



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

22451

38 p.
tables
diagrams

**SAHAND MINA
ENGINEERING CO LTD**



CONVERSION AND DEVELOPMENT OF
PROTOTYPES INTO R134A OZONE
FRIENDLY REFRIGERATION SYSTEM
At *BARD COMPANY*

PROJECT NUMBER
MP/IRA/99/161

Contract Number
2000/36P
Final Report

August 2000



شرکت مهندسی سهند مینا (با مسئولیت محدود)

SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

Conversion of Prototypes at Bard Company

Final Report

PROJECT NO. MP/IRA/99/109

Contract Number 2000/036P

Introduction

Please find below our Final Report, concerning calculation and redesign of the prototypes that have been made by the counterparts and they have been tested at counterpart hot chamber. These prototypes have been manufactured under our close engineering supervision and have been 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. Three prototypes have been made and tested successfully by Bard 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 Bard 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





شرکت مهندسی سهند مینا (با مسئولیت محدود)
SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

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 Bard Company. The redefinition of the existing refrigerator models in this company covers activities such as calculation and refrigeration system components selection.





شرکت مهندسی سهند مینا (با مسئولیت محدود)

SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره :

Date: تاریخ :

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.

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.





شرکت مهندسی سهند مینا (با مسئولیت محدود)

SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

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.

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





شرکت مهندسی سهند مینا (با مسئولیت محدود)
SAHAND MINA ENGINEERING CO. LTD.

Our Ref.: شماره:

Date: تاریخ:

Insulation foam blowing using CFC-11

Company Data

The Bard Co. is one of the manufacturers of commercial and domestic refrigerators and freezers located near Tehran. The enterprise is 100% indigenously owned and was established and commenced production in 1984. The enterprise employs about 105 persons. The enterprise reports no exports and being financially sound.

The Bard Co. has two main product lines. Production of 14 and 17 cuft. refrigerator / freezers ,water coolers, industrial freezers and chest freezers for commercial application. The products are depending on the markets. The Company produced in 1997 a total of 20,400 refrigerators & freezers and 6,805 chest freezers in 5 models. In the preceding 12 months (20 March 1998 to 20 March 1999), The Bard Co. produced a total of 16,800 refrigerators & freezers and 6,100 Chest freezers and consumed 13.676 MT of CFC-11 and 4.343 MT of CFC-12.





Our Ref.: شماره:

Date: تاریخ:

The total CFC consumption for commercial refrigeration products works out to 13.70 CFC-11 and 4,4 MT CFC-12 based on the data reported as above. All cabinets are fabricated from sheet metal.

Aim of the Project

The aim of the immediate project is to;

- Design, calculation and drafting 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 has been made for 3 models of commercial refrigerators made by Bard 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





Our Ref.: شماره:

Date: تاریخ:

Supply of the Material

Following components and material have been used to make prototypes .

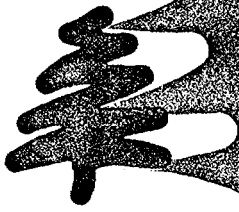
- R134a Compressors
- R134a Refrigerant
- Refrigerant Accumulators
- Specially designed filter drier
- Specially designed evaporator and condenser

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.
 - 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





Our Ref.: شماره:

Date: تاریخ:

- 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





Our Ref.: شماره :

Date: تاریخ :

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





شرکت مهندسی سهند مینا (با مسئولیت محدود)

SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

- Performance test
- Test results Evaluation.
- Refrigeration system adjustment.
- Selecting Prototype Model
- Refrigeration System components Familiarization
- Heat Load Calculation
- Thermostat Selection and Adjustment
- Refrigerant Charging Methods
- Testing Prototypes
- Analyzing Prototype Test Results





Our Ref.: شماره:

Date: تاریخ:

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. Tube 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

- a. Weight
- b. Material
- c. Model





Our Ref.: شماره:

Date: تاریخ:

5- Evaporator

- a. Roll Bond
- b. Wire on Tube
- c. Tube welded on Plate
- d. Tube 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

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

- b. Product Load

Food, Material, Ice, Etc.





Our Ref.: شماره:

Date: تاریخ:

- b. Starting Relay
- c. Voltage, Frequency and Current
- d. Electrical Circuit

6- Mounting Compressor

- a. Refrigerant Flow 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





شرکت مهندسی سهند مینا (با مسئولیت محدود)
SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

Volatage/Hertz 220V/50 Hz
Heat out Put= Capacity + Watt Consumption

**Conversion of Capacity From CECOMAF into ASHRAE
ASHRAE to CECOMAF**

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

Thermostat Adjustment

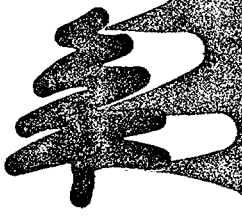
- Cut-in Time – 5 to –15 Compressor Connected
- Cut-out time –15 to –25 Compressor Dis-Connected
- Thermostat Setting, Max. Med, Min
- Thermostat Temperature Difference

- Refrigerant Type

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

- Methods of Refrigerant Charging





Our Ref.: شماره:

Date: تاریخ:

- 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

- **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





شرکت مهندسی سهند مینا (با مسئولیت محدود)
SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

- 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
 - 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





شرکت مهندسی سهند مینا (با مسئولیت محدود)

SAHAND MINA ENGINEERING CO.LTD.

Our Ref.: شماره:

Date: تاریخ:

- **Testing Procedure**
 - 1- Pull Down
 - 2- Continuous Run
 - 3- Cyclic Run
- **Duration of Test**
- **Reading Test Results**
- **Test Results Analysis**



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:

$$Q_c = \frac{Q_{GT} \times 16 \text{Hrs}}{24 \text{Hrs} / \text{C.O.P}}$$

Where :

Q_c = 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.

SAHAAD MINA ENGINEERING CO LTD

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

ΔT Temperature difference ($T_i - T_c$), where, T_i is inlet water temperature, and T_c is final cooled water temperature.

$$Q_3 = UA \Delta T$$

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.

ΔT Temperature difference ($T_a - T_c$), where, T_a is ambient temperature, and T_c is final cooled water temperature.

SAHAB MINA ENGINEERING CO LTD

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 ($T_i - T_c$), where, T_i is inlet water temperature, and T_c 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.

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, porcelaincoated- 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

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;

$$Q_{Total} = Q_{TL} + Q_{PL} + Q_{IL}$$

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

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.

SANAND MINA ENGINEERING CO LTD

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

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

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.

Units and Conversion of some most used units and constant

- 1- Multiply, (Btu. Ft/Hr. Ft². °F) by 1.731 to obtain W/(Mt. K)
- 2- Multiply, (Btu. in/(Hr. Ft². °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. Ft² by 3.155 to obtain Watt/ Mt²
- 6- Multiply, Btu/Hr. Ft² °F by 5.678 to obtain Watt/ Mt² K 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 (T_i) to freezing temperature (T_f) is ;

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

Where:

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

SAHAAD MINA ENGINEERING CO LTD

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

Where:

x = Insulation Thickness, mm

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

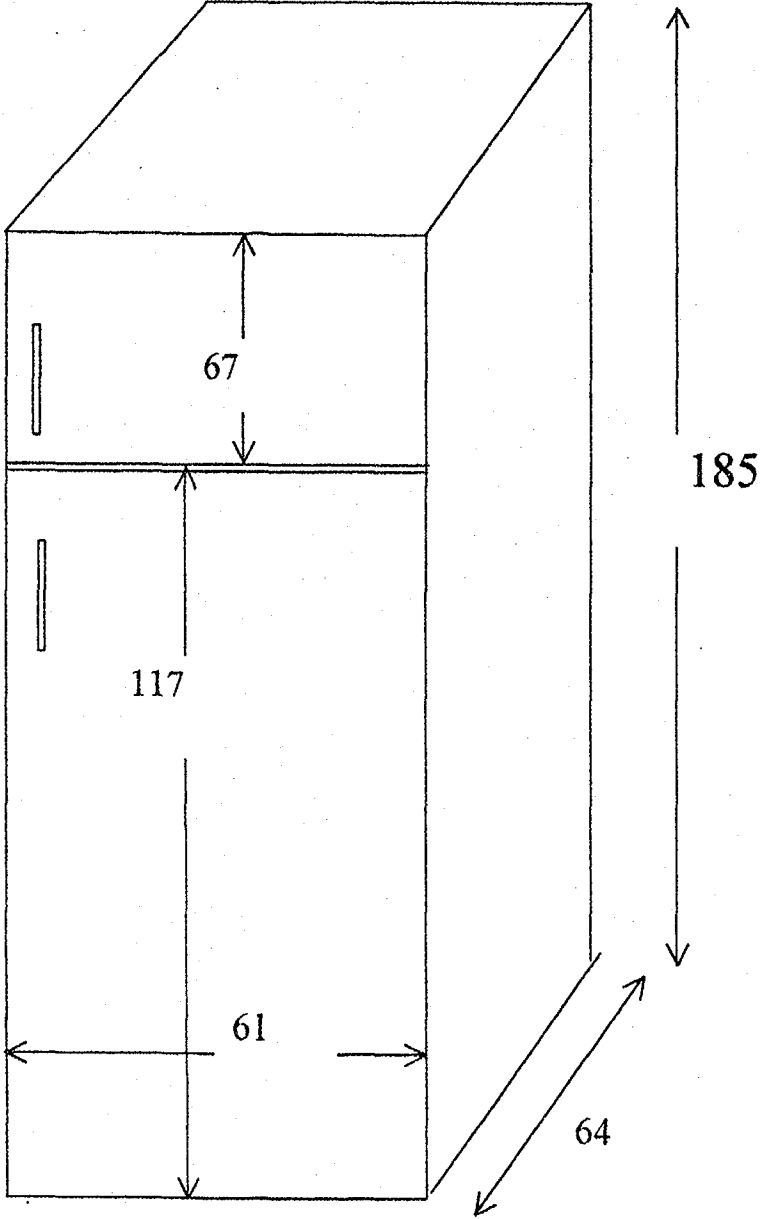
A = Outside Area, m^2

ΔT = 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 $0^\circ C = 0.025 W/Mt. \circ K$
- 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 $W/Mt. \circ K$

Sahand Mina Engineering Co. Ltd.



Refrigerator and Freezer
Model RF779

Sahand Mina Engineering Co. Ltd.

Product Load Calculation

Model Bard RF779

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		4180	1650	333	24	4	20	9.7	4.1	38.5

$$Q_1 = (10 \times 20 \times 4180) / 86400 = 9.7, Q_2 = (10 \times 18 \times 1950) / 86400 = 4.1, Q_3 = (10 \times 333000) / 86400 = 38.5$$

$$Total = Q_1 + Q_2 + Q_3 = 52.3 \text{ Watts}$$

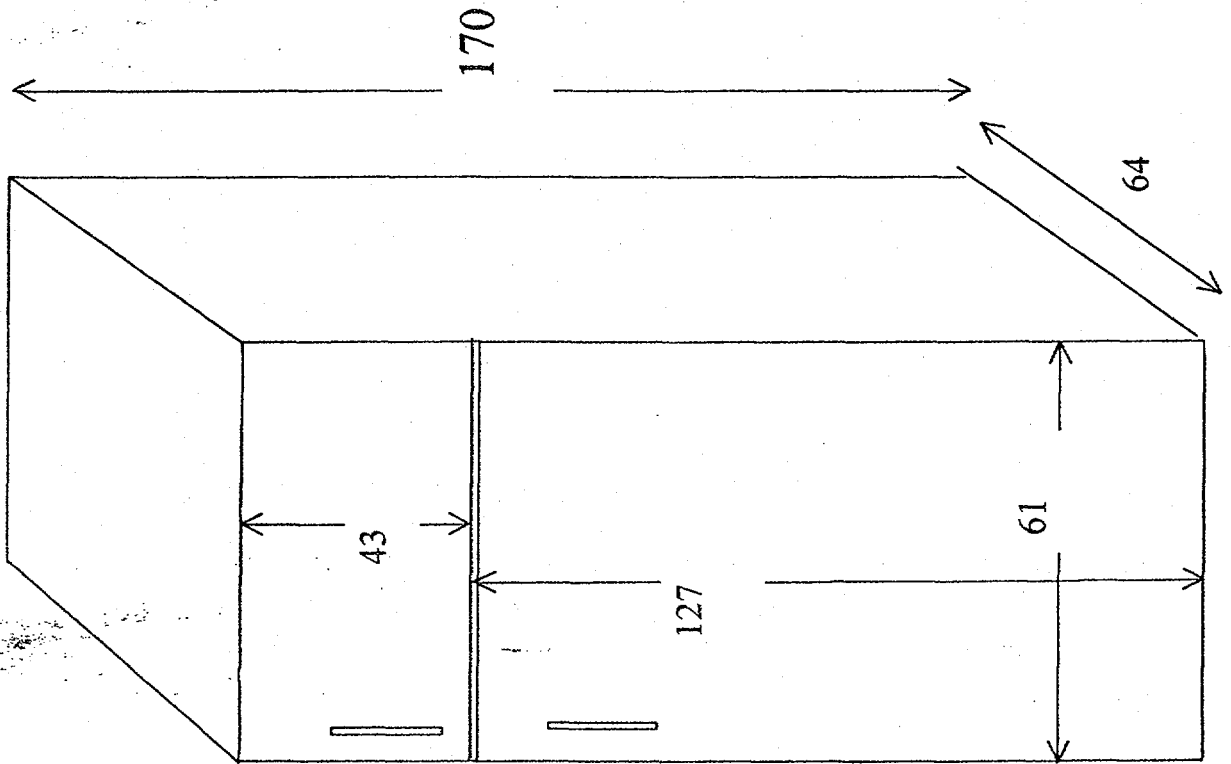
Miscellanies Heat Load

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 = 6.1 Mt. ΔT mean=39	Electrometer	Florescent Lamp	Total
$(0.400 \times 30 \times 75000) / 86400 = 10.4$	16.6	N/A	N/A	27

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
85.5	78.4	27	38	229

Sahand Mina Engineering Co. Ltd.



Refrigerator and Freezer
Model RF773

Sahand Mina Engineering Co. Ltd.

Product Load Calculation Model Bard RF773

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 <i>m C₁ ΔT</i>	Q_2 <i>m . C₂ . ΔT</i>	Q_3 <i>M . h</i>
ICE		4180	1650	333	24	4	20	9.7	4.1	38.5

$Q_1 = (10 \times 20 \times 4180) / 86400 = 9.7$, $Q_2 = (10 \times 18 \times 1950) / 86400 = 4.1$, $Q_3 = (10 \times 333000) / 86400 = 38.5$

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

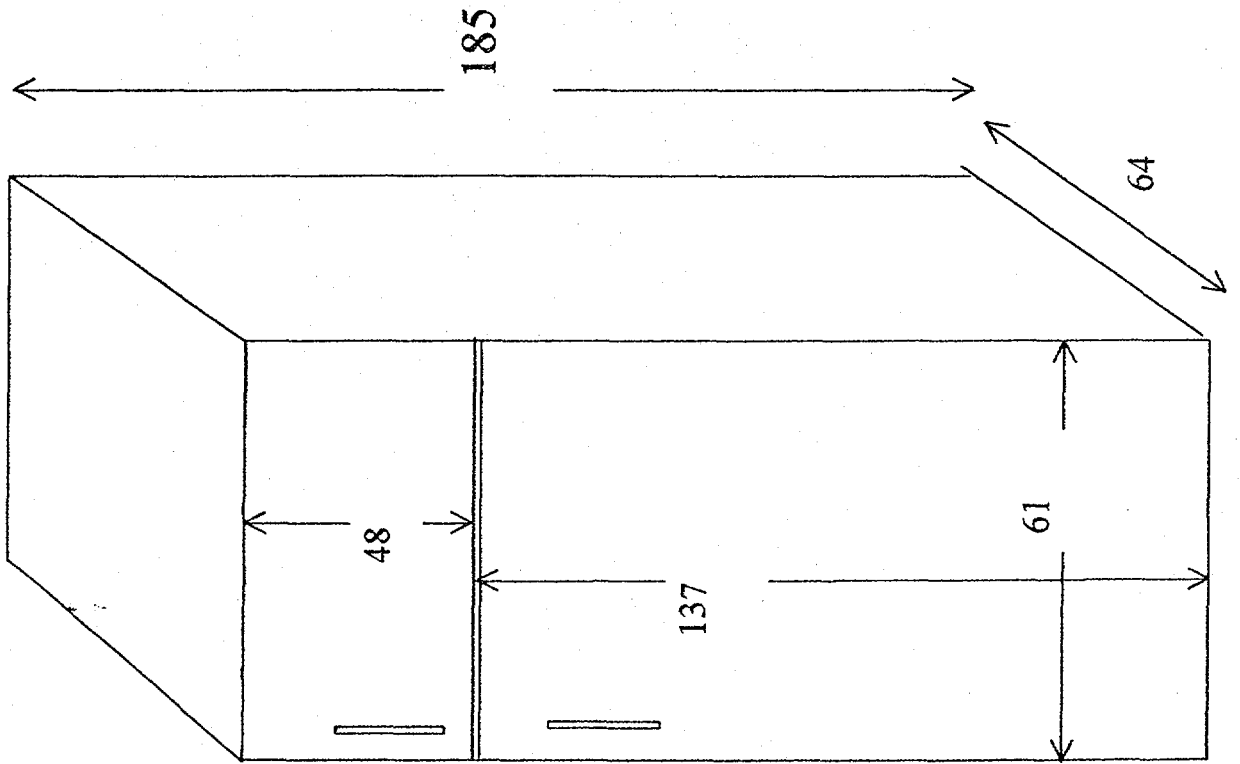
Miscellanies Heat Load

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 = 5.8 Mt. ΔT mean=39	Electrometer	Florescent Lamp	Total
$(0.343 \times 30 \times 75000) / 86400 = 8.9$	15.8	N/A	N/A	24.7

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
78.3	78.4	24.7	36	217

Sahand Mina Engineering Co. Ltd.



Refrigerator and Freezer
Model RF776

Sahand Mina Engineering Co. Ltd.

Product Load Calculation

Model Bard RF776

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 $m \cdot C_2 \cdot \Delta T$	Q_3 $M \cdot h$
ICE		4180	1650	333	24	4	20	9.7	4.1	38.5

$Q_1 = (10 \times 20 \times 4180) / 86400 = 9.7$, $Q_2 = (10 \times 18 \times 1950) / 86400 = 4.1$, $Q_3 = (10 \times 333000) / 86400 = 38.5$

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 = 6.1 Mt. ΔT mean=39	Electrometer	Florescent Lamp	Total
$(0.400 \times 30 \times 75000) / 86400 = 10.4$	16.6	N/A	N/A	27

Total refrigeration Load

Heal Leaks Through Walls	Product Load	Miscellanies Load	Safety Factors	Grand Total
82	78.4	27	37	224

SAHAAD MINA ENGINEERING CO LTD

SATURATION PROPERTIES COMPARISON

Tem P C	R12					R134a				
	P Kpa	Entholpy Kj/Kg	Entholpy Kj/Kg	Sp.Vo l Lit/Kg	Sp.Vo l 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	100.4 1	172.8 1	338.1 4	0.672	159.37	84.36	61.51	277.20 8	0.7100	0.22 19
-26	118.7 2	176.3 8	339.9 6	0.677	136.28	101.6 5	66.56	212.96	0.7171	0.18 68
-22	139.5 3	179.9 6	341.7 8	0.682	117.16	121.6 2	71.63	281.86	0.7243	0.15 70
-18	163.0 4	183.5 6	343.5 8	0.688	101.24	144.5 6	76.72	284.19	0.7318	0.13 13
-14	189.5 0	187.1 8	345.3 6	0.694	87.89	170.7 6	81.84	286.52	0.7396	0.11 38
-10	219.1 2	190.8 2	347.1 3	0.700	76.64	200.5 1	86.98	288.85	0.7475	0.09 41
-6	252.1 4	194.4 7	348.8 8	0.706	67.11	234.1 3	92.16 2	291.18	0.7558	0.08 43
-4	270.0 1	196.3 1	349.7 5	0.709	62.89	252.4 9	94.76	292.35	0.7600	0.07 84
-2	288.8 2	198.1 5	350.6 1	0.712	58.99	271.9 4	97.37 7	293.52 2	0.7643	0.07 30
0	308.6 1	200.0 0	351.4 7	0.715	55.38	292.5 2	100.0 0	294.68	0.7687	0.06 81
2	329.4 0	201.8 5	352.3 3	0.719	52.04	314.2 7	102.6 3	295.35	0.7732	0.06 35
4	351.2 4	203.7 1	353.1 7	0.722	48.94	337.2 4	105.2 8	297.01	0.7777	0.05 94
6	374.1 4	205.5 7	354.0 2	0.726	46.07	361.4 7	107.9 3	298.017	0.7823	0.05 55
8	398.1 5	207.4 4	354.8 5	0.729	43.40	387.0 1	110.6 0	299.33	0.7870	0.05 20
10	423.3 0	209.3 2	355.6 8	0.733	40.91	413.9 0	113.2 9	300.49	0.7918	0.04 87