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51 p. tables diagrams

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Final Report

Implementation of Prototype Improvement at;

Al- Asriam, Frigo Alaska, SAC for refrigeration, Frigo Khankhan, Engineering Enterprise, and Adam Refrigeration So Called The Second Group of Lebanese Small Commercial Refrigerator Manufacturers

Please find herewith below draft final report concerning implementation of development of prototypes at the second group of Lebanese Small Commercial Refrigerator Manufactures.

This companies consist of Al- Asriam, Frigo Alaska, SAC for refrigeration, Frigo Khankhan, Engineering Enterprise, and Adam Refrigeration.

Before we draw your attention to our activities to execute the contract. We wish to give you here a brief history of our company background and general information about the sector and main objectives of the project to phase out ODS in different Lebanese Small Commercial Refrigerator Manufacturers.

Sector Background

Lebanon has an area of 10452 sq km with a population of 4/1808 million in 1997. The population density is approximately 400 per square km. The urban population represents some 80% of the total .GNP is approximately USD

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1900 per Capita in 1993 (USD2250in 1975 before the war). Agriculture accounts for 14% of GNP, industry 26% and service sector 60% . Lebanon depends entirely on imports for its ODS consumption . Lebanon ratified the Vienna convention on March 31, 1993 (entered into force on June 29, 1993) and London amendments on March 31, 1993(entered into force on June 1993).

The ratification of the Copenhagen amendments is still in process. The country program (CP) for phasing out of ODS in Lebanon was prepared with the assistance of the national working committee on OZONE Depleting Substances, established in 1994 at the ministry of Environment. Although the CP is dated as March 1998, the statistic data on ODS consumption by different sub-sectors are limited to 1992-93. Forecast for the ODS consumption for 1995-2010 is prepared based on a very uncertain assumptions.
Information for the year 1994 is completely missing .it is relevant to mention that the country just stared to recover from the consequences of the 17 years civil war .because of the progress in political stabilization , the open market economy of the country , the favorable conditions for foreign investments established by the government's policy , etc.
All sectors of the national economy, in particular industry, are moving ahead very fast .

According to the clarifications of the ministry of Environment, this imbalance between usage of CFC-12 for production and service is caused by the fact that in 1992-93 due to the post war situation in the country, local manufacturing of domestic and commercial refrigeration equipment was very low, import of refrigerators was also limited due to low financial capacity of the local market. Therefore during that time, the refrigeration equipment (domestic and commercial) repairing and recharging sub-sector was the major user of CFC-12 , being very important from social point of view.
As a result of the progress of political and economic stabilization in Lebanon and in the region, the industrial and commercial scenario of ODS usage have been changed significantly in terms of ODS consumption redistribution within the relevant sectors and sub-sectors , although the overall forecast – and

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tendency of total ODS consumption for 1995-2010 indicated in the country program is valid.
The country programmers were submitted to the secretarial of the multilateral Fund for presentation at the 17th Executive Committee meeting, and it was reviewed and recommended for approval.
Due to a discrepancy in the accuracy of population data, provided by the country the OZONE Secretarial classified Lebanon as none article 5 parties. Therefore the executive committee decided at its 17th meeting (decision 1 7/1) to defer the submission of the country program of Lebanon and the projects included.
By its decision VII/20, the 7th meeting of the parties decided inter alia that in case of any discrepancy on the accuracy of the data, the data provided by the party to the OZONE Secretarial should be used. In compliance with this decision, the OZONE Secretarial reclassified Lebanon as a party operating under article 5.
This country program is now being updated as of December 1998.In 1993,Lebonan imported and used 923.1 ODP tones of ODS, equivalent to 0.24 Kg per capita compared to the year1997, Lebanon imported and used 646.82 ODP tones of ODS. The main substances used are CFC11, CFC12, CFC114, CFC115.

The scope of services

A study will be made on models manufactured by the companies mentioned, and include followings:

1- dimensional specifications.
2- Type and insulation thickness
3- Refrigerating unit component details
4- Working performances
5- Optimization of R134a charge

We will visit the project site at least three times during the execution of the project:

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a- first visit in order to:

- become familiar with counterpart's premise, local conditions and the counterpart's requirements and expectations.
- to prepare the scope of counterparts obligations and responsibilities to allow enough time for the counterparts to meet their obligations.

b- Second visit in order to

- selection of HFC-134a compatible components.
- redesigning of complete refrigeration circuit.
- Specifying necessary change in the cooling system if required
- Preparation of one prototype per model
- Train the counterpart staff in order to familiarize the know how to develop and test the prototypes.

c- third visit in order to

1) Testing prototypes for functionally and performance (hot room test) at the counterparts premises.
2) Evaluate the test results.
3) Perform necessary changes and modifications if required to the prototypes for production.

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Main Activities

Activities.

Following activities were achieved during implementation of project.

1- Visiting counterparts premises several times to assure precise technical data for providing necessary information for calculating refrigeration load calculation.
2- Assisting counterparts to select most common and well selling prototype models to be made and test under new circumstances.
3- Supervising related activities concerning making prototypes.
4- Conducting several briefing meeting and training session at our classroom located beside our hot chamber at our factory and counterparts premises to familiarize the counterparts technical staff with new refrigerant physical, chemical and operation properties and behavior.
5- Contacting UNDP and Ozone office in several occasion to plan for implementation of the project in time.
6- Coordinating with UNIDO staff and Ozone office staff in Beirut for execution of different activities foreseen in the contract.
7- Storing and preserving charging equipment at our warehouse to assure safe and trustful stocking as requested by UNIDO's project manager and Ozone Office.
8- Deliver all charging equipment to counterparts as they were received in accordance with packing list and project documents.
9- Assuring safe handling and equipment free of any defects by visual inspection due to possible mechanical damages, before delivery to the counterparts.
10- Explaining to the counterparts operation purposes and application of each machines as purchased and supplied by UNIDO and manufacturer.

11- Conducting an orientation course for technical staff of

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11- Conducting an orientation course for technical staff of counterparts to be familiarized with application of equipments and use of them.

Development of prototypes

We have trained the company's technical staff in two phases, at two sessions we gave them mainly general information about the Ozone, Montreal Protocol, and an introduction to safe use of R134a Refrigerant.

The topics that could be considered as remarkable issues of our taing program, could be summarized as follows.

In this report we discuss our methods of selection of refrigeration circuit component and the method that we use for calculating refrigeration coal to determine capacity of compressors to fit new criteria. The new criteria is defined as new operating condition under usage of R134a Ozone friendly refrigerant. As we learnt through our experience, following components have significant role to be adapted for new environmental and technical circumference.

1) Compressor,
2) Filter Drier
3) Refrigerant Charge
4) Capillary Tube.

Since size of evaporator and condenser for R12 system circuit for small and medium size cooling capacity refrigeration system are selected with certain limitation due to availability of component in the market, they usually selected upper size than what really needed, therefore we considered them to be remained unchanged due to their heat removal and absorbent capacity. We concentrated our activities in evaluating the different size of Compressor with regard of availability in Lebanese market and R12 compressor cooling capacity used in old models and also total refrigeration load in watts of cooling capacity calculated in accordance with conventional methods defined mainly in different ASHRAE handbooks, which were used as our main reference to calculate and get different data for calculating heat Transfer Load, Product Load, and Miscellaneous Loads such as door opening, infiltration, electromotor, and etc.

In this report we explain briefly how we calculated compressor cooling capacity, then how we select new components, and finally different activities achieved during execution of contract after preparation of our first progress report which was submitted to you in January 2001.

1- Methods of Refrigeration Load calculation for determination of compressor cooling capacity.

Four main elements are considered for calculation:

a) Transmission load;
Heat transfer through side walls by conduction

b) Product load;
Heat Removed from and produced by the products which are stored.

c) Internal load;
Heat produced by internal sources such as lights, fan or heaters;

d) Miscellaneous Load

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Heat gains associated with air entering the refrigerated space and door opening and etc.;

Transmission Load through side walls

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.

The resistance elements could be realized as Liner Resistance, Cabinet Sheet Metal Resistance, PU or Polystirene Insulator Resistance and Air Layer Moving inside and outside side walls. Heat is transferred through Inner Liner Resistance, Cabinet Sheet Metal Resistance, PU or Polystyrene Insulator Resistance by conduction while heat transfers by convection through moving or still air around cabinet and door side walls inside and outside of the appliances. All these heat transfer elements are considered in heat coefficient resistance formula.

Heat resistance factor of Inner Liner and Cabinet carbon or stainless steel is considered negligible due to their thickness and high thermal conductivities.

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

$1/h_o = 1/h_i = 1/9.34$ which are inside and outside air convection factor that we should consider into above formula.

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

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

Where:

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

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

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

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Where h = Latent heat of product, Kcal / Kg

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

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

Where:

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

For upright freezers or chest freezer, total product load is

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

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

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

Miscellaneous 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

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heat gain, or a percentage of amount of the above mentioned components. (Transmission load, product load and internal load). For example;

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

Refrigeration Load Calculation for different type of Water Coolers

Since Refrigeration Load Calculation Load for Water coolers are slightly different form conventional refrigerators and freezers we discuss this issue seperately.

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

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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.

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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, Ti is inlet water temperature, and Tc is final cooled water.

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

Q_2 Total heat removed from total drinking water flow (lit.) during specific period, 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 (T_i-T_c), where, Ti is inlet water temperature, and Tc is final cooled water temperature.

$Q_3 = UA\ \Delta T$

Where

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

U Heat Resistance Coefficient Factor in Kcal/Sq. mt. C
A Total Area which heat is transmitted by. In Sq. Mt.
ΔT Temperature difference ($T_a - T_c$), where, T is ambient temperature, and Tc is final cooled water temperature.

Different Calculation Methods Analysis

In preparation of the first progress report, we have chosen an appropriate method for our refrigeration load calculation. To respond our design and configuration requirements, choosing an appropriate method of refrigeration load calculation is the aim of selecting compatible components.

The method of refrigeration load calculation for a new design refrigerator could be completely different, in comparison with converting the existing Commercial refrigerators in production, because, in this case, we are not looking for the new nature of each refrigerator component or parts. In contemporary with designing new refrigerator model, we have to consider many parameters, such as heat leaks from outside through, wedge, corners, door gasket, door infiltration, door openings, heat radiation dissipated from condenser and compressor shell and etc.

A number of heat load parameters for cabinet loads in addition to the wall conduction loads could be considered. These include: electric defrost, penetrations, heaters and controls, fan heat, refrigerant line heat, in-wall evaporator, in-mullion evaporator, and in-wall condenser.

The total values shown for the cabinet type refrigerator are the hourly average loads, which must be removed by refrigeration system.

For the purpose of determination of energy consumption, two cooling capacities should be considered:

1) Evaporator load,
2) Net capacity.

Normally these two quantities are the same. If a cold-plate evaporator is used, however, the total evaporator load will be higher than the net capacity due to the heat going directly to the back of the evaporator through the insulation.

In our case, which the main consideration is selecting compatible components with existing refrigeration components, the method of refrigeration load calculation is different from the refrigeration load calculation of the new design products.

We will discuss three different methods of refrigeration load calculations, from following sources;

1) EPA Refrigerator Analysis Programme (ERA).
2) Ariston Co.'s methods of refrigeration load calculation.
3) ASHRAE standards of refrigeration load calculation.

EPA (Environmental Protection Agency) Refrigerator Analysis

For this method, following data are required for cabinet loads:

1) Cabinet Type and Dimension, as follows;

- Cabinet height is measured from the bottom to top of the cabinet, not the floor.
- Depth includes the cabinet door. This dimension measures the distance from the outside (front) surface of doors to the back of the cabinet
- Width of the gasket and the door edge thickness. The effects of door thickness on the internal volume are taken into account.
- Wedge dimensions, the cabinet wedge is the section of the cabinet near the door. In all cabinet types, except the chest freezer, the thickness of the insulation is reduced near the door to accommodate the door geometry.

2) Refrigerated volume;

ERA considers calculation of internal volume of the cabinet compartment based on the input data for the cabinet dimensions. The calculated volume is used in the simulation of the contribution to the cabinet loads from door openings.

Normally, the compressor will be located in a space at the near, bottom of the cabinet, where it is cooled by air blown over the condenser or by natural convection. This space requirement will reduce the storage volume of the cabinet located above, and will also affect the net external surface area available for heat exchange with the room.

3) Freezer and Fresh Food Cabinets;

The wall and door thickness and also insulation resistively for each wall element and door are required to calculate the sum of thermal resistivities. The resistivity and thickness determine the net resistance of each cabinet element.

The specified thickness of wall containing a sandwich of a foam and vacuum insulation panel should be the total thickness (neglecting the thickness of the liner). When a composite insulation system is used, an average resistivity for the wall should be specified. The general case assumes a vacuum insulation panel located between inner and outer foam panels and surrounded foam along all four edges.

4) Air and Cabinet Temperature

The room air and cabinet temperatures establish the heat loads of each compartment on the refrigeration system. For DOE closed door test simulation a room air temperature of 32.2 C° is ordinary specified, along with a freezer temperature of -15 C° and fresh food cabinet temperature of 3.3 C°. Temperatures must also be specified for under cabinet (where the compressor is normally located) and for "air entering the condenser."

5) Door Opening Schedule

The schedule of door opening is defined here to establish the net sensible and latent heat inputs to the cabinet during the hour. The controlling parameters are, the room relative humidity, the number of times each door is opened during the hour, and the average duration of each opening.

Parameters controlling the sensible and latent loads are, room temperature, cabinet temperature, room relative humidity, number of openings/hour, average duration of each door opening, and type of defrosting (manual or automatic). The typical schedule for door openings might be;

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Commercial Fresh food door	Opening/hr. 5	
	Duration (sec)	20
Freezer door	Opening/hr. 1	
	Duration (sec)	15

6) Gasket Heat Leak

The gasket areas around the cabinet doors are sources of heat due to conduction loads from the room air along the cabinet and door flanges, and through the gasket itself. Correct estimates of the heat leaks must take into consideration the geometry and materials used in the wall panels and doors.

All gasket heat leaks are expressed in units of conductance per length of the gasket. The net leak is determined by the program, from the total door perimeter and from the outside-inside air temperature difference.

7) Others such as: defrost and control's energy use, electrical anti-sweat heat, refrigerant line anti-sweat heat, and penetration heat input.

Method of Heat Load Calculation by Ariston Home Appliance Manufacturing Company of Italy

In this method, the whole refrigerator circuit is designed in such manners to face the possible leakage deriving from working under stand by conditions, with an ambient temperature of 43 degree centigrade, granting at the same time the freezing at least 3 kg/24hrs. of water at temperature of 48 °C or 5 kg/24hrs of water at 32 °C.

Determination of total heat loads;

1) In conservation at 43 °C of outside temperature.
2) In freezing at 32 °C of outside temperature.
3) Measuring all the thermal loss surfaces and thickness thereof.

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4) Calculate the (t) relevant to the single surfaces at following conditions;

- 43 °C outside temperature, except 60 °C compressor shell area
- 55 °C Condenser side.
- 0 °C refrigerator medium temp.
- -23 °C freezer air temp.
- -26 °C evaporator temp.

1) Determination of thermal loss for following areas;

- Refrigerator door.
- Crisper support area.
- Crisper back area.
- Crisper side area.
- Compressor upper area.
- Refrigerator side areas.
- Drops retainer.
- Back panel rear areas.
- Refrigerator gasket.
- Freezer side areas.
- Freezer gasket.

1) Determination of thermal conductivity for following materials.

- Expanded polyurethane.
- Magnetic gasket

Note. In order to make calculation easier, select the average thickness of sloping surfaces, assuming that the whole insulation thickness is of one single material in polyurethane, expanded polystrol PVC.

The total thermal loss in Kcal/hr. are those necessary to face all dispersions at 43 °C. Then, the heat in Kcal/hr. obtained at temperature of 32 °C are to be

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found and must be then added to those necessary to freeze 3 kg of water in 24 hr. In order to obtain functionality relation of the compressor at 43°C, we divide total thermal loss at 32 C° by total thermal loss at 43 C° ambient temperature.

Method of Heat Leak Load Calculation Established by ASHRAE Standard

1) Heat gain by conduction, in Kcal/hr. Through;

- Refrigerator side areas.
- Refrigerator gaskets.
- Refrigerator door.
- Crisper side areas.
- Freezer side areas.
- Mullion area, positive to freezer compartment.
- Back panel

2) Determination of thermal conductivity of following materials;

- Cabinet carbon steel.
- Polyurithane of foam.
- Door and freezer gasket.
- Inner liner plastic
- Air, between mullion and evaporator.

3) The heat resistance of coefficient factor, with regard to average thickness of each substance.

4) Determination of product heat load as follows;

- Heat removed from products above freezing point in fresh food compartment.

Note: The amount of product weight kept in fresh food compartment depends upon. Internal volume and different products selected by the

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manufacturer.

- Heat removed from products from initial temperature to freezing point in Freezer compartment.
- Heat removed from freezing point to final temperature below freezing point in Freezer compartment.
- Heat removal to freeze products (latent heat), in freezer compartment.

Note: The amount of product weight kept in Freezer compartment depends upon. Internal volume and different products selected by the manufacturer.

5) Calculation of total heat gain through refrigerator, evaporator, and heat removal per hour form product.

Note: The amount of heat removal from product are in 24 hrs. daily, in order to obtain total heat removal per hour we divide it by desired Compressor operating time in 24 hr.

6) To determine the grand total of the heat load, we add ten percent of the total heat gain. This ten to twenty percent additional load is for door openings, infiltration, and wedge and edge thermal loss, depending type of refrigerator and freezer.

The theoretical performances can be compared to one of the following CFC/HCFC fluids: R12, R502 and R22. The calculations are best used as a means of finding trends in fluid performance. The cycle has not been designed to model experimental equipment in detail. Several factors, such as those from heat exchangers and compressor volumetric inefficiencies are not included in the theoretical cycle.

Definition of the Theoretical Cycle:
The calculations are based on a point cycle. The points are as follows
(1) Evaporator Inlet - Liquid/vapour flash

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(2) Evaporator Outlet - Saturated Vapour
(3) Compressor Inlet - Superheated Vapour
(4) Compressor Outlet - Compressed Vapour
(5) Condenser Inlet - Saturated Vapour
(6) Condenser Outlet - Saturated Liquid
(7) Expansion Device Inlet - Subcooled Liquid

INPUT FIELDS

Evaporator Temperature: defined as the average of the liquid/vapour flash temperature at the evaporator inlet and that of the saturated vapour at the evaporator outlet. The latter is taken to be the dew point temperature at the calculated evaporator pressure. Unlike pure refrigerants, for the R32/R125/R134a blends the inlet and outlet temperature will be different.

Condenser Temperature: defined as the average of the temperature of the saturated vapour at the condenser inlet and the temperature of the saturated liquid at the condenser outlet. They are taken to be the the dew and bubble point temperatures respectively at the condenser pressure.

Superheating: defined as the temperature difference between the superheated vapour at the compressor inlet and the saturated vapour at the evaporator outlet. It is assumed that the compression process begins under identical conditions to those at the compressor inlet i.e. the compressor inlet conditions are the same as the suction conditions.

Sub-cooling: defined as the temperature difference between the saturated liquid at the condenser outlet and that of the sub-cooled liquid at the expansion device inlet.

Efficiency: An isentropic compression process is used for the theoretical cycle calculations. The isentropic efficiency is the value. relative to a theoretical maximum of 100%, of the efficiency with which the compressor can isentropically compress the superheated vapour from the suction pressure up to a pressure equivalent to the condenser pressure. It

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scales directly with the required compressor power.

The Constraint: Cooling Duty or Volumetric Flowrate:
In order to compare the calculations of several refrigerants on the same basis there is an option to constrain either the cooling duty or the volumetric flowrate of the superheated vapour prior to compression (i.e. the compressor inlet).

Cooling Duty: the required cooling capacity of the system. In this program, it is defined as the cooling that occurs from directly after the expansion device to the evaporator outlet i.e. the saturated vapour condition.

Volumetric Flowrate: defined for the superheated vapour immediately prior to the compression process (i.e.at the compressor inlet point).

DEFINITION OF CALCULATED FIELDS

Pressure: the pressure for which the average of the caculated evaporator inlet and outlet temperatures give the input evaporator temperature.

Condenser Pressure: the pressure for which the average of the calculated condenser inlet (dew point) and outlet (bubble point) temperatures give the input condenser temperature.

Coefficient of Performance: the ratio of the refrigeration effect to the heat of compression. The refrigeration effect is defined in two ways, as the difference between the evaporator inlet condition (expansion valve outlet) and either the evaporator outlet condition (exclusive of superheating), or the compressor inlet condition (inclusive of superheating). The heat of compression is defined as the enthalpy rise of the vapour as a result of the compression process.

EER - Energy Ratio: the ratio of the gross capacity (see below) in

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Btu/hr to the compressor power in watts. The EER has been defined in this way for all cycle calculations, including those in SI and METRIC units.

Cooling Duty: same definition as given in input fields.

Gross Capacity: The calculated gross cooling capacity of the system. It is defined as the cooling that occurs from directly after the expansion device to the compressor inlet i.e.. superheated vapour.

Compressor Power: The heat (enthalpy) required from the compressor.

Mass Flow rate: The refrigerant mass flow rate required around the system to meet the input constraint value at the input conditions.

Suction Line Temperature: The temperature of the superheated vapour at the compressor inlet point.

Discharge Temperature: The temperature of the compressed vapour at the compressor outlet, which in this cycle is also taken as the point at the end of the compression process.

Temperature Glide in the Evaporator: The difference between the evaporator inlet and outlet temperatures.

Temperature Glide in the Condenser: The difference between the condenser inlet and outlet temperatures.

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2- Component Selection

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.

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

Condenser & Evaporator

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

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

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

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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 seieve (by weight) in comparison with conventional types.

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Saturation Properties Comparison

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

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12- ***Testing Prototypes***

Testing prototype are the main objective of the project to assure the achievement of project to select proper components and optimum use of energy to reduce the emission of CO_2 indirectly by reducing energy consumption.

Testing prototypes consist of following stages which have been performed for each prototype. The test result sheets for each prototype are attached to this report.

Corrective action to adjust the fitness of components to refrigeration system were given to the counterparts to continue this program and practice making prototypes for all models produced by the counterparts.

Testing Prototypes

Step I

Testing Previously optimized
R12 Model

Step II
Hot Chamber Preparation
Step III

Loading Test Package, "M" Package
Meat, Water, Etc.

Step IV

Mounting Sensors

Step V

Ambiant Temperature Condition

- Tropical 43 C
- Sub-Tropical 38 C

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- Normal 32 C
- Sub – Normal 28 C
- Cold Condition 18 C

Relative Humidity 60% to 70%

Prototype Test Procedure

- Performing R12 Refrigeration System Optimization Test
- Hot Chamber Test Criteria
- Ambient Test Condition
- Different type of test methods
    - Operational Test
    - Performance Test
    - Energy Consumption
    - Ice Making Test
    - Humidity Test
    -
- Test Process
    - Pull Down
    - Continuous Run
    - Cyclic Run
    - Period of each test phase
- Test Results Data Collection
- Test Results Analysis

Trial Production

- Batch Production
- Customer Data System Feed Back
- Prototype Improvement
- Problem Solving
- Mass production

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Dimensional Schematic Products As presented by the counterparts.

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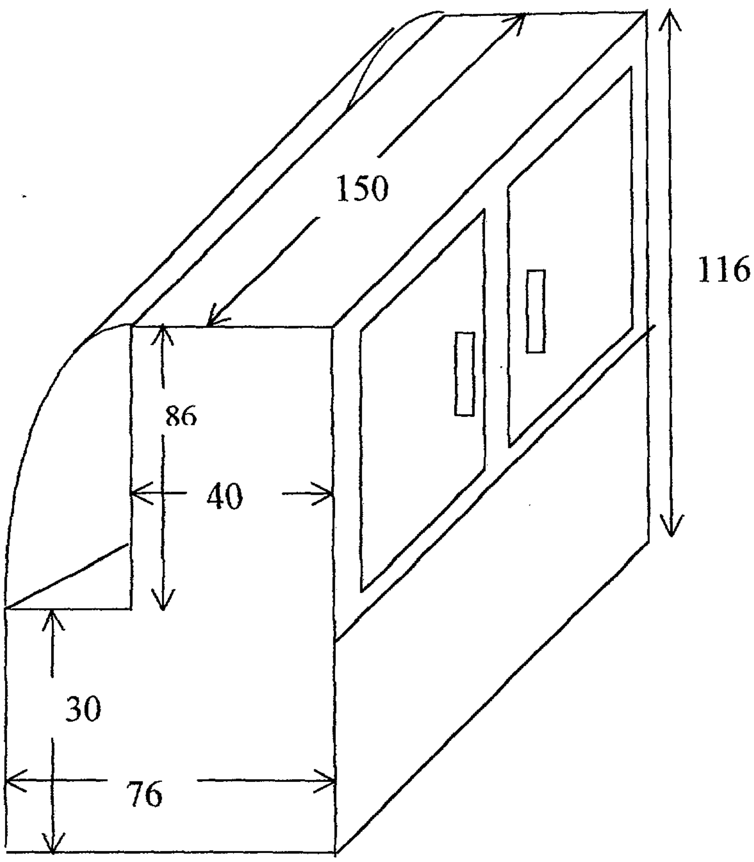
Vegetable Show Case
Model AS 150 Veg.



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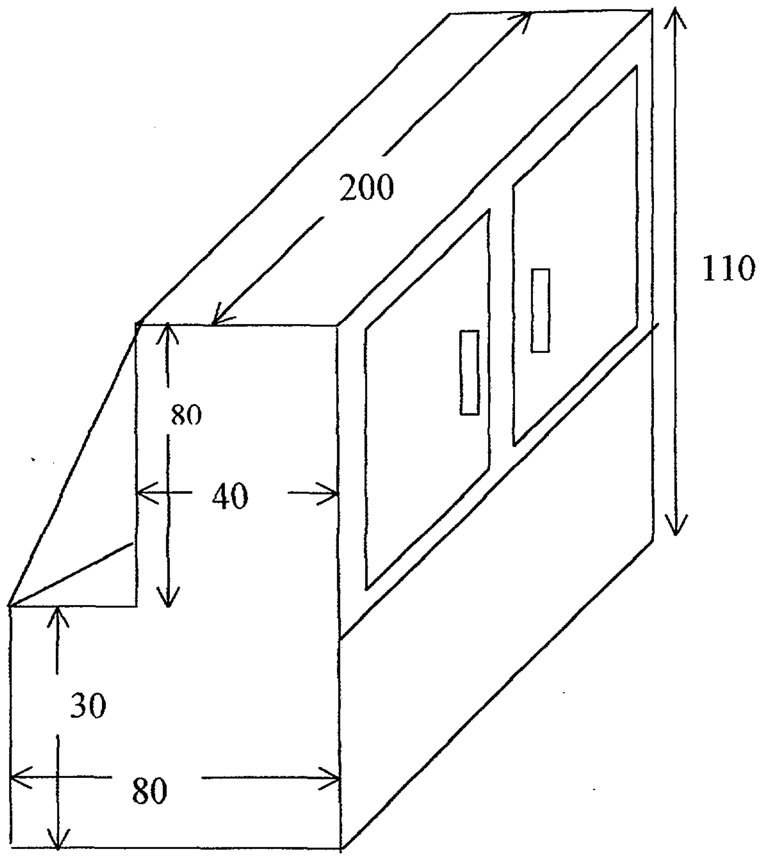
Engineering Enterprise

Dairy Show Case
Model SAC- 200D



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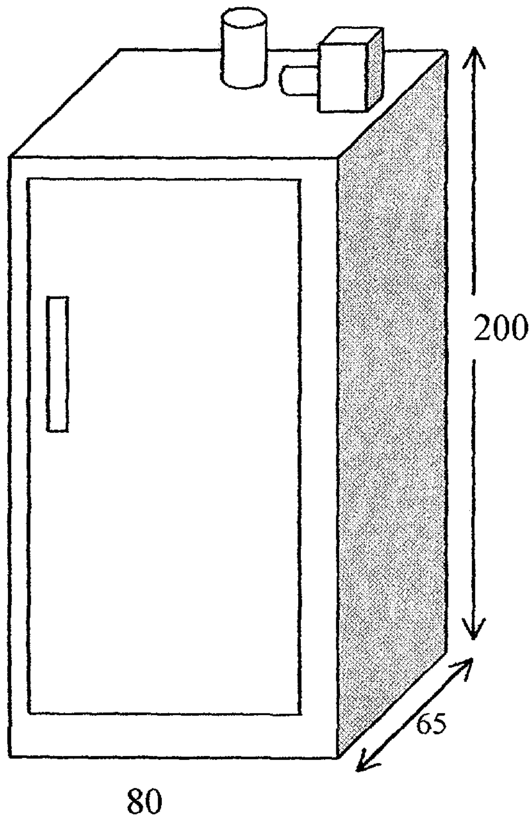
Frigo Alaska Workshop



Up Right Refrigerator
Model Alaska UPR-80

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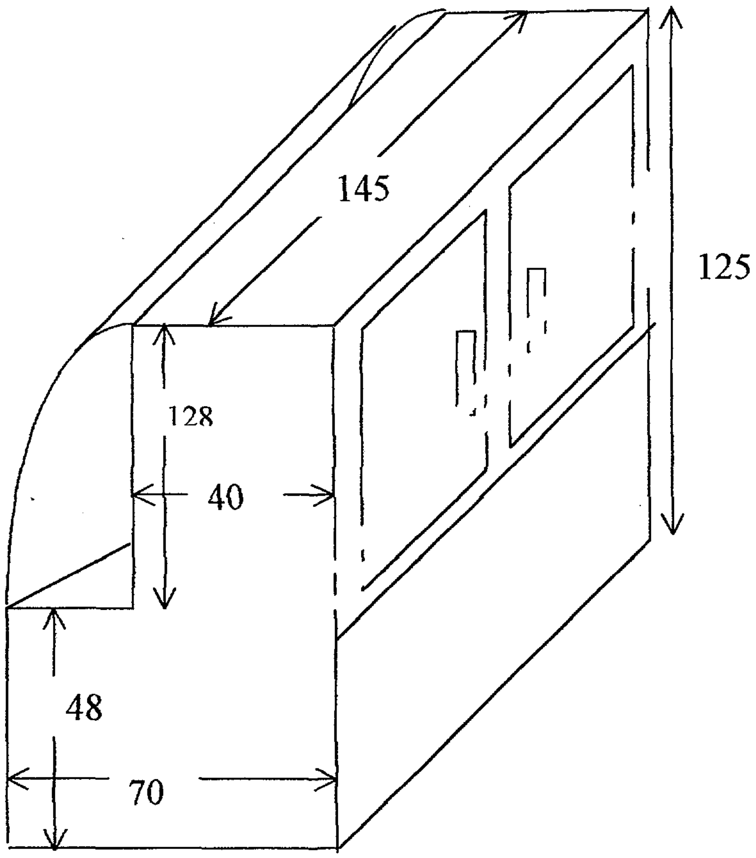
Engineering Enterprise

Vegetable Show Case
Model Eng.145RV
Adam Refrigerator Company



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Development of Prototypes.

We have planed to train the company's technical staff in two phases, at two sessions we gave them mainly general information about the Ozone, Montreal Protocol, and an introduction to safe use of R134a Refrigerant.

The topics that could be considered as remarkable issues of our taing program, could be summarized as follows.

Ozone

- Depletion, Its Causes And Results
- Cause & effect of Ozone Depletion
- Cause and Effect of Global Warming

Montreal Protocol

Ozone Depletion Substances

Ozone Friendly Alternatives

R134a Refrigerant

- Physical Properties
- Chemical Formula
- R134a Hazards
- Health & Safety
- R134a Application
- Main Agenda in using R134a
    - Lubrication
    - Vacuum

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- Leak
- Refrigerant Charge
- Dehydration
  (moisture)
- Component Change

Refrigeration Concept

- Review of Basic Refrigeration Principles
- Pressure Temperature Relationship
- Review of the Major Components
  - Compressor
  - Condenser
  - Expansion Valve
  - Capillary Tube
  - Evaporator
  - Filter Drier
  - Liquid Receiver

Cause of Leakage

Recovery, Recycling, Reclaiming

At the second phase of training which will be occurred before testing prototypes, and preparing our draft final report following subjects will be trained to the trainees.

Safe Handling & Storage of Compressed Gases

Model Design concept

- New Model Refrigerator
- Minor Changes to the existing Mode;
- Modification to the model for improvement

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- Conversion of model to fulfill new criteria

Refrigeration Load Calculation

- Dimensional Control
- New specification
- New Insulation
- Cooling capacity
- Compressor Change

Refrigeration System Component Selection

- Compressor
- Condenser
- Evaporator
- Capillary Tube
- Filter Drier
- Thermostat
- Refrigerant Charge

Refrigeration System Optimization Plan

- Compressor
- Energy Consummation
- Condenser
- Evaporator
- Capillary Tube
- Filter Drier
- Thermostat Adjustment
- Refrigerant Charge

Making Prototype

- Model Selection
- Refrigeration System Type

- Refrigeration System Components
- Refrigeration Load Calculation
- Compressor
- Refrigerant Type
- Electrical System and Accessories
- Environment Test Condition
    - ✓ CECOMAF Standard
    - ✓ ASHRAE Standard
    - ✓ System Conversion Factors
    - ✓ Thermostat Adjustment
    - ✓ Methods of Refrigerant Charges

Prototype Test Procedure

- Performing R12 Refrigeration System Optimization Test
- Hot Chamber Test Criteria
- Ambient Test Condition
- Prototype Product Loading
- Different type of test methods
    - ✓ Operational Test
    - ✓ Performance Test
    - ✓ Energy Consumption
    - ✓ Ice Making Test
    - ✓ Humidity Test
- Test Process
- Test Results Data Collection
- Test Results Analysis

Trial Production

- Batch Production
- Customer Data System Feed Back
- Prototype Improvement

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➢ Problem Solving

Mass production

Making Prototype

In order to Make prototypes we should take following steps.

a) Model Selection

b) Refrigeration System Type

- Defrost
- No-frost

c) Refrigeration System Components Definition

- Condenser
    1) Wire and Tube
    2) Tube on Plate
    3) Tube inserted Plate
    4) Tube inserted Fin
    5) Tube inserted Body

- Capillary Tube Function
    1. Permanently Open
    2. Flow depend on pressure drop across its length and condition of liquid entering it
    3. Capacity depends on Flow
    4. Stabilize Pressure
    5. Reduce Pressure
    6. Increase Velocity

- Capillary Tube Definition
    1. Tube Length

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2. Tube Inner Diameter
3. Tube Material

- Thermostatic Expansion Valve Function

  Regulate flow in response to amount of liquid required to satisfy load condition

- Thermostatic Expansion Valve type

  1. Internal Equalizer
  2. External equalizer

- Filter Drier

  1. Weight
  2. Material
  3. Size & Type

- Evaporator

  1) Wire and Tube
  2) Tube on Plate
  3) Roll Bond
  4) Tube inserted Fin
  5) Tube inserted Body

- Compressor Cooling System

  Static
  Oil
  Fan

- Compressor Pressure System

  LBP
  HBP

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MBP

- Compressor Type

Hermetic
Semi-Hermetic
Open

- Compressor refrigerant Type

R12
R134a
Isobutene
Blend

Compressor Electrical System and Accessories

Capacitor Type
Starting Relay
Voltage
Ampere
Wiring System

- Compressor Mounting Pad

Refrigerant Flow Direction
Top Mounting Pad
Bottom Mounting Pad

- Compressor Capacity

Watt
Kcal
BTU

- Compressor Test Condition

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CECOMAF Standards

- Evaporating Temp. – 25 C
- Condensing Temp. 55 C
- Ambient Temp. 32 C
- Suction Gas Temp. 32 C
- Liquid Temp. 55 C
- Voltage/Hertz 220/50Hz

Heat Output = Capacity + Watt Consumption

ASHRAE STANDARD

- Evaporating Temp. – 23.3 C
- Condensing Temp. 55 C
- Ambient Temp. 32 C
- Suction Gas Temp. 32 C
- Liquid Temp. 32 C
- Voltage/Hertz 220/50Hz
- Heat Output = Capacity + Watt Consumption

Conversion of Capacity From CECOMAF to ASHRAE Standard

R134a Multiply by 1.231
R22 Multiply by 1.097
R404 Multiply by 1.183

1 Watt = 0.86 Kcal/H
1Watt = 3.41 BTU/H

1 Kcal = 1/0162 Watt
1 BTU = 0.293 Watt

Compressor Capacity Relation to Different Evaporating Temp.

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Thermostat

Thermostat Adjustment

Cut In Time –5 to –15 C

Thermostat Setting
- Minimum
- Middle
- Maximum

Cut Out Time –15 to –25 C

Thermostat Setting
- Minimum
- Middle
- Maximum

Thermostat Working Temperature Range –5 to -25

New Refrigerant Operating Behavior

R12
R134a
R600 Isobutene
Blend, Butane & Propane

Refrigerant Charging Method

Cylinder (Bottle)
Portable Charger
Mass Production Evacuation and Charging machine

Charging Amount

Experimental, Trial and Error
Calculation Basis

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Comparison with other Refrigerant

Testing Prototypes

Step I

Testing Previously optimized
R12 Model

Step II
Hot Chamber Preparation
Step III

Loading Test Package, "M" Package
Meat, Water, Etc.

Step IV

Mounting Sensors

Step V

Ambiant Temperature Condition

- Tropical 43 C
- Sub-Tropical 38 C
- Normal 32 C
- Sub – Normal 28 C
- Cold Condition 18 C

Relative Humidity 60% to 70%

Prototype Test Procedure

- Performing R12 Refrigeration System Optimization Test
- Hot Chamber Test Criteria
- Ambient Test Condition

- Different type of test methods
  - ✓ Operational Test
  - ✓ Performance Test
  - ✓ Energy Consumption
  - ✓ Ice Making Test
  - ✓ Humidity Test
  - ✓

- Test Process
  - ✓ Pull Down
  - ✓ Continuous Run
  - ✓ Cyclic Run
  - ✓ Period of each test phase

- Test Results Data Collection
- Test Results Analysis

Trial Production

- Batch Production
- Customer Data System Feed Back
- Prototype Improvement
- Problem Solving

Mass production

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Al- Asria

Prototype Technical Specification	
Description	Specification
Company name	Al- Asria
Product Type	Vegetable Show case
Product model	None
Product Application	Fresh Vegetables
Ambient Operating Temperature	32 C
Climatic Condition	Standard "Normal"
Overall Dimension WxLxH "Cm"	116x76x150
Internal Volume "Liter"	700
Refrigerator Inside Temp.	5 C
Evaporating temperature	- 10 c
Insulation Type	Polystyrene
Insulation Thickness	8 Cm
Refrigerant type	R12
Refrigerant Weight	600 Grams
Compressor type, and model	Hermetic, Danfoss SC12B
Compressor Cooling Capacity	400 watts
Condenser Type, and Size	Fan Cooled Coil,
Condenser Material	Copper
Evaporator type	Copper Tube and Aluminum Fins
Evaporator Size	12.5t Mt. Length, 12 mm Diameter
Drier Type	Danfoss
Drier weight	30 Grams
Capillary Tube Size	Copper, 275 Cm, and 0.42 mm Dim
Double Glass Space	1.5 Cm
Glass Thickness	8 mm
Number or Doors	2x Steel doors

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SAC for Refrigeration

Prototype Technical Specification	
Description	Specification
Company name	SAC for Refrigeration
Product Type	Dairy Show Case
Product model	None
Product Application	Dairy
Ambient Operating Temperature	32 C
Climatic Condition	Standard "Normal"
Overall Dimension WxLxH "Cm"	110x80x200
Internal Volume "Liter"	950
Refrigerator Inside Temp.	5 C
Evaporating temperature	- 10 c
Insulation Type	Polystyrene
Insulation Thickness	5 Cm
Refrigerant type	R12
Refrigerant Weight	Not known
Compressor type, and model	Hermetic, Aspera 618-8277 BAOZ
Compressor Cooling Capacity	500 watts
Condenser Type, and Size	Fan Cooled Coil,
Condenser Material	Copper
Evaporator type	Copper Tube and Aluminum Fins
Evaporator Size	27 Mt. Length, 3/8" Diameter
Drier Type	Danfoss
Drier weight	50 Grams
Capillary Tube Size	Copper, 2.75 Cm, and 0.42 mm Dim
Double Glass Space	Triple 15 mm
Glass Thickness	8 mm
Number or Doors	2 Door

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Frigo Khankhan

Prototype Technical Specification	
Description	Specification
Company name	Frigo Khankhan
Product Type	Water Cooler
Product model	FWC80
Product Application	Drinking Water
Ambient Operating Temperature	32 C
Climatic Condition	Standard "Normal"
Overall Dimension WxLxH "Cm"	75x150x180
Internal Volume "Liter"	N/A
Water outlet Temp.	10 C
Evaporating temperature	- 10 c
Insulation Type	PU Foam
Insulation Thickness	7 Cm
Refrigerant type	R12
Refrigerant Weight	700 Grams
Compressor type, and model	Hermetic, Danfoss SC18B
Compressor Cooling Capacity	680 watts
Condenser Type, and Size	Fan Cooled Coil,
Condenser Material	Copper
Evaporator type	Copper Tube and Aluminum Fins
Evaporator Size	20 Mt. Length, 5/8" Diameter
Drier Type	Danfoss O23U4036 DN052
Drier weight	32 Grams
Capillary Tube Size	Copper, 400 Cm, and 0.64 mm Dim
Double Glass Space	N/A
Glass Thickness	N/A
Number or Doors	N/A

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Frigo Alaska

Prototype Technical Specification	
Description	Specification
Company name	Frigo Alaska
Product Type	Upright Refrigerator
Product model	Alaska UPR-80
Product Application	Meat Storage
Ambient Operating Temperature	32 C
Climatic Condition	Standard "Normal"
Overall Dimension WxLxH "Cm"	80x65x200
Internal Volume "Liter"	600
Refrigerator Inside Temp.	4 C
Evaporating temperature	- 10 c
Insulation Type	Polystyrene
Insulation Thickness	5 Cm
Refrigerant type	R12
Refrigerant Weight	700 Grams
Compressor type, and model	Hermetic, ASPERA E5187A
Compressor Cooling Capacity	600 watts
Condenser Type, and Size	Fan Cooled Coil, 2 Rows by 9 Lines
Condenser Material	Copper
Evaporator type	Copper Tube and Aluminum Fins
Evaporator Size	12 Mt. Length, 5/8" Diameter
Drier Type	FD-032 ¼ "
Drier weight	30 Grams
Capillary Tube Size	Copper, 200 Cm, and 0.48 mm Dim
Double Glass Space	N/A
Glass Thickness	N/A
Number or Doors	N/A

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Engineering Enterprise

Prototype Technical Specification	
Description	Specification
Company name	Engineering Enterprise
Product Type	Vegetable Show Case Refrigerator
Product model	Eng. 145 RV
Product Application	Vegetabe
Ambient Operating Temperature	32 C
Climatic Condition	Standard "Normal"
Overall Dimension WxLxH "Cm"	145x70x125
Internal Volume "Liter"	500
Refrigerator Inside Temp.	5 C
Evaporating temperature	- 10 c
Insulation Type	Polystyrene
Insulation Thickness	10 Cm
Refrigerant type	R12
Refrigerant Weight	700 Grams
Compressor type, and model	Hermetic, Danfoss SC18B
Compressor Cooling Capacity	715 watts
Condenser Type, and Size	Fan Cooled Coil, 2 Rows by 9 Lines
Condenser Material	Copper
Evaporator type	Copper Tube and Aluminum Fins
Evaporator Size	14 Mt. Length, ½ " Diameter
Drier Type	Danfoss
Drier weight	30 Grams
Capillary Tube Size	Copper, 300 Cm, and ¼ " Dim
Double Glass Space	N/A
Glass Thickness	8 mm
Number of Doors	2x Steel doors

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Adam Refrigerator Company

Prototype Technical Specification	
Description	Specification
Company name	Adam Refrigerator Company
Product Type	Dairy Show Case
Product model	CDR 150
Product Application	Dairy
Ambient Operating Temperature	32 C
Climatic Condition	Standard "Normal"
Overall Dimension WxLxH "Cm"	150x70x110
Internal Volume "Liter"	500
Refrigerator Inside Temp.	5 C
Evaporating temperature	- 10 c
Insulation Type	Polystyrene
Insulation Thickness	6 Cm
Refrigerant type	R12
Refrigerant Weight	750 Grams
Compressor type, and model	Hermetic, Aspera
Compressor Cooling Capacity	715 watts
Condenser Type, and Size	Fan Cooled Coil, 2 Rows by 9 Lines
Condenser Material	Copper
Evaporator type	Copper Tube and Aluminum Fins
Evaporator Size	14 Mt. Length, ½ " Diameter
Drier Type	Danfoss
Drier weight	30 Grams
Capillary Tube Size	Copper, 300 Cm, and 0.50 mm Dim
Double Glass Space	N/A
Glass Thickness	8 mm
Number of Doors	2x Steel doors