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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

شرکت مهندسی سهند مینا (با مسئولیت محدود)

SAHAND MINA ENGINEERING CO.LTD.

شماره: Our Ref.: تاریخ : Date:

22234

CONVERSION OF PROTOTYPES INTO R134A OZONE FRIENDLY REFRIGERANT AT

SABOUHI REFRIGERATION COMPANY

Project Number
MP/IRA/98/086

Contract Number, 99/042P

FINAL REPORT

August 1999

تهران ،خیابان شریعتی ، بالاتر از میرداماد ساختمان ۱۲۸۰ آپارتمان شماره ۱۲ کد پستی ۱۹۵۵۸ تلفن : ۲۲۵۰۳۳۰ ، ۲۲۷۴۹۳۶ نمابر: ۲۲۷۴۹۳۶
No 12, Building 1280,Shariati Ave.,Tehran 19558 Iran. Tel.:+98 21 225 03 30 Tel.Fax :+98 21 227 49 36
e.mail, sahandmina@hotmail. com

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Introduction

This report has been prepared based on Contract with UNIDO and relevant terms of references prepared by UNIDO. The aim of the contract is to develop and convert six models of currently in production, into Ozone Friendly Refrigerant cooling system.

Based on Montreal and I.R.Iranian agreement, R134a refrigerant was selected as suitable Ozone friendly Refrigerant replacement and an alternative for R12 refrigerant and also Cyclopentane and R141b as new blowing agent as a substitute for R11.

This change to the cooling system requires significant modification and improvement of cooling system. Due to the enhanced physical and chemical properties of the new refrigerant the main components of the cooling circuits must be replaced of adjusted as a consequence of substitution of R12 into R134a.

Please find below the calculation of prototypes for determination of cooling capacity of each prototypes and also selecting compatible compressor for substituting R12 compressor with R134a compressor, because this is the first step for making prototype. It is indeed a difficult job to find precise compressor capacity to match the installed R12 compressor in the I.R. Iranian market.

The data which has been collected from each company will help us to calculate required refrigeration load that should be produced by the compressor and evaporators. For making prototypes our policy is to keep the existing size of condenser and evaporator and perform minor changes as required in cooing circuit, we think that minor adjustment will be required in refrigerant weight charge and probably in length of capillary tube.

In this report we will give some detailed technical data in different tables for each prototype model and then we calculate the refrigeration load calculation for each prototype. The prototypes will be tested at appropriate hot chamber for determination of performance of each prototypes, at designated ambient temperature. The test results will be provided in the final report, and will be evaluated accordingly.

Project Definition

This project covers the conversion of Sabouhi refrigeration company in the Isfahan province of Iran and will phase out the use of CFC-11 and CFC-12 in the production of a range of commercial refrigeration equipment. CFC-11, which is used as a foam blowing agent in the production of polyurethane foam will be replaced by HFC-141b and CFC-12 which is used as the refrigerant in the cooling circuit of equipment will be replaced by HFC 134a The project includes technical assistance in design and implementation of the conversion.

General BACKGROUND

The Islamic Republic of Iran ratified the Montreal Protoocol in March 1990. Subsequently, Iran's Country Programme has outlined a plan for the reduction of the domestic use of ODS by 75% before 1999, and aims to be ODS free by 2005.

The overall unconstrained CFC consumption in the Islamic Republic of Iran was projected to rise from 2,445 ODP tonnes in 1991 to 7,778 ODP tonnes in 2010. This corresponds to an overall annual growth rate of 6.5%. The annual growth rate for the domestic refrigeration sector, however, was estimated to be 12% in the period 1991 to 1995 and 4% between 1996 and 2010.

The revised country programme indicates four sub-sectors within the refrigeration sector as shown in table 1 below.

Table 1 : ODS consumption in Iran in 1993 (Country Programme)

Sector	*ODS consumption [MT]*	*ODS substances*
Domestic refrigeration	*1,250*	*CFC-11, CFC-12*
Commercial, industrial & transport refrigeration	*900* *750*	*CFC-11* *CFC-12*
Compressor manufacturing industry	*40*	*CFC-12*
Mobile air-conditioning	*450*	*CFC-12*
Total	*3390*	

In terms of technology and equipment employed the commercial refrigeration sector is very similar to the domestic appliance sector. The primary differences are in the scale of equipment which is used, which can be greater in commercial applications, and the variety of products which are manufactured. Most companies manufacture several types of equipment from a wide ranges of applications, including the following:

- display and sales cabinets for supermarkets and individual suppliers of food,
- upright and chest freezers for commercial application,
- different sizes of drinking water coolers,
- blood cooling cabinets,
  - milk coolers,
  - soft ice freezers,
  - cooling chambers, cooling stores
  - insulated panels for larger cold stores,
  - window-type air conditioners and fan coil,
  - refrigeration equipment for trucks

In common with the domestic refrigeration sub-sector ozone depleting substances are consumed in commercial applications for :

- Charging of new appliances with CFC-12, R-502 and R22
- Refilling/topping up of appliances with CFC-12, R-502 and R-22 after repair work
- Insulation foam blowing using CFC-11

It can be seen from table1 that the commercial sector consumes approximately 900 MT of CFC-11 and 750 MT of CFC-12 annually. Due to the changing market conditions the number and types of products manufactured differ from year to year although the total consumption of CFCs is relatively stable.

General

All of Commercial Refrigerator Manufactures are similar in nature and operate using similar manufacturing techniques. In common with commercial refrigeration companies through Article countries, production is generally on a batch or to order basis and most companies manufacture a range of equipment, which can be tailored to suit the needs of the customer.

Production lines are generally in open plan factory units or workshops and consist of a series of workstations at which particular task can be carried out such as assembly, brazing, charging etc. Work in progress is moved from one station to another using trolleys or conveyors. In the majority of cases production lines can be reconfigured to suit the particular production and market requirements of the time and large equipment items are built in situ, by move production equipment to the equipment. In the case of cold stores and large industrial refrigerators and freezers, these are often built in place on the client site. It is therefore necessary for the manufacturing companies to have portable charging and leak detection equipment. A brief overview of each of the companies is given below.

Company Background

Sobouhi is located in Isfahan and was established over 40 years ago and is one of Irans oldest producers of commercial refrigeration equipment, the company currently produces:

Commercial Chest Freezers
Sandwich Panels
Large supermarket display cases
Cold chambers
Ice cream coolers

The company is wholly Iranian owned and employs 30 people, all products are manufactured and sold in Iran. The factory is typical of a medium sized commercial refrigeration manufacture and is based in a single story factory unit with an open plan manufacturing and assembly area of about 2,000m^2. Production is generally made to order and most production equipment such as charging machines and vacuum pumps are portable in order to be moved around the factory to the point of use.

The factory unit contains a single low pressure foaming machine, which is locally built and is fitted with built in polyol and isocyanate working tanks with electrically operated stirrers. Units are brought to the foaming station by hand or on trolleys or roller conveyors to be foamed. Sandwich panels are also produced using this foaming machine.

Production Data

Product	Compressors			Production		
	Type	No.	Power	1995	1996	1997
Display Cabinets	hermetic	1 or 2	3/4 - 3 HP	700	800	100
Cold Room Panels	semi - hermetic	1 or 2	3 - 30 HP	120	100	300
Milk Coolers	semi - hermetic	1	3 - 7.5 HP	15	20	25
Dinking Water Coolers	hermetic	1	3/4 - 1 HP	150	125	170
Tranportable Cold Stores	semi - hermetic	1	3 - 5 HP	15	15	25
Freezers	hermetic	1 or 2	3/4 - 1.5 HP	640	770	680

The products detailed in Table 4 are manufactured in separate areas of the factory, one for each product type. As with most commercial refrigeration manufacturers production is operated on a batch basis and the production lines are modified according to the product to be assembled. Evaporators and condensers are manufactured in house, compressors are imported.

ODS Consumption Data

Product		CFC-12		Foam	CFC-11	
	Annual Production	kg/unit	kg/year	kg/unit	kg/unit	Total kg/year
Display Cabinets	100	5.5	550	35	4.90	490

Cold Rooms	300	28	8,400	320	44.80	13,440
Milk Coolers	25	22	550	105	14.70	368
Dinking Water Coolers	170	2.3	391	14	1.96	333
Tranportable Cold Stores	25	18	450	161	22.54	564
Freezers	680	4	2,720	35	4.90	3,332
TOTAL			13,061			18,526
Total ODS kg per year:	**31,587**					

The refrigerant circuits are charged using mobile sight glass refrigerant charging machines and direct from refrigerant cylinder using refrigerant gauges to establish the correct charge level.

Supply of the Materia

Following components and material must be used to make prototypes as necessary.

- R134a CompressorsR134a Refrigerant
- Refrigerant Accumulators
- Specially designed filter drier
- Specially designed evaporator and condenser

Some necessary modification of the side panels as required with the new design criteria
Consumable material as required

Activities

In this report we will describe the activities achieved during execution of the contract for implementation of the project.

- Site survey of the counterpart premises in order to be familiar with the counterpart facility and production line and also define the prototypes for conversion.
- Site survey of the counterpart premises in order to collect necessary data for calculation of prototype.
- Preparation of Technical data sheet in order to define detail technical specification
- Review the existing technical drawing for the purpose of assessment of possible changes in the design criteria.
- Review each prototype refrigeration circuit for determination of cooling circuit components
- Review and assessment of design criteria following cooling circuit component in order to minimize possible changes and design improvement.
    - Compressor technical specification
    - Condenser type, material and design criteria
    - Evaporator type, material and design criteria
    - Capillary tube design, dimensions and material
    - Filter drier, size and material
    - Determination of R12 refrigerant charge for each prototype in order to adjust R134a charge weight
- Coordination with the counterparts for performing, performance test after completion of making prototypes
- Calculation of prototypes in order to determine the size of R134a compressor and implement necessary changes to the cooling circuits

- Preparation of Performance Test Results Sheet, in order to record all data obtained during functional test.

Preparation of prototypes for performance test as

The prototypes shall be tested under designated ambient temperature mostly at +32 C, the test performance revealed that no significant changes is necessary for refrigeration system circuit, because the original size of evaporator and condensers are much bigger than cooling requirements.

The adjustment will be applied to the mainly to the amount of refrigerant charge and length of capillary tube.

Each prototypes should under go for performance test at the following test criteria.

Pull down test at + 32 C

Continuos run Test at = 32 C ambient temperature

Cyclic run test at + 32 C ambient temperature.

The test condition was selected in accordance with appropriate ISO test standards.

The material as sample for making prototypes are supplied mainly from local market, due to the limitation for purchasing R134a compressor from local market we had to contact several manufacturers to find out the technical specification for appropriate compressor.

The prices for material specially R134a and R141b blended polyol are much higher than R12 and R11,

Training

Before making prototypes we conducted a training course to train the technical staffs to make their own prototypes and also make them familiar with the new technology.

The following topics were thought during the theatrical training course.

- An orientation to UNIDO CFC phases out project.
- Montreal Protocol
- Ozone Layer and CFC side effect to Ozone layer

- Familiarization with new R134a Refrigerant, application, safety precaution, use and maintenance.
- Familiarization with the new vacuum and charging equipment, vacuum pump and charging board.
- Recovery and recycling of R12 refrigerant, and also R134a.
- Alternative for R11 and R12.
- Some explanation about R141b blowing agent,
- Selection of refrigeration components to be replaced with R12 refrigeration system.
- Calculation and redesign of prototypes
- Performance test
- Test results Evaluation.
- Refrigeration system adjustment.

Following subjects were during conduction of the course

Refrigeration Load Calculation for different type of Water Coolers

Water cooler cabinet usually consist of a sheet metal housing built around a steel framework, inside this sheet housing there is usually a condensing unit, located near the floor, and above this is the water-cooling mechanism. The latter is the only part insulated (foamed plastic) from the room. The insulation is usually specially formed and between one and one half inches and two inches thick. These cabinets are made in such a way that one or more sides may be easily removed to gain access to the interior. The basin of the water cooler is generally made of porcelain-coated cast iron, porcelaicoated - steel, or stainless steel. Heat exchangers are frequently used on water coolers. These make use of the low temperature of waste water and the suction line to pre-cool the fresh water line to the evaporator coil.

Self-cooler are of two types,

1- Bottle Type.
2- Tap water type

The bottle cooler usually uses a 20 to 25 liter bottle of water inverted on the top of the cabinet. Overflow and drain water are stored in a container built the cabinet. These coolers use air-cooled condensing units exclusively. They are used where water and drains are not available or where available the plumbing insulation may be expensive.

Water cooler using a plumbing supply and drain connection, must be installed according the relevant approved standards. The plumbing should be concealed, a hand shutoff valve should be installed in the fresh water line. Drain pipe at least 1 inches in diameter provided, and rubber opening must be above the drain in such a way as to eliminate the chance for accidental siphoning of the drain water back into the fresh water system. The tap water models use variety of evaporator coil wrapped around the water-cooling tank.

Temperatures of the cooling water are variable depending on the persons who are drinking the water. We consider 10 C for the temperature of drinking water, while our inlet temperature is considered 24 C.

In large business establishment, in office buildings, or in factories, multiple water cooler, instead of individual ones, are popular. These

coolers have one large condensing unit supplying many bubbles and these may be of many different types.

Water cooler is a device that usually is used in the public area to supply cold drinking water to the customers and different people. The appliance is mainly used in the Airports, Railways Station, Coach Terminals, Banks, Offices, Parks, and etc. therefore, it is hard to specify an standard for cold water consumption during the day from the water cooler.

We consider three refrigeration load components that should be taken into our consideration.

Heat gain by heat transmission from, main water storage tank wall insulation.

Heat removed from water entering to the water tank at the initial refrigeration system operating condition, (water stored in storage tank during the night, with normal ambient temperature) which is divided by 24 hrs.

Heat removed from Drinking Water flow that are consumed during designated operating hours "$\dot{M}$"

The problem of determining the refrigeration load of a water-cooled installation is basically a specific heat and heat leakage problem combination. The water is cooled to temperature which vary upward from about 4 degree centigrade , and the amount heat removed from the water to cool it to a predetermined temperature is simple specific heat problem. The water, being maintained at these low temperature,

results in a heat leakage from room into the water, and this part involves the heat leakage portion of installation.

$Q1 = m C \Delta T$, Where:

Q1 Total heat removed from total drinking water tank volume capacity (lit.) during specific period, related to compressor cooling capacity power in Watts, at initial compressor start up, and early in the morning. When the water temperature is 30 C.

m total weight of water in the water cooler storage tank in Kg. Considering that one litter of water at 24 C is equal to approximately one Kg.

C Specific heat factor of water in Kcal/Kg °C

T Temperature difference (Ti-Tc), where, Ti is inlet water temperature, and Tc is final cooled water.

$$Q2 = \dot{M} \; C \Delta T$$

Q2 Total heat removed from total drinking water flow (lit.) during specific period, 16 hours. In Kcal.

$\dot{M}$ total weight of water flow during 16 hours. in Kg.

C Specific heat factor of water in Kcal/Kg °C

T Temperature difference (Ti-Tc), where, Ti is inlet water temperature, and Tc is final cooled water temperature.

$$Q3 = UA \Delta T$$

Where:

Q3 Total Leak, gained through side wall of drinking water storage tank by conduction in Kcal..

U Heat Resistance Coefficient Factor in Kcal/Sq. mt. C

A Total Area which heat is transmitted by. In Sq. Mt.

T Temperature difference (Ta – Tc), where, T is ambient temperature, and Tc is final cooled water temperature.

Refrigeration Load Calculation for different type of Domestic and Commercial Appliances

Refrigeration load consist of four individual components:

1- Transmission load;
Heat transfer through walls (sides, back panels, top and bottom) and door panel.

2 - Product load;
Heat Removed from and produced by the products which are brought and stored in the refrigerator;

3 - Internal load;
Heat produced by internal sources such as lights, fan or heaters;

4 - Infiltration load
Heat gains associated with air entering the refrigerated space;

The above mentioned components will be discussed separately to analyze and extract the most useful and practical equipment.

<u>Transmission Load</u>

Heat gain through walls of a refrigerated space depend on cabin Temperature, liner, insulation and cabin conductivity and also the surrounded ambient air. In other word, there are four different resistance opposing heat flow between cabin space and ambient air as given in resistance circuit.

Considering the above mentioned resistance, Rl, Rc and Ra are not comparable in magnitude with Ri (Insulation resistance) and so can be neglected in our calculations. Therefore, the resultant circuit and relevant equations are.

$R = \frac{x}{KA}$ Heat Resistance

$Q_{TL} = \frac{\Delta T}{R}$ Heat Transfer

Where:

x = Insulation Thickness, mm

K = Insulation Conductivity, $Wmm/m^2 \cdot C$

A = Outside Area, m^2

ΔT = Temperature difference (Ta - Tc), C

If the insulation thickness of side walls, back panels, top, bottom and door are different, heat transfer for each part can be calculated separately and then summed for two door refrigerators, due to different cabin temperature of freezer and refrigerator compartments, heat transfer for each compartment should be calculated separately and then added together.

Product Load

Heat removed from products (meat, fruits, vegetables, water and etc.) to reduce temperature from receiving to storage temperature is known as product load. Following steps can be taken to calculated of product loads.

1 - Heat removed from initial temperature (Ti) to storing temperature (Trs) in refrigerator compartment is;

$$Qrs = \dot{M} C (Ti - Trs)$$

Where:

$\dot{M}$ = Mass of product, Kg / h

C = Specific heat of product, Kcal / Kg

2 - Heat removed from intial temperature (Ti) to freezing temperature (Tf) is ;

$$Qaf = \dot{M} C (Ti - Tf)$$

Where :

$\dot{M}$ = Mass of product, Kg / h

C = Specific heat of product above freezing point, Kcal / Kg

3 - Latent heat of fusion for products is equal to;

$$QL = \dot{M} h$$

Where h = Latent heat of product, Kcal / Kg

4 - Heat removed from freezing temperature (Tf) to final storage temperature (Tfs) is;

$$Qbf = \dot{M}\ Cbf\ (Tf - Tfs)$$

Where: Cbf = Specific heat of products below freezing temperature.

For upright freezers or freezer compartment of refrigerators, total product load is

$$Qpl = Qaf + Ql + Qbf$$

For storage products to some lower temperatures above freezing temperature in refrigerator compartment is;

$$Qpl = Qrs$$

<u>Internal Load</u>

Electrical energy dissipated in the refrigerated space such as lights, fan motors, heaters, ... are included in the internal heat load. Due to the little amount of consumption of lighting, the effect of lighting can be negligible and only electrical

heaters of two door refrigerators or fan motors (if exist) are considered in our load calculation.

<u>Infiltration Load</u>

Infiltration air load is the heat transfer due to exchanging of refrigerated air with ambient caused by opening of the door or leakage through the gasket area. Infiltration load is one of the most important load components and roughly it is about 20 % of total refrigeration load.

<u>Total Refrigeration load</u>

As it was mentioned before, transmission load (Qtl), product load (Qpl) and internal load (Q il) can be calculated separately. For infiltration load (air exchange through doorways or gasket leakage), we can take into account from 10 to 25% of sum of the above mentioned components, (transmission load, product load and internal load). Therefore total refrigeration load can be expressed as:

$$\underline{QTL = 1.25\ (QTL + QPL + QIL)}$$

As per <u>ASHREA</u> standard we can use following formula which is depended directly to the number of air change per day and internal volume of the appliance.

$$\underline{Q = (V \times N \times H) \div 86400}$$

Where;

Q = Heat Load due to the Air Change
V = Appliance Internal Volume
H = Heat removed from cubic meter of air = 75000 jul/sec

Equipment Selection

Calculation of refrigeration load is the basis for selecting system equipment. First step is selection of a suitable compressor with cooling capacity comparable to calculated load, then a capillary tube should be selected so that the compressor and tube fix a balance point at the desired evaporating temperature, also two evaporator

and condenser should be selected to balance compressor capacity.

Compressor selection

Assuming 16 hours daily operating time for the compressor, the calculated refrigeration load will be modified to:

$$Qc = \frac{Q_{TL} \cdot 24}{16} = 1.5Q_{TL}$$

Where :

Qc = required cooling capacity

For selection of compressor from manufacturer's catalogue, we have to mention appropriate evaporating temperature;

- In refrigerators with ice compartment mounted inside, maximum evaporating temperature can be selected in order to have - 12 C (Two Stars) inside ice compartment.

- For upright freezers or freezer compartment of two door refrigerators, evaporating temperature should be in order to obtain -18 C (Three Stars) cabin temperature.

Capillary tube

Capillary tube is one of the most important components in refrigerator circuits . capillary acts as a pressure reducing device to meter the flow of refrigerant to the low pressure side (evaporator) of the system. In other word, capillary tube should be capable to pass refrigerant pumped by the compressor and feed it to evaporator at available load and demand conditions.

On the contrary of the R12 or R22 refrigerants, practical equations, charts or graphs are not available for calculation of capillary size in R134a refrigeration circuits. Comparing saturation properties of R134a with R12 at a certain temperature, R134a pressure is less than R12, therefore, capillary tube for R134a shall be adjusted at low evaporating temperatures in comparison with R12 system. The capillary for R134a refrigeration system must have an increase resistance which can be estimated about 10 - 15% increase in length for a definite bore. However the exact size (bore and length)

can be attainable after laboratory performance tests.

Condenser & Evaporator

The statically cooled condenser is designed for use in small refrigeration appliance with sufficient space for the necessary condenser area. These condensers are manufactured either in tube-on-finned plate type or wire-on-tube design. Assuming that compressor casing and tubing will dissipate 80% of the heat equivalent of electrical in put, the condenser should be capable to reject heat absorbed by the refrigerant in the evaporator plus 20% of compressor power input heat equivalent.

The evaporator should balance the selected compressor capacity, not the original calculated load. Most of the refrigerators mainly employ aluminum evaporators produced on the roll-bond principal, where wire-on tube evaporators are usually installed in upright freezers.

Due to the higher latent heat (hfg) of R134a in comparison with R12 and therefore less refrigerant charge in the system, it seems that evaporators and condensers used for R12 are also suitable for R134a refrigeration system. However more detailed information about role of these two components in the system would be cleared after laboratory performance tests. Therefore partial modifications should be done if needed.

Refrigerant charge

As mentioned in previous sections, R134a latent heat of vaporization is about 28-30% higher than R12 in temperature range -30 C up to + 10 C. Table 2-2 shows thermodynamics saturation properties (with respect to a certain temperature) for these two refrigerants. In practice, charging amount of R134a can be 10-15% less than R12 with
the same refrigeration load.

R134a is capable to absorb more humidity of the oil in comparison with R12. Therefore, the filter drier selected for R134a should be a drier with 3A desiccant with 20% more molecular sieve (by weight) in comparison with conventional types.

Sabouhi Upright Refrigerator Model SAB-150 Technical Specification	
Show Case Upright Refrigerator	Type of Product
2000 x 800 x 1500 mm	Overall Dimension
70 mm	Wall Thickness
P.U. Foam R11	Type of Foam
40 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
1200 lit.	Net Internal Volume
Danfoss, SC18B, Air Cooled	Type of Compressor
715 Watts at –10C	Compressor Cooling Capacity
530 Watts	Power Input
Inside Dim., 3/8"	Size of Condenser
Fin and Tube	Type of Evaporator
R12	Type of Refrigerant
R12, = 650 Gr.	Refrigerant Charge
35x50 Wartan Co.	Filter Drier Size
220/50	Power Source
- 10 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Upright Refrigerator Showcase Model SAB-150

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (200x80)	3.2	70mm	27 c
Back Panel	200x150	3	70mm	27 c
Top Surface	80x150	1.20	70mm	37 c
Bottom Surface	80x150	1.20	70mm	27 c
Door	200x150	3	15mm air	27 c

Insulation Type: Pu Foam with R141b blowing agent.

Thermal Conductivity for Foam = 0.0180 W/ mt. ° C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. ° C

Temperature Difference Refrigerator Compartment:
$\Delta T = 32 - (+5) = 27\ ^\circ C$
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +5 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = Q_{SW} + Q_{Back\ Panel} + Q_{door} + Q_{Bottom} + Q_{Top}$$

$$Q = U\,A\,(T_a - T_r)$$

$$U = \frac{1}{X_1 / K_1}$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity

Note : Due to the short thickness of cabinet out side panel (0.6 mm) and plastic inner liner (1.5 mm) heat resistance of these materials have been considered negligible.

Therefore:

1-$Q_{SideWalls}$ = $[U A (T_a - T_r)]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.070/ 0.0180) = 0.26 W/ sq.m °C

A = 3.2 Sq. Mt.,
T_a = 32 °C
T_f = + 5 °C
therefore
$Q_{SideWalls}$ = 0.26 x 3.2 x 27 = 22.46 Watts

$Q_{SideWalls}$ = 22.46 Watts

2 -Q_{Door} = $[U A (T_a - T_r)]$

U = 1 / (0.015/ 0.024) = 1.6 W/ sq.m °C
$T_a - T_r$ = 27
A = 3

Q_{door} = 1.6 x 3 x 27 = 129.6 Watts

Q_{door} = 129.6 Watts

3 -$Q_{Back\ panel}$ = $[U A (T_a - T_r)]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r$ = 27
A = 3

$Q_{Back\ panel}$ = 0.26 x 3 x 27 = 21.1 Watts

$Q_{Back\ panel}$ = 21.1 Watts

4 -Q_{Top} = $[U A (T_a - T_r)]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 1.2

$Q_{Top} = 0.26 \times 1.2 \times 37 = 11.5$ Watts

$$Q_{Top} = 11.5 \text{ Watts}$$

5 -$Q_{Bottom} = [\, U A (T_a - T_r) \,]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 1.2

$Q_{Bottom\ Surface} = 0.26 \times 1.2 \times 27 = 8.4$ Watts

$$Q_{Bottom\ Surface} = 8.4 \text{ Watts}$$

Total Refrigerator Heat Leak =22.5+129.6+21.1+11.5+ 8.4=194 W

Product Load

A product placed in a refrigerator at a temperature higher than the storage temperature will lose heat until it reaches the storage temperature. The quantity of heat to be removed may be calculated from knowledge of the product, including its state upon entering the refrigerator, its final state, its weight, specific heat above and below freezing point, its freezing temperature and latent heat. When a definite weight of product is cooled from one state and temperature to another state and temperature, some or all of the following calculations must be made:

Heat removal from intial temperature to some lower temperature above freezing.

$$Q = mc(T_1 - T_2)$$

Heat removal from initial temperature to freezing point of product.

$$Q = mc(T_i - T_f)$$

Heat removal to freeze product.

$$Q = mh_{if}$$

Heat removal from freezing point to final temperature below freezing.

$$Q = mc(T_f - T_3)$$

Where

Q = heat removed, Kj
M = weight of product, kg
C = specific heat of product above freezing point, Kj/Kg. K
T_1 = initial temp. C
T_2 = lower temperature above freezing, C
T_f = freezing temperature of product, C
H_{if} = latent heat of fusion, kj per kg

Since this product is mainly used for storing fresh Lamb meet and beef above freezing point at +5 C, we consider 200 Kg of meet to be stored in this refrigerator therefore we calculate as follow,

$$Q = mc(T_1 - T_2)$$

M = 500 kg
C = 0.67 Btu/(lb)F deg = 0.67 x 4.184 = 2.8 j/g K
T_1 = 25 C
T_2 = 5 C
Q = 500000x2.8x (25-5) =28000000 jul/86400 = 324 Watt

Internal Load

Electric Fan 2x10 = 20 Watt
Florescent Lamp = 20 watt

Door Opening
Refrigerator Internal Volume 1200 lit.
Number of air change as per ASHREA standard = 70 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 1.2x70x75000/86400 = 72.9 Watt

$$Q_{Total} = Q_{heat\ leak} + Q_{product\ load} + Q_{internal\ load} + Q_{air\ change}$$

$$Q_{Total} = 324 + 194 + 20 + 20 + 72.9 = 637$$

Considering 10 % of Q total for safety factor

$$Q_{\text{Grand Total}} = 637 + 10\%(64) = \mathbf{671} \text{ watts}$$

With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 700 watt at –10 degree centigrade evaporating temperature.

Sabouhi Upright Refrigerator Model SAB-200 Technical Specification	
Show Case Upright Refrigerator	Type of Product
2000 x 800 x 2000 mm	Overall Dimension
70 mm	Wall Thickness
P.U. Foam R11	Type of Foam
40 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
1200 lit.	Net Internal Volume
Danfoss, SC21B, Air Cooled	Type of Compressor
840 Watts at –10 C	Compressor Cooling Capacity
750 Watts	Power Input
Inside Dim., 3/8"	Size of Condenser
Fin and Tube	Type of Evaporator
R12	Type of Refrigerant
R12, = 920 Gr.	Refrigerant Charge
40x50 Wartan Co.	Filter Drier Size
220/50	Power Source
- 10 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Upright Refrigerator Showcase Model SAB-200

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (200x80)	3.2	70mm	27 c
Back Panel	200x200	4	70mm	27 c
Top Surface	80x200	1.60	70mm	37 c
Bottom Surface	80x200	1.60	70mm	27 c
Door	200x200	4	15mm air	27 c

Insulation Type: Pu Foam with R141b blowing agent.

Thermal Conductivity for Foam = 0.0180 W/ mt. ° C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. ° C

Temperature Difference Refrigerator Compartment:
$\Delta T = 32 - (+5) = 27\ ^\circ C$
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +5 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = Q_{SW} + Q_{Back\ Panel} + Q_{door} + Q_{Bottom} + Q_{Top}$$

$$Q = U A (T_a - T_r)$$

$$U = \frac{1}{X_1 / K_1}$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity

Note : Due to the short thickness of cabinet out side panel (0.6 mm) and plastic inner liner (1.5 mm) heat resistance of these materials have been considered negligible.

Therefore:

1-$Q_{SideWalls}$ = [U A (T_a - T_r)]

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.070/ 0.0180) = 0.26 W/ sq.m °C

A = 3.2 Sq. Mt.,
T_a = 32 °C
T_f = + 5 °C
therefore
$Q_{SideWalls}$ = 0.26 x 3.2 x 27 = 22.46 Watts

$Q_{SideWalls}$ = 22.46 Watts

2 -Q_{Door} = [U A (T_a - T_r)]

U = 1 / (0.015/ 0.024) = 1.6 W/ sq.m °C
T_a - T_r= 27
A = 4

Q_{door} = 1.6 x 4 x 27 = 172.8 Watts

Q_{door} = 172.8 Watts

2 -$Q_{Back\ panel}$ = [U A (T_a - T_r)]

U = 0.26 w/sq. Mt. °C,
T_a - T_r= 27
A = 4

$Q_{Back\ panel}$ = 0.26 x 4 x 27 = 28 Watts

$Q_{Back\ panel}$ = 28 Watts

3 -Q_{Top} = [U A (T_a - T_r)]

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 1.6

$Q_{Top} = 0.26 \times 1.6 \times 37 = 15.4$ Watts

$$Q_{Top} = 15.4 \text{ Watts}$$

3 -$Q_{Bottom} = [\, U\, A\, (T_a - T_r)\,]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 1.6

$Q_{Bottom\ Surface} = 0.26 \times 1.6 \times 27 = 11.2$ Watts

$$Q_{Bottom\ Surface} = 11.2 \text{ Watts}$$

Total Refrigerator Heat Leak =22.5+172.8+28+15.4+ 11.2= 249.9
Q total heat leak = 250 Watts

Product Load

A product placed in a refrigerator at a temperature higher than the storage temperature will lose heat until it reaches the storage temperature. The quantity of heat to be removed may be calculated from knowledge of the product, including its state upon entering the refrigerator, its final state, its weight, specific heat above and below freezing point, its freezing temperature and latent heat. When a definite weight of product is cooled from one state and temperature to another state and temperature, some or all of the following calculations must be made:

Heat removal from intial temperature to some lower temperature above freezing.

$$\mathbf{Q = mc(T_1 - T_2)}$$

Heat removal from initial temperature to freezing point of product.

$$\mathbf{Q = mc(T_i - T_f)}$$

Heat removal to freeze product.

$$Q = mh_{if}$$

Heat removal from freezing point to final temperature below freezing.

$$Q = mc(T_f - T_3)$$

Where

Q = heat removed, Kj
M = weight of product, kg
C = specific heat of product above freezing point, Kj/Kg. K
T_1 = initial temp. C
T_2 = lower temperature above freezing, C
T_f = freezing temperature of product, C
H_{if} = latent heat of fusion, kj per kg

Since this product is mainly used for storing fresh Lamb meet and beef above freezing point at +5 C, we consider 650 Kg of meet to be stored in this refrigerator therefore we calculate as follow,

$$Q = mc(T_1 - T_2)$$

M = 650 kg
C = 0.67 Btu/(lb)F deg = 0.67 x 4.184 = 2.8 j/g K
T_1 = 25 C
T_2 = 5 C
Q = 650000x2.8x (25-5) =36400000 jul/86400 = 421 Watt

Internal Load

Electric Fan 2x10 = 20 Watt
Florescent Lamp = 20 watt

Door Opening
Refrigerator Internal Volume 1800 lit.
Number of air change as per ASHREA standard = 70 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 1.8x70x75000/86400 = 109 Watt

$$Q_{Total} = Q_{heat\ leak} + Q_{product\ load} + Q_{internal\ load} + Q_{air\ change}$$

Q_{Total} = 421 + 250 + 20 + 20 + 109 = 820

Considering 10 % of Q total for safety factor

$Q_{Grand\ Total}$ = 820 + 10%(82) = 902 watts

With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 900 watt at –10 degree centigrade evaporating temperature. At CECOMAF Standard

Sabouhi Upright Refrigerator Model SAB-150GH Technical Specification	
Show Case Upright Refrigerator	Type of Product
2000 x 800 x 1500 mm	Overall Dimension
2x75x70 mm in Double Wall Glass	Upper Doors
2x75x70 mm in Double Wall Foam	Lower Door
70 mm	Wall Thickness
P.U. Foam R11	Type of Foam
40 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
1200 lit.	Net Internal Volume
Danfoss, SC18B, Air Cooled	Type of Compressor
715 Watts at –10C	Compressor Cooling Capacity
530 Watts	Power Input
Inside Dim., 3/8"	Size of Condenser
Fin and Tube	Type of Evaporator
R12	Type of Refrigerant
R12, = 650 Gr.	Refrigerant Charge
35x50 Wartan Co.	Filter Drier Size
220/50	Power Source
- 10 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Upright Refrigerator Model SAB-150GH

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (200x80)	3.2	70mm	27 c
Back Panel	200x150	3	70mm	27 c
Top Surface	80x150	1.20	70mm	37 c
Bottom Surface	80x150	1.20	70mm	27 c
Lower Door	2x75x70	1.05	70mm	27
Upper Door	2x75x70	1.05	15mm air	27 c

Insulation Type: Pu Foam with R141b blowing agent.

Thermal Conductivity for Foam = 0.0180 W/ mt. ° C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. ° C

Temperature Difference Refrigerator Compartment:
$\Delta T = 32 - (+5) = 27\ ^{\circ}C$
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +5 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = Q_{SW} + Q_{Back\ Panel} + Q_{doors} + Q_{Bottom} + Q_{Top}$$

$$Q = U A (T_a - T_r)$$

$$U = \frac{1}{X_1 / K_1}$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity

Note : Due to the short thickness of cabinet out side panel (0.6 mm) and plastic inner liner (1.5 mm) heat resistance of these materials have been considered negligible.

Therefore:

1-$Q_{SideWalls} = [U A (T_a - T_r)]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.070/ 0.0180) = 0.26 W/ sq.m °C

A = 3.2 Sq. Mt.,
T_a = 32 °C
T_f = + 5 °C
therefore
$Q_{SideWalls}$ = 0.26 x 3.2 x 27 = 22.46 Watts

$Q_{SideWalls}$ = 22.46 Watts

2 -$Q_{upper\ Door} = [U A (T_a - T_r)]$

U = 1 / (0.015/ 0.024) = 1.6 W/ sq.m °C
$T_a - T_r$= 27
A = 1.05

$Q_{upper\ door}$ = 1.6 x 1.05 x 27 = 45.36 Watts

Q_{door} = 45.36 Watts

3 -$Q_{lower\ Door} = [U A (T_a - T_r)]$

U = 1 / (0.070/ 0.018) = 0.26 W/ sq.m °C
$T_a - T_r$= 27
A = 1.05

$Q_{upper\ door}$ = 0.26 x 1.05 x 27 = 7.37 Watts

Q_{door} = 7.37 Watts

4 -$Q_{\text{Back panel}} = [\, U\, A\, (T_a - T_r)\,]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 3

$Q_{\text{Back panel}} = 0.26 \times 3 \times 27 = 21.1$ Watts

$Q_{\text{Back panel}} = 21.1$ Watts

5 -$Q_{\text{Top}} = [\, U\, A\, (T_a - T_r)\,]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 1.2

$Q_{\text{Top}} = 0.26 \times 1.2 \times 37 = 11.5$ Watts

$Q_{\text{Top}} = 11.5$ Watts

6 -$Q_{\text{Bottom}} = [\, U\, A\, (T_a - T_r)\,]$

U = 0.26 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 1.2

$Q_{\text{Bottom Surface}} = 0.26 \times 1.2 \times 27 = 8.4$ Watts

$Q_{\text{Bottom Surface}} = 8.4$ Watts

Total Refrigerator Heat Leak =

22.5+45.4+7.4+21.1+11.5+ 8.4=116 W

Product Load

A product placed in a refrigerator at a temperature higher than the storage temperature will lose heat until it reaches the storage temperature. The quantity of heat to be removed may be calculated from knowledge of the product, including its state upon entering the refrigerator, its final state, its weight, specific heat above and below freezing point, its freezing temperature and latent heat. When a definite weight of product is cooled from one state

and temperature to another state and temperature, some or all of the following calculations must be made:

Heat removal from intial temperature to some lower temperature above freezing.

$$Q = mc(T_1 - T_2)$$

Heat removal from initial temperature to freezing point of product.

$$Q = mc(T_i - T_f)$$

Heat removal to freeze product.

$$Q = mh_{if}$$

Heat removal from freezing point to final temperature below freezing.

$$Q = mc(T_f - T_3)$$

Where

Q = heat removed, Kj
M = weight of product, kg
C = specific heat of product above freezing point, Kj/Kg. K
T_1 = initial temp. C
T_2 = lower temperature above freezing, C
T_f = freezing temperature of product, C
H_{if} = latent heat of fusion, kj per kg

Since this product is mainly used for storing fresh Lamb meet and beef above freezing point at +5 C, we consider 500 Kg of meet to be stored in this refrigerator therefore we calculate as follow,

$$Q = mc(T_1 - T_2)$$

M = 500 kg
C = 0.67 Btu/(lb)F deg = 0.67 x 4.184 = 2.8 j/g K
T_1 = 25 C
T_2 = 5 C
Q = 500000x2.8x (25-5) =28000000 jul/86400 = 324 Watt

Internal Load

Electric Fan 2x10 = 20 Watt

Florescent Lamp = 10 watt

Door Opening
Refrigerator Internal Volume 1200 lit.
Number of air change as per ASHREA standard = 70 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 1.2x70x75000/86400 = 72.9 Watt

$$Q_{Total} = Q_{\text{heat leak}} + Q_{\text{product load}} + Q_{\text{internal load}} + Q_{\text{air change}}$$

$$Q_{Total} = 324 + 116 + 20 + 10 + 72.9 = 543$$

Considering 10 % of Q total for safety factor

$$Q_{\text{Grand Total}} = 543 + 10\%(54) = 597 \text{ watts}$$

With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 600 watt at –10 degree centigrade evaporating temperature.

Sabouhi Upright Refrigerator Model SAB-220GH Technical Specification	
Show Case Upright Refrigerator	Type of Product
2000 x 800 x 2200 mm	Overall Dimension
3x75x65 mm in Double Wall Glass	Upper Doors
3x75x65 mm in Double Wall Foam	Lower Door
70 mm	Wall Thickness
P.U. Foam R11	Type of Foam
40 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
1800 lit.	Net Internal Volume
Danfoss, SC21B, Air Cooled	Type of Compressor
840 Watts at –10C	Compressor Cooling Capacity
780 Watts	Power Input
Inside Dim., 3/8"	Size of Condenser
Fin and Tube	Type of Evaporator
R12	Type of Refrigerant
R12, = 650 Gr.	Refrigerant Charge
40x50 Wartan Co.	Filter Drier Size
220/50	Power Source
- 10 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Upright Refrigerator Model SAB-220HG

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (200x80)	3.2	70mm	27 c
Back Panel	200x220	4.4	70mm	27 c
Top Surface	80x220	1.76	70mm	37 c
Bottom Surface	80x220	1.76	70mm	27 c
Lower Door	3x75x70	1.57	70mm	27
Upper Door	3x75x70	1.57	15mm air	27 c

Insulation Type: Pu Foam with R141b blowing agent.

Thermal Conductivity for Foam = 0.0180 W/ mt. ° C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. ° C

Temperature Difference Refrigerator Compartment:
$\Delta T = 32 - (+5) = 27\ ^\circ C$
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +5 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = Q_{SW} + Q_{Back\ Panel} + Q_{doors} + Q_{Bottom} + Q_{Top}$$

$$Q = U\ A\ (T_a - T_r)$$

$$U = \frac{1}{X_1 / K_1}$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity

Note : Due to the short thickness of cabinet out side panel (0.6 mm) and plastic inner liner (1.5 mm) heat resistance of these materials have been considered negligible.

Therefore:

1-$Q_{SideWalls}$ = $[U A (T_a - T_r)]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.070/ 0.0180) = 0.26 W/ sq.m °C

A = 3.2 Sq. Mt.,
T_a = 32 °C
T_f = + 5 °C
therefore
$Q_{SideWalls}$ = 0.26 x 3.2 x 27 = 22.46 Watts

$Q_{SideWalls}$ = 22.46 Watts

2 -$Q_{upper\ Door}$ = $[U A (T_a - T_r)]$

U = 1 / (0.015/ 0.024) = 1.6 W/ sq.m °C
$T_a - T_r$= 27
A = 1.57

$Q_{upper\ door}$ = 1.6 x 1.57 x 27 = 67.8 Watts

Q_{door} = 67.8 Watts

3 -$Q_{lower\ Door}$ = $[U A (T_a - T_r)]$

U = 1 / (0.070/ 0.018) = 0.26 W/ sq.m °C
$T_a - T_r$= 27
A = 1.57

$Q_{upper\ door}$ = 0.26 x 1.57 x 27 = 11 Watts

Q_{door} = 11 Watts

and temperature to another state and temperature, some or all of the following calculations must be made:

Heat removal from intial temperature to some lower temperature above freezing.

$$Q = mc(T_1 - T_2)$$

Heat removal from initial temperature to freezing point of product.

$$Q = mc(T_i - T_f)$$

Heat removal to freeze product.

$$Q = mh_{if}$$

Heat removal from freezing point to final temperature below freezing.

$$Q = mc(T_f - T_3)$$

Where

Q = heat removed, Kj
M = weight of product, kg
C = specific heat of product above freezing point, Kj/Kg. K
T_1 = initial temp. C
T_2 = lower temperature above freezing, C
T_f = freezing temperature of product, C
H_{if} = latent heat of fusion, kj per kg

Since this product is mainly used for storing fresh Lamb meet and beef above freezing point at +5 C, we consider 600 Kg of meet to be stored in this refrigerator therefore we calculate as follow,

$$Q = mc(T_1 - T_2)$$

M = 600 kg
C = 0.67 Btu/(lb)F deg = 0.67 x 4.184 = 2.8 j/g K
T_1 = 25 C
T_2 = 5 C
Q = 600000x2.8x (25-5) =33600000 jul/86400 = 389 Watt

Internal Load

Electric Fan 2x10 = 20 Watt

Florescent Lamp = 10 watt

Door Opening
Refrigerator Internal Volume 1800 lit.
Number of air change as per ASHREA standard = 70 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 1.8x70x75000/86400 = 109 Watt

$$Q_{Total} = Q_{\text{heat leak}} + Q_{\text{product load}} + Q_{\text{internal load}} + Q_{\text{air change}}$$

$$Q_{Total} = 389 + 161 + 20 + 10 + 109 = 689$$

Considering 10 % of Q total for safety factor

$$Q_{\text{Grand Total}} = 689 + 10\%(69) = 758 \text{ watts}$$

With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 800 watt at –10 degree centigrade evaporating temperature.

Sabouhi Display Case **Model SAB-SC200 M Technical Specification**	
Show Case Upright Refrigerator	Type of Product
1275 x 755 x 2000 mm	Overall Dimension
1000x2000 mm	Main Show Glass
70 mm	Wall Thickness
P.U. Foam R11	Type of Foam
40 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
900 lit.	Net Internal Volume
Danfoss, SC21B, Air Cooled	Type of Compressor
715 Watts at –10C	Compressor Cooling Capacity
650 Watts	Power Input
Inside Dim., 3/8"	Size of Condenser
Fin and Tube	Type of Evaporator
R12	Type of Refrigerant
R12, = 550 Gr.	Refrigerant Charge
30x50 Wartan Co.	Filter Drier Size
220/50	Power Source
- 10 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Upright Refrigerator Showcase Model SAB-SC200M

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x42x127.5 2x33.5x41	1.07 0.27	70mm	27 c
Back Panel	127.5x200	2.55	70mm	27 c
Top Surface	42x200	0.84	70mm	37 c
Bottom Surface	80x220	1.76	70mm	27 c
Lower Front Panel	41x200	0.82	70mm	27
Front Glass	110x200	2.2	15mm air	27 c

Insulation Type: Pu Foam with R141b blowing agent.

Thermal Conductivity for Foam = 0.0180 W/ mt. ° C

Thermal Conductivity for glass. = 1.021 W/mt. ° C

Temperature Difference Refrigerator Compartment:
$\Delta T = 32 - (+5) = 27\ °C$
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +5 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = Q_{SW} + Q_{Back\ Panel} + Q_{glass} + Q_{Bottom} + Q_{top} + Q_{lower\ front\ panel}$$

$$Q = U A (T_a - T_r)$$

$$U = \frac{1}{X_1 / K_1}$$

Where :

U = Heat Resistance Coefficient Factor

K_1 = Foam Thermal Conductivity

Note : Due to the short thickness of cabinet out side panel (0.6 mm) and plastic inner liner (1.5 mm) heat resistance of these materials have been considered negligible.

Therefore:

1-$Q_{SideWalls} = [U A (T_a - T_r)]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.070/ 0.0180) = 0.26 W/ sq.m °C

A = 1.1 Sq. Mt.,
T_a = 32 °C
T_f = + 5 °C
therefore
$Q_{SideWalls}$ = 0.26 x 1.1 x 27 = 7.7 Watts

$Q_{SideWalls}$ = 7.7 Watts

2 -$Q_{lower\ front\ panel} = [U A (T_a - T_r)]$

U = 1 / (0.070/ 0.018) = 0.26 W/ sq.m °C
$T_a - T_r = 27$
A = 0.82

$Q_{lower\ front\ panel}$ = 0.26 x 0.82 x 27 = 5.8 Watts

$Q_{lower\ front\ panel}$ = 5.8 Watts

3 -$Q_{show\ case\ glass} = [U A (T_a - T_r)]$

U = 1 / (0.75/0.024+ 0.010/ 1.02) = 0.032 W/ sq.m °C
$T_a - T_r = 27$
A = 2.2

$Q_{show\ case\ glass}$ = 0.032 x 2.2 x 27 = 1.9 Watts

Q_{door} = 1.9 Watts

and temperature to another state and temperature, some or all of the following calculations must be made:

Heat removal from initial temperature to some lower temperature above freezing.

$$Q = mc(T_1 - T_2)$$

Heat removal from initial temperature to freezing point of product.

$$Q = mc(T_i - T_f)$$

Heat removal to freeze product.

$$Q = mh_{if}$$

Heat removal from freezing point to final temperature below freezing.

$$Q = mc(T_f - T_3)$$

Where

Q = heat removed, Kj
M = weight of product, kg
C = specific heat of product above freezing point, Kj/Kg. K
T_1 = initial temp. C
T_2 = lower temperature above freezing, C
T_f = freezing temperature of product, C
H_{if} = latent heat of fusion, kj per kg

Since this product is mainly used for storing fresh Lamb meet and beef above freezing point at +5 C, we consider 500 Kg of meet to be stored in this refrigerator therefore we calculate as follow,

$$Q = mc(T_1 - T_2)$$

M = 500 kg
C = 0.67 Btu/(lb)F deg = 0.67 x 4.184 = 2.8 j/g K
T_1 = 25 C
T_2 = 5 C
Q = 500000x2.8x (25-5) =28000000 jul/86400 = 324 Watt

Internal Load

Electric Fan 2x10 = 20 Watt

Florescent Lamp = 20 watt

Door Opening
Refrigerator Intemal Volume 900 lit.
Number of air change as per ASHREA standard = 70 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 0.9x70x75000/86400 = 54.7 Watt

$$Q_{Total} = Q_{heat\ leak} + Q_{product\ load} + Q_{internal\ load} + Q_{air\ change}$$

$$Q_{Total} = 324 + 58.4 + 20 + 54.7 = 457$$

Considering 20 % of Q total for safety factor

$$Q_{Grand\ Total} = 457 + 20\%(91) = 548 \text{ watts}$$

With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 600 watt at –10 degree centigrade evaporating temperature.

Refrigeration Load Calculation for different type of Water Coolers

Water cooler cabinet usually consist of a sheet metal housing built around a steel framework, inside this sheet housing there is usually a condensing unit, located near the floor, and above this is the water-cooling mechanism. The latter is the only part insulated (foamed plastic) from the room. The insulation is usually specially formed and between one and one half inches and two inches thick. These cabinets are made in such a way that one or more sides may be easily removed to gain access to the interior. The basin of the water cooler is generally made of porcelain-coated cast iron, porcelaicoated - steel, or stainless steel. Heat exchangers are frequently used on water coolers. These make use of the low temperature of waste water and the suction line to pre-cool the fresh water line to the evaporator coil.

Self-cooler are of two types,

1- Bottle Type.
2- Tap water type

The bottle cooler usually uses a 20 to 25 liter bottle of water inverted on the top of the cabinet. Overflow and drain water are stored in a container built the cabinet. These coolers use air-cooled condensing units exclusively. They are used where water and drains are not available or where available the plumbing insulation may be expensive.

Water cooler using a plumbing supply and drain connection, must be installed according the relevant approved standards. The plumbing should be concealed, a hand shutoff valve should be installed in the fresh water line. Drain pipe at least 1 inches in diameter provided, and rubber opening must be above the drain in such a way as to eliminate the chance for accidental siphoning of the drain water back into the fresh water system. The tap water models use variety of evaporator coil wrapped around the water-cooling tank.

Temperatures of the cooling water are variable depending on the persons who are drinking the water. We consider 10 C for the temperature of drinking water, while our inlet temperature is considered 24 C.

In large business establishment, in office buildings, or in factories, multiple water cooler, instead of individual ones, are popular. These

coolers have one large condensing unit supplying many bubbles and these may be of many different types.

Water cooler is a device that usually is used in the public area to supply cold drinking water to the customers and different people. The appliance is mainly used in the Airports, Railways Station, Coach Terminals, Banks, Offices, Parks, and etc. therefore, it is hard to specify an standard for cold water consumption during the day from the water cooler.

We consider three refrigeration load components that should be taken into our consideration.

1- Heat gain by heat transmission from, main water storage tank wall insulation.
2- Heat removed from water entering to the water tank at the initial refrigeration system operating condition, (water stored in storage tank during the night, with normal ambient temperature) which is divided by 24 hrs.
3- Heat removed from Drinking Water flow that are consumed during designated operating hours "$\dot{M}$ "

The problem of determining the refrigeration load of a water-cooled installation is basically a specific heat and heat leakage problem combination. The water is cooled to temperature which vary upward from about 4 degree centigrade , and the amount heat removed from the water to cool it to a predetermined temperature is simple specific heat problem. The water, being maintained at these low temperature, results in a heat leakage from room into the water, and this part involves the heat leakage portion of installation.

$Q_1 = m\, C\, \Delta T$, Where:

Q_1 Total heat removed from total drinking water tank volume capacity (lit.) during specific period, related to compressor cooling capacity power in Watts, at initial compressor start up, and early in the morning. When the water temperature is 30 C.

Tank Diameter 42 Cm. Tank Height 70 Cm
Tank Valume = 21x21x3.14x70 = 96931 Cubic Cm. = Approx. 97 lit

M = 97 liter = 96 Kg.

C Specific heat factor of water in Kcal/Kg °C = 1

T Temperature difference (Ti–Tc), where, Ti is inlet water temperature, and Tc is final cooled water.

Ti = 24 °C and Tc = 10 °C

Ti – Tc = 24-10 = 14 °C

Q_1 = m C ΔT = 97 x 1 x 14 = 1358 Kcal = 1358 x 1.163 = 1579 Watts/24 hrs

Q_1 = 1579 /24 water cooler operating time per day = 65.79 Watts

Q_1 = 65.79 Watts

$$Q_2 = \dot{M}\ C\ \Delta T$$

Q_2 Total heat removed from total drinking water flow (lit.) during specific period, 16 hours. In Kcal.

$\dot{M}$ total weight of water flow during 16 hours. in Kg. = H x N x M
where:
H = Total Water Cooler Usage Time (Hours) = 16
N = Number of Glass of Drinking Water per Hour = 50

M = Kg weight of water in one Glass of Water = 0.2 Kg

$\dot{M}$ = 2(16 x 50 x 0.2) = lit. + 20% Waste Water = 384
C Specific heat factor of water in Kcal/Kg °C = 1
T Temperature d(Ti – Tc), where, Ti is inlet water temperature, and Tc is final cooled water temperature.
Ti = 24 °C and T= 10 °C
Ti – Tc = 24-10 = 14 °C

Q_2 = m C ΔT = 384 x 1 x 14 = 5376 Kcal = 5376 x 1.163 = 6252 Watts/16 hrs

Q_2 = 1563/12.8 compressor operating time per day = 122 Watts

Q_2 = 260 Watts

Q_3 = UA ΔT, Where:

Tank Diameter 42 Cm. Tank Height 70 Cm
Tank Valume = 21x21x3.14x70 = 96931 Cubic Cm. = Approx. 97 lit

M = 97 liter = 96 Kg.

C Specific heat factor of water in Kcal/Kg °C = 1

T Temperature difference (Ti–Tc), where, Ti is inlet water temperature, and Tc is final cooled water.

Ti = 24 °C and Tc = 10 °C

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C Specific heat factor of water in Kcal/Kg °C = 1
T Temperature d(Ti – Tc), where, Ti is inlet water temperature, and Tc is final cooled water temperature.
Ti = 24 °C and T= 10 °C
Ti – Tc = 24-10 = 14 °C

Q_2 = m C ΔT = 384 x 1 x 14 = 5376 Kcal = 5376 x 1.163 = 6252 Watts/16 hrs

Q_2 = 1563/12.8 compressor operating time per day = 122 Watts

<u>**Q_2 = 260 Watts**</u>

Q_3 = UA ΔT, Where:

Q_3 Total Leak, gained through side wall of drinking water storage tank by conduction in Kcal..

U Heat Resistance Coefficient Factor in Kcal/Sq. mt. C

$$U = \frac{1}{x/K} = \frac{1}{0.060/0.018} = 0.33 \ Kcal/m^2.°C$$

A Total Area which heat is transmitted by. In Sq. Mt.

A = 42x3.14x70 = 9232 Sq. Cm = 0.923 Sq. Mt.

T Temperature difference (Ta – Tc), where, T is ambient temperature, and Tc is final cooled water temperature.

Ta = 30 °C and Tc = 10 °C

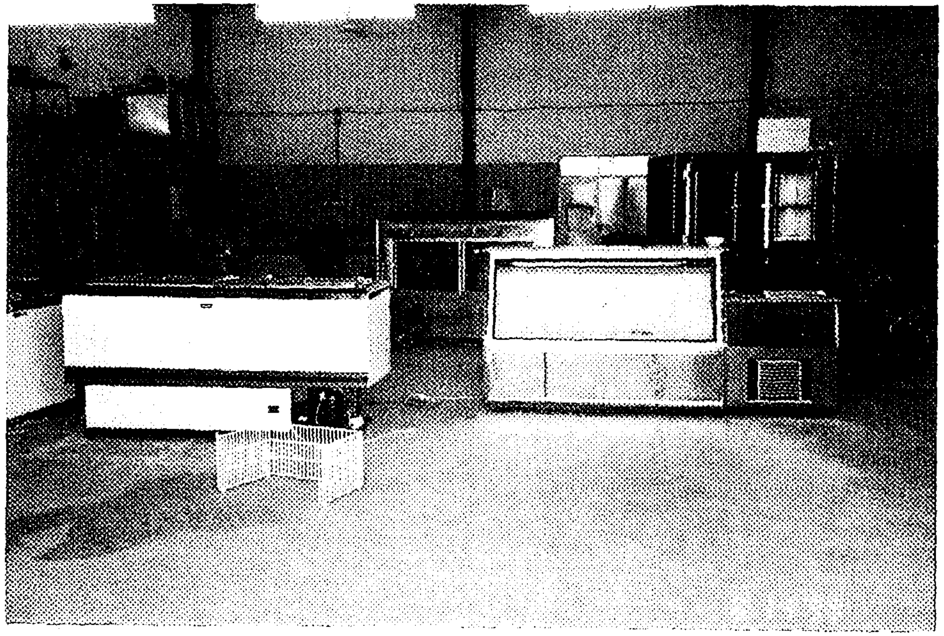
Ta – Tc = 30-10 = 20 °C

$Q_3 = UA\Delta T = 0.33 \times 0.923 \times 20 =$ 5.53 Watts

Q_3 = 13.4 Watts

$Q_t = Q_1 + Q_2 + Q_3$ = 65.8 + 260 + 6.1 = 332.4 + 20% safety factor = 399 Watts

Compressor R134a, Model FR7GH (total cooling capacity 525 watts) manufactured by Danfoss, is selected as a suitable compressor to replace R12 compressor model SC21B to operate at –10 C evaporating temperature.



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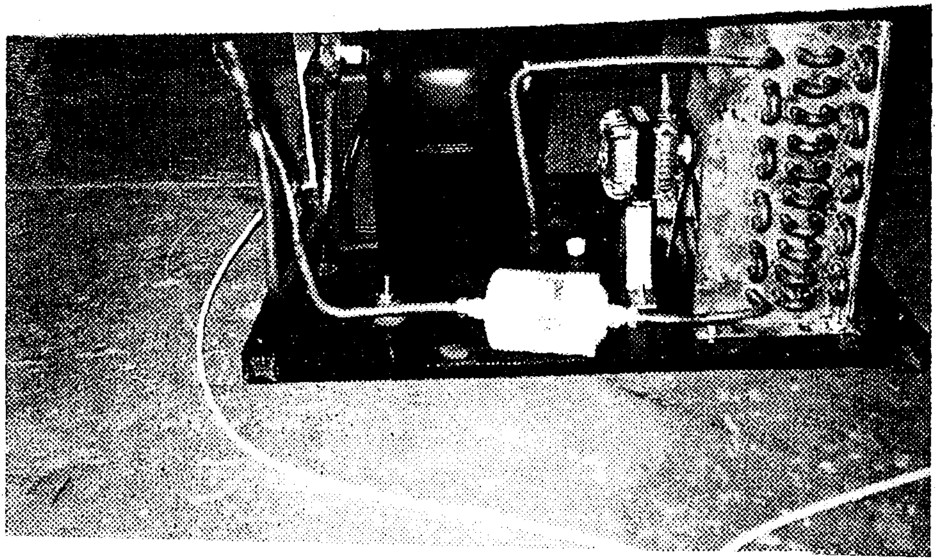

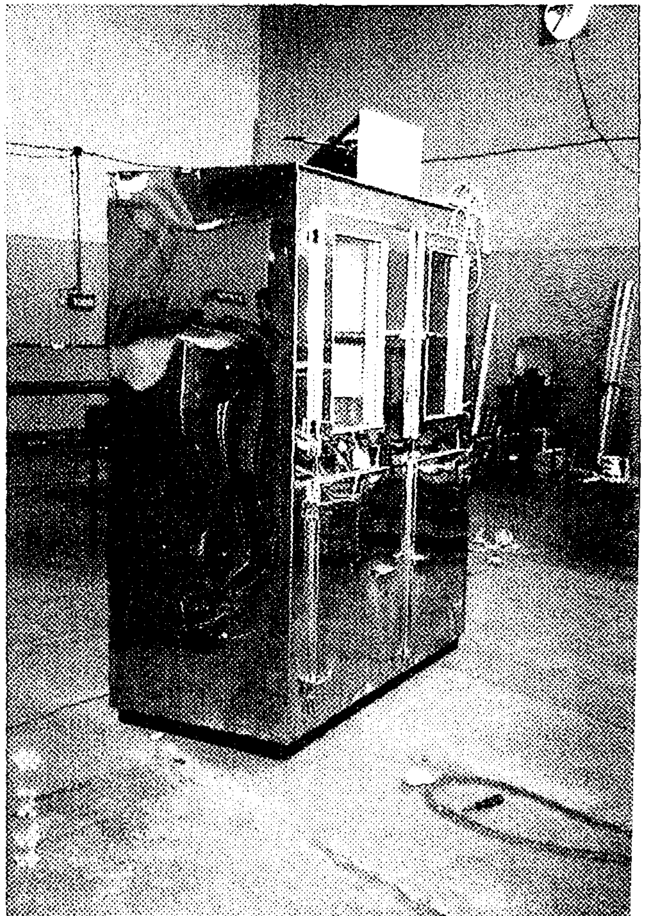

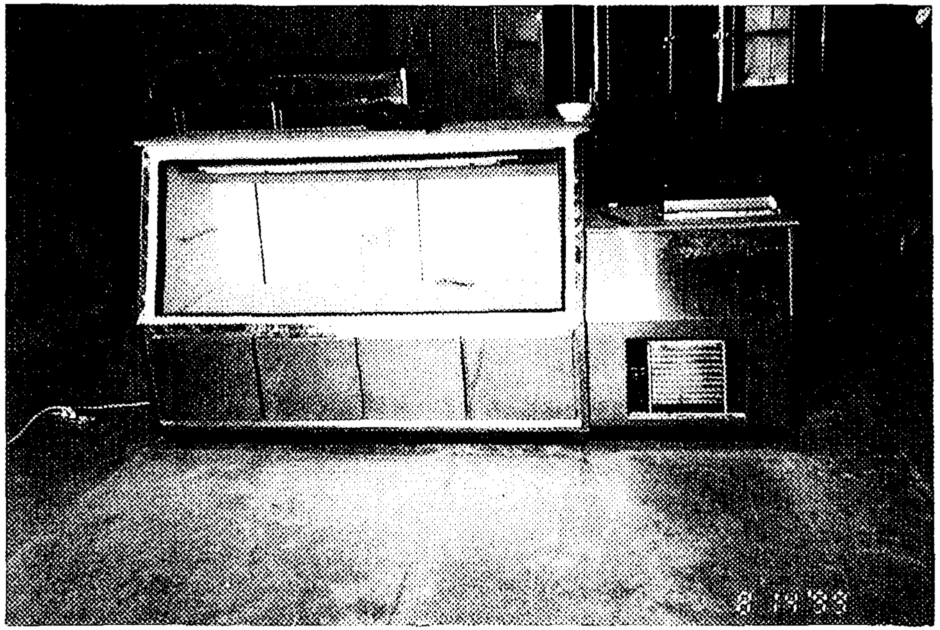

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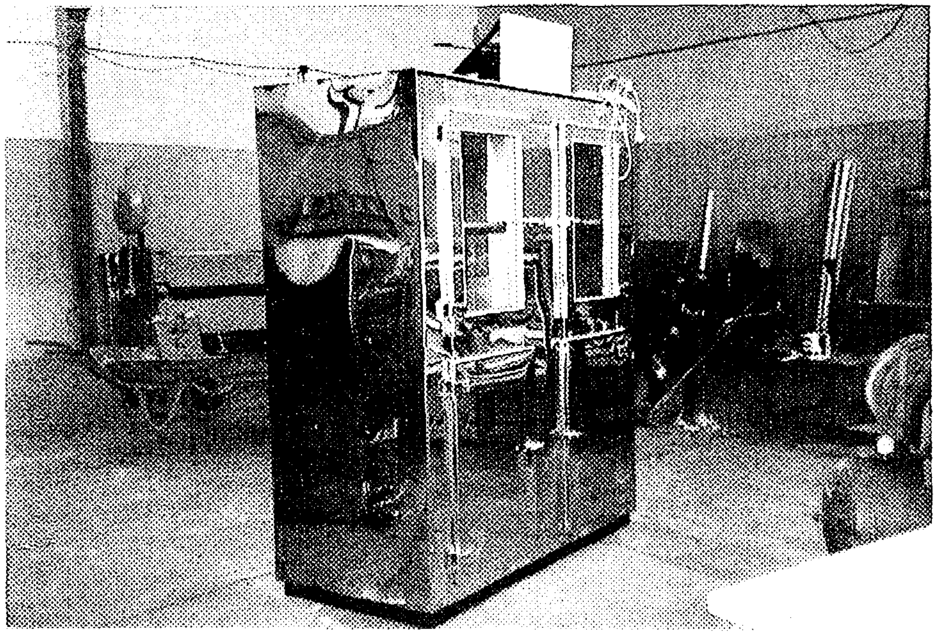

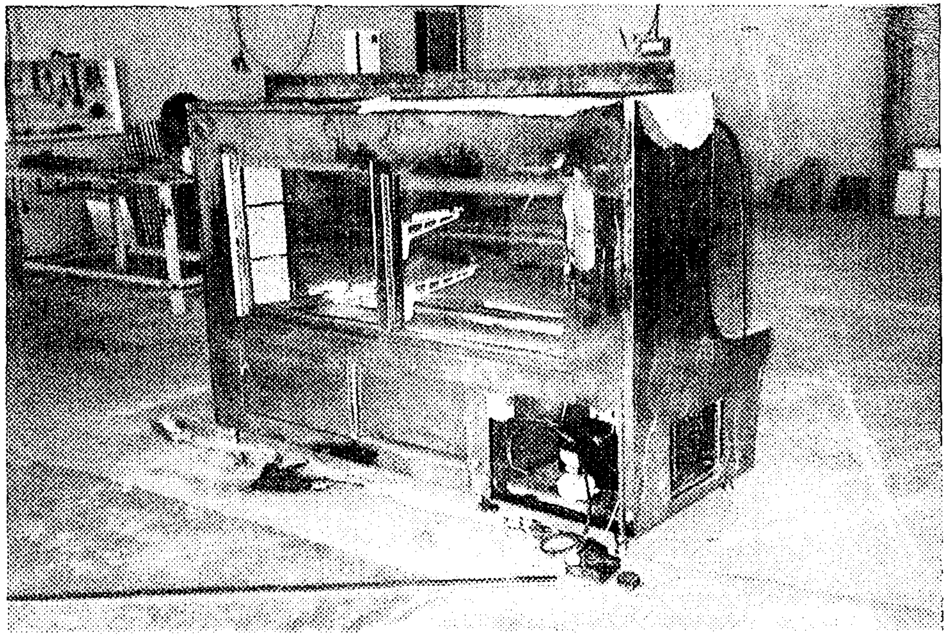

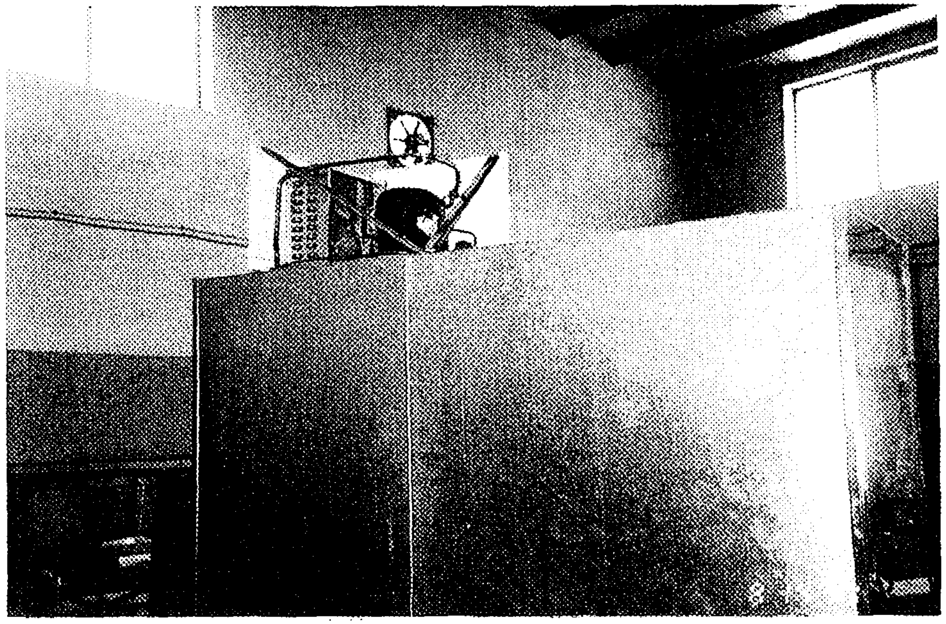

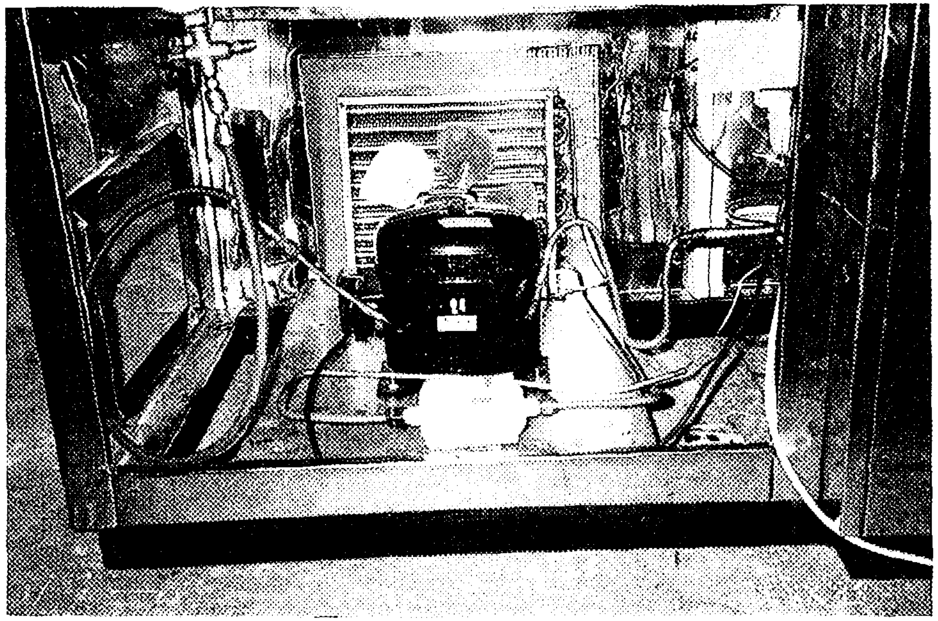

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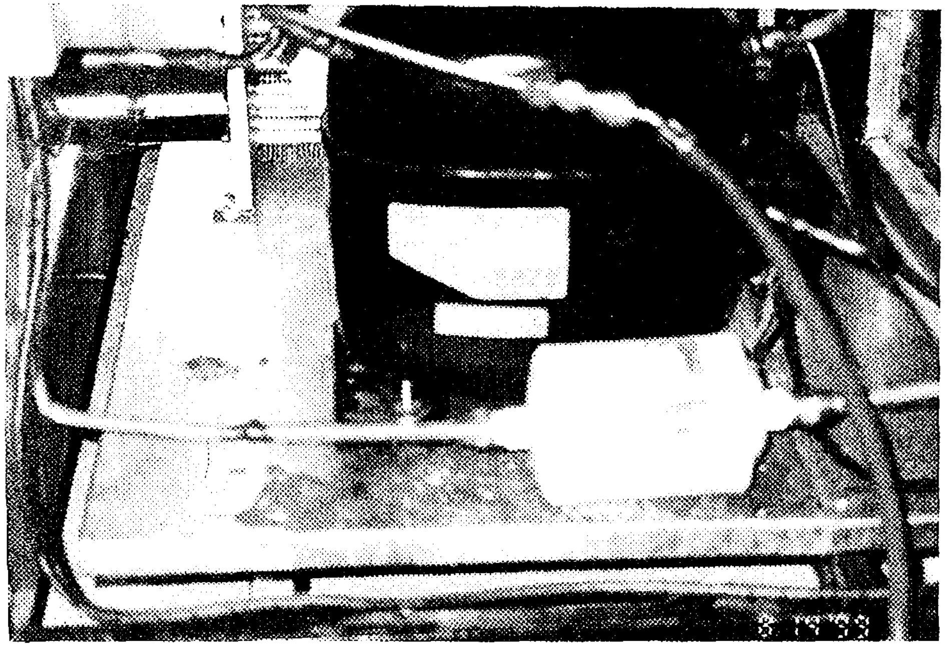

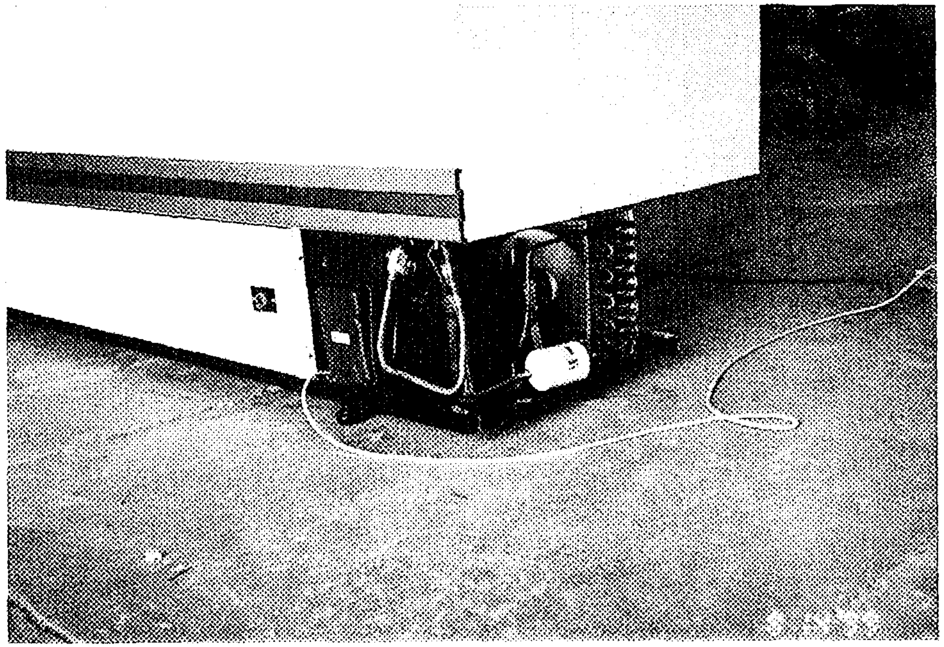

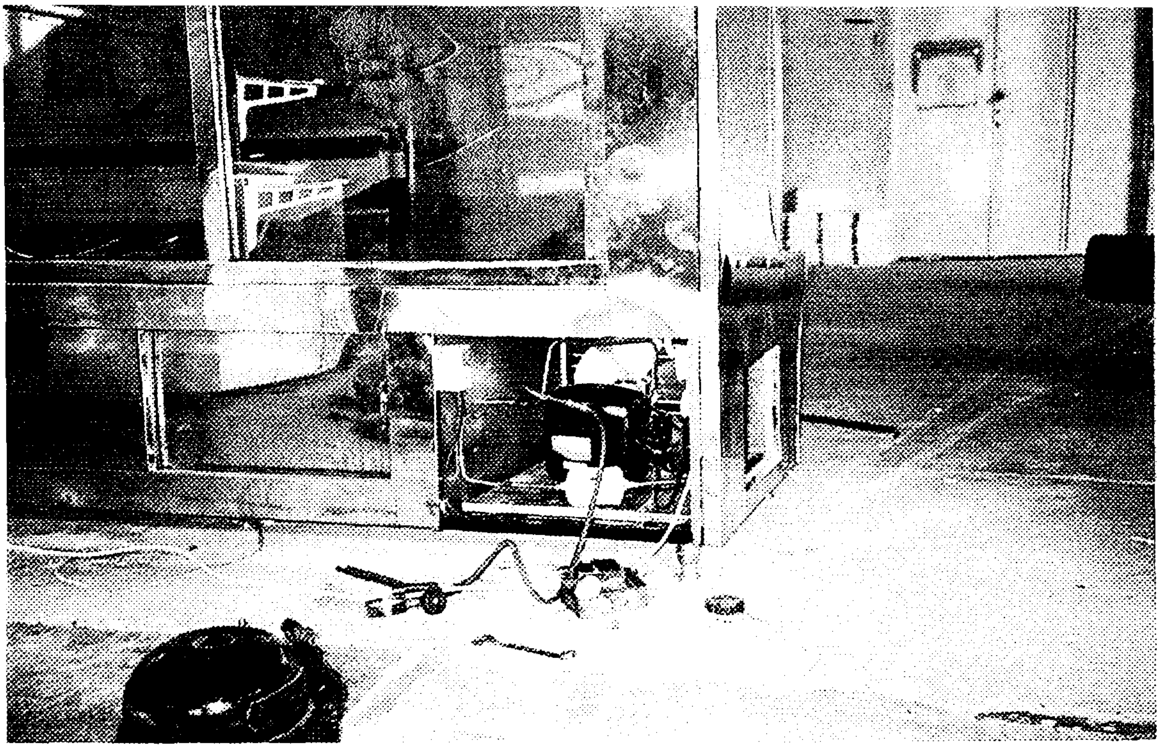

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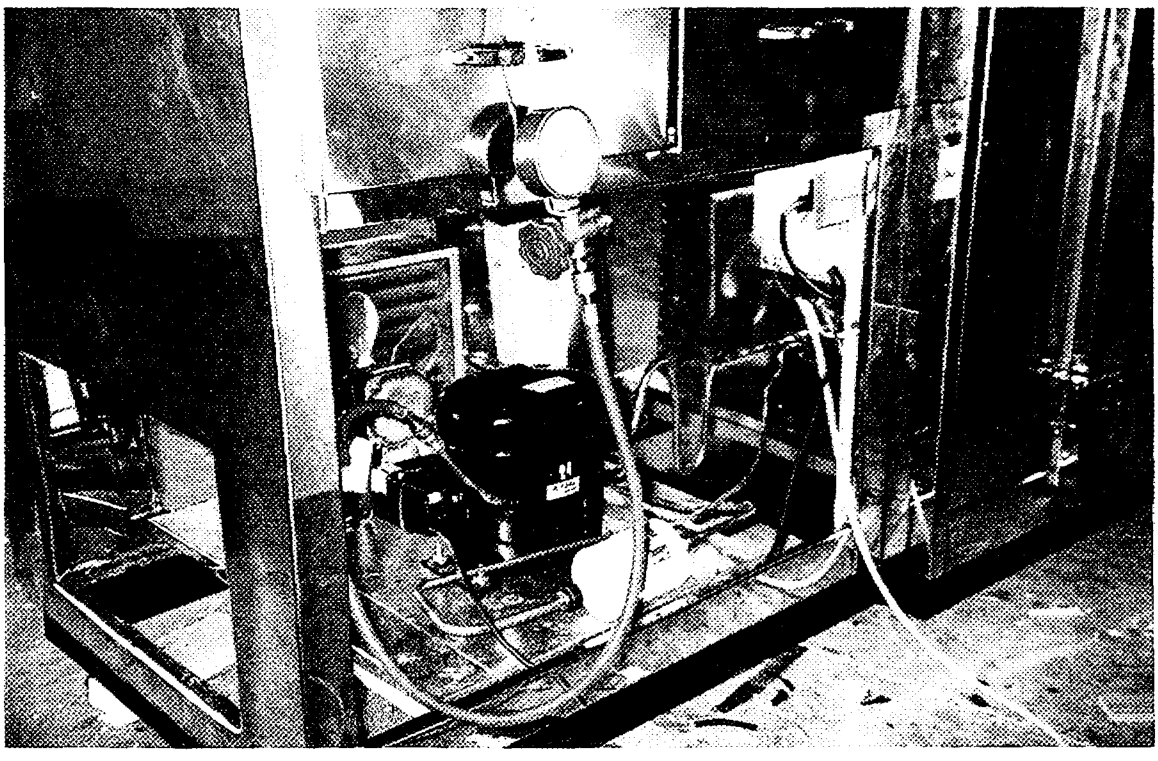

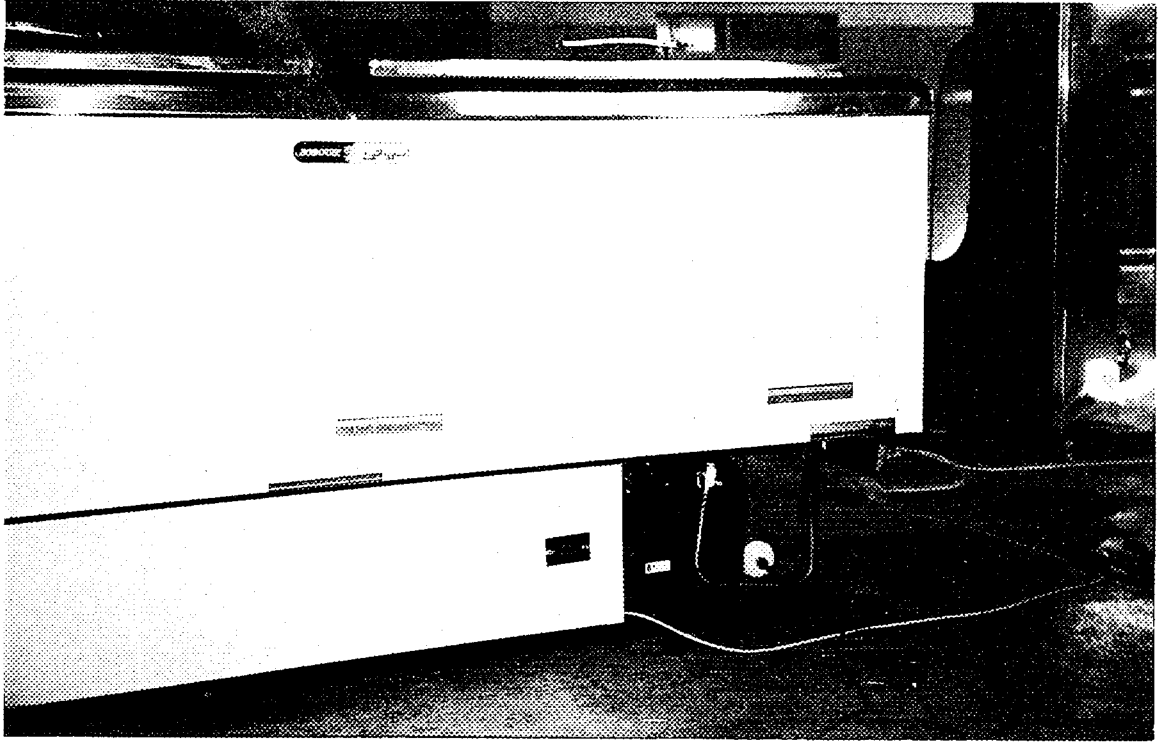

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