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

شماره Our Ref.:   تاریخ : Date:

22384

Conversion of Prototypes into R134a Ozone Friendly Refrigerant At Emersun Company

Project Number MP/IRA/99/109

Contract Number, 99/248P

Final Report

May 2000

تهران ،خیابان شریعتی ، بالاتر از میرداماد ساختمان ۱۲۸۰ آپارتمان شماره ۱۲ کد پستی ۱۹۵۵۸ تلفن : ۲۲۵۰۳۳۰ ، ۲۲۷۴۹۳۶ نمابر: ۲۲۷۴۹۳۶
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Introduction

Please find below our Final report, concerning calculation and redesign of the prototypes that have been made by counterpart and they been tested Successfully at counterpart hot chamber. These prototypes have been manufactured under our engineering supervision 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 final report could have satisfied the UNIDO in order to comply with our contract.

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 Emerson 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.

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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 Emerson 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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Project Summary

The project relates to the Emerson company accounting for phasing out CFC-11 and CFC-12, in small and medium-size companies in the commercial and industrial refrigeration sector in Iran.

This proposal covers the conversion of different models and will phase out the use of 38.52 tones of CFC-11 and 11.52 tones of 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 R141b 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.

The conversion of the production facilities includes all equipment necessary for charging and testing of refrigerating equipment and the equipment necessary for the production of polyurethane insulating foam.

The overall unconstrained CFC consumption in the Islamic Republic of Iran was projected to raise from 2,445 ODP tones in 1991 to 7,778 ODP tones 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.

Most Commercial Refrigerators Companies manufacture several types of equipment from 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,
- Soft ice freezers,

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Company Backgrounds

The Emerson Co. is one of the manufacturers commercial and domestic refrigerators and freezers located in the Industrial Estate of Kamard near Tehran. The enterprise is 100% indigenously owned and was established and commenced production in 1990. The enterprise employs about 220 persons. The enterprise reports no experts and being financially sound.

The Emerson Co. has two main product lines. Production of 16 and 18 cu. ft. refrigerator, 18 cu. Ft. refrigerator/ freezers, chest freezers for commercial application and water coolers. The products are depending on the markets. The company produced in 1997 a total of 28340 refrigerators and freezers and 1850 chest freezers and 280 water coolers. In the preceding 12 months (20 March 1998 to 20 March 1999). The Emerson Co. produced a total of 50000 refrigerators and freezers and 50 chest freezers and consumed 38.52 MT CFC-11 and 11.52 MT CFC-12.

The model-wise breakdown of commercial and, domestic refrigeration products, with their individual CFC data produced by the enterprise during the preceding 12 months period (20/3/98 to 20/3/99), is reported by them as below.

Model/Description	Units Produced	Foam Operation		Refrigeration Operation	
		Foam/Unit (gms)	CFC11/ Unit (gms)	Compressor	CFC-12/unit (gms)
Refrigerators	24,000	5700	760	¼ HP	220
Refrigerator/freezers	26,000	5800	780	¼ HP	240
Total/Weighted Average	50,000	5752	770	-----	230

The Emerson Co produced 50 chest freezers in the preceding 12 months (3/98 to 2/99), which is not considered in the calculation. The total CFC consumption for commercial refrigeration products works out to 38.52 MT CFC-11 and 11.52 MT. CFCX-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.

of the Contract

A study will be made for 4 models of commercial refrigerators made by Emersun 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.

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- 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 3specification
- 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.
- Achievement of Performance Test for each prototype
- Evaluation of test results sheet.
- Recommending appropriate changes to the refrigeration system component for necessary prototype improvement.
- Modifying necessary components.
- Supervision of Trial Production.

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

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Following subjects were taught 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, porcelain coated - 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

ΔT 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 ºC

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.

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

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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.

Transmission Load

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 resistançe, 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;

$$Q\,bf = \dot{M}\ Cbf\ \ (\ Tf - Tfs\ )$$

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;

$$Qpl = Qrs$$

Internal Load

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.

Infiltration Load

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.

Total Refrigeration load

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:

$$QTL = 1.25 (QTL + QPL + QIL)$$

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

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

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:

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

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.

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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.

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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

     a. Weight
     b. Material
     c. Model

  5- Evaporator

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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

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.

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- 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
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

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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

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

- 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

  5- Cold 18 °C
  6- Relative Humidity

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- 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

Water Cooler and Chest Freezer, Double Door Ref.Freezer and Display cases

Refrigeration load consist of three individual components:

1- Transmission load;
Heat transfer through side walls by conduction
2 - Product load;
Heat Removed from and produced by the products which are stored.
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 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.

$$T_{refrigerator} \leftarrow R_{liner} + R_{insulation} + R_{cabin} + R_{ambient} \leftarrow T_{ambient}$$

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.

$R = \frac{x}{KA}$ 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 ($T_a - T_c$), 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 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 (Tf) is ;

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

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;

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

Where h = Latent heat of product, Kcal / Kg

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

$$Q_{bf} = \dot{M} C_{bf} (Tf - Tfs)$$

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;

Qpl = Qrs

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 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;

$$\mathbf{Q_{TL} = 1.20\,(Q_{TL} + Q_{PL} + Q_{IL})}$$

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SAHAND MINA ENGINEERING CO.LTD.

شماره: Our Ref.: تاریخ: Date:

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, porcelai coated - 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.

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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.

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

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.

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

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SAHAND MINA ENGINEERING CO.LTD.

شماره: Our Ref.:   تاریخ : Date:

Refrigeration Load Calculation
Double Door Up-Right Refrigerator and Freezer

Model Emerson RF16

a) Transmission load calculation

Insulation Type: Pu Foam with R141b blowing agent.
Thermal Conductivity for Foam = 0.0175 W/ mt. ° C
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +4 °C
Temperature Difference Refrigerator Compartment:
ΔT = 32 - (+4) = 28 ° C
Freezer Air Temperature = -18 °C
Temperature Difference Freezer Compartment:
ΔT = 32 - (-18) = 50 ° C

Freezer Compartment

Freezer Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (56x58)	0.65	80 mm	50 c
Back Panel	66x56	0.37	80 mm	60 c
Top Panel	58x66	0.38	80 mm	50 c
Door	66x56	0.37	80 mm	50 c
Bottom Panel	58x66	0.38	80 mm	14 c

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Calculation :

Heat Leak For Freezer Compartment.

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

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

$U = \frac{1}{X_1 / K_1}$ = 1÷(0.080÷0.175) = 0.22 W/ sq.m °C

Where :

U = Heat Resistance Coefficient Factor

K_1 = Foam Thermal Conductivity = 0.0175 for R141b blowing agent foam

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

T_a = Ambient Temperature 32

T_r = refrigerator air Temperature -18

U = 1 / (0.080/ 0.0175) = 0.22 W/ sq.m °C

A = 0.65 Sq. Mt., T_a = 32 °C, T_f = -18 °C

$Q_{SideWalls}$ = 0.22 x 0.65 x 50 = 7.2 Watts

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

U = 1 / [(0.080/ 0.0175)] = 0.22 W/ sq.m °C ,

$T_a - T_r$= 50, A = 0.37,

Q_{doors} = 0.22 x 0.37 x 50 = 4.1Watts

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

U = 0.22 w/sq. Mt. °C,

$T_a - T_r$= 50 , A = 0.383

Q_{top} = 0.22 x 0.383 x 50 = 4.2 Watts

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

U = 0.22 w/sq. Mt. °C,

$T_a - T_r = 60$, A = 0.0.37

$Q_{back\ panel}$ = 0.22x 0.37 x 60 = 4.9 Watts

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

U = 0.22 w/sq. Mt. °C,

$T_a - T_r = 14$, A = 0.383

$Q_{Bottom\ Surface}$ = 0.22x 0.383 x 14 = 1.2 Watt

Heat Leak For Freezer Compartment.

$Q_{TL} = Q_{SW} + Q_{Back\ Panel} + Q_{door} + Q_{Bottom} + Q_{top} = 21.6$

Heat Leak For Refrigerator Compartment.

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (119x56)	1.33	80 mm	28 c
Back Panel	66x119	0.785	80 mm	38 c
Door	66x119	0.785	80 mm	28 c
Bottom Panel	58x66	0.383	80 mm	28 c

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

$U = \frac{1}{X_1 / K_1}$ = 1÷(0.080÷0.175) = 0.22 W/ sq.m °C

Where :

U = Heat Resistance Coefficient Factor

K_1 = Foam Thermal Conductivity = 0.0175 for R141b blowing agent foam

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

T_a = Ambient Temperature 32

T_r = refrigerator air Temperature 4

U = 1 / (0.080/ 0.0175) = 0.22 W/ sq.m °C

A = 1.33 Sq. Mt., T_a = 32 °C, T_f = + 4 °C

therefore

$Q_{SideWalls} = 0.22 \times 1.33 \times 28 = 8.2$ Watts

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

$U = 1 / [(0.080/ 0.0175)] = 0.22$ W/ sq.m °C ,

$T_a - T_r = 28$, $A = 0.78$,

$Q_{doors} = 0.22 \times 0.78 \times 28 = 4.8$ Watts

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

$U = 0.22$ w/sq. Mt. °C,

$T_a - T_r = 38$, $A = 0.78$

$Q_{back\ panel} = 0.22 \times 0.78 \times 38 = 6.6$ Watts

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

$U = 0.22$ w/sq. Mt. °C,

$T_a - T_r = 28$, $A = 0.383$

$Q_{Bottom\ Surface} = 0.22 \times 0.383 \times 28 = 2.3$ Watt

Total Refrigerator Heat Leak = 21.9 W

Total Transmission Heal Load Through Refrigerator and Freezer Compartment by Conduction through side walls = 21.9 + 21.6 = 43.5

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 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

We suppose that 20 Kgs of normal water (25 C)must be kept frozen for 24 hours at Freezing point -18 C, therefore, we calculate as follow,

$$Q_1 = mc(T_1 - T_2)$$

Q_1 = heat removal of water above freezing point

M = 20 kg

C = 4.23 j/g K

T_1 = 25 C

T_2 = 0 C

Q_1 = 20000x4.23x (25-0) =2115000 jul/86400 = 24.4 Watt

$$Q_2 = mc(T_1 - T_2)$$

Q_2 = heat removal of ice below freezing point

M = 20 kg

C = 2.10 j/g K

T_1 = 0 C

$T_2 = -18$ C

$Q_1 = 20000x2.10x\ [(0-(-18)] = 756000\ jul/86400 = 8.8 Watt$

Assuming only 90% of water present freezes, a good assumption for many foods is:

1- Latent heat of Freezing:
   334 x 0.9 = 300.6 kJ/kg
2- Sensible heat to cool the ice:
   2.10 x 18 = 37.8 kJ/kg
3- Sensible heat to cool unfrozen water:
   4.23 x 0.1 x 18 = 7.6 kJ/kg
4- Sensible heat to cool non-aqueous material, 25% of material is non-aqueous
   (0.25 x 0.84) 18 = 3.9 kJ/kg

Total = 349900 J/kg

Q_{total} = 349900 x 20 = 3499000 J = 6998000/86400= 81

Internal Load

Door Opening
Refrigerator Internal Volume 360 lit.
Number of air change as per ASHREA standard = 20 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 0.36x20x75000/86400 = 6.3 Watt

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

Q_{Total} = 43.5 + 114.2 + 6.3 = 164 Watts

Considering 20 % of Q total for safety factor

$Q_{Grand\ Total}$ = 164 + 20%(33) = **197** watts

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With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 197watt at – 23.3 degree centigrade evaporating temperature. We recommend compressor Danfoss model FR10G with 170 Watts cooling capacity at – 23.3 C evaporating temp. at ASHREA standards for about 15 Kg Ice making power per 24 hours or Compressor Matsoshita Model QA77C17GAX6 with 200 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards, or Aspera Model B3117Z with 203 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards, or Electrolux (Zanussi) Model GL80AA with 197.7 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards. Or Necchi Model ESC 9/9K with 205 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards. Or LE Model V 75 LAEG with 194 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards.

Refrigeration Load Calculation
Double Door Up-Right Refrigerator and Freezer

Model Emerson RF18

b) Transmission load calculation

Insulation Type: Pu Foam with R141b blowing agent.
Thermal Conductivity for Foam = 0.0175 W/ mt. ° C
Ambient Temperature = 32 °C
Refrigerator Air Temperature = +4 °C
Temperature Difference Refrigerator Compartment:
$\Delta T = 32 - (+4) = 28$ ° C
Freezer Air Temperature = -18 °C
Temperature Difference Freezer Compartment:
$\Delta T = 32 - (-18) = 50$ ° C

Freezer Compartment

Freezer Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (72x58)	0.83	80 mm	50 c
Back Panel	72x66	0.47	80 mm	60 c
Top Panel	58x66	0.38	120 mm	14 c
Door	72x66	0.47	80 mm	50 c
Bottom Panel	58x66	0.38	120 mm	60 c

Calculation :

Heat Leak For Freezer Compartment.

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

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

$U = \frac{1}{X_1 / K_1}$ W/ sq.m °C

Where :

U = Heat Resistance Coefficient Factor

K_1 = Foam Thermal Conductivity = 0.0175 for R141b blowing agent foam

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

T_a = Ambient Temperature 32

T_r = refrigerator air Temperature -18

U = 1 / (0.080/ 0.0175) = 0.22 W/ sq.m °C

A = 0.83 Sq. Mt., T_a = 32 °C, T_r = -18 °C

$Q_{SideWalls}$ = 0.22 x 0.83 x 50 = 9.2 Watts

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

U = 1 / [(0.080/ 0.0175)] = 0.22 W/ sq.m °C ,

$T_a - T_r = 50$, A = 0.47,

Q_{doors} = 0.22 x 0.47 x 50 = 5.2 Watts

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

U = 1/(0.120/0.0175) = 0.14 w/sq. Mt. °C,

$T_a - T_r = 50$, A = 0.383

Q_{top} = 0.14 x 0.383 x 50 = 0.8 Watts

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

U = 0.22 w/sq. Mt. °C,

$T_a - T_r = 60$, A = 0.0.47

therefore
$Q_{SideWalls} = 0.43 \times 1.33 \times 28 = 16$ Watts

2- $Q_{doors} = [\,U A\,(T_a - T_r)\,]$
$U = 1 / [(0.040/0.0175)] = 0.43$ W/ sq.m °C ,
$T_a - T_r = 28$, $A = 0.79$,
$Q_{doors} = 0.43 \times 0.79 \times 28 = 9.5$ Watts

4 -$Q_{back\ panel} = [\,U A\,(T_a - T_r)\,]$
$U = 0.43$ w/sq. Mt. °C,
$T_a - T_r = 38$, $A = 0.79$
$Q_{back\ panel} = 0.43 \times 0.79 \times 38 = 12.9$ Watts

5 -$Q_{Top} = [\,U A\,(T_a - T_r)\,]$
$U = 0.35$ w/sq. Mt. °C,
$T_a - T_r = 28$, $A = 0.383$
$Q_{Top} = 0.35 \times 0.383 \times 28 = 3.7$ Watt
$Q_{Top} = 3.7$ Watts

Total Refrigerator Heat Leak = 42.1 W

Total Transmission Heal Load Through Refrigerator and Freezer Compartment by Conduction through side walls = 21.9 + 42.1 = 64

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.

therefore
$Q_{SideWalls} = 0.43 \times 1.33 \times 28 = 16$ Watts

2- $Q_{doors} = [U A (T_a - T_r)]$
$U = 1 / [(0.040/ 0.0175)] = 0.43$ W/ sq.m °C ,
$T_a - T_r = 28$, $A = 0.79$,
$Q_{doors} = 0.43 \times 0.79 \times 28 = 9.5$ Watts

4 -$Q_{back\ panel} = [U A (T_a - T_r)]$
U = 0.43 w/sq. Mt. °C,
$T_a - T_r = 38$, $A = 0.79$
$Q_{back\ panel} = 0.43 \times 0.79 \times 38 = 12.9$ Watts

5 -$Q_{Top} = [U A (T_a - T_r)]$
U = 0.35 w/sq. Mt. °C,
$T_a - T_r = 28$, $A = 0.383$
$Q_{Top} = 0.35 \times 0.383 \times 28 = 3.7$ Watt
$Q_{Top} = 3.7$ Watts

Total Refrigerator Heat Leak = 42.1 W

Total Transmission Heal Load Through Refrigerator and Freezer Compartment by Conduction through side walls = 21.9 + 42.1 = 64

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.

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

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

We suppose that 20 Kgs of normal water (25 C)must be kept frozen for 24 hours at Freezing point -18 C, therefore, we calculate as follow,

$$Q_1 = mc(T_1 - T_2)$$

Q_1 = heat removal of water above freezing point

M = 20 kg

C = 4.23 j/g K

T_1 = 25 C

T_2 = 0 C

Q_1 = 20000x4.23x (25-0) =2115000 jul/86400 = 24.4 Watt

$$Q_2 = mc(T_1 - T_2)$$

Q_2 = heat removal of ice below freezing point

M = 20 kg

C = 2.10 j/g K

T_1 = 0 C

M = 20 kg
C = 2.10 j/g K
T_1 = 0 C
T_2 = -18 C
Q_1 = 20000x2.10x [(0-(-18)] =756000 jul/86400 = 8.8Watt
Assuming only 90% of water present freezes, a good assumption for many foods is:

5- Latent heat of Freezing:
   334 x 0.9 = 300.6 kJ/kg
6- Sensible heat to cool the ice:
   2.10 x 18 = 37.8 kJ/kg
7- Sensible heat to cool unfrozen water:
   4.23 x 0.1 x 18 = 7.6 kJ/kg
8- Sensible heat to cool non-aqueous material, 25% of material is non-aqueous
   (0.25 x 0.84) 18 = 3.9 kJ/kg

Total = 349900 J/kg
Q_{total} = 349900 x 20 = 3499000 J = 6998000/86400= 81

Internal Load

Door Opening
Refrigerator Internal Volume 360 lit.
Number of air change as per ASHREA standard = 20 per day
Heat removed per cubic meter of air 75000 j

Air Change load = 0.36x20x75000/86400 = 6.3 Watt

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

Q_{Total} = 64 + 114.2 + 6.3 = 184.5Watts

Considering 20 % of Q total for safety factor

$Q_{\text{Grand Total}}$ = 184 + 20%(36.9) = **203**watts

تهران ،خیابان شریعتی ، بالاتر از میرداماد ساختمان ۱۲۸۰ آپارتمان شماره ۱۲ کد پستی ۱۹۵۵۸ تلفن : ۲۲۵۰۳۳۰ ، ۲۲۷٤۹۳۶ نمابر: ۲۲۷٤۹۳۶
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

With respect to the above calculation we have to select a compressor of R134a with cooling capacity of approximately 203 watt at – 23.3 degree centigrade evaporating temperature. We recommend compressor Danfoss model FR10G with 170 Watts cooling capacity at – 23.3 C evaporating temp. at ASHREA standards for about 15 Kg Ice making power per 24 hours or Compressor Matsoshita Model QA77C17GAX6 with 200 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards, or Aspera Model B3117Z with 203 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards, or Electrolux (Zanussi) Model GL80AA with 197.7 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards. Or Necchi Model ESC 9/9K with 205 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards. Or LE Model V 75 LAEG with 194 watts cooling capacity at – 23.3 evaporating temp. ASHREA Standards.

Chest Freezer Model CF-120

a) Transmission Load Calculation

Dimension

	Dimension Cm.	Area (sq. mt.)	Insulation Thickness mm
Side Walls	2 x (65x85)	1.12	50
Front & Back Panel	2 x (125x85)	2.14	50
Chest Door	120 x 65	0.81	50
Bottom Floor	120 x 65	0.81	50

Insulation Type: Pu Foam R141b expanded blowing PU foam
R141b Foam Thermal Conductivity: 0.018 W /mt.C
Temperature Difference: (ΔT) = 32 - (-25) = 57 C
Ambient Temperature = 32 C
Freezer Air Temperature = - 25 C

Calculation :

$$Q_{TL} = Q_{side\ Walls} + Q_{Bottom} + Q_{Top}$$

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

$$U = \frac{1}{X_1 / K_1 + X_2 / K_2 + \dots\dots}$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity
X_1 = Foam Thickness

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:

$Q_{SideWalls} = [\,U\,A\,(T_a - T_f)\,]$

T_a = Ambient Temperature

T_f = Freezer air Temperature

U = 1 / (0.05/0.018) = 0.36 W/ sq.m C

A = 1.12 Sq. Mt.

T_a = 32 C, T_f = - 25 C

$Q_{SideWalls}$ = 0.36 x 1.12 x 57 = 23 Watts

$Q_{SideWalls}$ = 23 Watts

$Q_{Front\ Wall} = [\,U\,A\,(T_a - T_f)\,]$

T_a = Ambient Temperature

T_f = Freezer air Temperature

U = 1 / (0.050/0.018) = 0.36 W/ sq.m C

A = 1.07 Sq. Mt.

T_a = 32 C, T_f = - 25 C

$Q_{Front\ Wall}$ = 0.36 x 1.07 x 57 = 22 Watts

$Q_{Front\ Wall}$ = 22 Watts

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

T_a = Ambient Temperature

T_f = Freezer air Temperature

U = 1 / (0.050/0.018) = 0.36 W/ sq.m C

A = 1.07 Sq. Mt.

T_a = 42 C, T_f = - 25 C

$Q_{back\ panel}$ = 0.36 x 1.07 x 57 = 22 Watts

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

T_a = Ambient Temperature

T_f = Freezer air Temperature

U = 1 / (0.050/0.018) = 0.36 W/ sq.m C

A = 0.81 Sq. Mt.

T_a = 32 C, T_f = - 25 C

Q_{Top} = 0.36 x 0.81 x 57 = 17 Watts

Q_{Top} = 17 Watts

Q_{Bottom} = [U A (T_a - T_f)]
T_a = Ambient Temperature
T_f = Freezer air Temperature
U = 1/(0.050/ 0.018) = 0.36 W/ sq.m C
A = 0.81 Sq. Mt.
T_a = 42 C, T_f = - 25 C
Q_{Bottom} = 0.36 x 0.81 x 67 = 19 Watts

Total Heat Leaks;

Q_{TL} = 23 + 26 + 22 + 19 + 17 = 107 watts

$$Q_{\text{Total Heat Leaks}} = 107 \text{ Watts}$$

Ice Making Capacity = 5Kg x 1 x (15 - 0) x1.163= 87 Watts

c) Heat gain through infiltration;
We consider 10% safety factor for door opening and infiltration
Heat gain by infiltration = 0.1 x (total heat leaks)
Heat gain by infiltration = 0.1 x (87) = 9 Watts
Total Cooling Capacity Required is calculated as follows;

$Q_{\text{Grand Total}} = Q_{\text{Heat Leaks}} + Q_{\text{Ice Making}} + Q_{\text{Infiltration}}$

$Q_{\text{Grand Total}}$ = 107 + 87 + 9 = 203 Watts

$$Q_{\text{Grand Total}} = 203 \text{ Watts}$$

The suitable R134a compressor should be compatible with cooling capacity of 203 watt. A compressor compatible with Electrolux model P12Fw should be selected. Or Danfoss Model SC12G with cooling capacity of 183 watts at CECOMAF Condition and 226 watts at ASHREA CONDITION.

Chest Freezer Model CF-100

a) Transmission Load Calculation

Dimension

	Dimension Cm.	Area (sq. mt.)	Insulation Thickness mm
Side Walls	2 x (58x75)	0.87	50
Front & Back Panel	2 x (125x85)	2X78=1.56	50
Chest Door	105x 0.58	0.61	50
Bottom Floor	105X0.58	0.810.61	50

Insulation Type: Pu Foam R141b expanded blowing PU foam
R141b Foam Thermal Conductivity: 0.018 W /mt.C
Temperature Difference: $(\Delta T) =$ 32 - (-18) = 50 C
Ambient Temperature = 32 C
Freezer Air Temperature = - 18 C

Calculation :

$$Q_{TL} = Q_{side\ Walls} + Q_{Bottom} + Q_{Top}$$

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

$$U = \frac{1}{X_1 / K_1 + X_2 / K_2 + \ldots\ldots}$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity
X_1 = Foam Thickness

$Q_{SideWalls} = [U A (T_a - T_f)]$
T_a = Ambient Temperature
T_f = Freezer air Temperature

$U = 1 / (0.05/0.0175) = 0.34$ W/ sq.m C
$A = 0.87$ Sq. Mt.
$T_a = 32$ C, $T_f = -18$ C
$Q_{SideWalls} = 0.34 \times 0.87 \times 50 = 14.8$ Watts
$Q_{SideWalls} = 14.8$ Watts

$Q_{Front\ Wall} = [U A (T_a - T_f)]$
T_a = Ambient Temperature
T_f = Freezer air Temperature
$U = 1 / (0.050/0.0175) = 0.34$ W/ sq.m C
$A = 0.78$ Sq. Mt.
$T_a = 32$ C, $T_f = -18$ C
$Q_{Front\ Wall} = 0.34 \times 0.78 \times 50 = 13.3$ Watts
$Q_{Front\ Wall} = 13.3$ Watts

$Q_{Back\ panel} = [U A (T_a - T_f)]$
T_a = Ambient Temperature
T_f = Freezer air Temperature
$U = 1 / (0.050/0.0175) = 0.34$ W/ sq.m C
$A = 0.78$ Sq. Mt.
$T_a = 42$ C, $T_f = -18$ C
$Q_{back\ panel} = 0.34 \times 0.78 \times 60 = 15.9$ Watts

$Q_{Top} = [U A (T_a - T_f)]$
T_a = Ambient Temperature
T_f = Freezer air Temperature
$U = 1 / (0.050/0.0175) = 0.34$ W/ sq.m C
$A = 0.61$ Sq. Mt.
$T_a = 32$ C, $T_f = -18$ C
$Q_{Top} = 0.36 \times 0.61 \times 50 =$ Watts
$Q_{Top} = 10.4$ Watts

$Q_{Bottom} = [U A (T_a - T_f)]$
T_a = Ambient Temperature

T_f = Freezer air Temperature
U = 1/(0.050/ 0.0175) = 0.34 W/ sq.m C
A = 0.61 Sq. Mt.
T_a = 32 C, T_f = - 18 C
Q_{Bottom} = 0.34 x 0.61 x 50 = 10.4 Watts

Total Heat Leaks;

Q_{TL} = 14.8 + 15.9 + 10.4 + 10.4 + 13.3 = 64.8watts

$Q_{\text{Total Heat Leaks}}$ = 64.8 Watts

Ice Making Capacity = 5_{Kg} x 1 x (15 - 0) x1.163= 87 Watts

c) Heat gain through infiltration;
We consider 10% safety factor for door opening and infiltration
Heat gain by infiltration = 0.1 x (total heat leaks)
Heat gain by infiltration = 0.1 x (87) = 9 Watts
Total Cooling Capacity Required is calculated as follows;

$Q_{\text{Grand Total}} = Q_{\text{Heat Leaks}} + Q_{\text{Ice Making}} + Q_{\text{Infiltration}}$

$Q_{\text{Grand Total}}$ = 64.8 + 87 + 9 = 160.8 Watts

$Q_{\text{Grand Total}}$ = 160.8 Watts

The suitable R134a compressor should be compatible with cooling capacity of 160.8 watt. A compressor compatible with DANFOSS model FR8.5 should be selected. This model of compressor can deliver 153 watts of cooling capacity at ASHREA standard condition.

First type

EMERSUN

Setting

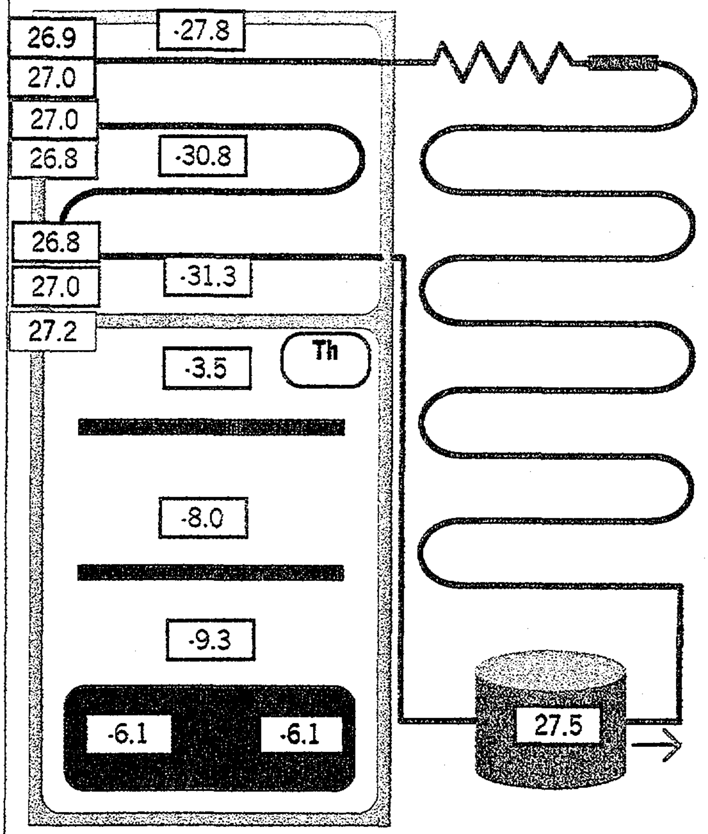
Test Date	Thu Feb 03-00
Test Type	----------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\11141341

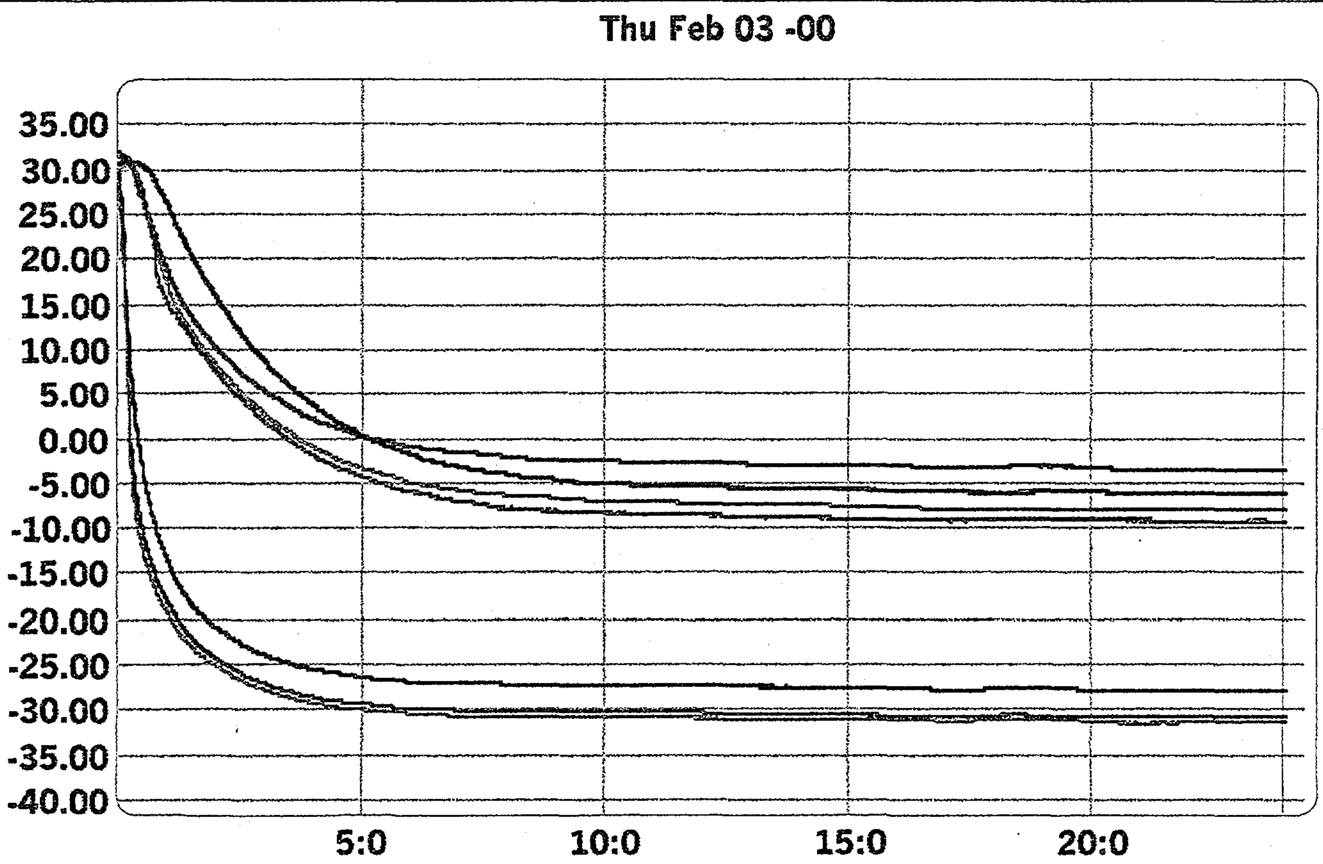
Product Specification

Product Type	RF 18
Compressor Type	MATUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	----------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	23:59
Working Time(h:m)	23:59
Working Percentage	100.0%
Energy Cons.(KWh)	3.337
Av. En. Cons.(KWh/Day)	3.339
No. of Thermostat	0
No. of Over Load	0





EMERSUN

Setting

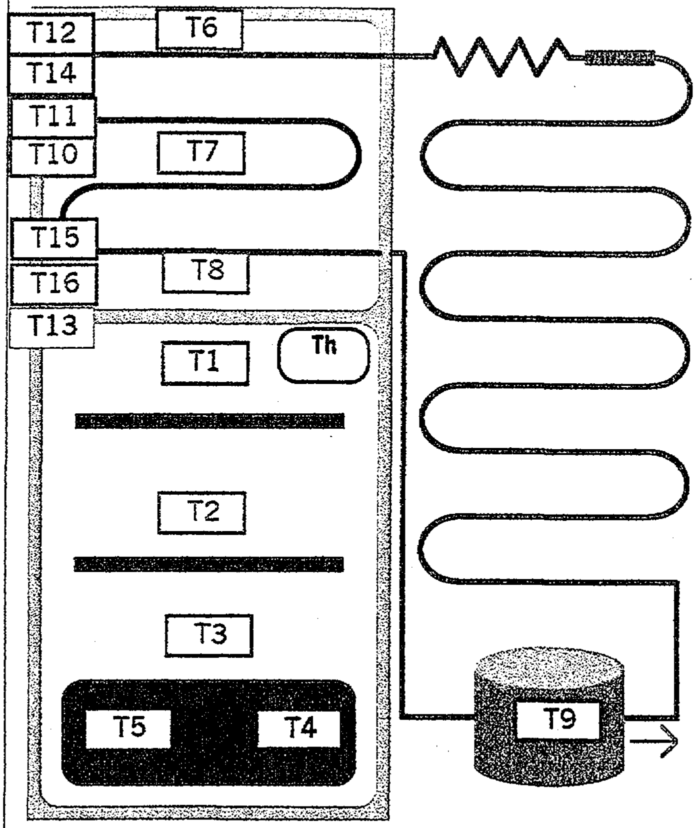
Test Date	Thu Feb 03-00
Test Type	------------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\11141341

Product Specification

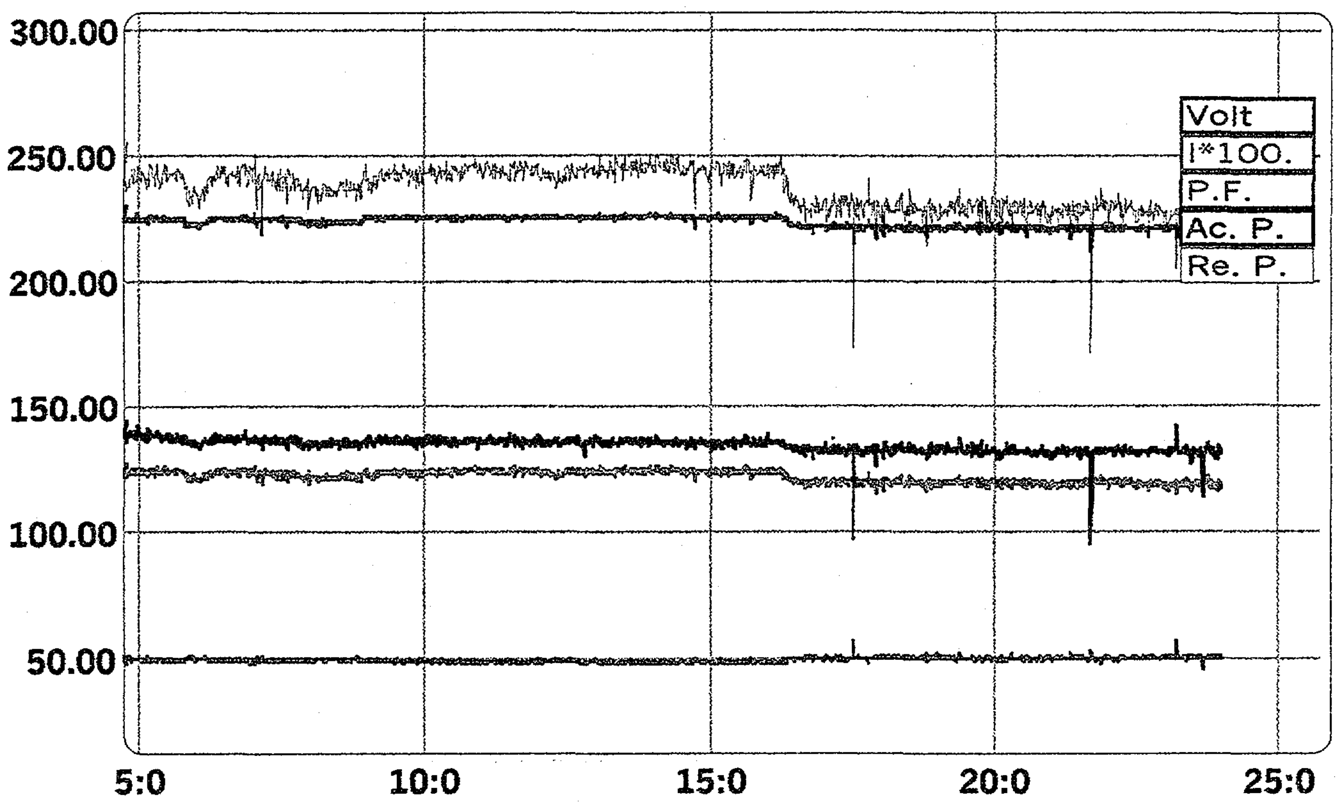
Product Type	RF 18
Compressor Type	MATUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	23:59
Working Time(h:m)	23:59
Working Percentage	100.0%
Energy Cons.(KWh)	3.337
Av. En. Cons.(KWh/Day)	3.339
No. of Thermostat	0
No. of Over Load	0



Thu Feb 03 -00



EMERSUN

Setting

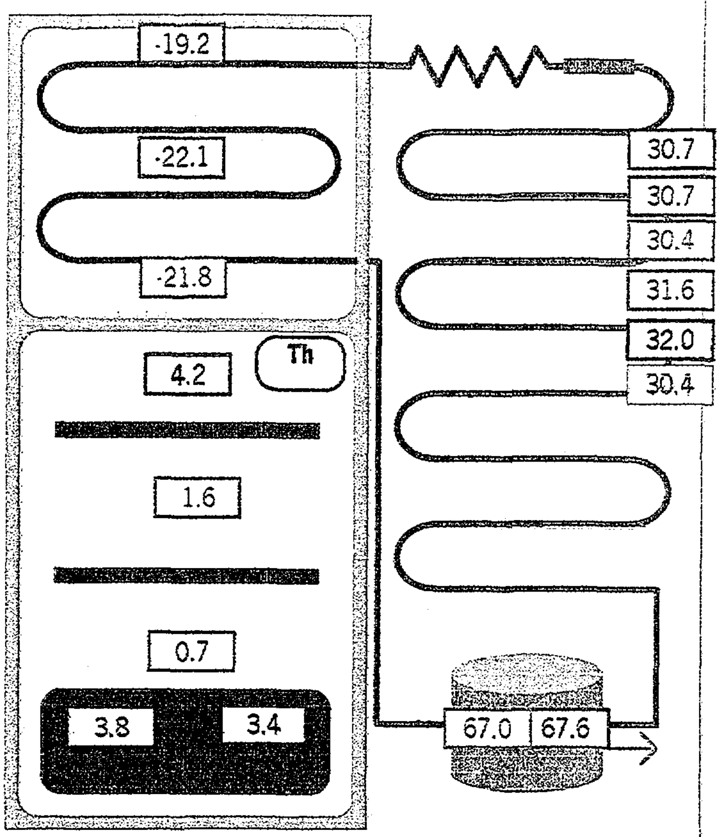
Test Date	Sat Jan 29-00
Test Type	----------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\F119R134

Product Specification

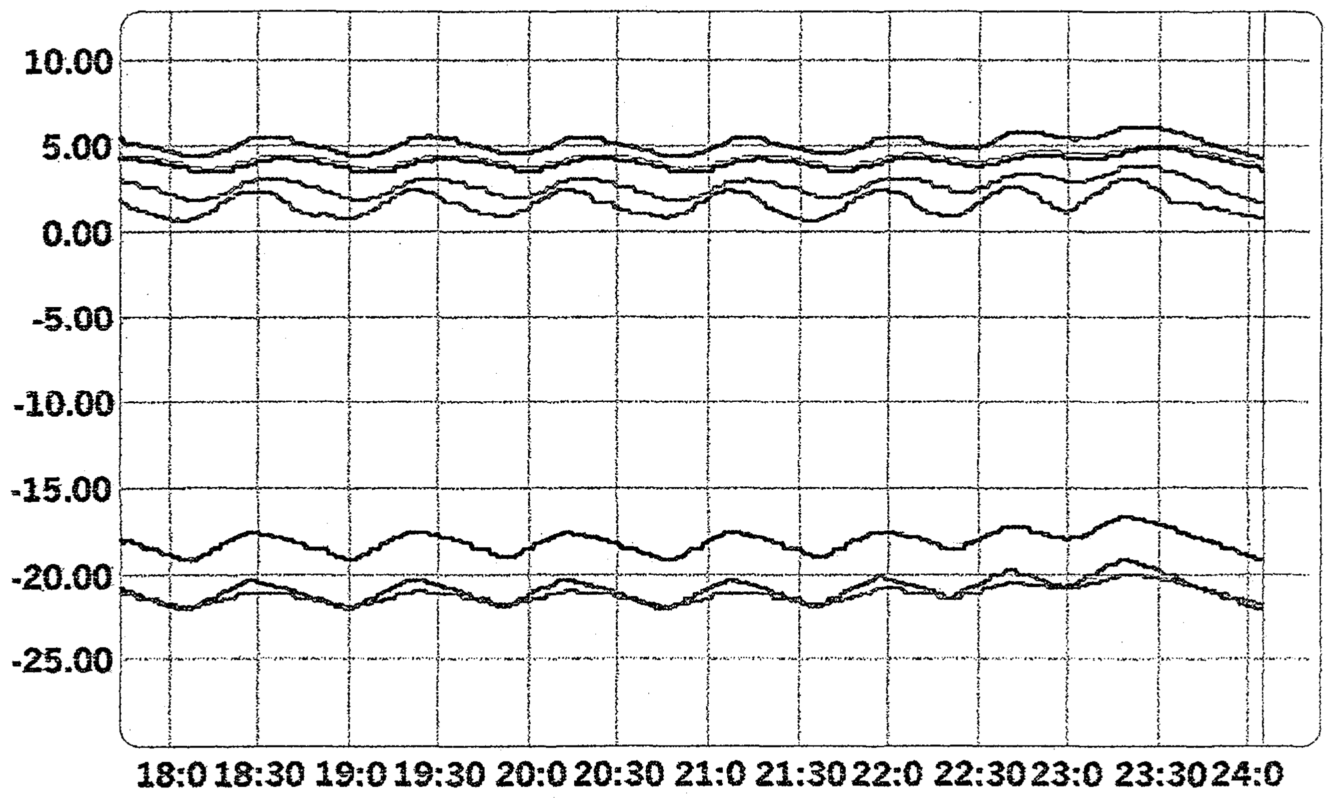
Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	---------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	24:03
Working Time(h:m)	15:33
Working Percentage	64.6%
Energy Cons.(KWh)	2.869
Av. En. Cons.(KWh/Day)	2.863
No. of Thermostat	31
No. of Over Load	0



Sat Jan 29 -00



EMERSUN

Setting

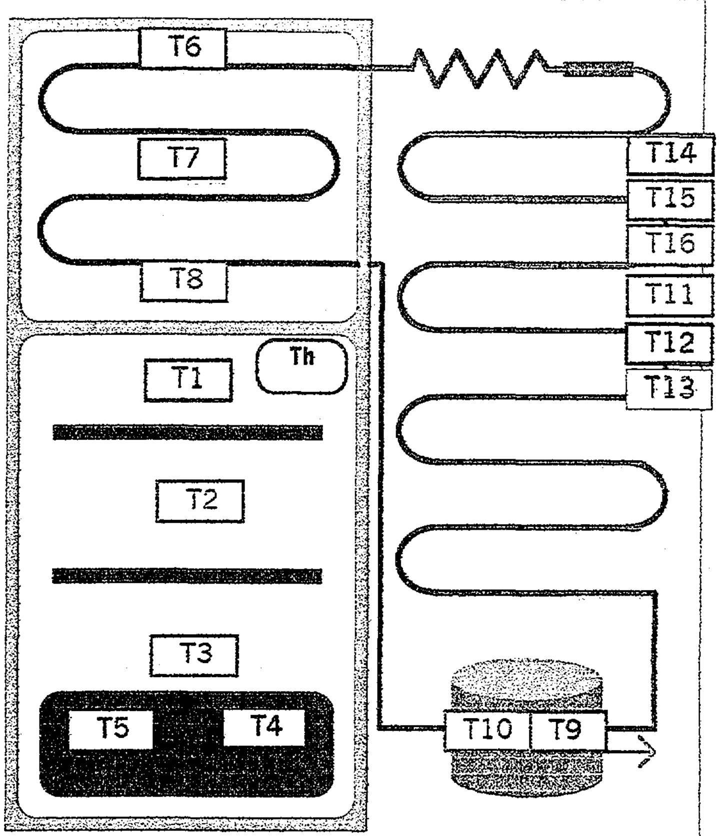
Test Date	Sat Jan 29-00
Test Type	----------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\F119R134

Product Specification

Product Type	RF 13
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	---------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	24:03
Working Time(h:m)	15:33
Working Percentage	64.6%
Energy Cons.(KWh)	2.869
Av. En. Cons.(KWh/Day)	2.863
No. of Thermostat	31
No. of Over Load	0



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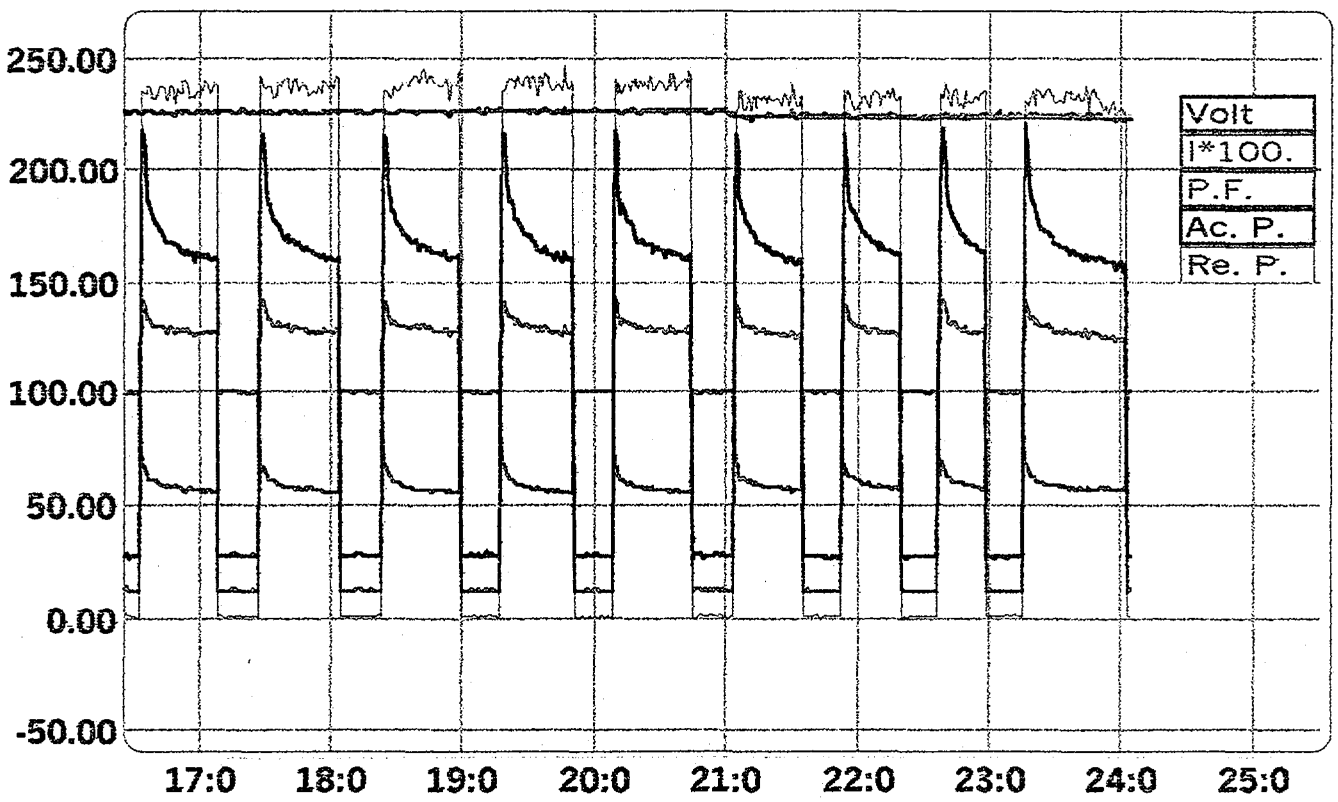


Second Type

EMERSUN

Setting

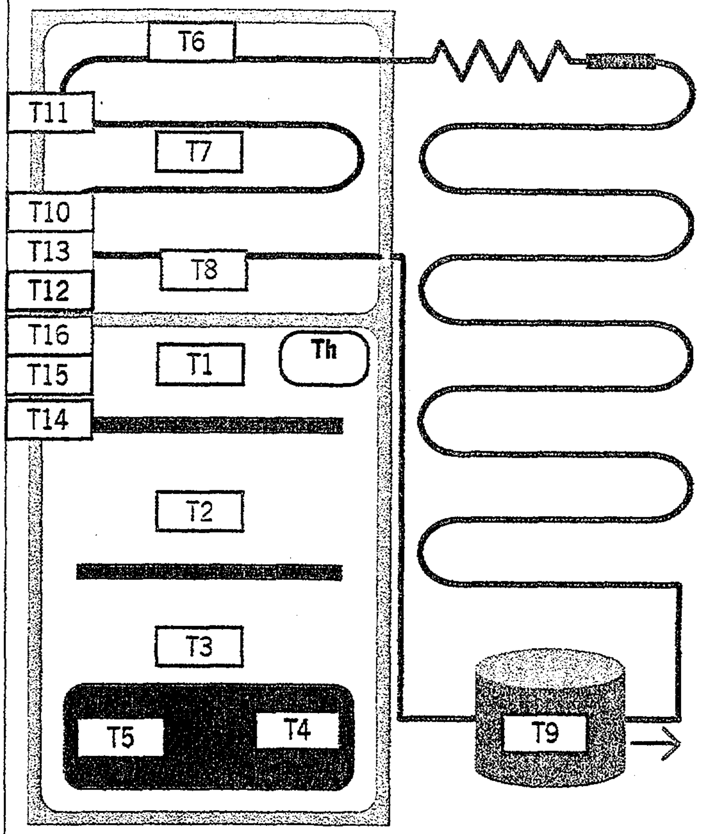
Test Date	Thu Feb 03-00
Test Type	-------------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\11141342

Product Specification

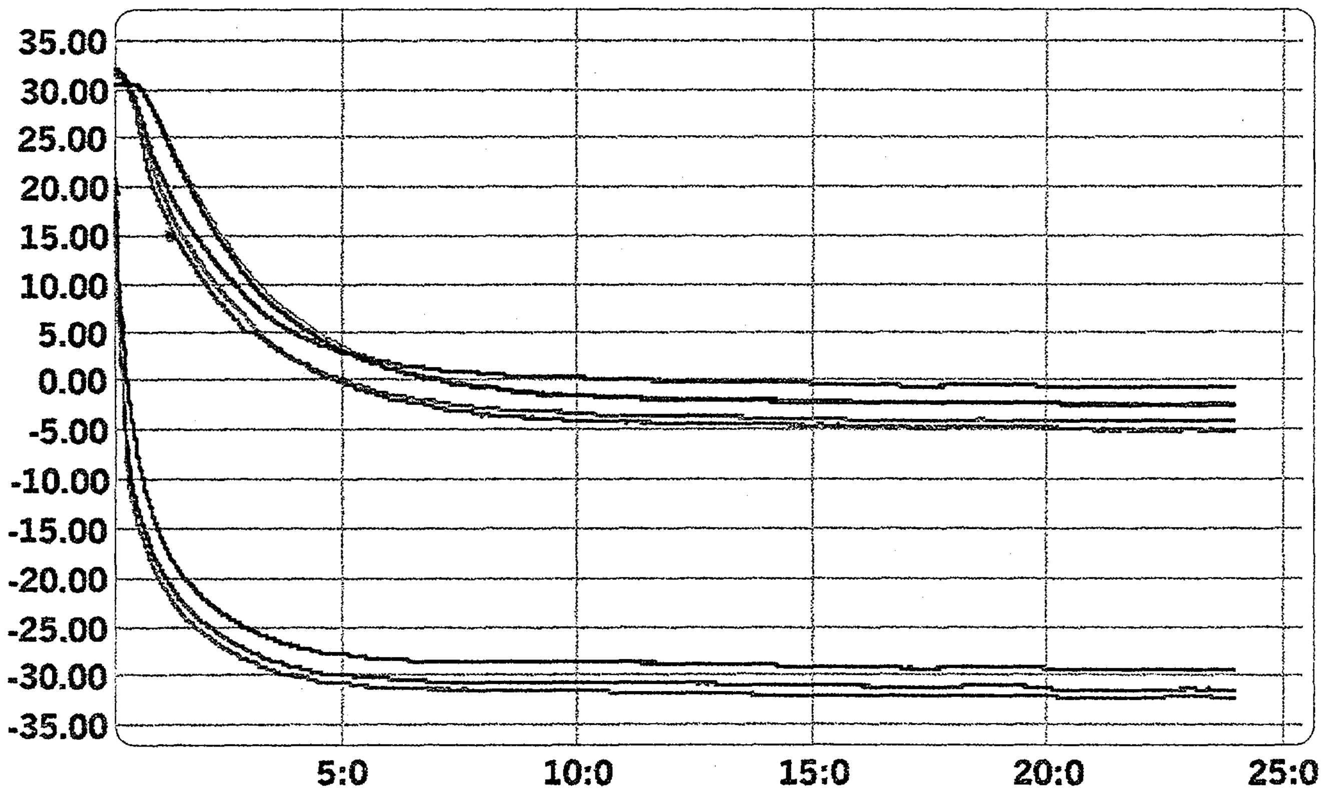
Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	23:59
Working Time(h:m)	23:59
Working Percentage	100.0%
Energy Cons.(KWh)	3.438
Av. En. Cons.(KWh/Day)	3.440
No. of Thermostat	0
No. of Over Load	0



Thu Feb 03 -00



EMERSUN

Setting

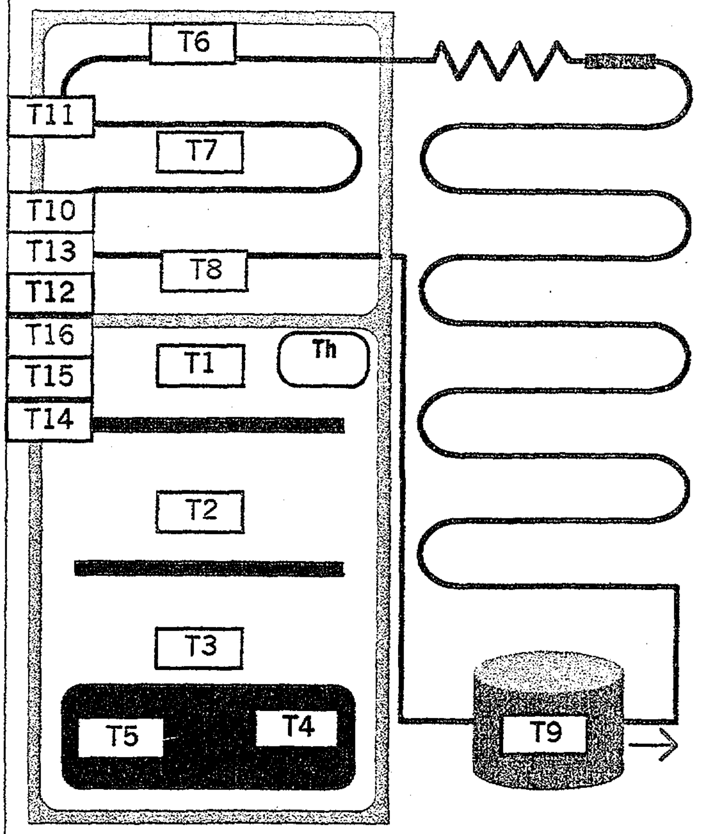
Test Date	Thu Feb 03-00
Test Type	-------------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\11141342

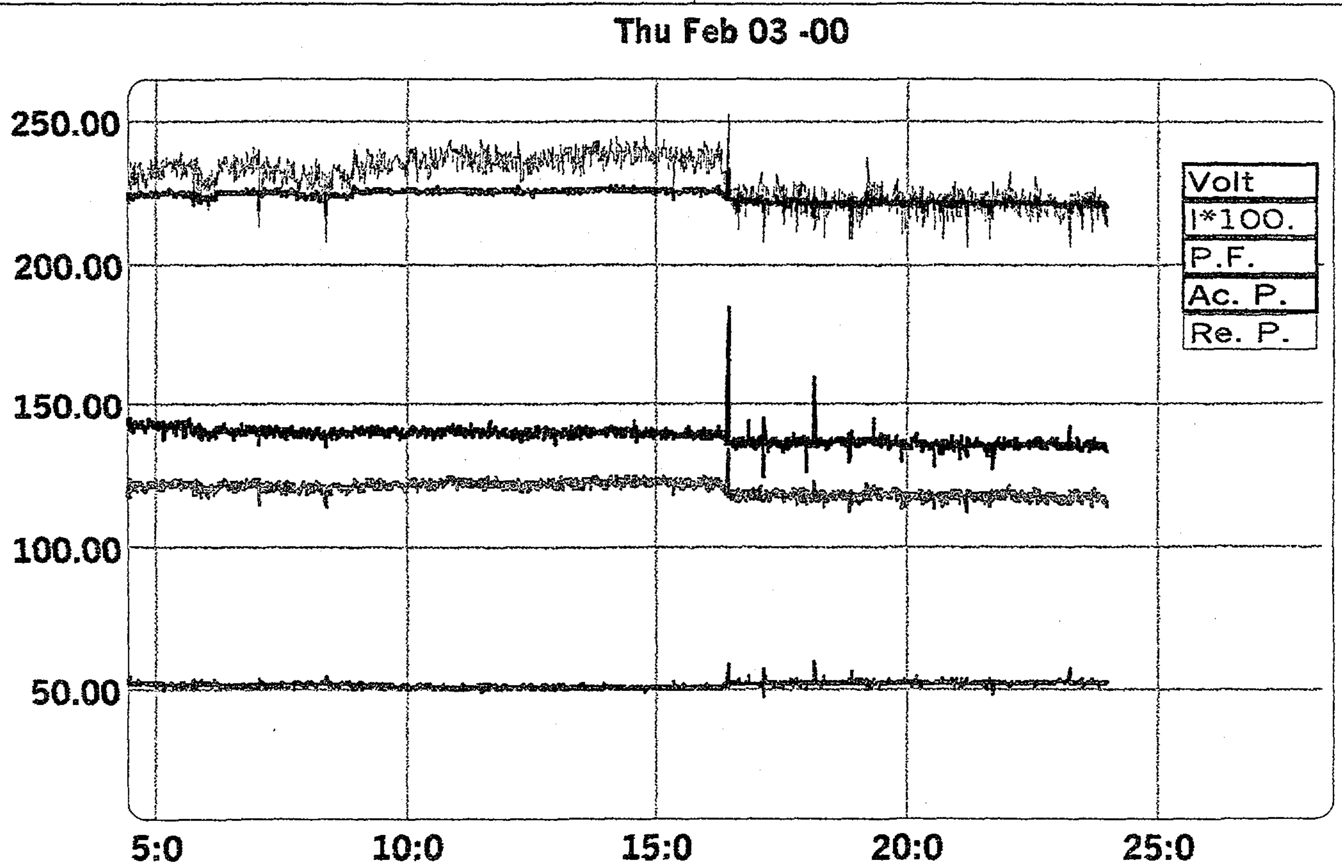
Product Specification

Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	23:59
Working Time(h:m)	23:59
Working Percentage	100.0%
Energy Cons.(KWh)	3.438
Av. En. Cons.(KWh/Day)	3.440
No. of Thermostat	0
No. of Over Load	0





EMERSUN

Setting

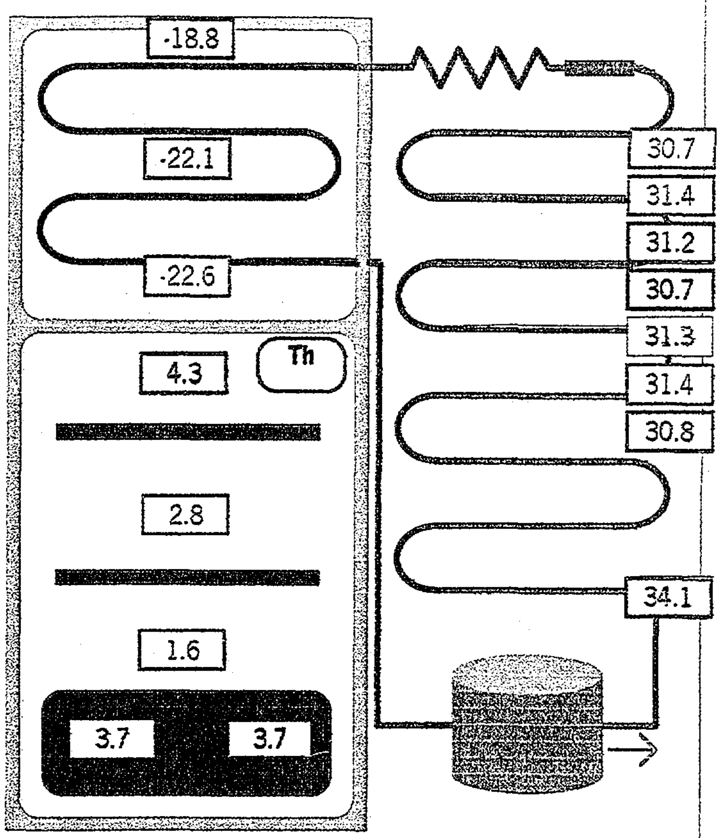
Test Date	Sat Jan 22-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	70
File Name	\LAB4\F112R134

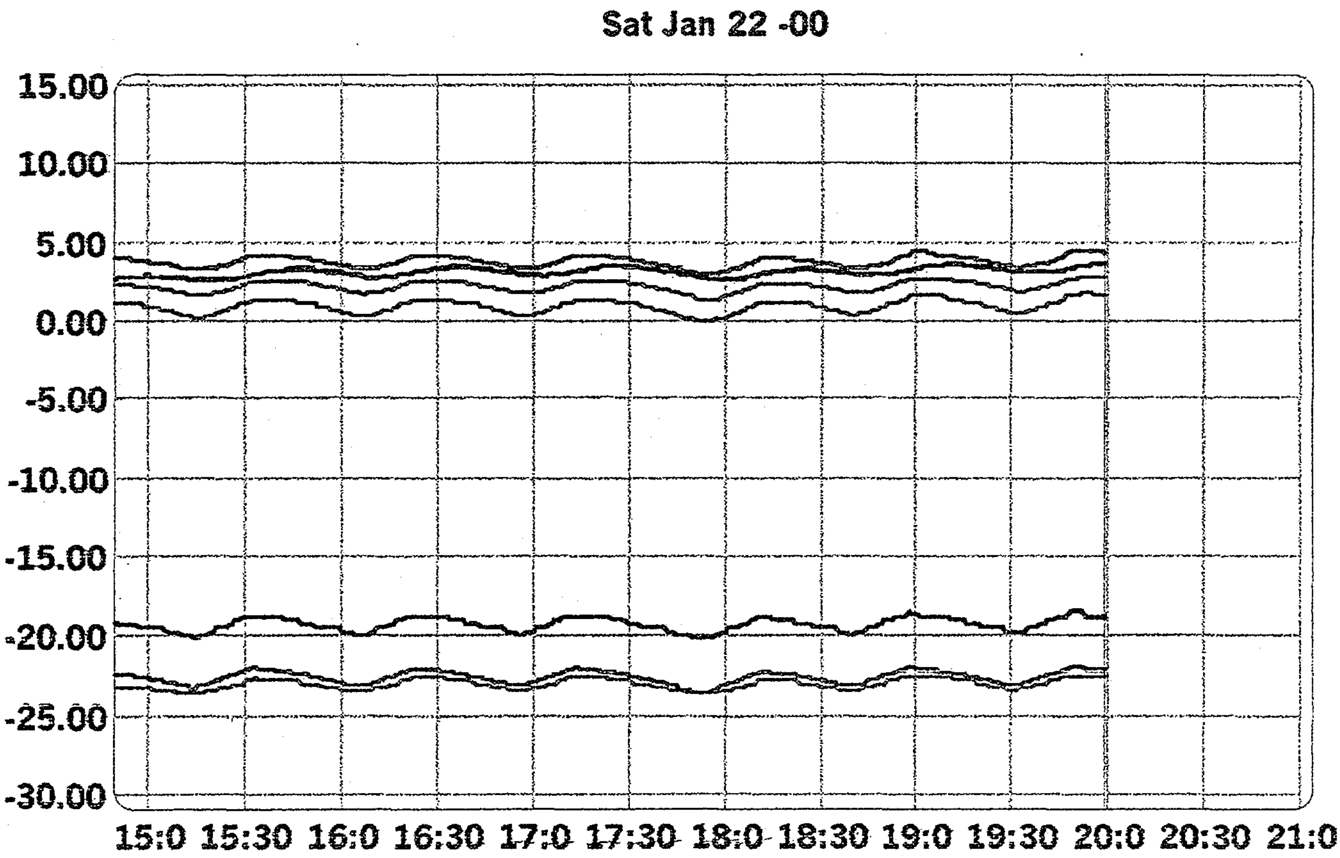
Product Specification

Product Type	RF18
Compressor Type	MATSUSHITA
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	-
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	19:58
Working Time(h:m)	13:51
Working Percentage	69.3%
Energy Cons.(KWh)	2.442
Av. En. Cons.(KWh/Day)	2.935
No. of Thermostat	23
No. of Over Load	0





EMERSUN

Setting

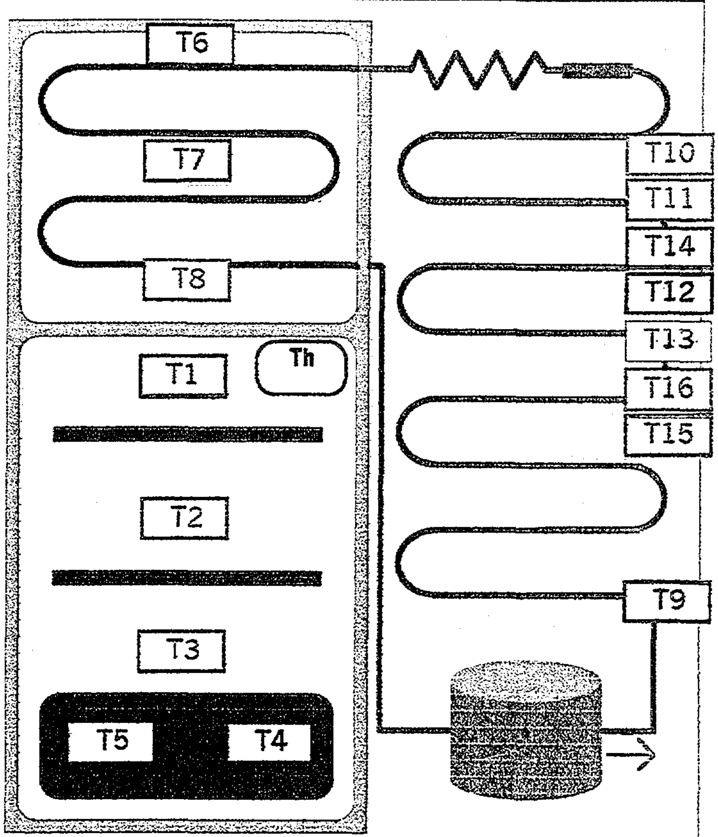
Test Date	Sat Jan 22-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	70
File Name	\LAB4\F112R134

Product Specification

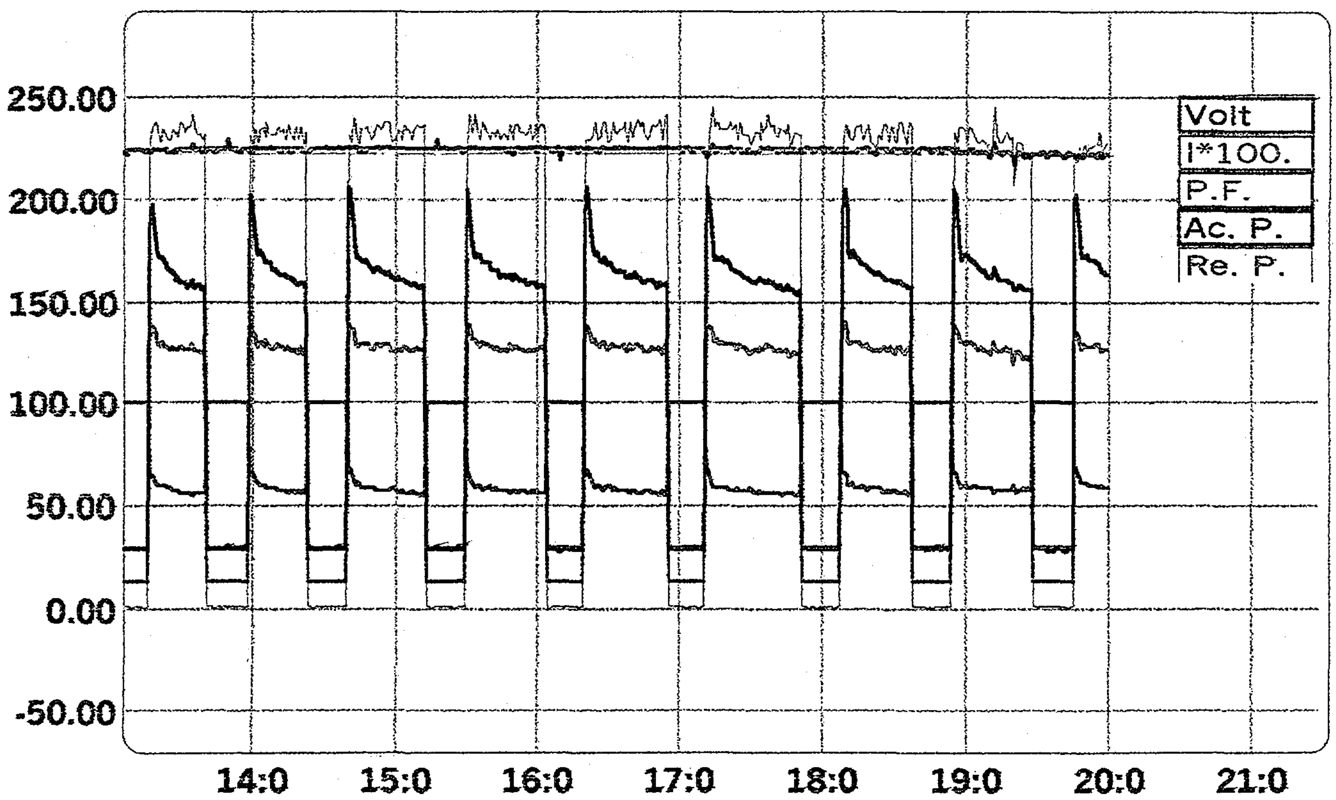
Product Type	RF13
Compressor Type	MATSUSHITA
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	-
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	19:58
Working Time(h:m)	13:51
Working Percentage	69.3%
Energy Cons.(KWh)	2.442
Av. En. Cons.(KWh/Day)	2.935
No. of Thermostat	23
No. of Over Load	0



Sat Jan 22 -00



third type

EMERSUN

Setting

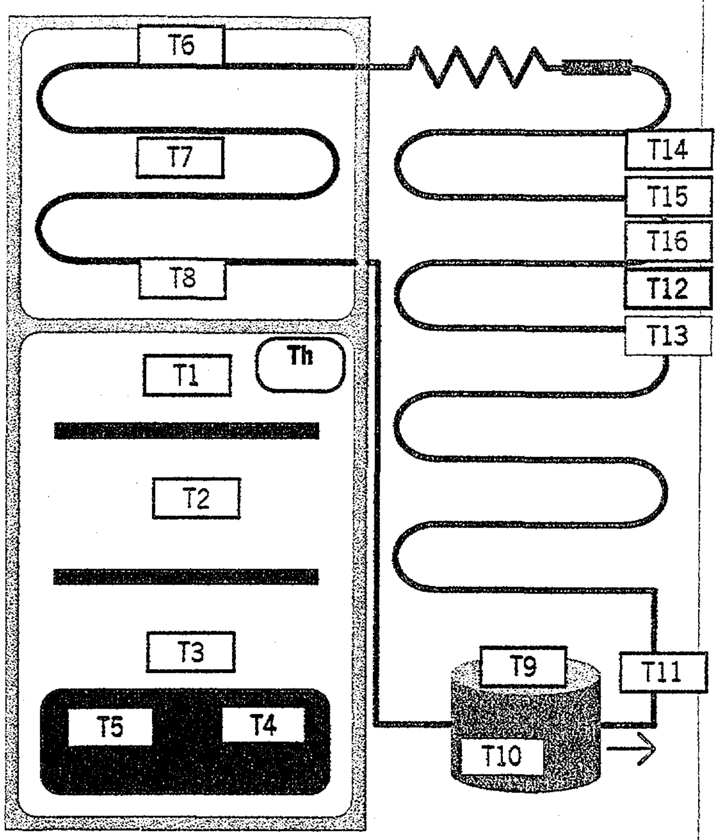
Test Date	Sun Jan 30-00
Test Type	--------------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\F1110134

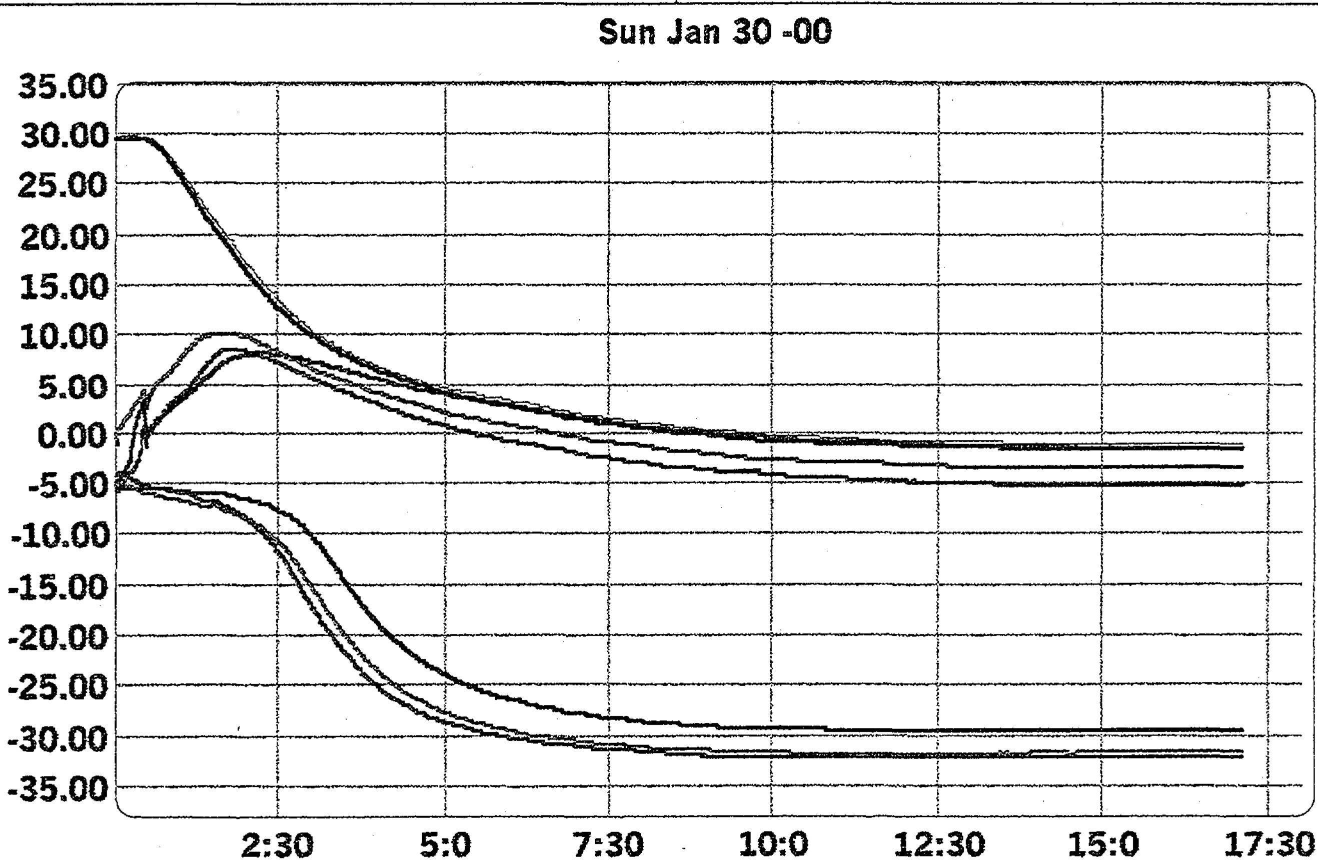
Product Specification

Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	17:08
Working Time(h:m)	17:00
Working Percentage	99.3%
Energy Cons.(KWh)	2.834
Av. En. Cons.(KWh/Day)	3.970
No. of Thermostat	1
No. of Over Load	0





EMERSUN

Setting

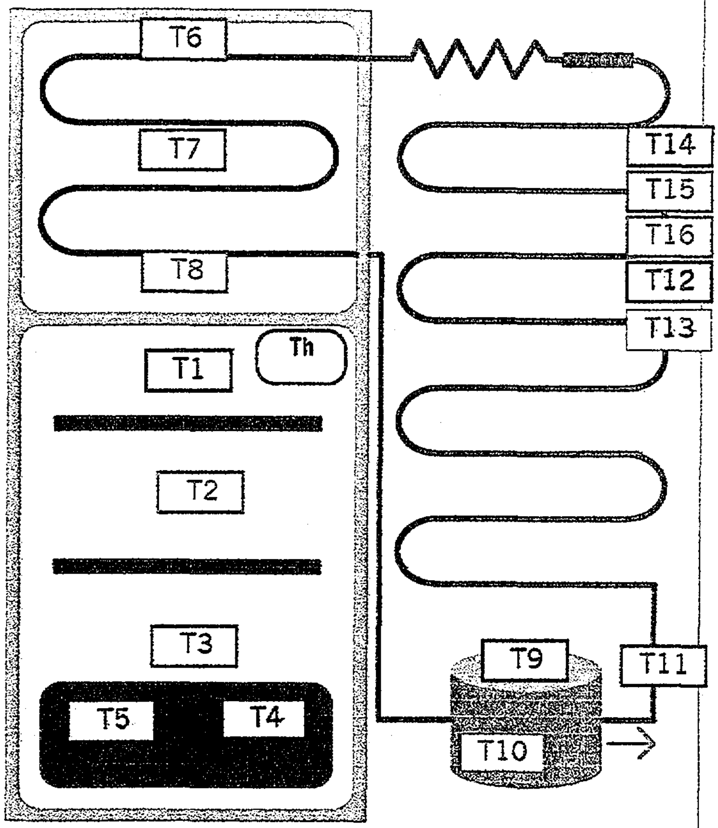
Test Date	Sun Jan 30-00
Test Type	------------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\F1110134

Product Specification

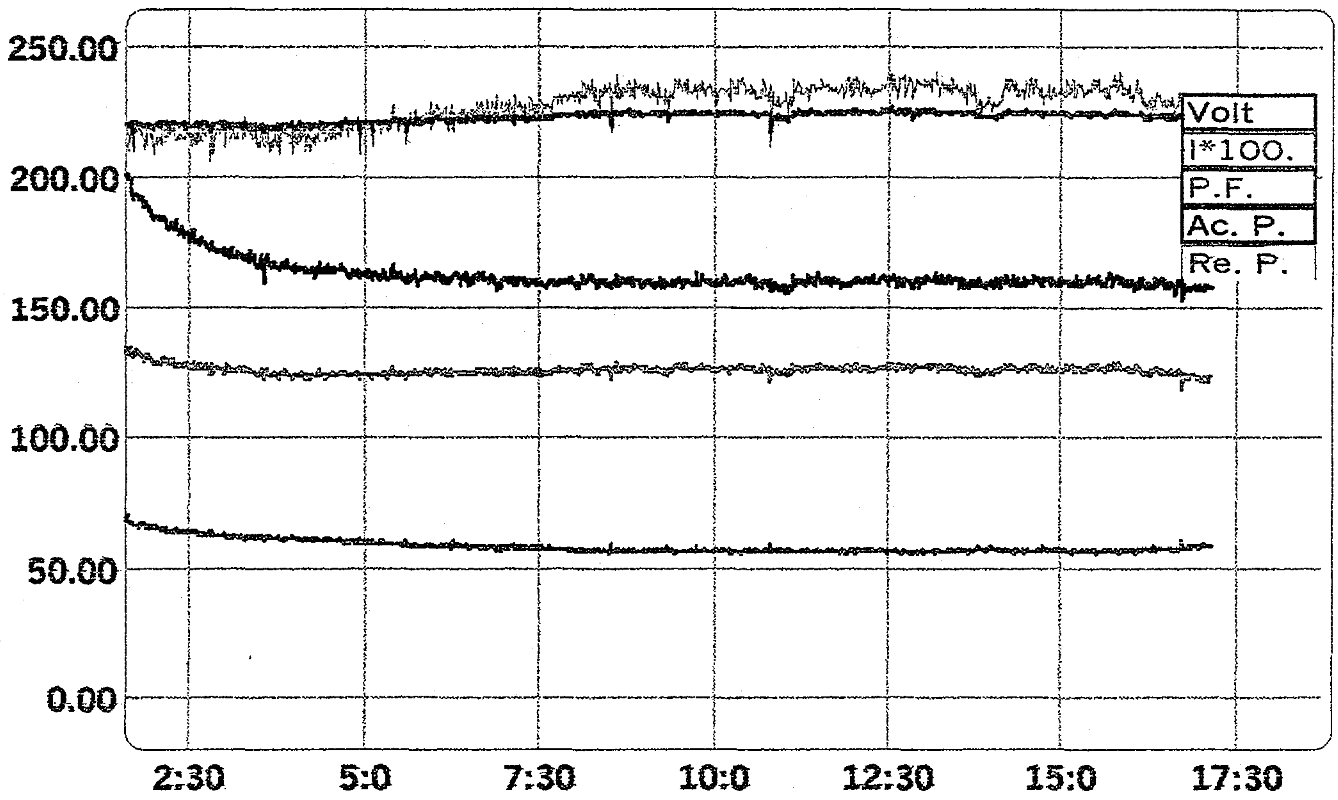
Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	17:08
Working Time(h:m)	17:00
Working Percentage	99.3%
Energy Cons.(KWh)	2.834
Av. En. Cons.(KWh/Day)	3.970
No. of Thermostat	1
No. of Over Load	0



Sun Jan 30 -00



EMERSUN

Setting

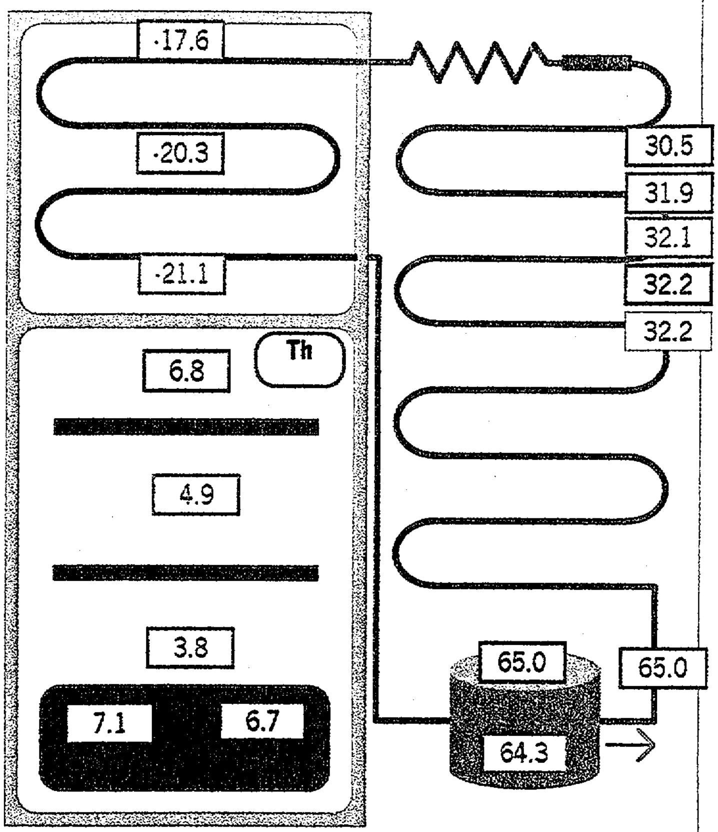
Test Date	Mon Jan 31-00
Test Type	----------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\F1111134

Product Specification

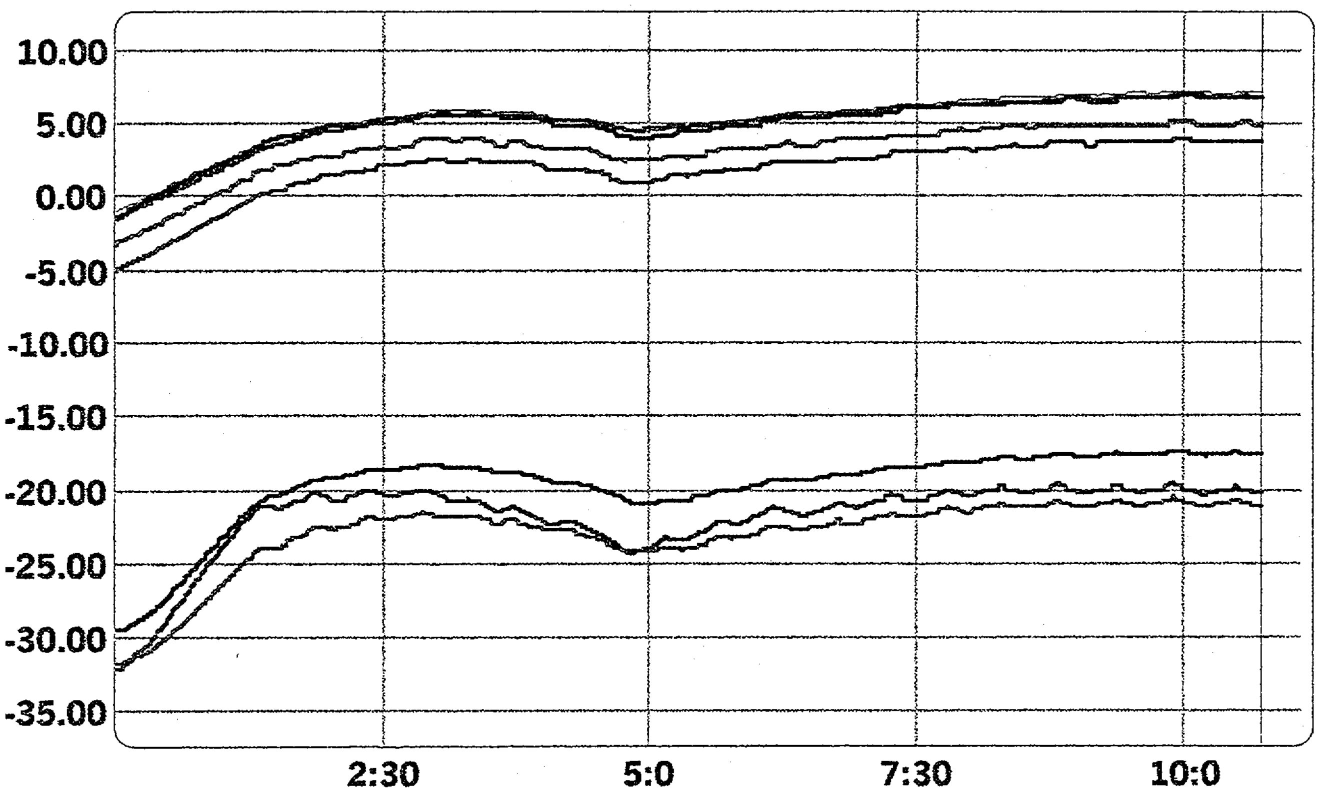
Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	-------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	10:43
Working Time(h:m)	05:30
Working Percentage	51.4%
Energy Cons.(KWh)	1.261
Av. En. Cons.(KWh/Day)	2.824
No. of Thermostat	44
No. of Over Load	0



Mon Jan 31 -00



EMERSUN

Setting

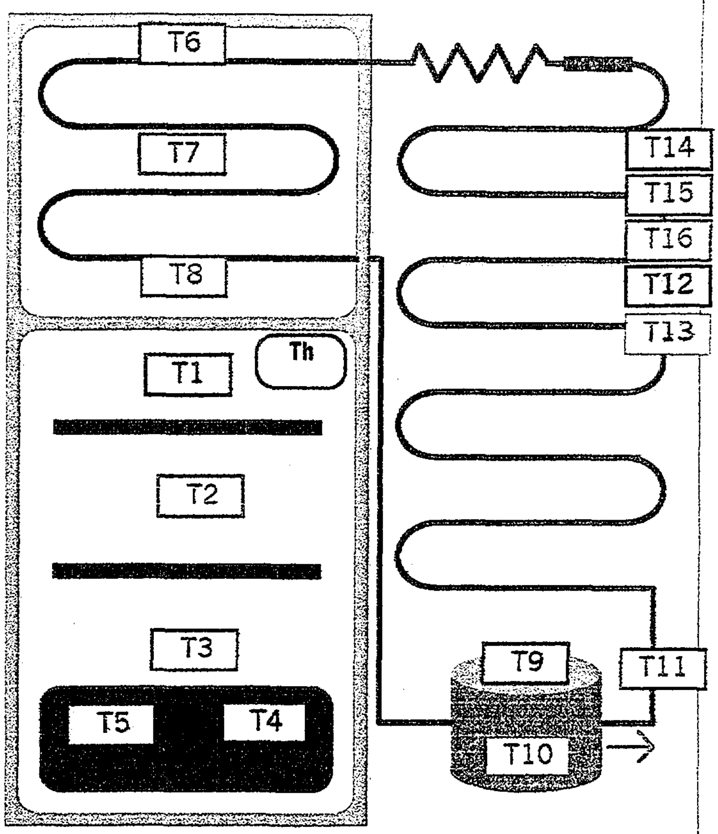
Test Date	Mon Jan 31-00
Test Type	----------
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\F1111134

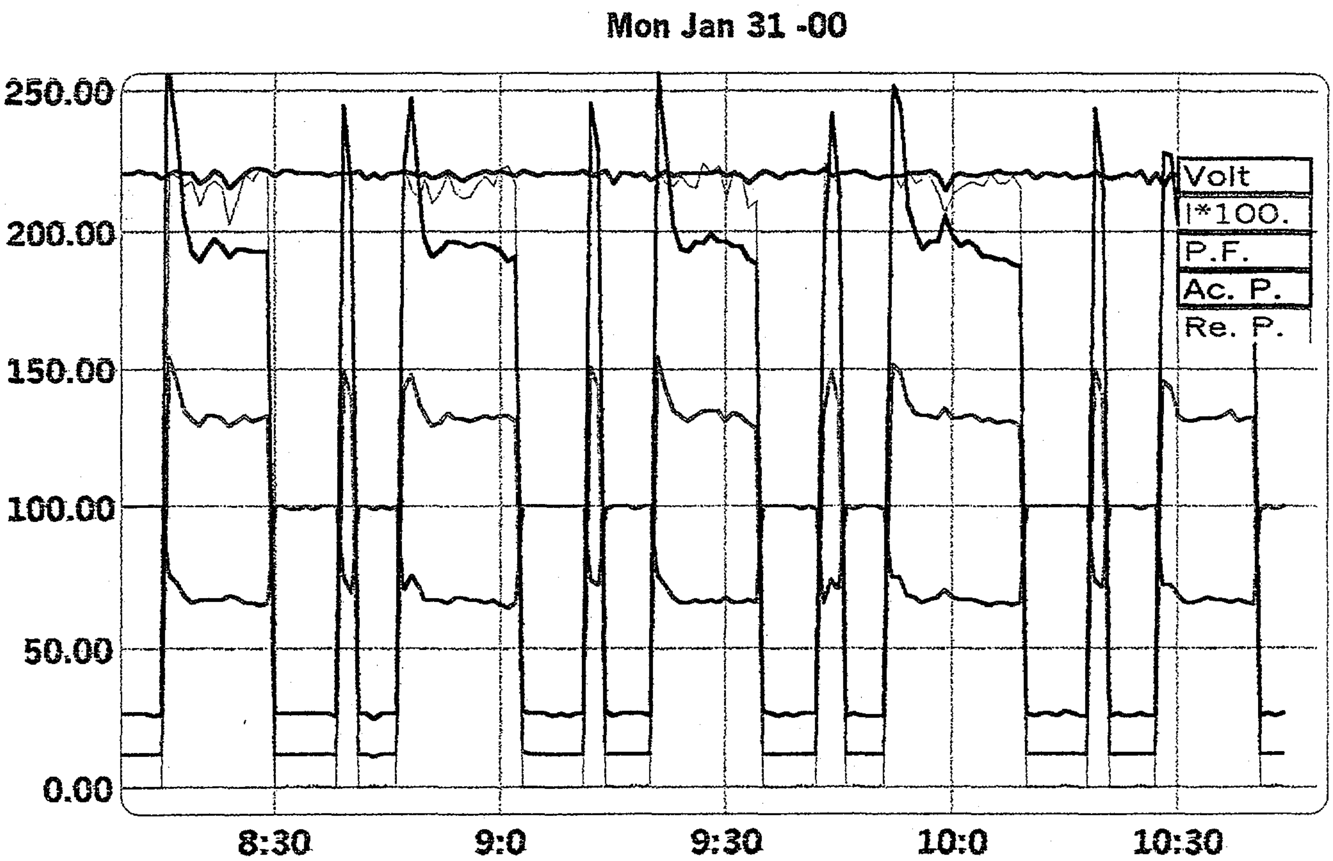
Product Specification

Product Type	RF 18
Compressor Type	MATSUSHITA 17G
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	------------
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	10:43
Working Time(h:m)	05:30
Working Percentage	51.4%
Energy Cons.(KWh)	1.261
Av. En. Cons.(KWh/Day)	2.824
No. of Thermostat	44
No. of Over Load	0





آشنا

EMERSUN

Setting

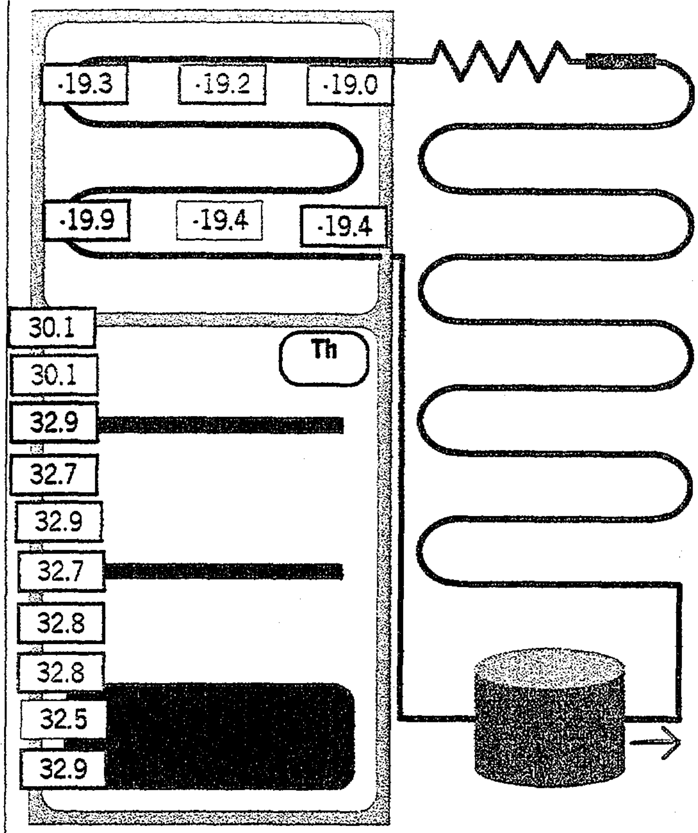
Test Date	Sun Feb 06-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\SAN11171

Product Specification

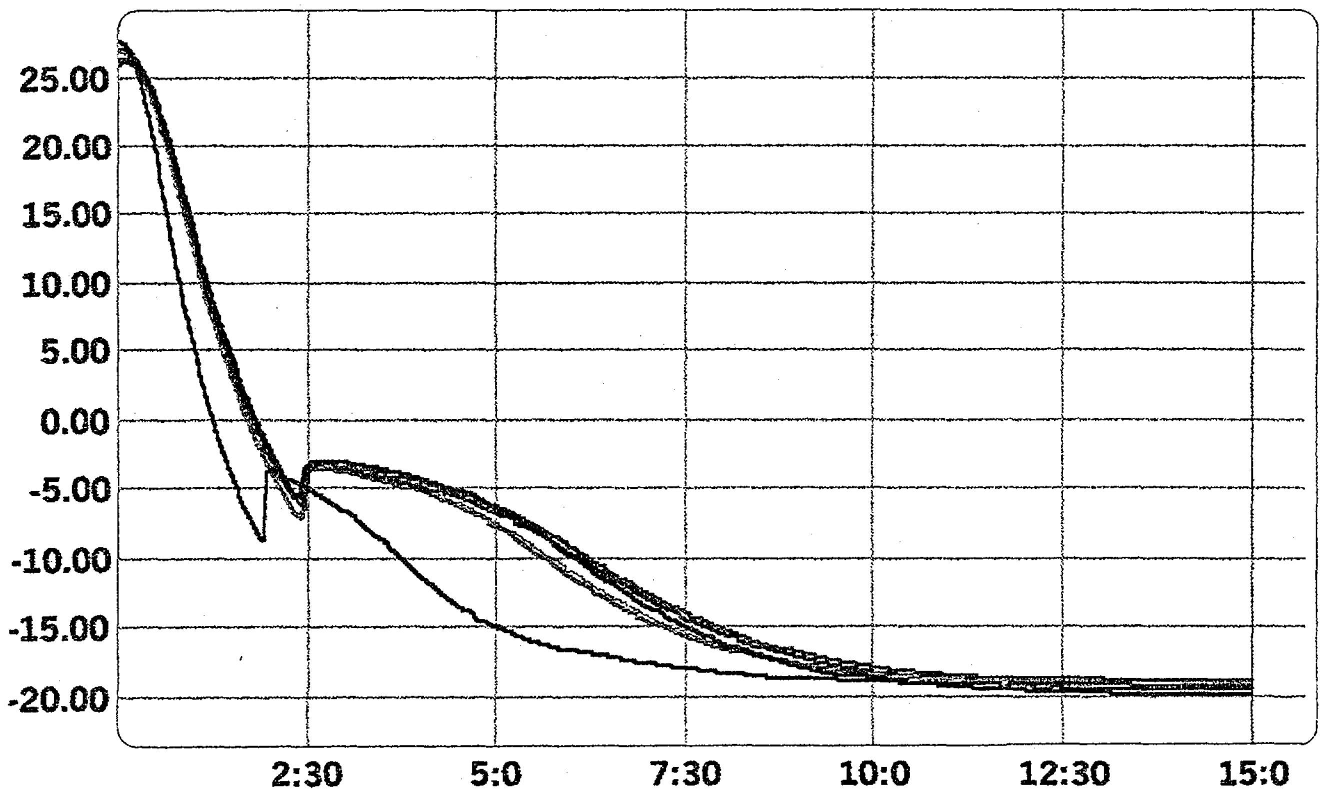
Product Type	-
Compressor Type	-
Refrigerant	-
Cappil. Length	-
Evap. Volume	-
Condensor Length	-
Thermostat Type	-

Test Result

Total Test Time(h:m)	14:59
Working Time(h:m)	14:59
Working Percentage	100.0%
Energy Cons.(KWh)	2.650
Av. En. Cons.(KWh/Day)	4.245
No. of Thermostat	0
No. of Over Load	0



Sun Feb 06 -00



EMERSUN

Setting

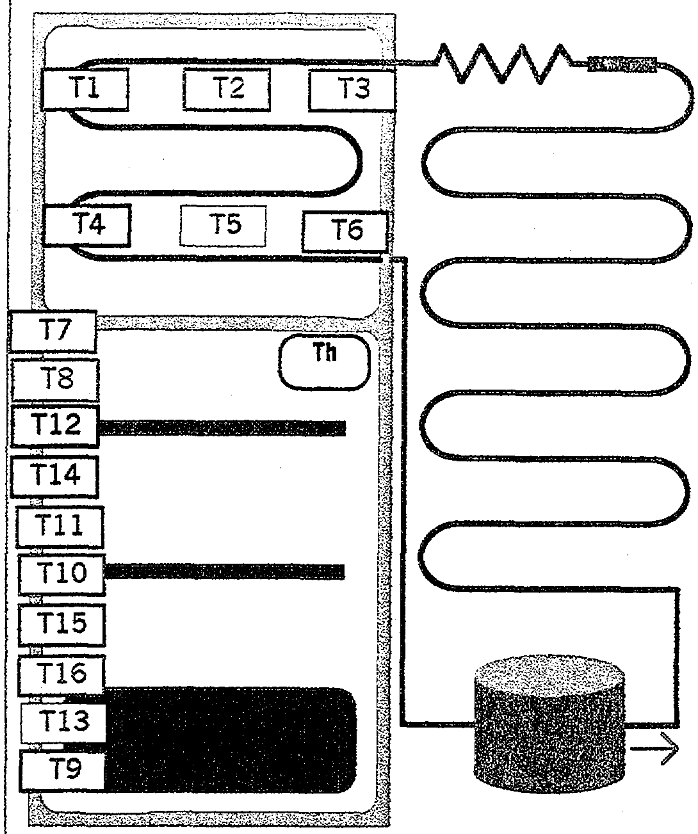
Test Date	Sun Feb 06-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\SAN11171

Product Specification

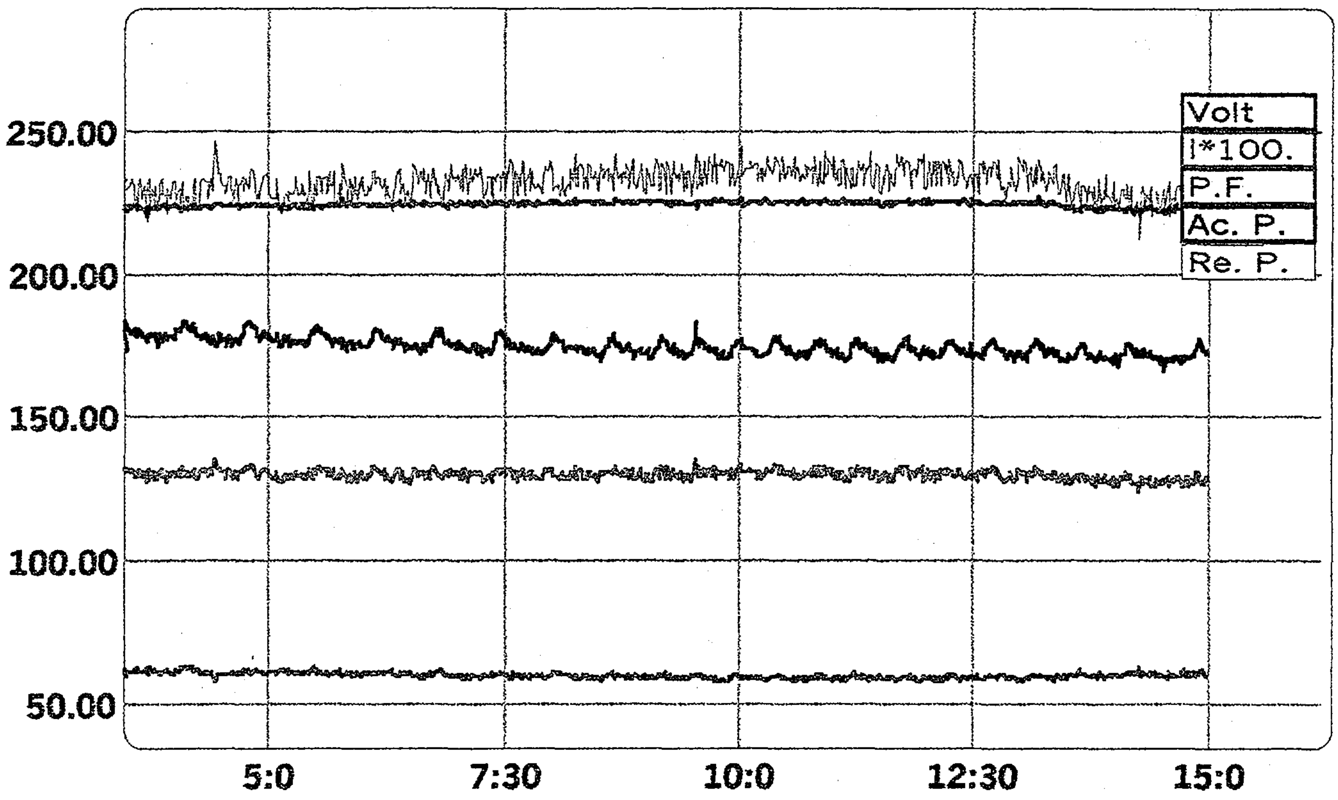
Product Type	-
Compressor Type	-
Refrigerant	-
Cappil. Length	-
Evap. Volume	-
Condensor Length	-
Thermostat Type	-

Test Result

Total Test Time(h:m)	14:59
Working Time(h:m)	14:59
Working Percentage	100.0%
Energy Cons.(KWh)	2.650
Av. En. Cons.(KWh/Day)	4.245
No. of Thermostat	0
No. of Over Load	0



Sun Feb 06 -00



EMERSUN

Setting

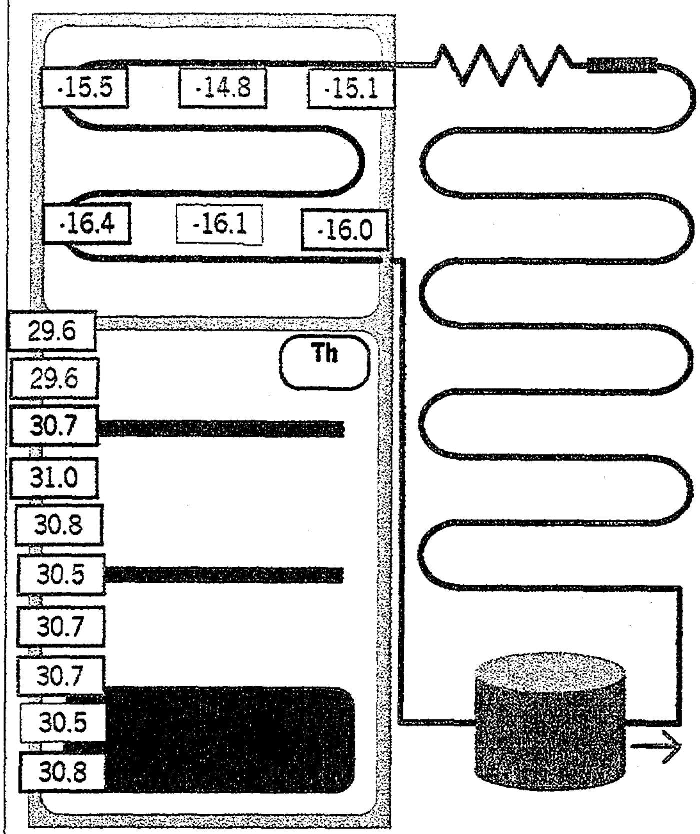
Test Date	Mon Feb 07-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\SAN11182

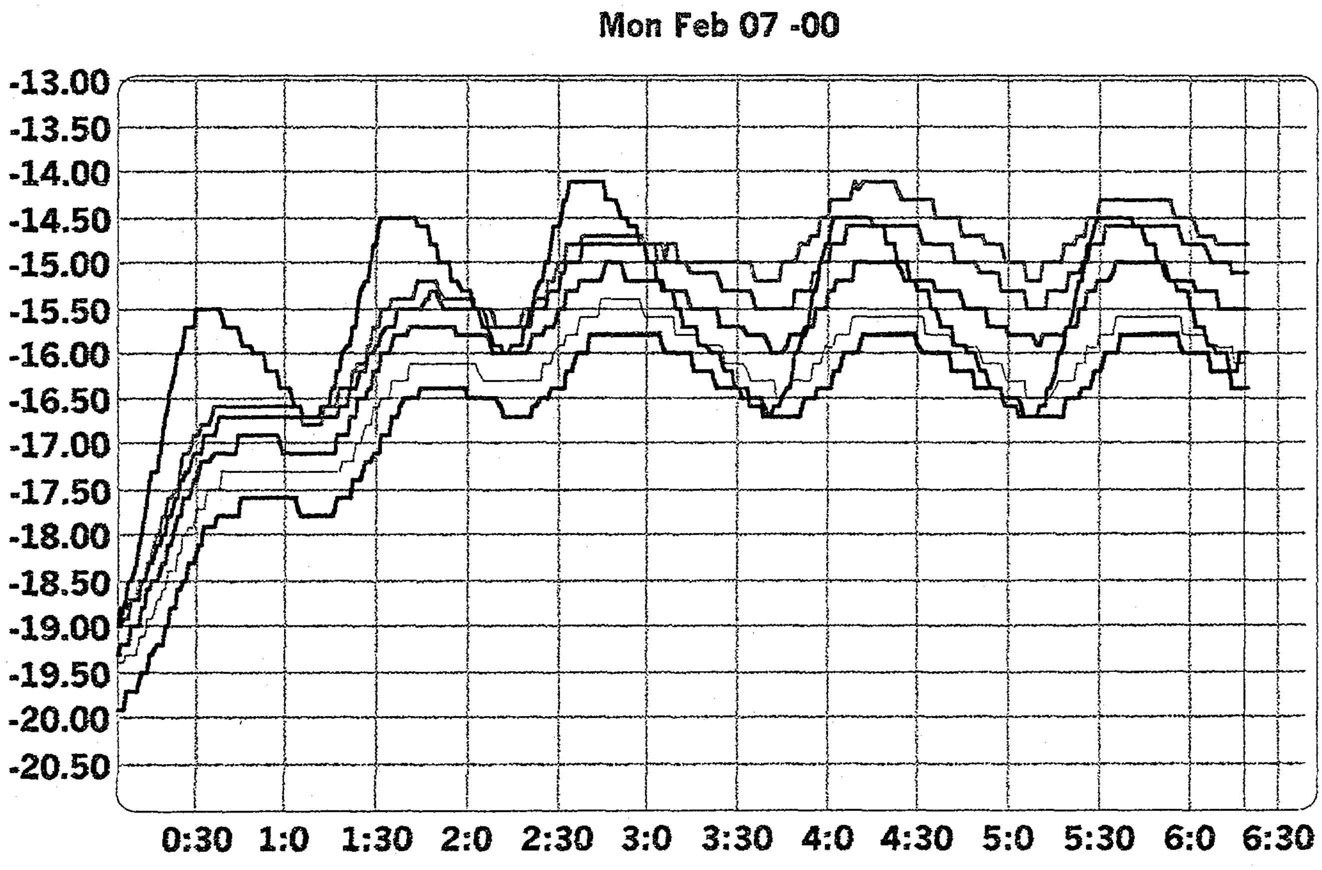
Product Specification

Product Type	-
Compressor Type	-
Refrigerant	-
Cappil. Length	-
Evap. Volume	-
Condensor Length	-
Thermostat Type	-

Test Result

Total Test Time(h:m)	06:20
Working Time(h:m)	04:21
Working Percentage	68.7%
Energy Cons.(KWh)	0.7810
Av. En. Cons.(KWh/Day)	2.960
No. of Thermostat	5
No. of Over Load	0





EMERSUN

Setting

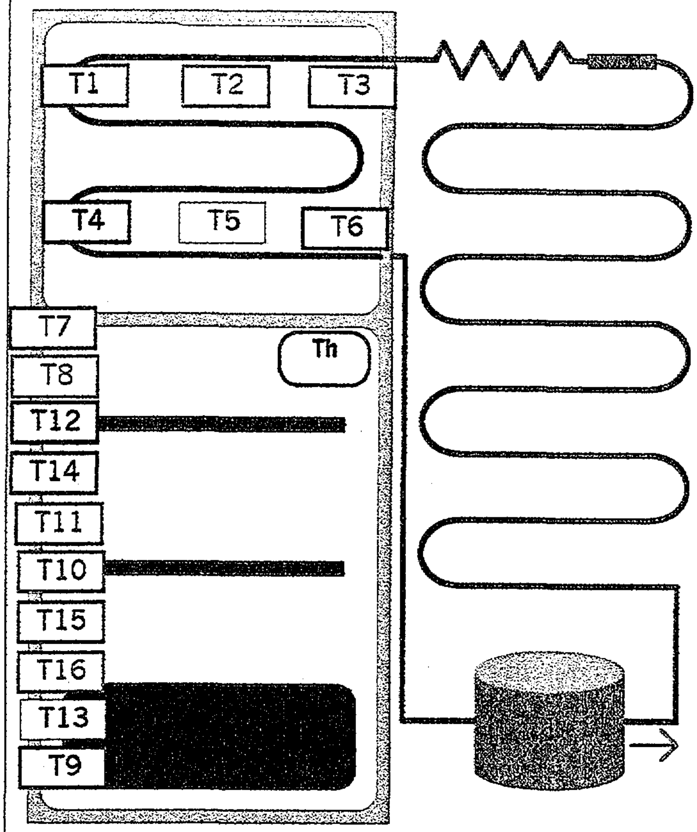
Test Date	Mon Feb 07-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	50
File Name	\LAB4\SAN11182

Product Specification

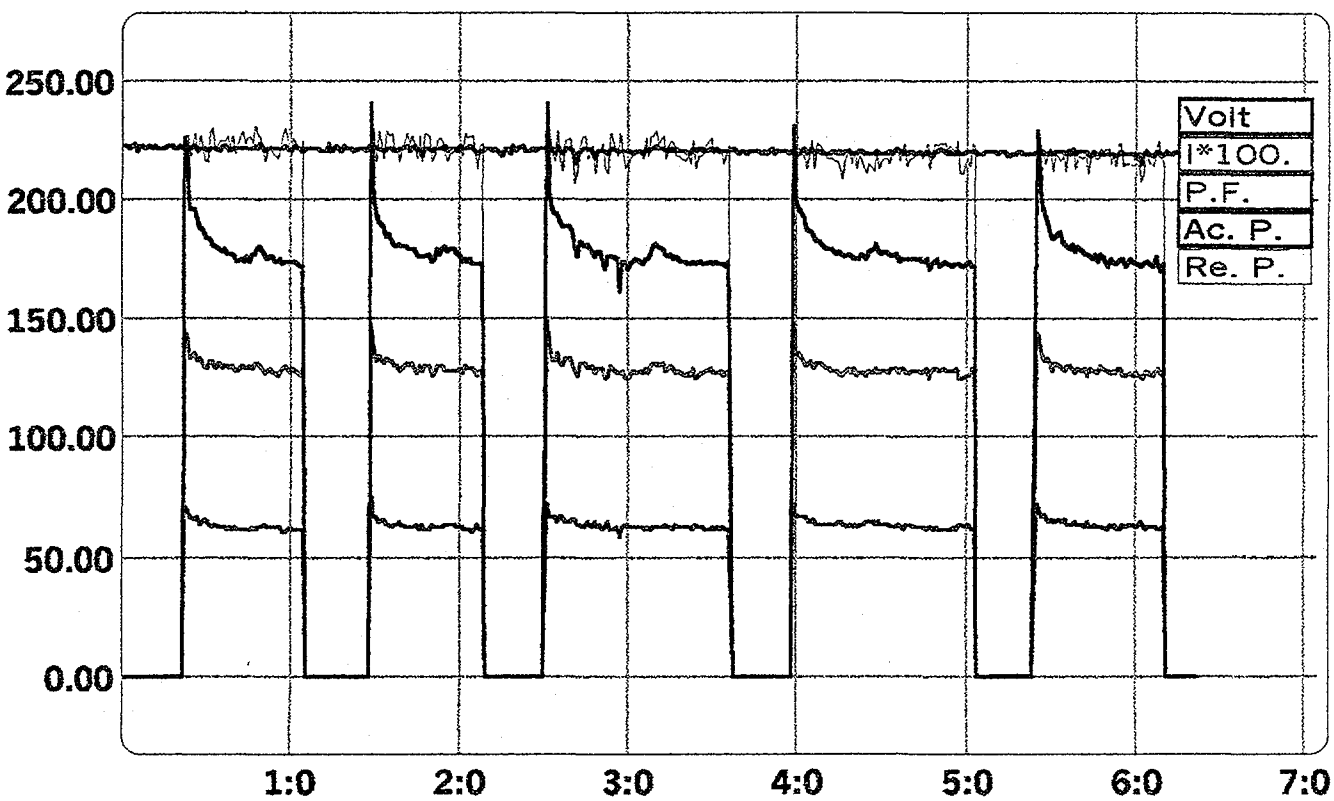
Product Type	-
Compressor Type	-
Refrigerant	-
Cappil. Length	-
Evap. Volume	-
Condensor Length	-
Thermostat Type	-

Test Result

Total Test Time(h:m)	06:22
Working Time(h:m)	04:21
Working Percentage	68.2%
Energy Cons.(KWh)	0.7810
Av. En. Cons.(KWh/Day)	2.944
No. of Thermostat	5
No. of Over Load	0



Mon Feb 07 -00



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EMERSUN

R134a O.K. نمونه تائید شده

Setting

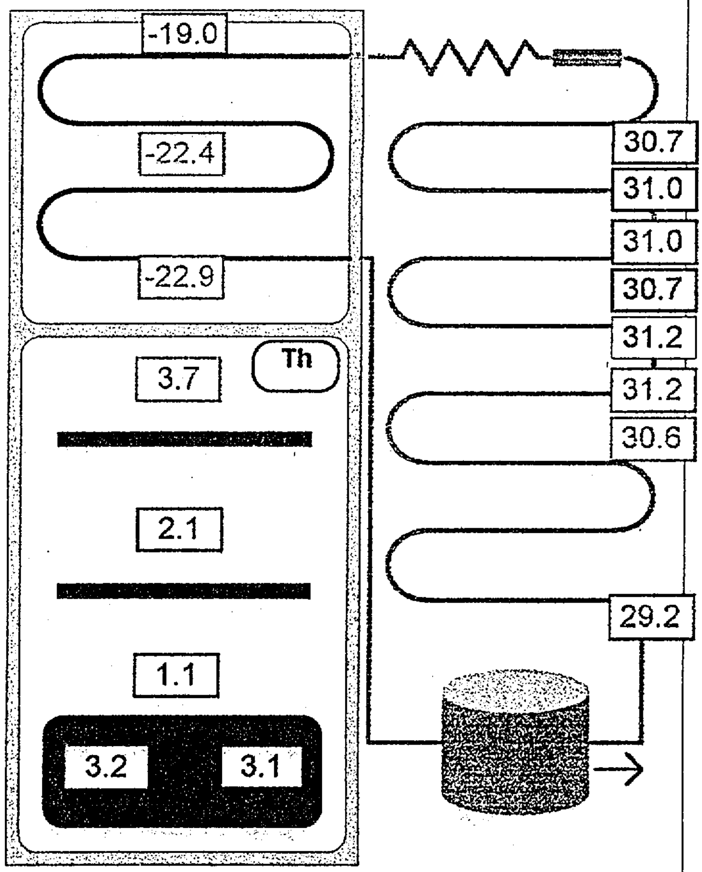
Test Date	Sat Jan 22-00
Test Type	-
Hot Room Temp.	32
Hot Room Hum.	70
File Name	\LAB4\F112R134

Product Specification

Product Type	RF18
Compressor Type	MATSUSHITA
Refrigerant	250g
Cappil. Length	031 470
Evap. Volume	-
Condensor Length	16m
Thermostat Type	DANFOSS

Test Result

Total Test Time(h:m)	19:40
Working Time(h:m)	13:37
Working Percentage	69.3%
Energy Cons.(KWh)	2.400
Av. En. Cons.(KWh/Day)	2.929
No. of Thermostat	23
No. of Over Load	0



Sat Jan 22 -00