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SAHAND MINA ENGINEERING CO LTD

UNIDO

CONVERSION AND DEVELOPMENT OF PROTOTYPES INTO R134A OZONE FRIENDLY REFRIGERATION SYSTEM AT SAIWAN SANAT CO.

PROJECT NUMBER
MP/IRA/99/164

Contract Number
2000/36P

Final Report

August 2000

Final report

PROJECT NO. MP/IRA/99/164

Contract Number 2000/036P

Introduction

Please find below our Final Report, concerning calculation and redesign of the prototypes that have been made the counterparts and they have been tested at counterpart hot chamber. These prototypes have been manufactured under our close engineering supervision and will be tested in accordance with appropriate ISO standard test procedure and relevant performance test characteristics for functionality and performance of the new Ozone friendly R134a refrigerant. We hope that this report could have satisfied the UNIDO in order to comply with our contract. Four prototypes have been made by Saiwan Ind. Company.

Synopsis

This report has been prepared based on the Contract between UNIDO and Sahandmina Engineering company.
This project will phase out the use of CFC-11 and CFC-12 in the production of commercial refrigeration equipment at Saiwan Ind. Company. CFC-11, which is used as a foam blowing agent in the production of polyurethane

foam will be replaced by **HCFC-141b** and CFC-12 which is used as the refrigerant in the cooling circuit of appliances will be replaced by **HFC-134a**. The project includes the modification of all cooling equipment produced and the conversion of the production facilities. The model redesign element of the project includes testing, trial manufacture and reliability tests. The cost of converting foaming machines to use HCFC-141b will be covered by the counterpart organizations.

General Background

This report has been prepared and based on the UNIDO's contract and relevant terms of reference prepared by UNIDO and Sahandmina Co. Proposal to UNIDO.

The project will phase out, use of CFC-11 and CFC-12 for the production of Commercial Refrigerators at Saiwan Ind. Company. The redefinition of the existing refrigerator models in this company covers activities such as calculation and refrigeration system components selection.

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SAHAND MINA ENGINEERING CO.LTD.

شماره: Our Ref.: تاریخ: Date:

Project Summary

The Islamic Republic of Iran ratified the Montreal Protocol 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.

Based on the data provided by the Ozone Layer Protection Center/Department of Environment of Iran, the Refrigeration Sector in Iran is estimated to comprise of about 300 enterprises. The annual ODS consumption in the domestic and commercial refrigeration sectors is reported to be about 2,500 ODP MT as of 1998, representing the bulk of the overall ODS consumption in Iran. The domestic and commercial refrigeration sub-sector each contributes about 50% of the total ODS consumption in this sector. The average growth rate in this sector has been about 6.5% annually.

In the domestic refrigeration sub-sector, there are about 10 large manufacturers and about 15 medium-sized manufacturers, with a combined production of about 2 million units. In the commercial refrigeration sub-sector, there are about 30 relatively large-sized enterprises, and the remaining (estimated to be about 240) are small and medium sized. Due to the relatively unsophisticated technology and practices prevailing in the small and medium enterprises, and being unorganized, they will present a challenge to reach out to for purposes of participation in the Montreal Protocol programme for ODS phase-out.

There are two indigenous manufacturers of hermetic refrigeration compressors in Iran, which produce compressors suitable for domestic refrigeration appliances using CFC-12 technology. Their combined production is estimated to be about 800,000 units, which meets only a part of the domestic demand, the balance being imported. The hermetic and semi-hermetic compressors required by the commercial refrigeration sub-sector are predominantly imported.

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The ODS phase-out activities in this sector in Iran began in 1993. Since then, 7 investment projects in the domestic refrigeration sub-sector (amounting to a phase-out of 1,130 ODP MT) and 6 investment projects in the commercial refrigeration sub-sector (amounting to a phase-out of 321 ODP MT) have been approved.

The Ozone Layer Protection Center/Department of Environment is leading the efforts for ODS phase-out under the Montreal Protocol, in co-operation with the consuming and supplying industry and with the assistance of the implementing agencies. Complete ODS phase-out is targeted for 2005 except essential uses. The Refrigeration Sector has been identified as a priority sector for ODS phase-out.

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UNIDO has recently completed a detailed study of the commercial refrigeration sub-sector which identified more than 240 companies currently operating in this sector. Consequently new figures of the consumption of CFCs in this sector have been determined.

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

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Company Data

The Saiwan Sanaat Iran (Saiwan Sanaat Co.) is one of the manufacturers of commercial and domestic refrigerators and freezers located in Shahrake Pardis, near Tehran. The enterprise is 100% indigenously owned and was established and commenced production in 1992. The enterprise employs about 120 persons. The enterprise reports no exports and being financially sound.

The Saiwan Sanaat Co. has two main product lines. Production of 12 and 14 cuft refrigerators , 16 cuft. refrigerator / freezers ,Water Coolers and and chest freezers for commercial application. The products are depending on the markets. The Company produced in 1997 a total of 25,400 refrigerators & freezers and 82 Chest freezers in 6 models and 64 Water Coolers. In the preceding 12 months (20 March 1998 to 20 March 1999), the Saiwan Sanaat Co. produced a total of 8,800 refrigerators & freezers 13,600 refrigerators and 35 Chest freezers and consumed 12,372 MT of CFC-11 and 4.022 MT of CFC-12.

Aim of the Project

The aim of the immediate project is to;

- Design, calculation and ing for model redefinition.
- Testing prototypes for functionality and performance criteria.
- Redesign the cooling units of the all models so that they could run on the new Ozone friendly R134a instead of the ODP active CFC12.

Scope of the Contract

A study will be made for 4 models of commercial refrigerators made by Saiwan Ind. Co. to specify;

- Dimensional specification;

- Type and thickness of insulation
- Refrigeration unit component details
- Working performance
- Energy consumption

Selection of HFC 134a compatible components
Redesign of the refrigeration circuit as necessary
Specifying necessary changes in the cooling system if required
Preparation of the trial equipment one prototype per model
Testing of two prototypes for functionality and performance
Evaluation of the test results

Supply of the Material

Following components and material have been used to make prototypes .

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

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.

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- 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

Continues 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.
- Selecting Prototype Model

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- Refrigeration System components Familiarization
- Heat Load Calculation
- Thermostat Selection and Adjustment
- Refrigerant Charging Methods
- Testing Prototypes
- Analyzing Prototype Test Results

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Making Prototypes

- Prototype Model Selection

- Refrigeration System Components Selection

    1- Defrost Type
    2- No-Frost Type

- Familiarization with Refrigeration System Components

    1- Condenser

        a. Wire on Tube
        b. Tube welded on Plate
        c. Tune on Plate
        d. Tube in the Body
        e. Tube on the fins

    2- Capillary Tube

        a. Tube Length
        b. Tube Diameter
        c. Tube Material

    3- Expansion Valve

        a. Size
        b. Capacity
        c. Material

    4- Filter Direr

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a. Weight
b. Material
c. Model

5- Evaporator

a. Roll Bond
b. Wire on Tube
c. Tube welded on Plate
d. Tune on Plate
e. Tube in the Body
f. Tube on the fins

- Refrigeration Load Calculation

1- Aim of Calculation

a. Model Re-Definition
b. Model Improvement
c. Model Modification
d. Conversion of Prototype
e. Model New Design

2- Methods of Refrigeration Load Calculation

a. ASHREA
b. Manufacturer
c. Institutes and Universities

3- Different Elements Required for Calculation

a. Heat Transfer

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Dimension, Insulation, Ambient, Working Condition
Gasket, etc.

b. Product Load

Food, Material, Ice, Etc.

c. Infiltration

Door Opening, Air Replacement

d. Miscellaneous devices and apparatus

Light, Fan, Etc.

- Compressor

1- Cooling System

a. Static
b. Oil
c. Air

2- Pressure

a. LBP (Low Back Pressure)
b. HBP (High Back Pressure)
c. MBP (Medium Back Pressure)

3- Model

a. Hermetic
b. Semi-Hermetic

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c. Open

4- Type of Refrigerant

a. R12
b. R134a
c. Isobutene
d. Blend

5- Accessories

a. Capacitor Type
b. Starting Relay
c. Voltage, Frequency and Current
d. Electrical Circuit

6- Mounting Compressor

a. Refrigerant Fellow Direction
b. Top on the Roof
c. Bottom on Base
d. Double Compressor Mounted

7- Compressor Capacity

a. Watt
b. Horse Power
c. B.T.U/Hr
d. Kcal/Hr

8- Compressor Test Condition

CECOMAF

Evaporating Temp.	-25° C
Condensing Temp.	55° C
Ambiant Temp.	32° C
Suction Gas Temp.	32° C
Liquid Temp.	55° C
Volatage/Hertz	220V/50 Hz

Heat out Put= Capacity+Watt Consumption

ASHRAE

Evaporating Temp.	-23.3° C
Condensing Temp.	55° C
Ambiant Temp.	32° C
Suction Gas Temp.	32° C
Liquid Temp.	32° C
Volatage/Hertz	220V/50 Hz

Heat out Put= Capacity+Watt Consumption

ASHRAE to CECOMAF

Conversion of Capacity From CECOMAF into ASHRAE

R134a Multiply by 1.231
R22 Multiply by 1.097
R404 Multiply by 1.183
1 Watt = 0.86 Kcal/h
1 Watt = 3.41 BTU/h
1 Kcal/h = 1.0162 Watt
1 BTU/h = 0.293 Watt

9- Evaporating Temp. and Selection of Compressor

10- Thermostat

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Thermostat Adjustment

a. Cut-in Time – 5 to –15 Compressor Connected
b. Cut-out time –15 to –25 Compressor Dis-Connected
c. Thermostat Setting, Max. Med, Min
d. Thermostat Temperature Difference

- Refrigerant Type

1- CFC- 12
2- HFC-134a
3- Isobutene, R-600
4- Blend, (Isobutene+ Propane)

- Methods of Refrigerant Charging

1- Bottle, 13.5 Kg. Cylinder
2- Portable Charger
3- Production, Evacuation and Charging Equipment

- Refrigerant Charge Weight

1- Experimental, trial and error
2- Calculation
3- Comparison with other Refrigerants

- Refrigeration Leak Detection Procedure

1- Conventional Method, (water and Soap)
2- Portable Electronic Leak Detector
3- Production Electronic Leak Detector
4- Nitrogen, and Helium Leak Detection Procedure

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- Accuracy and Precision of Leak Detection Procedure

    5- Conventional Method, (water and Soap)
    6- Portable Electronic Leak Detector
    7- Production Electronic Leak Detector
    8- Nitrogen, and Helium Leak Detection Procedure

- Recovery

- Recycling

- Reclaiming

Testing Prototypes

- Test Prototypes with R12 Refrigerant to get desired test results.

- Hot Chamber Specification

- Placing Prototypes at Hot Chamber

- Mounting Sensors and their Place and Location

- Testing Condition

    1- Tropical "T" 43 °C

    2- Sub-Tropical 38 °C

    3- Normal 32 °C

    4- Sub-Normal 28 °C

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5- Cold 18 °C
6- Relative Humidity

- Test Package

- « M » Package

- Meat

- Ice

- Different Tests

1- Operational
2- Performance
3- Energy Consumption
4- Ice Making
5- Humidity

- Testing Procedure

1- Pull Down
2- Continuous Run
3- Cyclic Run

- Duration of Test

- Reading Test Results

- Test Results Analysis

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Refrigeration Load Calculation, for selection of System Components

Refrigeration load consist of three individual components:

1- Transmission load;
Heat transfer through side walls by conduction, Radiation, and convection

2 - Product load;
Heat Removed from and produced by the products which are stored. Categorized by Heat removed above freezing point, heat removed below freezing point, and heat removed by latent heat of fusion,

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

4 - Infiltration load
Heat gains associated with air entering the refrigerated space and door opening and etc.;

In this section , the above mentioned components will be discussed separately to analyze and extract the most useful and practical equipment's.

Transmission Load

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

$$T_{refrigerator} \Longleftarrow (R_{liner} + R_{insulation} + R_{cabin} + R_{ambient}) \Longleftarrow T_{ambient}$$

Where; T = Temperature, and R = Resistance

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 related equations is.

$$Q = UA\,\Delta T$$

$$U = \frac{1}{x1/K1 + x2/K2 + x3/K3 + \ldots\ldots}$$

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

Where:

x = Insulation Thickness, mm

K = Insulation Conductivity, $Wmt./sqmt.\circ K$

A = Outside Area, m^2

$\Delta T =$ Temperature difference (T_a - T_c), C

"K" = Thermal conductivity for some materials are

1- Cyclopentane PU foam 0.0195 $W/Mt.\circ K$
2- R11 PU Foam 0.017 $W/Mt.\circ K$
3- R141b PU foam 0.0184 $W/Mt.\circ K$
4- Still Air at atmospheric pressure and 0 °C = 0.025 $W/Mt.\circ K$
5- High Vacuum Air = 00058 $W/Mt.\circ K$
6- Glass 0.721 $W/Mt.\circ K$
7- Glass Wool 0.0418 $W/Mt.\circ K$
8- Hard Woods 0.112/0.160 $W/Mt.\circ K$

Units and Conversion of some most used units and constant

1- Multiply, (Btu. Ft/Hr. Ft^2. °F) by 1.731 to obtain W/(Mt. K)
2- Multiply, (Btu. in/(Hr. Ft^2. °F) Thermal Conductivity "K" by 0.1442 to obtain W/(Mt. K)
3- Multiply, BTU/Hr By 0.2931 to obtain Watt
4- Multiply, Kcal/Hr By 1.163 to obtain Watt
5- Multiply, Btu/Hr. Ft^2 by 3.155 to obtain Watt/ Mt^2
6- Multiply, Btu/Hr. Ft^2 °F by 5.678 to obtain Watt/ Mt^2K
Overall Heat Coefficient "U"
7- Multiply Kilocalorie by 4.184 to obtain kJ/(kg. K)
8- Multiply Kilocalorie by 4187 to obtain kJ/s
9- J/s = Watt/s
10-Multiply Horsepower by 746 to obtain Watt

If the insulation thickness of sidewalls, back panels, top, bottom and door are different. Heat transfer for each part can be calculated separately and then summed for freezer and refrigerator compartments as necessary, 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 (T_i) to storing temperature (T_{rs}) in refrigerator compartment is;

$$Q_{rs} = \dot{M}C\,(T_i - T_{rs})$$

Where:

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

C = Specific heat of product, Kcal / Kg

2 - Heat removed from initial temperature (Ti) to freezing temperature (T_f) is ;

$$Q_{af} = \dot{M}\,C\,(T_i - T_f)$$

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;

$$Q_L = \dot{M}\, h$$

Where h = Latent heat of product, Kcal / Kg

4 - Heat removed from freezing temperature (T_f) to final storage temperature (T_{fs}) is;

$$Q_{bf} = \dot{M}\, C_{bf}\, (T_f - T_{fs})$$

Where:

C_{bf} = Specific heat of products below freezing temperature.

For upright freezers or chest freezer, total product load is

$$Q_{pl} = Q_{af} + Q_l + Q_{bf}$$

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

$$Q_{pl} = Q_{rs}$$

Internal Load

Electrical energy dissipated in the refrigerated space such as lights, fan motors, heaters, should be calculated as appropriate depending on type of display cases and other products.

Infiltration Load

Infiltration is an important factor that should be considered due to the big heat load exert to the system. 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 and /or open top freezer of show cases. Infiltration load is one of the most important load components.

Total Refrigeration load

As it was mentioned before, transmission load (Q_{tl}), product load (Q_{pl}) and internal load (Q_{IL}) can be calculated separately. For infiltration load (air exchange through doorways or gasket leakage), we have to take into account that depending on the type of models we have to consider different amount of heat gain, or a percentage of amount of the above mentioned components. (Transmission load, product load and internal load). For example;

$$\mathbf{Q_{Total} = Q_{TL} + Q_{PL} + Q_{IL}\ )}$$

$$\mathbf{Q_{Grand\ Total} = \{(Safety\ Factor\ 10\%\text{-}40\%) + Q_{total}\}}$$

Safety Factor Percentage could vary from model to model, application , type of product to be loaded, country, ambient temperature, and size of compressor to be used. Therefore there is no standard rule for choosing amount of safety factor percentage. It is up to the engineer who is redesigning the appliance and he/she has to consider the specific criteria of the model with respect to the situation and condition exist.

Refrigeration Load Calculation for 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-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 ½ 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 bubblers 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.

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

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

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

Q_2 Total heat removed from total drinking water flow (lit.) during specific period, in designated hours set by manufacturer of customer. In Kcal.

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

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

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

$$Q_3 = UA\ \Delta T$$

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

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

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

LOAD CALCULATION OF PROTOTYPES

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 and designated C.O.P of compressor by Manufacturer, 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:

$$Qc = \frac{Q_{GT} x16Hrs}{24Hrs / C.O.P}$$

Where :

Qc = required cooling capacity

C.O.P of compressor should be considered during selection of compressor Model from Manufacturer Catalogues

Capillary Tube

Practically all domestic refrigerators being built, and many of the smaller size commercial refrigerating systems built by mass production methods employ a capillary tube.

A capillary tube is simply a small diameter liquid line connecting the high side to the low side. Because of the pressure drop caused by the length and small bore of the tube, it controls the flow of refrigerant to the low side. Capillary tube reduces the amount of refrigerant charge required and permits the use of split phase hermetic motor compressor. It also allows the low side and high side pressure to equalize during the off cycle, thereby reducing the start torque requirement of the motor. The length of capillary tube should be adjusted as required to create more pressure drop and adjust liquid flow, during conversion of prototypes. 10% to 15% length increase is recommended

Condenser

A condenser is a heat exchanger device that changes the super heat gas into liquid phase under constant pressure, the size of condenser is equal to Cooling capacity of evaporator plus heat produced by compressor minus heat dissipated by compressor shell. The size of condenser usually will not change in hermetic compressor refrigerators, but for big size of compressor increasing condenser size should be considered.

Evaporator

Evaporator is a heat exchanger device that removes heat from the product load and also absorbs the heat which enters to the appliance through doors and walls, air change and heat produced by light, electro motor and etc. the evaporator size will not normally require any changes due to the amount of refrigeration load which remain unchanged during conversion.

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SATURATION PROPERTIES COMPARISON

	R12					R134a				
Temp C	P Kpa	Entholpy Kj/Kg	Entholpy Kj/Kg	Sp.Vol Lit/Kg	Sp.Vol Lit/Kg	P Kpa	Entholpy Kj/Kg	Entholpy Kj/Kg	Sp.Vol Lit/Kg	Sp. Vol Lit/Kg
		hf	hg	Vf	Vg		hf	hg	Vf	Vg
-30	100.41	172.81	338.14	0.672	159.37	84.36	61.51	277.208	0.7100	0.2219
-26	118.72	176.38	339.96	0.677	136.28	101.65	66.56	212.96	0.7171	0.1868
-22	139.53	179.96	341.78	0.682	117.16	121.62	71.63	281.86	0.7243	0.1570
-18	163.04	183.56	343.58	0.688	101.24	144.56	76.72	284.19	0.7318	0.1313
-14	189.50	187.18	345.36	0.694	87.89	170.76	81.84	286.52	0.7396	0.1138
-10	219.12	190.82	347.13	0.700	76.64	200.51	86.98	288.85	0.7475	0.0941
-6	252.14	194.47	348.88	0.706	67.11	234.13	92.162	291.18	0.7558	0.0843
-4	270.01	196.31	349.75	0.709	62.89	252.49	94.76	292.35	0.7600	0.0784
-2	288.82	198.15	350.61	0.712	58.99	271.94	97.377	293.522	0.7643	0.0730
0	308.61	200.00	351.47	0.715	55.38	292.52	100.00	294.68	0.7687	0.0681
2	329.40	201.85	352.33	0.719	52.04	314.27	102.63	295.35	0.7732	0.0635
4	351.24	203.71	353.17	0.722	48.94	337.24	105.28	297.01	0.7777	0.0594
6	374.14	205.57	354.02	0.726	46.07	361.47	107.93	298017	0.7823	0.0555
8	398.15	207.44	354.85	0.729	43.40	387.01	110.60	299.33	0.7870	0.0520
10	423.30	209.32	355.68	0.733	40.91	413.90	113.29	300.49	0.7918	0.0487

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Refrigeration Load Calculation
Heat Leaks Through Walls

$$Q = U \,.\, A \,.\, \Delta T$$

Model Saiwan 1298

Description	Dimension	Surface Area Sq. Mt.	Ambient Temp. °C	Reference Inside Temp.	ΔT Temp. Diff.	X Insulation Thickness	K Thermal Conductivity	U Coeff. Heat Resistance	Q U . A . ΔT *Watt*
Upper Side Walls	2x24x51	0.25	32	-9	41	35	0.0184	0.52	5.33
Upper Back Panel	24x60	0.14	42	-9	51	35	0.0184	0.52	3.71
Top surface	51x60	0.31	32	-9	41	35	0.0184	0.52	6.61
Bottom surface	51x60	0.31	32	+4	28	35	0.0184	0.52	4.51
Upper Door Section	24x60	0.14	32	-9	41	35	0.0184	0.52	2.98
Lower Door Section	138x60	0.83	32	+4	28	35	0.0184	0.52	12.10
Lower Side Walls	2x138x51	1.41	32	+4	28	35	0.0184	0.52	20.52
Lower Back Panel	138x60	0.83	42	+4	38	35	0.0184	0.52	16.40
Total									72.16

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Product Load Calculation
Model Saiwan 1298

Product to be loaded	Product Mass Load Kg.	Product Specific heat Above Freezing Point J/Kg. K	Product Specific heat Below Freezing Point J/Kg K	Latent Heat of Fusion J/Kg.	Product Initial Temp C	Product Final Temp. C	Temp. Diff.	Q_1 $m\, C_1\, \Delta T$	Q_2 $m\, .\, C_2\, .\, \Delta T$	Q_3 $M\, .\, h$
ICE	5	4180	1650	333	24	4	20	4.85	2.05	19.3

Q_1=(55x20x4180)/86400 =4.85, Q_2 = (5x18x1950)/86400=2.05, Q_3= (5x333000)/86400=19.3

Total* $= Q_1 + Q_2 + Q_3 = 52.3$ *Watts

Miscellanies Heat Load

Air Change = V . N . H V = Refrigerator Internal Volume N = Number of Air Change per Day H = Heat removed from cubic meter of air = 75000 jul/sec.	Gasket U . A. ΔT *U=0.07* *L =2.84 Mt.* ΔT= *28*	Electrometer	Florescent Lamp	Total
(0.274x30x75000)/86400 = 6.2	5.6	N/A	N/A	11.8

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
72.2	26.2	11.8	25	135

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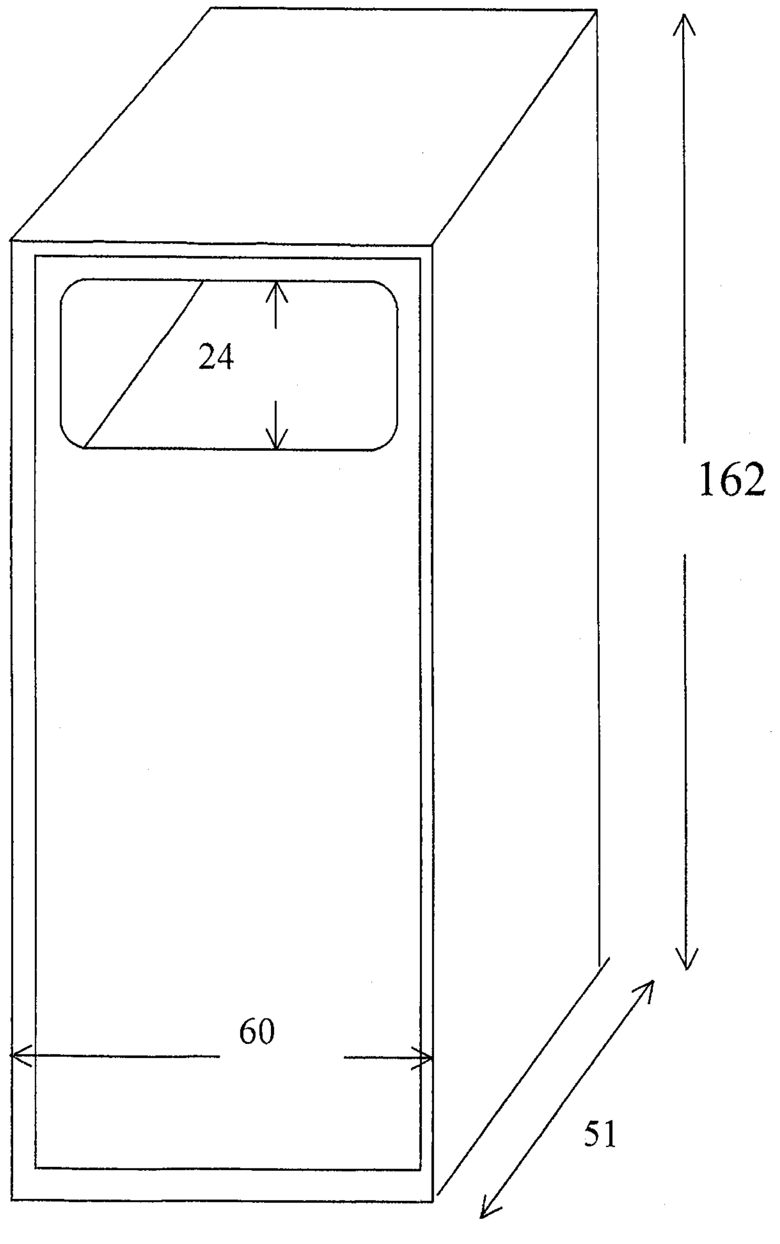

Refrigerator Model R1298

Sahand Mina Engineering Co. Ltd.

Refrigeration Load Calculation
Heat Leaks Through Walls
$Q = U \cdot A \cdot \Delta T$
Model Saiwan FR 1699

Description	Dimension	Surface Area Sq. Mt.	Ambient Temp. °C	Reference Inside Temp.	ΔT Temp. Diff.	X Insulation Thickness	K Thermal Conductivity	U Coeff. Heat Resistance	Q $U \cdot A \cdot \Delta T$ *Watt*
Upper Side Walls	2x42x57	0.48	32	-18	50	60	0.0184	0.31	7.44
Upper Back Panel	42x64	0.27	42	-18	60	60	0.0184	0.31	5.02
Top surface	64x57	0.36	32	-18	50	60	0.0184	0.31	5.58
Bottom surface	64x57	0.36	32	+10	22	35	0.0184	0.52	4.12
Upper Door Panel	42x64	0.27	32	-18	50	35	0.0184	0.52	7.02
Lower Door Panel	138x64	0.88	32	+4	28	35	0.0184	0.52	12.81
Lower Side Walls	2x138x57	1.57	32	+4	28	45	0.0184	0.52	22.86
Lower Back Panel	138x64	0.88	42	+4	38	45	0.0184	0.52	17.39
Total									82.24

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Product Load Calculation
Model Saiwain 1699

Product to be loaded	Product Mass Load Kg.	Product Specific heat Above Freezing Point J/Kg. K	Product Specific heat Below Freezing Point J/Kg K	Latent Heat of Fusion J/Kg.	Product Initial Temp C	Product Final Temp. C	Temp. Diff.	Q_1 $m\,C_1\,\Delta T$	Q_2 $m.\,C_2.\,\Delta T$	Q_3 $M.\,h$
ICE	20	4180	1650	333	24	4	20	19.35	8.11	77.1

Q_1=(20x20x4180)/86400 = 19.35, Q_2 = (20x18x1950)/86400=8.11, Q_3= (20x333000)/86400=77.1

$Total = Q_1 + Q_2 + Q_3 = 104.6 Watts$

Miscellanies Heat Load

Air Change = V . N . H V = Refrigerator Internal Volume N = Number of Air Change per Day H = Heat removed from cubic meter of air = 75000 jul/sec.	Gasket U . A. ΔT *U=0.07* *L =6.16Mt.* ΔT_{mean}= 39	Electrometer	Florescent Lamp	Total
(0.380x30x75000)/86400 = 9.9	16.8	N/A	N/A	26.7

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
82.24	104.6	26.7	36	220

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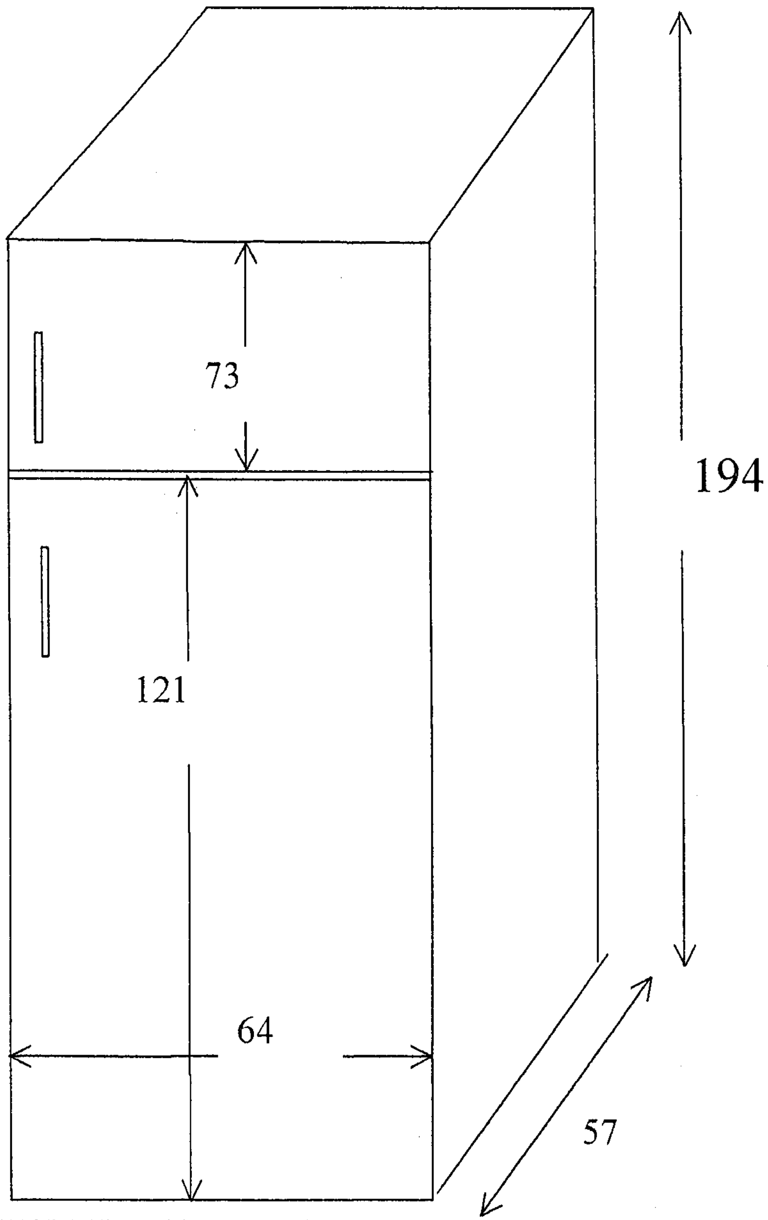

Refrigerator and Freezer
Model FR1699

Sahand Mina Engineering Co. Ltd.

Refrigeration Load Calculation
Heat Leaks Through Walls
$Q = U \cdot A \cdot \Delta T$
Model Saiwan FR 1800

Description	Dimension	Surface Area Sq. Mt.	Ambient Temp. °C	Reference Inside Temp.	ΔT Temp. Diff.	X Insulation Thickness	K Thermal Conductivity	U Coeff. Heat Resistance	Q $U \cdot A \cdot \Delta T$ *Watt*
Upper Side Walls	2x73x57	0.83	32	-18	50	60	0.0184	0.31	12.8
Upper Back Panel	73x64	0.47	42	-18	60	60	0.0184	0.31	8.74
Top surface	57x64	0.36	32	-18	50	60	0.0184	0.31	5.58
Bottom surface	57x64	0.36	32	+10	22	35	0.0184	0.52	4.12
Upper Door Panel	73x64	0.47	32	-18	50	35	0.0184	0.52	12.22
Lower Door Panel	121x64	0.77	32	+4	28	35	0.0184	0.52	11.21
Lower Side Walls	2x121x57	1.38	32	+4	28	45	0.0184	0.52	20.09
Lower Back Panel	121x57	0.69	42	+4	38	45	0.0184	0.52	13.63
Total									88.39

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Product Load Calculation
Model Saiwan 1699

Product to be loaded	Product Mass Load Kg.	Product Specific heat Above Freezing Point J/Kg. K	Product Specific heat Below Freezing Point J/Kg K	Latent Heat of Fusion J/Kg.	Product Initial Temp C	Product Final Temp. C	Temp. Diff.	Q_1 $m\ C_1\ \Delta T$	Q_2 $m\ .\ C_2\ .\ \Delta T$	Q_3 $M\ .\ h$
ICE	20	4180	1650	333	24	4	20	19.35	8.11	77.1

Q_1=(20x20x4180)/86400 = 19.35, Q_2 = (20x18x1950)/86400=8.11, Q_3= (20x333000)/86400=77.1

Total = $Q_1 + Q_2 + Q_3$ = 104.6Watts

Miscellanies Heat Load

Air Change = V . N . H V = Refrigerator Internal Volume N = Number of Air Change per Day H = Heat removed from cubic meter of air = 75000 jul/sec.	Gasket U . A. ΔT *U=0.07* *L =6.44 Mt.* ΔT_{mean}= *39*	Electrometer	Florescent Lamp	Total
(0.307x30x75000)/86400 = 8	17.6	N/A	N/A	25.6

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
88.4	104.6	25.6	40	258

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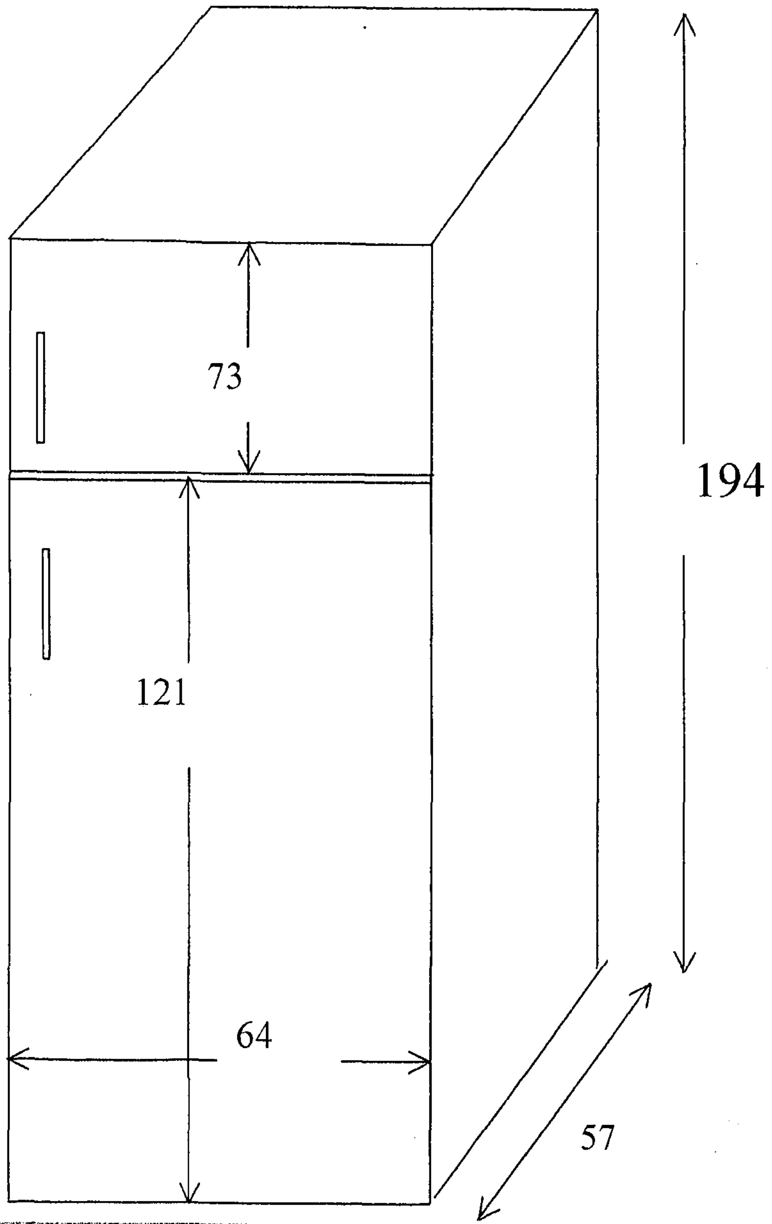

Refrigerator and Freezer
Model FR1800

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Refrigeration Load Calculation
Heat Leaks Through Walls
$Q = U \cdot A \cdot \Delta T$
Model F675

Description	Dimension	Surface Area Sq. Mt.	Ambient Temp. °C	Reference Inside Temp.	ΔT Temp. Diff.	X Insulation Thickness	K Thermal Conductivity	U Coeff. Heat Resistance	Q $U \cdot A \cdot \Delta T$ *Watt*
Side Walls	2x57x75	0.85	32	-18	50	50	0.0184	0.37	15.72
Front Side Panel	85x75	0.64	32	-18	50	50	0.0184	0.37	11.84
Back Side Panel	85x75	0.64	32	-18	50	50	0.0184	0.37	11.84
Top Door	57x85	0.48	32	-18	50	50	0.0184	0.37	8.88
Bottom surface	57x75	0.48	42	-18	60	50	0.0184	0.37	10.66
Total									58.94

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Product Load Calculation
Model Saiwan F675

Product to be loaded	Product Mass Load Kg.	Product Specific heat Above Freezing Point J/Kg. K	Product Specific heat Below Freezing Point J/Kg K	Latent Heat of Fusion J/Kg.	Product Initial Temp C	Product Final Temp. C	Temp. Diff.	Q_1 $m\,C_1\,\Delta T$	Q_2 $m\,.\,C_2\,.\,\Delta T$	Q_3 $M\,.\,h$
ICE	15	4180	1650	333	24	4	20	14.5	6.1	57.8

Q_1=(15x20x4180)/86400 = 14.5, Q_2 = (15x18x1950)/86400=6.1, Q_3= (20x333000)/86400=57.8

Total = $Q_1 + Q_2 + Q_3$ = 78.4Watts

Miscellanies Heat Load

Air Change = V . N . H V = Refrigerator Internal Volume N = Number of Air Change per Day H = Heat removed from cubic meter of air = 75000 jul/sec.	Gasket U . A. ΔT *U=0.07* *L =2.8* *Mt.* ΔT*=50*	Electrometer	Florescent Lamp	Total
(0.170x30x75000)/86400 = 4.4	9.8	N/A	N/A	14.2

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
58.9	78.4	14.2	30	181

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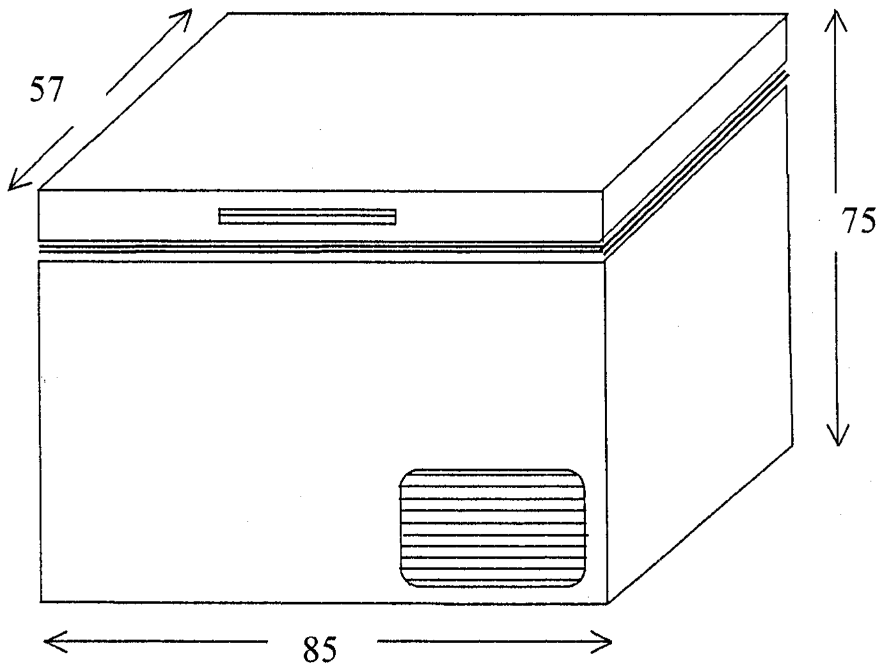

Chest Freezer
Model F675