University of Southern Queensland
Faculty of Engineering & Surveying

Improving the Performance of an Industrial Cold Room

A dissertation submitted by

Sean Looi Zi Qing

In fulfillment of the requirements of

ENG4112 Research Project

Toward the degree of

Bachelor of Engineering, Civil

Submitted: October, 2007

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in other course or institution, except where specifically stated.

Looi Zi Qing, Sean

Student Number: 0050060212

Signature

Date

Abstract

The aim of this project is to reduce the loss of energy escaping from open cold room doors. This project also aims to prevent the formation of ice in the insulation layer of the cold room floor, eliminating the effects of the bumpy floor surface. Ultimately, the purpose of the project is to find ways to reduce operational costs of the industrial cold room.

In the process of meeting the objectives, research and investigations are carried out on the industrial cold room. Because the structure is fully functional, many areas are considered off-limits; however, the following areas:

- Cold storage doors
- Door frame heaters
- Defrosting schedules
- Ground heater

The loss of energy from the open cold storage doors could be eliminated by using the concept of an air-curtain. A ground heater design was proposed for the cold room floor and optimum defrosting schedules were determined; however, there are difficulties in finding a solution for the door frame heaters.

The benefits obtained from these recommendations is that the operating costs of the industrial cold room can be reduced, defrosting of the air-blowers occurs when necessary, the problem of the uneven floor surface is solved and the elimination of the loss of energy from open cold room doors.

University of Southern Queensland
Faculty of Engineering & Surveying

ENG4111 & ENG4112 Research Project

Limitations of Use

Acknowledgements

This research was carried out under the principal supervision of the Vice President of Haisan, Ir. See Soo Teck, for his help in the research of the various and numerous aspects of the industrial cold room.

Appreciation is also due to my USQ supervisor, Dr. Talal Yusaf, for his support and guidance in the dissertation project.

Looi Zi Qing, Sean

University of Southern Queensland

October 2007

Contents

List of Figures

List of Tables

List of Appendices

Chapter 1

INTRODUCTION

This project revolves around the concept of refrigeration. Refrigeration is described as a process for drawing heat from substances to lower their temperature. Refrigeration is an indispensable aspect when it involves the storing, processing transporting and trade of fresh and frozen food. [1]

1.1 HISTORY OF REFRIGERATION

Before modern technology of refrigeration was invented, cool cellars or buckets lowered into wells were used to store food products. There is a method that is still used in certain parts of the world today; it involves a room that is built with porous walls, from which water trickles out. The room is cooled naturally as the water evaporates.

[1] HighBeam Encyclopedia, definition for "refrigeration"

The introduction of mechanical refrigeration systems began with an invention by Jacob Perkins from Great Britain, to whom the first patent was issued. It was based on the concept that as heat is absorbed by a fluid, it changes from a liquid to a gas which lowers the temperature of the object around it.

The conventional refrigerators that are used in common households today employ a compression system. A thermostat controls a compressor that exerts pressure on a vaporized refrigerant that is force to go through a condenser, where it loses heat and liquefies. The refrigerant then moves through the coils of the refrigeration compartment, where it finally vaporizes and draws heat from whatever is in the compartment. The cycle is repeated as the refrigerant passes back to the compressor.

As of today, there are many refrigeration systems that are created and used in a wide variety of applications. One of these includes the ammonia refrigeration system, which is incorporated into the design of the cold room being studied.

1.2 OVERVIEW OF DISSERTATION

This dissertation is organized as follows:

Chapter 1: Covers a brief history of refrigeration and the overview of the dissertation

Chapter 2: Includes some background information on Ammonia and Freon refrigeration systems. A comparison is made to show which is more feasible in the application of industrial cold rooms.

Chapter 3: Details the preliminary stages of industrial cold room design. This chapter discusses physical attributes, legal or governmental forces, social factors and economic forces.

Chapter 4: Based on the article "Economical and Effective Cold Storage Design", this chapter will discuss about the important elements of cold storage design.

Chapter 5: The process layout of the industrial cold room is described here.

Chapter 6: Various protection seals are compared and the factors leading to its selection is detailed.

Chapter 7: This chapter lists the scope of services offered by the architectural department, the civil and structural department, and the quantity surveying department.

Chapter 8: This is where the problems are identified and detailed.

Chapter 9: This chapter deals with the loss of energy caused by open cold storage doors. The current technologies are discussed and solutions to the problem are worked out.

Chapter 10: This chapter deals with finding a way to minimize energy costs by turning off the door frame heaters and turning it back on when necessary, as opposed to have the door frame heaters turned on 24 hours every day.

Chapter 11: This chapter deals with reducing the number of defrosts scheduled. The "defrost on demand" function is an integral part of the solution and is described here.

Chapter 12: The proposed design for a ground heater is detailed here. This is the solution for eliminating the formation of ice in the ground insulation layer.

Chapter 13: Concludes the dissertation and suggests further work for the air blower concept for cold storage doors.

Chapter 2

AMMONIA AND FREON SYSTEMS

2.1 AMMONIA REFRIGERATION SYSTEM

Ammonia is a compound with the formula NH_3 and it is normally in the form of a gas with a pungent odor. Exposure to concentrated amounts of gaseous ammonia can result in lung damage and death, this is the reason the U.S. Occupational Safety and Health Administration (OSHA) has set an exposure limit of 15 minutes for 35ppm by volume in the environmental air and an exposure limit of 8 hours for 25ppm by volume. Uses for ammonia include the production of fertilizers, explosives and synthesizing organitrogen compounds.

Ammonia is in the form of a colorless gas with a pungent smell equivalent to human urine. The gas has a density 0.589 times that of air and is easily made into a liquid because there is the strong hydrogen bonding between molecules. Liquid ammonia has a boiling point of -33°C and must be stored under pressure or at low temperatures. Ammonia solidifies at -77.7°C into white crystals.

Ammonia is widely used in refrigeration because of its thermodynamic properties; however, gaseous ammonia is toxic and corrosive to copper alloys. Even with a miniature fridge, more than a kilo of ammonia is needed, thus emerging a present risk of an escape bringing risk to life. In practice, there is an extremely small risk of ammonia escapes and so there is no control on the use of ammonia refrigeration in densely populated areas and buildings in almost all jurisdictions in the world (Wikipedia.org)

During the first world and third world times, ammonia was used for miniature and multifuel fridges i.e. minibars and caravan fridges. These ammonia absorption cycles are driven by temperature differences and the energy efficiency of such refrigerators are relatively low. Instead of the ammonia absorption cycle, solid state thermoelectric cooling is used in today's smallest refrigerators.

Ammonia continues to be used in large industrial processes such as bulk ice making and industrial food processing. It is becoming more widely accepted as a refrigerant because of the implications of haloalkenes being major contributors to ozone depletion.

A diagram of a typical ammonia refrigeration system is included in Appendix D.

2.2 FREON REFRIGERATION SYSTEM

Chlorodifluoromethane or difluoromonochloromethane is a hydrochlorofluorocarbon (HCFC). It is widely known under the code names of HCFC-22, R-22, Genetron 22 or Freon 22. Freon is a trade name for a group of chlorofluorocarbons used primarily as a refrigerant. “Freon” is a registered trademark belonging to DuPont. It is used in air conditioning applications i.e. residential split systems in the US, rooftop units and window air conditioners.

CFCs are compounds containing chlorine, fluorine and carbon only. They were used formerly used widely in industry as refrigerants, propellants and cleaning solvents. The Montreal Protocol has prohibited regular use of CFCs because the compound has a strong effect on the Ozone layer. HCFCs are a class of haloalkanes where not all hydrogen has been replaced by chlorine or fluorine. HCFC is used as a substitute for CFC because the ozone depleting effect is only 10% of the CFCs.

Freon was first used as an alternative to the ozone depleting CFC-11 and CFC-12, but later was found to be not environmentally friendly enough even though the its ozone depletion potential is among the lowest for chlorine-containing haloalkanes.

2.3 COMPARISON AND CONCLUSION

The choice between ammonia and Freon is determined based on many factors. These points are summarized in the following table.

Table 2.1 Comparison of refrigeration system for respective cold room components

No.	Features		Ammonia	Freon (R-22)
1	Compressor type		Heavy Duty Industrial	General Commercial
2	System piping		Steel – Heavy Duty	Copper – Light Duty
3	Degree of leakage detection		Easily identified by smell	Not easy to detect
4	Long term maintenance		Low maintenance	High maintenance
5	Environmentally friendly		Natural by-product	Man-made and banned in Europe
6	Cost per kg (for 1 cylinder)		1.80MYR	6.25MYR
7	Condenser type and c		Evaporative	Water/Air Cooled
8	Condensing temperature (CT)		+ 38°C	+45°C to +50°C
9	Condenser operating costs		Relatively lower	Relatively higher

The cost of Freon (R-22) is expected to rise in the near future because of its impact on the ozone layer. In Malaysia, the Ammonia Refrigeration System is used by most major plants such as KFC Food Processing Plant, Dindings Poultry, Carlsberg, Anchor Beer, IGLO and so on.

Chapter 3

PRELIMINARY STAGES OF DESIGN

Before a cold room is even designed, consideration must be made to the piece of land it will be built upon. Analyses must be made to see if the piece of land is feasible or not for the construction and operation of an industrial cold room. According the article titled "Estimating Land Values" [2], we can see that there are numerous principles and methods of land assessment; however, for this paper, only an overview will be provided. The factors that contribute to land value will be as shown below:

3.1 PHYSICAL ATTRIBUTES:

- Quality of location, fertility and climate;
- Convenience to shopping, schools and parks;
- Availability of water, sewers, utilities and public transportation;
- Absence of bad smells, smoke and noise;
- Patterns of land use, frontage, depth, topography, streets and lot sizes.

[2] Estimating Land Values, by Ted Gwartney, Arden, Delaware, July 1999

3.2 LEGAL OR GOVERNMENTAL FORCES

- Type and amount of taxation
- Zoning and building laws
- Planning and restrictions.

3.3 SOCIAL FACTORS

- Population growth or decline
- Changes in family sizes
- Typical ages
- Attitudes toward law and order
- Prestige and education levels

3.4 ECONOMIC FORCES

- Income levels
- Growth and new construction
- Vacancy and availability of land

Chapter 4

THE ELEMENTS OF COLD STORAGE DESIGN

An article titled "Economical and Effective Cold Storage Design"[3] provides insight on the design fundamentals of such a structure. It is written by John Bowater of FJB Systems, a corporation that specializes in cold storage and design management. Designing an industrial cold room has many layers and aspects of design. This article will be referred to give an overview on the planning and design of such a structure.

[3] Article website link: http://www.fjb.co.uk/contenteconomicalcoldstoragedesign.htm

Firstly the process layout should be determined after a business plan has been decided upon. The design of the cold room can then be determined after the process design has been confirmed. There are numerous elements involved in designing a cold room, these elements are as follows:

- Structural support systems
- Floor Design
- Vapor Sealing
- Insulation panel types
- Refrigeration Systems

4.1 STRUCTURAL SUPPORT SYSTEMS

There are two types of structural support systems specified in John Bowater's article. These support systems are explained in detail as follows:

4.1.1 EXTERNAL STEELWORK

- The panels are protected from the weather permanently.
- Exposed sheeting is subject to temperature variations from day to night, resulting in expansion and contraction effects. These will cause vapor leaks.
- Panels that are exposed to the sun will have to be light colored so the temperature on the surface will be reduced.
- This system is more versatile.
- More conventional and easier to construct.

4.1.2 INTERNAL STEELWORK

- Saves capital cost.
- It uses a smaller area of land, which is useful when the cost of land is very high.
- It is a more complicated structure to construct, therefore it is more expensive.
- Can be integrated with the racking steelwork.
- Complications will arise when there are two rooms with different temperatures i.e. -20°C and +10°C. This is because the rooms are separated by steel and there will be a loss in energy as it is transferred from one portion of steel to another.
- Even at sub-zero temperatures, the internal steelwork system will not experience much corrosion, unlike its external steelwork counterpart.
- The problem of roof space condensation is solved

4.2 FLOOR DESIGN

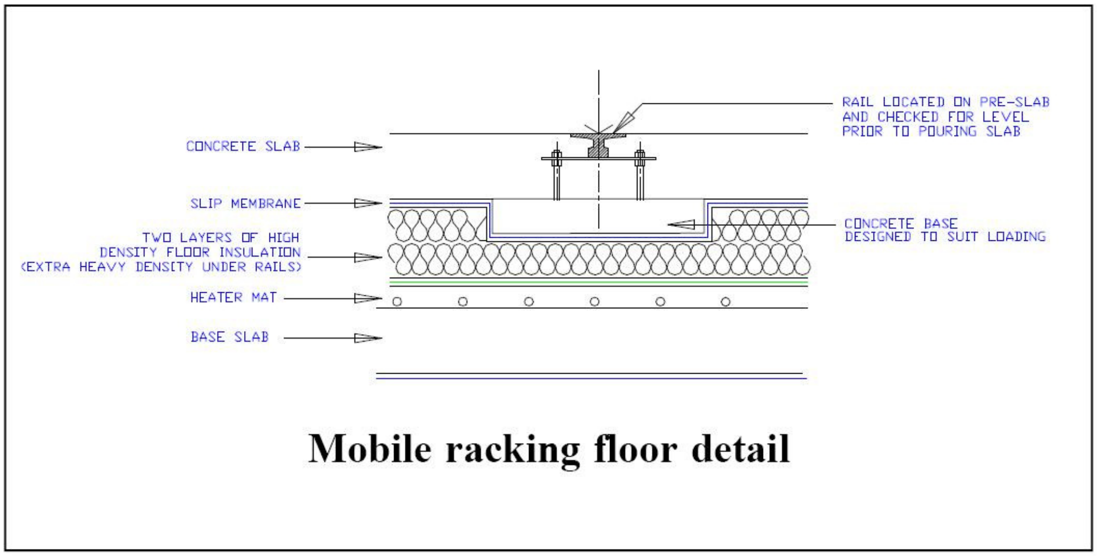

Figure 4.1 Cross section of mobile racking floor detail

The above sketch taken from the article shows a typical floor that is suitable for -25°c operation with mobile racking using high density Styrofoam of 150mm thickness. According to the article, the floor must be designed to take the heavy floor loads of racking and fork lift use. An electrical heater mat will be installed between the insulation and the concrete base slab. The heater will be able to prevent cold from penetrating the subsoil. A floor vapor seal, discussed in the following section, is placed directly above the heater mat. The final floor finish will be at least 150mm thick high specification reinforced concrete.

In areas where the climate is warm, it is more economical to use built-up loading banks so the infill under the cold store can be serviced with a succession of air pipes. These pipes will be placed at an angle so that air movement and consequential under floor heating can be encouraged.

4.3 VAPOR SEALING

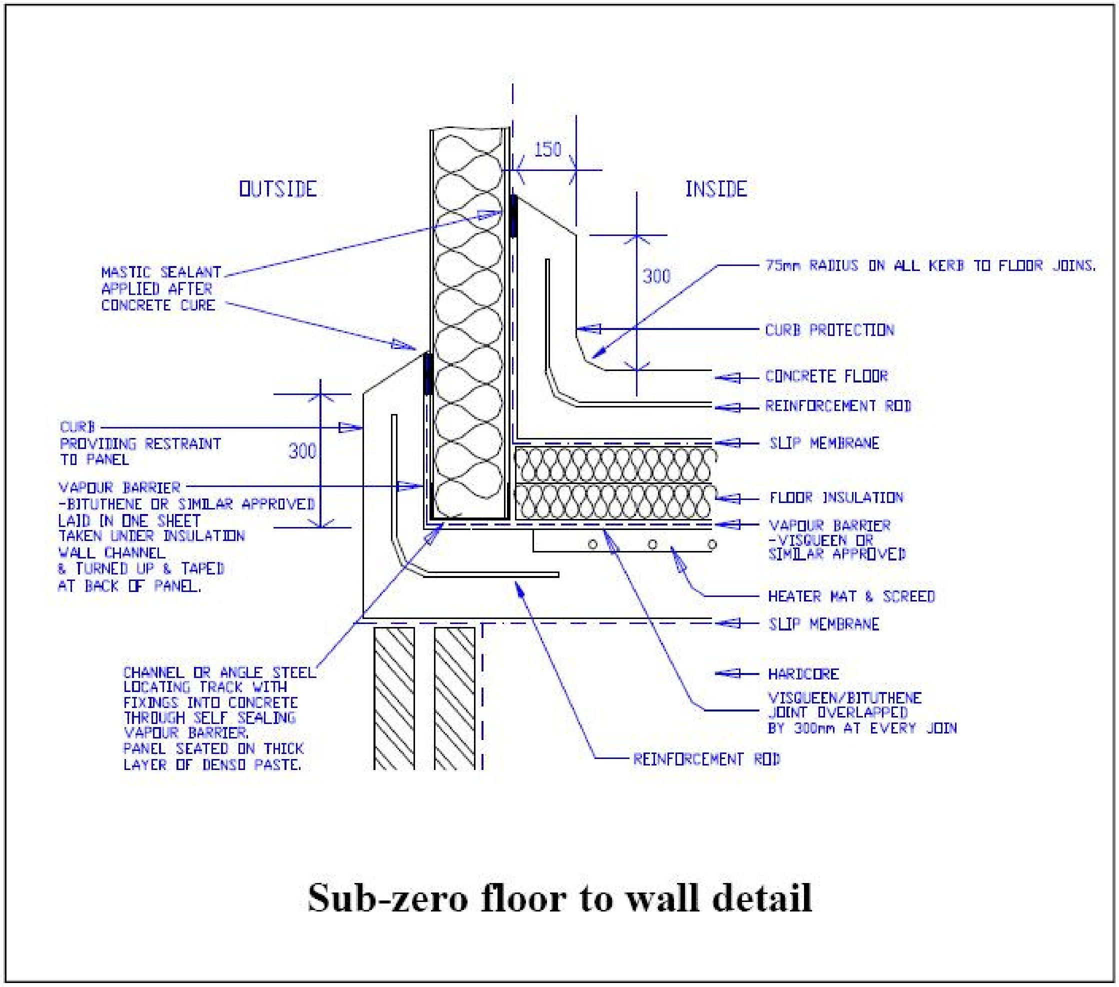

Figure 4.2 Cross section of sub-zero floor to wall detail

For an operation to be successful for the long-term, it has to be ensured that every joint of the paneling and every penetration is water and vapor tight. The figure above is taken from the article and shows the necessary aspects of design. Penetrations are required for evaporator supports and electrical wiring and refrigeration pipes. The optimum solution for this is to bore out a large enough hole in the panel, where the wires are sleeved with a PVC sleeve. All the relevant wiring will go through the sleeve and the penetration will be foamed and sealed with mastic together with an appropriate end cap.

4.4 INSULATION PANEL TYPES

100 mm Thick Panels (Chill Storage use)

Type of Panel	U Value w/m^{20}C	Weight	Installed Cost/m^2 (Approx)	Possible Water Absorp'n
Polystyrene**	0.34	11.2kg/m^2	£30	1.0%
Styrofoam	0.24	13.3kg/m^2	£36	0.5%
Polyurethane*	0.20	13.3kg/m^2	£38	2.0%
Mineral Wool	0.38	19.0kg/m^2	£43	50.0%

** Significant reduction in U value with ageing*

*** Since September 11th 2001 Polystyrene & Polyurethane panels attract highly prohibitive insurance penalties.*

Table from John Bowater's article

The selected cold room utilizes polyurethane panels for its structure. PU is preferred in this case because when compared to PS panels, PU panels have a higher fire resistance. Another factor to consider is the "W rating", which evaluates leakage that might result from water exposure after the product is cured for a specified period of time, approximately 30 days[4]. Different panel thicknesses are used for different parts of the structure.

The article is summarized into the following table.

[4] The "W" Factor, Bill McHugh and Mike Dominguez. (http://www.insulation.org/articles/article.cfm?id=IO050606)

Table 4.1 Advantages and disadvantages of different insulation panels

INSULATION TYPE	ADVANTAGES	DISADVANTAGES
Polystyrene	Most commonly used since the middle 1960's. More economical to erect. Lighter than the other materials	-
Styrofoam	Has a higher load bearing characteristic. Mainly used in cold store floors.	-
Polyurethane	Has a better "U" value. Mainly used on the European Continent.	Expensive. 15% deterioration occurs after around 10 years of usage.
Mineral Wool	Used in high fire risk situations.	Not cost effective for cold store construction, except for special fire wall requirements. Its water absorption characteristics can cause excessive ice formation and weight increase in the event of a vapor leak.

4.5 REFRIGERATION SYSTEMS

John Bowater's article describes this section as the "heart of a cold storage complex". There are three refrigeration systems specified in the article, and they are summarized as follows:

Table 4.2 John Bowater's comparison of different refrigeration system types

REFRIGERATION SYSTEM TYPE	NOTES
Direct Expansion DX "Freon" systems R22 (or substitute); R134a: Freon mixtures	For small cold store boxes. Low in capital cost and meets operational requirements.
Pumped refrigerant systems R11 (or substitute); NH3	Used for larger plant servicing cold stores (approx. 200'000 cubic feet and upwards).
Pumped NH3 with secondary refrigerant (Glycol)	Used if the operator is forced to abandon a pumped system due to alleged safety reasons.

It is important for the project requirements to be defined via detailed drawings and specifications before tendering. If these requirements are not defined, a contractor will have to quote for a plant that has the lowest first cost so that his business will be kept in operation, the client will bear the responsibility when the cold room fails.

Chapter 5

THE PROCESS LAYOUT

Before the actual designs are determined, the process layout is the first step to consider. The process layout of the selected cold room has a special concept. This concept, called the “No Break in Cold Chain”, is described in the company profile as an “integral part” of their services.

5.1 NO BREAK IN COLD CHAIN

The “no break in cold chain” concept maintains its quality of products throughout the transfer, there will not be any loss in energy, or in simple terms, a drop in temperature from the receiving point until it reaches the end of the supply chain. In this industrial cold room, products are stored in temperature levels ranging from +15°C to -28°C.

The following diagrams, taken from the Haisan company profile, show the process layout is. It shows the input and output of products, or pallets, from the cold room:

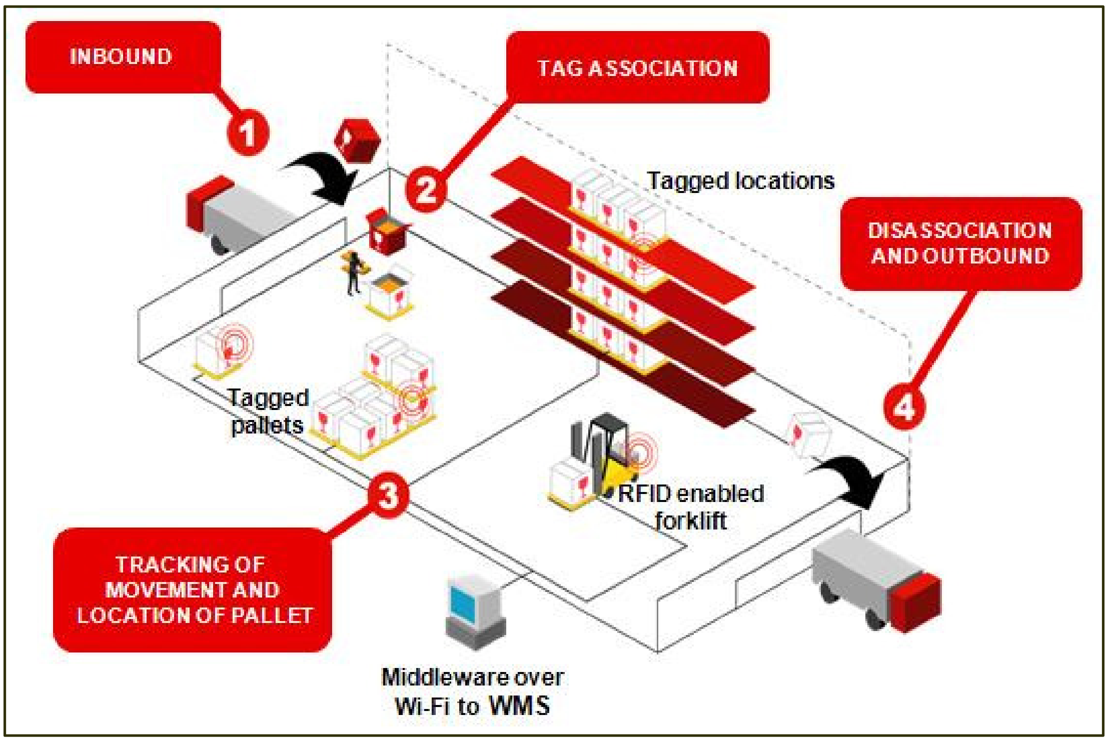

Figure 5.1 Process layout of the industrial cold room.

From the figure, the method on how the products will be transferred into the building, how it will be maneuvered around and how it will be retrieved can be observed. After the process layout has been determined, only then can the design of the cold room be worked on and specified.

5.2 PROCESS STAGES

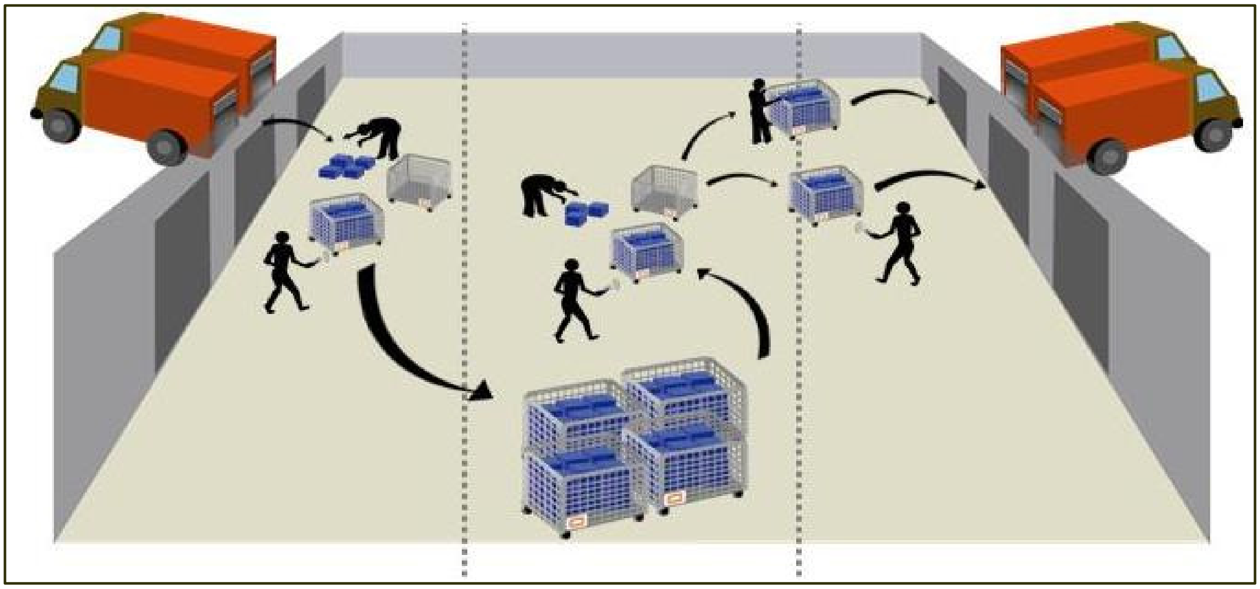

Figure 5.2 The remote-online compressor control system

What is shown above is another diagram on the input and output of products. There are three stages involved: (from the left to right) inbound, transit and outbound.

In the inbound stage, the suppliers send their products to the warehouse for sorting and delivery to the client. These products are stored in cages with RFID (Radio Frequency Identification) tags, where the information of the products is contained. In the transit stage, the products that are required by the clients are transferred to the respective delivery cages. The cages are kept in the storage area while waiting to be delivered. At the outbound stage will ensure that the tags are tallied so that consistency and accountability will be maintained.

The following diagram contains photographs showing the process of the product-flow from the receiving of products all the way to the final delivery.

Figure 5.3 No break in cold chain diagram

Chapter 6

PROTECTION SEALS

6.1 BACKGROUND

Refrigerated products must be transferred into the cold room with minimal contact with the air temperature. This brings forth the need to have a cross docking facility where the pallets are transferred from a cold environment to another. The following is the list of products from Atmoseal, a corporation that specializes in dock facility environmental protection seals.

Table 6.1 Comparison of different seal models, features and capacities.

MODEL	FEATURES	CAPACITIES	PHOTOGRAPH
Series V14/V18/V22 Adjustable Header Inflatable Seal	It is an ideal solution to eliminate potential wall damage. The unique sealing process seals effectively and completely even if the trailer is off centre	It is designed for door openings up to 8'W x 10'H and will service a wide variety of different trailer heights.	
Series 0101 Fixed Head Pad Truck Dock Seal	It is the most economical way to form an air-tight seal. The resilient foam pads covered with tough abrasion resistant fabrics create a tight seal.	It is designed for door openings up to 8'W x 8'H and will service vehicles of a generally standard size.	
Series V-1024 Inflatable Truck Dock Shelter	This provides the optimum solution where a fixed frame shelter is not feasible and a variety of different height and width trailers are serviced. It is uniquely designed to provide complete access to the trailer openings and ideal for problem dock areas such as sloped and difficult driveway approaches.	It is designed for door openings up o 10'W x 10'H	
Series 0201 Adjustable Curtain Truck Dock Sea	It is an economical way to form an air-tight seal where doors are over 9' in height and/or the trailers are of varying heights. The split head curtain allows adjustment after the trailer is in position, by means of rope and pulley assembly.	It is designed for door openings up to 8'W x 10'H	

Series 0401 Stationary Truck Dock Shelter	This series allows a complete and unobstructed access to the full width and height of the trailer interior and shipping door while providing outstanding weather protection. The sides and top are covered with rigid translucent plastic, while a tight seal is maintained through spring like fiberglass built into the side and top curtain as well as a foam bead at the leading edges.	It is designed for door openings up to 10'W x 10'H	
Series 0401A Inflatable Truck Shelter	This series eliminates wear and tear normally found on standard truck shelters. It provides an air-tight seal around a wide range of different width and height trailers. Super Seal's exclusive "RipStop" fabric developed specifically for inflatables will give you years of trouble free service.	It is designed for any size door opening	
Series 0501 Retractable Truck Shelter	It is designed to retract upon impact. Its collapsible scissor arms are spring loaded keeping the shelter in a projected position. When compressed by an incoming trailer, the panels create an air-tight seal. It is very effective where the driveway approach is difficult.	It is designed for door openings up to 10'W x 10'H	
Series 0601 Retractable Truck Shelter	The series is designed to provide an air-tight passage way from the loading dock to railcar doors. When the spring loaded shelter is released it automatically extends and seals itself against the railcar. When not in use it is manually retracted up against the building wall protected from moving railcars and wind	It is designed for door openings up to 10'W x 10'H	

6.2 SELECTION

The product that will be used in the cold room will be based on the following factors:

- Price

  The product with the lowest cost and, at the same time, being able to fulfill the requirements and functions of the building structure will be preferred in terms of pricing.

- Door opening size

  The door opening size will have to be able to cater to the various sizes of the local trailers and lorries.

- Availability of spare parts

  In the unfortunate event where the machine breaks down, it has to be serviced in the shortest time possible so the disruption of the flow of operation will be minimized.

The one that is used for this particular cold room is the V-1024 Series. By having a 10’W x 10’H door opening, it is able to accept the pallets being that is being transported by local lorries. This particular series is also good in the sense that it can be used in sloped areas with difficult driveway approaches, thus making this a versatile product that is efficient in most situations.

Chapter 7

SCOPE OF SERVICES

When the cold room design decided upon, it goes through a series of services. These services range from architectural services, civil and structural services and quantity surveying services

7.1 ARCHITECTURAL SERVICES

7.1.1 SCHEMATIC DESIGN PHASE

The Client's instructions are taken and the project brief is analyzed. The consultancy firm will then prepare layouts and preliminary conceptual sketch proposals to interpret the project brief. These sketches are developed into sketch designs to a stage that enables an application to be made for conversion and planning approval in principle to comply with relevant by laws. The firm then seeks the approval of relevant authorities by submitting the drawings and other necessary documents

7.1.2 DESIGN DEVELOPMENT PHASE

Once the proposal have been approved by the relevant authorities or the client, the drawings are then developed to a stage that enables other consultants to start detailed design works, which is then submitted to obtain statutory building approval

7.1.3 CONTRACT DOCUMENT PHASE

Once the client has approved the updated estimates of construction cost and the planning and implementation schedule, the detailed drawings and other details are prepared and finalized to the stage of completion adequate for bills of quantities to be prepared by an independent quantity surveyor. On behalf of the client, the firm then invites tenders for the work.

7.1.4 CONTRACT IMPLEMENTATION AND MANAGEMENT PHASE

The consultancy firm performs the functions and duties of the architect under the terms and conditions of the building contract. Information is provided and instructions issued to the contractor to enable the contractor to proceed with the works. The firm examines the works program submitted by the contractor and must be satisfied that the work can be reasonably completed within the contract period.

The works is inspected to see if it is being executed in general accordance with the building contract. This also enables the architect to certify the completion of the various stages of the work required in support of an application for a certificate of fitness for occupation from the relevant authority.

7.2 CIVIL AND STRUCTURAL SERVICES

Necessary drawings and calculations are prepared for Earthworks Road and Drainage for submission, approval and construction. Sewer reticulation mains and sewerage treatment plant drawings, structural drawings and calculations are submitted. Project meetings and site inspections are attended when required.

7.3 QUANTITY SURVEYING SERVICES

7.3.1 PRE-CONTRACT STAGE

Quantity surveyors will prepare preliminary estimates of the cost of the scheme and establish, in conjunction with the employer, the overall budget. Periodic reviews are made as more information evolves. Advice will be given concerning the following issues:

- Building cost relationship of alternative forms of construction.
- The most suitable procurement method.
- Selection of contractors to be invited to submit offers.
- The most appropriate contract to be used.

The Employer's Requirements documentation is drafted and produced, taking due regard of guidance and brief from the employer. Specialist consultants are liaised and their specifications incorporated. The tender document is prepared, incorporating the performance specifications. On the basis of the employer's requirements, a comparable estimate of the cost of the scheme is also prepared.

Approximate measurement of architectural and structural works are made and incorporated to compare with the bills of tenders received. Tenders are received, reexamined, and contract price is evaluated and analyzed. Suitable recommendations are made based on the assessment of contractor's proposal and advise where these differ from the employer's requirements as stated.

Negotiations are carried out with the selected contractor as to requirement, contract conditions and contract price. Contract sum analysis is verified to avoid early front loading on prices and excessive loading on a particular module. Finally, the contract documentation is produced.

7.3.2 CONTRACT STAGE

The quantity surveyor evaluates the work in progress and makes recommendations for interim payments. The financial effect of changes in the Employer's Requirements and provisional sums are assessed. An agreement is made on the cost with the contractor carrying out any required measurement and on the measured values. The employer is advised on potential claims for loss and expenses received from the contractor, if required, negotiations are carried out. The employer is advised at suitable intervals as to anticipate the final cost. Cash flow forecasts are also provided. The final negotiation is carried out for settlement of contractor's final account and the analysis of the final building cost is prepared for accounting and other purposes.

Chapter 8

PROBLEMS ENCOUNTERED

8.1 LOSS OF ENERGY FROM OPEN COLD STORAGE DOORS

8.1.1 THE PROBLEM

A problem is that there is no way to prevent the loss of cold air when the door is open. The loss of cold air in the cold room will result in the blowers working extra hard in order to counter the rise in temperature. Hot air rushing into the room when the door is open causes the problem of ice forming at the blowers whereas the cold air flowing out causes condensation of water on the floor outside the cold room.

8.1.2 COLD WIND

The heat gradient also causes the phenomena of "cold wind", thus creating discomfort to workers operating in this condition. It is actually more comfortable to be working in an environment where the temperature is low without wind compared to an environment with relatively higher temperature with cold wind. Therefore it would seem essential to provide a means of solving all these problems. The following diagram gives an idea of the problems that are caused when there is a loss of energy caused by the cold room doors.

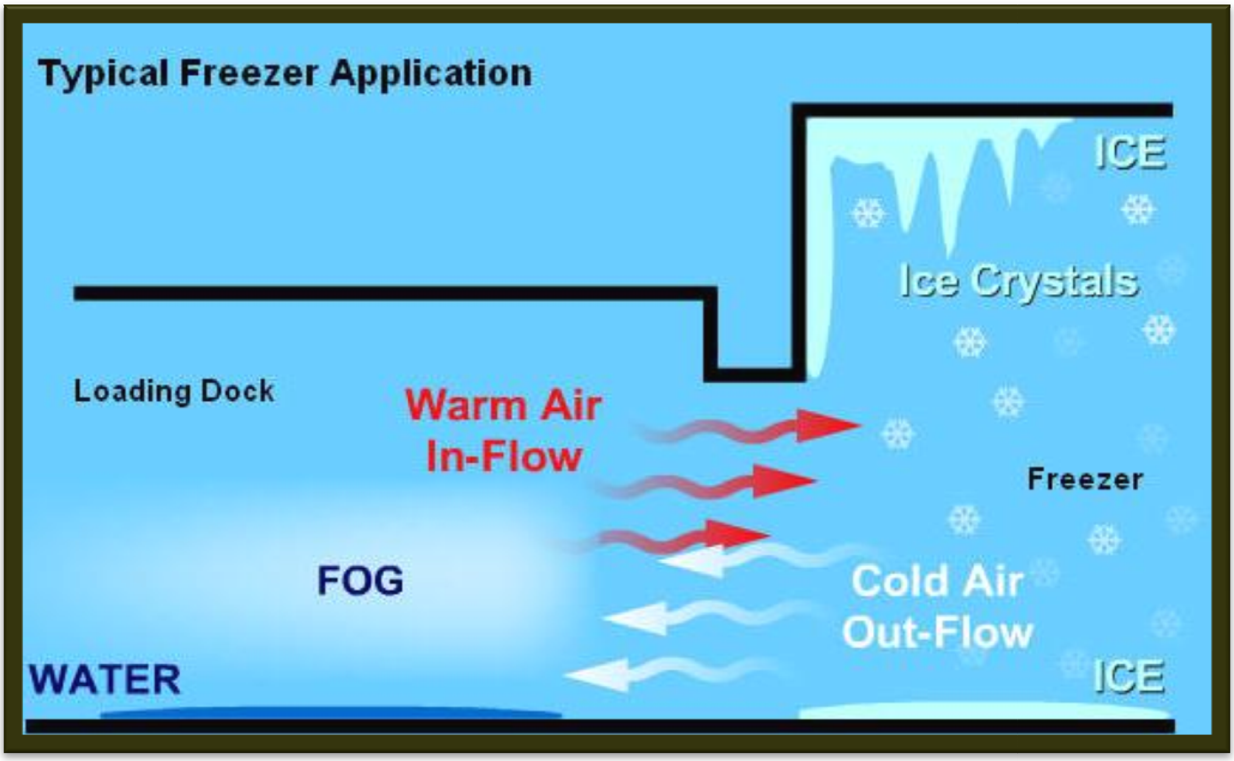

Figure 8.1 Problems caused by loss of energy due to open cold storage doors.

A more thorough elaboration of the problem is detailed in Appendix B.

8.1.3 SURVEY

A survey was carried out during my visit to the cold room. A total of 17 workers were approached and was asked which condition was more desirable –

(a) Relatively warmer environment with cold wind

(b) Relatively colder environment with no wind

The results were inserted into a Microsoft Excel chart and the results are shown:

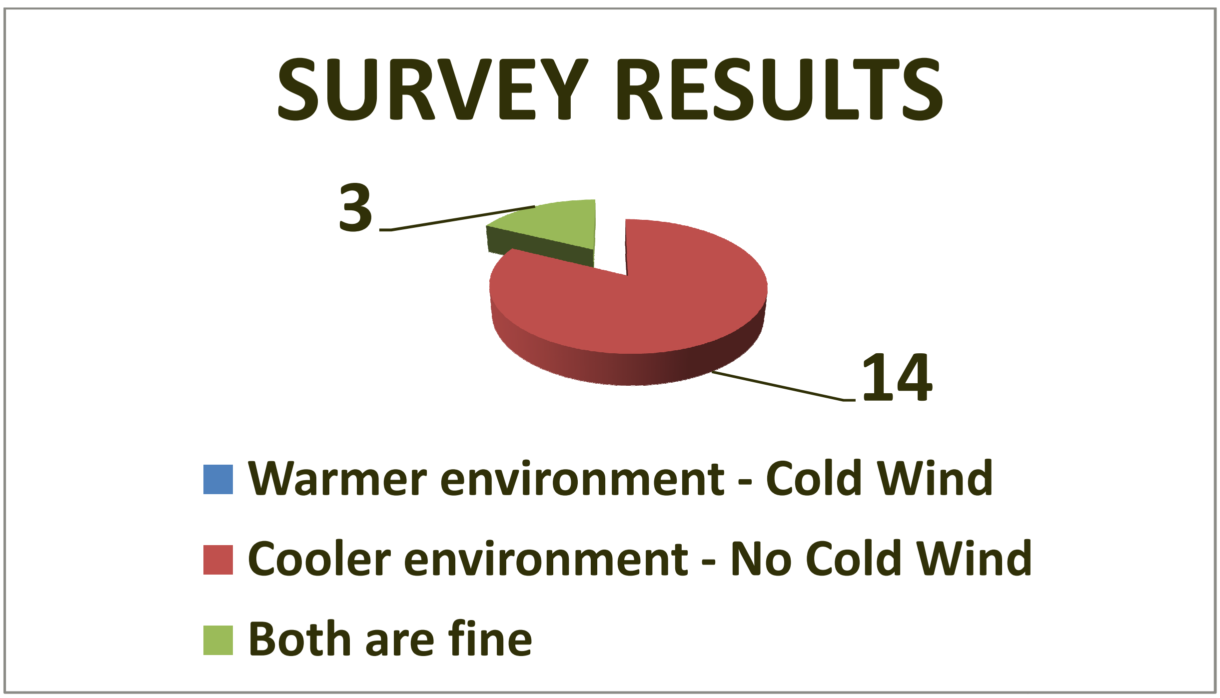

Figure 8.2 Results of survey in pie-chart form.

It can be observed that the majority (82%) chooses an environment with no cold wind with the remaining 18% not having a problem with either condition.

8.2 DOOR FRAME HEATERS

A problem involving the cold storage door used now is that the door heaters have to be switch on for 24 hours to prevent frost from forming. However it comes to question whether or not the heaters are required to be constantly on even at night when there will not be any activities conducted requiring access to the cold rooms and freezer rooms. It is then one of the objectives to determine if operation costs can be reduced by turning off the door frame heaters when they are not in use.

8.3 DEFROSTING SCHEDULE

8.3.1 BACKGROUND

There are times when the air blowers will get blocked by ice. This ice will hinder the cold air from entering the freezer rooms, thus increasing the room temperature significantly. To cope with the drastic temperature difference, the air blowers are required to work harder and this increases operation costs. This is where defrosting comes in as its function is to melt the ice blocking the air blowers.

8.3.2 PROBLEM

There is a fixed schedule for defrosting to take place; however, the schedule does not take into account to condition of the blower prior to defrost. This means that even if the air blower is not blocked by ice, defrosting will carry on. This will increase the operation costs as energy is used up unnecessarily.

8.4 LACK OF GROUND HEATER

During my visit to the cold room, it can be observed that the floor had a bumpy feel to it. This is caused by the accumulation of water vapor in the insulation layer of the flow, resulting in ice forming in that particular layer and resulting in the expansion of the upper layer. Currently not all terminals have ground heaters installed.

Chapter 9

ENERGY LOSS FROM COLD STORAGE DOORS

When the cold room doors are open, there is a loss of energy. This loss of energy causes various issues such as the formation of ice in the freezer room, the formation of water on the outside floor and the increase in operation costs of the air blowers. This chapter will investigate the current methods that are used by the cold room and its advantages and disadvantages. This chapter will also look into the various solutions on minimizing energy loss.

9.1 CURRENT COLD STORAGE DOOR TECHNOLOGIES USED

9.1.1 STRIP CURTAINS

Strip curtains are relatively inexpensive, costing of strips of plastic material. A transparent material is usually preferred as it offers better visibility. Because of its low cost, it is easily replaceable when the need arises. One plus point of the strip curtain is that it gives quick access in and out of the freezer room.

Just as there are advantages, there are also disadvantages associated with the strip curtains. These thin strips of plastic provide a very marginal door seal that allows energy to be lost. Also when there is a temperature difference, the curtains will be fogged up, resulting in obscured vision. This is a hazard as forklifts operate in and out of the room and a person could be hit because neither he nor the operator can see each other.

9.1.2 SLIDING DOORS

The use of sliding doors is widely known in almost every commercial sector. Its design is very conventional and because of that it is economical to purchase and integrate into the structure. When the door is open, it provides good visibility as there is nothing hindering the view.

On the other hand, when the doors are opened, the opening is left unsealed. This leaves the cold air to freely escape from the freezer room, encouraging the loss of energy. Using sliding doors also require a large footprint, using up valuable floor space in the structure.

9.1.3 ROLL UP DOORS

Similar to the sliding doors, roll up doors of a conventional design and is economical to construct. Unlike the sliding doors, however, it only requires a small footprint that does not take up as much floor space.

The disadvantages of the use of roll up doors include the fact that defrosting is required as ice is prone to forming on the mechanism. It is slower in operation because it takes longer to clear the opening compared to sliding doors. This is because the height of the cold room is greater than the width of the door.

A requirement for roll up doors is the need for a sensing edge. This sensing edge is used to detect any objects under the door such as people and objects. Research and testing and shown that the sensing edge has been proven unreliable in harsh cold environments.

9.2 SOLUTION ONE: AIR BLOWER CONCEPT

9.2.1 BACKGROUND

The concept of air blowers at the door has been utilized in shop houses and supermarkets for a long time. These air blowers provide an air curtain which prevents the hot air from entering the shop as well as preventing cold air from exiting. This reduces the power consumption of the air conditioning units in the shop as well as “sealing” the cold air in the shop.

9.2.2 APPLICATION IN THE COLD ROOM

This application in cold rooms takes this concept a step further. There are two blowers instead of one- a hot air blower and a cold air blower. By hot air blower, it actually means that the air is adjusted to be the temperature on the outside, whereas the cold air blower is adjusted to be the temperature inside the cold room. The air blowers are placed on the sides of the door to ensure that the air curtain is always perpendicular to the flow of air besides reducing the normally incurred air vortexes formed with overhead air blowers.

9.2.3 DIAGRAM

The following diagram shows how the air blower concept works. For a more thorough explanation, refer to Appendix C.

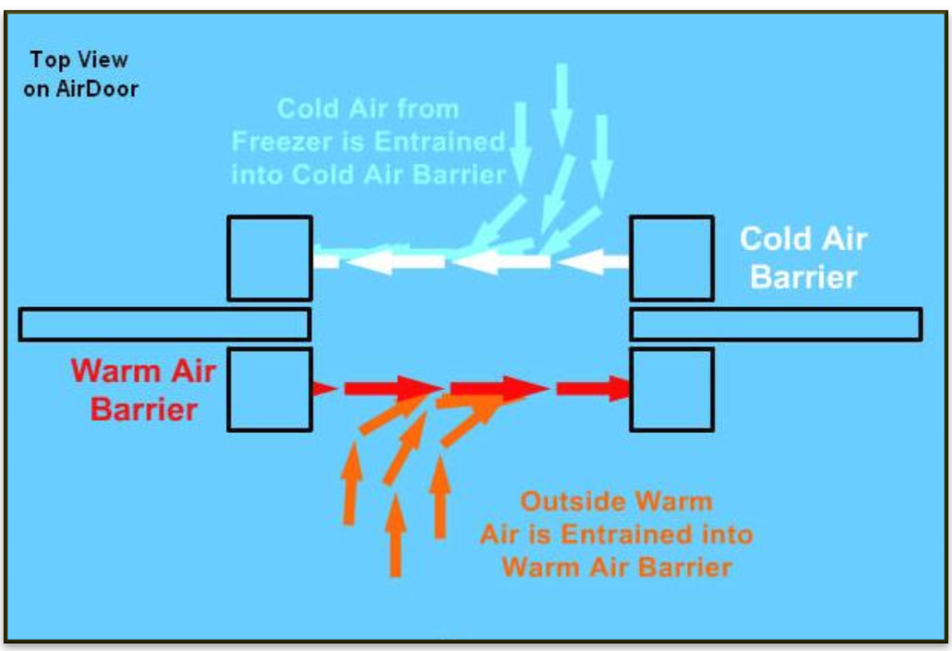

Figure 9.1 Top down cross section view of the cold storage doors with air blower installed

9.2.4 ADVANTAGES AND DISADVANTAGES

With the air blower system, temperatures can be maintained even with the absence of a door seal. The disadvantage of this system is there has to be enough space to place the air blowers on the inside and outside of the door.

Furthermore, there is no online information available to explain what sort of air velocity the air blowers are supposed to perform in order to achieve maximum efficiency as the concept is still new in the industrial sector.

9.3 SOLUTION TWO: THERMAL AIR SEAL

9.3.1 BACKGROUND

A more promising solution is the thermal air seal door. This technology replaces the door frame heater system with a circulated hot air duct system. The concept is similar to the floor ventilation pipe system. Using expandable thermal material, hot air is run through the door frame. This achieves the effect of avoiding frost formation and also seals the small gaps between the door and the wall.

9.3.2 ADVANTAGES AND DISADVANTAGES

The advantage of this system is that it does not require much space and at the same time it is also easier to integrate into the existing system. However, this system does not achieve the effect of reducing the mixing of cold air and hot air when the door is opened.

9.4 CONCLUSION

The methods above may be costly and it is difficult to investigate beforehand what kind of energy savings can be achieved as some are achieved indirectly; however, the air blower concept is the system that is looked into because with this system installed, there will be no loss in energy even if the cold room doors are open, lessening the burden put on the air blowers and ultimately reducing operation costs and improving cold room performance.

Chapter 10

DOOR FRAME HEATERS

10.1 BACKGROUND

Door frame heaters are necessary as it prevents ice from forming around the door mechanism, potentially causing the door to jam and lock up during attempts at opening them. Because of this, the current settings are such that the door frame heaters are operating at 24 hours every day.

This brings the question on whether it is necessary to have the heaters turned on constantly. There are moments of inactivity where the doors will not be operated. Such times include night-time hours where there is no access to the cold room because the staff operation the cold rooms will be at their homes. So it will be investigated to see if the door frame heaters can be turned on just before the doors are required to be operated.

10.2 INVESTIGATION ONE

10.2.1 METHODOLOGY

The aim of the investigation is to observe the formation of ice on the door frame and determine the amount of time that is taken by the heater to melt the ice. The planned procedure is as follows:

- A cold room is chosen on a day when there are no activities in the rooms.
- The door frame heater is switched off different time periods.
- The formation of ice on the door frame is observed.
- After the ice has formed, the door frame heaters are turned on.
- The door is checked every hour until the door can be opened completely.
- The time taken from the time the heater is enabled until the time for the door to open completely is noted down.
- The procedure is repeated a few times.
- The results are averaged to determine the approximate efficiency.

10.2.2 EXPECTED OUTCOME

At the end of the experiment, the duration required for the heaters to fully melt the ice gathered on the door frame after being deactivated for a long period of time. Thus, we would be able to achieve power conservation.

10.2.3 RESULTS

The results are tabulated as shown below:

Table 10.1 Tabulation of results from investigation one.

Attempt	t1 (hour)	t1 (min)	t3 (min)
1.	1	6.3	6.3
2.	2	14.2	7.1
3.	3	21.7	7.233
4.	4	32.4	8.1

Where t1: Time period that heater is off

t2: Time required for ice to melt

t3: Time required for ice to melt for each hour heater is off

10.2.4 CONCLUSION OF INVESTIGATION ONE

The average results of the time required for the ice to melt is 7.183 minutes for every hour the heater is turned off. With this theory, the door frame heaters will only need to be turned for this amount of time prior to the usage of the cold storage doors; however, this is in theory only and is does not reflect on the actual practice. To get more accurate results, another investigation will be carried out with a longer time duration instead of short time bursts.

10.3 INVESTIGATION TWO

In the first investigation, the door heaters were shut off for a short period of time. In the second investigation, the door heaters will be turned off from the time the workers leave the cold room right until the next morning.

10.3.1 METHODOLOGY

The procedure of this investigation is similar to the previous one, only that the time period is much longer:

- A cold room is chosen on the day when there are no activities
- The door heaters are switched off and left overnight.
- Ice is expected to form around the door.
- On the following morning, the door heater is turned on.
- The door is checked hourly until it can be opened completely
- The time taken for the ice to completely melt is noted.

10.3.2 RESULTS

The time heater was turned off:	8:24pm
The time heater was turned back on:	7:40am (following day)
Time duration that heater was off:	11 hours 16 minutes

The time door can be opened completely:	10:00am
Amount taken for heater to melt the ice:	180 minutes
Time taken to melt ice for each hour the heater was turned off:	16 minutes/hour

10.3.3 CONCLUSION OF INVESTIGATION TWO

It can be observed that the time period for melting the ice is slightly more than double that of investigation one when the ice is left to form for a longer period of time. This can be expected because the longer the ice is left to form, the thicker it will be, requiring more energy to completely melt it compared to the earlier investigations.

Theoretically speaking, the door heaters can be turned off during inactivity and turned back on when necessary. For every hour that the heater is turned off, the heater requires 16 minutes to melt the ice. So for example, the door heater has to be turned on 32 minutes before it is required to open if the door heaters have been left off for 2 hours.

However, during this discussion with the supervisors of the cold room, there are complications that arise when the heaters are turned off. This is detailed in the following section.

10.4 COMPLICATIONS

Although it is possible to switch the door frame heater off and then switch it on after a certain period. By doing so, there is the possibility of having a small leakage in the casing that will lead to the accumulation of water vapor in the wiring system. This will cause a short circuit the next time the heater is switched on. This is also the reason the lighting is constantly turned on.

When the heaters are turned on and off, the constant temperature change in the heater coil means more frequent maintenance work to ensure the heaters continue to run smoothly. This creates extra costs in labor, repairs and replacement parts.

10.5 CONCLUSION

Unfortunately, it is necessary to have the door frame heaters turned on constantly as the costs of maintenance will overshadow the operational costs saved.

Chapter 11

DEFROSTING SCHEDULE

As mentioned in section 7.3, the schedule for defrosting the air blowers are set regardless of whether the air blowers need to be defrosted or not. This chapter will detail the solution on how this problem can be overcome with the use of two sensors located in strategic locations of the air blower.

11.1 DEFROST ON DEMAND

It is suggested that the function of “Defrost on Demand” be enabled to cut on the energy costs. The basis of this function is to reduce the number of defrosts scheduled. What this feature does is that, when employed, defrosting will only carry out when the need arises such as when the air blower is blocked by ice.

11.2 USE OF SENSORS

Defrost on demand can be carried out through the usage of two sensors, S1 and S2 for example, where S1 is positioned at the air inlet of the blower and S2 is positioned in the air outlet of the blower. The sensors can be programmed to determine if there is a big difference in the temperature.

11.3 EXPLANATION

Under normal conditions, the change in temperature is within 1°C to 2°C. When ice forms and blocks the blower, the temperature difference will be significantly larger (5°C-6°C). When it is time for defrosting, programmed and scheduled, the Emerson Controller will check sensors S1 and S2 to determine if defrosting is required. Where the temperature difference is small, defrosting will be skipped; conversely, where the temperature difference is large, then defrosting will commence as required.

11.4 CONCLUSION

By using the *Defrost on Demand* function, this will ultimately cut on energy costs. The use of two sensors at the inlet and outlet of the air blowers will detect the change in temperature and defrost accordingly. This will cut down on operational costs as the defrost function is utilized sparingly.

Chapter 12

GROUND HEATER

In section 7.4, it was mentioned that the floor surface was uneven and bumpy. This was a result of the formation of ice in the insulation of the floor. The reason this occurs is that there is no way to eliminate the water vapor that forms in the floor. This chapter will detail the solution on how this problem can be eliminated.

12.1 PROPOSED DESIGN

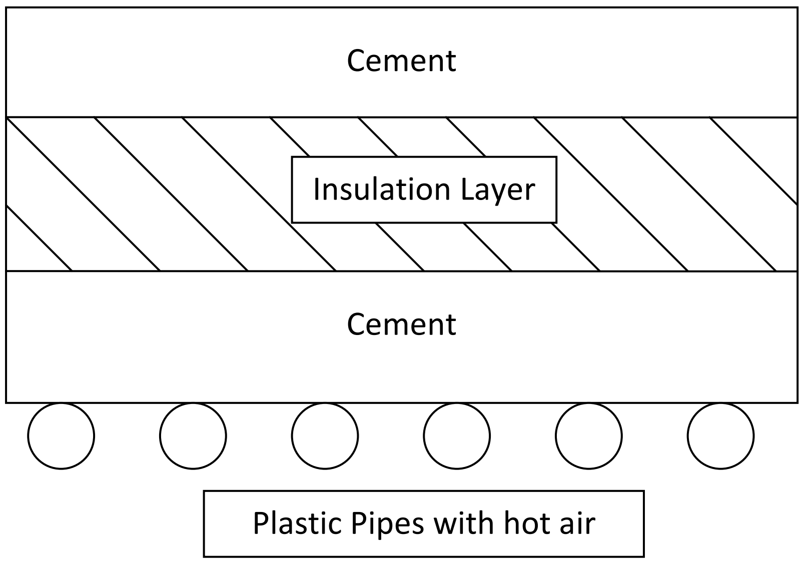

Figure 12.1 Cross section of flooring with ground heater

As shown in the diagram above, it can be observed that the proposed design has pipes running under the cement floor. A separate air blower will be installed and used to pump hot air through these pipes. This will prevent the water vapor from condensing and forming into ice, thus eliminating the problem of a bumpy floor surface.

12.2 LIMITATIONS

Because of the cold room is already up and running structure, it was not possible to run any simulation tests to determine of the said solution. But based on the design mentioned in section 4.2, it is a sound solution that has been agreed upon with my supervisors.

12.3 CONCLUSION

To install this into the current floor system is impossible as the whole floor has to be removed for the pipes to be installed underneath, which is not a feasible approach at all. What has been done is that this design has been submitted and is awaiting approval. It is noted that new cold rooms be constructed with ground heaters

Chapter 13

CONCLUSIONS AND FURTHER WORK

13.1 ACHIEVEMENT OF PROJECT OBJECTIVES

Throughout the course of the Research Project, the following objectives have been addressed:

13.1.1 DESIGN PROCESS OF INDUSTRIAL COLD ROOM

In the first few chapters, the fundamental design process of the industrial cold room was detailed. This gives some background information on the construction process of the structure. Due to the nature of this research paper, what is covered is only a small percentage of the total design.

13.1.2 COLD STORAGE DOORS

The loss of energy can be eliminated with the integration of the air blower concept. Air temperatures in the respective cold room can be maintained with the air curtain even though there is no door seal.

13.1.3 DOOR FRAME HEATERS

The optimum time was determined for the door frame heater to melt the ice. However because of the extra complications that may arise from turning the heater off, it was decided that the door frame heaters should be left on.

13.1.4 DEFROSTING SCHEDULE

The number of defrosts scheduled was lowered drastically because with the use of the two sensors, defrosting will only be carried out when necessary. This reduces operation and energy costs significantly.

13.1.5 GROUND HEATER

The proposed design for the ground heater is still undergoing approval. It is not feasible to install it into the current cold room, but recommended that ground heaters be installed when new cold rooms are being constructed

13.2 FURTHER WORK

There is much work left to be done that has not been able to be covered in this research project. The concept of the air curtain is new in terms of application for industrial cold rooms. I would commend that this be investigated in further detail. Data is required for optimum settings of the air blower to perform efficiently. Parameters that might be looked into include the air velocity, air temperature, mass flow rate, and so on.

REFERENCES

ARTICLES AND DOCUMENTATION

Bowater, John (1996), '*Economical and Effective Cold Storage Design'*

Draften Holdings Sdn. Bhd., '*Scope of Services'*

DuPont Fluoroproducts, (2004), '*Freon R22 Thermodynamic Properties'*

DuPont Fluoroproducts, (2007), 'R-22 Outlook, planning now for changes in refrigeration and air conditioning'

Ted, G & Arden, D, (1994), 'Estimating Land Values'

INTERNET

ATMOSEAL Dock Facility Environmental Protection Seals
http://www.loadmaster.com/ss_dk_sl.htm

Building a Cold Room
http://www.klob.org/articles-ColdRoom.htm

Cold Storage Doors from Edey Manufacturing

http://www.edeydoors.com/

Cold Storage Doors by Rite Hite

http://www.ritehite.com/ark/rhweb/rhprod.nsf/vProdCategories/Cold+Storage+Doors!OpenDocument

Economical and Effective Cold Storage Design

http://www.fjb.co.uk/contenteconomicalcoldstoragedesign.htm

Highbeam Encyclopedia, Refrigeration

http://www.encyclopedia.com/html/r/refriger.asp

InsulAir Cold Storage Air Door System

http://www.randallmfg.com/airdoor/index.html

New SOM/Academic Building Construction Effects

http://my.simmons.edu/archives/2006/06/new_somacademic.shtml

The "W" Factor, Bill McHugh and Mike Dominguez.

http://www.insulation.org/articles/article.cfm?id=IO050606

Wikipedia, '*Ammonia Refrigeration*'

http://en.wikipedia.org/wiki/Ammonia

Wikipedia, '*Haloalkene*'

http://en.wikipedia.org/wiki/HCFC

Appendix A

PROJECT SPECIFICATION

Appendix B

ENERGY LOSS ELABORATION

In this appendix, a step by step diagram will outline the problems that are caused by the loss of energy when the cold room doors are opened.

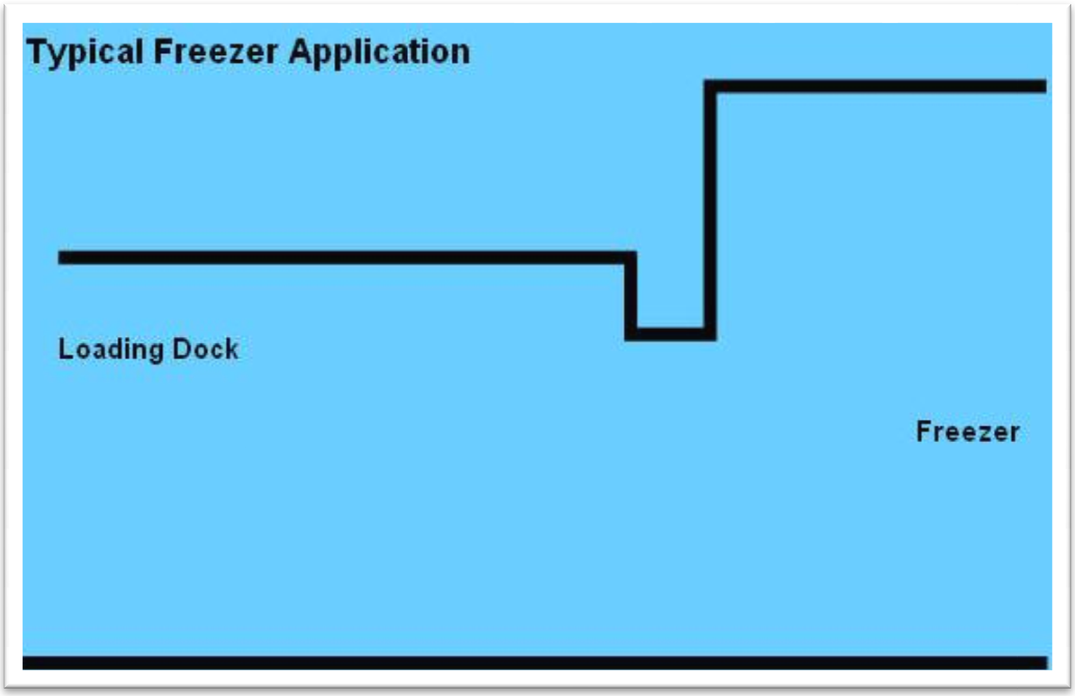

Figure B.1 Cross section of loading dock and freezer

This diagram shows the cross of section of the loading dock and the freezer room with the cold storage door being open. The following figures will show the complications that arise when energy is lost.

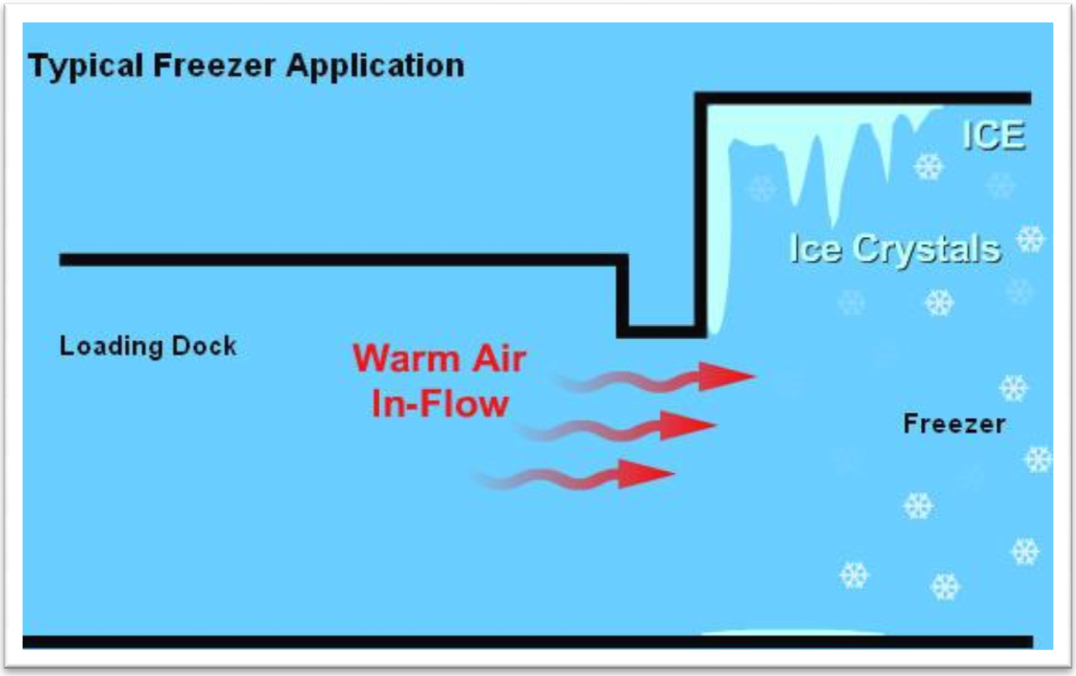

Figure B.2 Problems caused by warm air in-flow

We observe that when the relatively warmer air flows into the freezer room, ice crystals are formed on the ceiling. Furthermore, there will be ice being formed on the ground. The ice that is formed on the ceiling has the potential of blocking off the air blowers, increasing the overall temperature of the freezer room and thus causing the air blowers to overwork. This ultimately will increase energy costs.

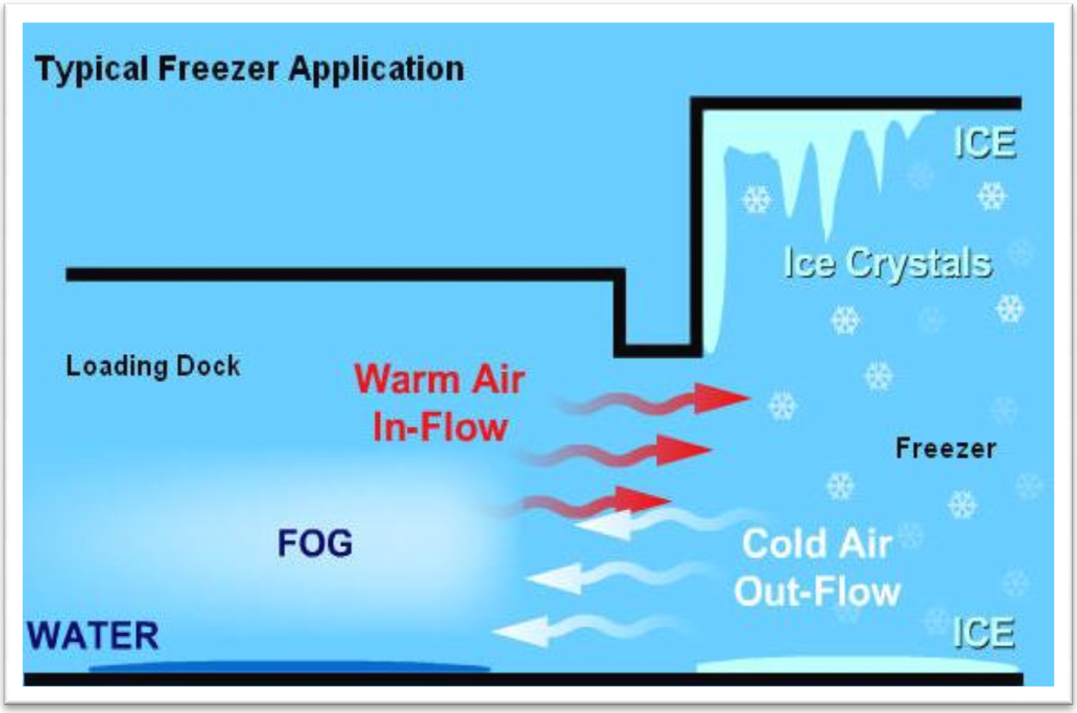

Figure B.3 Problems caused by cold air out-flow

As the cold air from the freezer room escapes into a region of warmer air temperature, water condenses and creates fog. This fog will obscure the views of the workers and might pose a hazard if forklift operators cannot see where they are going. Note that water will form on the floor area and might cause the workers to slip and injure themselves.

Appendix C

AIR BLOWER ELABORATION

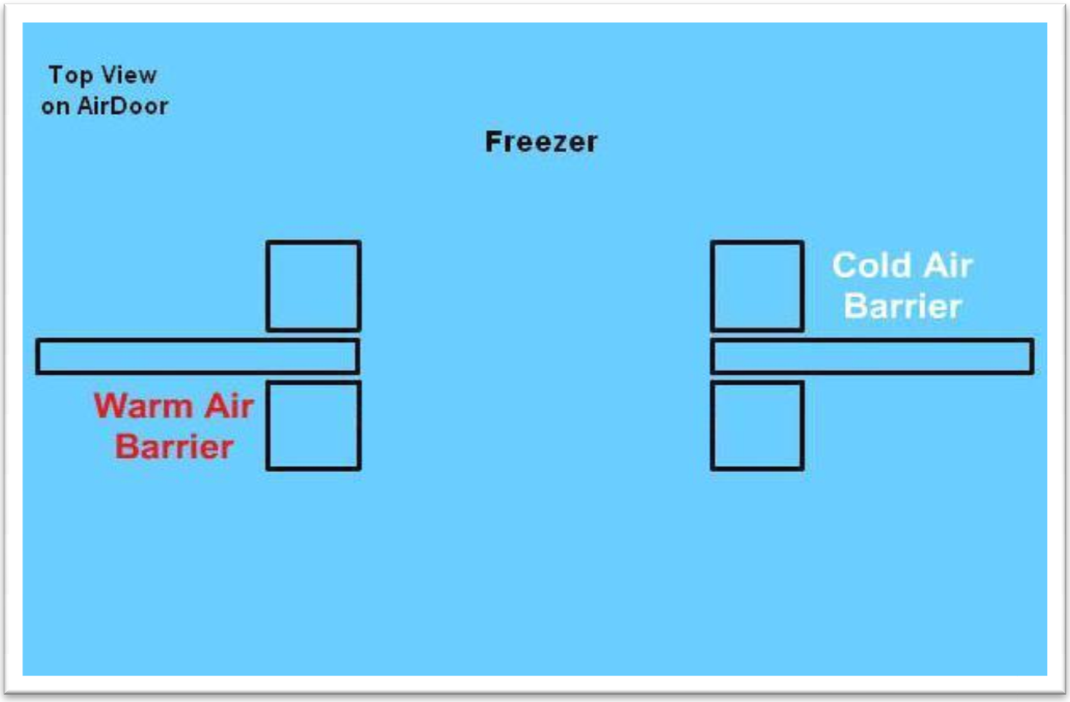

Figure C.1 Top down view of the air blower concept.

This is the top down view of the cold storage doors. Note that there is a warm air blower on the side of the loading dock and the cold air blower on the side of the freezer room. The following diagrams will show how the air blower will create an air curtain to eliminate the loss of energy.

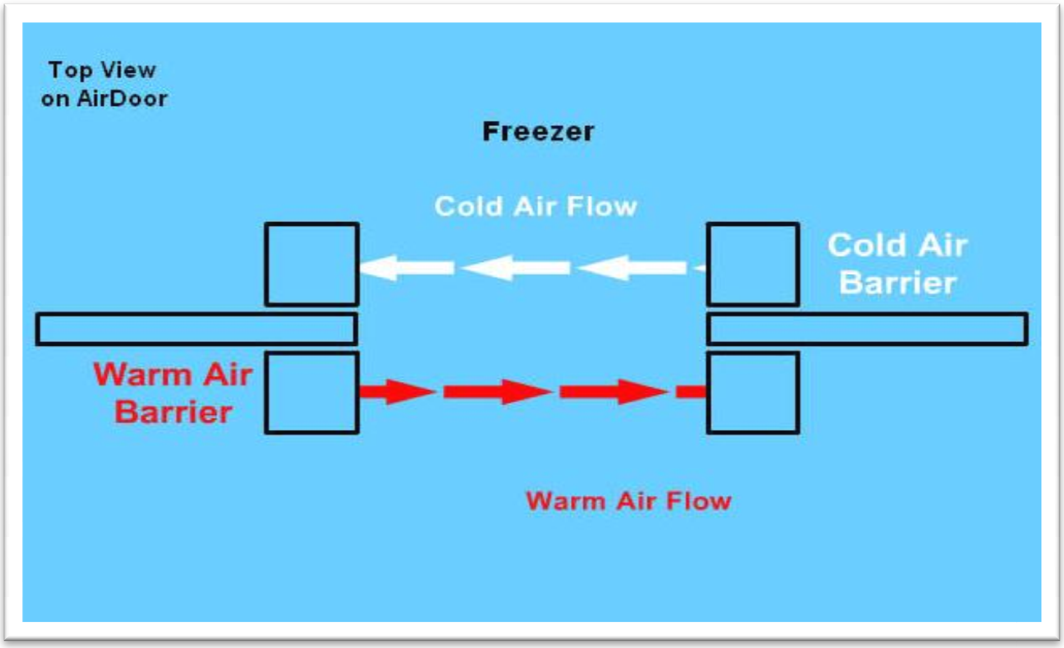

Figure C.2 Direction of air flow.

Here we observe the air blowers in operation. Note that the air flow is perpendicular to the direction that the energy will escape. With these two air flows working in tandem, an air curtain is created. The following diagram will show how this air curtain works.

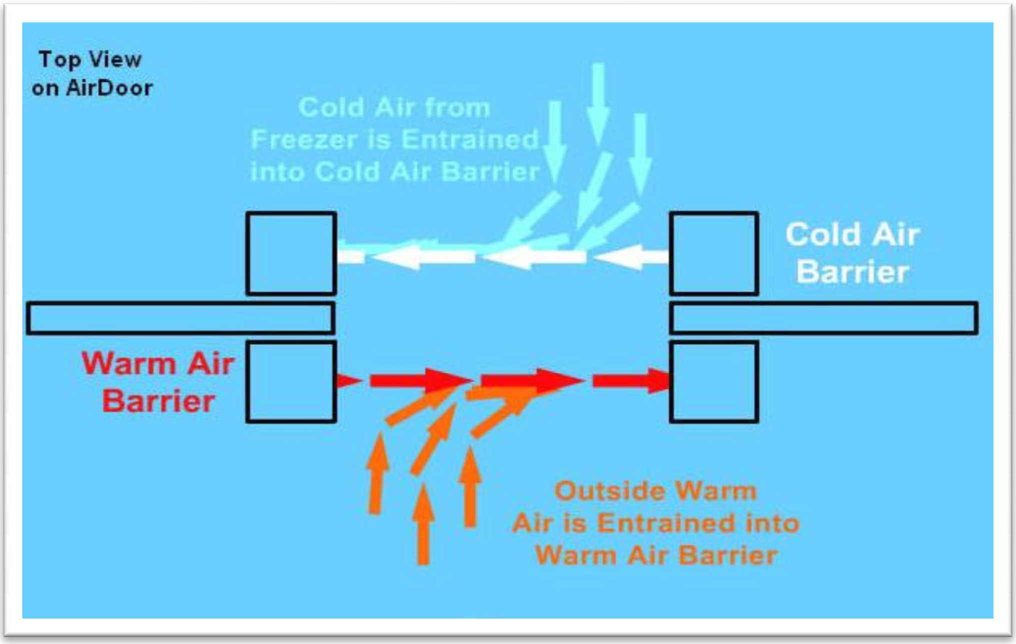

Figure C.3 Air curtain in operation

We can see that when the warmer air tries to enter the freezer room, the warm air is diverted because of the air flow from the warm air blower. Likewise, as the cold air attempts to escape from the freezer room, the cold air blower redirects the flow back into the freezer room.

It can be observed that even without a physical door seal (i.e. strip curtains), the temperature can still be maintained in their individual rooms.

Appendix D

AMMONIA REFRIGERATION SCHEMATICS

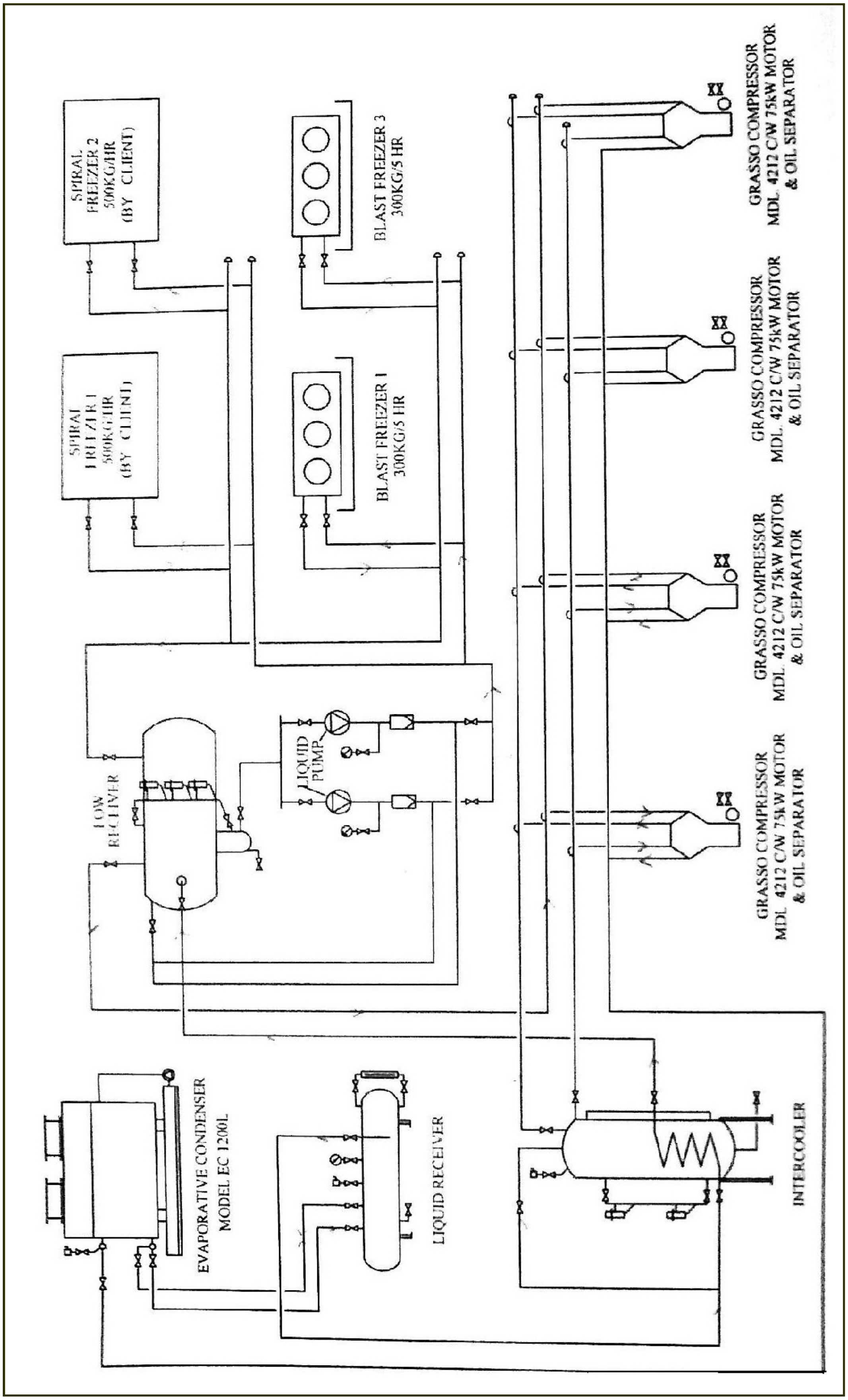

Figure D.1 Ammonia Refrigeration Schematics