90	1-6 months
Oranges	32-36	85-90	8-12 weeks
Sweet corn-baby	32	95-98	5-8 days
Cucumber	50-54	90-95	1-2 weeks
Egg plants (Brinjals)	50-54	90-95	1-2 weeks
Figs (fresh)	31-32	85-90	7-10 days
Garlic	32	65-70	6-7 months
Ginger	31-32	90-95	1-6 months
Grapes (table)	31-32	90-95	1-6 months
Lettuce	32	98-100	2-3 weeks
Lychee	34-36	90-95	3-5 weeks
Mango	55	85-90	2-3 weeks
Mushrooms	32	90	7-14 days

Products	Storage Temperature °F	Relative Humidity RH%	Approx. Storage Life
Okra (Bhindi)	45-50	90-95	7-10 days
Onions	32	65-70	1-8 months
Papaya	45-55	85-90	1-3 weeks
Chilli-fresh	41-50	85-95	2-3 weeks
Chilli-dry	32-50	60-70	6-9 months
Pineapple	45-55	85-90	2-4 weeks
Potatoes-depend on variety	39-54	95-98	5-10 months
Spinach	32	95-100	10-14 days
Sprouts	32	95-100	10-14 days
Tomatoes	50	90-95	7-14 days
Fresh Fish	34-41	95-100	10 days
Fresh Meat	32-34	85	1-3 weeks
Poultry-fresh	28-32	95-100	1-3 weeks
Butter	32	75-85	2-4 weeks
Milk Raw	32-39	-	2 days
Eggs	29-32	80-90	5-6 months
Eggs at farm cooler	50-55	70-75	2-3 weeks
Nuts-various types	32-50	65-75	8-12 months
Orange juice	30-34	-	3-6 weeks

Table 1.1

Frozen Products

Products	Storage Temperature °F	Relative Humidity RH%	Approx. Storage Life
Processed Fish Frozen	-22- -4	90-95	6-12 months
Meat Frozen	-4	90-95	6-12 months
Poultry Frozen	-4	90-95	12 months
Butter Frozen	-9	70-85	12-20 months
Ice cream 10% fat	-22- -13	90-95	3-23 months
Ice cream Premium	-35 - -40	90-95	3-23 months
Milk Chocolate	-4-34	40	6-12 months
Bread	-4		3 -12 weeks

Table 1.1

Summary

- Determining the primary field of application of a cold room is the first step.
- Based on temperature, humidity and shelf life, compatible products should be identified.
- Thought must also be put on basic traits of each product so as to identify any inherent cross-contamination issues if stored together.

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CHAPTER 2

COLD ROOM **DESIGN**

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Designing cold rooms

The process of designing cold rooms requires thorough understanding of key factors and is to be approached after meticulous planning. This chapter is built keeping in mind the various demands of a cold room design. The primary objective is to provide an understanding which would facilitate design processes, to look beyond quick-reference guides and to have a reliable brick-by-brick approach.

Basic elements for a good design

1. Environment-friendly equipment

Selected equipments should be highly efficient and deliver maximum output while utilizing minimum power. The selected refrigerant should have minimal Ozone Depleting Potential (ODP) and a low Global Warming Potential (GWP). Every effort should be made to restrict any possibility of refrigerant leakage and the system should be able to give trouble free, round the clock operations, without needing frequent maintenance. The processing/handling and disposal of damaged product should be planned so that it does not pollute the surroundings with waste material or foul smell.

2. Reliable high-ambient performance

The equipment should be capable of performing at the tropical ambient conditions likely to be encountered at the place of installation. In many places in India temperatures during summer can go as high as 116 to 118^{0}F and the equipment should operate without tripping due to high pressure at such conditions.

The unit needs to be tropicalised by providing higher condensing surface area and so forth with higher air flows and improved tube and fin design for condenser.

3. Better Condenser air circulation

To achieve higher air flow, one needs to use appropriate fans on the condenser side. The fans should be designed in such a way that the blades are aerodynamically shaped and capable of delivering maximum air flow with minimum diameter and consuming lower power. The design of this fan needs to be thought over carefully as it has to operate at very high ambient conditions. Fin Density also plays an important role, hence appropriate fin density needs to be decided.

4. High ambient startability

At high ambient conditions, the difference between condensing pressure and evaporating pressure is high. This high pressure may lead to unit start-up problem when the machine trips on the thermostat. The design should therefore provide means for quick pressure equalization. Appropriate selection of expansion valve and use of solenoid valve helps in quick pressure equalization.

5. Precise temperature control

Temperature in the cold room should be uniform across the entire area so that products, regardless of where they are placed in the room, will receive the necessary cooling air. The maximum temperature gradient should not exceed 1-2 ^{0}F within the cold room.

6. Quick pull-down rate

Often, products are loaded in the rooms in large quantities and the unit capacity selection should take into account quick temperature pull down requirements. For this purpose, if need be, the refrigeration unit should be of a bigger size or two units can be used, so that once the temperature is reached after initial pull down, one unit can be switched off and holding load can be taken up only by the remaining one unit.

7. Quick temperature recovery

To avoid hot outside air entering when the cold room door is opened, air curtains should be used. For places where the opening of the door is frequent, like in shopping malls, retail shops having dairy product storage cabinets and multi-product storage cold rooms, the units need to be of higher capacity to ensure quick temperature recovery.

Cold rooms located close to the place of harvesting would require their doors to be opened less frequently and hence, the unit capacity may be kept low.

8. Protection against harsh climate

The place of installation also plays a vital role in deciding the selection of condensing unit. The units located in dusty areas or those exposed to high ambient temperature conditions need to be provided with an extra condensing surface to ensure proper cooling. The condensing unit also needs to be protected from solar radiation and rain. If the unit is to be located on a terrace or at higher floors, it should be mounted on vibration isolators to ensure that the vibrations do not get transmitted to other occupied areas.

9. Reduced maintenance cost

Factory Produced Equipment ensures that it is a well-engineered product and is free from any internal contamination. Thus, it would be capable of giving trouble-free service for extended hours of operation with least maintenance requirements. The field-assembled units from components procured from various sources may lead to lower initial cost but would certainly end up with higher energy consumption and requiring frequent maintenance.

10. Size and shape of cold room matters

Heat from outside the cold room penetrates the walls, roof and flooring because of the high ambient temperature. Therefore, to keep this to a minimum, the areas exposed to the environment outside should be as small as possible.

Dimensions 1 ft*1 ft*1 ft
Surface Area : 6 Sqft
Floor Area : 1 Sqft
Aspect Ratio : 6

Dimensions 0.5ft*2ft*1ft
Surface Area : 7 Sqft
Floor Area : 1 Sqft
Aspect Ratio : 7

Aspect Ratio = Surface Area / Floor Area

Figure 2.1

The ideal shape of a cold room is that of a cubicle. The ratio of surface area to floor area known as Aspect Ratio has to be kept to a minimum. The example in the given image shows how the cubicle shape helps in less heat gain.

Considering the recommendations of good design, typical room sizes can be shown as in the figure below:

Typical Room Sizes	
Area (sqft)	**Room Size (ft)**
36	6*6*8
60	6*10*8
120	8*14*8 or 10*12*8
200	8*24*8 or 10*20*8
320	16*20*8
400	20*20*8
480	20*24*8
640	20*32*8
800	20*40*8
960	24*40*8
1120	28*40*8
1440	36*40*8

Table 2.1

Frost heaving and its prevention

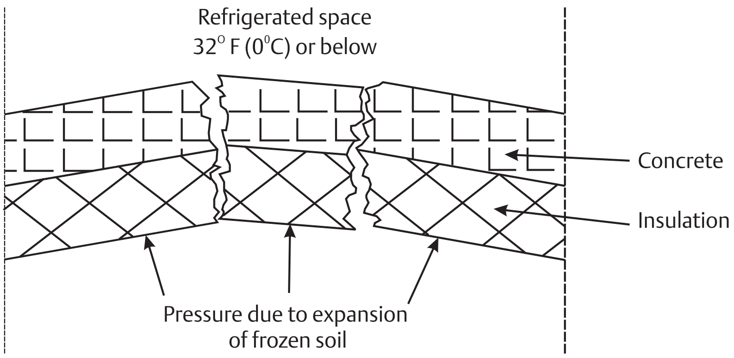

Figure 2.2

When the temperature of the ground below a cold room drops lower than the freezing temperature (32°F), moisture in the ground freezes and expands. This exerts abnormal pressure on the floor causing it to crack. This being a common phenomenon in many cold rooms, the maintenance and repairs become very expensive.

Proper design and installation can ensure that this is prevented. The flooring should be such that it doesn't let any water to seep through it to the ground below. Building a cold room just above a water source or building it in places where the subsoil has capillary movement of water would expose the cold room to possible frost heaving.

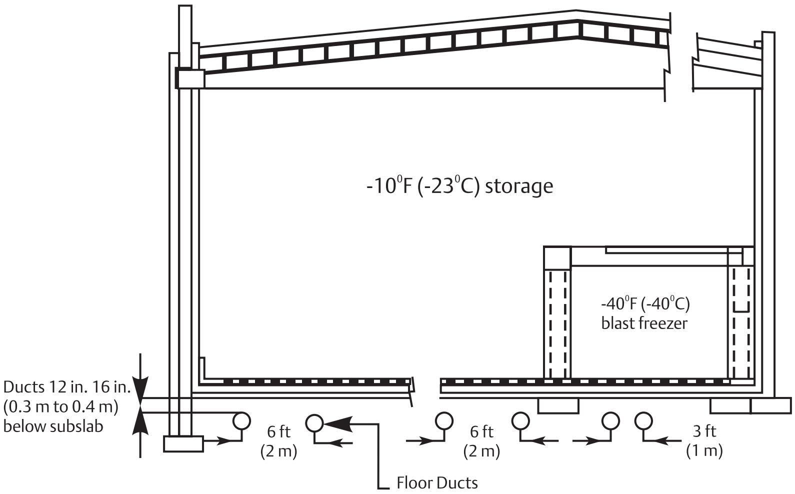

Figure 2.3

Proper under-floor heating system comprising of glycol solution circulation maintains the floor temperature at around 34 to 35°F, irrespective of the room temperature. An electrical heating system can also be used by placing resistance-heating cables or electrodes in the sub floor which will generate heat. The easiest and most-frequently used method is to ventilate the area below the floor by embedding pipes which are open at both ends. This practice is good for Indian conditions since the weather is mild or warm and air temperatures do not normally fall below 32°F in most parts of the country. The figure above shows typical arrangement of such an installation.

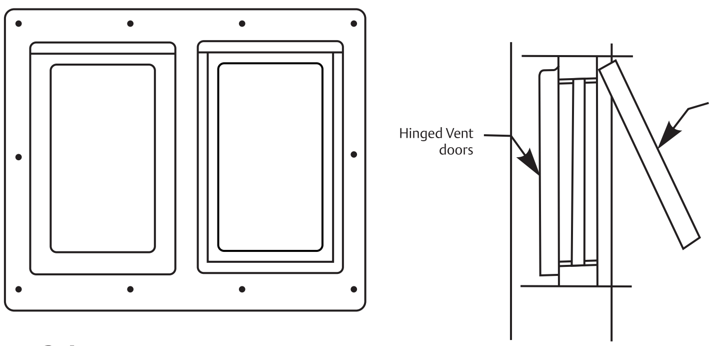

Figure 2.4

Pressure equalization vents

The change in temperature and pressure within the storage facility may cause catastrophic damage to the insulated structure if a pressure equalization device isn't included in the system design.

When the cooling process starts, the temperature of air within the refrigerated space decreases, and thus the pressure also decreases. If the structure is leak proof, which is normally the case with well-installed insulated panels, the pressure difference between outside ambient air and room air increases to such an extent that the panels are unable to withstand this load and the entire structure caves in. This has occurred in many installations in India especially for low-temperature cold rooms where the pressure difference is higher.

A pressure equalization device as shown in the figure is essential to prevent such damage. The device consists of two-side openings with hinged vent doors. One vent door swings inward, allowing air inflow, while the other swings outward for exhaust. An analysis for selection and calculation of vent area should be done and based on the requirement, one or two vents can be provided for each cold room.

Air changes

Recommended Minimum Air Changes / Hr
(Air Circulation Rate for selecting evaporator fan CFM)

Type of Application	Minimum	Maximum
Holding Freezer	40	80
Packaged Holding center	40	80
Meat Chill Room	80	120
Banana Ripening	120	200
Vegetable and Food Storage	30	60
Blast Freezer	150	300
Work areas	20	30
Unpackaged Meat Storage	30	60
Air Changes = Total CFM of Air Cooler * 60 / Internal Cold Room Volume		

Table 2.2

It has been observed in many cold rooms that while the refrigeration unit capacity (TR) is selected after load calculations, even the indoor unit is selected keeping this capacity in mind. The problem arises when the rooms are big and the air circulation fan does not deliver adequate air so as to reach all areas inside the room. This leads to uneven or inadequate cooling: overcooling for products close to the cooler and insufficient cooling of product at places away from it. It is therefore essential to select coolers with adequate air quantities and not only on the basis of capacity. This problem generally occurs for cold rooms, where precooled products are stored, which need smaller capacity in TR, but larger air circulation.

Recommended Insulation Requirement

Insulation thickness

Storage Temp ^{0}F	Difference ^{0}F	PUF Thickness (mm)	Polysterene/ Fibre glass
32	72	100	100
-10	95	150	200

Above details are for 104^{0}F ambient temperature and PUF thickness and will vary for other ambient conditions.
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Table 2.3

The performance of cold rooms is mainly dependent on how good the insulation and vapour barrier is.

Some of the desirable characteristics of the insulation are:

1. Low thermal conductivity
2. Low moisture permeability and retention
3. Fire resistance
4. Light weight
5. Sufficient strength
6. Durability
7. Ease of application

While the difference between ambient temperature and that inside the cold room is important to consider at the designing phase, it isn't the only thing to be considered. Moisture penetration is a major problem that afflicts cold rooms and unless thought about prior to installation, it might lead to many problems.

The designers of comfort air conditioning plants are normally less concerned with this aspect as the temperature/vapour pressure differences are small and thus, moisture penetration through the structure is insignificant.

Vapour pressure / Temperature differences

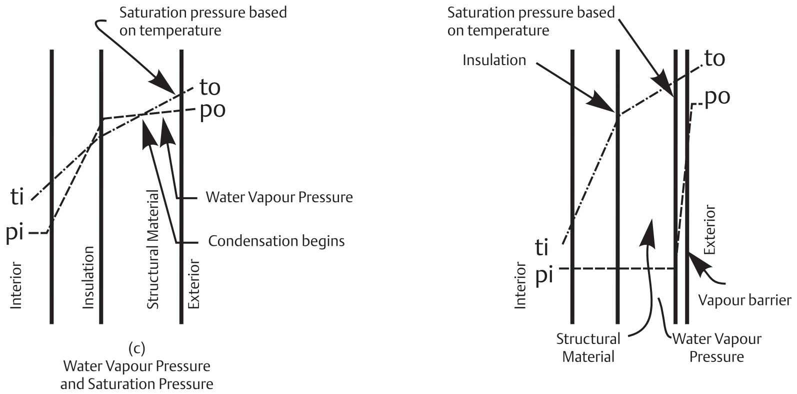

Figure 2.5

A frequent cause of structural damage in refrigerated warehouses is the condensation and formation of ice within the walls, roof or insulation. Atmospheric air always contains some water vapour. Atmospheric pressure is the sum of pressures exerted by dry air and water vapour.

The image shows the temperature and pressure gradients across the walls. As the temperature of the air inside the cold room drops, its ability to retain moisture reduces. The excess moisture settles on the coil and is drained off as condensate. The lowering of moisture content reduces the vapour pressure inside the room and creates a vapour pressure difference between the outside and the inside. This pressure difference makes the moisture from outside to penetrate inside, slipping into the insulation through cracks and porosity in the walls. The moisture trapped in the insulation reduces its thermal performance.

For example, in cold storages which operate at -4^{0}F or blast freezers operating at -40^{0}F (95 % RH vapour pressure 0.0036 psia of mercury and moisture content of 0.52 grains per pound of dry air), with outside ambient temperatures of 104^{0}F (30 % RH vapour pressure 0.655 psia of mercury has moisture content of 97.7750 grains per pound of dry air), the large difference in vapour pressures is a driving force for moisture ingress in cold storages. Since moisture ingress is invisible, it is normally overlooked but it affects cold room performance adversely.

The refrigeration plant designed and selected on the basis of temperatures thus fails to meet the necessary temperature and humidity levels as its capacity falls short due to the extra moisture and latent heat load. The presence of moisture can also lead to fungus formation, bacterial growth or formation of ice on the product, leading to damage.

Currently manufacturers prefer to use PUF insulation which has lower conductivity (K) value compared to others because of which the thickness required is less. Polystyrene and other materials are also used. The vapour retarding material could be plastic coatings, thin films of sealing sheets or pre-fabricated sandwich panels.
The latter appears to be the most efficient for constructing cold rooms as the construction time is considerably less.

It is therefore necessary to provide proper vapour barrier on the warmer side of the walls. Similarly the inside surface should never be made vapour tight which would trap moisture inside. The inside surface should therefore be allowed to breathe freely. This will ensure the moisture is carried to the cooling apparatus and is removed during coil defrosting. A properly-designed vapour barrier system is thus the one in which rate of moisture infiltration, if any at all, is equal to rate of moisture removal by refrigeration plant without detectable condensation.

Special care needs to be taken in making flooring and sloping (in the correct direction) and providing cleaning and draining arrangements too.

Key issues to be addressed

- Proper vapour barrier besides insulation
- Selection of cooling coil to achieve required relative humidity (RH)
- Proper air distribution
- Effective product loading pattern
- Appropriate selection and location of outdoor unit

Summary

Factors that need to be considered for cold room design

- Basic elements of design like equipments, area of construction, preparing for harsh climate and temperature control necessities.
- Size and shape of the cold room.
- Methods to prevent frost heaving.
- Using pressure equalization vents.
- Handling air changes.
- Understanding insulation thickness and moisture penetration.

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CHAPTER 3

HEAT LOAD **CONTRIBUTORS**

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Heat load contributors

Heat load being the amount of heat required to be removed within a certain period, the basic necessity for all heat load related design ideas should be to keep it to a minimum value. In this chapter, we will throw light on the various contributors to heat load in a cold room and the respective preventive measures to attenuate their impact.

Primary data required to start calculating heat load on a cold room:

a. Location
b. Type of product
c. Quantity to be stored
d. Frequency of opening doors
e. Expected duration of storage
f. Type of insulation and thickness
g. Product loading rate and cool-down period
h. Method of internal/external packaging

Four major categories that contribute to heat load:

1. Transmission load
2. Air change load
3. Product load
4. Miscellaneous loads

Let's now take a look at each individual contributor to heat load and how it is to be calculated.

1. Transmission Load

The heat transmission into a refrigerated space through its ceiling, floor and walls depends on:

a) Outside surface area

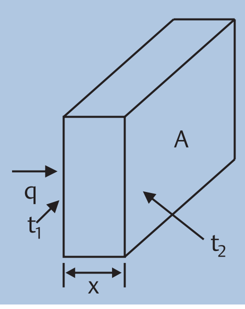
b) The temperature differential between the room and its surrounding area

c) The thermal conductivity of the insulation utilized.

Equation No. 1

Heat Gain in Btu/24hrs Q= 24 x K/X x A x TD

Transmission Load



$q = \frac{k}{x} A (t_1 - t_2)$

q = rate of heat transfer, W (Btu/hr)

K = conductivity of material, W/m.K (Btu/ hr.ft°F)

A = cross-sectional area of wall, $m^2(ft^2)$

X = thickness of wall, m (ft)

t_1 & t_2 = temperatures on opposite surfaces of wall, °C (°F)

Figure 3.1

(Inside and outside surface film conductance neglected for simplification. Reference: Emerson Refrigeration Manual, Section 12)

Steps to calculate various parameters:

1. Calculate area in sq. ft. for each of the four walls, the roof and the floor.
2. Establish the temperature difference between outside and inside conditions TD = t1 – t2

The actual temperature difference may be corrected for solar incidence, based on which way the walls face. The heat gain from solar radiation depends not only on the effect of exposure of the particular wall to solar radiation but also on the type of surface, its latitude and altitude, the time of the year, time of day and few other factors. While estimating load, the compensation due to solar radiation needs to be considered. The table below indicates the figures which need to be added to TD, based on orientation of the wall.

TYPE OF SURFACE	EAST WALL	SOUTH WALL	WEST WALL	FLAT ROOF
Dark colored surfaces such as Slate roofing Tar roofing Black Paints	8	5	8	20
Medium colored surfaces such as Unpainted wood Brick Red tile Dark cement Red, gray or green paint	6	4	6	15
Light colored surfaces such as White stone Light colored cement	4	2	4	9

Table 3.1

(Reference: Emerson Refrigeration Manual, Section 12, Table 6)

Note: Insulated floors are recommended for all rooms which will have storage temperatures below 32^{0}F.

2. Air Change Load

To calculate this load, we need to first determine the total volume of the cold room. Based on this, the air changes for normal and heavy duty operations are available in the tabulated form. For heavy duty usage the infiltration may be double the specified value or more.

Average air changes per 24 hours for storage rooms due to door opening and infiltration:

Storage room temperature		Heat Removed Per Airchange (% Relative Humidity of Outside Air)	
°F	°C	50	60
65	18.3	1.21	1.51
60	15.6	1.42	1.71
55	12.8	1.61	1.91
50	10.0	1.79	2.09
45	7.2	1.95	2.25
40	4.4	2.11	2.41
35	1.7	2.26	2.56
30	-1.1	2.40	2.70
25	-3.9	2.54	2.84
20	-6.7	2.68	2.97
15	-9.4	2.80	3.10
10	-12.2	2.93	3.22
5	-15.0	3.05	3.34
0	-17.8	3.16	3.46
-5	-20.6	3.28	3.58
-10	-23.3	3.40	3.70
-15	-26.1	3.52	3.81
-20	-28.9	3.64	3.93
-25	-31.7	3.75	4.05
-30	-34.4	3.88	4.17

Table 3.2
For heavy usage double the value in the table and for long-term storage multiply by 0.6.
(Reference: Emerson Refrigeration Manual, Section 13, Table 8)

Heat removed in cooling the air to storage room conditions (Btu per cubic feet) For temperature of 100°F (37.6°C) of outside air

Volume in cubic feet	Air changes per 24 hrs Rooms above 32°F(0°C)	Air changes per 24 hrs Rooms below32°F(0°C)
200	44	34
250	38	29
300	35	26
400	30	23
500	26	20
600	23	18
800	20	15
1000	18	14
1500	14	11
2000	12	9
3000	10	7
4000	8	6
5000	7	6
6000	7	5
8000	6	4
10000	5	4
15000	4	3
20000	4	3
25000	3	2
30000	3	2
40000	2	2
50000	2	2
100000	1	1

Table 3.3

(Reference: Emerson Refrigeration Manual, Section 13, Table 9)

Air change load is thus calculated as:

Equation No.2

Q= Volume * No of Air Changes * Heat removed per air change

As an alternative to the average air change method and by using the psychrometric chart and the formula given below, one may calculate the infiltration resulting from natural ventilation (no wind) through door openings. This is a more precise method. However, alternative (1) serves the purpose in most of the cases.

Alternative Method

$$\text{Vel fpm} = 4.88 \times \sqrt{H} \times \sqrt{TD}$$

Where Vel is Velocity in fpm, H is height of the door and TD is temperature differential.

As an example, through a door 8ft wide and 9ft high, with a temperature differential of 100^{0}F:

$$\text{Velocity} = 4.88 \times \sqrt{9} \times \sqrt{100}$$
$$= 146.4 \text{ fpm}$$

If the door remains open for 15 minutes per hour in a shift of a 12-hour operation, the 24-hour infiltration would be:

Cu.ft. = Velocity x Door area in Sqft/2 x Time open in minutes

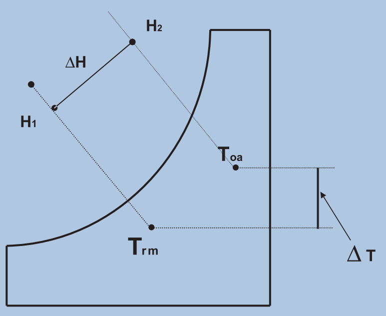
Cu.ft. = 146.4 x (8*9)/2 x 15 x 12 = 948,672

The area is normally divided by 2 since maximum velocity would be when either half of the door is open.

Once the infiltration volume is determined it can be factored by the table values given earlier.

Psychrometric calculation:

Psychrometric Analysis



$$Q = 4.5 \times cfm \times \Delta H$$
$$\Delta T = T_{oa} - T_{rm}$$

Figure 3.2

To calculate heat gain by using the psychrometric chart, we need to plot the values of outside air temperature and humidity to determine the enthalpy H2.

Similarly, finding the temperature inside the room and assuming saturation condition of air, we can also determine enthalpy of the air inside (H1).

After we have these two values, the following formula determines the heat gain through infiltration.

Heat Gain in Btu/24 hours = 24 x 4.5 x cfm x (H2-H1)

The above calculation provides a conservative load estimate since it presupposes that the total heat removed from the entering air is transferred to the evaporated refrigerant. This is not always the case as heat leaves the coil box via the heat content of the condensate as well. Accordingly, precise calculation of the refrigeration load in any instance in which entering air is cooled below its dew point would be calculated by subtracting latent heat of the condensate.

Additionally, a factor of 4.5 is needed to convert cfm into lbs/hr with standard dry air of 70^{0}F, and volume of 13.33 cu ft/lb. Therefore, additional safety is automatically built into the sample calculation since actual entering volume of 14.25 cu ft/lb would result in lower mass flow.

3. Product Load

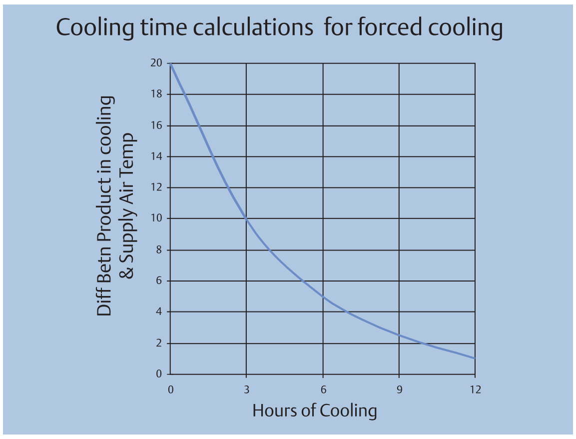


Figure 3.3

The rate of cooling of a product is not uniform. Initial cool-down is faster since the product is at a high temperature initially and the cold room is at a low temperature. As the product starts getting cooler, the temperature difference or the potential difference keeps reducing and thus it takes longer to achieve further temperature drop. When the product temperature nears room temperature, the time required to achieve the final temperature lengthens. Whenever a product having higher temperature is placed in a refrigerator or freezer room, the product will lose its heat until it reaches the storage temperature.

This heat load is made up of following components:

a. Sensible heat load above freezing

b. Latent heat load

c. Respiration load of the stored product

d. Sensible heat load below freezing

a. Specific Heat: It is the amount of heat which needs to be removed from one pound of a product in order to reduce its temperature by 1°F. There are two specific heats for each product i.e. one is the specific heat when the temperature of the product is above freezing point and the other is the specific heat when its temperature is below freezing point.

Applicable formula for calculating this heat load would be:

Equation No.3

Q sensible in Btu/24hrs = Daily loading rate x TD x Sp.Ht.

b. Latent Heat: The amount of heat that needs to be removed from one pound of product in order to freeze the product is called latent heat of fusion.

Most products have a freezing point in the range of 26°F to 31°F, and if the exact temperature is not known, it can be assumed as 28°F.

The applicable formula would be:

Equation No.4

Q latent per 24 hrs = Daily loading rate x latent heat/lb

There is definite relationship between water content of the product and its specific and latent heat.

Specific heat above freezing = 0.20 + (0.008 x % water content)
Specific heat below freezing = 0.20 + (0.003 x % water content)

Latent heat = 143.3 x % water content

c. Respiration: While being grown, fruits and vegetables are supplied with sugar from leaves through photosynthesis and with water and minerals through their roots. Once they are harvested, this supply is cut off, but plants continue to respire and mature using their own internal resources to generate energy required for metabolism.

Respiration - Fruits / Vegetables

- RESPIRATION - GROW - MATURE - DECAY WHEN PLANTED
  ROOTS - WATER / MINERALS
  LEAVES - SUGAR - PHOTOSYNTHESIS
- ON HARVESTING

OWN INTERNAL SOURCES FOR METABOLISM

COMMODITY	RATE OF RESPIRATION	STORAGE LIFE
POTATO / ONION / APPLES / CITRUS / FRUIT	LOW	LONG
LETTUCE / CAULIFLOWER / STRAWBERRY	MODERATE	SHORT – MODERATE
BRUSSELS SPROUTS / SPINACH	HIGH	SHORT
ASPARAGUS / MUSHROOM	VERY HIGH	VERY SHORT

Figure 3.4

Potatoes, onions and apples have low respiration necessities and hence have a longer storage life. Fruits like strawberry, pear and peach have moderate rate of respiration whereas vegetables like spinach, sprouts and mushrooms utilize a lot of their resources to respire giving them a very short storage life.

Even in refrigerated storage, fruits and vegetables generate heat which is called heat of respiration. They continuously undergo a change in which energy is released in the form of heat, which varies with the type and temperature of the product. This should be considered while calculating heat load. The important point to be noted is this value should be considered for the entire stored product and not only for the daily input.

The applicable formula is:

Equation No.5

Q respiration per 24 hrs = Daily loading rate x heat of respiration /lb

Tables indicating specific heats above and below freezing as well as heat of respiration are enclosed as Annexure 1 & 2 respectively.

d. Pull down time: Whenever the product load is to be calculated for anything other than a 24-hour pull down time, a correction factor of 24 hours/pull down time must be applied to the product load.

Equation No.6

Product load = 24x (Equation No. 3+ Equation No. 4+ Equation No. 5) / Pull Down Time

Following two examples should give a clear idea of this:

Suppose 10,000 lbs of unfrozen product has to be blast frozen in 2 hrs in the first freezer, the resultant daily rate would be:

Daily rate lbs/24 Hrs = 10,000 x 24/2 = 120,000 lbs/ 24 Hrs

In the second freezer, the same product, weighing the same 10,000 lbs is packed, boxed and palletized. Therefore, it requires 16 hrs to give up its heat. In this case, the daily rate would be:

Lbs/ 24 hrs = 10,000 x 24/16 = 15,000 lbs/ 24 Hrs

4. Miscellaneous Load

a. Lights: Typical storage requirements of lights are 1 to 1.5 watts per square feet. Cutting and processing rooms can have double the amount of lighting. Each watt is multiplied by 3.42 Btu/Watt to calculate the Btu/Hr. When multiplied by 24, it gives you the daily heat load due to the lights in the room.

Equation No. 7

Q Btu per 24 hrs = Watt x 3.42 x 24

b. Motors: Smaller horsepower motors are usually less efficient and tend to generate more heat per horsepower as compared to larger motors. Also, motors working in the refrigerated area will reject all its heat losses, but motors located outside, like conveyers, whose work extends inside the room, will reject less heat into the refrigerated space. If powered material handling equipment is used such as fork lifts, their effect must be included in motor heat loads. If battery-operated fork lift trucks are used, the heat gain would be 8000 to 15000 Btu/Hr or more over the period of operation.

Heat equivalent of electric motors

Motor HP	Connected load in refrigerated space Btu/HP/Hr	Motor losses outside refrigerated space Btu/HP/Hr	Connected load outside refrigerated space Btu/HP/Hr
1/8 to ½	4250	2545	1700
½ to 3	3700	2545	1150
3 to 20	2950	2545	400

Table 3.4

(Reference: Emerson Refrigeration Manual, Section 15, Table 16)

c. Occupancy: People working in the refrigerated space dissipate heat depending on the room temperature. Multiple occupancies over a short period should be averaged for a period of 24 hrs.

Heat equivalent of Occupancy

Cooler Temperature ^{0}F	Heat equivalent/Person/24 hrs
50	17, 280
40	20,160
30	22, 280
20	25, 200
10	28, 800
0	31, 200

Table 3.5

(Reference: Emerson Refrigeration Manual, Section 15, Table 17)

Equation No.8

Miscellaneous load = Equation No. 7 + Motor load + Occupancy load

We have now considered all the factors which need to be considered for load calculation for a cold storage facility. On a case-by-case basis, correction multipliers would need to be applied.
Eg. Pre-cooling of grapes (1.27), blast freezing (1.5).

The total heat load can be calculated using the following equations:

Total Load (In Btu/24 Hrs)	=	Equation No. 1 + Equation No. 2+ Equation No. 6 + Equation No. 8
Total Load (In Btu/Hr)	=	Total Load (In Btu/24 Hrs) / 18

Note: Operating time of equipment can be taken as 16 or 18 or 20 hours in a day depending on application, loading pattern & defrost period.

Altitude: The ratings by manufacturer are generally at sea level. Air density reduces as the altitude increases and the air quantity needed to be circulated over the condenser fan may need correction. Although there is no change in cfm, the mass flow rate gets affected. For example, density at sea level is 0.0749 lbs/ cu ft, at 1000 ft altitude it is 0.0719 lbs/ cu ft and at 2000 ft it is 0.0697 lbs/ cu ft. Therefore, the altitude of the place where the cold room is being installed should also be given consideration.

Sample Load Calculations:

Assumptions
• General Purpose Cold Room Store for Vegetables & Fruits
• Size 28' *8' * 8' (1792 cft – 224 sqft)
• Load as per Quick Selection 15400 Btu/Hr
• Basis of Design – Ambient 100^0 F (38^0 C), Room +35^0 F (2^0 C)
• Product Mixed – Specific Heat – 0.9 Btu/Hr/ ^{0}F
• Heat of Respiration – 0.6 Btu/lb/24 Hrs
• Loading Density – 13 lbs/cft = 9.982 Tons (75% Loaded Remaining Space for Air Circulation Storage Capacity 7.5 Ton)
• Product Loading Temperature – Wet Bulb Temperature 80^0 F
• Loading Rate 1 Ton/ Day to be Cooled in 24 Hrs
• Insulation – 4" Thermocole (Polysterene) around wall/roof/flooring

1. Product Load	**Btu/24 Hrs**
Sensible Latent Heat of Respiration for Stored Product	90720 8736
2. Transmission Load	
2 Side Walls 2 Side Walls Roof Floor	38707 11059 24192 9676
Sub Total	83634
3. Air Change Load	
1792 cft	52649
4. Additional Loads	
Fan Motor Light 1 W/sqft	20400 18385
Total 1 to 4	274524
Assuming Run Time 18 Hrs Load in Btu/Hr = 274524/18	15251 Btu/Hr

Figure 3.6

The details of sample load calculations shown in figure 3.6 are as follows.

Daily Loading rate = 1 Ton/day = 2240 lb/day

1. Product Load:

a) Sensible heat Q sensible in

Btu/24hrs	= Daily loading rate x TD x Sp.Ht
	= 2240* (80-35)*0.9
	= 90720

b) Latent Heat of Respiration for Stored product of

Q respiration per 24 hrs	= (Capacity of cold room-Daily loading rate) x heat of respiration/lb
	= (7.5-1) Ton*2240*0.6
	= 8736

2. Transmission Load:

Heat Gain in Btu/24hrs

Q = 24 x K/X x A x TD

a) 24*0.24/4*28*8*(9 ... 38707

b) 24*0.24/4*8*8*(95 ... 11059

c) 24*0.24/4*28*8*(1 ... 24192

d) 24*0.24/4*28*8*(65-35) (Floor) 9676

Wall thickness is inch unit why not convert to foot unit follow the conductivity

Sub Total 83634

3. Air Change Load:

For 1750 Cft Volume, the required number of air changes are13 and the heat removed is 2.26 Btu/Cft.

(Refer Table 3.2 and Table 3.3)

Q = Volume * No. of Air Changes * Heat removed per air change

= 1792 * 13 * 2.26

= 52649

4. Additional Loads:

a) Fan Motor

Assuming fan motor of 0.2 HP (Refer Table 3.4)

Q = Motor HP * Heat equivalent of motors * 24

= 0.2 HP * 4250 * 24

= 20400

b) Lighting Load

Q = Watts/Sqft * Total Sqft * 3.42 * 24

= 1W/sqft * 224 * 3.42 * 24

=18385

Total 1 to 4 = 274524

Assuming Run Time 18 Hrs

Load in Btu/Hr = 274524/18 = 15251 Btu/Hr

Ready Reckoner - Walkin

Room size (Sqft.)	Area (Sqft.)	Room Temperature 35.6-39.2 °F Cooling Load (Btu/Hr)	Emerson Condensing Unit with R22	TXV Valve Body	TXV Orifice	Solenoid Valve
6*10*8	60	7600	KHJ513PAE	TIE-HW	TIO-001	50RB4
8*14*8/10*12*8	120	10700	KHR522MAE	TIE-HW	TIO-001	50RB4
14*14*8/10*20*8	200	14400	ZX0200	TIE-HW	TIO-001	100RB2
16*20*8	320	19400	ZX0300	TIE-HW	TIO-002	100RB2
20*20*8	400	21800	ZX0400	TIE-HW	TIO-002	100RB2
20*24*8	480	25000	ZX0400	TIE-HW	TIO-002	200RB3
20*32*8	640	31000	ZX0600	TIE-HW	TIO-003	200RB3
20*40*8	800	34000	ZX0600	TIE-HW	TIO-003	200RB3
24*40*8	960	43000	ZX0760	TIE-HW	TIO-003	200RB3
28*40*8	1120	48500	ZX0400 x2	TIE-HWx2	TIO-002x2	200RB3x2
36*40*8	1440	59000	ZX0500 x2	TIE-HWx2	TIO-003x2	200RB3x2

Figure 3.7

- Average door opening considered.
- Above models are air cooled, water cooled models are also available.
- Hermetic & Semi Hermetic technology options also available.
- Refrigerant options also available.
- TIE-HW are the TXV Valve Body and TIO -. are orifice numbers.
- Solenoid Valve model mentioned are without solenoid coil which needs to be procured separately.

Ready Reckoner - Freezer

Room size (Sqft.)	Area (Sqft.)	Room Temperature -9.4 °F Cooling Load (Btu/Hr)	Emerson Condensing Unit with R404a	TXV Valve Body	TXV Orifice	Solenoid Valve
6*6*8	36	6100	ZXL020E	TI(S)(E)-SW75	TIO-001	50RB4
6*10*8	60	8900	ZXL030E	TI(S)(E)-SW75	TIO-002	50RB4
8*14*8/10*12*8	120	12000	ZXL035E	TI(S)(E)-SW75	TIO-002	100RB2
14*14*8/10*20*8	200	16400	ZXL050E	TI(S)(E)-SW75	TIO-003	100RB2
16*20*8	320	21500	ZXL075E	TTI(S)(E)-SW75	TIO-004	100RB2
20*20*8	400	24000	ZXL035E x 2	TI(S)(E)-SW75x2	TIO-002x2	100RB2x2
20*24*8	480	27000	ZXL035E x 2	TI(S)(E)-SW75x2	TIO-003x2	100RB2x2
20*32*8	640	33000	ZXL050E x 2	TI(S)(E)-SW75x2	TIO-003x2	100RB2x2
20*40*8	800	36000	ZXL060E x 2	TI(S)(E)-SW75x2	TIO-003x2	100RB2x2
24*40*8	960	46000	ZXL075E x 2	TI(S)(E)-SW75x2	TIO-004x2	200RB3x2

Figure 3.8

- Negative temperature products loaded in pre-cooled condition.
- Average door opening considered.
- Above models are air cooled, water cooled models are also available.
- Hermetic & Semi Hermetic technology options also available.
- Refrigerant options also available.
- TIE-SW75 are the TXV Valve Body and TIO-... are orifice numbers.
- Solenoid Valve model mentioned are without solenoid coil which needs to be procured separately.

Summary
We looked at various factors contributing to heat load. The heat contributing parameters are divided into four major categories and are calculated for a period of 24 hours. The total heat load of a cold room will thus be the sum total of each of the following individual factors:
• Transmission load through walls/roof/floor. • Air change load due to outside air during door opening. • Product load. • Miscellaneous load like effect of fan motor, lighting and occupancy. The methods to calculate each of these individually will help in working out a more reliable refrigeration capacity of the cold room. Irrespective of the requirement, all these factors have to be considered and accommodated for in the final design.

For further assistance, please contact your nearest Emerson representative or call our Toll Free no. 1800 209 1700.

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CHAPTER 4

INSTALLATION & **HANDLING**

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Once the design and heat load calculations have been done, it is then down to the process of installing the system. The installation needs to be in an ordered manner and handling the equipment becomes crucial. In this chapter, we'll elaborate on the important facets of installation and handling.

1. Installation

Dos

- Get all details before selecting equipment.
- Plan the size for permissible range or limit. In case of any uncertainty, go for a higher size.
- Calculate load as a counter-check even if quick selection charts are available.
- For a positive temperature room, select indoor unit with a TD of 10^{0}F.
- For a negative temperature room, select indoor unit with a TD of 12^{0}F.
- Though R22 (refrigerant) can be used for both positive and negative temperature rooms, prefer R404A for negative temperature rooms and R134A for positive temperature rooms.
- Provide adequate airflow over product.

Don'ts

- Do not assume any data.
- Do not economise on equipment at the cost of quality.
- Do not rely on quick selection guides as final selection.
- Do not exceed a TD of 14^{0}F for any application.
- Do not recommend only one refrigerant for all applications.

Best practices

The accompanying figure suggests the arrangements for cooler location to achieve uniform cooling. If a single cooler is used, in front of the door, a baffle should be used to divert air towards the ceiling so that its does not leak out from the door when opened.

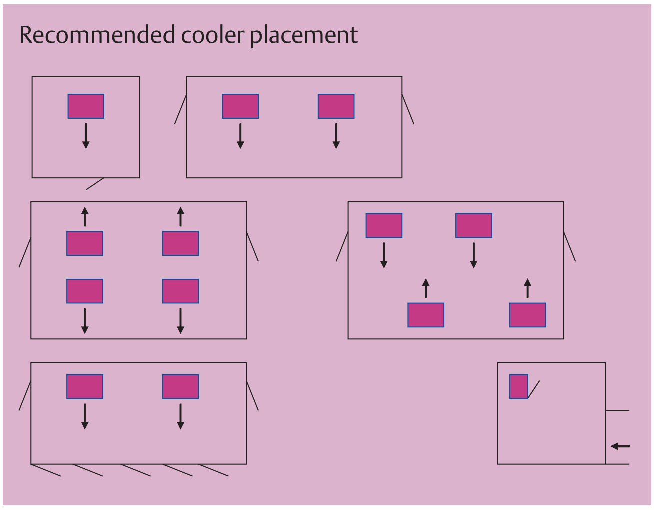


Figure 4.1

Cold room construction panels

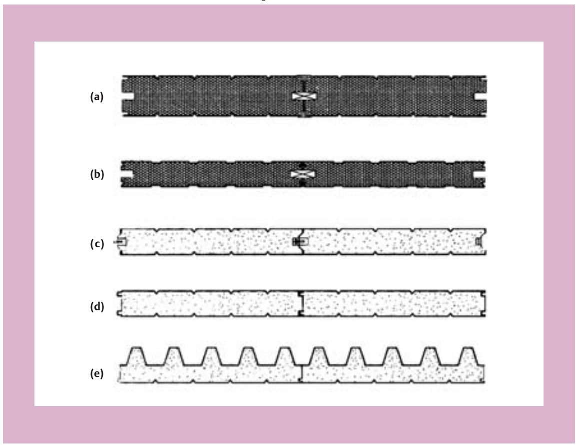


Figure 4.2

(Types of panel (a) continuous laminated panel (b) composite panel (c) foam injected panel with lock (d) foam injected panel and (e) continuous foam panel.)

Till recently, cold rooms had brick or concrete walls and polystyrene or fiberglass sheets were used with sand and cement plaster. Prefabricated insulated panels are rapidly replacing this.

These panels are simply an insulation core sandwiched between two outer layers of metal sheets. The insulation core is made from polystyrene or urethane, since these materials tend favourably to panel construction.

The outer skin of the panel, facing the warm side, also acts as good and effective vapour retarder. The panels can be attached to the structural members or they can be of a free-standing type. They are available in various sizes and can be attached to each other.

The advantages of using prefabricated insulated panels are as follows:

1. They lead to overall construction economy.
2. They can be easily repaired and replaced in view of their modular construction.
3. They have a better appearance.
4. The construction time required for the cold storage facility is very less compared to conventional methods of construction.
5. The insulating and vapour barrier properties are much better.
6. The panels can be easily dismantled and capacity and size of cold storage facility can be easily modified.

Other key issues to be addressed:

- A proper vapour barrier should be provided besides the insulation.
- Correct selection of coil will help achieve required RH.
- Air distribution mechanism must be good.
- Product loading pattern should be thought about.
- Outside unit must be appropriately selected and located.

Handling

a. Loading and unloading

Care while loading / unloading

Loading/unloading work should be done quickly.

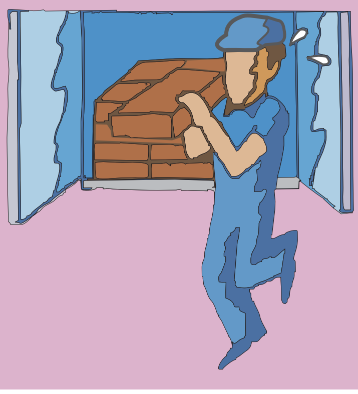


Figure 4.3

The shorter the duration the door is kept open, the better. It is thus important to load and unload products quickly. Doing this in evenings will help in keeping the temperature differential low since ambient temperature will be lower than it will be during day time.

b. Packaging

(i) Requirements for outer packaging

- The package should be such that it protects the product.
- It should be able to withstand stacking height of up to 2.5 m.
- It should be able to withstand high humidity.
- Ventilation holes and other appropriate arrangements should be in place for proper air flow.

(ii) Handling, loading and unloading should be very easy.

(iii) Requirements for inner packaging

- Materials like plastic film, bags or wrappings, nets, paper bags or plastic coated bags should be used for supporting products inside the packing.

The above guidelines for the product packaging should help in deciding the inside and outside packaging material, carton/box size and its material so that products do not get damaged due to load or moisture. The packaging material should also be such that it does not contaminate the products. Adequate air circulation for the product to cool rapidly is also very essential.

c. Storage techniques

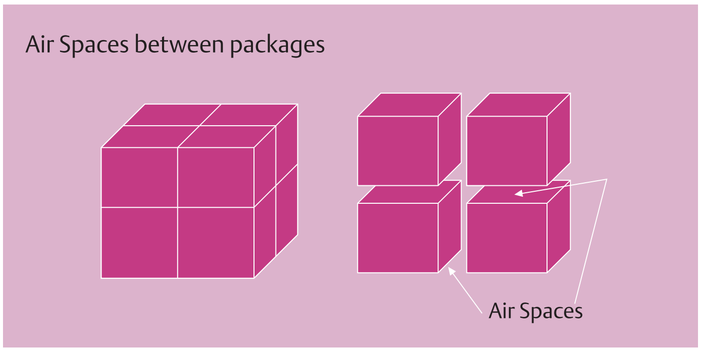


Figure 4.4

The products need to be stacked in such a manner that the cold air envelopes the product completely. If the product boxes are stacked one above the other or compactly, the surfaces touching each other cannot be cooled and we lose uniformity. Enough gaps need to be provided between the boxes. This will also shorten cooling time for packages.

d. Need for moisture modulation

• Deterioration of stored product due to moisture loss

Moisture removal leads to weight loss and thus to loss of revenue. We know that cooling coil removes moisture. Where does this moisture come from? It either comes from the trapped air inside the space or from the product. As the air is cooled, it sheds moisture and the same settles on the coil. However this is a small quantity compared to water-loss from the product.

Refrigeration engineers must keep this important point always in mind. If we design and select equipment so that moisture loss from the product is kept to a bare minimum, then we will not be guilty of taking out moisture from the product. If we allow it to settle on the cooling coil, remove it from the room with efficient defrost methods and then try to devise ways and means to inject additional moisture to increase humidity, majority of such efforts fail miserably. When air is saturated, additional moisture injected will always be suspended moisture in mist form and would settle on the product and cause product damage.

• Importance of moisture modulation

The temperature difference between coil air outlet and the cabin should be minimal so that moisture from the product does not get absorbed into air. This reduces the risk of it subsequently travelling to the coil, due to vapour pressure difference between the commodity and the surrounding atmosphere.

To achieve this, higher Apparatus Dew Point (ADP) and a larger air volume needs to be provided. Perishable products require high humidity (over 95%) at a temperature close to 32^{0}F. It is practically impossible to have evaporator coil temperature lower than circulating air temperature by say 2^{0}F without water condensing on the coil surface, thereby lowering Relative Humidity (RH). Maintenance of correct humidity and temperature therefore reduces water-loss.

As an example to stress the effect of water-loss on revenue, let's consider 10 Tons of apples being transported. If they have a water-loss of 6%, the end product would only weigh 9.4 Tons, leading to a loss of 0.6 Ton. At the rate of Rs. 30/kg, the total loss comes up to Rs.18000 for that single trip!

RH is also a misleading indicator of moisture content, because warm air may contain more moisture than cool air for a similar RH.

E.g.

90% RH at 41^0 F has 0.6 g/kg moisture

whereas , 90% RH at 59^{0}F has 1.2 g/kg moisture.

Another way of keeping the humidity high is therefore to inject fresh, warm and humid air from outside. The limiting factor is however increased refrigeration load and power consumption.

e. Importance of humidification

It is essential to keep temperature difference to a minimum level which will help maintain appropriate humidity so that the product does not lose moisture. One should therefore design and select the condensing unit and indoor product cooler accordingly.

The following general recommendations for evaporator Temperature Difference (TD) have proven to be satisfactory in most normal applications:

Temperature Range	Desired Relative Humidity	TD (Refrigerant to Air)
25 °F to 45 °F	90%	8 °F to 12 °F
25 °F to 45 °F	85%	10 °F to 14 °F
25 °F to 45 °F	80%	12 °F to 16 °F
25 °F to 45 °F	75%	16 °F to 22 °F
10 °F and Below	___	15 °F or Less

Table 4.1

It is however recommended that one should restrict the TD to 10-12^{0}F (maximum), while selecting normal storage products. Also there, very high RH is to be maintained for fruits like grapes; TD should not exceed 5^{0}F. Special coolers which are designed to maintain high humidity should be selected.

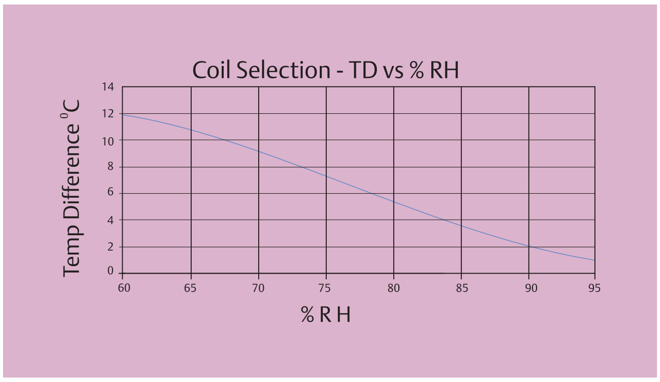
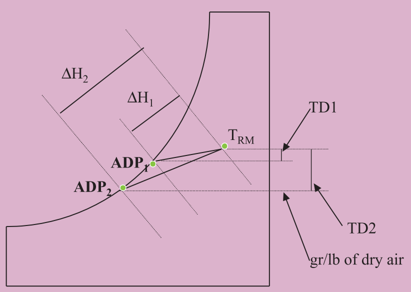


Figure 4.5

Psychrometric Analysis



$Q = U \times A \times \Delta T$

$Q = 4.5 \times cfm \times \Delta H$

$TD = T_{RM} - T_{ADP} (T_{evap})$

- Smaller TD less weight loss / less moisture Removed TD1<TD2
- For same heat removal Q, smaller TD - More area, bigger coil
- For same heat removal Q, smaller ΔH – More cfm – Bigger fan
- Smaller TD, more expensive initial cost - lower power consumption / running cost

Figure 4.6

The psychrometric chart shows that as the TD is increased, more moisture is removed from the product.

Summary

Installation requirements, best practices and handling procedures round-off the comprehensive, step-by-step process of building cold rooms.

- The dos and don'ts of installation have to be followed to get the optimum performance.
- For cold room construction panels and cooler placements, a set of common ideas need to be incorporated.
- Moisture modulation, focus on humidification, storage methods, loading, unloading and packaging are important constructing and operating strategies to consider.

For further assistance, please contact your nearest Emerson representative or call our Toll Free no. 1800 209 1700.

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