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AZMAYESH INDUSTRIAL FACTORIES CO.

PROJECT NO. MP/IRA/94/403

UNIDO,s CONTRACT NO. 94/097

FINAL REPORT

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EDITED AND APPROVED BY: UNIDO

September 1995

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AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER I

INTRODUCTION

DATE: 27 August 1995

INTRODUCTION

We are pleased to forward you our Final report regarding the execution of contract No. 94/097 which has been nominated as the first phase of CFC Phase Out project in AZMAYESH Co., as a part of project No. MP/IRA/94/403 in Iran.

AZMAYESH Co., under supreme supervision of UNIDO and UNDP in Tehran began the execution of this contract on first of Nov. 1994. Nevertheless we have been involved in this project directly or indirectly since 1992 by using reduced CFC gas as blowing agent in our insulation material, also we were the first refrigerator manufacture in Iran, that signed a contract with LIEBHERR of Germany to manufacture, no frost refrigerators and freezers, using Ozone friendly HFC R134a refrigerant.

AZMAYESH Co.'s main consideration is to achieve this programme timely and in the best and fastest possible way. As a leading manufacture in Iran we are proud that we could conduct the first international symposium of application of Ozone Friendly Gases in Iran, with collaboration of some German manufacturers such as BAYER and LEIBHERR, in October 1994. In this symposium more than 150 experts from Iranian local manufacturers as well as Iran Environmental Department and some universities were taking part.

This report contains following subjects.

1 - Project back ground in AZMAYESH Co.;
2 - Synopsis;
3 - Activities;
4 - Tasks
5 - Prototypes evaluation and analysis;
6 - Conclusion;
7 - Recommendations;
8 - Bibliography and References;
9 - Attachments;

PROJECT BACKGROUND IN AZMAYESH CO.

AZMAYESH Industrial Factories Co. As a leading home appliance manufacturer in Iran was established in 1959. the main activities of AZMAYESH Co.. In Marvdasht plant is producing eight models of refrigerators and freezers. as well as washing machine and vacuum cleaner. The older factory in located near Tehran and produces convector heaters and water coolers as well as water heaters.

The total production rate of refrigerators and freezers are estimated to be more than 250.000 units per year at maximum capacity. More than 1200 people are working in Marvdasht plant and 600 production personnel are working in refrigerator production department. Laboratory department is taking care of testing of performance criteria of our refrigerators and freezers. as well as material acceptance tests.

The total annual ODP consumption rate. are estimated 159 MT (33 MT of CFC-12 and 126 MT of CFC-11). 3 MT of CFC-12 are considered for our service stations. Approximately more than 2,000,000 refrigerator and freezer units have been manufactured by AZMAYESH Co., and are still in service in Iran. The average service lives of our refrigerator units are 15 years. More than 180 authorized service agents are repairing our refrigerator units and give services to our customers in Iran. Refrigerator components such as Compressor Unit. Thermostat and driers are imported.

The existing high pressure foaming machines are three. one is used for refrigerators and the other for freezers. the smaller one is used for doors. The wet parts of our foaming machines are made of ELASTOGRAN and dry parts are made of PERROS. More than eighty sets of vacuum pumps are LEYBOLD model D2A.
Our charging equipment and leak detectors are old and should be replaced with new equipments.

AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER II

SYNOPSIS

DATE: 27 August 1995

SYNOPSIS

The project No. MP/IRA/94/403 has been nominated to Islamic Republic of Iran for the Multilateral Fund for the implementation of The Montreal Protocol Financing.

AZMAYESH Industrial Factories Company, under UNIDO's contract No. 94/097 has executed the design calculation and drafting for model redefinition prototyping, testing prototypes for functionality and performance of five models of refrigerators and ref.freezers; i.e., to redesign the cooling units of all models so that they could run on the new ozone friendly refrigerant R134a instead of the ODP active CFC-12.

Under this contract AZMAYESH Co. has prepared a study of following subjects.

A) Dimensional specifications;
Type and insulation thickness;
Refrigerator unit component details;
Working performance;
Energy consumption;

B) Selection of HFC 134a compatible component;
C) Redesigning of the complete refrigeration circuit;
D) Specifying necessary changes in the refrigeration system;
E) Preparation of trial equipment;
F) Testing of prototypes for functionality and performance;
G) Evaluation of test results;

Two progress reports were prepared in order to comply with the contract's requirements. the reports discuss following subjects:

1- First Progress Report

1 - 1 Method of Refrigeration Load Calculation.
1 - 2 Method of Product Load Calculation.
1 - 3 Refrigeration System Condition
1 - 4 Equipment Selection
1 - 5 Refrigeration Unit Governing Relations and Equations.
1 - 6 Refrigerator Model AR06 Load Calculation and Equipment Selection.
1 - 7 Refrigerator Model AR08 Load Calculation and Equipment Selection.
1 - 8 Refrigerator Model AR10 Load Calculation and Equipment Selection.
1 - 9 Refrigerator Model AR12 Load Calculation and Equipment Selection.
1 - 10 Refrigerator Model ARF2 Load Calculation and Equipment Selection.

2 - Second Progress Report

2 - 1 Products Specifications.
2 - 2 Working Performance Characteristics.
2 - 3 Determination of Constant " C "
2 - 4 Selection of R134a Compatible Components.
2 - 5 Evaluation of Prototypes.
2 - 6 Temperature Test Procedure.
2 - 7 Energy Consumption.
2 - 8 Optimization Method
2 - 9 Preperation of Trial Equipment.

AZMAYESH INDUSTRIAL FACTORIES COMPANY

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CHAPTER III

ACTIVITIES

DATE: 27 August 1995

ACTIVITIES

Following activities were accomplished during execution of the contract since Nov. 1994 as well as other activities regarding project No. MP/IRA/94/403.

1 - Corresponding with UNIDO in Vienna and UNDP in Tehran concerning execution of the contract with respect to the contract requirements.

2 - Coordination with Marvdasht Plant in order to identify models, which are going to be modified and collect necessary information in this regard.

3 - Deliberation of required equipments for modifying the first prototype in Marvdasht plant.

4 - Corresponding with UNIDO and UNDP office in Tehran in order to give them. the requested information regarding number of jigs and fixtures existed in Marvdasht plant. for the purpose of accomplishing required modifications.

5 - Preparing Marvdasht plant's layout plan for the purpose of preparing Term of Reference of modification and purchasing foaming machines.

6 - Corresponding with UNDP office in Tehran, regarding suppling necessary equipments such as vacuum pumps and a leak detector and also refrigerant chargers. required for execution of the contract.

7 - Making three more prototypes (AR08, AR10 & AR12) in our service center in Tehran as well as twenty prototypes made in Marvdasht plant, for the purpose of research and development.

8 - Shipping one of prototype Model AR08 to dkk- FORON research center in Germany with close cooperation and coordination with UNDP office in Tehran and

UNIDO, in order to test the functionality and performance of the prototype.

9 - Sending two prototypes Model AR12 and AR10 to Sharif Industrial University of Tehran's research center, to check the performance of each prototype.

10 - Review and study of performance characteristics and specifications of more than thirty four-different kinds of compressors from different manufacturers. such as DANFOSS. ZANUSSI. NECCHI. GOLDSTAR. MATSUSHITA. ASPERA & TECOMSEH. In order to select the most suitable compressor fitted to our refrigeration system.table one of the second progress report shows the model and type of each compressor.

11 - Modifying water drain tray under evaporator compartment. in order to keep evaporator temperature constant and steady.

12 - Determination of a suitable amount of R134a refrigerant charge for each model.

13 - Determination of correct length of capillary tube.

14 - Selecting Drier type XH-9 and XH-7 which have the higher potential of absorbing humidity in a refrigeration cycle.

15 - Ordering 1500 units of R134a compressors. as well as driers and R134a refrigerant for production of 1500 refrigerator units for field test programme.

16 - Designing new test sheet for recording prototype performance data.

17 - Preparing two progress reports as follows;

1 - Redesign. calculation and modification of models AR06. AR08. AR10. AR12 and ARF2.

2 - Component selection. prototype testing and evaluation of performance of five models.

18 - Coordinating and corresponding with Ministry of Commerce, Ministry of Foreign Affairs, Bureau of Customs, Bank Markazi of IR IRAN, in order to get Authorization for release of five sets of chargers and leak detectors, for ARJ, AZMAYESH, BAHMAN, IRAN POUYA and PARS, on behalf of UNIDO and UNDP.

19 - Coordinating and corresponding with ARJ, BAHMAN, IRAN POUYA and PARS APPLIANCES Co., in order to deliver four sets of charger and leak detector as well as spare parts. These equipments were purchased by UNIDO, from A'GRAMKOW, under Multilateral Fund Financing Programme, through project No. MP/IRA/94/403.

20 - Performing more than ten site surveys, in Marvdasht plant, in order to follow up all project activities in Marvdasht, and coordinate with authorities.

21 - Participating in an academic seminar and practical laboratory course of research and design of new refrigeration technology for phasing out CFC's and minimizing ODP impact. Held at dkk- FORON research center at Scharfenstein Germany on behalf of UNIDO, from 27th Feb. 1995 till 17th March 1995.

22- Visiting Liebherr and Foron Manufacturing facilities in Germany, in order to see their new technologies in this regard.

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CHAPTER IV

TASKS

DATE: 27 August 1995

TASKS

For the execution of the said contract, the following tasks have been accomplished.

1 - Preparation of the first progress report, including

1 - 1- Refrigeration Load Calculations:

In this section all necessary information has been gathered to calculate heat loads.

The following items have been considered to determine heat loads.

1 - 1 - 1 Heat gain by conduction through walls.
1 - 1 - 2 Determination of Coefficient of heat transmission.
1 - 1 - 3 Determination of temperature difference between Ambient and Freezer and Refrigerator Compartments.
1 - 1 - 4 Determination of thermal conductivity of, foam, carbon steel and ABS plastic.
1 - 1 - 5 Determination of product load calculations governing rules and equations.
1 - 1 - 6 Determination of product, latent heat, freezing point and specific heat.

1 - 2 Refrigeration System Condition:

The following subjects were considered to be discussed as important tasks in the first progress report. In this section all information, required for Determination of refrigeration system conditions, such as inlet and outlet temperature and pressure have been discussed.

1 - 2 - 1 Compressor working condition.

1 - 3 - 2 Condenser working condition.
1 - 2 - 3 Capillary tube working condition.
1 - 2 - 4 Evaporator working condition.
1 - 2 - 5 C.O.P.. Compressor coefficient of performance.

1 - 3 Equipment Selection:

In this section the method of refrigeration system components selection. has been discussed. The desired compressor operating time and also minor changes in the amount of refrigerant charge and possibility of increasing capillary tube were explained.

A comparison table of existing R12 and R134a compressors was prepared to show the differences of compressors cooling capacity.

1 - 4 Refrigeration Unit Governing Rules and Equations:

All governing rules and equations necessary to calculate and determine the capacities of refrigeration system were brought in this section.

1 - 5 In sections I through X. the methods of refrigeration load calculation and equipment selection for five Models of AR06. AR08. AR10. AR12 and ARF2 have been discussed.

ANALYSIS

The first progress report has been prepared mainly to discuss theorical issues of choosing new R134a refrigerant. In this report ASHRAE handbook of fundamentals of refrigeration was used to calculate heat load and etc.. nevertheless there are many other methods in the other references. which are similar. with a slight difference. We have to take into our consideration the point that since our Model Refrigerators are already existed and we do not have to design a new refrigerator unit. it is not necessary to consider all details for heat load calculations.

For example heat leaks through cabinet edges and door gasket and door openings could be neglected, because we already add ten percent of total heat loss to this figure.

For determination of product load calculation, there are two ideas in this regard;

a) To consider maximum product capacity of refrigerator and freezer units with respect to the actual internal volume of the unit. And calculate all heat gains from products either in refrigerator or freezer compartments.

b) To consider and calculate, the Kcal/hrs require to make least three Kg ice in the freezer compartment.

ASHRAE standard has selected the first method above, and we have chosen this method respectively.

2 - Second progress report

In order to prepare the second progress report the following tasks were achieved.

2 - 1 Making twenty-three prototypes, for the purpose of functionality and performance test run, as follow; .

2 -1-1 Model AR06	Four units
2 -1-2 Model AR08	Five units
2 -1-3 Model AR10	Five units
2 -1-4 Model AR12	Five units
2 -1-5 Model ARF2	Five units

2 - 2 Designing a new test sheet in accordance with ISO standard requirement, for the purpose of recording test data.

2 - 3 Preparing non CFC refrigeration trial production compressor selection form. for comparing different compressors technical specifications in comparison with our cooling capacity requirements.

2 - 4 Testing following compressor models on our prototypes:

2-4-1 ASPERA	MODEL. BP 1048 Z 22
2-4-2 ASPERA	MODEL, BP 1111 Z
2-4-3 ASPERA	MODEL. B 1116 Z
2-4-4 ASPERA	MODEL. B 1118 Z
2-4-5 GOLDSTAR	MODEL. NR 58 LAEG
2-4-6 GOLDSTAR	MODEL. NR 62 LAEG
2-4-7 GOLDSTAR	MODEL. V75 LAEG
2-4-8 DANFOSS	MODEL. FR 8.5 G
2-4-9 TECAMSEH	MODEL. AE 360 KS 561

2 - 5 Testing following R12 compressors to compare with R134a compressors:

2-5-1 ZANUSSI	MODEL, G45AW
2-5-2 MATSUSHITA	MODEL, FN51Q11G
2-5-3 MATSUSHITA	MODEL. FN77G18G

2 -6 Testing models AR12. ARF2. AR08. prototypes under 18. 32 and 43 degree centigrade ambient temperature test condition.

2 -7 Testing Models AR06 and AR10, prototypes under 43 degree centigrade ambient temperatures.

2 - 8 Testing four prototypes model AR12. under following conditions:

2 -8 -1 Under 18, 32 and 43 degree centigrade ambient temperature condition, with ten percent refrigerant charges reduced and the same capillary tube length as R12 system.

2 - 8 - 2 Under 43 degrees ambient temperature condition. with ten percent

increase in capillary tube length and the same refrigerant charge as R12 system.
2 - 8 - 3 Under 43 degree centigrade temperature conditions, with the same refrigerant charge and capillary tube length as R12 system.

2 - 9 Comparing R12 system performance with R134 system performance.

2 - 10 Preparing product specifications.

2 - 11 Preparing working performance characteristics.

2 - 12 Preparing method of determination of constant "C."

2 - 13 Selection of R134a compatible components.

2 - 14 Performing evaluation of prototypes' actual performance.

2 - 15 Preparing temperature test procedure.

2 - 16 Preparing method of determination of energy consumption.

2 - 17 Preparing method of refrigeration system optimization.

2 - 18 Preparation of trial test equipments.

2 - 19 Editing two-progress report for accuracy and completeness.

2 - 20 Reviewing all available documents regarding changing refrigerant R12 into R134a, such as technical specification of different refrigerators form other manufacturers.

2 - 21 Collecting all necessary information from different sources, such as the department of environmental of USA.

AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER V

PROTOTYPES EVALUATION AND ANALYSIS

DATE: 27 August 1995

PROTOTYPES EVALUATION AND 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 an existing in production refrigerators, 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 section 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, and 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.

In this chapter we are going to 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;

a) Cabinet height is measured from the bottom to top of the cabinet, not the floor.
b) Depth includes the cabinet door. This dimension measures the distance from the outside (front) surface of doors to the back of the cabinet
c) Width of the gasket and the door edge thickness. The effects of door thickness on the internal volume are taken into account.
d) 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 food 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 resistivity for each wall element and door are required to calculate the sum of thermal resistivities. The net resistance of each cabinet element is determined by the resistivity and thickness.

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) Mullion

The mullion is the wall between the fresh food and freezer sections of the refrigerator. Typically the resistivity of the mullion insulation is less than that of the foam walls since a removable insulation is often installed in this area. Yhe resistivity is normally half that of the walls.

5) 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."

6) 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;

Fresh food door	Opening/hr.	2.5
	Duration (sec)	20
Freezer door	Opening/hr	1
	Duration (sec)	15

7) 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 programme from the total door perimeter and from the outside-inside air temperature difference.

8) 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.
4) Calculate the (t) revelant to the single surfaces at following conditions; 43 C outside temperature, except 60 C compressor shell area and 55 C Condenser side.
   0 C refrigerator medium temp.
   - 23 C freezer air temp.
   - 26 C evaporator temp.
5) 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.

6) 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 found and must be then added to those necessary to freeze 3 kg of water in 24 hrs. 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 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 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 hrs.

6) To determine the grand total of the heat load, we add ten percent of the total heat gain. This ten percent additional load is for door openings, infiltrations, and wedge and edge thermal loss.

Conclusion

The three above calculation methods were reviewed and studied, due to the Azmayesh Prtotypes Natures and since our models have been already designed by SILTAL Co. of Italy, we preferred to choose ASHRAE's method of heat load calculation. Specially when our selected test conditions for our prototypes are ASHRAE standards.

Prototypes Performance Evaluations

1) With respect to the contract requirements, we made four prototype units for each model, for the purpose of functionality and performance tests of prototypes. Following prototypes were made and more than thirty performance and life tests were accomplished.

- Model AR06	Four units
- Model AR08	Five units
- Model AR10	Five units
- Model AR12	Five units
- Model ARF2	Four units

2) Testing more than nine different kinds of R134a compressor samples from different specifications and manufacturers, as follows:

- Aspera	Model, BP 1048 Z 22
- Aspera	Model, BP 1111 Z
- Aspera	Model, B 1116 Z
- Aspera	Model, B1118 Z
- Goldstar	Model, NR 58 LEAG
- Goldstar	Model, NR 62 LEAG
- Goldstar	Model, V75 LEAG
- Danfoss	Model, FR 8.5 G
- Tecamseh	Model, AE 360 KS 561

3) Planning for testing following R134a compressor samples, in addition to above-mentioned compressor samples.

- Zanussi	Model, GL40AA
- Zanussi	Model, GL45AA
- Zanussi	Model, GL50AA

- Zanussi	Model, GL60AA
- Zanussi	Model, GL80AA
- Matsushita	Model. S48C10KAX0
- Matsushita	Model. S48C13KAX5
- Matsushita	Model. QA57C13RAX5
- Matsushita	Model. QA77C18RAX5
- Matsushita	Model. QA91C20rAX
- Necchi	Model. ESC511
- Necchi	Model. ESC8H
- Necchi	Model. ESC9H

4) Selecting following R12 test samples to compare with R134a compressor performance test results.

- Zanussi	Model. G45Aw
- Matsushita	Model. FN51Q11G
- Matsushita	Model. FN77G18G

5) Following prototype samples were tested 18, 32, and 43 degree centigrade ambient temperature.

- AR12
- ARF2
- AR08

6) In order to optimize refrigerant charge weight and capillary tube length, prototype sample model AR12 was tested at following test conditions.

a) At 18, 32, and 43 C ambient temperature with 10 percent refrigerant charge reduced and the same capillary tube length as R12 refrigeration system.

b) At 43 C ambient temperature, with 10 percent increase in capillary tube length, and the same refrigerant charge weight as R12 refrigeration system.

c) At 43 C ambient temperature, with the same refrigerant charge and capillary tube as R12 refrigeration system.

7) Preparation of compressor comparison charts in order to compare different R134a compressor specifications in relation with our refrigerator and ref-freezers specifications.

8) Selecting the most suitable R134a compressor with respect to our cooling capacity requirements and COP of the compressor.

9) Analyzing R134a compressors power input. in order to determine minimum power consumption rates. with respect to our cooling capacity requirement.

10) Applying ISO 8187: 1991(E), first edition no. 1991-03-01, for testing our prototype samples.

Analysis

1) Table 1 through 4 compare the performance of R12 and R134a compressors for refrigerator and ref-freezers models. AR08, AR10, AR12, and ARF2. The main point for us to approve the R134a compressor performance is the freezer (evaporator) air temperature, in accordance with ISO 8187 the acceptable freezer air temperature for two star refrigerator is -12 C and for three star ref-freezer is -18 C or less. Please note that the freezer air temperatures for different models are as follows which are acceptable in accordance with ISO 8187.

- Model AR06 — Freezer Air Temp. **
- Model AR08 — Freezer Air Temp. = -20
- Model AR10 — Freezer Air Temp. = -20
- Model AR12 — Freezer Air Temp. = -20
- Model ARF2 — Freezer Air Temp. = -15

** The refrigeration system for refrigerator models AR06 and AR08 are the same.

2) Table 5 shows prototype model AR12 performance at different conditions as follows;

Mode(I): Test condition at 43 C ambient temp. with 10% decrease in refrigerant charge weight, without capillary tube length change.

Mode(II): Test condition at 43 ambient temp. with 10% decrease in refrigerant charge weight. and 10% increase in capillary tube length.

Mode(III): Test condition at 43 C ambient temp. with no change in refrigerant charge weight and capillary tube length.

R12 and R134a Refrigeratorand Ref-Freezer Performance Comparison Chart Model AR08		
Description	**R12 Model**	**R134 Model**
Compressor Model	Zanussi, G45AW	Aspera, BP1048Z22
Ambient Temperature	+ 43 C	+ 43 C
Refrigerant Charge	110 Gr.	100 Gr.
Air Freezer Mean Temp.	- 13 C	- 20 C
Refrigerator Mean Temp.	+ 5 C	+ 3 C
Crisper Mean Temp.	+ 10 C	+ 6 C
Compressor Shell Temp.	+ 65 C	+ 75
Condesor Inlet Temp.	+ 65 C	+ 65
Condenser Outlet Temp.	+ 51 C	+ 50
Suction Temp.	+ 45 C	+ 45
Compressor Running %	52 %	65 %
Cooling Capacity	108 Watts	108 Watts
Power Consumption Rate	1.3 Kw/24 Hrs.	1.25 Kw/24 Hrs.

Table (1)

R12 and R134a Refrigeratorand Ref-Freezer Performance Comparison Chart Model AR10		
Description	**R12 Model**	**R134a Model**
Compressor Model	Matsushita, FN51Q11G	Aspera, BP1111Z
Ambient Temperature	+ 43 C	+ 43 C
Refrigerant Charge	140 Gr.	125 Gr.
Air Freezer Mean Temp.	- 12 C	- 13 C
Refrigerator Mean Temp.	+ 2.5C	+ 6 C
Crisper Mean Temp.	+ 6 C	+ 7 C
Compressor Shell Temp.	+ 58 C	+ 86
Condesor Inlet Temp.	+ 48 C	+ 77
Condenser Outlet Temp.	+ 38 C	+ 50
Suction Temp.	+ 32 C	+ 45
Compressor Running %	35 %	56 %
Cooling Capacity	125 Watts	125 Watts
Power Consumption Rate	1.85Kw/24 Hrs.	1.9 Kw/24 Hrs.

Table (2)

R12 and R134a Refrigeratorand Ref-Freezer Performance Comparison Chart Model AR12		
Description	**R12 Model**	**R134a Model**
Compressor Model	Matsushita, FN51Q11G	Danfoss, FR8.5G
Ambient Temperature	+ 43 C	+ 43 C
Refrigerant Charge	150 Gr.	130 Gr
Air Freezer Mean Temp.	- 12 C	- 20 C
Refrigerator Mean Temp.	+ 5 C	+ 5 C
Crisper Mean Temp.	+ 7 C	+ 12 C
Compressor Shell Temp.	+ 64 C	+ 85
Condesor Inlet Temp.	+ 50 C	+ 72
Condenser Outlet Temp.	+ 40 C	+ 55
Suction Temp.	+ 33 C	+ 44
Compressor Running %	37 %	68 %
Cooling Capacity	158 Watts	158 Watts
Power Consumption Rate	2.25 Kw/24 Hrs.	2.10 Kw/24 Hrs.

Table (3)

R12 and R134a Refrigeratorand Ref-Freezer Performance Comparison Chart Model ARF2		
Description	**R12 Model**	**R134a Model**
Compressor Model	Matsushita.FN77G18	Aspera. B1118 Z
Ambient Temperature	+ 43 C	+ 43 C
Refrigerant Charge	220 Gr.	180 Gr.
Air Freezer Mean Temp.	- 24 C	- 15 C
Refrigerator Mean Temp.	+ 4.3 C	+ 2 C
Crisper Mean Temp.	+ 7 C	+ 7 C
Compressor Shell Temp.	+ 59 C	+ 85
Condesor Inlet Temp.	+ 55 C	+ 90
Condenser Outlet Temp.	+ 42 C	+ 50
Suction Temp.	+ 33 C	+ 45
Compressor Running %	53 %	74 %
Cooling Capacity	204 Watts	204 Watts
Power Consumption Rate	3 Kw/24 Hrs.	2.75 Kw/24 Hrs.

Table (4)

Refrigerator Model AR12, R134a Optimizing Test Results			
Description	**Mode I**	**Mode II**	**Mode III**
Ambient Temp.	43 C	43 C	43 C
Refrigerant Charge	150	135 Gr.	130 Gr.
Capillary Tube Length	No Increase	10% Increase	No Increase
Freezer air Temp.	- 15 C	- 24 C	-20 C
Refrigerator Air Temp.	+ 7 C	+ 6 C	+ 5 C
Crisper Temp.	+ 10 C	+ 13 C	+ 12 C
Compressor Shell	+ 80 C	+ 80 C	+ 85 C
Condenser Inlet Temp.	+ 70 C	+ 75 C	+ 72 C
Condenser Outlet Temp.	+ 50 C	+ 55 C	+ 55 C
Suction Temp.	+ 44 C	+ 48 C	+ 44 C
Compressor Running %	64 %	61 %	68 %
Condenser Change	No Change	No Change	No Change

Table (5)

AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER VI

CONCLUSION

DATE: 27 August 1995

Conclusion

With regard to the test results of different prototype performance tests, we found out that there is no need to change our capillary tube length and also condenser surfaces, we can produce the above five models of the refrigerator and ref-freezers by only decreasing 10% of refrigerant charge weight as of R12 refrigerant and in order to have better air temperature distribution in the fresh food compartment we have to modify our mullion design, which is located under the evaporator compartment in the shape of the water drain tray.

For five Prototypes samples the performance life test runs are being achieved since last three months, and we observed no major problem in this regard. We hope that we could continue these life tests for three more months. Meanwhile, our production for the field test and trial test of more than 1500 units from five models will start as soon as refrigerant charger from A'GRAMKOW will be installed and commissioned by A'GRAMKOW in mid September.

AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER VII

RECOMMENDATIONS

DATE: 27 August 1995

Recommendations

AZMAYESH Industrial Factories Co. Is proud that could achieve the execution of UNIDO's contract No. 94/097, timely and in a good manner. We will be glad if we could have the opportunity to give our experience to other manufacturers in Iran and abroad in this regard, because AZMAYESH Co. Was the first home appliance manufacturer in Iran, which could finish with this contract sooner, and could provide all contracts' requirements in accordance with UNIDO's plans and programmes.

1) During the time of contract, we found out that, there are many different methods of calculation for redefinition and redesign of the prototypes, that could be used in different manners, but through our experience and high production rate of refrigerator and ref-freezer in Marvdasht plant, we found out that most of these methods are suitable for designing new products, and do not fit our requirements. Therefore we decided to choose ASHRAE's method of heat load calculation and components selection, for following reasons;

- More reliable elements and parameters applied.
- Real figures and data used for determination of cooling capacity.
- More information, regarding type of materials and products are provided.
- There is a very accurate method of calculating heat gain by fresh food and frozen food in refrigerator and freezer compartments.
- All equations and rules regarding calculation of the evaporator, condenser and capillary tube are defined and stated clearly.
- All test conditions used by compressor manufacturers, are ASHRAE

standards, which it could be helpful during compressor section with regard to tests' requirements.

With respect to above listed reasons we recommend, that ASHRAE method of calculation for determination of heat load for redefinition of prototypes be used by other groups of the refrigerator manufacturer.

2) Since there are numerous kinks of R134a compressors in the market, and usually all compressor manufacturers believe that their design fit to the refrigerator manufacture's requirements, and it could not be proved unless performing condition tests at different ambient temperature, we recommend;

All redefined and redesigned refrigerator prototypes made by refrigerator manufacturers, be tested at least with three different R134a compressor samples, from different manufacturers. In order to find out the real capability of the new refrigeration system with new conditions.

3) Since redesigning, calculation, modification, and performance test of each prototype, needs a lot of activities and tasks to be performed and varieties of compressor test should be accomplished, at different ambient tests, therefore the time for executing the contract are not enough, we recommend;

The period of executing the contract should be increased, with respect to the number of prototypes and models to be redesigned and close coordination with contactor prior to signing the contract.

4) To get a better result from prototypes performance tests, and in order to get more test figures for the purpose of energy consumption and working performance, assessments we recommend;

At least one prototype from each model should be continuous run tested at 18, 32, and 43 degree centigrade ambient temperature.

5) Due to the time and man-hours required to execute such a contract, it seems that, the contract fee for these activities are not enough and should be reconsidered and evaluated again, because the sum of US $ 46.500 for redesigning, making, and testing five models including twenty prototypes, does not cover expenses spent, for accomplishment of contracts' requirements. We recommend:

A change to the contract is necessary, and the contract fee for redesigning, prototyping, testing, and modifying for each model should be increased as follows;

Model, Redesign, Prototype Testing, Contract Fee Change Recommendation		
Description	Contract Fee	Recommended Fee
Design, calculation, & draft per model	US $ 1.300	US $ 2.000
Prototyping, per model	US $ 1,000	US $ 3.000
Prototype testing, per model	US $ 1.000	US $ 2,000

AZMAYESH Industrial Factories Co. would like to give its sincere appreciation to those people, which helped us sincerely in execution of this contract.

We would like to give our special tanks to Dr.Malayeri, Mr. Nowotny from UNIDO, Mrs. Latrech UNIDO's contract officer, Mr. I. Banafsheh UNDP programme manager from UNDP office in Tehran, Ministry of Industry, and Department of Environmental, for their kind and keen cooperation and coordination with AZMAYESH Co., in this regard.

AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER VIII

BIBLIOGRAPHY AND REFERENCES

DATE: 27 August 1995

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9 - Carrier Refrigeration and air conditioning Handbook.

10 - Ariston's Co. Calculation of heat load balancing

11 - DuPont, HFC 134a properties, uses, storage, and handling.

12 - Suva, refrigerant HFC-134a, thermodynamic properties.

13 - Goldstar's reciprocating compressor division, R134a

14 - Electrolux. R134a refrigerant application guide lines

AZMAYESH INDUSTRIAL FACTORIES COMPANY

UNIDO'S CONTRACT NO. 94/097

CHAPTER IX

ATTACHMENTS

DATE: 27 August 1995

Attachments

1 - First progress report dated February 1995

2 - Second Progress Report date May 1995

3 - Ariston's Co. Calculation of heat load balancing

4 - DuPont, HFC 134a properties, uses, storage, and handling.

5 - Suva, refrigerant HFC-134a, thermodynamic properties.

6 - Goldstar's reciprocating compressor division, R134a

7 - Electrolux, R134a refrigerant application guide lines

CALCULATION OF BALANCING - REFRIGERATOR MODEL TMG 300

The whole refrigerating circuit is to be designed in such a way as to face the possible leakages deriving from working under stand-by conditions, with an ambient temperature of 43°C, according to ISO standards, granting at the same time the freezing of at least 3 Kg/24h at temperature of 48°C.

The design of refrigerating circuit foresees a quite considerable number of strictly connected variables, in which the quantity of refrigerating units necessary in both sections of the refrigerator is controlled by the thermostat placed in the lower area, inside which temperature changes with more frequency tha inside the freezer section. The evaporator of freezer section is to be powerful enough to face the possible leakages of chiller, heat box and refrigerator at a 43°C, but it should not keep the temperature above 0°C at an ambient temperature of 18°C during freezing phase.

The above mentioned variables are to be added to t', K KS and capillary's capacity factors, which will be calculated according to production experience. However, as the mathematical results are usually far from practice, it will be necessary to prepare more than one prototype to obtain satisfactory results.

A. DETERMINATION OF COMPRESSOR'S POWER

1) In conservation at 43°C of outside temperature
2) In freezing at 32°C of outside temperature

a) Measure all the thermal loss surfaces and thickness thereof

b) calculate the t° relevant to the single surfaces

43°C outside temperature
(except 58°C compressor area
55°C condenser side)

0°C refrigerator medium temperature
-23°C freezer air temperature
-26°C evaporator temperature

c) Apply the formula hereunder for each surface :

$$P = \frac{1}{S} \times K \times S \quad t^{\circ}$$

Whereby :

P = power in Kcal/h per each single surface

s = thickness in m. of the single surfaces

k = Kcal/h x m x °C - coefficient of transmission of insulating material adopted

$$k = Kcal. \frac{1}{h.m.c.}$$

h = hours

m = length in m. of test specimen

°C = temperature displacement between the two sides of test specimen s = surface in m2 of area to be considered

t° = temperature displacement between the two sides of dispersant surfaces

NOTE : in order to make calculation easier, select the average thickness of sloping surface, assuming that the whole insulation thickness is of one single material in polyurethane, expanded polystirol PVC.

K will be

Expanded polyurethane :	density 20 to 30 kg/m3 k=0,023 to 0,025 (with 50% R11)
Magnetic gasket :	ARISTON Type k=0,07
Expanded polystyrene :	Density 30 to 35 kg/m3 k=0,019 to 0,07

Chiller lower area :
$$\frac{1}{0{,}040} \times 0{,}027 \times (0{,}297 \times 0{,}547) \times 43 = 4{,}716 \text{ Kcal/h}$$

Compressor back area :
$$\frac{1}{0{,}055} \times 0{,}027 \times (0{,}235 \times 0{,}545) \times 60 = 3{,}773 \text{ Kcal/h}$$

Compressor upper area:
$$\frac{1}{0{,}052} \times 0{,}027 \times (0{,}160 \times 0{,}245) \times 60 \times 28 = 1{,}222 \text{ Kcal/h}$$

Chiller side area :
$$\frac{1}{0{,}041} \times 0{,}027 \times (0{,}308 \times 0{,}236) \times 2 \times 43 = 4{,}117 \text{ Kcal/h}$$

Refrigerator side area :
$$\frac{1}{0{,}042} \times 0{,}027 \times \left(\frac{0{,}460 \times 0{,}804}{2}\right) \times 2 \times 43 = 20{,}447 \text{ Kcal/h}$$

Freezer back area : $\frac{1}{0,035} \times 0,027 \times (0,49 \times 0,241) \times 81 = 3,690$ Kcal/h

Liner inlet area : $\frac{1}{0,035} \times 0,027 \times (1,4 \times 0,576)$ 43 = 26,750 Kcal/h

Gasket area: $\frac{1}{0,17} \times 0,027 \times 0,019 [(1,4+0,576) \times 2] (0,074 \times 0,358)$ 43 = 13,295 Kcal/h

TOTAL **105,764 Kcal/h**

These 105,764 Kcal/h. are those necessary to face all dispersions at 43°C. Now Kcal./h. obtained at a temperature of 32 °C are to be found and must be then added to those necessary to freeze 3 Kg.

Considering : 58°C compressor cell area
53°C condenser area

4,716	x	32/43	=	3,510	Kcal/h
3,773	x	58/60	=	3,648	Kcal/h
1,222	x	58/60	=	1,182	Kcal/h
4,117	x	32/43	=	3,064	Kcal/h
20,447	x	32/43	=	15,217	Kcal/h
0,120	x	32/43	=	0,090	Kcal/h
0,734	x	32/43	=	0,547	Kcal/h
1,510	x	32/43	=	1,124	Kcal/h
3,268	x	53/55	=	3,150	Kcal/h
1,634	x	53/55	=	1,575	Kcal/h
10,896	x	79/81	=	10,627	Kcal/h
0,569	x	53/55	=	0,549	Kcal/h
0,289	x	53/55	=	0,274	Kcal/h
1,199	x	32/43	=	0,893	Kcal/h
4,708	x	32/43	=	3,504	Kcal/h
2,827	x	32/43	=	2,104	Kcal/h
3,690	x	79/81	=	3,599	Kcal/h
26,750	x	32/43	=	19,907	Kcal/h
13,295	x	32/43	=	9,894	Kcal/h
			=	84,458	Kcal/h

Refrigerator side area : $\frac{1}{0{,}044} \times 0{,}027 \times \frac{(0{,}126 \times 0{,}36)}{2} \times 2 \times 43 = 0{,}120$ Kcal/h

Refrigerator side area : $\frac{1}{0{,}041} \times 0{,}027 \times (0{,}332 \times 0{,}039) \times 2 \times 43 = 0{,}734$ Kcal/h

Refrigerator side area : $\frac{1}{0{,}0405} \times 0{,}027 \times (0{,}325 \times 00{,}080) \times 2 \times 43 = 1{,}510$ Kcal/h

Drops retainer : $\frac{1}{0{,}0435} \times 0{,}027 \times (0{,}517 \times 0{,}183)$ 55 = 3,268 Kcal/h

Back panel rear area : $\frac{1}{0{,}055} \times 0{,}027 \times (0{,}117 \times 0{,}517)$ 55 = 1,634 Kcal/h

Chiller back area : $\frac{1}{0{,}055} \times 0{,}027 \times (0{,}530 \times 0{,}517) \times 81 = 10{,}896$ Kcal/h

Back area without evap: $\frac{1}{0{,}055} \times 0{,}027 \times (0{,}041 \times 0{,}541) \times 55 = 0{,}569$ Kcal/h

Back area with evap. : $\frac{1}{0{,}092} \times 0{,}027 \times (0{,}33 \times 0{,}541) \times 55 = 0{,}289$ Kcal/h

Liner upper area : $\frac{1}{0{,}004} \times 0{,}27 + 0{,}025 \times (0{,}78 \times 0{,}55) \times 43 = 1{,}199$ Kcal/h

Freezer side area : $\frac{1}{0{,}017} \times 0{,}27 \times (0{,}367 \times 0{,}241) \times 69 = 4{,}708$ Kcal/h

Freezer upper area: $\frac{1}{0{,}115} \times \frac{[(0{,}027 \times 0{,}069) + (0{,}025 \times 0{,}046)]}{0{,}115}$

$\times (0{,}367 \times 0{,}49) \times 69 = 2{,}827$

$\times 81 = 3{,}690$ Kcal/h

The chosen compressor will be V 62JEG which delivers 89,5 Kcal/h with and with an evaporation temperature of - 30 °C.

In this way you can establish the functionality relation of the compressor at 43 °C

$$\frac{84{,}458 \text{ Kcal/h} \times 100}{89{,}5 \text{ Kcal/h}} = 94{,}5\ \%$$

The formula to applicate to determine the power necessary to freeze 3 kg in 24 h is the following :

$$P = [(GxC\ \ t1) + (GxC1) + (GxCx\ \ t2)]\ \frac{1}{24}$$

P : Imput power in Kcal/h

G : Weight to be freezing in Kg

C : Heating power in Kcal

t1 : difference between external temperature and 0°C

C1 : Latent heat in Kcal/Kg

t2 : Difference between 0°C and - 18°C

1/24: As the freezing last for 24 hours, it will be necessary to divide by 24 to obtain the hour/power

Note : C and C1 change following the material in case of testing packing

C = 0,77 Kcal

C1 = 60 Kcal/Kg

$$P\ [(3x0,77x32) + (3x60) + (3x0,77x18)]\ .\ \frac{1}{24}$$

$$= (73,92 + 180 + 41,58)\ .\ \frac{1}{24} = 12,313\ \text{Kcal/h}$$

$$= 295,5\ X\ \frac{1}{24}$$

Additioning these 13,579 Kcal/h to the 51,03 Kcal/h due to dispersion, we obtain 64,612 Kcal/h which represent the compressor power necessary in freezing phase, being always under those necessary to face the dispersions St 38°C.

B. DETERMINATION OF CONDENSER'S POWER

The condenser is to be up to exchange the Kcal/h required to condensate the quantity of freon necessary to attain the prefixed temperatures.

The calculation formula is the following :

$$KS = \frac{\text{Kcal/h provided by compressor} \times 1{,}25}{t°}$$

Whereby :

KS = coefficient of trasmission in $\frac{\text{Kcal/h}}{°C}$. This coefficient is indicated by the condenser's manufacturer, and changes according to type material, technolgy and surface

t° in °C = Displacement between outlet temperature of freon and ambient temperature

1,25 = Displacement in entalphies between condensation and evaporator phases, keeping into account the overheating value (Kolier)

For condenser too the worst operating conditions must be determined:

Preservation at 43°C $\frac{84{,}458 \text{ kcal/h}}{56-43} \times 1{,}25 = 8{,}798$ kcal/h/°C

Freezing at 32°C $\frac{96{,}770 \text{ kcal/h}}{53-32} \times 1{,}25 = 5{,}760$ kcal/h/°C

The chosen condenser, built with Bentler pipe diam. 4,7 with wires diam. 1,4 distanced of 6,35 and width 578 allows following KS:

W	H	KS
578	812	8,40
578	914	9,30
578	1016	10,30
578	1118	11,25
578	1219	12,20

This condenser should be 914 high.
It should work also at 48°C
That's why we choose: 1016 min.

C. DETERMINATION OF CAPILLARY'S CAPACITY

As regards this particular component, it is recommended to rely on the experience acquired during tests, and this because the capacity of capillary depends on length, internal diameter, glazing of surface and on the type of mixture (liquid-gas) of freon passing through it. Therefore the allowances on all these elements could by themselves effect sensibly the theoretical results.

Assuming a condensation temperature of 55 °C the compressor would deliver 2,6 kg/h of R 12.

Going back to the Molier diagram for R 12 freon, the following specific volumes would be attained at an evaporation temperature of - 30 °C and an absolute pressure of 1,025 kg/cm2 :

- liquid : 0,6728 l/kg
- vapour : 0,1633 m3/kg

Assuming an outlet of R 12 under form of vapor only, the capacity freon in l/min. can be calculated as follows :

$$Pc = Pf \times Psv \times \frac{1000}{60}$$

Pc : Capillary capacity in l/min

Pf : freon q.ty produced by compressor in Kg/h

Psv : steam specific gravity q.ty in m3/kg

1000 : transformation from m3 to l.

60 : transformation from hours to minutes.

$$Pc = 2{,}6 \times 0{,}1633 \times \frac{1000}{60} = 7{,}076 \text{ l/min}$$

Comparing R 12 in AIR capillary you can apply following formula :

Va = 2,35 . P2 - 1 . Ø 2,5 . 1-0,5

Va : capillary capacity (with air passing) in l/min

P : condensation pressure in Kg/cm2

Ø : capillary internal diameter

l : length of capillary

$$7,076 = 2,35 \cdot 13,862^2 - 1 \cdot 0,71^{2,5} \cdot l^{-0,5}$$

$$7,076 = 2,35 \cdot 191,32 \cdot 0,424 \cdot l^{-0,5}$$

$$l^{-0,5} = \frac{7,076}{2,35 \cdot 13,83 \cdot 0,424} = \frac{7,076}{13,780} = 0,5135$$

l = 3,79 m

The theoretical length of the capillary examined therefore corresponds to 4 m but due to our experience it should be 3 or 4 meters. In any case this value should be confirmed by adequate laboratory tests.

As per compressor and condenser, you must check if the higher power to be exchanged is at preservation 43°C or at freezing 25°C ambient temperature.

Concerning the freezer evaporators:

Refrig./freezer separation area : $\frac{1}{0,071}$ x0,027x(0,111x0,542)x26 =
= 0,595 Kcal/h

Refrig./freezer : $\frac{1}{\text{-----}}$ x 0,027 x (0,255x0,546)x 26 =
= 1,778 Kcal/h

freezer side area :		4,708 Kcal/h
freezer upper area :		2,827 Kcal/h
freezer back area :		3,690 Kcal/h
freezer gasket area :	1 x 0,07x0,007	1,667 Kcal/h
freezer door area :		1,335 Kcal/h
TOTAL at 43°C preservation		16,61 Kcal/h

Taking into account that at 25°C there are:
58°C in compressor area
53°C in condenser area

Dispersions will change as follows:

Refrig./freezer separation area:		= 0,595 Kcal/h
Refrig./freezer separation area:		= 1,778 Kcal/h
freezer side area:	4,708x32/43	= 3,504 Kcal/h
freezer upper area:	2,827x32/43	= 2,104 Kcal/h
freezer back area:	3,690x79/81	= 3,599 Kcal/h

D) DETERMINATION OF EVAPORATOR

The evaporating surface is to be up to deliver the Kcal/h leaked by the refrigerating system. The calculation formula is the following :

$$P = K \times S \times t^{\circ}$$

Whereby :

P : power to be exchanged by the evaporator in Kcal/h

K : coefficient of transmission of the evaporator, changing according to the type of material employed and to the constructive technology, in $Kcal/m^2/^{\circ}C$

S : surface of evaporator, in m^2

t°: displacement of temperature between evaporation temperature and air to be cooled

K is much variable for many factors but principally it depens on the thickness of the back part of the cell and on the flatness (in the refrigerator). The thickness is inversely proportional to the thermic conductivity.
K = 8,5 for an evaporator made up by aluminium pipe dia. 8, thk. 1, coupled with a steel plate thk. 0,4.
K = 6,5 for an evaporator made up by aluminium pipe dia. 8, thk 1, coupled with a steel plate thickness 0,4 and with one of ABS from 1 to 1,5.

freezer gasket area:	= 1,677 Kcal/h
freezer door area:	= 1,335 Kcal/h

TOTAL at freezing dispersions ---------------
14,592 Kcal/h

To these 14,592 Kcal/h must be added 12,313 Kcal/h of freezing of 3 Kg. Total will be 26,905 Kcal/h, quantity to be exchanged by the eveporator.

Freezer evaporator surface will be:
26,905 = 8,5 x 5 x (30,83)

$$S = \frac{26,905}{89,5} = 0,452 \text{ m}^2$$

For constructive reasons the freezer evaporator has depth 322 mm and development 1419 that is 0,456 m^2.

As far as refrigerator evaporator is concerned the Kcal/h dispersed from freezer, will be substracted from dispersions at 43 C conservation phase.

Refrig/freezer separation area:	= -0,595 Kcal/h
Refrig/freezer separation area:	= -1,778 Kcal/h
freezer gasket area:	= -1,677 Kcal/h
freezer door area:	= -1,335 Kcal/h
crisper support area:	= 4,716 Kcal/h
crisper back area:	= 3,773 Kcal/h
compressor upper area:	= 1,222 Kcal/h
crisper side area:	= 4,117 Kcal/h
refrigerator side area:	= 20,447 Kcal/h

refrigerator side area:	=	0,120	Kcal/h
refrigerator side area:	=	0,734	Kcal/h
refrigerator side area:	=	1,510	Kcal/h
refrigerator drops retainer area:	=	3,268	Kcal/h
back panel rear area:	=	1,634	Kcal/h
back panel rear area:	=	10,896	Kcal/h
back panel rear area:	=	0,569	Kcal/h
back panel rear area:	=	0,289	Kcal/h
refrigerator gasket area:	=	13,295	Kcal/h
TOTAL	=	61,205	Kcal/h

By applying the formula $P = K \times S \times t'$
we have $61,205 = 6,5 \times S \times (30-0) = 6,5 \times S \times 30$

$$S = \frac{61,205}{195} = 0,313\ m^2$$

Always for constructive reasons our evaporator is 495 mx 525 mm equal to 0,259 m^2, that is insufficient.

Factor K should be therefore increased favouring transmission between evaporator and coil, by means of some pieces of adhesive aluminium.

F 134a

DuPont HFC-134a

Properties, Uses, Storage and Handling

SUVA® 134a refrigerant
SUVA® *Cold-MP* refrigerant
SUVA® *Trans A/C* refrigerant
FORMACEL® Z-4 foam expansion agent
DYMEL® 134a aerosol propellant
DYMEL® 134a/P aerosol propellant

DU PONT

INTRODUCTION

BACKGROUND

HFC-134a has been introduced by DuPont as a replacement for chlorofluorocarbons (CFCs) in many applications. CFCs, which were developed over 60 years ago, have many unique properties. They are low in toxicity, nonflammable, noncorrosive and compatible with other materials. In addition, they offer the thermodynamic and physical properties that make them ideal for a variety of uses. CFCs are used as refrigerants; as blowing agents in the manufacture of insulation, packaging and cushioning foams; as cleaning agents for metal and electronic components; and in many other applications.

However, the stability of these compounds, coupled with their chlorine content, has linked them to depletion of the earth's protective ozone layer. As a result, DuPont plans to phase out production of CFCs and introduce environmentally acceptable alternatives, such as hydrofluorocarbon (HFC) 134a.

HFC-134a—AN ENVIRONMENTALLY ACCEPTABLE ALTERNATIVE

HFC-134a does not contain chlorine; therefore, it has an ozone depletion potential (ODP) of zero. Listed below are all generic and DuPont trade names:

- Hydrofluorocarbon-134a
- HFC-134a
- HFA-134a
- SUVA® 134a
- SUVA® Trans A/C (automotive market)
- SUVA® Cold MP (stationary refrigeration/air conditioning market)
- FORMACEL® Z-4 (foam blowing agent market)
- DYMEL® 134a /P (aerosol pharmaceutical market)
- DYMEL® 134a (general aerosol market)

The chemical properties of HFC-134a are listed below.

HFC-134a

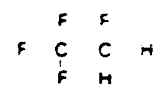
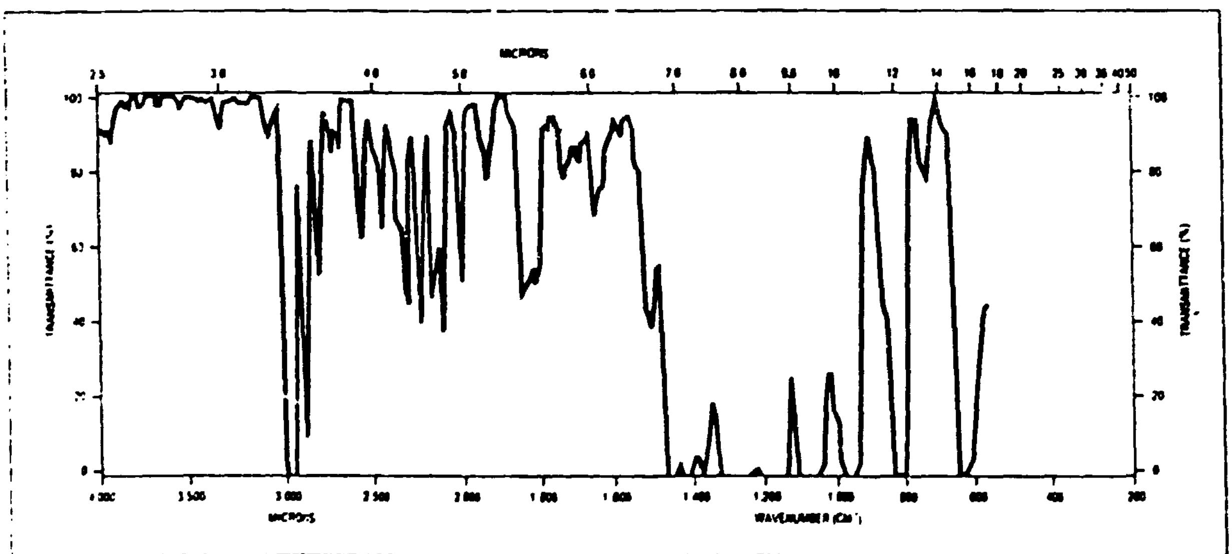
Chemical Name	1,1,1, 2-tetrafluoroethane
Molecular Formula	CH_2FCF_3
CAS Registry Number	811-97-2
Molecular Weight	102.0
Chemical Structure	

Figure 1. **Infrared Spectrum of HFC-134a Vapor at 400 mm Hg Pressure (53.3 kPa) in a 10-cm Cell.**



USES

HFC-134a can be used in many applications that currently use dichlorodifluoromethane (CFC-12). These include refrigeration, polymer foam blowing and aerosol products. However, equipment design changes are sometimes required to optimize the performance of HFC-134a in these applications.

The thermodynamic and physical properties of HFC-134a, coupled with its low toxicity, make it a very efficient and safe replacement refrigerant for CFC-12 in many segments of the refrigeration industry, most notably in automotive air conditioning, appliances, small stationary equipment, medium-temperature supermarket cases and industrial and commercial chillers. *Table 1* provides a comparison of the theoretical performance of CFC-12 and HFC-134a at medium-temperature conditions.

TABLE 1
Theoretical Cycle Comparison of CFC-12 and HFC-134a*

	CFC-12	HFC-134a
Capacity (as % CFC-12)	100	99.7
Coefficient of Performance (COP)	3.55	3.43
Compressor		
Exit Temperature, °C (°F)	86.8 (188.2)	83.1 (181.5)
Exit Pressure, kPa (psia)	1349 (195.6)	1473 (213.7)
Compression Ratio	4.1	4.7

* Temperatures were as follows: Condenser, 54.4°C (130.0°F); Evaporator, 1.7°C (35.0°F); Compressor Suction, 26.7°C (80.0°F); Expansion Device, 51.7°C (125.0°F).

As a blowing agent in polymer foams, HFC-134a can be used to replace CFC-12 in many thermoplastic foam applications. Recent developments, however, are also providing new technology that uses HFC-134a as a replacement for CFC-12 in thermoset foams. HFC-134a features properties that are advantageous for high value-in-use products and meets the requirements of safety/environmental issues. HFC-134a is nonflammable, has negligible photochemical reactivity and low vapor thermal conductivity.

HFC-134a is also being developed for use in pharmaceutical inhalers because of its low toxicity and nonflammability. Other aerosol applications may use HFC-134a where these properties are critical. See DuPont DYMEL® Bulletin ATB-30 (H-44691) for additional information on aerosol applications of HFC-134a.

PHYSICAL PROPERTIES

Physical properties of HFC-134a are given in *Table 2* and *Figures 2* to *8*. Additional physical property data may be found in other DuPont publications. Bulletin ART-1 (H-43855-1) contains viscosity, thermal conductivity and heat capacity data for saturated liquid and vapor in addition to heat capacity data and heat capacity ratios for both saturated and superheated vapors. Thermodynamic tables in English and SI units are available in Bulletins T-134a-ENG (H-47751) and T-134a-SI (H-47752). Liquid and vapor densities are included in the thermodynamic tables.

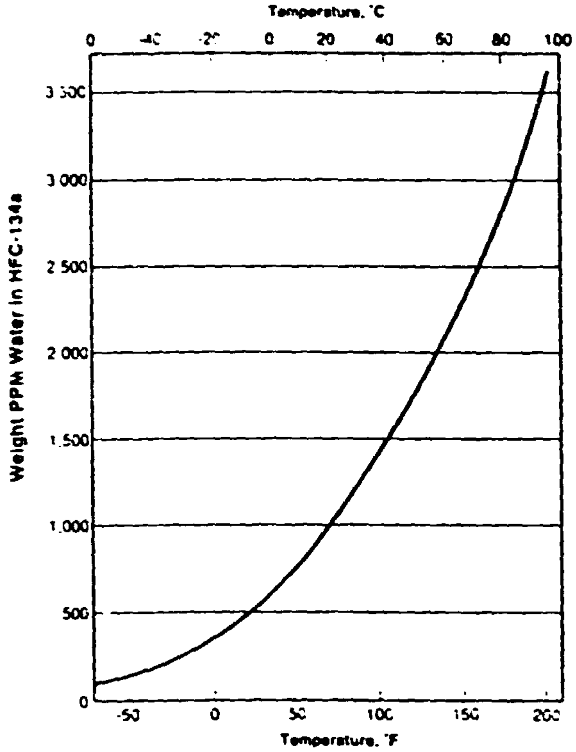
TABLE 2
Physical Properties of HFC-134a

Physical Properties	Units	HFC-134a
Chemical Name	—	Ethane, 1,1,1,2-Tetrafluoro
Chemical Formula	—	CH_2FCF_3
Molecular Weight	—	102.03
Boiling Point at 1 atm (101.3 kPa or 1.013 bar)	°C °F	−26.1 −14.9
Freezing Point	°C °F	−103.0 −153.9
Critical Temperature	°C °F	101.1 213.9
Critical Pressure	kPa lb/in.^{2} abs	4060 588.9
Critical Volume	m^3/kg ft^3/lb	1.94×10^{-3} 0.0311
Critical Density	kg/m^3 lb/ft^3	515.3 32.17
Density (Liquid) at 25°C (77°F)	kg/m^3 lb/ft^3	1206 75.28
Density (Saturated Vapor) at Boiling Point	kg/m^3 lb/ft^3	5.26 0.328
Heat Capacity (Liquid) at 25°C (77°F)	kJ/kg·K or Btu/(lb) (°F)	1.44 0.340
Heat Capacity (Vapor at Constant Pressure) at 25°C (77°F) and 1 atm (101.3 kPa or 1.013 bar)	kJ/kg·K or Btu/(lb) (°F)	0.852 0.204
Vapor Pressure at 25°C (77°F)	kPa bar psia	666.1 6.661 96.61
Heat of Vaporization at Boiling Point	kJ/kg Btu/lb	217.1 93.4
Thermal Conductivity at 25°C (77°F)		
Liquid	W/m·K Btu/hr·ft°F	0.0824 0.0478
Vapor at 1 atm (101.3 kPa or 1.013 bar)	W/m·K Btu/hr·ft°F	0.0145 0.00836
Viscosity at 25°C (77°F)		
Liquid	mPa·S (cP)	0.202
Vapor at 1 atm (101.3 kPa or 1.013 bar)	mPa·S (cP)	0.012
Solubility of HFC-134a in Water at 25°C (77°F) and 1 atm (101.3 kPa or 1.013 bar)	wt %	0.15
Solubility of Water in HFC-134a at 25°C (77°F)	wt %	0.11
Flammability Limits in Air at 1 atm (101.3 kPa or 1.013 bar)	vol %	None
Autoignition Temperature	°C °F	770 1418
Ozone Depletion Potential	—	0
Halocarbon Global Warming Potential (HGWP) (For CFC-11, HGWP = 1)	—	0.28
Global Warming Potential (GWP) (100 yr. ITH. For CO_2, GWP = 1)	—	1200
TSCA Inventory Status	—	Reported/Included
Toxicity AEL[a] (8- and 12-hr TWA)	ppm (v/v)	1,000

[a] AEL (Acceptable Exposure Limit) is an airborne exposure limit established by DuPont scientists for substances to ensure the safe handling and use of that substance.

Note: kPa is absolute pressure.

Figure 2. Solubility of Water in HFC-134a.



CHEMICAL/THERMAL STABILITY

THERMAL DECOMPOSITION

HFC-134a vapors will decompose when exposed to high temperatures from flames or electric resistance heaters. Decomposition may produce toxic and irritating compounds, such as hydrogen fluoride. The pungent odors released will irritate the nose and throat and generally force people to evacuate the area. Therefore, it is important to prevent decomposition by avoiding exposure to high temperatures.

STABILITY WITH METALS AND REFRIGERATION LUBRICANTS

Stability tests for refrigerants with metals are typically performed in the presence of refrigeration oils. The results of sealed tube stability tests are available for CFC-12/mineral oil combinations, which have shown long-term stability in contact with copper, steel and aluminum in actual refrigeration systems. Polyalkylene glycol (PAG) and polyol ester (POE) lubricants will most likely be used with HFC-134a. Sealed tube tests were, therefore, run to determine the relative long-term stability of HFC-134a/metals in the presence of these lubricants.

The method followed was generally the same as ASHRAE 97 with several minor modifications. A 3-mL volume of refrigerant/lubricant solution was heated in the presence of copper, steel and aluminum strips in an oven for 14 days at 175°C (347°F). Both the neat lubricant and a mixture of lubricant and refrigerant (50/50 volume ratio) were tested. Visual ratings were obtained on both the liquid solutions and the metal coupons after the designated exposure time. The visual ratings ranged from 0 to 5, with 0 being the best and 5 being the worst.

After the visual ratings were obtained, sample tubes were opened and the lubricant and refrigerant (if present) were analyzed. The lubricant was typically checked for halide content and viscosity, while the refrigerant was examined for the presence of decomposition products. *Table 3* summarizes typical data for both HFC-134a and CFC-12. Visual ratings are listed for the neat lubricant, the lubricant/refrigerant solution and the three metals that were present in the lubricant/refrigerant solutions. Viscosity was determined on the unused lubricant, the tested neat lubricant and the lubricant tested in the presence of refrigerant. A percent change was calculated for the two tested lubricants. The decomposition products listed are HFC-143a (the predominant decomposition product for HFC-134a) and fluoride ion. Both species are typically measured in the low parts per million (ppm) range.

As the CFC-12/mineral oil combinations have been proven in actual service, these tests indicate that HFC-134a/PAG and HFC-134a/POE solutions have acceptable chemical stability. In several other tests, results have confirmed that the HFC-134a molecule is as chemically stable as CFC-12.

Figure 3 Pressure vs Temperature (English Units).

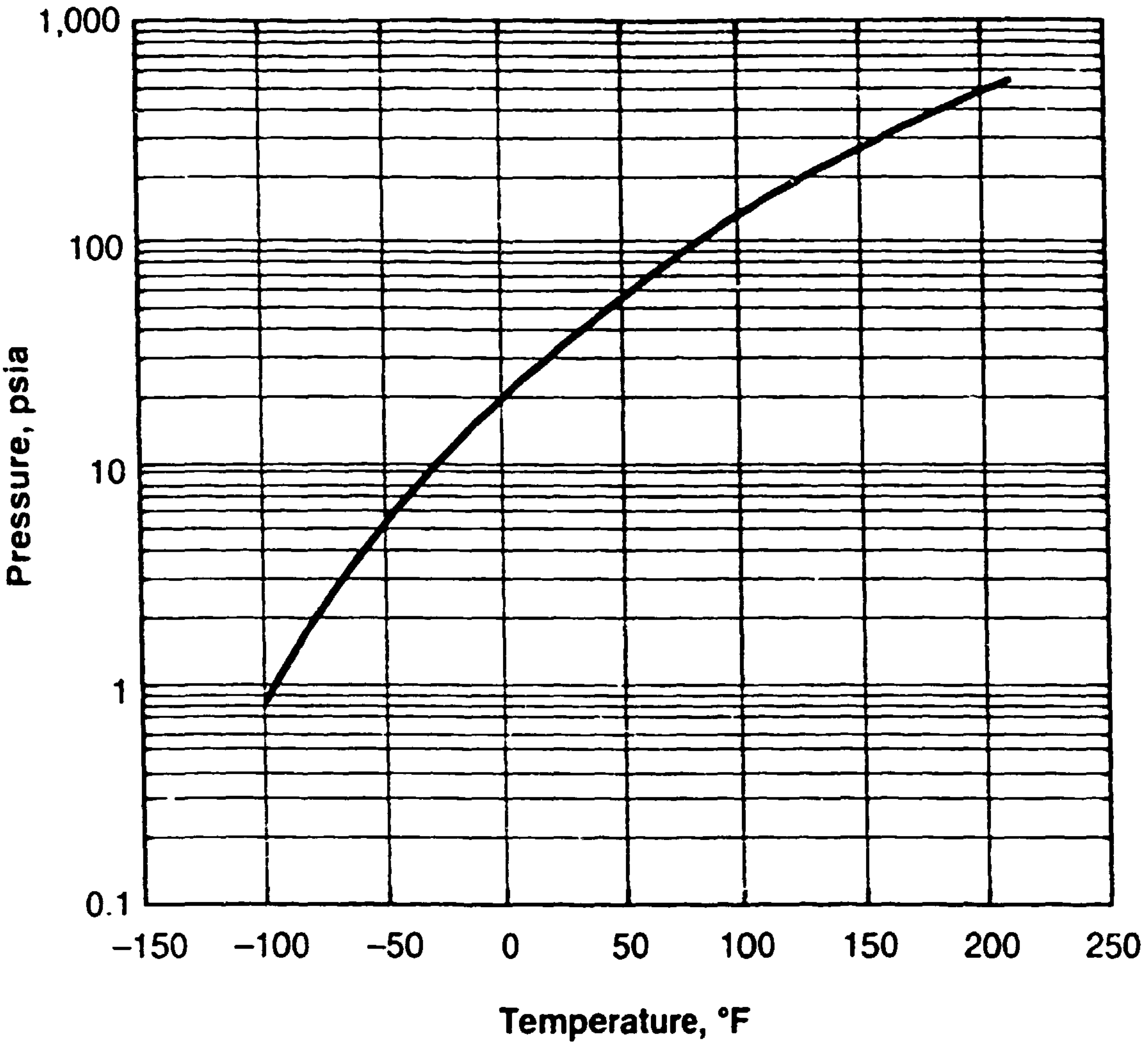


Figure 4. Pressure vs. Temperature (SI Units).

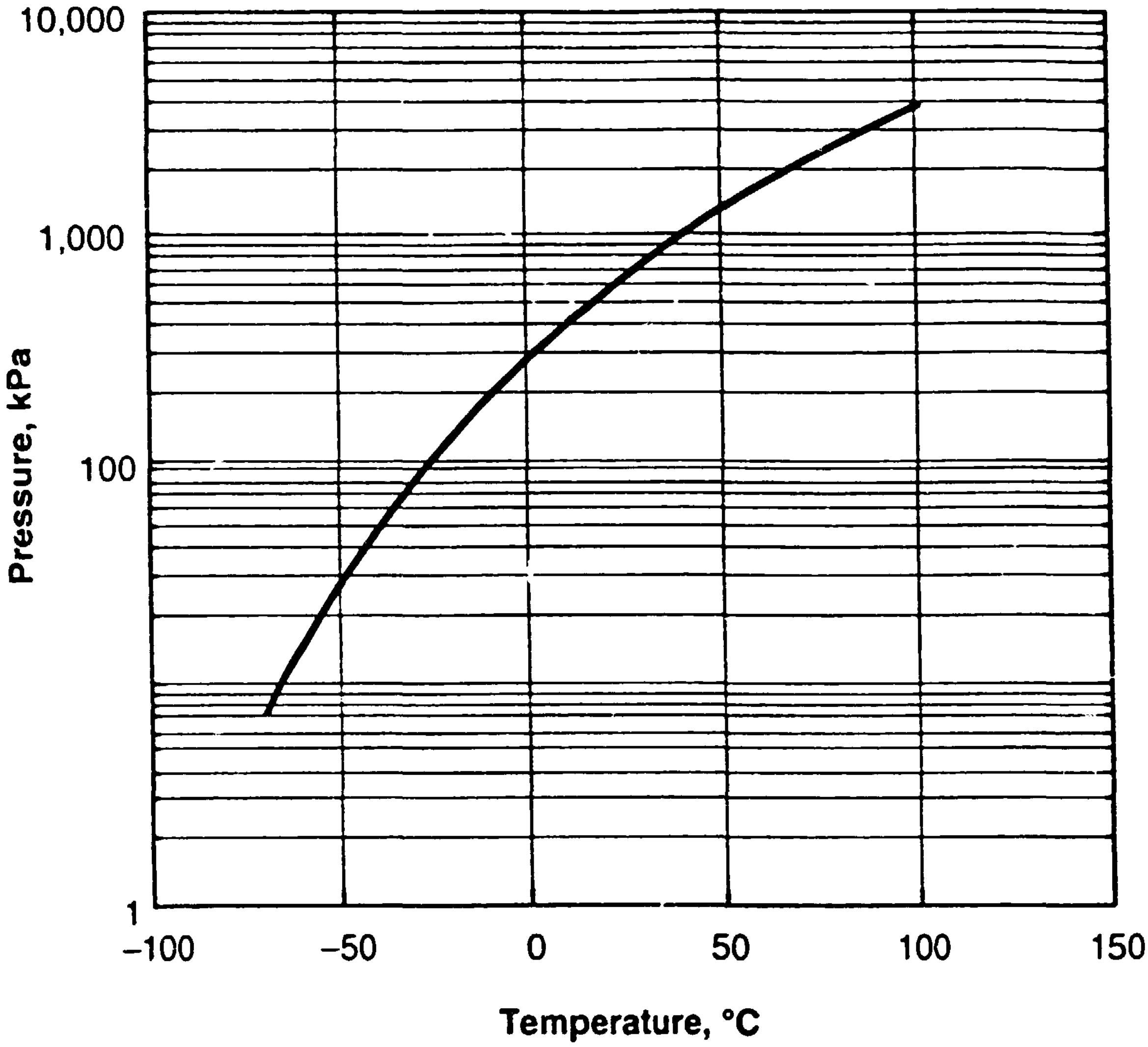


Figure 5. Vapor Thermal Conductivity of HFC-134a at Atmospheric Pressure (English Units).

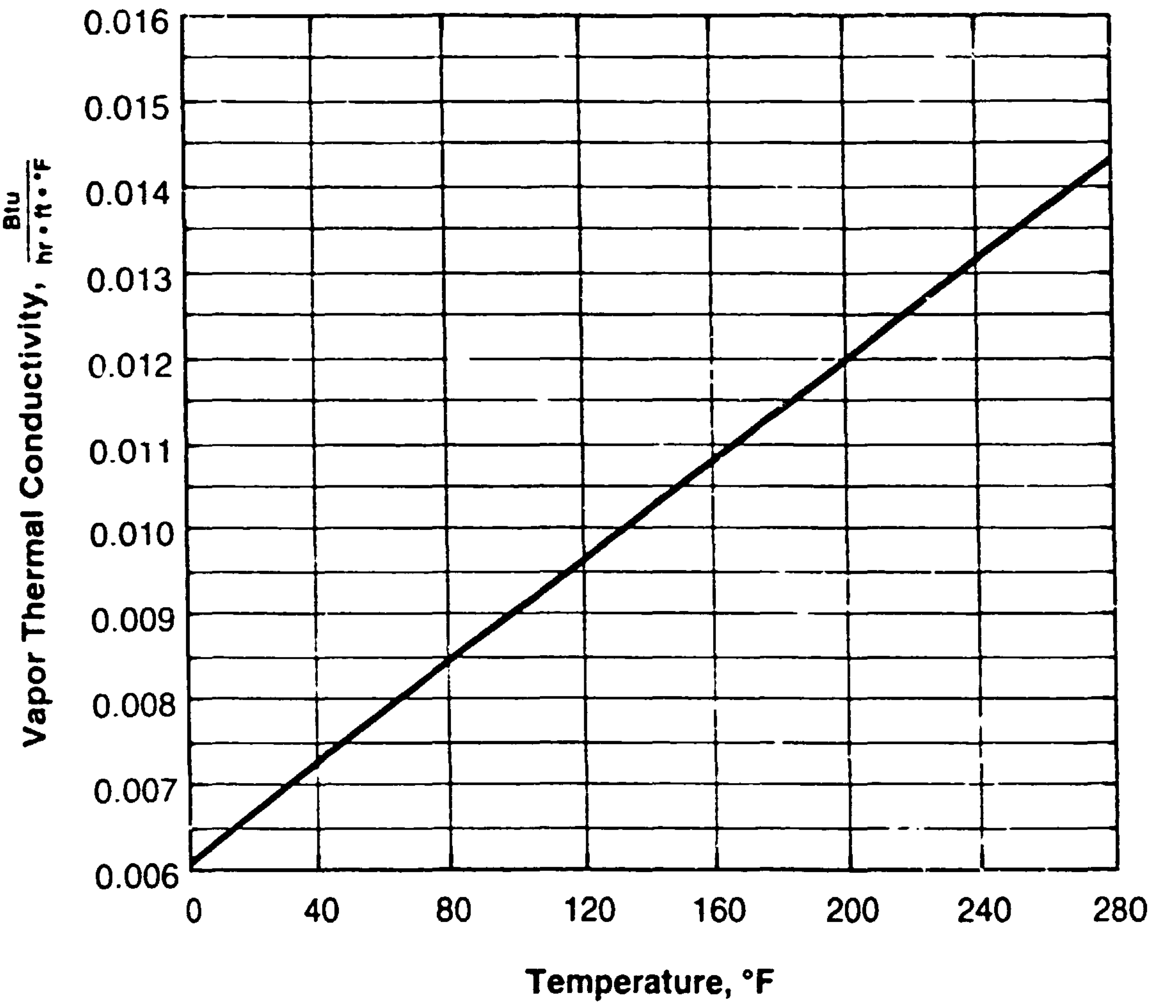


Figure 6. Vapor Thermal Conductivity of HFC-134a at Atmospheric Pressure (SI Units).

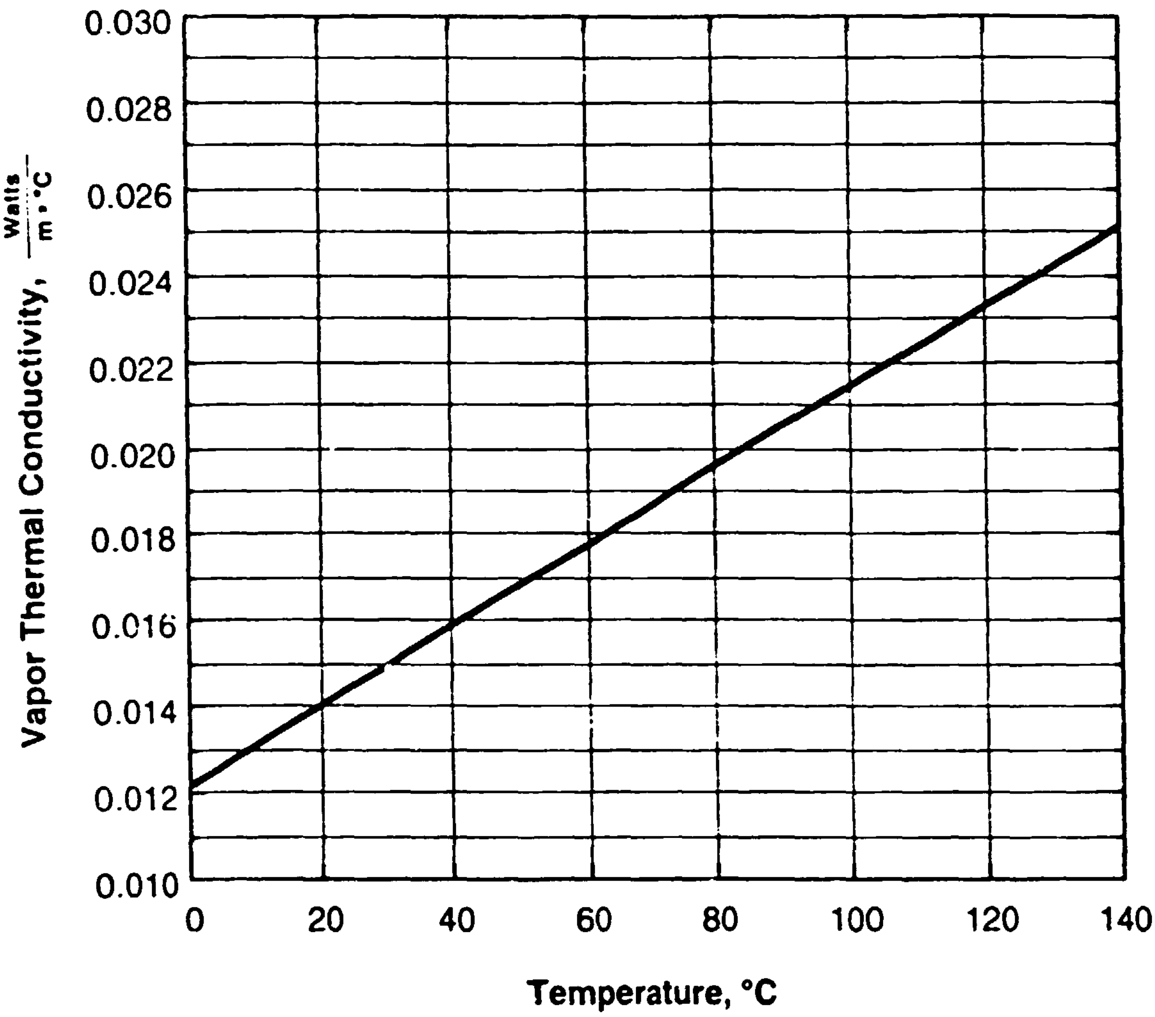


TABLE 3
Stability of HFC-134a with Metals and Lubricating Oils

Oil	Mineral Oil	Mineral Oil	UCON RO-W-6602[a]	Mobil EAL Arctic 32[b]	Castrol Icematic SW 100[b]
Oil Viscosity, cSt at 40°C (104°F)	30.7	125	134	29.4	108.8
Refrigerant	R-12	R-12	HFC-134a	HFC-134a	HFC-134a
Ratings					
Neat Oil	—	—	0	0	0
Oil/Refrigerant	4	4	0	0	0
Copper	2	2	0	0	0
Iron	3	3	0	0	0
Aluminum	2	2	0	0	0
Viscosity Change					
% Change Neat	ND	ND	<1	−3.1	4.3
% Change with Refrigerant	ND	ND	−12.7	−36.2	−27.1
Decomposition Analysis					
HFC-143a, ppm	ND	ND	<7	<3	<0.3
Fluoride, ppm	ND	420	<0.7	—	<7

(a) Polyalkylene glycol lubricant.
(b) Polyol ester lubricant.
ND = Not determined.

Stability Ratings: 0 to 5
0 = Best
3 = Failed
5 = Coked

STABILITY WITH FOAM CHEMICALS

As with other alternative blowing agents, the stability of HFC-134a in foam chemicals (B-side systems) is being studied. The first tests evaluated HFC-134a stability in a sucrose-amine polyether polyol with either an amine catalyst, a potassium catalyst, a tin catalyst or an amine catalyst neutralized with an organic acid. The initial tests, which included analysis of the volatile components, showed no degradation of HFC-134a in any of the systems, even at elevated temperatures. The results are summarized in *Table 4*.

TABLE 4
Stability of HFC-134a with Foam Chemicals

Catalyst	Degradation, %
Amine	<0.001
Potassium	<0.001
Tin	<0.001
Neutralized Amine	<0.001

Test Conditions
Six weeks at 60°C (140°F).
25% (wt.) HFC-134a
Two parts catalyst per 100 parts polyol by weight.
One part water per 100 parts polyol by weight.
Type 1010 steel test coupon.

COMPATIBILITY CONCERNS IF HFC-134a AND CFC-12 ARE MIXED

HFC-134a and CFC-12 are chemically compatible with each other; this means that they do NOT react with each other and form other compounds. However, when the two materials are mixed together, they form what is known as an "azeotrope." An azeotrope is a mixture of two components that acts like a single compound, but has physical and chemical properties different than either of the two components. An example of this is FREON® 502, which is an azeotrope of HCFC-22 and CFC-115. When HFC-134a and CFC-12 are mixed in certain concentrations, they form a high-pressure (low boiling) azeotrope. This means that the vapor pressure of the azeotrope is higher than that of either of the two components by themselves. At 109 psia (752 kPa absolute) the azeotrope contains 46 weight percent HFC-134a. In general, compressor discharge pressures will be undesirably high if refrigeration equipment is operated with a mixture of HFC-134a and CFC-12.

Another characteristic of an azeotrope is that it is very difficult to separate the components once they are mixed together. Therefore, a mixture of HFC-134a and CFC-12 cannot be separated in an on-site recycle machine or in the typical facilities of an off-site reclaimer. Mixtures of HFC-134a and CFC-12 will usually have to be disposed of by incineration.

Figure 7. Pressure-Enthalpy Diagram for HFC-134a (English Units).

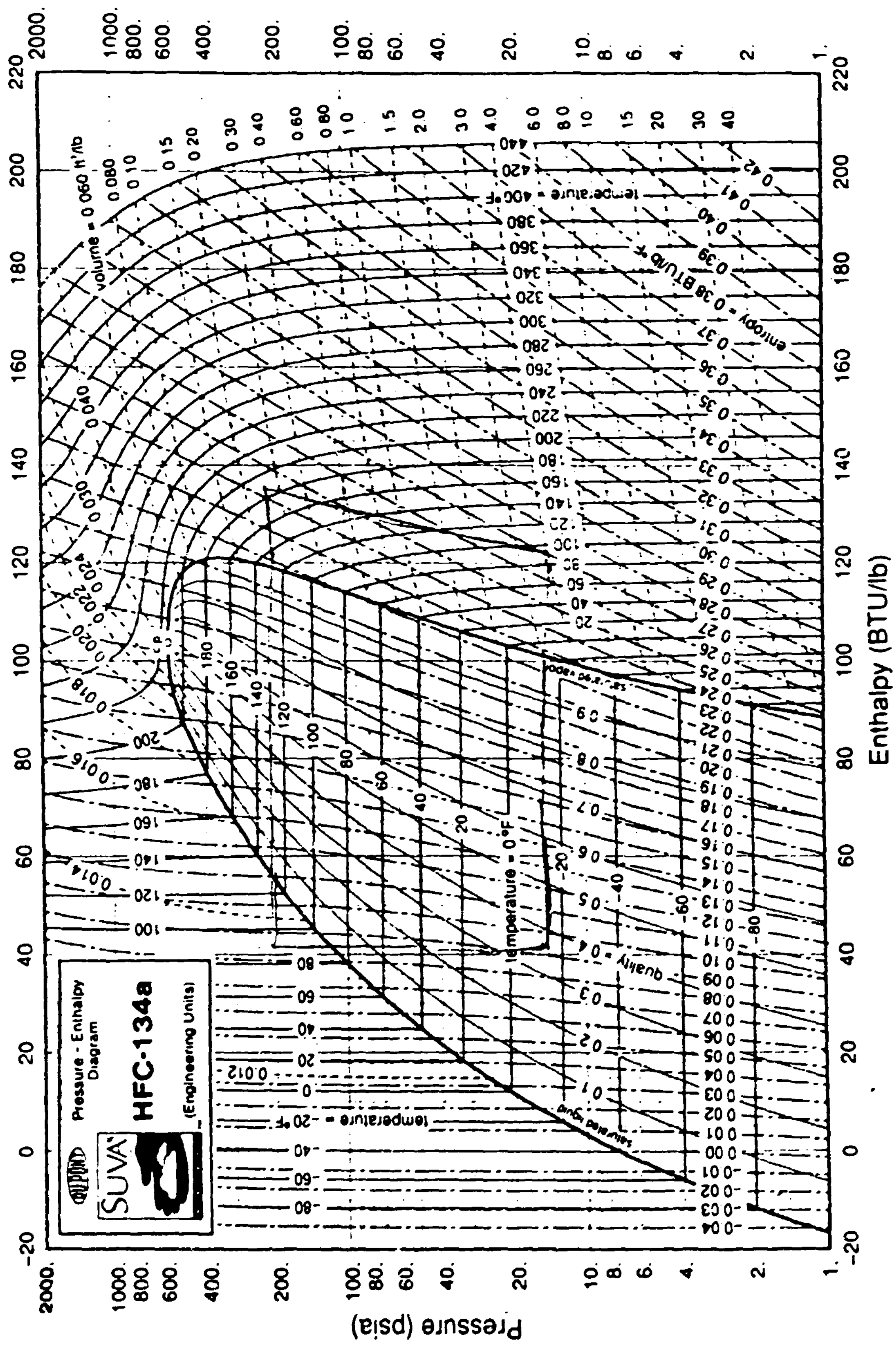
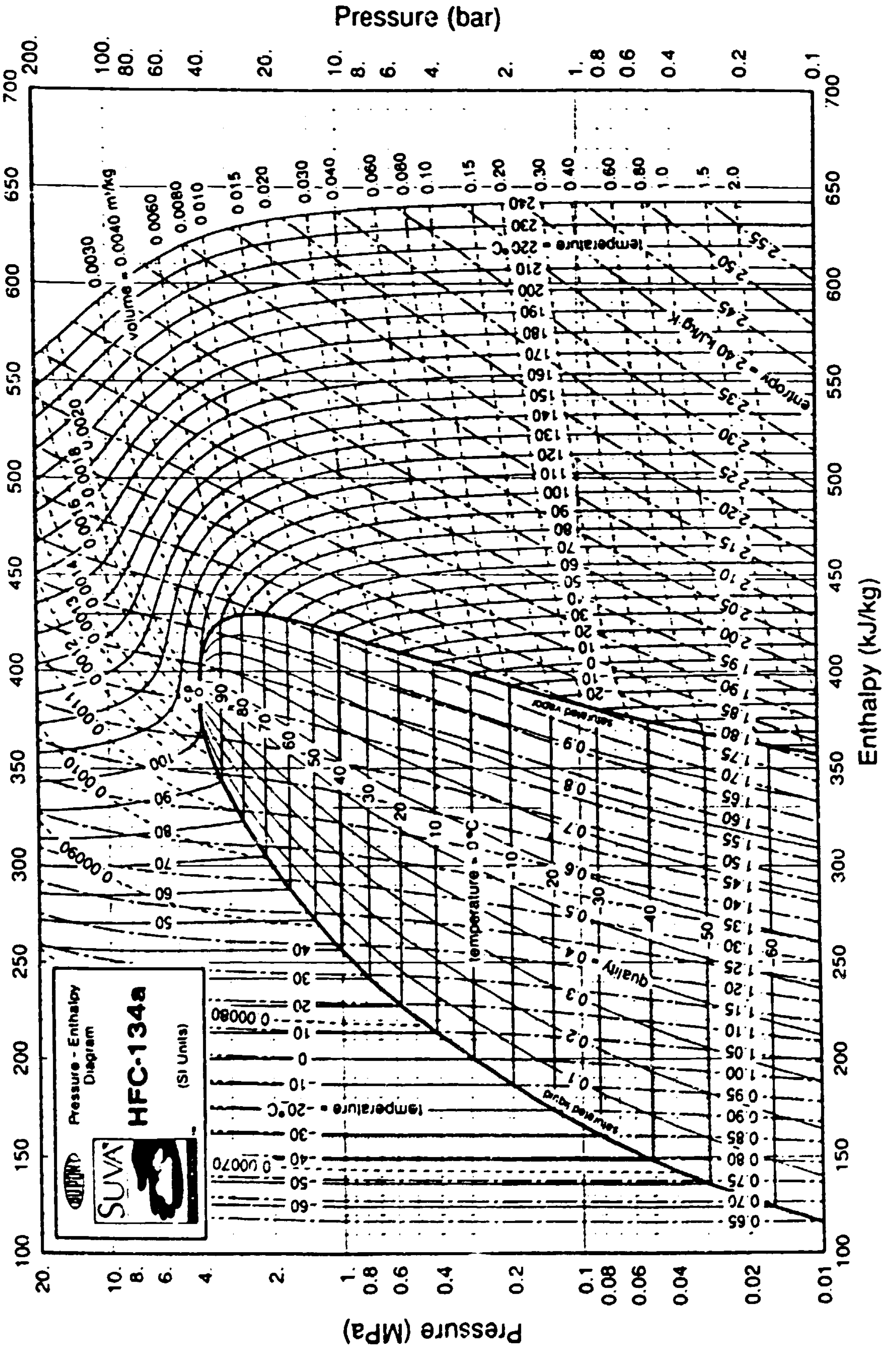


Figure 8. Pressure-Enthalpy Diagram for HFC-134a (SI Units).



MATERIALS COMPATIBILITY

Because HFC-134a is used in many applications, it is important to review materials of construction for compatibility when designing new equipment, retrofitting existing equipment or preparing storage and handling facilities.

PLASTICS

Customary industry screening tests, in which twenty-three typical plastic materials were exposed to liquid HFC-134a in sealed glass tubes at room temperature, are summarized in *Table 5*. Observations of weight gain and physical change were used to separate materials meriting further laboratory and/or field testing from materials which appeared unacceptable. The majority of the materials tested merit further evaluation.

Since the performance of plastic materials is affected by polymer variations, compounding agents, fillers, and molding processes, verifying compatibility using actual fabricated parts under end-use conditions is advised.

ELASTOMERS

Compatibility results for HFC-134a and CFC-12 are compared for 11 typical elastomers in *Tables 6* through *17*. It should be recognized, however, that effects on specific elastomers depend on the nature of the polymer, the compounding formulation used and the curing or vulcanizing conditions. Actual samples should be tested under end-use conditions before specifying elastomers for critical components.

Recommendations, based on the detailed data in *Tables 7* through *17*, are given in *Table 6*. Data on "temporary" elastomer swell and hardness changes were used as the prime determinants of compatibility. The subsequent "final" data were used as a guide to indicate if the seals in a refrigeration system should be replaced after equipment tear down.

Most polymeric materials used in refrigeration equipment are exposed to a mixture of refrigerant and refrigeration oil. Data on the compatibility of elastomers and motor materials with HFC-134a in combination with mineral oils and a PAG lubricant are available in Bulletins ARTD-18 (H-26845) and ARTD-30 (H-32123). Data for nylon and for graphite-filled TEFLON fluorocarbon resin are included in ARTD-30. Additional data are being developed by equipment manufacturers.

HOSE PERMEATION

Elastomeric hoses are used in mobile air conditioning systems and for transferring HFC-134a in other applications. The permeation rates of HFC-134a and CFC-12 through several automotive A/C hoses were measured as a guide to hose selection.

TABLE 5

Plastics Compatibility of HFC-134a

Test Conditions: Plastic specimens exposed to liquid HFC-134a (no lubricant) in sealed glass tubes for two weeks at room temperature.

Chemical Type	Trade Name
Plastic materials meriting further testing	
ABS	KRALASTIC®
Acetal	DELRIN®
Epoxy	
Fluorocarbons	
PTFE	TEFLON®
ETFE	TEFZEL®
PVDF	
Ionomer	SURLYN®
Polyamide	
6/6 Nylon	ZYTEL®
Polyarylate	ARYLON®
Polycarbonate	TUFFAK®
Polyester	
PBT	VALOX®
PET	RYNITE®
Polyetherimide	ULTEM®
Polyethylene-HD	ALATHON®
Polyphenylene Oxide	NORYL®
Polyphenylene Sulfide	RYTON®
Polypropylene	
Polystyrene	STYRON®
Polysulfone	POLYSUFONE®
Polyvinyl Chloride	
PVC	
CPVC	
Plastic materials exhibiting unacceptable change	
Acrylic	LUCITE®
Cellulosic	ETHOCEL®

TABLE 6
Elastomer Compatibility of HFC-134a

	Ratings					
	CFC-12			HFC-134a		
	25°C (77°F)	80°C (176°F)	141°C (285°F)	25°C (77°F)	80°C (176°F)	141°C (285°F)
ADIPRENE L	1	5		2	5	
Buna N	1*	0*	2*	1	0*	1
Buna S	3	4		3	2	
Butyl Rubber	2	4		0	3	
HYPALON* 48	1	0	0	1*	0	0
Natural Rubber	4	5		0	2	
Neoprene W	0*	1*		0	2	
NORDEL* Elastomer	2*	2*		1	1	
Silicone	5	5		2	2	
THIOKOL* FA	1	1		1*	0	
VITON* A	5	5		5	5	

*Recommend elastomer replacement after equipment teardown.
HYPALON, NORDEL* and VITON* are DuPont registered trademarks.
ADIPRENE* is a Uniroyal registered trademark.
THIOKOL* FA is a Morton Thiokol registered trademark.

Codes: 0 = No change
1 = Acceptable change
2 = Borderline change
3 = Slightly unacceptable change
4 = Moderately unacceptable change
5 = Severely unacceptable change

The studies were run at 80 C (176 F) with an initial 8[illegible] volume percent liquid loading of HFC-134a in 76-cm (30-in.) lengths of 15.9-mm (5.8-in.) inside diameter automotive air conditioning hose. Hose construction and permeation rates are summarized in *Table 18*. Based on these tests, hoses lined with nylon, as well as those made of HYPALON 48, appear to be suitable for use with HFC-134a. Note, however, that these rate measurements provide a comparison of the various hoses at a single temperature and should not be used as an indication of actual permeation losses from an operating system.

DESICCANTS

Dryers filled with desiccant are typically used in refrigeration systems and bulk storage facilities. A common molecular sieve desiccant used with CFC-12, UOP's (formerly Union Carbide Molecular Sieve) 4A-XH-5, is not compatible with HFC-134a; however, UOP has developed other molecular sieve desiccants, such as XH-7 and XH-9, which perform well in HFC-134a service. In addition, several other manufacturers offer loose-fill and molded-core desiccants that are compatible with HFC-134a and lubricants. Be sure to indicate your specific HFC-134a application when ordering a dryer or desiccant.

REFRIGERATION LUBRICANTS

Most compressors require a lubricant to protect internal moving parts. The compressor manufacturer usually recommends the type of lubricant and viscosity that should be used to ensure proper operation and equipment durability. Recommendations are based on several criteria, such as lubricity, compatibility with materials of construction, thermal stability and refrigerant/oil miscibility. To ensure efficient operation and long equipment life, it is important to follow the manufacturer's recommendations.

Current lubricants used with CFC-12 are fully miscible over the range of expected operating conditions, easing the problem of getting the lubricant to flow back to the compressor. Refrigeration systems using CFC-12 take advantage of this full miscibility when considering lubricant return. Refrigerants such as HFC-134a, with little or no chlorine, may exhibit less solubility with many existing mineral oil or alkylbenzene lubricants.

The search for lubricants for use with HFC-134a started with commercially available products. *Table 19* shows solubilities of various refrigerant/lubricant combinations. Current naphthenic, paraffinic and alkylbenzene lubricants have very poor solubility with HFC-134a. PAGs with low viscosity show good solubility but, as viscosity increases, they become less soluble. Ester lubricants, of which there are many types, generally show good solubility with HFC-134a. When compared to PAGs, ester lubricants are more compatible with hermetic motor components and are less sensitive to mineral oil and CFC-12 remaining in a refrigeration system.

Although HFC-134a and CFC-12 are chemically compatible with each other, such is not the case with CFC-12 and PAG lubricants. Specifically, the chlorine contained in CFC-12 or other chlorinated compounds can react with the PAG and cause lubricant degradation. CFC-11, which is often used as a cleaning or flushing agent, is also incompatible with PAGs. At contaminant levels of 1 percent CFC-11 or 2 to 10 percent residual mineral oil (saturated with CFC-12), the stability of the system is affected enough to cause possible degradation. Lubricant degradation can result in poor lubrication and premature failure. In addition, sludge will be formed that can plug orifice tubes and other small openings.

TABLE 7
Compatibility of Refrigerants with ADIPRENE® L

Test Conditions 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final).

	25°C (77°F)		80°C (176°F)	
	CFC-12	HFC-134a	CFC-12	HFC-134a
Length Change (%)				
Temporary	1.8	5.5	2.1	5.0
Final	0.3	0.1	(a)	−0.5
Weight Change (%)				
Temporary	8.5	20	5.2	20
Final	1.2	0.3	(a)	−0.5
Shore A Hardness				
Original	60	61	60	63
Temporary, Δ SH	−2	−4	(a)	−28
Final, Δ SH	0	1	—	−19
Elasticity Rating				
Temporary	0	0	5(a)	4(b)
Final	0	0	5(a)	5(c)
Visual Rating				
Liquid	0	0	0	0
Polymer				
Temporary	0	0	0	1(d)
Final	0	0	5(a)	2(d)

(a) Sample disintegrated
(b) More elastic
(c) Broke when stretched
(d) Sticky

TABLE 8
Compatibility of Refrigerants with Buna N

Test Conditions: 27 days immersion of the polymer at 25°C (77°F), 80°C (176°F) and 141°C (285°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final).

	CFC-12			HFC-134a		
	25°C (77°F)	80°C (176°F)	141°C (285°F)	25°C (77°F)	80°C (176°F)	141°C (285°F)
Length Change (%) (±0.5)						
Temporary	2	1	2	2	2	3
Final	0	−1	0	0	0	0
Weight Change (%) (±0.5)						
Temporary	7	6	8	8	8	8
Final	0	−1	2	0	0	0
Shore A Hardness						
Original	77	76	72	77	74	75
Temporary, Δ SH	−6	−1	9	−5	−1	−3
Final, Δ SH	7	9	14	5	7	4
Elasticity Rating						
Temporary	0	1	1(a)	0	1	1
Final	0	0	0	0	0	0
Visual Rating						
Liquid	0	0	0	0	0	0
Polymer						
Temporary	0	1	1(b)	0	0	0
Final	0	1	1(b)	0	0	0

(a) More elastic
(b) Surface dulled

TABLE 9
Compatibility of Refrigerants with Buna S

Test Conditions 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final).

	25°C (77°F)		80°C (176°F)	
	CFC-12	**HFC-134a**	**CFC-12**	**HFC-134a**
Length Change (%)				
Temporary	–0.1	1.1	0.7	0.8
Final	–2.5	<0.1	–2.6	0.3
Weight Change (%)				
Temporary	2.8	1.9	2.9	2.5
Final	–6.2	–0.1	–6.2	–0.1
Shore A Hardness				
Original	85	84	83	81
Temporary, Δ SH	–12	–12	–16	–9
Final, Δ SH	8	–2	–9	–2
Elasticity Rating				
Temporary	0	0	0	1[a]
Final	3[b]	1[a]	3[c]	0
Visual Rating				
Liquid	0	0	0	0
Polymer				
Temporary	0	0	0	0
Final	0	0	0	0

[a] More elastic

[b] Less elastic

TABLE 10
Compatibility of Refrigerants with Butyl Rubber

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final)

	25°C (77°F)		80°C (176°F)	
	CFC-12	**HFC-134a**	**CFC-12**	**HFC-134a**
Length Change (%)				
Temporary	6.3	1.2	7.6	1.3
Final	–1.2	0	–0.8	0.4
Weight Change (%)				
Temporary	34	2.0	36	3.7
Final	–2.6	–0.1	–1.2	0.6
Shore A Hardness				
Original	54	54	57	58
Temporary, Δ SH	–8	–1	–14	–4
Final, Δ SH	–1	–2	–10	–3
Elasticity Rating				
Temporary	1[a]	1[a]	3[a]	0
Final	0	0	2[a]	0
Visual Rating				
Liquid	0	0	3[b]	0
Polymer				
Temporary	0	0	3[c]	4[c]
Final	0	0	1[d]	2[d]

[a] More elastic

[b] White solids in liquid

[c] White deposit on elastomer

[d] White film on elastomer

TABLE 11
Compatibility of Refrigerants with HYPALON® 48

Test Conditions: 27 days immersion of the polymer at 25°C (77°F), 80°C (176°F) and 141°C (285°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final).

	CFC-12			HFC-134a		
	25°C (77°F)	80°C (176°F)	141°C (285°F)	25°C (77°F)	80°C (176°F)	141°C (285°F)
Length Change (%) (±0.5)						
Temporary	1	0	1	0	0	1
Final		0	0	0	0	0
Weight Change (%) (±0.5)						
Temporary	7	5	9	0	1	2
Final	2	1	4	0	0	1
Shore A Hardness						
Original	79	81	81	76	82	82
Temporary, Δ SH	−4	0	0	3	1	1
Final, Δ SH	4	2	2	8	1	4
Elasticity Rating						
Temporary	0	0	0	0	0	0
Final	0	0	0	0	0	0
Visual Rating						
Liquid	0	0	0	0	0	0
Polymer						
Temporary	0	1	1[a]	0	0	0
Final	0	1	1[a]	0	0	0

[a] Surface dulled

TABLE 12
Compatibility of Refrigerants with Natural Rubber

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final).

	25°C (77°F)		80°C (176°F)	
	CFC-12	HFC-134a	CFC-12	HFC-134a
Length Change (%)				
Temporary	14	1.3	14	2.0
Final	−1.1	−0.3	−0.8	0.4
Weight Change (%)				
Temporary	51	4.5	55	5.8
Final	−2.6	−0.5	−2.6	−0.6
Shore A Hardness				
Original	55	56	56	57
Temporary, Δ SH	−9	−1	−17	−8
Final, Δ SH	−5	−4	−8	−4
Elasticity Rating				
Temporary	0	0	1[a]	1[a]
Final	0	0	2[a]	0
Visual Rating				
Liquid	0	0	0	0
Polymer				
Temporary	0	0	0	0
Final	0	0	0	0

[a] More elastic

TABLE 13
Compatibility of Refrigerants with Neoprene W

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final)

	25°C (77°F)		80°C (176°F)	
	CFC-12	HFC-134a	CFC-12	HFC-134a
Length Change (%)				
Temporary	0.2	0.7	0.9	1.4
Final	−7.6	−0.5	−7.3	−0.3
Weight Change (%)				
Temporary	6.6	2.3	6.8	2.9
Final	−12	−0.6	−13	−1.8
Shore A Hardness				
Original	73	73	73	72
Temporary, Δ SH	−1	0	−5	−7
Final, Δ SH	−10	0	5	−5
Elasticity Rating				
Temporary	2[a]	0	1[a]	0
Final	2[a]	0	2[b]	0
Visual Rating				
Liquid	1[c]	0	1[d]	0
Polymer				
Temporary	0	0	1[e]	0
Final	0	0	0	0

(a) Less elastic
(b) More elastic
(c) Clear yellow
(d) Hazy
(e) White film

TABLE 14
Compatibility of Refrigerants with NORDEL® Elastomer

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final).

	25°C (77°F)		80°C (176°F)	
	CFC-12	HFC-134a	CFC-12	HFC-134a
Length Change (%)				
Temporary	−0.6	0.5	−0.4	0.7
Final	−8.2	−0.2	−8.4	0.4
Weight Change (%)				
Temporary	5.5	2.8	6.1	4.4
Final	−22	<0.1	−22	−0.2
Shore A Hardness				
Original	66	66	65	63
Temporary, Δ SH	−4	−3	0	−6
Final, Δ SH	19	−4	20	0
Elasticity Rating				
Temporary	2[a]	0	2[b]	1[b]
Final	2[a]	0	2[b]	0
Visual Rating				
Liquid	0	0	0	1[d]
Polymer				
Temporary	0	0	0	0
Final	0	0	1[c]	0

(a) Less elastic
(b) More elastic
(c) White film
(d) Hazy

TABLE 15
Compatibility of Refrigerants with Silicone

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final)

	25°C (77°F)		80°C (176°F)	
	CFC-12	HFC-134a	CFC-12	HFC-134a
Length Change (%)				
Temporary	41	6.1	44	5.5
Final	−0.1	0.1	−0.2	−0.2
Weight Change (%)				
Temporary	173	20	187	20.3
Final	0.7	−0.1	−0.7	−0.3
Shore A Hardness				
Original	60	61	60	58
Temporary, Δ SH	−13	−8	−15	−6
Final, Δ SH	−7	−4	−7	−2
Elasticity Rating				
Temporary	0	1[a]	1[a]	0
Final	0	0	0	0
Visual Rating				
Liquid	0	0	0	0
Polymer				
Temporary	5[b]	0	4[b]	0
Final	0	0	0	0

[a] Less elastic
[b] Swollen

TABLE 16
Compatibility of Refrigerants with THIOKOL FA

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final)

	25°C (77°F)		80°C (176°F)	
	CFC-12	HFC-134a	CFC-12	HFC-134a
Length Change (%)				
Temporary	1.3	0.8	1.4	−0.2
Final	−0.5	−0.2	−0.5	−0.9
Weight Change (%)				
Temporary	1.9	1.0	3.7	1.9
Final	−0.2	−0.1	−0.8	−0.8
Shore A Hardness				
Original	70	69	74	74
Temporary, Δ SH	−6	−4	−6	0
Final, Δ SH	−5	−6	−1	0
Elasticity Rating				
Temporary	1[b]	1[b]	0	1[b]
Final	0	0	1[a]	2[a]
Visual Rating				
Liquid	0	0	0	0
Polymer				
Temporary	0	0	0	0
Final	0	0	0	0

[a] Less elastic
[b] More elastic

TABLE 17
Compatibility of Refrigerants with VITON A

Test Conditions: 27 days immersion of the polymer at 25°C (77°F) and 80°C (176°F) in liquid (temporary) plus two weeks drying in air at about 25°C (77°F) (final)

	25°C (77°F)		80°C (176°F)	
	CFC-12	**HFC-134a**	**CFC-12**	**HFC-134a**
Length Change (%)				
Temporary	5.5	13	4.9	12
Final	0.7	−0.1	1.2	0.3
Weight Change (%)				
Temporary	19	48	20	49
Final	1.8	0.7	2.5	1.2
Shore A Hardness				
Original	74	74	73	73
Temporary, Δ SH	−19	−30	−23	−31
Final, Δ SH	−7	−8	−10	−6
Elasticity Rating				
Temporary	2[b]	2[b]	3[a]	3[a]
Final	0	0	0	0
Visual Rating				
Liquid	0	0	0	0
Polymer				
Temporary	0	1[c]	0	0
Final	0	1[d]	0	5[e]

[a] Less elastic
[b] More elastic
[c] Very slightly tacky
[d] Oily sheen
[e] Puffed mounds—5% of surface

TABLE 18
HFC-134a Permeation Through Elastomeric Hoses

	Permeation Rate, gm/cm-yr (lb/ft-yr)			
	Nylon	**HYPALON® 48**	**Nitrile #1**	**Nitrile #2**
CFC-12	4.5 (0.3)	14.9 (1.0)	22.3 (1.5)	28.3 (1.9)
HFC-134a	3.0 (0.2)	3.0 (0.2)	26.8 (1.8)	40.2 (2.7)
Hose Construction:				
Inner Liner	Nylon	HYPALON® 48	Nitrile (NBR)	
Second Layer	—	Rayon	Rayon	
Reinforcement	Nylon	2 Braids	2 Braids	
Outer Cover	Chlorobutyl	EPDM	EPDM	

TABLE 19
Solubilities of HFC-134a in Lubricants

Temperature Range: –50°C to 93°C (–58°F to 199°F)

Oil Type	Percent Refrigerant in Mixture 30%	60%	90%
500 SUS Naphthenic	2 phase	2 phase	2 phase
500 SUS Paraffinic	2 phase	2 phase	2 phase
125 SUS Dialkylbenzene	2 phase	2 phase	2 phase
300 SUS Alkylbenzene	2 phase	2 phase	2 phase
165 SUS PAG	–50 to >93[a]	–50 to >93	–50 to +73
525 SUS PAG	–50 to >93	–40 to +35	–23 to –7
100 SUS Ester	–40 to >93	–35 to >93	–35 to >93
150 SUS Ester	–50 to >93	–50 to >93	–50 to >93
300 SUS Ester	–50 to >93	–50 to >93	–50 to >93
500 SUS Ester	–40 to >93	–35 to >93	–35 to >93

[a] One phase in this temperature range, °C

INHALATION TOXICITY

HFC-134a poses no acute or chronic hazard when it is handled in accordance with DuPont recommendations and when exposures are maintained at or below the DuPont Acceptable Exposure Limit (AEL) of 1,000 ppm (8- and 12-hour Time-Weighted Average or TWA).

An AEL is an airborne exposure limit established by DuPont scientists that specifies time-weighted average (TWA) airborne concentrations to which nearly all workers may be repeatedly exposed without adverse effects. The AEL for HFC-134a has the same value as the Threshold Limit Values (TLVs) established for CFC-12 and HCFC-22. TLVs are established by the American Conference of Governmental and Industrial Hygienists (ACGIH).

However, inhaling high concentrations of HFC-134a vapor may cause temporary central nervous system depression with narcosis, lethargy and anesthetic effects. Other effects that may occur include dizziness, a feeling of intoxication and a loss of coordination. Continued breathing of high concentrations of HFC-134a vapors may produce cardiac irregularities (cardiac sensitization), unconsciousness and, with gross overexposure, death. Intentional misuse or deliberate inhalation of HFC-134a may cause death without warning. This practice is *extremely dangerous*.

If you experience *any* of the initial symptoms, move to fresh air and seek medical attention.

CARDIAC SENSITIZATION

If vapors are inhaled at a concentration of 75,000 ppm, which is well above the AEL, the heart may become sensitized to adrenaline, leading to cardiac irregularities and, possibly, to cardiac arrest. The likelihood of these cardiac problems increases if you are under physical or emotional stress.

Medical attention must be given immediately if exposed to high concentrations of HFC-134a. Do **not** treat with adrenaline (epinephrine) or similar drugs. These drugs may *increase* the risk of cardiac arrhythmias and cardiac arrest. If the person is having difficulty breathing, administer oxygen. If breathing has stopped, give artificial respiration.

SPILLS OR LEAKS

If a large release of vapor occurs, such as from a large spill or leak, the vapors may concentrate near the floor or low spots and displace the oxygen available for breathing, causing suffocation.

Evacuate *everyone* until the area has been ventilated. Use blowers or fans to circulate the air at floor level. Do not reenter the affected area unless you are equipped with a self-contained breathing apparatus or unless an area monitor indicates that the concentration of HFC-134a vapors in the area is below the AEL.

Always use self-contained breathing apparatus or an air-line mask when entering tanks or other areas where vapors might exist. Use the buddy system *and* a lifeline. Refer to the Material Safety Data Sheet (MSDS) for HFC-134a for more information.

HFC-134a vapors have a slightly sweet odor that can be difficult to detect. Therefore, frequent leak checks and the installation of permanent area monitors may be necessary in enclosed spaces. Refer to ASHRAE Standards 15 and 34 for refrigeration machinery rooms.

To ensure safety when working with HFC-134a in enclosed areas:

1. Route relief and purge vent piping (if present) outdoors, away from air intakes.
2. Make certain the area is well ventilated, using auxiliary ventilation, if necessary, to move vapors.
3. Make sure the area is clear of vapors prior to beginning work.
4. Install air monitoring equipment to detect leaks. (Monitors are discussed in the next section, Monitors and Leak Detection.)

SKIN AND EYE CONTACT

At room temperature, HFC-134a vapors have little or no effect on the skin or eyes. However, in liquid form, HFC-134a can freeze skin or eyes on contact, causing frostbite. Following contact, soak the exposed area in lukewarm water, not cold or hot. If medical treatment cannot begin immediately, apply a light coat of a nonmedicated ointment, such as petroleum jelly. If the exposed area is in a location where the presence of the ointment would be awkward, such as on the eye, apply a light bandage. In *all* cases of frostbite, seek medical attention as soon as possible.

Always wear protective clothing when there is a risk of exposure to liquid HFC-134a. Where splashing is possible, always wear eye protection and a face shield.

COMBUSTIBILITY OF HFC-134a

HFC-134a is *nonflammable* at ambient temperatures and atmospheric pressure. However, tests have shown HFC-134a to be combustible at pressures as low as 5.5 psig (139.3 kPa absolute) at 177°C (350°F) when mixed with air at concentrations generally greater than 60 volume % air. At lower temperatures, higher pressures are required for combustibility. (HCFC-22 is also combustible at pressures above atmospheric in the presence of high air concentrations.) Test results and calculations have shown:

- At ambient temperature, all concentrations of HFC-134a in air are nonflammable at pressures below 15 psig (205 kPa absolute).
- Combustible mixtures of air and HFC-134a will not form when liquid HFC-134a is pumped into a closed vessel if the initial air pressure in the vessel is limited to one atmosphere absolute and the final pressure is limited to 300 psig (2,170 kPa absolute). If the initial air pressure is greater than one atmosphere, combustible mixtures may form as the tank is filled.

Based on the above information, the following operating practices are recommended.

- **Leak Testing**
  - Equipment should **never** be leak tested with a pressurized mixture of HFC-134a and air. HFC-134a may be safely pressured with dry nitrogen.
- **Bulk Delivery and Storage**
  - Tanks should normally be evacuated at the start of filling, and should never be filled while under positive air pressure.

    Tank pressure should never be allowed to exceed 300 psig (2,170 kPa) when filling with HFC-134a. Relief devices on either the tanks or the HFC-134a supply system usually prevent this.
  - Tank pressures should be monitored routinely.
  - Air lines should never be connected to storage tanks.
- **Filling and Charging Operations**
  - Before evacuating cylinders or refrigeration equipment, any remaining refrigerant should be removed by a recovery system.
  - Vacuum pump discharge lines should be free of restrictions that could increase discharge pressures above 15 psig (205 kPa) and result in the formation of combustible mixtures.
  - Cylinders or refrigeration equipment should normally be evacuated at the start of filling, and should never be filled while under positive air pressure.
  - Final pressures should not exceed 300 psig (2,170 kPa).
  - Filled cylinders should periodically be analyzed for air (nonabsorbable gas or NAG).

- **Refrigerant Recovery Systems**

  Efficient recovery of refrigerant from equipment or containers requires evacuation at the end of the recovery cycle. Suction lines to a recovery compressor should be periodically checked for leaks to prevent compressing air into the recovery cylinder during evacuation. In addition, the recovery cylinder pressure should be monitored, and evacuation stopped in the event of a rapid pressure rise indicating the presence of noncondensable air. The recovery cylinder contents should then be analyzed for NAG, and the recovery system leak checked if air is present. Do not continue to evacuate a refrigeration system that has a major leak.

MONITORS AND LEAK DETECTION

Service personnel have used leak detection equipment for years when servicing equipment. Leak detectors exist not only for pinpointing specific leaks, but also for monitoring an entire room on a continual basis. There are several reasons for leak pinpointing or area monitoring, including conservation of HFCs, protection of valuable equipment, reduction of fugitive emissions and protection of employees.

Leak detectors can be placed into two broad categories: leak pinpointers and area monitors. Before purchasing a monitor or pinpointer, several instrumental criteria should be considered, including sensitivity, detection limits and selectivity.

TYPES OF DETECTORS

Using selectivity as a criterion, leak detectors can be placed into one of three categories: nonselective, halogen-selective or compound-specific. In general, as the specificity of the monitor increases, so does the complexity and cost. Another method used to find leaks is to add fluorescent dyes to the system.

A detailed discussion of leak detection, along with a list of manufacturers of leak detection equipment, is given in Bulletin ARTD-27 (H-31753-2).

NONSELECTIVE DETECTORS

Nonselective detectors are those that will detect any type of emission or vapor present, regardless of its chemical composition. These detectors are typically quite simple to use, very rugged, inexpensive and almost always portable. However, their inability to be calibrated, long-term drift, lack of selectivity and lack of sensitivity limit their use for area monitoring.

Some nonselective detectors designed for use with CFC-12 may have a much lower sensitivity when used with HFC-134a. However, newly designed detectors with good HFC-134a sensitivity are now available. Be sure to consult with the manufacturer before selecting or using a nonselective detector with HFC-134a.

HALOGEN-SELECTIVE DETECTORS

Halogen-selective detectors use a specialized sensor that allows the monitor to detect compounds containing fluorine, chlorine, bromine and iodine without interference from other species. The major advantage of such a detector is a reduction in the number of "nuisance alarms"—false alarms caused by the presence of some compound in the area other than the target compound.

These detectors are typically easy to use, feature higher sensitivity than the nonselective detectors (detection limits are typically <5 ppm when used as an area monitor and <0.05 oz/yr (<1.4 gm/yr) when used as a leak pinpointer), and are very durable. In addition, due to the partial specificity of the detector, these instruments can be calibrated easily.

COMPOUND-SPECIFIC DETECTORS

The most complex detectors, which are also the most expensive, are compound-specific detectors. These units are typically capable of detecting the presence of a single compound without interference from other compounds.

FLUORESCENT DYES

Fluorescent dyes have been used in refrigeration systems for several years. These dyes, invisible under ordinary lighting, but visible under ultraviolet (UV) light, are used to pinpoint leaks in systems. The dyes are typically placed into the refrigeration lubricant when the system is serviced. Leaks are detected by using a UV light to search for dye that has escaped from the system.

Recent innovations in dye technology have allowed fluorescent dyes to be used with HFC-134a. However, before adding dyes to a system, the compatibility of the specific dye with the lubricant and refrigerant should be tested.

DuPont has formed a partnership with Spectronics Corporation to supply refrigerant mixed with fluorescent additives and to assist in developing additives that are compatible with new alternative refrigerants. For additional information, contact DuPont.

STORAGE AND HANDLING

SHIPPING CONTAINERS IN THE U.S.

HFC-134a is a liquefied compressed gas. According to the U.S. Department of Transportation (DOT), a nonflammable compressed gas is defined as a nonflammable material having an absolute pressure greater than 40 psi at 21°C (70°F) and/or an absolute pressure greater than 104 psi at 54°C (130°F).

The appropriate DOT designations are as follows.

Proper shipping name: Refrigerant Gas, N.O.S. (Tetrafluoroethane)

Hazard class: Nonflammable Gas

UN/NA No.: UN 1078

A list of the different types of containers that can be used to ship HFC-134a in the United States, along with their water capacities, dimensions, DOT specifications and the net weights of HFC-134a, are provided in *Table 20*. All pressure relief devices used on the containers must be in compliance with the corresponding Compressed Gas Association (CGA) Standards for compressed gas cylinders, cargo and portable tanks.

The 30-lb and 123-lb cylinders designed for refrigerant applications are a light blue color with labels that bear the name of the product in light blue. The color designation is "Light Blue (Sky)," PMS 2975.

The 30-lb cylinder, known as a "Dispose A Can™" (D.A.C.) fits into a box that measures 10 in. x 10 in. x 17 in. Dispose A Can is DuPont's registered trade name for this type of single-use container. When used to ship SUVA* Cold-MP for the stationary refrigeration market, these 30-lb cylinders have the same outlet fittings as cylinders of CFC-12. However, when used for SUVA* Trans A/C for the automotive industry, these cylinders have a CGA-167 valve outlet. This fitting was specified by the Society of Automotive Engineers (SAE) to avoid mixing CFC-12 and HFC-134a when servicing mobile air conditioning systems. Additional unique fittings used with HFC-134a in automotive service applications are discussed in Bulletin ART-12 (H-45948).

The 123-lb cylinders are equipped with a nonrefillable liquid vapor CGA-660 valve. With this two-way valve, HFC-134a can be removed from the cylinder as either a vapor or as a liquid, without inverting the cylinder. The vapor handwheel is located on the top. The liquid wheel is on the side of the valve and attached to a dip tube extending to the bottom of the cylinder. Each is clearly identified as vapor or liquid.

The 4,400-gal cylinder is known as an ISO tank. The dimensions referenced in *Table 20* represent the frame in which the container is shipped. The tank itself has the same length of 20 ft and an outside diameter of approximately 86 in. ISO tanks are used for export shipments of HFC-134a from the United States.

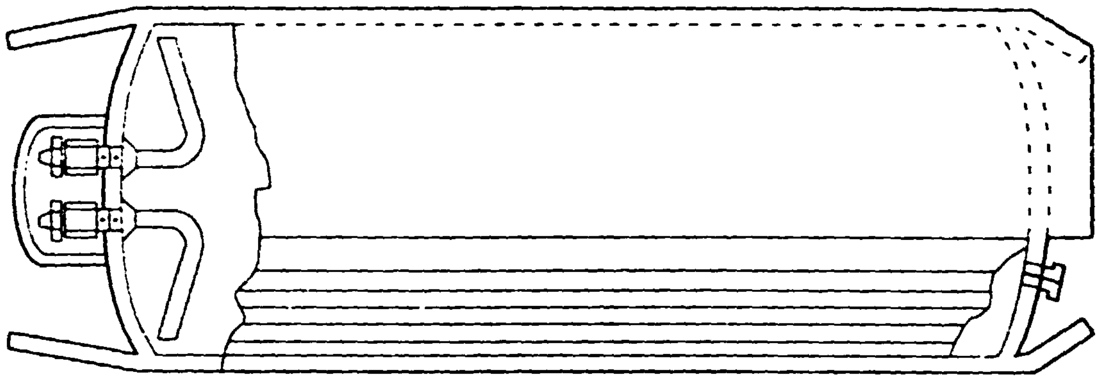
The general construction of a one-ton returnable container is shown in *Figure 9*. Notice that one end of the container is fitted with two valves. When the container is turned so that the valves are lined up vertically, the top valve will discharge vapor and the bottom valve will discharge liquid. The valves are protected by a dome cover.

TABLE 20
Specifications of Shipping Containers for HFC-134a

Water Capacity	Dimensions	DOT Specification	Net Weight (lb) HFC-134a
30 lb Dispose A Can**	10" x 10" x 17" (box)	39	30
123 lb	55" H x 10" OD	4BA300	125
1,682 lb	82" L x 30" OD	110A500W	1,750
5,000 gal	Tank Truck	MC-330 or -331	40,000
4,400 gal ISO	8' x 8.5' x 20' (frame)	51	30,865
170,000 lb	Tank Rail Car	114A340W	—

Dispose A Can is a registered trademark of the DuPont Company

Figure 9 One-Ton Returnable Container.



Ton containers are equipped with two fusible plugs in each end. The fusible metal in the plugs is designed to start melting at 69 C (157 F) and completely melt at 74 C (165 F). Containers should never be heated to temperatures higher than 52 C (125 F). One spring-loaded pressure relief valve is also located in each end of the ton container.

BULK STORAGE SYSTEMS

DuPont sells storage systems, at cost, to its HFC-134a customers. The systems are prefabricated, tested and ready to install on site. The units are designed to optimize economy, efficiency and safety in the storage and dispensing of HFC-134a. The delivered systems include all components, such as storage tanks, pumps, piping, valves, motors and gauges, as an integrated unit. All systems are equipped with the DuPont F.E.E.D. (Fluorochemical Emission Elimination Delivery) system to prevent emissions during deliveries, and with dual pumps to provide an installed spare. The units are skid-mounted and require only placement on a concrete pad and connection to electrical and process systems.

A typical bulk storage system is shown in *Figure 10*.

Your DuPont Marketing Representative can arrange for guidance on site selection, purchase, installation, start-up and maintenance.

CONVERTING BULK STORAGE TANKS FROM CFC-12 TO HFC-134a

Before switching from CFC-12 to HFC-134a, the existing storage equipment must be checked to verify that it is adequate. Storage tanks built to the specifications of the American Society of Mechanical Engineers (ASME) Pressure Vessel Code are required to have a metal nameplate indicating each tank's maximum allowable working pressure (MAWP). This rating must be 185 psig (1377 kPa absolute) or higher for HFC-134a service. In most cases, existing storage tanks that have been properly designed to contain CFC-12 will have an adequate pressure rating for HFC-134a. The set pressure of the relief devices on the top of the tanks must also be verified and changed if necessary.

We recommend that storage tanks be **completely** emptied of all CFC-12 liquid and vapor before introducing HFC-134a. In general, converting a storage tank from CFC-12 to HFC-134a requires:

1. Removing CFC-12 from the storage tank, lines and equipment
2. Evacuating the storage tank to 25 inches of mercury vacuum (16.7 kPa absolute pressure) and purging with compressed dry nitrogen gas
3. Making necessary repairs to the tank after initial evacuation and purging
4. Repeating step 2 until CFC-12 and moisture analyses are within acceptable limits
5. Refilling system with HFC-134a

The above is a simplified outline of what is actually a lengthy procedure. Your DuPont Marketing Representative can assist in obtaining the equipment, instrumentation and technical assistance to safely and effectively make the conversion.

MATERIAL COMPATIBILITY CONCERNS

Most metal components suitable for use with CFC-1[2] are also compatible with HFC-134a, including standar[d] types of carbon steel, aluminum and copper. Som[e] elastomeric or nonmetallic components suitable f[or] CFC-12 may not be adequate. Therefore, all elast[o]meric or nonmetallic components throughout the sy[s]tem must be identified and their compatibility with HF[C-]134a verified. See Materials Compatibility section. F[or] complete reliability, any component that cannot be pr[op]erly identified should be replaced.

In a fluorocarbon storage system, elastomers are most commonly found in:

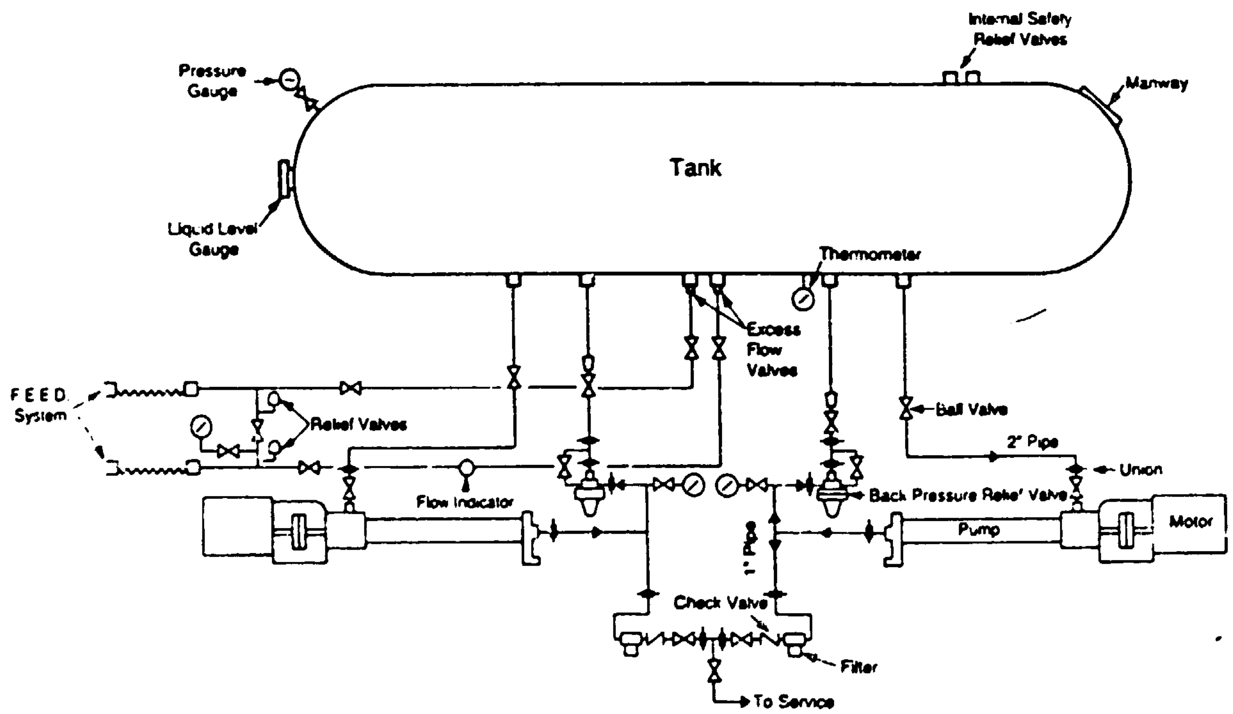
- Packing and seats of manual valves
- Pressure-relief device seats
- Flange and manway gaskets
- Mechanical pump seals
- Wet-end pump gaskets and O-rings
- Filter O-rings
- Sight-flow indicator gaskets
- Back-pressure regulator diaphragms and O-rings.

HANDLING PRECAUTIONS FOR HFC-134a SHIPPING CONTAINERS

The following rules for handling HFC-134a containers are strongly recommended:

- Use personal protective equipment, such as side shield glasses, gloves and safety shoes when handling HFC-134a containers.
- Avoid skin contact with liquid HFC-134a, since it may cause frostbite.
- Never heat a container to a temperature higher than 52°C (125°F).
- Never apply direct flame or live steam to a container or valve.
- Never refill disposable cylinders with anything. The shipment of refilled disposable cylinders is prohibited by DOT regulations.
- Never refill returnable cylinders without DuPont consent. DOT regulations forbid transportation of returnable cylinders refilled without DuPont's authorization.
- Never use a lifting magnet or sling (rope or chain) when handling containers. A crane may be used when a safe cradle or platform is used to hold the container.

Figure 10. Typical Bulk Storage System.



- Never use containers as rollers, supports or for any purpose other than to carry HFC-134a
- Protect containers from any object that will result in a cut or other abrasion in the surface of the metal
- Never tamper with the safety devices in the valves or containers
- Never attempt to repair or alter containers or valves.
- Never force connections that do not fit. Make sure the threads on the regulators or other auxiliary equipment are the same as those on the container valve outlets.
- Keep valves tightly closed and valve caps and hoods in place when the containers are not in use.
- Store containers under a roof to protect them from weather extremes.
- Use a vapor recovery system to collect HFC-134a vapors from lines after unloading.

RECOVERY, RECLAMATION, RECYCLE AND DISPOSAL

Responsible use of HFC-134a requires that the product be recovered for reuse or disposal whenever possible. DuPont purchases used refrigerants for reclamation through its distributor networks in the United States, Canada and Europe. In the United States, used HFC-134a is accepted as part of this program. Recovery and reuse of HFC-134a makes sense from an environmental and economic standpoint. In addition, the U.S. Clean Air Act will prohibit known venting of HFC-134a in late 1995 during the maintenance, servicing or disposal of refrigeration equipment.

RECOVERY

Recovery refers to the removal of HFC-134a from equipment and collection in an appropriate external container. As defined by the Air Conditioning and Refrigeration Institute (ARI), a U.S. organization, recovery does not involve processing or analytical testing. HFC-134a may be recovered from refrigeration equipment using permanent on-site equipment or one of the portable recovery devices now on the market. The portable devices contain a small compressor and an air cooled condenser, and may be used for vapor or liquid recovery. At the end of the recovery cycle, the system is evacuated to remove vapors. In the United States, the Environmental Protection Agency (EPA) sets standards for recovery equipment. Before purchasing a specific recovery unit, check with the manufacturer to be sure that it contains elastomeric seals and a compressor oil compatible with HFC-134a.

RECLAMATION

Reclamation refers to the reprocessing of used HFC-134a to new product specifications. Quality of reclaimed product is verified by chemical analysis. In the United States, HFC-134a is included in DuPont's refrigerant reclamation program. Contact DuPont or one of its authorized distributors for further information.

Reclamation offers advantages over on-site refrigerant recycling procedures because these systems cannot guarantee complete removal of contaminants. Putting refrigerants that do not meet new product specifications back into expensive equipment may cause damage.

RECYCLE

Refrigerant recycle refers to the reduction of used refrigerant contaminants using devices that reduce oil, water, acidity and particulates. Recycle is usually a field or shop procedure with no analytical testing of refrigerant. HFC-134a may be recycled using one of the devices now on the market. In the United States, the EPA sets standards for these devices. Recycle is becoming the accepted practice in the U.S. mobile air conditioning service industry. Consult with the manufacturer before specifying a recycle device for HFC-134a.

DISPOSAL

Disposal refers to the destruction of used HFC-134a. Disposal may be necessary when HFC-134a has become badly contaminated with other products and no longer meets the acceptance specifications of DuPont or other reclaimers. Although DuPont does not presently accept severely contaminated refrigerants for disposal, licensed waste disposal firms are available. Be sure to check the qualifications of any firm before sending them used HFC-134a.

DuPont Chemicals
Fluorochemicals Customer Service Center
Wilmington, DE 19898

For sales information:
1-800-441-9442
In Delaware (302) 774-2099

For technical information:
1-800-582-5606
In Delaware (302) 999-3129

Europe
DuPont de Nemours
International S.A.
2 Chemin du Pavillon
P.O. Box 50
CH-1218 Le Grand-Saconnex
Geneva, Switzerland
41-22-717-5111

Canada
DuPont Canada, Inc
P.O. Box 2200, Streetsville
Mississauga, Ontario
L5M 2H3
(416) 821-3300

Mexico
DuPont, S.A. de C.V
Homero 206
Col. Chapultepec Morales
C.P. 11570 Mexico, D.F.
52-5-250-8000

South America
DuPont do Brasil S.A.
Alameda Itapicuru, 506
Alphaville 06400 Barueri
São Paulo, Brazil
55-11-421-8509

DuPont Argentina S.A.
Casilla Correo 1888
Correo Central
1000 Buenos Aires, Argentina
54-1-311-8167

Pacific
DuPont Australia
P.O. Box 930
North Sydney, NSW 2060
Australia
61-2-923-6165

Japan
Mitsui DuPont Fluoro-
chemicals Company, Ltd.
Mitsui Seimei Building
2-3, 1-Chome Ohtemachi
Chiyoda-Ku, Tokyo 100 Japan
81-3-3216-8451

Asia
DuPont Taiwan
P.O. Box 81-777
Taipei, Taiwan
886-2-514-4400

DuPont Asia Pacific Limited
P.O. Box TST 98851
Tsim Sha Tsui
Kowloon, Hong Kong
852-734-5345

DuPont Thailand
P.O. Box 2398
Bangkok 10501, Thailand
66-2-238-4361

DuPont China Ltd.
Room 1704, Union Bldg
100 Yanan Rd. East
Shanghai, PR China 200 002
Phone 86-21-328-3738
Telex 33448 DCLSH CN
Fax 86-21-320-2304

DuPont Far East Inc
P.O. Box 12396
50776 Kuala Lumpur,
Malaysia
Phone 60-3-232-3522
Telex (784) 30391 DUFE M
Fax 60-3-238-7250

DuPont Korea Ltd.
C.P.O. Box 5972
Seoul, Korea
82-2-721-5114

DuPont Singapore Pte. Ltd.
1 Maritime Square #07 01
World Trade Centre
Singapore 0409
65-273-2244

DuPont Far East, Philippines
5th Floor, Solid Bank Bu[illegible]
777 Paseo de Roxas
Makati, Metro Manila
Philippines
63-2-818-9911

DuPont Far East Inc.
7A Murray's Gate Road
Alwarpet
Madras, 600 018 India
91-44-454-029

DuPont Far East Inc.—
Pakistan
9 Khayaban-E-Shaheen
Defence Phase 5
Karachi, Pakistan
92-21-533-350

DuPont Far East Inc.
P.O. Box 2553/Jkt
Jakarta 10001
Indonesia
62-21-517-800

(Stock number on last page of text)

Goldstar Company

RECIPROCATING COMPRESSOR DIVISION

VS / NR / V – Series
L B P
220 – 240V / 50Hz

R134a

PARTS LIST OF GOLDSTAR COMPRESSOR

TO : GOLDSTAR COMP. EXPORT SECTION
FAX : 82-2-787-3074
FROM :

◆ CUSTOMER :

◆ COMP. MODEL :

◆ SPEC. NO. :

DATE : . .

DRAWN	APPROVED

* RATED VOLTAGE :

* LIST OF ACCESSORY PARTS

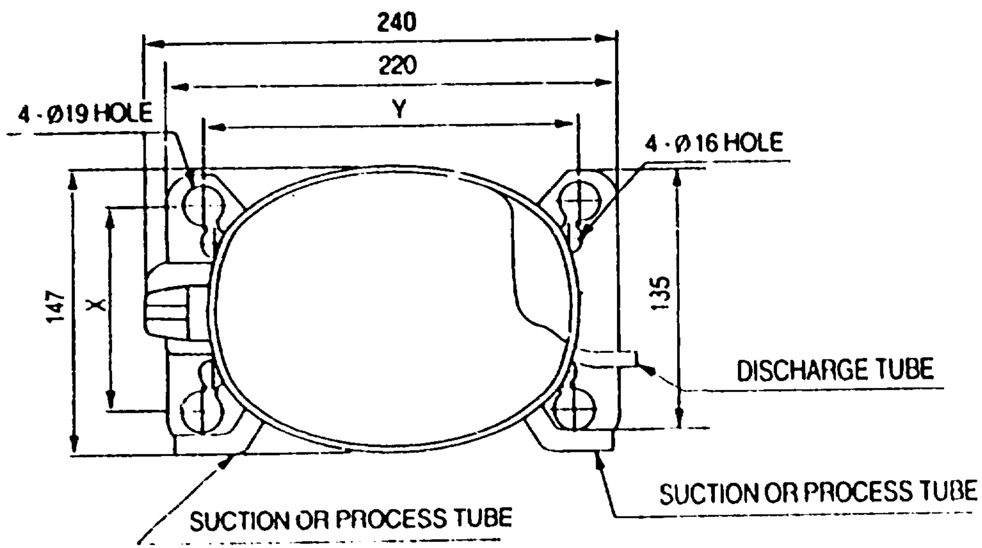
	DWG. NO.	PART NO.	Q'TY	SPECIFICATION
ELECTRICAL PARTS				
OVERLOAD PROTECTOR				
P T C				
PTC COVER				
MOUNTING PARTS				
SEAT RUBBER				
BOLT				
PIECE MOUNTINC				
PLAIN WASHER				
SPRING WASHER				
NUT				

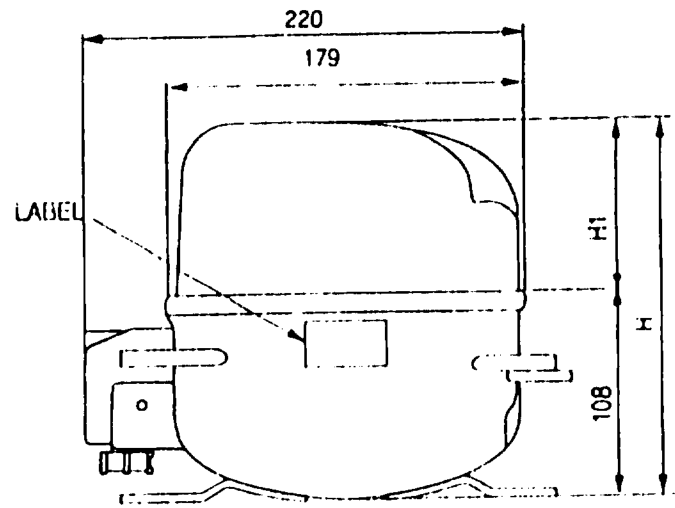
• CUSTOMER'S MEMO •

CUSTOMER'S DECISION
Decision : YES , NO
Signature :

• Please return one copy of this page on your approval.

NR – Series





* TUBE SPECIFICATION

	Suction & Process Tube (T 0.7)	Discharge Tube (T 1.0)
O.D/ I.D (mm) COPPER	8.0 / 6.6 8.0 / 6.1	6.95/ 4.95

* MOUNTING PITCH

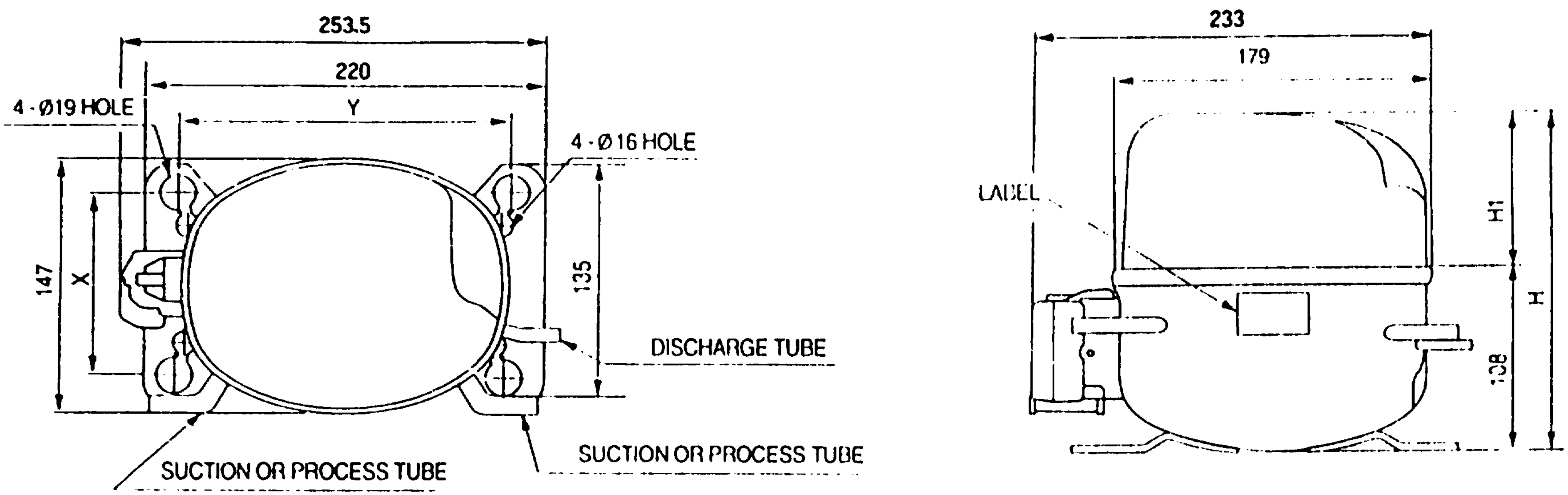
TYPE	X	Y
FLAT	106	184
	70	170

MODEL	H	H1
NR45/52	173	65
NR58/62	177	69

TITLE	COMP. APPEARANCE
DWG. NO.	APR – F142

GoldStar

NR – Series



*** TUBE SPECIFICATION**

	Suction & Process Tube (T 0.7)	Discharge Tube (T 1.0)
O.D/ I.D (mm) COPPER	8.0 / 6.6 8.0 / 6.1	6.95 / 4.95

*** MOUNTING PITCH**

TYPE	X	Y
FLAT	106	184
	70	170

MODEL	H	H1
NR45/52	173	65
NR58/62	177	69

TITLE	COMP. APPEARANCE
DWG. NO.	APR – FI52

R134a, 50Hz/LBP Application

Series	Model	Displacement	Motor Type	Compressor Cooling	Refrigerant Control	Oil Charge	Weight	"ASHRAE" Performance												"CECOMAF" Performance				
								Capacity						Power consumption						Capacity				
								Evaporating temp. (℃)						Evaporating temp. (℃)						Evaporating temp. (℃)				
								-30	-25	-23.3	-20	-15	-10	-30	-25	-23.3	-20	-15	-10	-30	-25	-20	-15	-10
		cc				cc	kg(lb)	kcal/h	kcal/h	kcal/h	kcal/h	kcal/h	kcal/h	w	w	w	w	w	w	kcal/h	kcal/h	kcal/h	kcal/h	kcal/h
VS	VS24L	2.42	RSIR	N	C	200	4.8 (10.6)	–	39	43	54	73	94	–	76	78	83	92	100	–	31	43	59	76
	VS28L	2.84	RSIR	N	C	200	5.8 (12.8)	–	48	55	67	92	120	–	78	80	86	95	104	–	39	54	75	97
	VS36L	3.58	RSIR	N	C	200	5.8 (12.8)	–	67	72	88	115	146	–	89	93	100	112	125	–	54	72	93	119
NR	NR45L	4.50	RSIR	N	C	210	8.5 (18.7)	59	84	93	114	146	189	87	100	104	114	126	143	49	67	90	117	149
	NR52L	5.20	RSIR	N	C	210	8.5 (18.7)	75	101	113	135	173	220	98	112	119	128	146	164	61	82	108	140	179
	NR62L	6.22	RSIR	N	C	210	8.8 (19.4)	87	122	134	163	209	267	108	128	132	148	167	190	69	99	131	166	215
V	V75L	7.46	RSIR	F, O	C	390	10.2 (22.5)	110	152	167	204	262	334	127	150	157	172	193	224	87	123	162	212	269

1) Performance data were obtained under 230V/50Hz running condition.
2) The High Efficiency models "RSCR" can be also available with permanent run capacitor
3) Refrigerant Control : C (Capillary tube)
4) Voltage range : 187V~264V

Compressor Cooling

N = Natural Convection
O = Oil Cooling
F = Fan Cooling

Test Conditions

	ASHRAE	CECOMAF
Condensing temperature	54.4 ℃ (130 °F)	55 ℃ (131 °F)
Gas superheated to	32.2 ℃ (90 °F)	32 ℃ (90 °F)
Liquid subcooled to	32.2 ℃ (90 °F)	55 ℃ (131 °F)
Ambient temperature	32.2 ℃ (90 °F)	32 ℃ (90 °F)

Notes

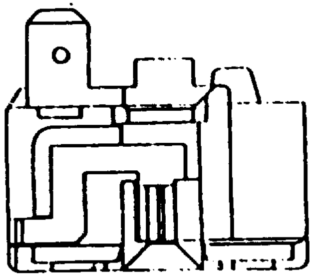
1) Capacity Conversion
1kcal/h = 3.97 Btu/h
1kcal/h = 1.16 Watt

2) $\text{E.E.R(Btu/Wh)} = \dfrac{\text{Capacity (kcal/h)} \times 3.97}{\text{Motor input(Watt)}}$

3) RSIR = Resistance Start Induction Run
RSCR = Resistance Start Capacitor Run

TITLE	PERFORMANCE DATA
DWG. NO.	PER--HF5A

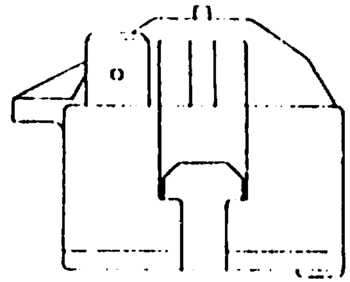
• OLP (TEXAS INSTRUMENT)



ex) 4TM 330 KFB YY−52

- 4TM — Basic Name of Thermal Motor Protector
- 330 — Three digit Heater Code
- KFB — Designate Disc, Operating Temp. and Tolerance
- YY — Denotes Contact Capacity
- 52 — External Terminations (Male Quick Connects)

• PTC Starter



ex) P 6R8 M C

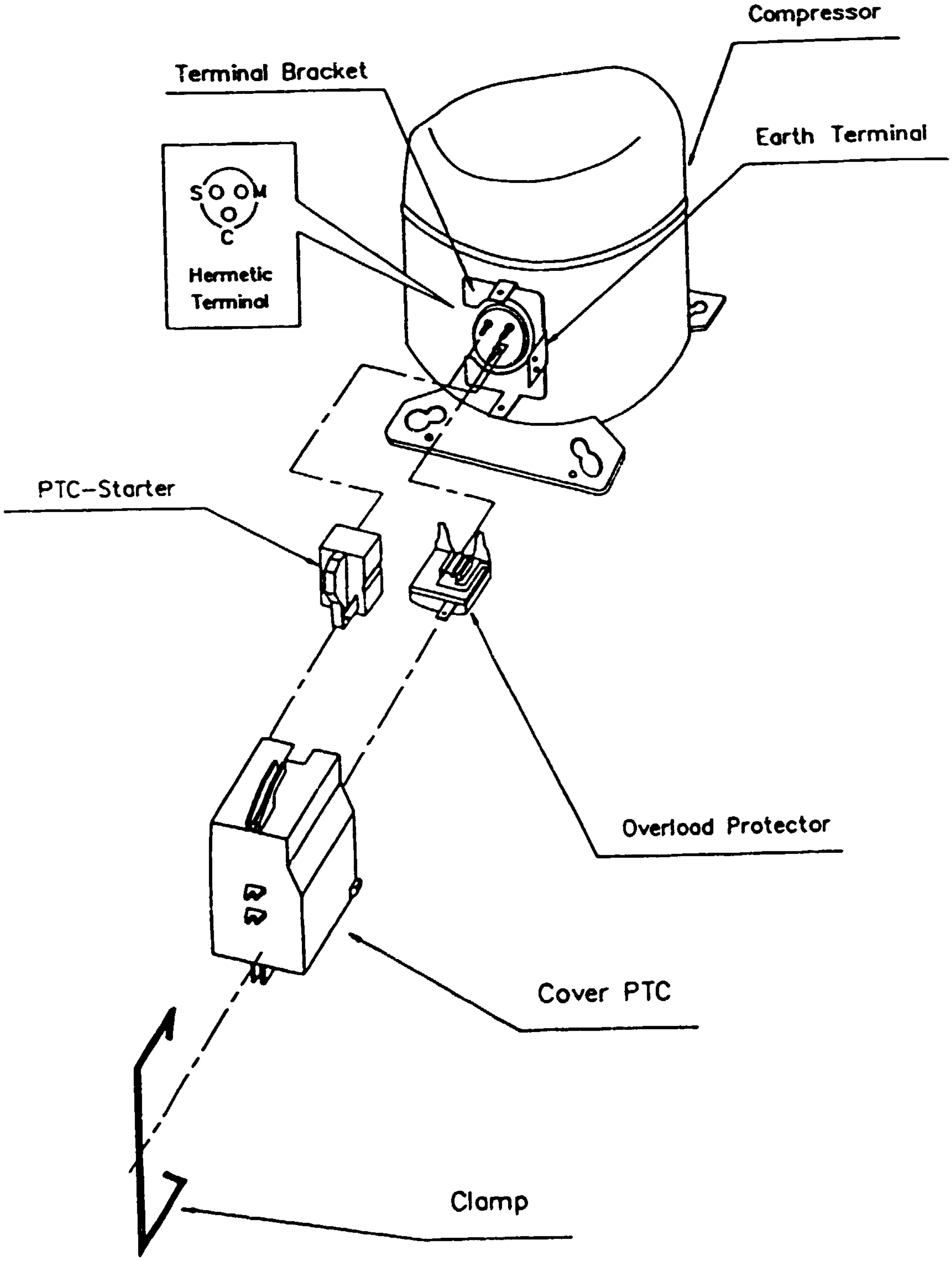
- P — PTC Starter
- 6R8 — Norminal resistance(6.8 ohms)
- M — Tolerance of the resistance(±20%)
- C — Starting type

			VS24LAEG	VS28LAEG	VS36LAEG	NR45LAEG	NR52LAEG	NR62LAEG	V75LAEG
OLP	TYPE (Part No)		4TM117SFB (3C00301D)	4TM149NFB (3C00301A)	4TM149NFB (3C00301A)	4TM166RFB (3C00301H)	4TM232NFB (3C00301G)	4TM205RFB (3C00404L)	4TM276LFB (3C00301F)
	OPEN TEMP. (℃)		135^{+10}_{-5}	120^{+10}_{-5}	120^{+10}_{-5}	130^{+10}_{-5}	120^{+10}_{-5}	130^{+10}_{-5}	110^{+10}_{-5}
	CLOSE TEMP. (℃)		61±9	61±9	61±9	61±9	61±9	61±9	61±9
	ULTIMATE TRIP CURRENT(A)		0.8～1.2	0.95～1.2	0.95～1.2	1.1～1.44	1.57～1.90	1.6～2.0	1.62～2.0
	SHORT TIME	CURRENT(A)	3.5	4.3	4.3	4.92	7.47	6.46	9.09
		FIRST TRIP TIME(SEC)	10±5	10±5	10±5	10±5	10±5	10±5	10±5
		RECOVERY TIME(SEC)	MIN. 50	MIN. 50	MIN. 50	MIN. 50	MIN. 50	MIN. 50	MIN. 50
PTC	TYPE (Part No)		P220MC (2C00146A)	P220MC (2C00146A)	P220MC (2C00146A)	P220MC (2C00146A)	P330MC (2C00146C)	P330MC (2C00146C)	P470MC (2C00146B)
	RESISTANCE AT 25 ℃ (Ω)		22±20%	22±20%	22±20%	22±20%	33±20%	33±20%	47±20%
	Max. VOLTAGE(Vrms)		300	300	300	300	355	355	400
	Max. CURRENT(Arms)		7	7	7	7	6	6	5

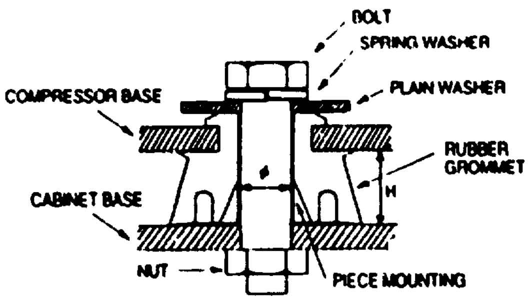
TITLE	ELECTRICAL PARTS
DWG. NO.	ELE－1510

GoldStar

TITLE	EXPLODED VIEW
DWG. NO.	EXP-WCT1

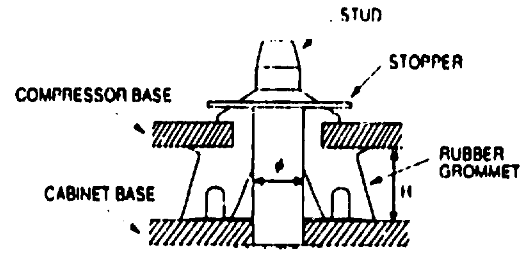


* BOLT TYPE



	P / NO	ϕ	H
RUBBER GROMMET	3C00434A	ϕ 9	10
	4022C-0101A	ϕ 8	10.5
	4022C-0102A	ϕ 11	9.5
	3C00181A	ϕ 8.3	16
	3C00413A	ϕ 8.3	22
	3C00181B	ϕ 8.3	22
	3C00181C	ϕ 8.3	28

* SNAP-ON TYPE



1) BOLT TYPE ASSEMBLY

CHECK	RUBBER GROMMET	BOLT (M6*P1)	PIECE MOUNTING	PLAIN WASHER (O.D 25)	SPRING WASHER	NUT (M6*P1)
( ) ( )	3C00434A 4022C-0101A	1BHD0603906	3C00286D	4040C-0101A	1WSD0600030	NHC3030D
( )	4022C-0102A	1BHD0603906	3C00286F	4040C-0101A	1WSD0600030	NHC3030D
( )	3C00181A	1BHD0604306	3C00286E	4040C-0101A	1WSD0600030	NHC3030D
( ) ( )	3C00413A 3C00181B	1BHD0604806	3C00286A	4040C-0101A	1WSD0600030	NHC3030D
( )	3C00181C	1BHD0605106	3C00286B	4040C-0101A	1WSD0600030	NHC3030D

2) SNAP-ON TYPE ASSEMBLY

CHECK	RUBBER GROMMET	STUD	STOPPER
( ) ( )	3C00413A 3C00181B	3C00388A	4J02686A
( ) ( )	3C00434A 4022C-0101A	3C00388B	4J02686A

* Checked(V) Item will be supplied

TITLE	MOUNTING ACCESSORY
DWG. NO.	ACC-0001

SUVA®

Refrigerant

HFC-134a

(1,1,1,2-TETRAFLUOROETHANE)

DU PONT

T-134a

Thermodynamic Properties of SUVA® Refrigerant HFC-134a

(1,1,1,2-TETRAFLUOROETHANE)

PROPRIÉTÉS THERMODYNAMIQUES DU FLUIDE FRIGORIGÈNE HFC-134a
THERMODYNAMISCHE EIGENSCHAFTEN DES KÄLTEMITTELS FKW-134a
PROPRIETÀ TERMODINAMICHE DEL REFRIGERANTE HFC-134a
PROPIEDADES TERMODINAMICAS DEL REFRIGERANTE HFC-134a
TERMODYNAMISKE EGENSKAPER FOR HFC-134a KJØLEVÆSKE

DU PONT

TABLE I: SATURATION PROPERTIES SUVA HFC - 134a

TEMP t °C	PRESS p bar	DENSITY ρ' (kg/m³) liquid	ρ" vapour	ENTHALPY h' (kJ/kg) liquid	h"-h' latent	h" vapour	ENTROPY s' (kJ/(kg·K)) liquid	s" vapour	SPEC. HEAT CAP. cp' (kJ/(kg·K)) liquid	cp" vapour	TENS σ N/m	TEMP t °C
-99	[illegible]	1577.8	0.044	78.4	259.4	337.8	0.451	1.941	[illegible]	[illegible]	0.0274	[illegible]
-98	[illegible]	1575.0	0.049	79.5	257.8	338.4	0.458	1.936	[illegible]	[illegible]	0.0272	-98
-97	[illegible]	1572.3	0.054	80.7	258.2	339.0	0.465	1.931	[illegible]	[illegible]	0.0270	-97
-96	0.009	1569.5	0.059	81.9	257.7	339.5	0.471	1.926	[illegible]	[illegible]	0.0269	-96
-95	[illegible]	1566.8	0.065	83.0	[illegible]	340.1	0.478	1.921	[illegible]	[illegible]	0.0267	-95
-94	0.010	1564.1	0.072	84.2	256.5	340.7	0.484	1.916	1.151	0.605	0.0265	-94
-93	0.012	1561.3	0.079	85.3	256.0	341.3	0.491	1.912	1.151	0.608	0.0263	-93
-92	0.013	1558.6	0.086	86.5	255.4	341.9	0.497	1.907	1.152	0.610	0.0262	-92
-91	0.014	1555.8	0.094	87.6	254.9	342.5	0.503	1.903	1.152	0.612	0.0260	-91
-90	0.015	1553.1	0.103	88.8	254.3	343.1	0.510	1.896	1.153	0.614	0.0258	-90
-89	0.017	1550.4	0.112	89.9	253.8	343.7	0.516	1.894	1.153	0.617	0.0257	-89
-88	0.018	1547.6	0.122	91.1	253.2	344.3	0.522	1.890	1.154	0.619	0.0255	-88
-87	0.020	1544.9	0.133	92.3	252.7	344.9	0.528	1.886	1.155	0.621	0.0253	-87
-85	0.022	1542.1	0.145	93.4	252.1	345.5	0.534	1.892	1.156	0.624	0.0251	-86
-85	0.024	1539.4	0.158	94.6	251.6	346.2	0.541	1.878	1.157	0.626	0.0250	-85
-84	0.026	1536.7	0.171	95.7	251.0	346.8	0.547	1.874	[illegible]	[illegible]	0.0248	-84
-83	0.029	1533.9	0.185	96.9	250.5	347.4	0.553	1.870	[illegible]	[illegible]	0.0246	-83
-82	0.031	1531.2	0.201	98.0	249.9	348.0	0.559	1.867	[illegible]	[illegible]	0.0245	-82
-81	0.034	1528.5	0.217	99.2	249.4	348.6	0.565	1.863	[illegible]	[illegible]	0.0243	-81
-80	0.037	1525.7	0.235	100.4	248.8	349.2	0.571	1.859	[illegible]	[illegible]	0.0241	-80
-79	0.040	[illegible]	0.253	101.5	248.3	349.8	0.577	1.856	1.165	0.640	0.0240	-79
-78	0.043	1520.2	0.273	102.7	247.7	350.4	0.583	1.853	1.167	0.642	0.0238	-78
-77	0.047	1517.5	0.295	103.9	247.2	351.1	0.589	1.849	1.168	0.645	0.0236	-77
-76	0.051	1514.8	0.317	105.0	246.6	351.7	0.595	1.846	1.170	0.647	0.0235	-76
-75	0.055	1512.0	0.341	106.2	246.1	352.3	0.601	1.843	1.172	0.649	0.0233	-75
-74	0.059	1509.3	[illegible]	107.4	245.5	352.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-74
-73	[illegible]	1506.5	[illegible]	[illegible]	[illegible]	353.5	0.613	[illegible]	[illegible]	[illegible]	[illegible]	-73
-72	[illegible]	1503.8	[illegible]	[illegible]	244.4	354.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-72
-71	0.074	1501.0	[illegible]	[illegible]	[illegible]	354.8	[illegible]	1.831	[illegible]	[illegible]	[illegible]	-71
-70	0.080	1498.3	[illegible]	[illegible]	[illegible]	355.4	0.630	1.828	[illegible]	[illegible]	0.0225	-70
-69	0.086	1495.5	0.520	113.3	242.8	356.0	0.636	1.825	1.182	0.664	0.0223	-69
-68	0.092	1492.8	0.556	114.5	242.2	356.6	0.642	1.822	1.184	0.667	0.0221	-68
-67	0.039	1490.0	0.594	115.6	241.6	357.3	0.648	1.820	1.186	0.669	0.0220	-67
-66	0.106	1487.3	0.634	116.8	241.1	357.9	0.653	1.817	1.188	0.672	0.0218	-66
-65	0.114	1484.5	0.677	118.0	240.5	358.5	0.659	1.814	1.190	0.674	0.0216	-65
-64	0.122	1481.8	0.722	119.2	239.9	359.2	0.665	1.812	1.192	0.677	0.0215	-64
-63	0.130	1479.0	0.769	120.4	239.4	359.8	0.670	1.810	1.194	0.679	0.0213	-63
-62	0.139	1476.3	0.819	121.6	238.8	360.4	0.676	1.807	1.196	0.682	0.0212	-62
-61	0.149	1473.5	0.871	122.8	238.2	361.0	0.682	1.805	1.198	0.684	0.0210	-61
-60	0.159	1470.7	0.926	124.0	237.7	361.7	0.687	1.802	1.200	0.687	0.0208	-60
-59	0.170	1468.0	0.984	125.2	237.1	362.3	0.693	1.800	1.202	0.690	0.0207	-59
-58	0.181	1465.2	1.044	126.4	236.5	362.9	0.699	1.798	1.204	0.692	0.0205	-58
-57	0.193	1462.4	1.108	127.6	236.0	363.6	0.704	1.796	1.206	0.695	0.0204	-57
-56	0.205	1459.6	1.175	128.8	235.4	364.2	0.710	1.794	1.208	0.698	0.0202	-56
-55	0.218	1456.9	1.245	130.0	234.8	364.8	0.715	1.792	1.210	0.701	0.0200	-55
-54	0.232	1454.1	1.318	131.2	234.2	365.4	0.721	1.790	1.212	0.703	0.0199	-54
-53	0.246	1451.3	1.395	132.4	233.6	366.1	0.726	1.788	1.214	0.706	0.0197	-53
-52	0.261	1448.5	1.476	133.7	233.1	366.7	0.732	1.786	1.216	0.709	0.0196	-52
-51	0.277	1445.7	1.560	134.9	232.5	367.3	0.737	1.784	1.218	0.712	0.0194	-51
-50	0.294	1442.9	1.648	136.1	231.9	368.0	0.743	1.782	1.220	0.714	0.0192	-50

SYMBOLS AND UNITS

Texte en français

TABLEAU I SUVA FLUIDE FRIGORIGÈNE HFC-134a - PROPRIETES DE SATURATION

TEMP	PRESS	MASSE VOLUMI		ENTHALPIE			ENTROPIE		CAPACITE SPECIF		TENS	TEMP
t	p	ρ'	ρ''	h'	h''-h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		liquide	vapeur	liquide	latente	vapeur	liquide	vapeur	liquide	vapeur		

Deutscher Text

TABELLE I SUVA KÄLTEMITTEL FKW-134a - SÄTTIGUNGSEIGENSCHAFTEN

TEMP	DRUCK	DICHTE		ENTHALPIE			ENTROPIE		SPEZ WARMEKAP		SPANN	TEMP
t	p	ρ'	ρ''	h'	h''-h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		flüssig	dampf	flüssig	latent	dampf	flüssig	dampf	flüssig	dampf		

Texto en español

CUADRO I PROPIEDADES DE SATURACION DEL SUVA FLUIDO FRIGORIFICO HFC-134a

TEMP	PRESION	MASA VOLUMET		ENTHALPIA			ENTROPIA		CALOR ESPECIF		TENS	TEMP
t	p	ρ'	ρ''	h'	h''-h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·grd)		kJ/(kg·grd)		N/m	°C
		liquido	vapor	liquido	latente	vapor	liquido	vapor	liquido	vapor		

Testo in italiano

TABELLA I PROPRIETÀ DI SATURAZIONE DEL SUVA FLUIDO FRIGORIGENO HFC-134a

TEMP	PRESS	VOLUME MASSICO		ENTHALPIA			ENTROPIA		CALORE ESPECIF		TENS	TEMP
t	p	ρ'	ρ''	h'	h''-h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		liquido	vapore	liquido	latente	vapore	liquido	vapore	liquido	vapore		

Norsk tekst

TABELL I EGENSKAPER VED METNINGSPUNKT FOR SUVA REFRIGERANT HFC-134a

TEMP	TRYKK	TETTHET		ENTHALPY			ENTROPY		SPESIF VARMEKAP		SPENN	TEMP
t	p	ρ'	ρ''	h'	h''-h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		vaeske	damp	vaeske	latent	damp	vaeske	damp	vaeske	damp		

TABLE I: SATURATION PROPERTIES SUVA HFC - 134a

TEMP	PRESS	DENSITY		ENTHALPY			ENTROPY		SPEC. HEAT CAP.		TENS	TEMP
t	p	ρ'	ρ''	h'	h''-h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		liquid	vapour	liquid	latent	vapour	liquid	vapour	liquid	vapour		
1	3.04	[illegible]	14.946	201.3	198.0	399.4	1.005	1.727	1.344	0.893	0.0116	1
2	3.15	[illegible]	15.472	202.7	197.3	400.0	1.010	1.727	1.347	0.897	0.0115	2
3	3.26	1283.4	16.013	204.0	196.5	400.5	1.015	1.726	1.350	0.902	0.0113	3
4	3.39	[illegible]	16.539	205.4	195.7	401.1	1.020	1.726	1.353	0.905	0.0112	4
5	3.50	[illegible]	17.140	206.8	194.3	401.7	1.024	1.725	1.357	0.911	0.0110	5
6	3.62	1273.4	17.725	208.1	194.2	402.3	1.029	1.725	1.360	0.915	0.0109	6
7	3.75	1270.0	18.329	209.5	193.4	402.8	1.034	1.724	1.363	0.920	0.0107	7
8	3.88	1266.5	18.948	210.8	192.6	403.4	1.039	1.724	1.366	0.925	0.0106	8
9	4.01	1263.2	19.583	212.2	191.8	404.0	1.044	1.723	1.370	0.929	0.0105	9
10	4.15	1259.8	20.236	213.6	190.9	404.5	1.049	1.723	1.373	0.934	0.0103	10
11	4.29	1256.3	20.906	215.0	190.1	405.1	1.053	1.722	1.377	0.939	0.0102	11
12	4.43	1252.9	21.594	216.4	189.3	405.6	1.058	1.722	1.380	0.944	0.0100	12
13	4.58	1249.4	22.301	217.7	188.5	406.2	1.063	1.722	1.384	0.949	0.0099	13
14	4.73	1245.9	23.025	219.1	187.6	406.8	1.068	1.721	1.387	0.954	0.0095	14
15	4.89	1242.3	23.770	220.5	186.8	407.3	1.073	1.721	1.391	0.960	0.0096	15
16	5.05	1238.8	24.533	221.9	185.9	407.8	1.077	1.720	1.395	0.965	0.0095	16
17	5.21	1235.2	25.317	223.3	185.1	408.4	1.082	1.720	1.399	0.970	0.0094	17
18	5.38	1231.6	26.121	224.7	184.2	408.9	1.087	1.720	1.402	0.976	0.0092	18
19	5.55	1228.0	26.945	226.1	183.3	409.5	1.092	1.719	1.406	0.981	0.0091	19
20	5.72	1224.4	27.791	227.5	182.5	410.0	1.096	1.719	1.410	0.987	0.0089	20
21	5.90	1220.7	28.659	228.9	181.6	410.5	1.101	1.719	1.414	0.992	0.0088	21
22	6.08	1217.0	29.549	230.4	180.7	411.0	1.105	1.718	1.418	0.998	0.0087	22
23	6.27	1213.3	30.462	231.8	179.8	411.6	1.111	1.718	1.423	1.004	0.0085	23
24	6.46	1209.6	31.399	233.2	178.9	412.1	1.116	1.718	1.427	1.010	0.0084	24
25	6.66	1205.9	32.359	234.6	178.0	412.6	1.120	1.717	1.431	1.015	0.0083	25
26	6.86	1202.1	33.344	236.1	177.0	413.1	1.125	1.717	1.435	1.022	0.0081	26
27	7.07	1198.2	34.354	237.5	176.1	413.6	1.130	1.717	1.440	1.028	0.0080	27
28	7.28	1194.4	35.389	238.9	175.2	414.1	1.135	1.716	1.445	1.035	0.0079	28
29	7.49	1190.5	36.451	240.4	174.2	414.5	1.139	1.716	1.449	1.041	0.0077	29
30	7.71	1186.7	37.540	241.8	173.3	415.1	1.144	1.716	1.454	1.048	0.0076	30
31	7.93	1182.8	38.657	243.3	172.3	415.6	1.149	1.715	1.459	1.055	0.0075	31
32	8.16	1178.8	39.802	244.8	171.3	416.1	1.153	1.715	1.464	1.062	0.0073	32
33	8.40	1174.9	40.975	246.2	170.3	416.6	1.158	1.715	1.469	1.069	0.0072	33
34	8.64	1170.8	42.179	247.7	169.3	417.0	1.163	1.714	1.474	1.076	0.0071	34
35	8.88	1166.8	43.413	249.2	168.3	417.5	1.168	1.714	1.479	1.084	0.0069	35
36	9.13	1162.7	44.679	250.6	167.3	418.0	1.172	1.714	1.485	1.091	0.0068	36
37	9.38	1158.6	45.977	252.1	166.3	418.4	1.177	1.713	1.490	1.099	0.0067	37
38	9.64	1154.5	47.308	253.6	165.3	418.9	1.182	1.713	1.496	1.107	0.0065	38
39	9.91	1150.3	48.672	255.1	164.2	419.3	1.186	1.713	1.501	1.115	0.0064	39
40	10.18	1146.1	50.072	256.5	163.2	419.8	1.191	1.712	1.507	1.123	0.0063	40
41	10.45	1141.9	51.508	258.1	162.1	420.2	1.196	1.712	1.513	1.132	0.0062	41
42	10.73	1137.6	52.980	259.6	161.0	420.6	1.201	1.712	1.520	1.140	0.0060	42
43	11.02	1133.3	54.490	261.1	159.9	421.1	1.205	1.711	1.526	1.149	0.0059	43
44	11.31	1128.9	56.040	262.7	158.8	421.5	1.210	1.711	1.533	1.159	0.0058	44
45	11.61	1124.5	57.630	264.2	157.7	421.9	1.215	1.711	1.539	1.168	0.0057	45
46	11.91	1120.0	59.261	265.7	156.6	422.3	1.220	1.710	1.546	1.178	0.0055	46
47	12.22	1115.6	60.934	267.3	155.4	422.7	1.224	1.710	1.553	1.188	0.0054	47
48	12.54	1111.0	62.652	268.8	154.3	423.1	1.229	1.709	1.561	1.198	0.0053	48
49	12.86	1106.4	64.415	270.4	153.1	423.5	1.234	1.709	1.568	1.209	0.0052	49
50	13.19	1101.8	66.225	271.9	151.9	423.8	1.238	1.709	1.576	1.220	0.0050	50

	English	Français	Deutsch	Español	Italiano	Norsk
t	temperature	température	Temperatur	temperatura	temperatura	temperatur
ρ	density	masse volumique	Dichte	masa volumetrica	densità	tetthet
h	enthalpy	enthalpie	Enthalpie	entalpía	entalpia	enthalpy
s	entropy	entropie	Entropie	entropía	entropia	entropy
cp	specific capacity	capacité spécifique	spez. Wärmekapazität	calor específico	calore specifico	spesifikk varmekap.
c	speed of sound	vitesse du son	Schallgeschwindigkeit	velocidad del sonido	velocità del suono	lydens hastighet

Texte en français

TABLEAU II SUVA FLUIDE FRIGORIGÈNE HFC-134a-VAPEUR SURCHAUFFÉE

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]=kJ/(kg•K) [cp]=kJ/(kg•K) [c]=m/s température de saturation entre parenthèses

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	cp	c	t

Deutscher Text

TABELLE II SUVA KÄLTEMITTEL FKW-134a - ÜBERHITZTER DAMPF

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]=kJ/(kg•K) [cp]=kJ/(kg•K) [c]=m/s Sättigungstemperatur in Klammern

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	cp	c	t

Texto en español

CUADRO II SUVA FLUIDO FRIGORIFICO HFC-134a-VAPOR RECALENTADO

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]=kJ/(kg•K) [cp]=kJ/(kg•K) [c]=m/s temperatura de saturación entre paréntesis

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	cp	c	t

Testo in italiano

TABELLA II SUVA FLUIDO FRIGORIGENO HFC-134a-VAPORE SURRISCALDATO

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]=kJ/(kg•K) [cp]=kJ/(kg•K) [c]=m/s temperature d'equilibrio fra parantesi

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	cp	c	t

Norsk tekst

TABELL II SUVA REFRIGERANT HFC-134a-OVERHETET DAMP

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]=kJ/(kg•K) [cp]=kJ/(kg•K) [c]=m/s metningstemperature i parantes

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	cp	c	t

The reference point for enthalpy is 200 kJ/kg for the liquid at 0 °C   The reference point for entropy is 1.000 kJ/(kg•K) for the liquid at [illegible] [illegible]

TABLE I: SATURATION PROPERTIES SUVA HFC - 134a

TEMP	PRESS	DENSITY		ENTHALPY			ENTROPY		SPEC. HEAT CAP.		TENS	TEMP
t	p	ρ'	ρ''	h'	h''- h'	h''	s'	s''	cp'	cp''	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		liquid	vapour	liquid	latent	vapour	liquid	vapour	liquid	vapour		
51	13.52	1097.1	68.084	273.5	150.7	424.2	1.243	1.709	1.584	1.232	0.0049	51
52	13.87	1092.4	69.992	275.1	149.5	424.6	1.248	1.708	1.592	1.243	0.0048	52
53	14.21	1087.6	71.952	276.6	148.3	424.9	1.253	1.707	1.601	1.256	0.0047	53
54	14.57	1082.6	73.965	278.2	147.0	425.3	1.257	1.707	1.609	1.268	0.0045	54
55	14.93	1077.9	76.035	279.3	145.8	425.6	1.262	1.706	1.618	1.282	0.0044	55
56	15.29	1072.9	78.162	281.4	144.5	425.9	1.267	1.706	1.628	1.295	0.0043	56
57	15.67	1067.9	80.348	283.0	143.2	426.2	1.272	1.706	1.638	1.310	0.0042	57
58	16.05	1062.8	82.596	284.6	141.9	426.5	1.277	1.705	1.648	1.325	0.0041	58
59	16.43	1057.7	84.908	286.3	140.5	426.8	1.281	1.704	1.659	1.340	0.0039	59
60	16.83	1052.5	87.287	287.9	139.2	427.1	1.286	1.704	1.670	1.356	0.0038	60
61	17.23	1047.2	89.735	289.5	137.8	427.4	1.291	1.703	1.681	1.373	0.0037	61
62	17.64	1041.8	92.255	291.2	136.4	427.6	1.296	1.703	1.693	1.391	0.0036	62
63	18.05	1036.4	94.851	292.9	135.0	427.9	1.301	1.702	1.706	1.410	0.0035	63
64	18.47	1030.9	97.526	294.5	133.6	428.1	1.305	1.702	1.719	1.429	0.0034	64
65	18.91	1025.3	100.283	296.2	132.1	428.3	1.310	1.701	1.732	1.450	0.0032	65
66	19.34	1019.6	103.125	297.9	130.6	428.5	1.315	1.700	1.747	1.471	0.0031	66
67	19.79	1013.8	106.058	299.6	129.1	428.7	1.320	1.700	1.762	1.494	0.0030	67
68	20.24	1008.0	109.085	301.3	127.5	428.8	1.325	1.699	1.778	1.519	0.0029	68
69	20.70	1002.0	112.212	303.0	126.0	429.0	1.330	1.698	1.794	1.544	0.0028	69
70	21.17	995.9	115.442	304.8	124.4	429.1	1.335	1.697	1.812	1.572	0.0027	70
71	21.65	989.7	118.783	306.5	122.7	429.2	1.340	1.695	1.830	1.601	0.0026	71
72	22.14	983.4	122.239	308.3	121.1	429.3	1.345	1.695	1.850	1.632	0.0025	72
73	22.63	977.0	125.818	310.1	119.4	429.4	1.350	1.695	1.871	1.665	0.0024	73
74	23.13	970.4	129.527	311.8	117.6	429.5	1.355	1.694	1.894	1.701	0.0023	74
75	23.64	963.7	133.373	313.7	115.8	429.5	1.360	1.692	1.918	1.739	0.0022	75
76	24.16	956.9	137.365	315.5	114.0	429.5	1.365	1.691	1.943	1.781	0.0021	76
77	24.69	949.9	141.514	317.3	112.2	429.5	1.370	1.690	1.971	1.825	0.0019	77
78	[illegible]	[illegible]	145.830	319.2	110.3	429.4	1.375	1.689	2.001	1.875	[illegible]	78
79	[illegible]	935.4	[illegible]	321.0	108.3	429.3	1.380	1.686	2.023	1.926	0.0017	79
80	26.33	[illegible]	155.010	322.9	106.3	429.2	1.385	1.685	2.068	1.986	0.0016	80
81	26.59	920.1	159.934	324.9	104.2	429.1	1.391	1.685	2.106	2.051	0.0015	81
82	27.47	912.1	[illegible]	326.8	102.1	428.9	1.396	1.683	2.148	2.122	0.0015	82
83	28.05	903.9	170.383	328.8	99.9	428.7	1.401	1.682	2.195	2.201	0.0014	83
84	26.65	895.5	176.010	330.7	97.7	428.4	1.407	1.680	2.246	2.290	0.0013	84
85	29.25	886.7	181.929	332.8	95.3	428.1	1.412	1.678	2.304	2.390	0.0012	85
86	29.87	877.9	188.169	334.8	92.9	427.7	1.418	1.676	2.369	2.503	0.0011	86
87	30.49	868.2	194.766	336.9	90.4	427.3	1.423	1.674	2.443	2.633	0.0010	87
88	31.13	858.4	201.761	339.0	87.7	426.8	1.429	1.672	2.528	2.784	0.0009	88
89	31.77	848.1	209.206	341.2	85.0	426.2	1.435	1.669	2.627	2.959	0.0008	89
90	32.43	837.3	217.162	343.4	82.1	425.5	1.441	1.667	2.744	3.167	0.0007	90
91	33.10	826.0	225.705	345.7	79.1	424.8	1.447	1.664	2.884	3.418	0.0006	91
92	33.78	814.0	234.936	348.0	75.9	423.9	1.453	1.661	3.055	3.724	0.0006	92
93	34.47	801.1	244.978	350.4	72.5	422.9	1.459	1.657	3.269	4.108	0.0005	93
94	35.18	787.4	256.005	353.0	68.9	421.8	1.466	1.653	3.546	4.602	0.0004	94
95	35.89	772.3	268.255	355.6	64.9	420.5	1.473	1.649	3.917	5.261	0.0003	95
96	36.63	755.8	282.079	358.4	60.5	418.9	1.480	1.644	4.442	6.184	0.0003	96
97	37.37	737.1	298.029	361.3	55.7	417.0	1.488	1.638	5.241	7.566	0.0002	97
98	38.13	715.4	317.065	364.6	50.0	414.6	1.496	1.631	6.600	9.862	0.0001	98
99	38.91	688.5	341.133	368.4	43.2	411.5	1.506	1.622	9.392	14.406	0.0001	99
100	39.70	651.4	375.503	373.2	33.8	407.0	1.519	1.609	18.008	27.554	0.0000	100

TABLE I: SATURATION PROPERTIES SUVA HFC - 134a

TEMP	PRESS	DENSITY		ENTHALPY			ENTROPY		SPEC. HEAT CAP.		TENS	TEMP
t	p	ρ'	ρ"	h'	h"-h'	h"	s'	s"	cp'	cp"	σ	t
°C	bar	kg/m³		kJ/kg			kJ/(kg·K)		kJ/(kg·K)		N/m	°C
		liquid	vapour	liquid	latent	vapour	liquid	vapour	liquid	vapour		
-49	0.31	1440.1	1.740	137.3	231.3	368.6	0.749	1.780	1.222	0.717	0.0191	-49
-48	0.33	1437.3	1.835	138.5	230.7	369.2	0.754	1.778	1.224	0.720	0.0189	-48
-47	0.35	1434.5	1.935	139.8	230.1	369.9	0.759	1.777	1.226	0.723	0.0188	-47
-46	0.37	1431.6	2.040	141.0	229.5	370.5	0.765	1.775	1.228	0.726	0.0186	-46
-45	0.39	1428.9	2.149	142.2	228.9	371.1	0.770	1.773	1.230	0.729	0.0185	-45
-44	0.41	1426.0	2.263	143.5	228.3	371.8	0.775	1.772	1.232	0.732	0.0183	-44
-43	0.44	1423.2	2.382	144.7	227.7	372.4	0.781	1.770	1.234	0.735	0.0182	-43
-42	0.46	1420.3	2.505	145.9	227.1	373.0	0.786	1.769	1.237	0.736	0.0180	-42
-41	0.49	1417.5	2.633	147.2	226.5	373.7	0.791	1.767	1.239	0.741	0.0178	-41
-40	0.51	1414.6	2.767	148.4	225.9	374.3	0.797	1.766	1.241	0.744	0.0177	-40
-39	0.54	1411.8	2.906	149.6	225.3	374.9	0.802	1.764	1.243	0.747	0.0175	-39
-38	0.57	1408.9	3.050	150.9	224.7	375.5	0.807	1.763	1.245	0.750	0.0174	-38
-37	0.60	1406.0	3.200	152.1	224.0	376.2	0.813	1.761	1.247	0.753	0.0172	-37
-36	0.63	1403.1	3.356	153.4	223.4	376.8	0.818	1.760	1.250	0.756	0.0171	-36
-35	0.56	1400.2	3.518	154.6	222.8	377.4	0.823	1.759	1.252	0.759	0.0169	-35
-34	0.69	1337.4	3.686	155.9	222.2	378.1	0.828	1.757	1.254	0.762	0.0168	-34
-33	0.73	1394.5	3.861	157.1	221.5	378.7	0.834	1.756	1.256	0.766	0.0166	-33
-32	0.77	1391.5	4.042	158.4	220.9	379.3	0.839	1.755	1.259	0.769	0.0165	-32
-31	0.80	1388.6	4.229	159.7	220.3	379.9	0.844	1.754	1.261	0.772	0.0163	-31
-30	0.84	1385.7	4.424	160.9	219.6	380.5	0.849	1.753	1.263	0.775	0.0162	-30
-29	0.88	1382.8	4.625	162.2	219.0	381.2	0.854	1.751	1.265	0.779	0.0160	-29
-28	0.93	1379.8	4.833	163.5	218.3	381.8	0.860	1.750	1.268	0.782	0.0159	-28
-27	0.97	1376.9	5.049	164.7	217.7	382.4	0.865	1.749	1.270	0.785	0.0157	-27
-26	1.02	1373.9	5.273	166.0	217.1	383.1	0.870	1.748	1.272	0.789	0.0156	-26
-25	1.06	1371.0	5.504	167.3	216.4	383.7	0.875	1.747	1.275	0.792	0.0154	-25
-24	1.11	1368.0	5.743	168.6	215.7	384.3	0.880	1.746	1.277	0.796	0.0153	-24
-23	1.16	1365.0	5.991	169.9	215.1	384.9	0.885	1.745	1.279	0.799	0.0151	-23
-22	1.22	1362.0	6.247	171.1	214.4	385.5	0.890	1.744	1.282	0.803	0.0150	-22
-21	1.27	1359.0	6.511	172.4	213.7	386.2	0.895	1.743	1.284	0.806	0.0148	-21
-20	1.33	1356.0	6.784	173.7	213.1	386.8	0.901	1.742	1.287	0.810	0.0147	-20
-19	1.39	1353.0	7.066	175.0	212.4	387.4	0.906	1.741	1.289	0.813	0.0145	-19
-18	1.45	1349.9	7.357	176.3	211.7	388.0	0.911	1.740	1.292	0.817	0.0144	-18
-17	1.51	1346.9	7.653	177.6	211.0	388.6	0.916	1.740	1.294	0.821	0.0142	-17
-16	1.57	1343.8	7.968	178.9	210.4	389.2	0.921	1.739	1.297	0.824	0.0141	-16
-15	1.64	1340.8	8.288	180.2	209.7	389.8	0.926	1.738	1.299	0.828	0.0139	-15
-14	1.71	1337.7	8.618	181.5	209.0	390.4	0.931	1.737	1.302	0.832	0.0138	-14
-13	1.78	1334.6	8.958	182.8	208.3	391.1	0.936	1.736	1.305	0.836	0.0136	-13
-12	1.85	1331.5	9.309	184.1	207.6	391.7	0.941	1.736	1.307	0.839	0.0135	-12
-11	1.93	1328.4	9.671	185.4	206.9	392.3	0.946	1.735	1.310	0.843	0.0133	-11
-10	2.01	1325.3	10.044	186.7	206.2	392.9	0.951	1.734	1.313	0.847	0.0132	-10
-9	2.09	1322.1	10.428	188.0	205.4	393.5	0.956	1.733	1.315	0.851	0.0130	-9
-8	2.17	1319.0	10.823	189.3	204.7	394.1	0.961	1.733	1.318	0.855	0.0129	-8
-7	2.26	1315.8	11.231	190.7	204.0	394.7	0.966	1.732	1.321	0.859	0.0127	-7
-6	2.34	1312.6	11.650	192.0	203.3	395.3	0.971	1.731	1.324	0.863	0.0126	-6
-5	2.43	1309.4	12.082	193.3	202.5	395.9	0.976	1.731	1.326	0.867	0.0125	-5
-4	2.53	1306.2	12.526	194.6	201.8	396.4	0.980	1.730	1.329	0.871	0.0123	-4
-3	2.62	1303.0	12.983	196.0	201.1	397.0	0.985	1.730	1.332	0.875	0.0122	-3
-2	2.72	1299.8	13.454	197.3	200.3	397.6	0.990	1.729	1.335	0.880	0.0120	-2
-1	2.82	1296.5	13.937	198.7	199.6	398.2	0.995	1.728	1.338	0.884	0.0119	-1
0	2.93	1293.3	14.435	200.0	198.8	398.8	1.000	1.728	1.341	0.808	0.0117	0

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] °C [ρ] kg/m³ [h] kJ/kg [s] kJ/(kg·K) [cp] kJ/(kg·K) [c] m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=0.080 bar (ts=-70°C)					ps=0.086 bar (ts=-69°C)					ps=0.092 bar (ts=-68°C)					
-70	0.495	355.4	1.828	0.662	136.9	-	-	-	-	-	-	-	-	-	-	-70
-65	0.474	358.7	1.844	0.671	138.4	0.503	358.7	1.838	0.671	138.4	0.540	358.7	1.832	0.672	138.3	-65
-60	0.462	362.1	1.860	0.680	140.0	0.497	362.1	1.854	0.680	140.0	0.535	362.0	1.848	0.681	139.9	-60
-55	[illegible]	365.5	1.876	0.690	141.5	0.481	365.5	1.870	0.690	141.5	0.520	365.5	1.864	0.690	141.5	-55
-50	0.441	369.0	1.892	0.699	143.0	0.474	369.0	1.886	0.699	143.0	[illegible]	368.9	1.880	0.699	143.0	-50
-45	0.431	372.5	1.907	0.708	144.5	0.463	372.5	1.901	0.709	144.5	0.499	372.5	1.895	0.709	144.5	-45
-40	0.422	376.1	1.922	0.717	146.0	0.454	376.0	1.917	0.717	146.0	0.488	376.0	1.911	0.717	145.9	-40
-35	0.413	379.7	1.938	0.727	147.5	0.444	379.7	1.932	0.726	147.5	0.477	379.6	1.926	0.726	147.4	-35
-30	0.404	383.3	1.953	0.735	149.0	0.435	383.3	1.947	0.735	149.0	0.467	383.3	1.941	0.735	148.9	-30
-25	0.396	387.0	1.968	0.744	150.4	0.426	387.0	1.962	0.744	150.4	0.457	387.0	1.956	0.745	150.3	-25
-20	0.388	390.8	1.983	0.753	151.8	0.417	390.7	1.977	0.754	151.8	0.448	390.7	1.971	0.754	151.7	-20
-15	0.380	394.6	1.998	0.763	153.2	0.408	394.5	1.992	0.763	153.2	0.440	394.5	1.986	0.763	153.1	-15
-10	0.373	398.4	2.013	0.772	154.6	0.401	398.4	2.007	0.772	154.6	0.431	398.4	2.001	0.772	154.5	-10
-5	0.366	402.3	2.027	0.781	156.0	0.394	402.3	2.021	0.781	155.9	0.423	402.2	2.015	0.781	155.9	-5
0	0.359	406.2	2.042	0.790	157.3	0.386	406.2	2.036	0.790	157.3	0.415	406.2	2.030	0.790	157.3	0
5	0.353	410.2	2.056	0.799	158.7	0.373	410.2	2.050	0.799	158.6	0.408	410.1	2.044	0.799	158.6	5
10	0.347	414.2	2.071	0.808	160.0	0.373	414.2	2.065	0.808	160.0	0.400	414.2	2.059	0.808	159.9	10
15	0.340	418.2	2.085	0.817	161.3	0.365	418.2	2.079	0.817	161.3	0.393	418.2	2.073	0.817	161.3	15
20	0.335	422.3	2.093	0.825	162.6	0.360	422.3	2.093	0.825	162.5	0.387	422.3	2.087	0.826	162.6	20
25	0.329	426.5	2.113	0.834	163.9	0.354	426.5	2.107	0.834	163.9	0.380	426.5	2.101	0.834	163.9	25
30	0.323	430.7	2.127	0.843	165.2	0.348	430.7	2.121	0.843	165.2	0.374	430.7	2.115	0.843	165.2	30
35	0.318	434.9	2.141	0.852	165.5	0.342	434.9	2.135	0.852	166.5	0.368	434.9	2.129	0.852	166.4	35
40	0.313	439.2	2.154	0.860	167.7	0.337	439.2	2.149	0.860	167.7	0.352	439.2	2.143	0.860	167.7	40
45	0.308	443.5	2.168	0.869	169.0	0.331	443.5	2.162	0.869	169.0	0.356	443.5	2.156	0.869	169.0	45
50	0.303	447.9	2.182	0.877	170.2	0.326	447.9	2.176	0.877	170.2	0.351	447.9	2.170	0.877	170.2	50
	ps=0.099 bar (ts=-67°C)					ps=0.106 bar (ts=-66°C)					ps=0.114 bar (ts=-65°C)					
-65	0.585	358.6	1.826	0.673	138.3	0.631	358.5	1.820	0.673	138.2	0.677	358.5	1.815	0.674	138.2	-65
-60	0.574	362.0	1.842	0.682	139.9	0.616	362.0	1.835	0.682	139.8	0.660	361.9	1.831	0.682	139.8	-60
-55	0.560	365.4	1.858	0.691	141.4	0.601	365.4	1.852	0.691	141.4	0.645	365.4	1.847	0.692	141.3	-55
-50	0.547	368.9	1.874	0.700	142.9	0.587	368.9	1.868	0.700	142.9	0.630	368.8	1.862	0.701	142.9	-50
-45	0.535	372.4	1.890	0.709	144.5	0.574	372.4	1.884	0.709	144.4	0.616	372.4	1.878	0.710	144.4	-45
-40	0.523	376.0	1.905	0.718	145.9	0.562	376.0	1.899	0.718	145.9	0.602	375.9	1.893	0.719	145.9	-40
-35	0.512	379.6	1.920	0.727	147.4	0.550	379.5	1.914	0.727	147.4	0.589	379.5	1.909	0.728	147.3	-35
-30	0.501	383.3	1.936	0.736	148.9	0.538	383.2	1.930	0.736	148.8	0.577	383.2	1.924	0.737	148.8	-30
-25	0.491	387.0	1.951	0.745	150.3	0.527	386.9	1.945	0.745	150.3	0.565	386.9	1.939	0.746	150.2	-25
-20	0.481	390.7	1.965	0.754	151.7	0.516	390.7	1.960	0.754	151.7	0.554	390.7	1.954	0.755	151.7	-20
-15	0.472	394.5	1.980	0.763	153.1	0.506	394.5	1.975	0.763	153.1	0.543	394.5	1.969	0.764	153.1	-15
-10	0.463	398.3	1.995	0.772	154.5	0.496	398.3	1.989	0.772	154.5	0.532	398.3	1.984	0.773	154.5	-10
-5	0.454	402.2	2.010	0.781	155.9	0.487	402.2	2.004	0.781	155.9	0.522	402.2	1.998	0.782	155.8	-5
0	0.445	406.2	2.024	0.790	157.2	0.478	406.1	2.018	0.790	157.2	0.512	406.1	2.013	0.791	157.2	0
5	0.437	410.1	2.039	0.799	158.6	0.469	410.1	2.033	0.799	158.5	0.503	410.1	2.027	0.800	158.5	5
10	0.430	414.1	2.053	0.808	159.9	0.461	414.1	2.047	0.808	159.9	0.494	414.1	2.042	0.808	159.9	10
15	0.422	418.2	2.067	0.817	161.2	0.453	418.2	2.061	0.817	161.2	0.485	418.2	2.056	0.817	161.2	15
20	0.415	422.3	2.081	0.826	162.5	0.445	422.3	2.075	0.826	162.5	0.477	422.3	2.070	0.826	162.5	20
25	0.408	426.5	2.095	0.835	163.8	0.438	426.5	2.090	0.835	163.8	0.469	426.4	2.084	0.835	163.8	25
30	0.401	430.7	2.109	0.843	165.1	0.430	430.6	2.104	0.843	165.1	0.461	430.6	2.098	0.844	165.1	30
35	0.395	434.9	2.123	0.852	166.4	0.423	434.9	2.117	0.852	166.4	0.454	434.9	2.112	0.852	166.4	35
40	0.388	439.2	2.137	0.860	167.7	0.416	439.2	2.131	0.861	167.7	0.446	439.2	2.126	0.861	167.7	40
45	0.382	443.5	2.151	0.869	169.0	0.410	443.5	2.145	0.869	169.0	0.439	443.5	2.139	0.869	168.9	45
50	0.376	447.9	2.164	0.878	170.2	0.404	447.9	2.158	0.878	170.2	0.433	447.8	2.153	0.878	170.2	50
55	0.370	452.3	2.178	0.886	171.4	0.397	452.3	2.172	0.886	171.4	0.426	452.3	2.166	0.886	171.4	55
	ps=0.122 bar (ts=-64°C)					ps=0.130 bar (ts=-63°C)					ps=0.139 bar (ts=-62°C)					
-60	0.708	361.9	1.825	0.684	139.7	0.758	361.8	1.819	0.684	139.6	0.811	361.8	1.814	0.685	139.6	-60
-55	0.691	365.3	1.841	0.692	141.3	0.740	365.3	1.835	0.693	141.2	0.791	365.2	1.830	0.694	141.1	-55
-50	0.675	368.8	1.857	0.701	142.8	0.722	368.8	1.851	0.702	142.7	0.773	368.7	1.845	0.703	142.7	-50
-45	0.660	372.3	1.872	0.710	144.3	0.706	372.3	1.867	0.711	144.3	0.755	372.2	1.861	0.711	144.2	-45
-40	0.645	375.9	1.888	0.719	145.8	0.691	375.9	1.882	0.720	145.9	0.739	375.8	1.877	0.720	145.7	-40
-35	0.631	379.5	1.903	0.728	147.3	0.676	379.5	1.897	0.729	147.3	0.723	379.5	1.892	0.729	147.2	-35
-30	0.618	383.2	1.918	0.737	148.8	0.661	383.1	1.913	0.737	148.7	0.707	383.1	1.907	0.738	148.7	-30
-25	0.605	386.9	1.933	0.746	150.2	0.648	386.9	1.928	0.746	150.2	0.693	386.8	1.922	0.747	150.1	-25
-20	0.593	390.6	1.948	0.755	151.6	0.635	390.6	1.943	0.755	151.6	0.679	390.6	1.937	0.756	151.5	-20
-15	0.581	394.4	1.963	0.764	153.0	0.622	394.4	1.958	0.764	153.0	0.665	394.4	1.952	0.765	153.0	-15
-10	0.570	398.3	1.978	0.773	154.4	0.610	398.3	1.972	0.773	154.4	0.653	398.2	1.967	0.774	154.4	-10
-5	0.559	402.2	1.993	0.782	155.8	0.599	402.1	1.987	0.782	155.8	0.640	402.1	1.982	0.783	155.7	-5
0	0.549	406.1	2.007	0.791	157.2	0.588	406.1	2.002	0.791	157.1	0.628	406.1	1.996	0.791	157.1	0
5	0.539	410.1	2.022	0.800	158.5	0.577	410.1	2.016	0.800	158.5	0.617	410.0	2.010	0.800	158.5	5
10	0.529	414.1	2.036	0.809	159.9	0.566	414.1	2.030	0.809	159.8	0.606	414.1	2.025	0.809	159.8	10
15	0.520	418.2	2.050	0.817	161.2	0.557	418.1	2.045	0.818	161.2	0.595	418.1	2.039	0.818	161.1	15
20	0.511	422.3	2.064	0.826	162.5	0.547	422.3	2.059	0.826	162.5	0.585	422.2	2.053	0.827	162.5	20
25	0.503	426.4	2.078	0.835	163.8	0.538	426.4	2.073	0.835	163.8	0.575	426.4	2.067	0.835	163.8	25
30	0.494	430.6	2.092	0.844	165.1	0.529	430.6	2.087	0.844	165.1	0.565	430.6	2.081	0.844	165.1	30
35	0.486	434.9	2.106	0.852	166.4	0.520	434.8	2.101	0.852	166.4	0.556	434.8	2.095	0.853	166.3	35
40	0.478	439.1	2.120	0.861	167.6	0.512	439.1	2.114	0.861	167.6	0.547	439.1	2.109	0.861	167.6	40
45	0.471	443.5	2.134	0.869	168.9	0.504	443.5	2.128	0.869	168.9	0.538	443.4	2.123	0.870	168.9	45
50	0.463	447.8	2.147	0.878	170.2	0.496	447.8	2.142	0.878	170.1	0.530	447.8	2.136	0.878	170.1	50
55	0.456	452.2	2.161	0.886	171.4	0.488	452.2	2.155	0.886	171.4	0.522	452.2	2.150	0.886	171.4	55
60	0.449	456.7	2.174	0.895	172.6	0.481	456.7	2.169	0.895	172.6	0.514	456.7	2.163	0.895	172.6	60

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t]= °C [ρ]= kg/m³ [h]= kJ/kg [s]= kJ / (kg·K) [cp]= kJ / (kg·K) [c]= m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=0.149 bar (ts=-61°C)					ps=0.159 bar (ts=-60°C)					ps=0.170 bar (ts=-59°C)					
-60	0.865	361.7	1.808	0.685	139.5	0.926	361.7	1.802	0.687	139.4	-	-	-	-	-	-60
-55	0.846	365.2	1.824	0.695	141.1	0.904	365.1	1.818	0.696	141.0	0.965	365.1	1.813	0.695	140.9	-55
-50	0.825	368.7	1.840	0.703	142.6	0.883	368.6	1.834	0.704	142.5	0.942	368.5	1.829	0.705	142.5	-50
-45	0.807	372.2	1.856	0.712	144.2	0.862	372.2	1.850	0.713	144.1	0.921	372.1	1.845	0.713	144.0	-45
-40	0.789	375.8	1.871	0.721	145.7	0.843	375.7	1.866	0.721	145.6	0.900	375.7	1.860	0.722	145.6	-40
-35	0.772	379.4	1.886	0.730	147.2	0.825	379.4	1.881	0.730	147.1	0.881	379.3	1.876	0.731	147.1	-35
-30	0.755	383.1	1.902	0.739	148.6	0.808	383.0	1.896	0.739	145.6	0.862	383.0	1.891	0.739	148.5	-30
-25	0.740	386.8	1.917	0.747	150.1	0.791	386.8	1.911	0.748	150.0	0.844	386.7	1.906	0.748	150.0	-25
-20	0.725	390.5	1.932	0.756	151.5	0.775	390.5	1.926	0.757	151.5	0.827	390.5	1.921	0.757	151.4	-20
-15	0.711	394.4	1.947	0.765	152.9	0.760	394.3	1.941	0.765	152.9	0.811	394.3	1.936	0.766	152.8	-15
-10	0.697	398.2	1.961	0.774	154.3	0.745	398.2	1.956	0.774	154.3	0.795	398.2	1.951	0.775	154.2	-10
-5	0.684	402.1	1.976	0.783	155.7	0.731	402.1	1.971	0.783	155.7	0.780	402.0	1.965	0.783	155.6	-5
0	0.671	406.0	1.991	0.792	157.1	0.717	406.0	1.985	0.792	157.0	0.765	406.0	1.980	0.792	157.0	0
5	0.659	410.0	2.005	0.800	158.4	0.704	410.0	2.000	0.801	153.4	0.751	410.0	1.994	0.801	158.4	5
10	0.647	414.0	2.019	0.809	159.8	0.691	414.0	2.014	0.809	159.8	0.738	414.0	2.009	0.810	159.7	10
15	0.636	418.1	2.034	0.818	161.1	0.679	418.1	2.028	0.818	161.1	0.725	418.1	2.023	0.818	161.1	15
20	0.625	422.2	2.048	0.827	162.4	0.667	422.2	2.042	0.827	162.4	0.712	422.2	2.037	0.827	162.4	20
25	0.614	426.4	2.062	0.835	163.7	0.656	426.4	2.056	0.836	163.7	0.700	426.3	2.051	0.835	163.7	25
30	0.604	430.6	2.076	0.844	165.0	0.645	430.6	2.070	0.844	165.0	0.688	430.5	2.065	0.844	165.0	30
35	0.594	434.8	2.090	0.853	166.3	0.635	434.8	2.084	0.853	166.3	0.677	434.8	2.079	0.853	166.3	35
40	0.585	439.1	2.103	0.861	167.6	0.624	439.1	2.098	0.861	167.6	0.665	439.1	2.093	0.862	167.5	40
45	0.575	443.4	2.117	0.870	168.8	0.614	443.4	2.112	0.870	168.8	0.655	443.4	2.106	0.870	168.8	45
50	0.566	447.8	2.131	0.878	170.1	0.605	447.8	2.125	0.878	170.1	0.645	447.8	2.120	0.878	170.1	50
55	0.558	452.2	2.144	0.887	171.3	0.595	452.2	2.139	0.887	171.3	0.635	452.2	2.134	0.887	171.3	55
60	0.549	456.7	2.158	0.895	172.6	0.587	456.5	2.152	0.895	172.6	0.626	456.6	2.147	0.895	172.5	60
	ps=0.181 bar (ts=-58°C)					ps=0.193 bar (ts=-57°C)					ps=0.205 bar (ts=-56°C)					
-55	1.029	365.0	1.807	0.697	140.9	1.097	364.9	1.802	0.698	140.8	1.169	364.9	1.797	0.699	140.7	-55
-50	1.005	368.5	1.823	0.706	142.4	1.072	368.5	1.818	0.707	142.4	1.141	368.4	1.813	0.708	142.3	-50
-45	0.982	372.1	1.839	0.714	144.0	1.047	372.0	1.834	0.715	143.9	1.115	372.0	1.829	0.716	143.8	-45
-40	0.960	375.7	1.855	0.723	145.5	1.024	375.6	1.849	0.723	145.4	1.090	375.5	1.844	0.724	145.4	-40
-35	0.939	379.3	1.870	0.731	147.0	1.001	379.2	1.865	0.732	146.9	1.066	379.2	1.860	0.733	146.9	-35
-30	0.919	383.0	1.885	0.740	148.5	0.980	382.9	1.880	0.741	148.4	1.044	382.9	1.875	0.741	148.4	-30
-25	0.900	386.7	1.901	0.749	149.9	0.959	386.7	1.895	0.749	149.9	1.022	386.6	1.890	0.750	149.8	-25
-20	0.882	390.5	1.916	0.757	151.4	0.940	390.4	1.910	0.758	151.3	1.001	390.4	1.905	0.758	151.3	-20
-15	0.864	394.3	1.931	0.766	152.8	0.921	394.2	1.925	0.767	152.8	0.981	394.2	1.920	0.767	152.7	-15
-10	0.848	398.1	1.945	0.775	154.2	0.903	398.1	1.940	0.775	154.2	0.962	398.1	1.935	0.776	154.1	-10
-5	0.831	402.0	1.960	0.784	155.6	0.886	402.0	1.955	0.784	155.6	0.943	402.0	1.950	0.785	155.5	-5
0	0.816	405.9	1.975	0.793	157.0	0.869	405.9	1.969	0.793	156.9	0.926	405.9	1.964	0.793	156.9	0
5	0.801	409.9	1.989	0.801	158.3	0.854	409.9	1.984	0.802	158.3	0.909	409.9	1.979	0.802	158.3	5
10	0.787	414.0	2.003	0.810	159.7	0.838	413.9	1.998	0.810	159.7	0.893	413.9	1.993	0.811	159.6	10
15	0.773	418.0	2.018	0.819	161.0	0.823	418.0	2.012	0.819	161.0	0.877	418.0	2.007	0.819	161.0	15
20	0.759	422.2	2.032	0.827	162.3	0.809	422.1	2.027	0.828	162.3	0.861	422.1	2.021	0.828	162.3	20
25	0.746	426.3	2.046	0.836	163.7	0.795	426.3	2.041	0.836	163.6	0.847	426.3	2.035	0.836	163.6	25
30	0.734	430.5	2.060	0.845	165.0	0.782	430.5	2.055	0.845	164.9	0.833	430.5	2.050	0.845	164.9	30
35	0.722	434.8	2.074	0.853	166.2	0.769	434.7	2.069	0.853	166.2	0.819	434.7	2.063	0.854	166.2	35
40	0.710	439.0	2.088	0.862	167.5	0.757	439.0	2.082	0.862	167.5	0.806	439.0	2.077	0.862	167.5	40
45	0.699	443.4	2.101	0.870	168.8	0.745	443.4	2.096	0.870	168.8	0.793	443.3	2.091	0.870	168.7	45
50	0.688	447.7	2.115	0.879	170.0	0.733	447.7	2.110	0.879	170.0	0.780	447.7	2.105	0.879	170.0	50
55	0.677	452.2	2.128	0.887	171.3	0.722	452.1	2.123	0.887	171.3	0.768	452.1	2.118	0.887	171.2	55
60	0.667	456.6	2.142	0.895	172.5	0.711	456.6	2.137	0.895	172.5	0.757	456.6	2.132	0.896	172.5	60
65	0.657	461.1	2.155	0.904	173.7	0.700	461.1	2.150	0.904	173.7	0.746	461.1	2.145	0.904	173.7	65
	ps=0.218 bar (ts=-55°C)					ps=0.232 bar (ts=-54°C)					ps=0.246 bar (ts=-53°C)					
-55	1.245	364.8	1.792	0.701	140.6	-	-	-	-	-	-	-	-	-	-	-55
-50	1.215	368.3	1.808	0.709	142.2	1.293	368.3	1.802	0.710	142.1	1.375	368.2	1.797	0.711	142.0	-50
-45	1.187	371.9	1.823	0.717	143.8	1.263	371.8	1.818	0.718	143.7	1.343	371.8	1.813	0.719	143.6	-45
-40	1.161	375.5	1.839	0.725	145.3	1.235	375.5	1.834	0.726	145.2	1.313	375.4	1.829	0.727	145.1	-40
-35	1.135	379.2	1.854	0.733	146.8	1.207	379.1	1.849	0.734	146.7	1.284	379.0	1.844	0.735	146.7	-35
-30	1.111	382.8	1.870	0.742	148.3	1.181	382.8	1.865	0.743	148.2	1.256	382.7	1.860	0.743	148.2	-30
-25	1.088	386.6	1.885	0.750	149.8	1.157	386.5	1.880	0.751	149.7	1.230	386.5	1.875	0.752	149.6	-25
-20	1.065	390.3	1.900	0.759	151.2	1.133	390.3	1.895	0.760	151.2	1.205	390.3	1.890	0.760	151.1	20
-15	1.044	394.2	1.915	0.768	152.7	1.110	394.1	1.910	0.768	152.6	1.180	394.1	1.905	0.769	152.5	-15
-10	1.024	398.0	1.930	0.776	154.1	1.089	398.0	1.925	0.777	154.0	1.157	397.9	1.920	0.777	154.0	-10
-5	1.004	401.9	1.944	0.785	155.5	1.068	401.9	1.939	0.785	155.4	1.135	401.9	1.934	0.786	155.4	-5
0	0.985	405.9	1.959	0.794	156.9	1.048	405.8	1.954	0.794	156.8	1.114	405.8	1.949	0.794	156.8	0
5	0.967	409.9	1.974	0.802	158.2	1.028	409.8	1.968	0.803	158.2	1.093	409.8	1.963	0.803	158.1	5
10	0.950	413.9	1.988	0.811	159.6	1.010	413.9	1.983	0.811	159.5	1.073	413.8	1.978	0.812	159.5	10
15	0.933	418.0	2.002	0.820	160.9	0.992	417.9	1.997	0.820	160.9	1.054	417.9	1.992	0.820	160.8	15
20	0.917	422.1	2.016	0.828	162.2	0.975	422.1	2.011	0.828	162.2	1.036	422.0	2.006	0.829	162.2	20
25	0.901	426.2	2.030	0.837	163.6	0.958	426.2	2.025	0.837	163.5	1.018	426.2	2.020	0.837	163.5	25
30	0.886	430.5	2.044	0.845	164.9	0.942	430.4	2.039	0.845	164.8	1.001	430.4	2.034	0.846	164.8	30
35	0.871	434.7	2.058	0.854	166.2	0.926	434.7	2.053	0.854	166.1	0.985	434.7	2.048	0.854	166.1	35
40	0.857	439.0	2.072	0.862	167.4	0.911	439.0	2.067	0.862	167.4	0.969	439.0	2.062	0.863	167.4	40
45	0.844	443.3	2.086	0.871	168.7	0.897	443.3	2.081	0.871	168.7	0.953	443.3	2.076	0.871	168.6	45
50	0.831	447.7	2.099	0.879	170.0	0.883	447.7	2.094	0.879	169.9	0.938	447.7	2.089	0.879	169.9	50
55	0.818	452.1	2.113	0.887	171.2	0.869	452.1	2.108	0.888	171.2	0.924	452.1	2.103	0.888	171.2	55
60	0.805	456.6	2.127	0.896	172.4	0.856	456.5	2.122	0.896	172.4	0.910	456.5	2.117	0.896	172.4	60
65	0.793	461.1	2.140	0.904	173.7	0.843	461.1	2.135	0.904	173.7	0.896	461.1	[illegible]	[illegible]	[illegible]	65

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] = °C [ρ] = kg/m³ [h] = kJ/kg [s] = kJ/(kg·K) [cp] = kJ/(kg·K) [c] = m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=0.261 bar (ts=-52°C)					ps=0.277 bar (ts=-51°C)					ps=0.294 bar (ts=-50°C)					
-50	1.462	368.1	1.792	0.712	141.9	1.552	368.1	1.787	0.713	141.8	1.648	368.0	1.782	0.714	141.7	-50
-45	1.427	371.7	1.808	0.720	143.5	1.516	371.6	1.803	0.721	143.4	1.609	371.6	1.798	0.722	143.3	-45
-40	1.395	375.3	1.824	0.728	145.1	1.481	375.3	1.819	0.729	145.0	1.572	375.2	1.814	0.730	144.9	-40
-35	1.364	379.0	1.839	0.736	146.6	1.448	378.9	1.834	0.737	146.5	1.537	378.9	1.829	0.738	146.4	-35
-30	1.334	382.7	1.855	0.744	148.1	1.417	382.6	1.850	0.745	148.0	1.504	[illegible]	1.845	0.746	147.9	-30
-25	1.307	386.4	1.870	0.752	149.6	1.387	386.4	1.865	0.753	149.5	1.472	386.3	1.860	0.754	149.4	-25
-20	1.280	390.2	1.885	0.761	151.0	1.359	390.2	1.880	0.761	151.0	1.442	390.1	1.875	0.762	150.9	-20
-15	1.254	394.0	1.900	0.769	152.5	1.331	394.0	1.895	0.770	152.4	1.413	393.9	1.890	0.770	152.4	-15
-10	1.229	397.9	1.915	0.778	153.9	1.305	397.9	1.910	0.778	153.9	1.385	397.8	1.905	0.779	153.8	-10
-5	1.206	401.8	1.929	0.786	155.3	1.280	401.8	1.924	0.787	155.3	1.358	401.7	1.920	0.787	155.2	-5
0	1.183	405.8	1.944	0.795	156.7	1.255	405.7	1.939	0.795	156.7	1.332	405.7	1.934	0.796	156.6	0
5	1.161	409.8	1.958	0.803	158.1	1.232	409.7	1.954	0.804	158.0	1.309	409.7	1.949	0.804	158.0	5
10	1.140	413.8	1.973	0.812	159.4	1.210	413.8	1.968	0.812	159.4	1.284	413.7	1.963	0.813	159.4	10
15	1.120	417.9	1.987	0.820	160.8	1.189	417.8	1.982	0.821	160.8	1.261	417.8	1.977	0.821	160.7	15
20	1.100	422.0	2.001	0.829	162.1	1.168	422.0	1.996	0.829	162.1	1.239	421.9	1.992	0.830	162.0	20
25	1.082	426.2	2.015	0.838	163.5	1.148	426.1	2.011	0.838	163.4	1.218	426.1	2.006	0.838	163.4	25
30	1.063	430.4	2.029	0.846	164.8	1.128	430.3	2.025	0.846	164.7	1.197	430.3	2.020	0.847	164.7	30
35	1.046	434.6	2.043	0.854	166.1	1.110	434.6	2.038	0.855	166.0	1.177	434.5	2.034	0.855	166.0	35
40	1.029	438.9	2.057	0.863	167.3	1.092	438.9	2.052	0.863	167.3	1.158	438.9	2.047	0.863	167.3	40
45	1.012	443.3	2.071	0.871	168.6	1.074	443.2	2.066	0.871	168.6	1.140	443.2	2.061	0.872	168.5	45
50	0.997	447.6	2.085	0.880	169.9	1.058	447.6	2.080	0.880	169.8	1.122	447.5	2.075	0.880	169.8	50
55	0.981	452.1	2.098	0.888	171.1	1.041	452.0	2.093	0.888	171.1	1.104	452.0	2.088	0.888	171.1	55
60	0.966	456.5	2.112	0.896	172.4	1.025	456.5	2.107	0.896	172.3	1.087	456.5	2.102	0.897	172.3	60
65	0.952	461.0	2.125	0.904	173.6	1.010	461.0	2.120	0.905	173.6	1.071	461.0	2.115	0.905	173.5	65
70	0.935	465.6	2.139	0.913	174.8	0.995	465.5	2.133	0.913	174.8	1.055	465.5	2.129	0.913	174.8	70
	ps=0.312 bar (ts=-49°C)					ps=0.330 bar (ts=-48°C)					ps=0.349 bar (ts=-47°C)					
-45	1.707	371.5	1.793	0.723	143.2	1.809	371.4	1.788	0.725	143.1	1.917	371.3	1.783	0.726	143.0	-45
-40	1.667	375.1	1.809	0.731	144.8	1.765	375.0	1.804	0.732	144.7	1.872	375.0	1.799	0.733	144.6	-40
-35	1.630	378.8	1.824	0.739	146.3	1.728	378.7	1.819	0.740	146.2	1.831	378.7	1.814	0.741	146.1	-35
-30	1.595	382.5	1.840	0.747	147.8	1.691	382.4	1.835	0.748	147.8	1.791	382.4	1.830	0.749	147.7	-30
-25	1.561	386.3	1.855	0.755	149.3	1.654	386.2	1.850	0.756	149.2	1.752	386.1	1.845	0.756	149.2	-25
-20	1.528	390.1	1.870	0.763	150.8	1.620	390.0	1.865	0.764	150.7	[illegible]	[illegible]	[illegible]	[illegible]	150.7	-20
-15	1.498	393.9	1.885	0.771	152.3	1.587	393.8	1.880	0.772	152.2	1.681	393.8	1.875	0.773	152.1	-15
-10	1.468	397.8	1.900	0.779	153.7	1.555	397.7	1.895	0.780	153.7	1.648	397.7	1.890	0.781	153.6	-10
-5	1.439	401.7	1.915	0.788	155.1	1.525	401.6	1.910	0.788	155.1	1.615	401.6	1.905	0.789	155.0	-5
0	1.412	405.6	1.929	0.796	156.5	1.496	405.5	1.925	0.797	156.5	1.585	405.5	1.920	0.797	156.4	0
5	1.386	409.6	1.944	0.805	157.9	1.468	409.6	1.939	0.805	157.9	1.555	409.6	1.934	0.806	157.8	5
10	1.361	413.7	1.956	0.813	159.3	1.442	413.7	1.953	0.814	159.2	1.527	413.6	1.949	0.814	159.2	10
15	1.337	417.8	1.972	0.822	160.7	1.416	417.7	1.968	0.822	160.6	1.499	417.7	1.963	0.822	160.5	15
20	1.313	421.9	1.987	0.830	162.0	1.391	421.9	1.982	0.830	161.9	1.473	421.8	1.977	0.831	161.9	20
25	1.291	426.1	2.001	0.838	163.3	1.367	426.0	1.995	0.839	163.3	1.448	426.0	1.991	0.839	163.2	25
30	1.269	430.3	2.015	0.847	164.5	1.344	420.3	2.010	0.847	164.5	1.423	430.2	2.005	0.848	164.5	30
35	1.248	434.5	2.029	0.855	165.9	1.322	434.5	2.024	0.856	165.9	1.400	434.4	2.019	0.856	165.9	35
40	1.227	438.8	2.043	0.864	167.2	1.300	438.8	2.038	0.864	167.2	1.377	438.8	2.033	0.864	167.1	40
45	1.208	443.2	2.056	0.872	168.5	1.279	443.2	2.052	0.872	168.5	1.355	443.1	2.047	0.872	168.4	45
50	1.189	447.5	2.070	0.880	169.8	1.259	447.5	2.065	0.881	169.7	1.333	447.5	[illegible]	[illegible]	[illegible]	50
55	1.170	452.0	2.084	0.889	171.0	1.240	452.0	2.079	0.889	171.0	1.313	451.9	2.074	0.889	171.0	55
60	1.153	456.4	2.097	0.897	172.3	1.221	456.4	2.092	0.897	172.2	1.293	456.3	2.088	0.897	172.2	60
65	1.135	460.9	2.111	0.905	173.5	1.203	460.9	2.106	0.905	173.5	1.273	460.9	2.101	0.905	173.4	65
70	1.119	465.5	2.124	0.913	174.7	1.185	465.5	2.119	0.913	174.7	1.254	465.4	2.114	0.913	174.7	70
75	1.102	470.1	2.137	0.921	176.0	1.169	470.1	2.132	0.921	175.9	1.235	470.0	2.128	0.921	175.9	75
	ps=0.370 bar (ts=-46°C)					ps=0.391 bar (ts=-45°C)					ps=0.413 bar (ts=-44°C)					
-45	2.031	371.2	1.778	0.727	142.8	2.150	371.1	1.773	0.729	142.7	.	.	.	.	.	-45
-40	1.983	374.9	1.794	0.735	144.4	2.099	374.8	1.789	0.736	144.3	2.221	374.7	1.784	0.737	144.2	-40
-35	1.939	378.6	1.810	0.742	146.0	2.051	378.5	1.805	0.743	145.9	2.170	378.4	1.800	0.744	145.8	-35
-30	1.896	382.3	1.825	0.750	147.6	2.005	382.2	1.820	0.751	147.5	2.122	382.1	1.816	0.752	147.4	-30
-25	1.855	386.1	1.840	0.757	149.1	1.962	386.0	1.836	0.758	149.0	2.076	385.9	1.831	0.759	148.9	-25
-20	1.817	389.9	1.856	0.765	150.6	1.922	389.8	1.851	0.766	150.5	2.032	389.7	1.846	0.767	150.4	-20
-15	1.779	393.7	1.871	0.773	152.1	1.882	393.7	1.866	0.774	152.0	1.991	393.6	1.861	0.775	151.9	-15
-10	1.744	397.6	1.886	0.781	153.5	1.845	397.6	1.881	0.782	153.4	1.951	397.5	1.876	0.783	153.3	-10
-5	1.710	401.5	1.900	0.790	154.9	1.809	401.5	1.896	0.790	154.9	1.912	401.4	1.891	0.791	154.8	-5
0	1.677	405.5	1.915	0.798	156.4	1.774	405.5	1.910	0.799	156.3	1.876	405.4	1.906	0.799	156.2	0
5	1.646	409.5	1.930	0.806	157.7	1.741	409.5	1.925	0.807	157.7	1.841	409.4	1.920	0.807	157.6	5
10	1.616	413.6	1.944	0.815	159.1	1.709	413.5	1.939	0.815	159.1	1.807	413.5	1.935	0.815	159.0	10
15	1.587	417.7	1.958	0.823	160.5	1.679	417.6	1.954	0.823	160.4	1.774	417.6	1.949	0.824	160.4	15
20	1.559	421.8	1.973	0.831	161.8	1.649	421.8	1.968	0.832	161.8	1.743	421.7	1.963	0.832	161.7	20
25	1.532	426.0	1.987	0.840	163.2	1.621	425.9	1.982	0.840	163.1	1.713	425.9	1.978	0.840	163.1	25
30	1.506	430.2	2.001	0.848	164.5	1.593	430.2	1.996	0.848	164.4	1.684	430.1	1.992	0.849	164.4	30
35	1.481	434.4	2.015	0.856	165.8	1.566	434.4	2.010	0.857	165.8	1.655	434.4	2.006	0.857	165.7	35
40	1.457	438.8	2.029	0.864	167.1	1.541	438.7	2.024	0.865	167.1	1.629	438.7	2.019	0.865	167.0	40
45	1.434	443.1	2.042	0.873	168.4	1.516	443.1	2.038	0.873	168.3	1.602	443.0	2.033	0.873	168.3	45
50	1.411	447.5	2.056	0.881	169.7	1.492	447.4	2.051	0.881	169.6	1.577	447.4	2.047	0.882	169.6	50
55	1.389	451.9	2.070	0.889	170.9	1.469	451.9	2.065	0.889	170.9	1.552	451.8	2.060	0.890	170.8	55
60	1.368	456.4	2.083	0.897	172.2	1.446	456.3	2.078	0.898	172.1	1.529	456.3	2.074	0.898	172.1	60
65	1.347	460.9	2.096	0.905	173.4	1.425	460.8	2.092	0.906	173.4	1.506	460.8	2.087	0.906	173.3	65
70	1.327	465.4	2.110	0.914	174.6	1.403	465.4	2.105	0.914	174.6	1.483	465.4	2.101	0.914	174.6	70
75	1.308	470.0	2.123	0.922	175.9	1.382	470.0	2.119	0.922	175.8	1.461	470.0	2.114	0.922	175.8	75

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] °C [ρ] kg/m³ [h] kJ/kg [s] kJ/(kg K) [cp] kJ/(kg K) [c] m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=0.436 bar (ts=-43°C)					ps=0.460 bar (ts=-42°C)					ps=0.485 bar (ts=-41°C)					
-40	2.348	374.6	1.780	0.739	144.1	2.481	374.5	1.775	0.740	143.9	2.621	374.4	1.770	0.742	143.8	-40
-35	2.234	378.3	1.795	0.746	145.7	2.424	378.2	1.791	0.747	145.5	2.560	378.1	1.786	0.749	145.4	-35
-30	2.243	[illegible]	1.811	0.753	147.2	2.370	382.0	1.806	0.754	[illegible]	2.502	381.9	1.802	0.755	147.0	-30
-25	2.194	385.9	1.826	0.760	148.8	2.315	385.5	1.822	0.762	148.7	2.449	385.7	1.817	0.763	148.5	-25
-20	2.148	389.7	1.842	0.768	150.3	2.267	389.6	1.837	0.769	150.2	2.396	389.5	1.832	0.770	150.1	-20
-15	2.104	393.5	1.857	0.776	151.8	2.222	393.5	1.852	0.777	151.7	2.346	393.4	1.848	0.778	151.6	-15
-10	2.061	397.4	1.872	0.784	152.3	2.177	397.4	1.867	0.785	153.2	2.299	397.3	1.863	0.786	153.1	-10
-5	2.021	401.4	1.886	0.792	154.7	2.134	401.3	1.882	0.792	154.6	2.253	401.2	1.877	0.793	154.5	-5
0	1.982	405.3	1.901	0.800	156.1	2.093	405.3	1.897	0.801	156.0	2.209	405.2	1.892	0.801	156.0	0
5	1.945	409.4	1.916	0.808	157.5	2.054	409.3	1.911	0.809	157.5	2.168	409.3	1.907	0.809	157.4	5
10	1.909	413.4	1.930	0.816	158.9	2.016	413.4	1.926	0.817	158.9	2.127	413.3	1.921	0.817	158.8	10
15	1.875	417.5	1.945	0.824	160.3	1.979	417.5	1.940	0.825	160.2	2.083	417.4	1.936	0.825	160.2	15
20	1.841	421.7	1.959	0.833	161.7	1.944	421.6	1.954	0.833	161.6	2.052	421.6	1.950	0.834	161.5	20
25	1.810	425.9	1.973	0.841	163.0	1.910	425.8	1.968	0.841	162.9	2.016	425.8	1.964	0.842	162.9	25
30	1.779	430.1	1.987	0.849	164.3	1.878	430.0	1.983	0.843	164.3	1.982	430.0	1.978	0.850	164.2	30
35	1.749	434.3	2.001	0.857	165.7	1.847	434.3	1.997	0.858	165.6	1.949	434.3	1.992	0.853	165.5	35
40	1.720	438.6	2.015	0.865	167.0	1.816	438.5	2.010	0.866	166.9	1.917	438.6	2.006	0.866	166.9	40
45	1.693	443.0	2.029	0.874	168.3	1.787	443.0	2.024	0.874	168.2	1.886	442.9	2.020	0.874	168.1	45
50	1.655	447.4	2.042	0.882	169.5	1.759	447.3	2.038	0.882	169.5	1.855	447.3	2.033	0.882	169.4	50
55	1.640	451.8	2.056	0.890	170.8	1.731	451.8	2.051	0.890	170.8	1.827	451.7	2.047	0.891	170.7	55
60	1.615	456.3	2.069	0.898	172.1	1.704	456.3	2.065	0.898	172.0	1.798	456.2	2.061	0.899	172.0	60
65	1.590	460.8	2.083	0.906	173.3	1.679	460.8	2.078	0.906	173.3	1.771	460.7	2.074	0.907	173.2	65
70	1.567	465.3	2.096	0.914	174.5	1.654	465.3	2.092	0.914	174.5	1.745	465.3	2.087	0.915	174.5	70
75	1.544	469.9	2.110	0.922	175.8	1.630	469.9	2.105	0.922	175.7	1.719	469.9	2.101	0.923	175.7	75
80	1.521	474.5	2.123	0.930	177.0	1.607	474.5	2.118	0.930	176.9	1.694	474.5	2.114	0.931	176.9	80
	ps=0.511 bar (ts=-40°C)					ps=0.539 bar (ts=-39°C)					ps=0.557 bar (ts=-38°C)					
-40	2.757	374.3	1.766	0.744	143.5	-	-	-	-	-	-	-	-	-	-	-40
-35	2.702	378.2	1.781	0.750	145.2	2.851	377.9	1.777	0.752	145.1	3.007	377.8	1.772	0.754	145.0	-35
-30	2.641	381.9	1.797	0.757	146.9	2.785	381.7	1.792	0.758	146.7	2.935	381.6	1.788	0.760	146.6	-30
-25	2.582	385.6	1.813	0.764	148.4	2.725	385.5	1.808	0.765	148.3	2.873	385.4	1.803	0.767	148.2	-25
-20	2.528	389.4	1.828	0.771	150.0	2.666	389.3	1.823	0.773	149.9	2.811	389.3	1.819	0.774	149.7	-20
-15	2.475	393.3	1.843	0.779	151.5	2.611	393.2	1.839	0.780	151.4	2.752	393.1	1.834	0.781	151.3	-15
-10	2.425	397.2	1.858	0.786	153.0	2.557	397.1	1.854	0.787	152.9	2.693	397.1	1.849	0.788	152.8	-10
-5	2.377	401.2	1.873	0.794	154.4	2.507	401.1	1.868	0.795	154.3	2.642	401.0	1.864	0.796	154.2	-5
0	2.331	405.2	1.888	0.802	155.9	2.458	405.1	1.883	0.803	155.8	2.590	405.0	1.879	0.804	155.7	0
5	2.287	409.2	1.902	0.810	157.3	2.411	409.1	1.898	0.811	157.2	2.541	409.1	1.893	0.812	157.1	5
10	2.245	413.3	1.917	0.818	158.7	2.366	413.2	1.912	0.819	158.6	2.494	413.1	1.908	0.819	158.5	10
15	2.204	417.4	1.931	0.826	160.1	2.323	417.3	1.927	0.827	160.0	2.448	417.3	1.922	0.827	159.9	15
20	2.164	421.5	1.945	0.834	161.5	2.282	421.5	1.941	0.835	161.4	2.404	421.4	1.937	0.835	161.3	20
25	2.127	425.7	1.960	0.842	162.8	2.242	425.7	1.955	0.843	162.7	2.362	425.6	1.951	0.843	162.7	25
30	2.090	429.9	1.974	0.850	164.2	2.204	429.9	1.969	0.851	164.1	2.322	429.8	1.965	0.851	164.0	30
35	2.055	434.2	1.988	0.858	165.5	2.166	434.2	1.983	0.859	165.4	2.283	434.1	1.979	0.859	165.4	35
40	2.021	438.5	2.002	0.867	166.8	2.131	438.5	1.997	0.867	166.7	2.245	438.4	1.993	0.867	166.7	40
45	1.989	442.9	2.015	0.875	168.1	2.095	442.8	2.011	0.875	168.0	2.209	442.8	2.007	0.875	168.0	45
50	1.957	447.2	2.029	0.883	169.4	2.062	447.2	2.025	0.883	169.3	2.173	447.2	2.020	0.884	169.3	50
55	1.926	451.7	2.043	0.891	170.7	2.030	451.7	2.038	0.891	170.6	2.139	451.6	2.034	0.892	170.6	55
60	1.897	456.2	2.056	0.899	171.9	1.999	456.1	2.052	0.899	171.9	2.105	456.1	2.048	0.900	171.8	60
65	1.868	460.7	2.070	0.907	173.2	1.969	460.7	2.065	0.907	173.1	2.074	460.6	2.061	0.908	173.1	65
70	1.840	465.3	2.083	0.915	174.4	1.939	465.2	2.079	0.915	174.4	2.043	465.2	2.074	0.916	174.3	70
75	1.813	469.9	2.096	0.923	175.5	1.911	469.8	2.092	0.923	175.5	2.013	469.8	2.088	0.923	175.5	75
80	1.787	474.5	2.110	0.931	176.9	1.883	474.4	2.105	0.931	176.8	1.984	474.4	2.101	0.931	176.8	80
	ps=0.597 bar (ts=-37°C)					ps=0.628 bar (ts=-36°C)					ps=0.661 bar (ts=-35°C)					
-35	3.170	377.7	1.768	0.755	144.8	3.340	377.6	1.763	0.757	144.6	3.518	377.4	1.759	0.759	144.5	-35
-30	3.097	381.5	1.783	0.762	146.4	3.263	381.4	1.779	0.763	145.3	3.437	381.2	1.774	0.765	146.1	-30
-25	3.028	385.3	1.799	0.768	148.0	3.190	385.2	1.795	0.770	147.9	3.359	385.1	1.790	0.771	147.7	-25
-20	2.962	389.2	1.814	0.775	149.5	3.120	389.1	1.810	0.777	149.5	3.286	389.0	1.806	0.778	149.3	-20
-15	2.900	393.1	1.830	0.782	151.1	3.054	393.0	1.825	0.783	151.0	3.216	392.9	1.821	0.785	150.9	-15
-10	2.840	397.0	1.845	0.790	152.6	2.991	396.9	1.840	0.791	152.5	3.149	396.8	1.836	0.792	152.4	-10
-5	2.783	400.9	1.860	0.797	154.1	2.931	400.9	1.855	0.798	154.0	3.085	400.8	1.851	0.799	153.9	-5
0	2.729	405.0	1.874	0.805	155.5	2.874	404.9	1.870	0.806	155.5	3.025	404.8	1.866	0.807	155.4	0
5	2.677	409.0	1.889	0.812	157.0	2.819	408.9	1.885	0.813	156.9	2.966	408.8	1.880	0.814	156.8	5
10	2.627	413.1	1.904	0.820	158.4	2.766	413.0	1.899	0.821	158.4	2.911	412.9	1.895	0.822	158.3	10
15	2.579	417.2	1.918	0.828	159.8	2.715	417.1	1.914	0.829	159.8	2.857	417.1	1.909	0.829	159.7	15
20	2.533	421.4	1.932	0.836	161.2	2.666	421.3	1.928	0.837	161.1	2.806	421.2	1.924	0.837	161.1	20
25	2.488	425.6	1.947	0.844	162.6	2.619	425.5	1.942	0.844	162.5	2.756	425.4	1.938	0.845	162.4	25
30	2.445	429.8	1.961	0.852	163.9	2.574	429.7	1.956	0.852	163.9	2.708	429.7	1.952	0.853	163.8	30
35	2.404	434.1	1.975	0.860	165.3	2.530	434.0	1.970	0.860	165.2	2.662	434.0	1.966	0.861	165.1	35
40	2.364	438.4	1.989	0.868	166.6	2.488	438.3	1.984	0.868	166.5	2.618	438.3	1.980	0.869	166.5	40
45	2.325	442.8	2.002	0.876	167.9	2.448	442.7	1.998	0.876	167.8	2.575	442.7	1.994	0.877	167.8	45
50	2.288	447.1	2.016	0.884	169.2	2.409	447.1	2.012	0.884	169.1	2.534	447.1	2.008	0.885	169.1	50
55	2.252	451.6	2.030	0.892	170.5	2.371	451.5	2.026	0.892	170.4	2.494	451.5	2.021	0.893	170.4	55
60	2.218	456.1	2.043	0.900	171.8	2.334	456.0	2.039	0.900	171.7	2.455	456.0	2.035	0.901	171.6	60
65	2.184	460.6	2.057	0.908	173.0	2.298	460.5	2.053	0.908	173.0	2.418	460.5	2.048	0.909	172.9	65
70	2.151	465.1	2.070	0.916	174.3	2.264	465.1	2.066	0.916	174.2	2.382	465.1	2.062	0.916	174.2	70
75	2.120	469.7	2.083	0.924	175.5	2.230	469.7	2.079	0.924	175.5	2.346	469.7	2.075	0.924	175.4	75
80	2.089	474.4	2.097	0.932	176.7	2.198	474.3	2.092	0.932	176.7	2.312	474.3	2.088	0.932	176.6	80
85	2.059	479.1	2.110	0.939	177.9	2.167	479.0	2.106	0.940	177.9	2.279	479.0	2.101	0.940	177.9	85

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]= kJ / (kg·K) [cp]= kJ / (kg·K) [c]=m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=0.694 bar (ts=-34°C)					ps=0.729 bar (ts=-33°C)					ps=0.766 bar (ts=-32°C)					
-30	[illegible]	381.1	1.770	0.767	[illegible]	3.806	381.0	1.766	0.769	145.8	4.004	380.9	[illegible]	[illegible]	[illegible]	-30
-25	3.535	385.0	1.785	0.773	147.6	3.719	384.8	1.781	0.775	147.4	3.912	384.7	[illegible]	[illegible]	147.2	-25
-20	3.457	388.9	1.801	0.779	149.2	3.637	388.7	1.797	0.781	149.0	3.824	388.6	1.793	0.783	148.9	-20
-15	3.380	392.8	1.817	0.785	150.7	3.553	392.7	1.812	0.788	150.6	3.742	392.6	1.808	0.790	150.4	-15
-10	3.310	396.7	1.832	0.793	152.3	3.484	396.6	1.827	0.794	152.1	3.663	396.5	1.823	0.796	152.0	-10
-5	3.240	400.7	1.847	0.800	153.8	3.412	400.5	1.842	0.801	153.6	3.583	400.5	[illegible]	[illegible]	153.5	-5
0	3.172	404.7	1.862	0.808	155.3	3.345	404.6	1.857	0.809	155.1	3.517	404.5	[illegible]	[illegible]	155.0	0
5	3.120	408.8	1.876	0.815	156.7	3.281	408.7	1.872	0.816	156.6	3.448	408.6	1.867	[illegible]	156.5	5
10	3.061	412.9	1.891	0.823	158.2	3.218	412.8	1.887	0.823	158.0	3.383	412.7	1.882	0.824	157.9	10
15	3.005	417.0	1.905	0.830	159.6	3.159	416.9	1.901	0.831	159.5	3.320	416.8	1.897	0.832	159.4	15
20	2.951	421.2	1.920	0.838	161.0	3.102	421.1	1.915	0.839	160.9	3.259	421.0	1.911	0.839	160.8	20
25	2.898	425.4	1.934	0.845	162.3	3.047	425.3	1.930	0.846	162.2	3.202	425.2	1.926	0.847	162.2	25
30	2.848	429.5	1.948	0.854	163.7	2.994	429.6	1.944	0.854	163.5	3.146	429.5	1.940	0.855	163.5	30
35	2.799	433.9	1.962	0.861	165.1	2.943	433.9	1.958	0.862	165.0	3.092	433.8	1.954	0.863	164.9	35
40	2.753	438.2	1.976	0.869	166.4	2.893	438.2	1.972	0.870	166.3	3.040	438.1	1.968	0.870	166.2	40
45	2.708	442.6	1.990	0.877	167.7	2.846	442.6	1.985	0.878	167.6	2.990	442.5	1.982	0.878	167.5	45
50	2.654	447.0	2.004	0.885	169.0	2.800	447.0	1.999	0.886	168.9	2.942	446.9	1.995	0.886	168.9	50
55	2.622	451.5	2.017	0.893	170.3	2.755	451.4	2.013	0.894	170.2	2.895	451.4	2.009	0.894	170.2	55
60	2.581	455.9	2.031	0.901	171.6	2.713	455.9	2.027	0.901	171.5	2.850	455.8	2.023	0.902	171.5	60
65	2.542	460.5	2.044	0.909	172.8	2.671	460.4	2.040	0.909	172.8	2.806	460.4	2.036	0.910	172.7	65
70	2.504	465.0	2.058	0.917	174.1	2.631	465.0	2.054	0.917	174.0	2.764	464.9	2.049	0.917	174.0	70
75	2.467	469.6	2.071	0.925	175.3	2.592	469.6	2.067	0.925	175.3	2.723	469.5	2.063	0.925	175.2	75
80	2.431	474.3	2.084	0.932	176.5	2.554	474.2	2.080	0.933	176.5	2.683	474.2	2.076	0.933	176.5	80
85	2.396	479.0	2.097	0.940	177.8	2.518	478.9	2.093	0.940	177.8	2.645	478.9	2.089	0.941	177.7	85
90	2.362	483.7	2.110	0.948	179.0	2.482	483.6	2.106	0.948	179.0	2.607	483.6	2.102	0.949	178.9	90
	ps=0.804 bar (ts=-31°C)					ps=0.843 bar (ts=-30°C)					ps=0.884 bar (ts=-29°C)					
-30	4.209	380.7	1.757	0.773	145.4	4.423	380.6	1.753	0.775	145.2	-	-	-	-	-	-30
-25	4.112	384.6	1.773	0.779	147.1	4.320	384.5	1.769	0.781	146.9	4.535	384.3	1.764	0.783	[illegible]	-25
-20	4.019	388.5	1.788	0.784	148.7	4.223	388.4	1.784	0.786	148.5	4.435	388.2	[illegible]	0.788	148.3	-20
-15	3.932	392.4	1.804	0.791	150.3	4.130	392.3	1.799	0.792	150.1	4.337	392.2	1.795	0.794	149.9	-15
-10	3.849	396.4	1.819	0.797	151.8	4.043	396.3	1.815	0.799	151.7	4.244	396.2	[illegible]	[illegible]	151.5	-10
-5	3.770	400.4	1.834	0.804	153.4	3.959	400.3	1.830	0.805	153.2	4.155	400.2	[illegible]	[illegible]	153.1	-5
0	3.694	404.4	1.849	0.811	154.9	3.879	404.3	1.845	0.812	154.7	4.072	404.2	[illegible]	[illegible]	154.6	0
5	3.622	408.5	1.864	0.818	156.4	3.803	408.4	1.859	0.819	156.2	3.992	408.3	1.855	0.820	156.1	5
10	3.553	412.5	1.878	0.825	157.8	3.731	412.5	1.874	0.826	157.7	3.915	412.4	1.870	0.827	157.6	10
15	3.487	416.8	1.893	0.833	159.3	3.661	416.7	1.889	0.834	159.1	3.842	416.6	1.885	0.835	159.0	15
20	3.423	421.0	1.907	0.840	160.7	3.594	420.9	1.903	0.841	160.6	3.771	420.8	1.899	0.842	160.5	20
25	3.362	425.2	1.921	0.848	162.1	3.529	425.1	1.917	0.849	162.0	3.703	425.0	1.913	0.849	161.9	25
30	3.303	429.4	1.935	0.856	163.4	3.458	429.4	1.932	0.856	163.3	3.639	429.3	1.928	0.857	163.2	30
35	3.247	433.7	1.950	0.863	164.8	3.408	433.7	1.946	0.864	164.7	3.576	433.6	1.942	0.865	164.6	35
40	3.192	438.1	1.964	0.871	166.1	3.350	438.0	1.960	0.872	166.1	3.515	437.9	1.956	0.872	166.0	40
45	3.139	442.4	1.977	0.879	167.5	3.295	442.4	1.973	0.879	167.4	3.457	442.3	1.969	0.880	167.3	45
50	3.089	446.9	1.991	0.887	168.8	3.242	446.8	1.987	0.887	168.7	3.401	446.7	[illegible]	[illegible]	168.6	50
55	3.040	451.3	2.005	0.894	170.1	3.190	451.2	2.001	0.895	170.0	[illegible]	451.2	[illegible]	[illegible]	169.9	55
60	2.992	[illegible]	2.019	0.902	171.4	[illegible]	455.7	2.015	0.903	171.3	[illegible]	455.7	[illegible]	[illegible]	[illegible]	60
65	2.946	[illegible]	2.032	0.910	172.7	[illegible]	460.3	2.028	0.910	172.6	[illegible]	460.2	[illegible]	[illegible]	[illegible]	65
70	2.902	464.9	2.045	0.918	173.9	3.045	464.8	2.041	0.918	173.8	3.194	464.8	[illegible]	[illegible]	173.8	70
75	2.859	469.5	2.059	0.925	175.2	[illegible]	469.5	2.055	0.925	175.1	3.146	469.4	2.051	0.926	175.0	75
80	2.817	474.2	2.072	0.933	176.4	2.956	474.1	2.068	0.934	176.4	3.100	474.1	2.064	0.934	176.3	80
85	2.776	478.8	2.085	0.941	177.6	2.913	478.8	2.081	0.941	177.6	3.056	478.7	2.077	0.942	177.5	85
90	2.737	483.6	2.098	0.949	178.9	2.872	483.5	2.094	0.949	178.8	3.012	483.5	2.090	0.949	178.7	90
	ps=0.926 bar (ts=-28°C)					ps=0.970 bar (ts=-27°C)					ps=1.02 bar (ts=-26°C)					
-25	4.764	384.2	1.760	0.785	146.5	5.001	384.0	1.756	0.787	146.3	5.247	383.8	1.751	0.790	146.0	-25
-20	4.656	388.1	1.776	0.790	148.1	4.886	388.0	1.771	0.792	147.9	5.125	387.8	1.767	0.794	147.7	-20
-15	4.552	392.1	1.791	0.795	149.8	4.777	391.9	1.787	0.798	149.6	5.011	391.8	1.783	0.800	149.4	-15
-10	4.455	396.1	1.806	0.802	151.4	4.674	395.9	1.802	0.803	151.2	4.902	395.8	1.798	0.805	151.0	-10
-5	4.362	400.1	1.821	0.808	152.9	4.576	400.0	1.817	0.810	152.8	4.798	399.8	1.813	0.811	152.6	-5
0	4.273	404.1	1.836	0.815	154.5	4.482	404.0	1.832	0.816	154.3	4.700	403.9	1.828	0.817	154.1	0
5	4.188	408.2	1.851	0.821	156.0	4.393	408.1	1.847	0.823	155.8	4.606	408.0	1.843	0.824	155.7	5
10	4.106	412.4	1.866	0.828	157.4	4.308	412.3	1.862	0.830	157.3	4.516	412.2	1.858	0.831	157.2	10
15	4.030	416.5	1.881	0.836	158.9	4.227	416.4	1.877	0.837	158.8	4.430	416.3	1.873	0.838	158.6	15
20	3.956	420.7	1.895	0.843	160.3	4.148	420.6	1.891	0.844	160.2	4.348	420.5	1.887	0.845	160.1	20
25	3.885	424.9	1.909	0.850	161.7	4.074	424.9	1.905	0.851	161.6	4.269	424.8	1.901	0.852	161.5	25
30	3.816	429.2	1.924	0.858	163.1	4.001	429.1	1.920	0.859	163.0	4.193	429.1	1.916	0.859	162.9	30
35	3.750	433.5	1.938	0.865	164.5	3.932	433.4	1.934	0.866	164.4	4.120	433.4	1.930	0.867	164.3	35
40	3.686	437.9	1.952	0.873	165.9	3.865	437.8	1.948	0.874	165.8	4.050	437.7	1.944	0.874	165.7	40
45	3.626	442.3	1.965	0.881	167.2	3.801	442.2	1.962	0.881	167.1	3.983	442.1	1.958	0.882	167.0	45
50	3.566	446.7	1.979	0.888	168.5	3.739	446.6	1.975	0.889	168.5	3.917	446.5	1.971	0.889	168.4	50
55	3.509	451.1	1.993	0.896	169.9	3.679	451.1	1.989	0.897	169.8	3.854	451.0	1.985	0.897	169.7	55
60	3.454	455.6	2.007	0.904	171.2	3.621	455.6	2.003	0.904	171.1	3.793	455.5	1.999	0.905	171.0	60
65	3.401	460.2	2.020	0.911	172.4	3.565	460.1	2.016	0.912	172.4	3.734	460.1	2.012	[illegible]	172.3	65
70	3.349	464.7	2.034	0.919	173.7	3.511	464.7	2.030	0.920	173.6	3.678	464.6	2.026	0.920	173.6	70
75	3.299	469.4	2.047	0.927	175.0	3.458	469.3	2.043	0.927	174.9	3.622	469.3	2.039	0.928	174.8	75
80	3.250	474.0	2.060	0.934	176.2	3.407	474.0	2.056	0.935	176.2	3.569	473.9	2.052	0.935	176.1	80
85	3.204	478.7	2.073	0.942	177.5	3.358	478.7	2.069	0.942	177.4	3.517	478.6	2.066	0.943	177.3	85
90	3.158	483.4	2.086	0.950	178.7	3.310	483.4	2.083	0.950	178.6	3.467	483.3	2.079	0.950	178.5	90
95	3.114	488.2	2.099	0.957	179.9	3.263	488.2	2.096	0.958	179.8	3.418	488.1	2.092	0.958	179.8	95

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] in °C [ρ] in kg/m³ [h] in kJ/kg [s] in kJ/(kg•K) [cp] in kJ/(kg•K) [c] in m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=1.05 bar (ts=-25°C)					ps=1.11 bar (ts=-24°C)					ps=1.16 bar (ts=-23°C)					
-25	5.504	383.7	1.747	0.792	145.8	-	-	-	-	-	-	-	-	-	-	-25
-20	5.375	387.7	1.763	0.797	147.5	5.635	387.5	1.759	0.799	147.3	5.906	387.3	1.755	0.802	147.1	-20
-15	5.254	391.6	1.779	0.802	149.2	5.507	391.5	1.774	0.804	149.0	5.770	391.3	1.770	0.806	[illegible]	-15
-10	5.133	395.7	1.794	0.807	[illegible]	[illegible]	395.5	1.790	0.809	150.5	5.642	395.4	1.786	0.811	150.4	-10
-5	[illegible]	399.7	1.809	0.813	[illegible]	[illegible]	399.5	1.805	0.815	152.2	5.520	399.4	1.801	0.816	152.0	-5
0	4.926	403.8	1.824	0.819	[illegible]	[illegible]	403.7	1.821	0.821	153.8	5.405	403.5	1.816	0.822	153.6	0
5	[illegible]	407.9	1.839	0.825	[illegible]	[illegible]	[illegible]	1.836	0.827	155.4	5.295	407.7	1.831	0.829	155.2	5
10	4.732	[illegible]	1.854	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.833	156.9	5.191	411.8	1.846	0.835	156.7	10
15	4.640	416.2	1.869	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.840	158.4	5.091	416.0	[illegible]	[illegible]	[illegible]	15
20	4.555	420.4	1.883	[illegible]	[illegible]	[illegible]	420.3	1.879	0.847	159.8	4.995	420.2	1.875	0.848	159.7	20
25	4.472	424.7	1.897	0.853	161.4	4.664	424.6	1.894	0.854	161.3	4.903	424.5	1.890	0.855	161.1	25
30	4.393	429.0	1.912	0.860	162.8	[illegible]	428.9	1.908	0.861	162.7	4.815	428.6	1.904	0.862	162.5	30
35	4.316	433.3	1.926	0.868	164.2	4.513	433.2	1.922	0.863	164.1	4.730	433.1	1.918	0.869	164.0	35
40	4.243	437.5	1.940	0.875	165.6	4.442	437.6	1.936	0.876	165.5	4.649	437.5	1.932	0.877	165.3	40
45	4.172	442.0	1.954	0.883	166.9	4.367	442.0	1.951	0.883	166.8	4.571	441.9	1.946	0.884	166.7	45
50	4.103	446.5	1.968	0.890	168.3	4.296	446.4	1.964	0.891	168.2	4.495	446.3	1.960	0.891	168.1	50
55	4.037	450.9	1.981	0.898	169.6	4.225	450.9	1.977	0.898	169.5	4.423	450.8	1.974	0.899	169.4	55
60	3.973	455.4	1.995	0.905	170.9	4.159	455.4	1.991	0.906	170.8	4.353	455.3	1.987	0.906	170.7	60
65	3.911	460.0	2.008	0.913	172.2	4.094	459.9	2.005	0.913	172.1	4.285	459.9	2.001	0.914	172.0	65
70	3.852	464.6	2.022	0.920	173.5	4.031	464.5	2.018	0.921	173.4	4.219	464.5	2.014	0.921	173.3	70
75	3.793	469.2	2.035	0.928	174.8	3.970	469.1	2.032	0.929	174.7	4.155	469.1	2.028	0.929	174.6	75
80	3.738	473.9	2.049	0.936	176.0	3.912	473.8	2.045	0.936	175.9	4.093	473.7	2.041	0.937	175.9	80
85	3.683	478.6	2.062	0.943	177.3	3.855	478.5	2.058	0.944	177.2	4.034	478.4	2.054	0.944	177.1	85
90	3.630	483.3	2.075	0.951	178.5	3.800	483.2	2.071	0.951	178.4	3.976	483.2	2.067	0.952	178.4	90
95	3.580	488.1	2.088	0.958	179.7	3.746	488.0	2.084	0.959	179.7	3.919	488.0	2.080	0.959	179.6	95
	ps=1.22 bar (ts=-22°C)					ps=1.27 bar (ts=-21°C)					ps=1.33 bar (ts=-20°C)					
-20	6.187	387.1	1.750	0.804	146.9	6.479	387.0	1.746	0.807	146.6	6.784	386.8	1.742	0.810	146.3	-20
-15	6.043	391.2	1.766	0.808	148.5	6.328	391.0	1.762	0.811	148.3	6.624	390.8	1.758	0.813	148.1	-15
-10	5.905	395.2	1.782	0.813	150.2	6.185	395.1	1.778	0.815	150.0	6.474	394.9	1.774	0.819	[illegible]	-10
-5	[illegible]	399.3	1.797	0.818	151.6	[illegible]	399.2	1.793	0.820	151.6	6.331	399.0	1.789	0.822	151.4	-5
0	[illegible]	403.4	1.812	0.824	153.1	[illegible]	403.3	1.808	0.826	153.3	6.195	403.1	1.804	0.828	153.1	0
5	[illegible]	407.5	1.827	0.830	155.0	[illegible]	407.4	1.823	0.831	154.8	[illegible]	407.3	[illegible]	[illegible]	[illegible]	5
10	5.432	411.7	1.842	0.836	156.5	5.686	411.6	1.838	0.838	156.4	5.947	411.5	[illegible]	0.839	[illegible]	10
15	5.328	415.9	1.857	0.843	[illegible]	5.574	415.8	1.853	0.844	157.9	[illegible]	415.7	1.849	0.845	157.7	15
20	5.227	420.1	1.871	0.849	[illegible]	5.463	420.0	1.863	0.851	159.4	5.719	419.9	1.864	0.852	159.2	20
25	5.131	424.4	1.886	0.856	161.0	5.367	424.3	1.882	0.857	160.9	5.612	424.2	1.878	0.858	160.7	25
30	5.039	428.7	1.900	0.863	162.4	5.270	428.6	1.896	0.864	162.3	5.511	428.5	1.892	0.865	162.1	30
35	4.950	433.0	1.914	0.870	163.8	5.176	432.9	1.910	0.871	163.7	5.412	432.8	1.907	0.872	163.6	35
40	4.864	437.4	1.928	0.878	165.2	5.087	437.3	1.925	0.878	165.1	5.318	437.2	1.921	0.879	165.0	40
45	4.782	441.8	1.942	0.885	166.5	5.001	441.7	1.939	0.885	166.5	5.228	441.6	1.935	0.886	166.4	45
50	4.703	446.2	1.956	0.892	168.0	4.917	446.2	1.952	0.893	167.9	5.141	446.1	1.949	0.894	167.7	50
55	[illegible]	450.7	1.970	0.900	[illegible]	[illegible]	450.7	1.965	0.900	169.2	5.057	450.6	1.962	0.901	169.1	55
60	4.552	455.2	1.984	0.907	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	170.5	4.976	[illegible]	[illegible]	[illegible]	[illegible]	60
65	4.491	459.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65
70	4.413	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	70
75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	174.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75
80	4.281	473.7	2.037	0.937	[illegible]	[illegible]	473.6	2.034	0.937	175.7	[illegible]	[illegible]	[illegible]	[illegible]	175.6	80
85	4.218	478.4	2.051	0.944	[illegible]	4.410	478.3	2.047	0.945	177.0	4.609	478.2	2.043	0.945	176.9	85
90	4.158	483.1	2.064	0.952	178.3	4.347	483.1	2.060	0.952	178.2	4.542	483.0	2.056	0.953	178.1	90
95	4.093	487.9	2.077	0.959	179.5	4.285	487.8	2.073	0.960	179.4	4.478	487.8	2.069	0.960	179.4	95
100	4.042	492.7	2.090	0.967	180.7	4.225	492.7	2.086	0.967	180.7	4.415	492.6	2.082	0.968	180.6	100
	ps=1.39 bar (ts=-19°C)					ps=1.45 bar (ts=-18°C)					ps=1.51 bar (ts=-17°C)					
-15	6.931	390.6	1.754	0.816	147.8	7.251	390.5	1.750	0.819	147.5	7.583	390.3	1.746	0.822	147.3	-15
-10	6.773	394.7	1.770	0.820	149.5	7.084	394.5	1.766	0.822	149.3	7.407	394.4	1.762	0.825	149.0	-10
-5	6.623	398.8	1.785	0.824	151.2	6.925	398.7	1.781	0.827	151.0	7.240	398.5	1.777	0.829	150.7	-5
0	6.480	403.0	1.801	0.829	152.8	6.775	402.8	1.797	0.832	152.6	7.082	402.7	1.793	0.834	152.4	0
5	6.345	407.1	1.816	0.835	154.4	6.634	407.0	1.812	0.837	154.2	6.933	406.8	1.808	0.839	154.0	5
10	6.217	411.3	1.831	0.841	156.0	6.499	411.2	1.827	0.842	155.8	6.791	411.1	1.823	0.844	155.6	10
15	6.095	415.5	1.845	0.847	157.6	6.370	415.4	1.841	0.848	157.4	6.656	415.3	1.838	0.850	157.2	15
20	5.978	419.8	1.860	0.853	159.1	6.248	419.7	1.856	0.855	158.9	6.527	419.5	1.852	0.856	158.7	20
25	5.865	424.1	1.874	0.860	160.5	6.130	424.0	1.871	0.861	160.4	6.403	423.8	1.867	0.862	160.2	25
30	5.759	428.4	1.889	0.866	162.0	6.018	428.3	1.885	0.868	161.8	6.285	428.2	1.881	0.869	161.7	30
35	5.657	432.7	1.903	0.873	163.4	5.910	432.6	1.899	0.874	163.3	6.173	432.5	1.895	0.875	163.1	35
40	5.558	437.1	1.917	0.880	164.8	5.807	437.0	1.913	0.881	164.7	6.063	436.9	1.910	0.882	164.6	40
45	5.463	441.5	1.931	0.887	166.2	5.707	441.5	1.927	0.888	166.1	5.959	441.4	1.924	0.889	166.0	45
50	5.372	446.0	1.945	0.894	167.6	5.611	445.9	1.941	0.895	167.5	5.859	445.8	1.938	0.896	167.4	50
55	5.284	450.5	1.959	0.902	169.0	5.519	450.4	1.955	0.903	168.9	5.763	450.3	1.951	0.903	168.7	55
60	5.198	455.0	1.972	0.909	170.3	5.430	454.9	1.969	0.910	170.2	5.669	454.8	1.965	0.910	170.1	60
65	5.116	459.6	1.986	0.916	171.6	5.343	459.5	1.982	0.917	171.5	5.579	459.4	1.979	0.918	171.4	65
70	5.037	464.2	2.000	0.924	172.9	5.261	464.1	1.996	0.924	172.8	5.492	464.0	1.992	0.925	172.7	70
75	4.961	468.8	2.013	0.931	174.2	5.180	468.7	2.009	0.932	174.1	5.408	468.7	2.006	0.932	174.0	75
80	4.887	473.5	2.026	0.938	175.5	5.103	473.4	2.023	0.939	175.4	5.327	473.3	2.019	0.940	175.3	80
85	4.814	478.2	2.040	0.946	176.8	5.027	478.1	2.036	0.946	176.7	5.248	478.1	2.032	0.947	176.6	85
90	4.744	482.9	2.053	0.953	178.0	4.955	482.9	2.049	0.954	178.0	5.172	482.8	2.046	0.954	177.9	90
95	4.677	487.7	2.066	0.961	179.3	4.884	487.7	2.062	0.961	179.2	5.098	487.6	2.059	0.962	179.1	95
100	4.611	492.6	2.079	0.968	180.5	4.816	492.5	2.075	0.968	180.4	5.025	492.4	2.072	0.969	180.4	100
105	4.548	497.4	2.092	0.975	181.7	4.749	497.4	2.088	0.976	181.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	105

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]= kJ / (kg·K) [cp]= kJ / (kg·K) [c]=m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=1.57 bar (ts=-16°C)					ps=1.64 bar (ts=-15°C)					ps=1.71 bar (ts=-14°C)					
-15	7.929	393.1	1.742	0.825	147.0	8.295	369.8	1.738	0.828	146.7	-	-	-	-	-	-15
-10	7.742	394.2	1.758	0.828	148.8	8.091	394.0	1.754	0.831	148.5	8.452	393.8	1.750	0.834	148.2	-10
-5	7.566	398.3	1.773	0.832	150.5	7.905	399.1	1.770	0.834	150.2	8.257	398.0	1.766	0.837	150.0	-5
0	7.400	402.5	1.789	0.836	152.2	7.731	402.3	1.785	0.838	151.9	8.073	402.1	1.781	0.841	151.7	0
5	7.243	406.7	1.804	0.841	153.8	7.565	406.5	1.800	0.843	153.6	7.893	406.4	1.796	0.845	153.4	5
10	7.094	410.9	1.819	0.845	155.4	7.403	410.8	1.815	0.848	155.2	7.733	410.6	1.811	0.850	155.0	10
15	6.952	415.1	1.834	0.852	157.0	7.253	415.0	1.830	0.853	156.8	7.577	414.8	1.826	0.855	156.6	15
20	6.816	419.4	1.849	0.857	158.5	7.116	419.3	1.845	0.859	158.3	7.427	419.1	1.841	0.861	158.1	20
25	6.687	423.7	1.863	0.864	160.0	6.981	423.6	1.859	0.865	159.9	7.285	423.5	1.856	0.867	159.7	25
30	6.563	428.1	1.878	0.870	161.5	6.851	427.9	1.874	0.871	161.4	7.148	427.8	1.870	0.873	161.2	30
35	6.444	432.4	1.892	0.877	163.0	6.726	432.3	1.888	0.878	162.8	7.018	432.2	1.885	0.879	162.7	35
40	6.331	436.8	1.905	0.883	164.4	6.607	436.7	1.902	0.884	164.3	6.893	436.5	1.899	0.886	164.1	40
45	6.221	441.3	1.920	0.890	165.8	6.492	441.1	1.916	0.891	165.7	6.773	441.0	1.913	0.892	165.5	45
50	6.116	445.7	1.934	0.897	167.2	6.382	445.6	1.930	0.898	167.1	6.657	445.5	1.927	0.899	167.0	50
55	6.015	450.2	1.943	0.904	168.6	6.276	450.1	1.944	0.925	168.5	6.546	450.0	1.941	0.906	168.3	55
60	5.917	454.8	1.962	0.911	170.0	6.173	454.7	1.958	0.912	169.8	6.440	454.6	1.954	0.913	169.7	60
65	5.822	459.3	1.975	0.918	171.3	6.075	459.2	1.972	0.919	171.2	6.336	459.2	1.968	0.920	171.1	65
70	5.732	463.9	1.989	0.926	172.6	5.980	463.9	1.985	0.926	172.5	6.236	463.8	1.982	0.927	172.4	70
75	5.643	468.6	2.002	0.933	173.9	5.885	468.5	1.999	0.934	173.8	6.140	468.4	1.995	0.934	173.7	75
80	5.558	473.3	2.016	0.940	175.2	5.798	473.2	2.012	0.941	175.1	6.047	473.1	2.009	0.941	175.0	80
85	5.476	478.0	2.029	0.947	176.5	5.713	477.9	2.025	0.948	176.4	5.957	477.8	2.022	0.949	176.3	85
90	5.395	482.7	2.042	0.955	177.8	5.629	482.7	2.039	0.955	177.7	5.869	482.6	2.035	0.956	177.6	90
95	5.319	487.5	2.055	0.962	179.0	5.548	487.5	2.052	0.963	178.9	5.785	487.4	2.048	0.963	178.8	95
100	5.244	492.4	2.068	0.969	180.3	5.470	492.3	2.065	0.970	180.2	5.703	492.2	2.061	0.970	180.1	100
105	5.171	497.2	2.081	0.977	181.5	5.394	497.2	2.078	0.977	181.4	5.623	497.1	2.074	0.978	181.3	105
	ps=1.78 bar (ts=-13°C)					ps=1.85 bar (ts=-12°C)					ps=1.93 bar (ts=-11°C)					
-10	8.828	393.6	1.746	0.837	147.9	9.218	393.3	1.742	0.840	147.6	9.623	393.1	1.738	0.844	147.3	-10
-5	8.622	397.8	1.762	0.840	149.7	9.001	397.5	1.758	0.843	149.4	9.394	397.3	1.754	0.846	149.1	-5
0	8.428	402.0	1.777	0.843	151.4	8.795	401.8	1.773	0.846	151.1	9.178	401.6	1.770	0.848	150.9	0
5	8.245	406.2	1.793	0.847	153.1	8.603	406.0	1.789	0.850	152.9	8.975	405.8	1.785	0.852	152.6	5
10	8.071	410.4	1.808	0.852	154.8	8.421	410.3	1.804	0.854	154.5	8.783	410.1	1.800	0.856	154.3	10
15	7.905	414.7	1.823	0.857	156.4	8.247	414.5	1.819	0.859	156.1	8.601	414.4	1.815	0.861	155.9	15
20	7.749	419.0	1.837	0.862	157.9	8.083	418.9	1.834	0.864	157.7	8.428	418.7	1.830	0.866	157.5	20
25	7.600	423.3	1.852	0.868	159.5	7.926	423.2	1.848	0.870	159.3	8.264	423.0	1.845	0.871	159.1	25
30	7.457	427.7	1.867	0.874	161.0	7.775	427.5	1.863	0.876	160.8	8.105	427.4	1.859	0.877	160.6	30
35	7.320	432.1	1.881	0.880	162.5	7.633	431.9	1.877	0.882	162.3	7.955	431.8	1.874	0.883	162.1	35
40	7.190	436.5	1.895	0.887	164.0	7.495	436.4	1.892	0.888	163.8	7.812	436.2	1.888	0.889	163.6	40
45	7.063	440.9	1.909	0.893	165.4	7.364	440.8	1.906	0.894	165.2	7.674	440.7	1.902	0.896	165.1	45
50	6.942	445.4	1.923	0.900	166.8	7.237	445.3	1.920	0.901	166.7	7.541	445.2	1.916	0.902	166.5	50
55	6.825	449.9	1.937	0.907	168.2	7.114	449.8	1.934	0.908	168.1	7.414	449.7	1.930	0.909	167.9	55
60	6.714	454.5	1.951	0.914	169.6	6.998	454.4	1.947	0.915	169.4	7.292	454.3	1.944	0.916	169.3	60
65	6.606	459.1	1.965	0.921	170.9	6.884	459.0	1.961	0.922	170.8	7.174	458.9	[illegible]	0.923	170.7	65
70	6.503	463.7	1.978	0.928	172.3	6.776	463.6	1.975	0.929	172.2	7.060	463.5	[illegible]	0.929	172.0	70
75	6.400	468.3	[illegible]	[illegible]	173.6	6.671	468.3	[illegible]	[illegible]	173.5	6.950	468.2	[illegible]	[illegible]	173.4	75
80	[illegible]	473.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80
85	6.219	477.3	[illegible]	0.949	176.2	[illegible]	[illegible]	2.015	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	176.0	85
90	6.119	482.5	2.031	0.956	177.5	6.375	482.5	2.028	0.957	177.4	6.641	[illegible]	[illegible]	0.958	177.3	90
95	6.029	487.3	2.045	0.964	178.9	6.283	487.3	2.041	0.964	178.7	6.544	487.2	[illegible]	0.965	178.5	95
100	5.944	492.2	2.059	0.971	180.0	6.193	492.1	2.054	0.971	179.9	6.451	492.0	2.051	0.972	179.8	100
105	5.862	497.0	2.071	0.978	181.2	6.107	497.0	2.067	0.978	181.2	6.360	496.9	2.064	0.979	181.1	105
110	5.781	501.9	2.083	0.985	182.5	6.023	501.9	2.080	0.985	182.4	6.273	501.8	2.077	0.986	182.3	110
	ps=2.01 bar (ts=-10°C)					ps=2.09 bar (ts=-9°C)					ps=2.17 bar (ts=-8°C)					
-10	10.044	392.9	1.734	0.847	146.9	-	-	-	-	-	-	-	-	-	-	-10
-5	9.802	397.1	1.750	0.849	148.8	10.225	396.9	1.746	0.852	148.5	10.664	396.6	1.742	0.855	148.1	-5
0	9.575	401.4	1.766	0.851	150.6	9.985	401.1	1.762	0.854	150.3	10.412	400.9	1.758	0.857	150.0	0
5	9.361	405.6	1.781	0.855	152.3	9.761	405.4	1.778	0.857	152.0	10.175	405.2	1.774	0.860	151.7	5
10	9.159	409.9	1.797	0.858	154.0	9.548	409.7	1.793	0.861	153.8	9.951	409.5	1.789	0.863	153.5	10
15	8.968	414.2	1.812	0.863	155.7	9.347	414.0	1.808	0.865	155.4	9.740	413.8	1.804	0.867	155.2	15
20	8.786	418.5	1.827	0.868	157.3	9.155	418.4	1.823	0.870	157.1	9.540	418.2	1.819	0.872	156.9	20
25	8.613	422.9	1.841	0.873	158.9	8.975	422.7	1.838	0.875	158.7	9.350	422.6	1.834	0.877	158.4	25
30	8.448	427.3	1.856	0.879	160.4	8.802	427.1	1.852	0.880	160.2	9.168	427.0	1.849	0.882	160.0	30
35	8.291	431.7	1.870	0.884	161.9	8.637	431.5	1.867	0.886	161.7	8.995	431.4	1.863	0.888	161.5	35
40	8.140	436.1	1.884	0.891	163.4	8.479	436.0	1.881	0.892	163.2	8.829	435.8	1.877	0.893	163.1	40
45	7.995	440.6	1.899	0.897	164.9	8.328	440.4	1.895	0.898	164.7	8.672	440.3	1.892	0.899	164.5	45
50	7.857	445.1	1.913	0.903	166.3	8.183	445.0	1.909	0.904	166.2	8.520	444.8	1.906	0.906	166.0	50
55	7.723	449.6	1.927	0.910	167.8	8.043	449.5	1.923	0.911	167.6	8.374	449.4	1.920	0.912	167.4	55
60	7.596	454.2	1.940	0.917	169.2	7.909	454.1	1.937	0.918	169.0	8.234	453.9	1.934	0.919	168.8	60
65	7.472	458.8	1.954	0.923	170.5	7.779	458.7	1.951	0.924	170.4	8.098	458.6	1.947	0.925	170.2	65
70	7.353	463.4	1.968	0.930	171.9	7.656	463.3	1.964	0.931	171.8	7.969	463.2	1.961	0.932	171.6	70
75	7.238	468.1	1.981	0.937	173.2	7.536	468.0	1.978	0.938	173.1	7.843	467.9	1.974	0.939	173.0	75
80	7.127	472.8	1.995	0.944	174.6	7.420	472.7	1.991	0.945	174.4	7.721	472.6	1.988	0.946	174.3	80
85	7.019	477.5	2.008	0.951	175.9	7.306	477.4	2.005	0.952	175.7	7.605	477.3	2.001	0.953	175.6	85
90	6.916	482.3	2.021	0.958	177.2	7.199	482.2	2.018	0.959	177.0	7.491	482.1	2.014	0.960	176.9	90
95	6.815	487.1	2.034	0.965	178.4	7.094	487.0	2.031	0.966	178.3	7.382	486.9	2.028	0.967	178.2	95
100	6.717	491.9	2.047	0.972	179.7	6.991	491.9	2.044	0.973	179.6	7.276	491.8	2.041	0.974	179.5	100
105	6.623	496.8	2.060	0.980	181.0	6.893	495.7	2.057	0.980	180.9	7.173	[illegible]	[illegible]	0.981	180.8	105
110	6.531	501.7	2.073	0.987	182.2	6.797	501.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.988	182.0	110

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] in °C [ρ] in kg/m³ [h] in kJ/kg [s] in kJ/(kg·K) [cp] in kJ/(kg·K) [c] in m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=2.26 bar (ts=-7°C)					ps=2.34 bar (ts=-6°C)					ps=2.43 bar (ts=-5°C)					
-5	11.113	396.4	1.739	0.853	147.8	11.592	396.1	1.735	0.863	147.4	12.081	395.9	1.731	0.867	147.0	-5
0	10.853	400.7	1.754	0.851	149.6	11.311	400.4	1.751	0.964	149.3	11.786	400.2	1.747	0.958	148.9	0
5	10.604	[illegible]	1.770	0.853	151.4	11.043	404.9	1.766	0.866	151.1	11.529	404.5	1.763	0.869	150.8	5
10	10.363	409.3	1.785	0.866	153.2	10.922	409.1	1.782	0.869	152.9	11.249	408.9	1.779	0.872	152.6	10
15	10.147	413.7	1.801	0.872	154.9	10.565	413.5	1.797	0.872	154.6	[illegible]	413.3	1.793	0.875	154.3	15
20	9.937	[illegible]	1.816	[illegible]	156.6	10.339	417.8	1.812	0.876	156.3	10.772	417.5	1.808	[illegible]	156.0	20
25	9.727	422.4	1.830	0.973	159.2	10.139	422.2	1.827	0.981	157.9	10.552	422.3	1.823	0.883	157.7	25
30	9.547	426.8	1.845	0.894	159.8	9.929	426.5	1.842	[illegible]	159.5	10.343	426.5	1.938	0.897	159.3	30
35	9.365	431.2	1.860	0.859	161.3	9.749	431.1	1.855	0.891	161.1	10.145	430.9	1.853	0.893	160.9	35
40	9.191	435.7	1.874	0.895	162.9	9.557	435.5	1.871	0.896	162.6	9.954	435.4	1.867	0.898	162.4	40
45	9.026	440.2	1.888	0.901	164.3	9.393	440.0	1.885	0.902	164.2	9.773	439.9	1.881	0.904	163.9	45
50	8.858	444.7	1.902	0.907	165.8	9.229	444.6	1.899	0.908	165.5	9.600	444.4	1.895	0.910	165.4	50
55	8.715	449.2	1.916	[illegible]	167.3	9.068	449.1	1.913	0.914	167.1	9.432	449.0	1.909	0.915	166.9	55
60	8.569	453.8	1.930	[illegible]	168.7	[illegible]	453.7	1.927	0.921	168.5	9.273	453.6	1.923	0.922	168.3	60
65	8.428	458.4	1.944	[illegible]	170.1	8.769	458.3	1.940	0.927	169.9	9.118	458.2	1.937	0.928	169.8	65
70	8.291	463.1	1.958	[illegible]	171.5	8.626	463.0	1.954	0.934	171.3	8.970	462.9	1.951	0.935	171.2	70
75	8.151	467.8	1.971	0.940	172.8	8.488	467.7	1.968	0.941	172.7	8.826	467.6	1.964	0.941	172.5	75
80	8.034	472.5	1.984	0.946	174.2	8.357	472.4	1.981	0.947	174.0	8.689	472.3	1.978	0.948	173.9	80
85	7.912	477.2	1.998	0.953	175.5	8.228	477.1	1.995	0.954	175.4	8.556	477.0	1.991	0.955	175.2	85
90	7.794	482.0	2.011	0.960	176.8	8.105	481.9	2.008	0.961	176.7	8.427	481.8	2.005	0.962	176.5	90
95	7.679	486.5	2.024	0.967	178.1	7.995	486.7	2.021	0.968	178.0	8.303	485.7	2.018	0.969	177.9	95
100	7.568	491.7	2.037	0.974	179.4	7.871	491.6	2.034	0.975	179.3	8.182	491.5	2.031	0.975	179.1	100
105	7.461	496.6	2.050	0.981	180.6	7.759	496.5	2.047	0.982	180.5	8.066	496.4	2.044	0.982	180.4	105
110	7.357	501.5	2.053	0.988	181.9	7.650	501.4	2.060	0.989	181.8	7.953	501.3	2.057	0.989	181.7	110
115	7.256	506.5	2.076	0.995	183.1	7.545	506.4	2.073	0.995	183.0	7.842	506.3	2.070	0.996	182.9	115

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=2.53 bar (ts=-4°C)					ps=2.62 bar (ts=-3°C)					ps=2.72 bar (ts=-2°C)					
0	12.278	399.9	1.743	0.871	148.5	12.788	399.7	1.739	0.875	148.2	[illegible]	399.4	1.735	0.873	147.8	0
5	11.987	404.3	1.759	0.873	150.5	12.481	404.0	1.755	0.876	150.1	12.994	403.8	1.751	0.880	149.7	5
10	11.719	408.7	1.774	0.875	152.3	12.193	408.4	1.771	0.879	152.0	12.691	408.2	1.767	0.881	151.6	10
15	11.455	413.0	1.793	0.877	154.0	11.922	412.8	1.796	0.883	153.7	12.405	412.6	1.783	0.883	153.4	15
20	11.212	417.4	1.805	0.881	155.9	11.657	417.2	1.801	0.893	155.5	12.127	417.0	1.799	0.955	155.2	20
25	10.981	421.9	1.820	0.885	157.4	11.425	421.7	1.816	0.887	157.2	[illegible]	421.5	[illegible]	[illegible]	155.9	25
30	10.762	426.3	1.835	0.889	159.1	11.195	426.1	1.831	0.892	158.8	11.647	425.9	1.826	0.894	158.5	30
35	10.554	430.7	1.849	0.894	160.7	10.977	430.6	1.945	0.896	160.4	11.414	430.4	1.842	0.898	160.2	35
40	10.355	435.2	1.864	0.900	162.2	10.759	435.1	1.860	0.901	162.0	11.195	434.9	1.857	0.903	161.8	40
45	10.165	439.7	1.878	0.905	163.7	10.570	439.6	1.874	0.907	153.5	10.988	439.4	1.871	0.909	163.3	45
50	9.984	444.2	1.892	0.911	165.2	10.380	444.1	1.889	0.912	165.0	10.788	444.0	1.885	0.914	164.8	50
55	9.808	448.9	1.906	0.917	166.7	10.198	448.7	1.903	0.918	166.5	10.597	448.6	1.899	0.920	166.3	55
60	9.642	453.5	1.920	0.923	168.2	10.022	453.3	1.917	0.924	168.0	10.415	453.2	1.913	0.926	167.8	60
65	9.481	458.1	1.934	0.929	169.6	9.854	458.0	1.930	0.931	169.4	10.240	457.8	1.927	0.932	169.2	65
70	9.325	462.7	1.947	0.936	171.0	9.692	452.5	1.944	0.937	170.8	10.071	462.5	1.941	0.938	170.7	70
75	9.176	467.4	1.961	0.942	172.4	[illegible]	467.3	1.958	0.943	172.2	9.909	467.2	1.954	0.944	172.0	75
80	9.033	472.2	1.975	0.949	173.7	9.387	472.1	1.971	0.950	173.6	9.752	471.9	1.968	0.951	173.4	80
85	8.894	476.9	1.988	0.956	175.1	9.241	476.8	1.985	0.957	174.9	[illegible]	476.7	1.981	[illegible]	174.8	85
90	8.760	[illegible]	2.001	0.962	176.4	[illegible]	[illegible]	[illegible]	[illegible]	176.2	[illegible]	[illegible]	[illegible]	0.964	[illegible]	90
95	8.630	486.3	2.014	0.969	177.7	8.966	[illegible]	[illegible]	0.970	177.5	9.314	[illegible]	2.008	[illegible]	[illegible]	95
100	8.504	491.4	2.029	0.976	179.0	8.835	491.3	2.024	0.977	178.9	9.177	491.2	2.021	0.978	178.8	100
105	8.382	496.3	2.041	0.983	180.3	8.708	496.2	2.037	0.964	180.2	9.044	496.1	2.034	0.984	180.1	105
110	8.264	501.2	2.054	0.990	181.6	8.585	501.2	2.050	0.991	181.5	8.917	501.1	2.047	0.991	181.3	110
115	8.150	506.2	2.066	0.997	182.8	8.466	506.1	2.063	0.997	182.7	8.792	506.0	2.060	0.998	182.6	115
120	9.039	511.2	2.079	1.004	184.1	8.351	511.1	2.076	1.004	184.0	8.672	511.0	2.073	1.005	183.9	120

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=2.82 bar (ts=-1°C)					ps=2.93 bar (ts= 0°C)					ps=3.04 bar (ts= 1°C)					
0	13.866	399.1	1.732	0.884	147.4	14.435	398.8	1.728	0.888	147.0	-	-	-	-	-	0
5	13.525	403.5	1.748	0.884	149.4	14.075	403.2	1.744	0.889	149.0	14.645	403.0	1.740	0.892	148.6	5
10	13.206	407.9	1.763	0.884	151.3	13.739	407.7	1.760	0.888	150.9	14.291	407.4	1.756	0.892	150.5	10
15	12.906	412.4	1.779	0.886	153.1	13.424	412.1	1.775	0.889	152.8	13.959	411.9	1.772	0.893	152.4	15
20	12.624	416.8	1.794	0.889	154.9	13.128	416.6	1.791	0.892	154.5	13.648	416.3	1.787	0.895	154.2	20
25	12.358	421.3	1.809	0.892	156.6	12.848	421.0	1.806	0.895	156.3	13.354	420.8	1.802	0.897	156.0	25
30	12.105	425.7	1.824	0.896	158.3	12.583	425.5	1.821	0.898	158.0	13.077	425.3	1.817	0.901	157.7	30
35	11.865	430.2	1.839	0.900	159.9	12.332	430.0	1.835	0.902	159.6	12.814	429.8	1.832	0.905	159.4	35
40	11.637	434.7	1.853	0.905	161.5	12.093	434.5	1.850	0.907	161.3	12.564	434.4	1.847	0.909	161.0	40
45	11.419	439.3	1.868	0.910	163.1	11.864	439.1	1.864	0.912	162.8	12.325	438.9	1.861	0.914	162.6	45
50	11.213	443.8	1.882	0.915	164.6	11.647	443.7	1.879	0.917	164.4	12.098	443.5	1.875	0.919	164.2	50
55	11.013	448.4	1.896	0.921	166.1	11.440	448.3	1.893	0.923	165.9	11.881	448.1	1.889	0.924	165.7	55
60	10.822	453.0	1.910	0.927	167.6	11.241	452.9	1.907	0.928	167.4	11.673	452.7	1.903	0.930	167.2	60
65	10.638	457.7	1.924	0.933	169.0	11.048	457.5	1.921	0.934	168.9	11.473	457.4	1.917	0.936	168.7	65
70	10.462	462.4	1.938	0.939	170.5	10.865	462.2	1.934	0.940	170.3	11.281	462.1	1.931	0.942	170.1	70
75	10.292	467.1	1.951	0.945	171.9	10.688	466.9	1.948	0.947	171.7	11.095	466.8	1.945	0.948	171.5	75
80	10.128	471.8	1.965	0.952	173.3	10.518	471.7	1.962	0.953	173.1	10.918	471.6	1.958	0.954	172.9	80
85	9.971	476.6	1.978	0.958	174.6	10.353	476.5	1.975	0.959	174.5	10.746	476.4	1.972	0.960	174.3	85
90	9.818	481.4	1.992	0.965	176.0	10.194	481.3	1.988	0.966	175.8	10.580	481.2	1.985	0.967	175.7	90
95	9.672	486.2	2.005	0.972	177.3	10.041	486.1	2.002	0.972	177.2	10.421	486.0	1.998	0.973	177.0	95
100	9.529	491.1	2.018	0.978	178.6	9.893	491.0	2.015	0.979	178.5	10.268	490.9	2.012	0.980	178.3	100
105	9.392	496.0	2.031	0.985	179.9	9.749	495.9	2.028	0.986	179.8	10.118	495.8	2.025	0.987	179.7	105
110	9.259	501.0	2.044	0.992	181.2	9.611	500.9	2.041	0.993	181.1	9.974	500.8	2.031	0.993	181.0	110
115	9.130	505.9	2.057	0.999	182.5	9.476	505.9	2.054	0.999	182.4	9.833	505.8	2.051	1.000	182.2	115
120	9.003	511.0	2.070	1.005	183.7	9.345	510.9	2.067	1.006	183.6	9.694	510.8	2.063	1.007	183.5	120

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]= kJ / (kg·K) [cp]= kJ / (kg·K) [c]=m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=4.29 bar (ts=11°C)					ps=4.43 bar (ts=12°C)					ps=4.58 bar (ts=13°C)					
15	21.452	408.8	1.736	0.936	148.1	21.245	408.5	1.732	0.941	147.5	22.055	408.1	1.729	[illegible]	147.1	15
20	20.944	413.5	1.752	0.933	150.2	21.633	413.2	1.748	0.938	149.7	21.473	412.9	1.744	0.943	149.3	20
25	20.462	418.2	1.767	0.931	152.1	21.152	417.9	1.764	0.936	151.8	20.945	417.5	1.760	0.940	151.2	25
30	19.912	422.6	1.783	0.931	154.2	20.719	422.5	1.779	0.935	153.8	20.449	422.2	1.776	0.939	153.4	30
35	19.533	427.5	1.798	0.932	156.1	19.276	427.2	1.795	0.920	155.7	19.983	426.9	1.791	[illegible]	155.3	35
40	19.132	432.1	1.813	0.934	157.9	19.819	431.9	1.810	0.937	157.5	19.545	431.6	1.807	0.94	157.2	40
45	17.877	436.8	1.828	0.936	159.7	19.456	436.6	1.825	0.939	159.2	19.134	436.3	1.821	0.94	159.0	45
50	17.451	441.5	1.843	0.940	161.4	18.094	441.3	1.839	0.942	161.1	18.745	441.0	1.836	0.945	160.7	50
55	17.126	445.2	1.857	0.943	163.1	17.742	445.0	1.854	0.945	162.8	18.379	445.8	1.851	0.947	162.5	55
60	16.803	450.9	1.871	0.947	164.7	17.405	450.7	1.868	0.943	164.4	18.023	450.5	1.865	0.951	164.1	60
65	16.495	455.7	1.885	0.952	166.3	17.083	455.5	1.882	0.953	166.0	17.589	455.3	1.879	0.955	165.7	65
70	16.202	460.5	1.899	0.955	167.9	16.782	460.3	1.896	0.958	167.6	17.372	460.1	1.893	0.960	167.3	70
75	15.923	465.3	1.913	0.951	169.4	16.485	465.1	1.910	0.953	169.2	17.056	464.9	1.907	0.96	168.9	75
80	15.653	470.1	1.927	0.967	170.9	16.207	459.9	1.924	0.968	170.7	16.775	469.7	1.921	0.97	170.4	80
85	15.393	474.9	1.941	0.972	172.4	15.937	474.5	1.938	0.973	172.2	16.495	474.6	1.935	0.97	171.9	85
90	15.147	479.8	1.954	0.978	173.8	15.677	479.6	1.951	0.979	173.6	16.227	479.5	1.948	0.980	173.4	90
95	14.908	484.7	1.968	0.984	175.3	15.429	484.5	1.965	0.985	175.1	15.968	484.4	1.962	0.986	174.8	95
100	14.676	489.6	1.981	0.989	176.7	15.190	489.5	1.978	0.991	176.5	15.718	489.3	1.975	0.992	176.3	100
105	14.453	494.6	1.994	0.995	178.1	14.959	494.4	1.991	0.997	177.9	15.476	494.3	1.988	0.998	177.7	105
110	14.238	499.6	2.007	1.002	179.4	14.734	499.4	2.004	1.003	179.2	15.246	499.3	2.001	1.004	179.1	110
115	14.031	504.6	2.020	1.008	180.8	14.519	504.5	2.017	1.009	180.6	15.019	504.3	2.014	1.010	180.4	115
120	13.830	509.7	2.033	1.014	182.1	14.312	509.5	2.030	1.015	181.9	14.804	509.4	2.027	1.015	181.8	120
125	13.537	514.7	2.046	1.020	183.4	14.103	514.6	2.043	1.021	183.2	14.593	514.5	2.040	1.022	183.1	125
130	13.447	519.9	2.059	1.027	184.7	13.914	519.7	2.056	1.027	184.5	14.390	519.6	2.053	1.028	184.4	130
135	13.266	525.0	2.072	1.033	186.0	13.723	524.9	2.069	1.034	185.9	14.195	524.8	2.066	1.035	185.7	135

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=4.73 bar (ts=14°C)					ps=4.89 bar (ts=15°C)					ps=5.05 bar (ts=16°C)					
15	22.895	407.7	1.725	0.953	145.5	22.770	407.3	1.721	0.950	145.9	-	-	-	-	-	15
20	22.288	412.5	1.741	0.948	148.7	23.125	412.1	1.737	0.954	148.2	23.934	411.7	1.734	0.960	147.6	20
25	21.725	417.2	1.757	0.945	150.9	22.533	416.8	1.753	0.950	150.4	23.353	416.5	1.750	0.955	149.9	25
30	21.203	421.9	1.773	0.943	152.9	21.953	421.6	1.763	0.943	152.5	22.789	421.2	1.766	0.952	152.0	30
35	20.714	426.5	1.788	0.943	154.9	21.470	426.3	1.785	0.947	154.4	22.250	426.0	1.781	0.951	154.0	35
40	20.255	431.3	1.803	0.944	156.8	20.990	431.1	1.800	0.947	155.4	21.745	430.8	1.797	0.951	156.0	40
45	19.825	436.1	1.818	0.945	158.6	20.538	435.9	1.815	0.949	158.2	21.273	435.5	1.812	0.952	157.9	45
50	19.417	440.5	1.833	0.947	160.4	20.111	440.5	1.830	0.950	160.0	20.825	440.3	1.825	0.953	159.7	50
55	19.032	445.5	1.847	0.950	162.1	19.710	445.3	1.8[illegible]	0.952	161.8	20.404	445.0	1.841	0.955	161.4	55
60	18.655	450.3	1.852	0.954	163.8	19.323	450.1	1.859	0.956	163.5	20.005	449.8	1.856	0.958	163.2	60
65	18.315	455.1	1.876	0.958	165.5	18.952	454.9	1.873	0.960	165.2	19.523	454.6	1.870	0.952	164.8	65
70	17.985	459.9	1.890	0.962	167.1	18.516	459.7	1.887	0.964	165.8	19.264	459.4	1.884	0.956	165.5	70
75	17.665	464.7	1.904	0.966	168.6	18.293	464.5	1.901	0.968	168.4	18.918	464.3	1.898	0.970	168.1	75
80	17.361	469.5	1.918	0.971	170.2	17.967	469.3	1.915	0.973	169.9	18.556	469.2	1.912	0.975	169.7	80
85	17.070	474.4	1.932	0.976	171.7	17.661	474.2	1.929	0.979	171.4	18.263	474.0	1.926	0.980	171.2	85
90	16.790	479.2	1.945	0.982	173.2	17.370	479.1	1.942	0.983	172.9	17.957	478.9	1.939	0.984	172.7	90
95	16.520	484.2	1.959	0.987	174.6	17.089	484.1	1.956	0.989	174.4	17.675	483.9	1.953	0.99	174.2	95
100	16.261	489.2	1.972	0.993	176.1	16.818	489.0	1.969	0.994	175.9	17.392	488.8	1.966	0.99	175.6	100
105	[illegible]	494.2	1.985	[illegible]	177.5	[illegible]	494.0	1.982	1.000	177.3	17.124	493.9	1.979	[illegible]	[illegible]	105
110	15.769	499.2	1.999	1.005	179.0	[illegible]	499.0	1.995	1.006	[illegible]	16.862	498.7	1.992	[illegible]	[illegible]	110
115	15.537	504.2	2.012	1.011	180.2	16.085	504.1	2.009	1.012	180.1	16.612	503.9	2.005	1.013	179.9	115
120	15.312	509.3	2.024	1.017	181.6	15.833	509.1	2.022	1.018	181.4	16.370	509.0	2.019	1.019	181.2	120
125	15.093	514.4	2.037	1.023	182.9	15.607	514.2	2.035	1.024	182.8	16.134	514.1	2.032	1.025	182.5	125
130	14.882	519.5	2.050	1.029	184.2	15.368	519.4	2.047	1.030	184.1	15.906	519.2	2.044	1.031	183.9	130
135	14.679	524.7	2.063	1.035	185.5	15.175	524.5	2.060	1.036	185.4	15.687	524.4	2.057	1.037	185.2	135

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=5.21 bar (ts=17°C)					ps=5.38 bar (ts=18°C)					ps=5.55 bar (ts=19°C)					
20	24.893	411.3	1.730	0.966	147.1	25.824	410.9	1.726	0.972	146.5	26.790	410.4	1.723	0.979	145.9	20
25	24.233	416.1	1.745	0.961	149.3	25.125	415.7	1.743	0.965	148.8	25.054	415.3	1.739	0.972	148.2	25
30	23.623	420.9	1.762	0.957	151.5	24.486	420.5	1.759	0.962	151.0	25.377	420.2	1.755	0.967	150.4	30
35	23.057	425.7	1.778	0.955	153.5	23.850	425.3	1.774	0.950	153.1	24.750	425.0	1.771	0.964	152.6	35
40	22.527	430.5	1.793	0.955	155.5	23.334	430.1	1.790	0.958	155.1	24.166	429.8	1.787	0.953	154.6	40
45	22.031	435.2	1.808	0.955	157.4	22.813	434.9	1.805	0.959	157.0	23.620	434.6	1.802	0.962	156.5	45
50	21.554	440.0	1.823	0.956	159.3	22.324	439.7	1.820	0.959	158.9	23.108	439.4	1.817	0.963	158.5	50
55	21.123	444.8	1.838	0.958	161.1	21.862	444.5	1.835	0.961	160.7	22.625	444.3	1.832	0.964	160.3	55
60	20.703	449.6	1.852	0.961	162.8	21.427	449.3	1.849	0.964	162.5	22.168	449.1	1.845	0.965	162.1	60
65	20.303	454.4	1.867	0.964	164.5	21.013	454.2	1.864	0.967	164.2	21.735	453.9	1.861	0.969	163.9	65
70	19.933	459.2	1.881	0.968	166.2	20.617	459.0	1.878	0.970	165.9	21.325	458.8	1.875	0.972	165.6	70
75	19.570	464.1	1.895	0.972	167.8	20.241	463.9	1.892	0.974	167.5	20.933	463.5	1.889	0.976	167.2	75
80	19.225	469.0	1.909	0.977	169.4	19.852	468.7	1.906	0.978	169.1	20.559	468.5	1.903	0.980	168.8	80
85	18.896	473.8	1.923	0.981	170.9	19.538	473.6	1.920	0.983	170.7	20.201	473.4	1.917	0.985	170.4	85
90	18.580	478.8	1.936	0.986	172.5	19.239	478.6	1.933	0.988	172.2	19.859	478.4	1.930	0.989	171.9	90
95	18.276	483.7	1.950	0.991	173.9	18.894	483.5	1.947	0.993	173.7	19.529	483.3	1.944	0.994	173.5	95
100	17.986	488.7	1.963	0.997	175.4	18.592	488.5	1.960	0.998	175.2	19.214	488.3	1.957	1.000	174.9	100
105	17.702	493.7	1.977	1.002	176.9	18.299	493.5	1.974	1.004	176.6	18.913	493.3	1.971	1.005	176.4	105
110	17.433	498.7	1.990	1.008	178.3	18.018	498.5	1.987	1.009	178.1	18.620	498.4	1.984	1.010	177.8	110
115	17.171	503.8	2.003	1.014	179.7	17.745	503.6	2.000	1.015	179.5	18.339	503.4	1.997	1.016	179.3	115
120	16.921	508.8	2.016	1.020	181.0	17.483	508.7	2.013	1.021	180.9	18.065	508.5	2.010	1.022	180.7	120
125	16.675	514.0	2.029	1.026	182.4	17.231	513.8	2.026	1.027	182.2	17.804	513.7	2.023	1.028	182.0	125
130	16.441	519.1	2.042	1.032	183.7	16.987	519.0	2.039	1.033	183.6	17.550	518.8	2.036	1.034	183.4	130
135	16.210	524.3	2.054	1.038	185.1	16.749	524.1	2.052	1.039	184.9	17.304	524.0	2.049	1.040	184.7	135
140	15.992	529.5	2.067	1.044	186.4	16.519	529.3	2.064	1.045	186.2	17.065	529.2	2.061	[illegible]	[illegible]	140

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] = °C [ρ] = kg/m³ [h] = kJ/kg [s] = kJ/(kg·K) [cp] = kJ/(kg·K) [c] = m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=3.15 bar (ts= 2°C)					ps=3.26 bar (ts= 3°C)					ps=3.38 bar (ts= 4°C)					
5	15.235	402.7	1.737	0.895	148.2	15.848	402.3	1.733	0.901	147.7	16.482	402.0	1.729	0.906	147.3	5
10	14.852	407.1	1.752	0.895	150.1	15.454	406.8	1.749	0.900	149.7	16.067	406.5	1.745	0.904	149.3	10
15	14.513	411.6	1.768	0.895	152.0	15.087	411.3	1.765	0.900	151.7	15.691	411.1	1.761	0.904	151.3	15
20	14.160	416.1	1.784	0.898	153.9	14.743	415.8	1.780	0.901	153.5	15.319	415.6	1.776	0.904	153.2	20
25	13.876	420.6	1.799	0.900	155.7	14.420	420.4	1.795	0.903	155.3	14.979	420.1	1.792	0.906	155.0	25
30	13.587	425.1	1.814	0.902	157.4	14.115	424.9	1.810	0.906	157.1	14.653	424.7	1.807	0.909	156.8	30
35	13.311	429.6	1.829	0.907	159.1	13.825	429.4	1.825	0.909	158.8	14.350	429.2	1.822	0.912	158.5	35
40	13.049	434.2	1.844	0.911	160.7	13.551	434.0	1.840	0.913	160.5	14.069	433.8	1.836	0.915	160.2	40
45	12.800	438.7	1.858	0.916	162.3	13.291	438.5	1.854	0.918	162.1	13.796	438.4	1.851	0.920	161.9	45
50	12.563	443.3	1.872	0.921	163.9	13.042	443.1	1.869	0.922	163.7	13.537	443.0	1.855	0.924	163.4	50
55	12.335	447.9	1.886	0.926	165.5	12.804	447.8	1.883	0.927	165.2	13.287	447.6	1.880	0.929	165.0	55
60	12.118	452.5	1.900	0.931	167.0	12.576	452.4	1.897	0.933	166.7	13.050	452.3	1.894	0.934	166.5	60
65	11.908	457.3	1.914	0.937	168.4	12.359	457.1	1.911	0.939	168.2	12.823	456.9	1.908	0.940	168.0	65
70	11.709	462.0	1.928	0.943	169.9	12.151	461.8	1.925	0.944	169.7	12.605	461.7	1.921	0.945	169.5	70
75	11.517	466.7	1.942	0.949	171.3	11.950	466.5	1.938	0.950	171.1	12.396	466.4	1.935	0.951	171.0	75
80	11.330	471.4	1.955	0.955	172.8	11.755	471.3	1.952	0.955	172.6	12.195	471.2	1.949	0.957	172.4	80
85	11.151	476.2	1.969	0.961	174.1	11.570	476.1	1.965	0.962	174.0	12.001	476.0	1.962	0.963	173.8	85
90	10.980	481.1	1.982	0.968	175.5	11.391	480.9	1.979	0.959	175.3	11.813	480.9	1.976	0.970	175.2	90
95	10.814	485.9	1.995	0.974	176.9	11.218	485.8	1.992	0.975	176.7	11.633	485.7	1.989	0.976	176.5	95
100	10.653	490.8	2.008	0.981	178.2	11.050	490.7	2.005	0.982	178.0	11.459	490.6	2.002	0.982	177.9	100
105	10.497	495.7	2.022	0.987	179.5	10.888	495.6	2.018	0.988	179.4	11.290	495.5	2.015	0.989	179.2	105
110	10.347	500.7	2.035	0.994	180.8	10.731	500.6	2.031	0.995	180.7	11.126	500.4	2.028	0.995	180.5	110
115	10.200	505.7	2.047	1.001	182.1	10.579	505.5	2.044	1.001	182.0	10.970	505.4	2.041	1.002	181.8	115
120	10.060	510.7	2.060	1.007	183.4	10.433	510.6	2.057	1.008	183.3	10.815	510.5	2.054	1.009	183.1	120
125	9.923	515.7	2.073	1.014	184.6	10.290	515.6	2.070	1.015	184.5	10.657	515.5	2.067	1.015	184.4	125
	ps=3.50 bar (ts= 5°C)					ps=3.62 bar (ts= 6°C)					ps=3.88 bar (ts= 7°C)					
5	17.140	401.7	1.725	0.911	146.8	-	-	-	-	-	-	-	-	-	-	5
10	15.732	406.2	1.741	0.905	148.9	17.360	405.9	1.738	0.913	148.4	18.041	405.6	1.734	0.918	148.0	10
15	15.295	410.8	1.757	0.905	150.9	15.331	410.5	1.754	0.912	150.4	17.589	410.2	1.750	0.915	150.0	15
20	15.915	415.3	1.773	0.908	152.8	15.531	415.0	1.769	0.912	152.4	17.153	414.5	1.765	0.915	152.0	20
25	15.558	419.9	1.788	0.909	154.6	15.156	419.5	1.785	0.913	154.3	15.774	419.3	1.781	0.915	153.9	25
30	15.222	424.4	1.803	0.911	156.4	15.824	424.2	1.800	0.914	155.1	16.434	423.9	1.797	0.918	155.7	30
35	14.905	429.0	1.818	0.914	158.2	15.471	428.7	1.815	0.917	157.9	16.055	428.5	1.812	0.920	157.5	35
40	14.604	433.5	1.833	0.918	159.9	15.155	433.3	1.830	0.920	159.6	15.725	433.1	1.826	0.923	159.3	40
45	14.316	438.2	1.848	0.922	161.5	14.857	438.0	1.844	0.924	161.2	15.413	437.7	1.841	0.926	161.0	45
50	14.045	442.8	1.862	0.926	163.2	14.572	442.6	1.859	0.928	162.9	15.115	442.4	1.856	0.930	162.5	50
55	13.788	447.4	1.876	0.931	164.7	14.303	447.2	1.873	0.933	164.5	14.832	447.0	1.870	0.935	164.2	55
60	13.540	452.1	1.890	0.936	166.3	14.043	451.9	1.887	0.938	166.0	14.563	451.7	1.884	0.939	165.8	60
65	13.302	456.8	1.904	0.941	167.8	13.796	455.5	1.901	0.943	167.5	14.304	456.4	1.898	0.944	167.3	65
70	13.074	461.5	1.918	0.947	169.3	13.557	461.3	1.915	0.948	169.1	14.057	461.2	1.912	0.950	168.8	70
75	12.856	466.2	1.932	0.953	170.8	13.330	466.1	1.929	0.954	170.5	13.818	465.9	1.926	0.955	170.3	75
80	12.647	471.0	1.946	0.958	172.2	13.111	470.9	1.943	0.960	172.0	13.591	470.7	1.939	0.961	171.8	80
85	12.445	475.8	1.959	0.965	173.6	12.900	475.7	1.956	0.966	173.4	13.372	475.5	1.953	0.967	173.2	85
90	12.249	480.7	1.973	0.971	175.0	12.698	480.5	1.970	0.972	174.9	13.159	480.4	1.966	0.973	174.6	90
95	12.061	485.5	1.986	0.977	176.4	12.501	485.4	1.983	0.978	176.2	12.953	485.3	1.980	0.979	176.0	95
100	11.879	490.4	1.999	0.983	177.7	12.312	490.3	1.996	0.984	177.6	12.759	490.2	1.993	0.985	177.4	100
105	11.704	495.4	2.012	0.990	179.1	12.129	495.3	2.009	0.991	178.9	12.569	495.1	2.006	0.992	178.7	105
110	11.534	500.3	2.025	0.996	180.4	11.954	500.2	2.022	0.997	180.2	12.385	500.1	2.019	0.998	180.1	110
115	11.370	505.3	2.038	1.003	181.7	11.784	505.2	2.035	1.004	181.6	12.207	505.1	2.032	1.004	181.4	115
120	11.212	510.4	2.051	1.009	183.0	11.618	510.3	2.048	1.010	182.8	12.035	510.1	2.045	1.011	182.7	120
125	11.057	515.4	2.064	1.016	184.3	11.458	515.3	2.061	1.017	184.1	11.870	515.2	2.058	1.017	184.0	125
	ps=3.98 bar (ts= 8°C)					ps=4.01 bar (ts= 9°C)					ps=4.15 bar (ts=10°C)					
10	18.747	405.3	1.730	0.923	147.5	19.478	404.9	1.727	0.929	147.0	20.235	404.5	1.723	0.934	146.4	10
15	18.270	409.9	1.746	0.921	149.5	18.976	409.5	1.743	0.925	149.1	19.706	409.2	1.739	0.930	148.5	15
20	17.827	414.5	1.762	0.920	151.6	18.509	414.2	1.759	0.924	151.1	19.214	413.8	1.755	0.928	150.7	20
25	17.413	419.1	1.778	0.920	153.5	18.074	418.8	1.774	0.922	153.1	18.756	418.5	1.771	0.927	152.7	25
30	17.024	423.7	1.793	0.921	155.4	17.656	423.4	1.790	0.924	155.0	18.328	423.1	1.786	0.928	154.6	30
35	16.659	428.3	1.808	0.923	157.2	17.282	428.0	1.805	0.926	156.8	17.925	427.9	1.802	0.929	156.5	35
40	16.313	432.9	1.823	0.925	158.9	16.920	432.6	1.820	0.928	158.6	17.546	432.4	1.816	0.931	158.3	40
45	15.986	437.5	1.838	0.929	160.6	16.578	437.3	1.835	0.931	160.3	17.187	437.1	1.831	0.934	160.0	45
50	15.675	442.2	1.852	0.932	162.3	16.252	442.0	1.849	0.935	162.0	16.847	441.7	1.845	0.937	161.7	50
55	15.380	446.8	1.867	0.937	163.9	15.944	446.6	1.863	0.939	163.7	15.526	446.4	1.860	0.941	163.4	55
60	15.098	451.5	1.881	0.941	165.5	15.647	451.3	1.878	0.943	165.3	16.217	451.1	1.875	0.945	165.0	60
65	14.828	456.3	1.895	0.945	167.1	15.366	455.1	1.892	0.948	166.8	15.923	455.9	1.889	0.950	166.5	65
70	14.565	461.0	1.909	0.951	168.5	15.096	460.8	1.906	0.953	168.4	15.642	460.6	1.903	0.955	168.1	70
75	14.321	465.8	1.923	0.957	170.1	14.840	465.6	1.920	0.958	169.9	15.373	465.4	1.916	0.960	169.6	75
80	14.083	470.6	1.936	0.962	171.6	14.591	470.4	1.933	0.964	171.4	15.114	470.2	1.930	0.965	171.1	80
85	13.855	475.4	1.950	0.968	173.0	14.352	475.2	1.947	0.969	172.8	14.866	475.1	1.944	0.971	172.6	85
90	13.636	480.3	1.963	0.974	174.4	14.123	480.1	1.960	0.975	174.2	14.626	480.0	1.957	0.976	174.0	90
95	13.422	485.1	1.977	0.980	175.8	13.905	485.0	1.974	0.981	175.7	14.398	484.8	1.971	0.982	175.5	95
100	13.217	490.1	1.990	0.986	177.2	13.690	489.9	1.987	0.987	177.0	14.175	489.8	1.984	0.988	176.9	100
105	13.020	495.0	2.003	0.992	178.6	13.484	494.9	2.000	0.993	178.4	13.963	494.7	1.997	0.994	178.2	105
110	12.828	500.0	2.016	0.999	179.9	13.285	499.8	2.013	1.000	179.8	13.756	499.7	2.010	1.001	179.6	110
115	12.645	505.0	2.029	1.005	181.2	13.094	504.9	2.026	1.006	181.1	13.555	504.7	2.023	1.007	180.9	115
120	12.465	510.0	2.042	1.012	182.5	12.908	509.9	2.039	1.012	182.4	13.363	509.8	2.036	1.013	182.3	120
125	12.293	515.1	2.055	1.018	183.8	12.727	515.0	2.052	1.019	183.7	13.176	514.9	2.049	1.020	183.6	125
130	12.125	520.2	2.068	1.025	185.1	12.552	520.1	2.065	1.025	185.0	12.994	520.0	2.062	1.026	[illegible]	[illegible]

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t]=°C [ρ]=kg/m³ [h]=kJ/kg [s]=kJ/(kg·K) [cp]=kJ/(kg·K) [c]=m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=7.49 bar (ts=29°C)					ps=7.71 bar (ts=30°C)					ps=7.93 bar (ts=31°C)					
30	36.220	415.7	1.719	1.038	144.0	37.540	415.1	1.716	1.048	143.2	-	-	-	-	-	30
35	35.142	420.8	1.730	1.026	145.7	36.398	420.3	1.733	1.034	145.9	37.698	419.9	1.729	1.043	145.2	35
40	34.161	425.9	1.753	1.017	[illegible]	35.351	425.5	1.749	1.024	148.5	36.601	425.3	1.746	1.031	147.8	40
45	33.252	431.0	1.763	1.012	[illegible]	[illegible]	430.6	1.765	1.016	150.9	35.600	430.1	1.762	1.022	150.3	45
50	32.432	435.0	1.784	1.007	[illegible]	[illegible]	435.5	1.781	1.011	153.2	34.550	435.2	1.778	1.016	152.6	50
55	31.650	441.0	1.800	1.002	155.9	32.729	440.7	1.797	1.007	155.4	33.924	440.3	1.793	1.012	154.8	55
60	30.941	446.0	1.816	1.000	157.3	31.976	445.7	1.812	1.005	157.4	33.038	445.3	[illegible]	[illegible]	156.9	60
65	30.257	451.0	1.833	1.000	159.3	31.255	450.7	1.827	1.004	159.5	32.298	450.4	1.824	1.008	159.0	65
70	29.629	456.0	1.844	1.000	161.8	30.509	455.7	1.847	1.004	161.4	31.601	455.4	1.839	1.007	161.0	70
75	29.033	461.1	1.859	1.002	163.7	29.381	460.7	1.856	1.005	163.3	30.950	460.4	1.851	1.008	162.9	75
80	28.468	466.1	1.873	1.034	165.5	29.395	465.9	1.870	1.006	165.1	30.332	465.5	1.867	1.009	164.7	80
85	27.927	471.1	1.887	1.006	167.2	28.526	470.3	1.884	1.009	166.9	29.748	470.5	1.882	1.011	166.5	85
90	27.417	476.1	1.901	1.009	168.3	28.292	475.9	1.898	1.012	168.6	29.193	475.6	1.895	1.014	168.2	90
95	26.925	481.2	1.915	1.013	170.6	27.788	480.9	1.912	1.015	170.3	26.661	480.7	1.909	1.017	169.9	95
100	26.459	485.3	1.929	1.016	172.2	27.300	486.0	1.925	1.019	171.9	28.162	485.8	1.923	1.021	171.6	100
105	26.015	491.3	1.942	1.021	173.8	25.836	491.1	1.940	1.023	173.5	27.680	490.9	1.937	1.024	173.2	105
110	25.586	496.5	1.956	1.025	175.4	26.391	496.2	1.953	1.027	175.1	27.215	495.0	1.950	1.029	174.8	110
115	25.176	501.6	1.969	1.030	176.9	25.965	501.4	1.966	1.031	176.6	26.774	501.2	1.964	1.033	176.4	115
120	24.782	506.8	1.982	1.035	178.4	25.555	506.6	1.980	1.036	178.1	26.344	506.3	1.977	1.038	177.9	120
125	24.399	511.9	1.995	1.040	179.9	25.161	511.7	1.993	1.041	179.6	25.938	511.5	1.990	1.042	179.4	125
130	24.032	517.2	2.008	1.045	181.3	24.782	517.0	2.006	1.046	181.1	25.543	516.8	2.003	1.047	180.8	130
135	23.681	522.4	2.021	1.050	182.7	24.415	522.2	2.019	1.051	182.5	25.165	522.0	2.016	1.053	182.3	135
140	23.337	527.7	2.034	1.056	184.1	24.060	527.5	2.032	1.057	183.9	24.798	527.3	2.029	1.058	183.7	140
145	23.009	532.9	2.047	1.061	185.5	23.720	532.5	2.044	1.062	185.3	24.442	532.5	2.042	1.063	185.1	145
150	22.589	538.3	2.060	1.067	186.9	23.355	538.1	2.057	1.068	186.7	24.099	537.9	2.054	1.069	186.5	150
	ps=8.16 bar (ts=32°C)					ps=8.40 bar (ts=33°C)					ps=8.64 bar (ts=34°C)					
35	39.044	419.3	1.725	1.052	144.4	40.445	418.7	1.721	1.062	143.6	41.900	418.1	1.718	1.072	142.8	35
40	37.983	424.5	1.742	1.033	147.1	39.213	424.0	1.738	1.047	146.4	40.592	423.4	1.735	1.056	145.6	40
45	36.825	429.6	1.758	1.029	149.6	38.096	429.2	1.755	1.036	148.9	39.411	428.7	1.751	1.044	148.3	45
50	35.857	434.8	1.774	1.022	152.0	37.076	434.3	1.771	1.028	151.4	38.333	433.9	1.767	1.035	150.7	50
55	34.963	439.9	1.790	1.017	154.3	36.134	439.5	1.787	1.023	153.7	37.344	439.0	1.783	1.028	153.1	55
60	34.132	444.9	1.805	1.014	155.4	35.253	444.6	1.802	1.019	155.9	36.428	444.2	1.799	1.024	155.3	60
65	33.356	450.0	1.820	1.012	158.5	34.451	449.6	1.817	1.016	158.0	35.577	449.3	1.814	1.021	157.5	65
70	32.630	455.1	1.835	1.011	160.5	33.694	454.7	1.832	1.015	160.0	34.779	454.4	1.829	1.019	159.5	70
75	31.951	460.1	1.850	1.011	162.4	32.977	459.8	1.847	1.015	162.0	34.035	459.5	1.844	1.019	161.5	75
80	31.307	465.2	1.864	1.012	164.3	32.305	464.9	1.861	1.016	163.9	33.331	464.6	1.858	1.019	163.5	80
85	30.692	470.2	1.879	1.014	166.1	31.669	470.0	1.876	1.017	165.7	32.568	469.7	1.872	1.020	165.3	85
90	30.114	475.3	1.893	1.017	167.9	31.069	475.0	1.890	1.019	167.5	32.043	474.8	1.887	1.022	167.1	90
95	29.565	480.4	1.907	1.019	169.6	30.495	480.1	1.904	1.022	169.2	31.444	479.9	1.901	1.024	168.9	95
100	29.037	485.5	1.920	1.023	171.3	29.945	485.3	1.918	1.025	170.9	30.875	485.0	1.915	1.027	170.6	100
105	28.539	490.6	1.934	1.026	172.9	29.425	490.4	1.931	1.028	172.6	30.335	490.1	1.929	1.031	172.3	105
110	28.058	495.8	1.948	1.030	174.5	28.925	495.5	1.945	1.032	174.2	29.816	495.3	1.942	1.034	173.9	110
115	27.601	500.9	1.961	1.035	176.1	28.449	500.7	1.958	1.036	175.8	29.320	500.5	1.955	1.038	175.5	115
120	27.156	506.1	1.974	1.039	177.6	27.992	505.9	1.971	1.041	177.3	28.842	505.7	1.969	1.043	177.0	120
125	26.735	511.3	1.987	1.044	179.1	27.547	511.1	1.985	1.045	179.0	28.385	510.9	1.982	1.047	178.6	125
130	26.325	516.5	2.000	1.049	180.6	27.120	516.4	1.998	1.050	180.3	27.945	516.2	1.995	1.052	180.1	130
135	25.930	521.8	2.013	1.054	182.0	26.719	521.6	2.011	1.055	181.8	27.523	521.4	2.008	1.057	181.5	135
140	25.547	527.1	2.026	1.059	183.5	26.325	526.9	2.024	1.060	183.2	27.117	526.7	2.021	1.062	183.0	140
145	25.184	532.4	2.039	1.064	184.9	25.946	532.2	2.036	1.066	184.7	26.723	532.0	2.034	1.067	184.4	145
150	24.829	537.8	2.052	1.070	186.3	25.579	537.5	2.049	1.071	186.1	26.344	537.4	2.046	1.072	185.8	150
155	24.485	543.1	2.064	1.075	187.6	25.219	542.9	2.052	1.075	187.4	25.977	542.8	2.059	1.077	187.2	155
	ps=8.88 bar (ts=35°C)					ps=9.13 bar (ts=36°C)					ps=9.39 bar (ts=37°C)					
35	43.413	417.5	1.714	1.084	141.9	-	-	-	-	-	-	-	-	-	-	35
40	42.024	422.9	1.731	1.065	144.8	43.510	422.3	1.727	1.076	144.0	45.053	421.7	1.724	1.086	143.2	40
45	40.773	428.2	1.748	1.052	147.5	42.184	427.6	1.744	1.060	146.8	43.646	427.1	1.741	1.069	146.0	45
50	39.635	433.4	1.764	1.042	150.1	40.982	432.9	1.761	1.049	149.4	42.375	432.4	1.757	1.057	148.7	50
55	38.593	438.6	1.780	1.034	152.5	39.883	438.1	1.777	1.041	151.8	41.216	437.7	1.774	1.047	151.2	55
60	37.631	443.7	1.796	1.029	154.8	38.872	443.3	1.793	1.035	154.2	40.152	442.9	1.789	1.040	153.6	60
65	36.738	448.9	1.811	1.025	156.9	37.935	448.5	1.808	1.030	156.4	39.169	448.1	1.805	1.035	155.8	65
70	35.907	454.0	1.826	1.023	159.0	37.062	453.6	1.823	1.028	158.5	38.253	453.2	1.820	1.032	158.0	70
75	35.126	459.1	1.841	1.022	161.1	36.249	458.8	1.838	1.026	160.6	37.397	458.4	1.835	1.030	160.1	75
80	34.391	464.2	1.855	1.022	163.0	35.479	463.9	1.853	1.026	162.6	36.595	463.5	1.850	1.030	152.1	80
85	33.701	469.3	1.870	1.023	164.9	34.756	469.0	1.867	1.026	164.5	35.844	468.7	1.864	1.030	164.0	85
90	33.044	474.5	1.884	1.025	166.7	34.077	474.2	1.881	1.028	166.3	35.131	473.8	1.878	1.031	165.9	90
95	32.423	479.6	1.898	1.027	168.5	33.425	479.3	1.895	1.030	168.1	34.457	479.0	1.892	1.032	167.7	95
100	31.829	484.7	1.912	1.030	170.2	32.811	484.5	1.909	1.032	169.9	33.818	484.2	1.906	1.035	169.5	100
105	31.265	489.9	1.926	1.033	171.9	32.225	489.6	1.923	1.035	171.6	33.209	489.3	1.920	1.037	171.2	105
110	30.726	495.1	1.939	1.036	173.6	31.663	494.8	1.937	1.038	173.2	32.623	494.5	1.934	1.041	172.9	110
115	30.210	500.2	1.953	1.040	175.2	31.132	500.0	1.950	1.042	174.9	32.069	499.8	1.947	1.044	174.5	115
120	29.718	505.5	1.966	1.044	176.8	30.616	505.2	1.963	1.046	176.5	31.538	505.0	1.961	1.048	176.2	120
125	29.246	510.7	1.979	1.049	178.3	30.124	510.5	1.977	1.050	178.0	31.030	510.2	1.974	1.052	177.7	125
130	28.789	515.9	1.992	1.053	179.8	29.656	515.7	1.990	1.055	179.5	30.538	515.5	1.987	1.056	179.3	130
135	28.351	521.2	2.005	1.058	181.3	29.199	521.0	2.003	1.060	181.0	30.066	520.8	2.000	1.061	180.8	135
140	27.930	526.5	2.018	1.063	182.8	28.757	526.3	2.016	1.064	182.5	29.613	526.1	2.013	1.066	182.3	140
145	27.519	531.9	2.031	1.068	184.2	28.336	531.7	2.029	1.069	184.0	29.175	531.5	2.026	1.071	183.7	145
150	27.125	537.2	2.044	1.073	185.6	27.930	537.0	2.041	1.074	185.4	28.754	536.8	2.039	1.076	185.2	150
155	26.746	542.6	2.057	1.079	187.0	27.539	542.4	2.054	1.080	186.8	28.343	542.2	2.051	1.081	186.6	155

TABLE II: SUPERHEATED VAPOUR PROPERTIES   SUVA HFC - 134a

[t]=°C   [p]= kg/m³   [h]=kJ/kg   [s]= kJ/(kg·K)   [cp]= kJ/(kg·K)   [c]=m/s   Saturation temperature in brackets

t	p	h	s	cp	c	p	h	s	cp	c	p	h	s	cp	c	t
	ps=7.49 bar (ts=29°C)					ps=7.71 bar (ts=30°C)					ps=7.93 bar (ts=31°C)					
30	36.220	415.7	1.719	1.028	144.0	37.540	415.1	1.716	1.048	143.2	-	-	-	-	-	30
35	35.142	420.8	1.736	1.025	145.7	36.399	420.3	1.733	1.034	145.3	37.63?	419.8	1.729	1.043	145.2	35
40	34.161	425.9	1.753	1.017	149.1	35.351	425.5	1.749	1.024	148.5	36.521	425.0	1.746	1.031	147.8	40
45	33.262	431.0	1.769	1.010	151.5	34.413	430.6	1.765	1.016	150.9	35.522	430.1	1.762	1.022	150.3	45
50	32.432	435.0	1.784	1.025	153.7	33.539	435.6	1.781	1.011	153.2	34.682	435.2	1.778	1.016	152.6	50
55	31.660	441.0	1.800	1.022	155.9	32.723	440.7	1.797	1.007	155.4	33.829	440.3	1.793	1.012	154.8	55
60	30.941	446.0	1.815	1.003	157.9	31.975	445.7	1.812	1.003	157.4	33.038	445.3	1.809	1.009	156.9	60
65	30.267	451.0	1.830	1.002	159.9	31.265	450.7	1.827	1.004	159.5	32.298	450.4	1.824	1.005	159.0	65
70	29.629	456.0	1.844	1.003	161.8	30.602	455.7	1.841	1.004	161.4	31.601	455.4	1.838	1.007	161.0	70
75	29.033	461.1	1.859	1.002	163.7	29.981	460.7	1.855	1.005	163.3	30.950	460.4	1.853	1.004	162.9	75
80	28.469	466.1	1.873	1.004	165.5	29.355	465.8	1.870	1.005	165.1	30.332	465.5	1.867	1.009	164.7	80
85	27.927	471.1	1.887	1.006	167.2	28.826	470.9	1.884	1.007	166.9	29.745	470.5	1.882	1.011	166.5	85
90	27.417	476.1	1.901	1.009	168.9	28.232	475.9	1.898	1.012	168.6	29.193	475.6	1.896	1.014	168.2	90
95	26.925	481.2	1.915	1.013	170.6	27.785	480.9	1.912	1.015	170.3	28.661	480.7	1.909	1.017	169.9	95
100	26.459	486.3	1.929	1.016	172.2	27.302	486.0	1.926	1.019	171.9	28.162	485.8	1.923	1.021	171.6	100
105	26.016	491.3	1.942	1.021	173.8	26.836	491.1	1.940	1.023	173.5	27.690	490.9	1.937	1.024	173.2	105
110	25.586	496.5	1.956	1.025	175.4	26.391	496.2	1.953	1.027	175.1	27.215	496.0	1.950	1.029	174.8	110
115	25.176	501.6	1.969	1.030	176.9	25.965	501.4	1.966	1.031	176.6	26.774	501.2	1.964	1.033	176.4	115
120	24.782	506.8	1.982	1.035	178.4	25.555	506.6	1.980	1.036	178.1	26.344	506.3	1.977	1.038	177.9	120
125	24.399	511.9	1.995	1.040	179.9	25.161	511.7	1.993	1.041	179.6	25.938	511.5	1.990	1.042	179.4	125
130	24.032	517.2	2.008	1.045	181.3	24.782	517.0	2.006	1.046	181.1	25.543	516.8	2.003	1.047	180.8	130
135	23.681	522.4	2.021	1.050	182.7	24.415	522.2	2.019	1.051	182.5	25.165	522.0	2.016	1.053	182.3	135
140	23.337	527.7	2.034	1.056	184.1	24.060	527.5	2.032	1.057	183.9	24.798	527.3	2.029	1.058	183.7	140
145	23.009	532.9	2.047	1.061	185.5	23.720	532.8	2.044	1.062	185.3	24.442	532.6	2.042	1.063	185.1	145
150	22.589	535.3	2.063	1.057	186.9	23.388	538.1	2.057	1.068	185.7	24.093	537.9	2.054	1.069	186.5	150
	ps=8.16 bar (ts=32°C)					ps=8.40 bar (ts=33°C)					ps=8.64 bar (ts=34°C)					
35	39.044	419.3	1.725	1.052	144.4	40.445	418.7	1.721	1.062	143.6	41.900	418.1	1.718	1.072	142.8	35
40	37.583	424.5	1.742	1.039	147.1	39.213	424.0	1.738	1.047	146.4	40.592	423.4	1.735	1.056	145.6	40
45	36.825	429.5	1.758	1.029	149.6	38.096	429.2	1.755	1.036	148.9	39.411	428.7	1.751	1.044	148.3	45
50	35.657	434.5	1.774	1.022	152.0	37.075	434.3	1.771	1.028	151.4	38.333	433.9	1.768	1.035	150.7	50
55	34.963	439.9	1.790	1.017	154.3	36.134	439.5	1.787	1.023	153.7	37.344	439.0	1.783	1.028	153.1	55
60	34.132	444.9	1.805	1.014	156.4	35.263	444.6	1.802	1.019	155.9	36.428	444.2	1.799	1.024	155.3	60
65	33.358	450.0	1.820	1.012	158.5	34.451	449.5	1.817	1.015	158.0	35.577	449.3	1.814	1.021	157.5	65
70	32.633	455.1	1.835	1.011	160.5	33.694	454.7	1.832	1.015	160.0	34.779	454.4	1.829	1.019	159.5	70
75	31.951	460.1	1.850	1.011	162.4	32.977	459.8	1.847	1.015	162.0	34.035	459.5	1.844	1.019	161.5	75
80	31.307	465.2	1.864	1.012	164.3	32.335	464.9	1.861	1.015	163.9	33.331	464.6	1.858	1.019	163.5	80
85	30.692	470.2	1.879	1.014	166.1	31.669	470.0	1.876	1.017	165.7	32.668	469.7	1.873	1.020	165.3	85
90	30.114	475.3	1.893	1.017	167.9	31.069	475.0	1.890	1.019	167.5	32.043	474.8	1.887	1.022	167.1	90
95	29.565	480.4	1.907	1.019	169.6	30.495	480.1	1.904	1.022	169.2	31.444	479.9	1.901	1.024	168.9	95
100	29.037	485.5	1.920	1.023	171.3	29.946	485.3	1.918	1.025	170.9	30.875	485.0	1.915	1.027	170.6	100
105	28.539	490.6	1.934	1.026	172.9	29.425	490.4	1.931	1.028	172.6	30.335	490.1	1.928	1.031	172.3	105
110	28.058	495.5	1.948	1.030	174.5	28.925	495.5	1.945	1.032	174.2	29.815	495.3	1.942	1.034	173.9	110
115	27.601	500.7	1.961	1.035	176.1	28.449	500.7	1.958	1.036	175.8	29.322	500.5	1.955	1.038	175.5	115
120	27.156	505.1	1.974	1.039	177.6	27.992	505.3	1.971	1.041	177.3	28.843	505.7	1.969	1.043	177.0	120
125	26.735	511.3	1.987	1.044	179.1	27.547	511.1	1.985	1.045	178.8	28.385	510.9	1.982	1.047	178.5	125
130	26.325	516.6	2.000	1.049	180.6	27.125	516.4	1.998	1.050	180.3	27.945	516.2	1.995	1.052	180.1	130
135	25.933	521.9	2.013	1.054	182.0	26.719	521.5	2.011	1.055	181.8	27.523	521.4	2.008	1.057	181.5	135
140	25.547	527.1	2.026	1.059	183.5	26.335	526.9	2.024	1.060	183.2	27.117	526.7	2.021	1.062	183.0	140
145	25.184	532.4	2.039	1.064	184.9	25.946	532.2	2.036	1.065	184.7	26.723	532.0	2.034	1.067	184.4	145
150	24.829	537.8	2.052	1.070	186.3	25.579	537.6	2.049	1.071	186.1	26.344	537.4	2.046	1.072	185.8	150
155	24.485	543.1	2.064	1.075	187.6	25.219	542.9	2.062	1.076	187.4	25.977	542.8	2.059	1.077	187.2	155
	ps=8.88 bar (ts=35°C)					ps=9.13 bar (ts=36°C)					ps=9.38 bar (ts=37°C)					
35	43.413	417.5	1.714	1.054	141.9	-	-	-	-	-	-	-	-	-	-	35
40	42.024	422.9	1.731	1.065	144.8	43.510	422.3	1.727	1.076	144.0	45.053	421.7	1.724	1.086	143.2	40
45	40.773	428.2	1.748	1.052	147.5	42.184	427.5	1.744	1.060	146.8	43.546	427.1	1.741	1.069	146.0	45
50	39.635	433.4	1.764	1.042	150.1	40.982	432.9	1.761	1.049	149.4	42.375	432.4	1.757	1.057	148.7	50
55	38.593	435.6	1.780	1.034	152.5	39.883	438.1	1.777	1.041	151.8	41.216	437.7	1.774	1.047	151.2	55
60	37.631	443.7	1.796	1.029	154.8	38.872	443.3	1.793	1.035	154.2	40.152	442.9	1.789	1.040	153.6	60
65	36.738	448.9	1.811	1.025	156.9	37.935	448.5	1.808	1.030	156.4	39.169	448.1	1.805	1.035	155.8	65
70	35.907	454.0	1.826	1.023	159.0	37.062	453.6	1.823	1.028	158.5	38.253	453.2	1.820	1.032	158.0	70
75	35.126	459.1	1.841	1.022	161.1	36.249	458.8	1.838	1.026	160.6	37.397	458.4	1.835	1.030	160.1	75
80	34.391	464.2	1.855	1.022	163.0	35.479	463.9	1.853	1.026	162.6	36.595	453.5	1.850	1.030	152.1	80
85	33.701	469.3	1.870	1.023	164.9	34.756	469.0	1.867	1.026	164.5	35.844	468.7	1.864	1.030	154.0	85
90	33.044	474.5	1.884	1.025	166.7	34.077	474.2	1.881	1.028	166.3	35.131	473.8	1.878	1.031	165.9	90
95	32.421	479.6	1.893	1.027	168.5	33.425	479.3	1.895	1.030	168.1	34.457	479.0	1.892	1.032	167.7	95
100	31.829	484.7	1.912	1.030	170.2	32.811	484.5	1.909	1.032	169.9	33.818	484.2	1.906	1.035	169.5	100
105	31.265	489.9	1.926	1.033	171.9	32.225	489.6	1.923	1.035	171.6	33.209	489.3	1.920	1.037	171.2	105
110	30.726	495.1	1.939	1.036	173.6	31.663	494.8	1.937	1.038	173.2	32.623	494.5	1.934	1.041	172.9	110
115	30.210	500.2	1.953	1.040	175.2	31.132	500.0	1.950	1.042	174.9	32.069	499.8	1.947	1.044	174.5	115
120	29.718	505.5	1.966	1.044	176.8	30.616	505.2	1.963	1.046	176.5	31.538	505.0	1.961	1.048	176.2	120
125	29.246	510.7	1.979	1.049	178.3	30.124	510.5	1.977	1.050	178.0	31.030	510.2	1.974	1.052	177.7	125
130	28.789	515.9	1.992	1.053	179.8	29.656	515.7	1.990	1.055	179.5	30.538	515.5	1.987	1.056	179.3	130
135	28.351	521.2	2.005	1.058	181.3	29.199	521.0	2.003	1.060	181.0	30.066	520.8	2.000	1.061	180.9	135
140	27.930	526.5	2.018	1.063	182.8	28.757	526.3	2.016	1.064	182.5	29.613	526.1	2.013	1.066	182.3	140
145	27.519	531.9	2.031	1.068	184.2	28.336	531.7	2.029	1.069	184.0	29.175	531.5	2.026	1.071	183.7	145
150	27.125	537.2	2.044	1.073	185.6	27.930	537.0	2.041	1.074	185.4	28.754	536.8	2.039	1.076	185.2	150
155	26.748	542.6	2.057	1.079	187.0	27.539	542.4	2.054	1.080	186.8	28.347	542.2	2.051	1.081	186.6	155

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] °C   [ρ] kg/m³   [h] kJ/kg   [s] kJ/(kg·K)   [cp] kJ/(kg·K)   [c] m/s   Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=12.22 bar (ts=47°C)					ps=12.54 bar (ts=48°C)					ps=12.86 bar (ts=49°C)					
50	59.541	426.2	[illegible]	[illegible]	[illegible]	61.655	425.5	1.717	1.183	138.9	63.892	424.7	[illegible]	1.201	137.8	50
55	57.454	432.0	[illegible]	1.140	143.3	59.434	431.3	1.735	1.153	142.3	61.50[illegible]	430.5	1.731	1.167	141.3	55
60	55.502	437.6	1.756	[illegible]	145.3	57.465	437.0	1.752	1.130	145.4	59.424	436.4	1.748	1.142	144.5	60
65	53.939	443.2	1.772	[illegible]	[illegible]	55.704	442.6	1.733	1.113	148.3	57.535	442.2	1.765	[illegible]	147.5	65
70	52.433	448.7	1.788	1.092	151.8	[illegible]	448.1	1.785	1.100	151.0	55.553	447.5	1.782	1.108	150.3	70
75	51.050	454.1	1.804	1.083	154.3	52.658	453.6	1.801	1.090	153.6	54.222	[illegible]	1.796	1.097	152.9	75
80	49.775	459.5	1.819	1.075	156.7	[illegible]	459.0	1.816	1.082	156.3	52.916	458.5	1.813	1.085	155.4	80
85	48.602	464.9	1.834	1.072	158.9	50.073	464.4	1.831	1.077	158.3	51.623	464.2	1.829	1.082	157.7	85
90	47.498	470.2	1.849	1.068	[illegible]	48.935	469.8	1.846	1.073	160.6	50.422	469.4	1.843	1.078	160.0	90
95	46.450	475.6	1.864	1.067	163.2	[illegible]	475.2	1.861	1.071	162.7	49.239	474.9	1.858	1.075	162.0	95
100	45.500	480.9	1.879	1.065	165.2	[illegible]	480.5	1.875	1.070	164.7	48.243	480.1	1.873	1.073	164.2	100
105	44.597	485.2	1.892	1.066	167.2	[illegible]	485.9	1.890	1.069	166.7	47.222	485.5	1.887	1.073	166.2	105
110	43.733	491.6	1.905	1.067	169.1	45.033	491.2	1.904	1.070	168.6	46.315	490.3	1.901	1.073	168.2	110
115	42.910	496.9	1.920	1.068	170.9	44.151	496.5	1.918	1.071	170.5	45.432	496.2	1.915	1.074	170.1	115
120	42.136	502.2	1.934	1.070	172.7	43.347	501.9	1.931	1.073	172.3	44.597	501.5	1.929	1.075	171.9	120
125	41.394	507.5	1.947	1.073	174.4	42.582	507.3	1.945	1.075	174.1	43.792	507.0	1.942	1.078	173.7	125
130	40.692	513.0	1.961	1.076	175.1	41.847	512.7	1.958	1.078	175.8	43.035	512.4	1.956	1.080	175.4	130
135	40.012	518.4	1.974	1.079	177.8	41.145	518.1	1.972	1.081	177.4	42.300	517.8	1.969	1.083	177.1	135
140	39.364	523.8	1.987	1.082	179.4	40.473	523.5	1.985	1.084	179.1	41.605	523.2	1.982	1.086	178.8	140
145	38.739	529.2	2.000	1.085	181.0	39.825	528.9	1.999	1.088	180.7	40.941	528.7	1.995	1.090	180.4	145
150	38.145	534.6	2.013	1.090	182.5	39.208	534.4	2.011	1.092	182.3	40.301	534.1	2.008	1.094	182.0	150
155	37.567	540.1	2.026	1.095	184.1	38.614	539.8	2.024	1.096	183.8	39.684	539.6	2.021	1.098	183.5	155
160	37.013	545.6	2.039	1.099	185.6	38.044	545.3	2.036	1.101	185.3	39.090	545.1	2.034	1.102	185.0	160
165	36.482	551.1	2.051	1.104	187.1	37.483	550.9	2.049	1.105	185.8	38.520	550.6	2.047	1.106	186.5	165
170	35.965	556.5	2.064	1.108	188.5	36.952	556.4	2.062	1.110	188.3	37.974	556.2	2.059	1.111	188.0	170
	ps=13.19 bar (ts=50°C)					ps=13.52 bar (ts=51°C)					ps=13.97 bar (ts=52°C)					
50	66.225	423.8	1.709	1.220	136.6	-	-	-	-	-	-	-	-	-	-	50
55	63.657	429.5	1.727	1.182	140.3	65.927	429.1	1.723	1.199	139.2	68.262	428.3	1.719	1.216	138.0	55
60	61.419	435.7	1.745	1.154	143.6	63.515	435.0	1.741	1.167	142.5	65.699	434.2	1.737	1.181	141.5	60
65	59.436	441.4	1.762	1.133	146.5	61.405	440.8	1.758	1.144	145.8	63.453	440.1	1.755	1.155	144.8	65
70	57.656	447.0	1.778	[illegible]	149.5	59.521	446.4	1.775	1.126	148.7	61.454	445.9	1.771	1.136	147.9	70
75	56.041	452.6	1.794	1.104	152.2	57.817	452.0	1.791	1.112	151.4	59.654	451.4	1.789	1.121	150.7	75
80	54.562	458.1	1.810	1.095	154.7	56.256	457.6	1.807	1.102	154.0	58.015	457.0	1.804	1.109	153.3	80
85	53.199	463.5	1.825	1.088	157.1	54.832	463.0	1.822	1.094	156.5	56.520	462.5	1.819	1.100	155.9	85
90	51.944	468.9	1.840	1.083	159.4	53.509	468.5	1.837	1.088	158.8	55.126	468.0	1.834	1.094	158.2	90
95	50.773	474.4	1.855	1.080	151.5	52.279	473.9	1.852	1.084	161.1	53.843	473.5	1.849	1.089	160.5	95
100	49.667	479.7	1.870	1.078	163.7	51.133	479.3	1.867	1.082	163.2	52.639	478.9	1.864	1.086	162.7	100
105	48.635	485.1	1.884	1.076	165.8	50.056	484.7	1.881	1.080	165.3	51.517	484.4	1.878	1.084	164.8	105
110	47.658	490.5	1.898	1.075	167.7	49.048	490.1	1.895	1.080	167.3	50.452	489.8	1.893	1.083	165.8	110
115	46.737	495.3	1.912	1.077	169.5	48.088	495.0	1.903	1.080	169.2	49.473	495.2	1.907	1.083	168.7	115
120	45.870	501.3	1.926	1.078	171.5	47.174	500.9	1.923	1.081	171.1	48.517	500.6	1.921	1.084	170.6	120
125	45.042	506.7	1.940	1.080	173.2	46.215	506.4	1.937	1.083	172.9	47.527	506.2	1.934	1.086	172.5	125
130	44.253	512.1	1.953	1.082	175.0	45.495	[illegible]	1.950	1.085	174.7	46.775	511.5	1.948	1.087	174.3	130
135	43.495	517.5	1.966	1.085	176.7	44.714	517.2	1.964	1.089	176.4	45.963	516.9	1.961	1.090	[illegible]	135
140	42.769	522.9	1.980	1.088	178.4	43.954	522.7	1.977	1.090	178.1	45.193	522.4	1.974	1.092	177.7	140
145	42.082	528.4	1.993	[illegible]	[illegible]	43.240	528.1	1.990	1.094	179.7	44.443	527.9	1.987	1.095	179.4	145
150	41.418	533.9	2.006	1.096	181.7	42.555	533.5	2.003	1.097	181.3	43.730	533.3	2.001	1.099	181.0	150
155	40.777	539.3	2.019	1.099	183.2	41.902	539.1	2.016	1.101	182.9	43.053	538.8	2.014	1.103	182.6	155
160	40.108	[illegible]	2.031	1.104	184.9	41.269	544.6	2.029	1.105	184.5	42.394	544.3	2.026	1.107	184.2	160
165	39.575	550.4	2.044	1.108	186.3	40.660	550.1	2.042	1.109	185.0	41.762	549.9	2.039	1.111	185.7	165
170	39.004	555.9	2.057	[illegible]	187.8	40.067	555.7	2.054	1.114	187.5	41.152	555.5	2.052	1.115	187.2	170
	ps=14.21 bar (ts=53°C)					ps=14.57 bar (ts=54°C)					ps=14.93 bar (ts=55°C)					
55	70.727	427.4	1.715	1.236	136.8	73.314	426.5	1.711	1.258	135.6	76.035	425.6	1.706	1.282	134.3	55
60	67.976	[illegible]	1.733	1.197	140.5	70.353	432.7	1.729	1.214	139.4	72.839	431.9	1.725	1.232	138.2	60
65	65.580	439.4	1.751	1.168	143.9	67.792	438.7	1.747	1.181	142.9	70.095	437.9	1.744	1.196	141.9	65
70	63.457	445.2	1.768	1.146	147.0	65.536	444.5	1.764	1.157	145.1	[illegible]	443.9	1.761	1.169	145.2	70
75	61.554	450.9	1.784	1.129	149.9	63.520	450.3	1.781	1.139	149.1	65.557	449.6	1.778	1.149	148.2	75
80	59.832	456.5	1.800	1.117	152.6	61.705	455.9	1.797	1.125	151.8	63.635	455.3	1.794	1.133	151.1	80
85	58.252	462.0	1.816	1.107	155.1	60.040	461.5	1.813	1.114	154.4	61.883	461.0	1.810	1.121	153.7	85
90	56.795	467.5	1.831	1.100	157.6	58.505	467.1	1.828	1.105	156.9	60.282	466.6	1.825	1.112	156.3	90
95	55.455	473.0	1.846	1.095	159.9	57.101	472.6	1.843	1.100	159.3	58.804	472.1	1.840	1.106	158.7	95
100	54.195	478.5	1.861	1.091	162.1	55.791	478.1	1.858	1.096	161.5	57.436	477.6	1.855	1.101	161.0	100
105	53.016	483.9	1.876	1.089	164.2	54.553	483.5	1.873	1.093	163.7	56.155	483.1	1.870	1.097	163.2	105
110	51.923	489.4	1.890	1.087	166.3	53.414	489.0	1.887	1.091	165.8	54.953	488.6	1.884	1.095	165.3	110
115	50.875	494.8	1.904	1.087	168.3	52.329	494.4	1.901	1.090	167.8	53.828	494.1	1.898	1.094	167.3	115
120	49.900	500.3	1.918	1.087	170.2	51.313	499.9	1.915	1.091	169.7	52.766	499.5	1.912	1.094	169.3	120
125	48.970	505.7	1.932	1.088	172.1	50.345	505.3	1.929	1.091	171.6	51.751	505.0	1.926	1.094	171.2	125
130	48.080	511.1	1.945	1.090	173.9	49.423	510.8	1.943	1.093	173.5	50.798	510.5	1.940	1.096	173.1	130
135	47.237	516.6	1.959	1.092	175.6	48.549	516.3	1.956	1.095	175.3	49.892	516.0	1.953	1.097	174.9	135
140	46.440	522.1	1.972	1.095	177.4	47.721	521.8	1.969	1.097	177.0	49.025	521.4	1.967	1.100	176.6	140
145	45.667	527.5	1.985	1.098	179.1	46.916	527.2	1.983	1.100	178.7	48.205	526.9	1.980	1.102	178.3	145
150	44.925	533.0	1.998	1.101	180.7	46.159	532.8	1.996	1.103	180.4	47.408	532.5	1.993	1.105	180.0	150
155	44.222	538.6	2.011	1.105	182.3	45.425	538.3	2.009	1.107	182.0	46.651	538.0	2.006	1.109	181.7	155
160	43.542	544.1	2.024	1.109	183.9	44.722	543.8	2.022	1.110	183.5	45.924	543.6	2.019	1.112	183.3	160
165	42.894	549.6	2.037	1.113	185.4	44.042	549.4	2.034	1.114	185.1	45.221	549.1	2.032	1.116	184.9	165
170	42.261	555.2	2.049	1.117	187.0	43.394	555.0	2.047	1.118	186.7	44.550	554.7	2.045	1.120	186.4	170
175	41.652	560.8	2.062	1.121	188.4	42.769	560.6	2.060	1.123	188.2	[illegible]	[illegible]	2.057	1.124	187.9	175

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] in °C [ρ] in kg/m³ [h] in kJ/kg [s] in kJ/(kg·K) [cp] in kJ/(kg·K) [c] in m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=9.84 bar (ts=38°C)					ps=9.91 bar (ts=39°C)					ps=10.18 bar (ts=40°C)					
40	46.659	421.1	1.720	1.098	142.3	48.330	420.4	1.716	1.110	141.4	50.072	419.8	1.712	1.123	140.4	40
45	45.164	425.5	1.737	1.079	145.2	46.739	425.9	1.734	1.093	144.4	48.376	425.3	1.730	1.100	143.5	45
50	43.818	431.9	1.754	1.065	147.9	45.313	431.3	1.750	1.074	147.2	46.863	430.8	1.747	1.083	146.4	50
55	42.535	437.2	1.770	1.054	150.5	44.021	436.7	1.767	1.062	149.8	45.437	436.2	1.763	1.070	149.1	55
60	41.475	442.4	1.786	1.047	152.9	42.541	442.0	1.783	1.053	152.3	44.252	441.5	1.779	1.060	151.6	60
65	40.442	447.5	1.802	1.041	155.3	41.755	447.2	1.798	1.047	154.7	43.110	446.9	1.795	1.052	154.0	65
70	39.460	452.6	1.817	1.037	157.5	40.749	452.4	1.814	1.042	156.9	42.054	452.0	1.811	1.047	156.3	70
75	38.585	458.0	1.832	1.035	159.5	39.815	457.6	1.829	1.039	159.1	41.077	457.2	1.826	1.044	158.5	75
80	37.753	463.2	1.847	1.033	161.6	38.950	462.8	1.844	1.037	161.1	40.153	462.5	1.841	1.042	160.6	80
85	36.965	468.4	1.861	1.033	163.6	38.115	468.0	1.858	1.037	163.1	39.297	467.7	1.855	1.041	162.6	85
90	36.225	473.5	1.875	1.034	165.5	37.338	473.2	1.873	1.037	165.0	38.491	472.9	1.870	1.041	164.6	90
95	35.521	478.7	1.890	1.035	167.3	36.610	478.4	1.887	1.038	166.9	37.723	478.1	1.884	1.041	166.5	95
100	34.850	483.9	1.904	1.037	169.1	35.914	483.6	1.901	1.040	168.7	37.003	483.3	1.898	1.043	169.3	100
105	34.217	489.1	1.917	1.040	170.9	35.256	488.8	1.915	1.042	170.5	36.318	488.5	1.912	1.045	170.1	105
110	33.615	494.3	1.931	1.042	172.6	34.523	494.0	1.928	1.045	172.2	35.662	493.7	1.926	1.047	171.8	110
115	33.037	499.5	1.945	1.046	174.2	34.022	499.2	1.942	1.048	173.9	35.037	499.0	1.939	1.050	173.5	115
120	32.483	504.7	1.958	1.050	175.8	33.451	504.5	1.955	1.052	175.5	34.443	504.2	1.953	1.054	175.2	120
125	31.952	510.0	1.971	1.054	177.4	32.901	509.8	1.969	1.055	177.1	33.873	509.5	1.966	1.058	176.8	125
130	31.444	515.3	1.984	1.058	179.0	32.374	515.0	1.982	1.060	178.7	33.326	514.8	1.979	1.062	178.4	130
135	30.956	520.6	1.998	1.063	180.5	31.866	520.4	1.995	1.064	180.2	32.803	520.1	1.992	1.066	180.0	135
140	30.483	525.9	2.011	1.067	182.0	31.382	525.7	2.008	1.069	181.7	32.295	525.5	2.005	1.070	181.5	140
145	30.030	531.3	2.023	1.072	183.5	30.913	531.0	2.021	1.073	183.2	31.811	530.8	2.018	1.075	183.0	145
150	29.593	536.5	2.036	1.077	184.9	30.460	536.4	2.034	1.078	184.7	31.343	536.2	2.031	1.080	184.4	150
155	29.171	542.0	2.049	1.082	186.4	30.023	541.8	2.046	1.083	186.1	30.893	541.6	2.044	1.085	185.9	155
160	28.765	547.4	2.061	1.087	187.8	29.601	547.3	2.059	1.088	187.5	30.452	547.1	2.056	1.090	187.3	160
	ps=10.45 bar (ts=41°C)					ps=10.73 bar (ts=42°C)					ps=11.02 bar (ts=43°C)					
45	50.077	424.7	1.726	1.112	142.6	51.848	424.0	1.722	1.124	141.7	53.693	423.4	1.718	1.138	140.7	45
50	48.470	430.2	1.743	1.092	145.6	50.138	429.6	1.740	1.103	144.7	51.871	429.0	1.736	1.114	143.9	50
55	47.024	435.6	1.760	1.078	148.3	48.605	435.1	1.756	1.087	147.6	50.246	434.5	1.753	1.096	146.8	55
60	45.711	441.0	1.776	1.067	150.9	47.219	440.5	1.773	1.074	150.2	48.780	439.9	1.769	1.082	149.5	60
65	44.509	446.3	1.792	1.059	153.4	45.953	445.8	1.789	1.065	152.7	47.445	445.3	1.785	1.072	152.1	65
70	43.400	451.6	1.807	1.053	155.7	44.788	451.1	1.804	1.058	155.1	46.220	450.7	1.801	1.064	154.5	70
75	42.371	456.9	1.823	1.049	158.0	43.705	456.4	1.820	1.054	157.4	45.090	456.0	1.816	1.059	156.8	75
80	41.411	462.1	1.838	1.046	160.1	42.707	461.7	1.835	1.050	159.6	44.032	461.3	1.832	1.055	159.0	80
85	40.519	467.3	1.852	1.045	162.1	41.762	466.9	1.849	1.049	161.7	43.050	466.5	1.846	1.053	161.1	85
90	39.671	472.5	1.867	1.044	164.1	40.884	472.2	1.864	1.048	163.7	42.136	471.8	1.861	1.052	163.2	90
95	38.878	477.7	1.881	1.045	166.1	40.056	477.4	1.878	1.048	165.6	41.268	477.1	1.875	1.051	165.2	95
100	38.124	483.0	1.895	1.046	167.9	39.271	482.6	1.892	1.049	167.5	40.449	482.3	1.890	1.052	167.1	100
105	37.403	488.2	1.909	1.048	169.7	38.529	487.9	1.906	1.050	169.3	39.676	487.6	1.904	1.053	168.9	105
110	36.724	493.4	1.923	1.050	171.5	37.817	493.1	1.920	1.052	171.1	38.942	492.8	1.917	1.055	170.7	110
115	36.076	498.7	1.936	1.053	173.2	37.146	498.4	1.934	1.055	172.8	38.233	498.1	1.931	1.053	172.5	115
120	35.459	504.0	1.950	1.056	174.9	36.505	503.7	1.947	1.058	174.5	37.575	503.4	1.945	1.060	174.2	120
125	34.869	509.3	1.963	1.060	176.5	35.888	509.0	1.961	1.062	176.2	36.935	508.7	1.958	1.064	175.8	125
130	34.303	514.6	1.977	1.063	178.1	35.302	514.3	1.974	1.066	177.8	36.325	514.1	1.971	1.067	177.5	130
135	33.755	519.9	1.991	1.068	179.7	34.740	519.6	1.987	1.069	179.4	35.740	519.4	1.985	1.071	179.1	135
140	33.233	525.2	2.003	1.072	181.2	34.193	525.0	2.000	1.073	180.9	35.177	524.8	1.998	1.075	180.6	140
145	32.733	530.6	2.016	1.076	182.7	33.678	530.4	2.013	1.078	182.4	34.639	530.1	2.011	1.079	182.2	145
150	32.249	536.0	2.028	1.081	184.2	33.170	535.8	2.026	1.083	183.9	34.123	535.6	2.023	1.084	183.7	150
155	31.780	541.4	2.041	1.086	185.5	32.686	541.2	2.039	1.087	185.4	33.619	541.0	2.036	1.089	185.1	155
160	31.327	546.9	2.054	1.091	187.1	32.221	546.7	2.051	1.092	186.8	33.139	546.4	2.049	1.093	186.6	160
165	30.890	552.3	2.066	1.095	188.5	31.772	552.1	2.064	1.097	188.3	32.670	551.9	2.061	1.098	188.0	165
	ps=11.31 bar (ts=44°C)					ps=11.61 bar (ts=45°C)					ps=11.91 bar (ts=46°C)					
45	55.617	422.6	1.715	1.152	139.7	57.629	421.9	1.711	1.168	138.6	-	-	-	-	-	45
50	53.672	428.3	1.732	1.126	142.9	55.550	427.7	1.728	1.139	142.0	57.503	427.0	1.725	1.152	141.0	50
55	51.946	433.9	1.749	1.106	145.9	53.713	433.3	1.746	1.116	145.1	55.547	432.7	1.742	1.128	144.2	55
60	50.395	439.4	1.766	1.091	148.7	52.070	438.8	1.763	1.100	148.0	53.804	438.2	1.759	1.109	147.1	60
65	48.987	444.8	1.782	1.079	151.4	50.583	444.3	1.779	1.087	150.6	52.232	443.8	1.775	1.095	149.9	65
70	47.697	450.2	1.798	1.071	153.8	49.225	449.7	1.795	1.077	153.2	50.801	449.2	1.791	1.084	152.5	70
75	46.514	455.5	1.813	1.065	156.2	47.980	455.1	1.810	1.070	155.6	49.494	454.6	1.807	1.077	154.9	75
80	45.404	460.9	1.829	1.060	158.5	46.827	460.4	1.825	1.065	157.9	48.283	460.0	1.822	1.071	157.3	80
85	44.383	466.1	1.843	1.057	160.5	45.749	465.7	1.840	1.062	160.1	47.148	465.3	1.837	1.067	159.5	85
90	43.422	471.4	1.858	1.056	162.7	44.741	471.0	1.855	1.060	162.2	46.093	470.6	1.852	1.064	161.6	90
95	42.512	476.7	1.872	1.055	164.7	43.798	476.3	1.870	1.059	164.2	45.116	476.0	1.867	1.063	163.7	95
100	41.661	482.0	1.887	1.055	166.6	42.914	481.6	1.884	1.059	166.2	44.191	481.3	1.881	1.062	165.7	100
105	40.856	487.2	1.901	1.056	168.5	42.066	486.9	1.898	1.059	168.1	43.316	486.6	1.895	1.062	167.6	105
110	40.090	492.5	1.915	1.058	170.3	41.269	492.2	1.912	1.061	169.9	12.488	491.9	1.909	1.064	169.5	110
115	39.364	497.8	1.928	1.060	172.1	40.520	497.5	1.926	1.063	171.7	41.699	497.2	1.923	1.065	171.3	115
120	38.669	503.1	1.942	1.063	173.8	39.801	502.8	1.939	1.065	173.4	40.949	502.5	1.937	1.068	173.1	120
125	38.013	508.5	1.955	1.066	175.5	39.114	508.2	1.953	1.068	175.1	40.239	507.9	1.950	1.070	174.8	125
130	37.380	513.8	1.969	1.069	177.1	38.458	513.5	1.966	1.071	176.8	39.559	513.2	1.963	1.073	176.5	130
135	36.771	519.1	1.982	1.072	178.8	37.825	518.9	1.979	1.075	178.4	38.903	518.6	1.977	1.077	178.1	135
140	36.185	524.5	1.995	1.077	180.3	37.224	524.3	1.992	1.079	180.0	38.278	524.0	1.990	1.080	179.7	140
145	35.630	529.9	2.008	1.081	181.9	36.646	529.7	2.005	1.083	181.6	37.677	529.4	2.003	1.084	181.3	145
150	35.092	535.3	2.021	1.085	183.4	36.083	535.1	2.018	1.087	183.1	37.107	534.9	2.016	089	182.8	150
155	34.576	540.8	2.034	1.090	184.9	35.552	540.5	2.031	1.092	184.6	36.544	540.3	2.029	.093	184.4	155
160	34.072	546.2	2.046	1.095	186.4	35.027	546.0	2.044	1.096	186.1	36.013	545.8	2.041	1.098	185.8	160
165	33.592	551.7	2.059	1.100	187.8	34.522	551.5	2.056	1.101	187.6	35.498	551.1	2.054	1.102	187.3	165

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] °C [ρ] kg/m³ [h] kJ/kg [s] kJ/(kg·K) [cp] kJ/(kg·K) [c] m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=15.29 bar (ts=56°C)					ps=15.67 bar (ts=57°C)					ps=16.05 bar (ts=58°C)					
60	75.443	[illegible]	[illegible]	1.262	[illegible]	[illegible]	432.1	1.717	1.274	135.8	81.051	429.1	1.713	1.298	134.5	60
65	72.499	[illegible]	1.740	1.212	142.6	75.049	436.3	1.736	1.229	139.7	77.631	435.5	1.732	1.247	138.6	65
70	69.930	443.1	1.757	1.182	144.2	[illegible]	442.4	1.755	1.195	143.2	74.693	[illegible]	1.752	[illegible]	142.2	70
75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	146.4	[illegible]	[illegible]	1.767	[illegible]	145.5	75
80	65.634	[illegible]	[illegible]	1.142	[illegible]	[illegible]	[illegible]	1.787	1.152	149.4	69.651	[illegible]	1.784	[illegible]	148.6	80
85	63.790	[illegible]	[illegible]	[illegible]	[illegible]	65.754	453.8	1.803	[illegible]	[illegible]	67.801	453.0	1.802	[illegible]	151.5	85
90	62.111	[illegible]	1.822	1.119	[illegible]	63.932	[illegible]	1.819	1.126	154.9	65.929	[illegible]	1.816	1.130	154.2	90
95	60.505	[illegible]	1.837	[illegible]	[illegible]	62.265	[illegible]	1.834	1.119	157.4	64.231	470.6	1.831	1.124	156.7	95
100	59.123	[illegible]	1.852	[illegible]	[illegible]	62.858	476.2	1.849	[illegible]	159.8	62.543	476.2	1.846	1.117	159.1	100
105	57.780	[illegible]	1.867	1.102	162.6	59.457	482.2	1.854	1.107	162.0	61.156	481.8	1.861	[illegible]	161.4	105
110	56.53[illegible]	488.2	1.881	1.093	[illegible]	58.155	487.7	1.879	1.104	164.2	59.827	48[illegible]	1.876	1.108	163.7	110
115	55.359	493.7	1.896	1.094	[illegible]	56.929	493.3	1.893	1.102	166.3	58.546	492.8	1.890	[illegible]	165.8	115
120	54.250	[illegible]	1.910	1.097	168.8	55.781	498.8	1.907	1.101	168.3	57.343	498.4	1.904	1.105	167.9	120
125	53.204	504.6	1.924	1.098	170.8	54.681	504.3	1.921	1.101	170.3	56.211	503.9	1.918	1.104	169.8	125
130	52.212	510.1	1.937	1.099	172.6	53.551	509.8	1.935	1.102	172.2	55.141	509.4	1.932	1.105	171.8	130
135	51.257	515.5	1.951	1.100	174.5	52.672	515.3	1.948	1.103	174.1	54.125	514.9	1.946	1.105	173.6	135
140	50.368	521.1	1.954	1.102	176.2	51.751	520.8	1.962	1.105	175.9	53.157	520.5	1.959	1.107	175.5	140
145	49.517	526.6	1.978	1.105	178.0	50.830	526.3	1.975	1.107	177.6	52.235	526.0	1.972	1.109	177.2	145
150	48.689	532.2	1.991	1.107	179.7	50.003	531.9	1.988	1.110	179.3	51.360	531.6	1.986	1.112	179.0	150
155	47.908	537.7	2.004	1.111	181.3	49.197	537.4	2.001	1.113	181.0	50.517	537.1	1.999	1.115	180.7	155
160	47.158	543.3	2.017	1.114	183.0	48.415	543.0	2.014	1.116	182.6	49.705	542.7	2.012	1.118	182.3	160
165	46.432	548.9	2.029	1.118	184.5	47.674	548.6	2.027	1.120	184.2	48.939	548.3	2.025	1.121	183.9	165
170	45.737	554.5	2.042	1.122	186.1	46.955	554.2	2.040	1.123	185.8	48.189	553.9	2.037	1.125	185.5	170
175	45.065	560.1	2.055	1.125	187.5	46.260	559.9	2.052	1.127	187.4	47.471	559.5	2.050	1.129	187.1	175
180	44.425	565.7	2.067	1.130	189.1	45.595	565.5	2.065	1.131	188.9	45.784	565.2	2.063	1.133	188.6	180
	ps=16.43 bar (ts=59°C)					ps=16.83 bar (ts=60°C)					ps=17.23 bar (ts=61°C)					
60	84.082	428.1	1.708	1.326	133.1	87.285	427.1	1.704	1.356	131.7	-	-	-	-	-	60
65	80.330	434.6	1.729	1.258	137.4	83.263	433.7	1.724	1.290	136.1	86.297	[illegible]	1.719	[illegible]	134.8	65
70	77.233	440.8	1.746	1.225	141.1	79.877	440.0	1.742	1.244	140.0	82.643	439.2	1.738	1.262	138.9	70
75	74.495	446.9	1.764	1.196	144.5	76.953	446.2	1.760	1.209	143.5	79.513	445.4	1.756	1.224	142.6	75
80	72.075	452.8	1.780	1.170	147.7	74.381	452.1	1.777	1.184	146.8	76.775	451.4	1.773	1.196	145.9	80
85	69.911	458.6	1.797	1.155	150.5	72.087	458.0	1.793	1.164	149.8	74.342	457.3	1.790	1.175	149.0	85
90	67.943	464.4	1.813	1.141	153.4	70.010	463.8	1.810	1.150	152.6	72.158	463.2	1.806	1.158	151.9	90
95	66.147	470.0	1.828	1.131	156.0	68.128	469.5	1.825	1.138	155.3	70.175	468.9	1.822	1.146	154.5	95
100	[illegible]	475.7	1.840	1.122	158.5	66.392	475.2	1.840	1.129	157.8	68.341	474.6	1.837	[illegible]	157.1	100
105	62.966	481.3	1.858	1.117	160.8	64.778	480.8	1.855	1.123	160.2	66.568	480.3	1.853	1.129	159.5	105
110	61.529	486.9	1.873	1.113	163.1	63.294	486.4	1.870	1.118	162.5	65.106	485.9	1.867	1.123	161.9	110
115	60.202	492.4	1.887	1.110	165.3	61.904	492.0	1.885	1.115	164.7	63.654	491.5	1.882	1.119	164.2	115
120	58.952	498.0	1.902	1.109	167.3	60.608	497.5	1.899	1.113	166.8	62.295	497.1	1.895	1.117	165.3	120
125	57.773	503.5	1.915	1.108	169.4	59.374	503.1	1.913	1.111	168.3	61.014	502.7	1.910	1.115	168.4	125
130	56.655	509.0	1.929	1.108	171.3	58.218	508.7	1.927	1.111	170.9	59.811	508.3	1.924	1.115	170.4	130
135	55.593	514.6	1.942	1.109	173.3	57.124	514.2	1.940	1.112	172.8	58.671	513.9	1.938	1.115	172.3	135
140	54.594	520.1	1.957	1.110	175.1	56.078	519.8	1.954	1.113	174.7	57.593	519.4	1.951	1.115	174.2	140
145	53.541	525.7	1.970	1.112	176.8	55.094	525.3	1.967	1.114	176.5	56.560	[illegible]	1.965	1.117	176.1	145
150	52.735	531.2	1.983	1.114	178.6	54.141	530.9	1.981	1.117	178.2	55.594	[illegible]	1.978	[illegible]	177.8	150
155	51.860	536.8	[illegible]	[illegible]	[illegible]	53.24[illegible]	536.5	1.994	[illegible]	179.9	[illegible]	[illegible]	1.991	[illegible]	179.6	155
160	51.032	542.4	2.009	1.120	182.0	52.376	542.1	2.007	1.122	181.6	53.752	[illegible]	2.004	1.124	181.3	160
165	50.223	548.0	2.022	1.123	183.5	51.542	547.7	2.020	1.125	183.3	[illegible]	547.4	2.017	1.127	183.0	165
170	49.455	553.6	2.035	1.127	185.2	50.751	553.4	2.033	1.129	184.9	52.079	553.1	2.030	1.130	184.5	170
175	48.720	559.3	2.048	1.131	186.8	49.985	559.0	2.045	1.132	186.5	51.290	558.7	2.043	1.134	186.2	175
180	48.002	565.0	2.060	1.134	188.3	49.252	564.7	2.058	1.136	188.0	50.532	564.4	2.055	1.138	187.7	180
	ps=17.64 bar (ts=62°C)					ps=18.05 bar (ts=63°C)					ps=18.47 bar (ts=64°C)					
65	89.495	431.7	1.715	1.343	132.4	92.676	430.6	1.710	1.374	131.9	96.453	429.5	1.706	1.409	130.4	65
70	85.540	438.0	1.734	1.283	137.6	88.580	437.3	1.730	1.306	136.4	91.768	436.3	1.725	1.331	135.0	70
75	82.181	444.6	1.752	1.241	141.4	84.967	443.7	1.749	1.258	140.3	87.872	442.9	1.745	1.277	139.2	75
80	79.252	450.7	1.770	1.209	144.9	81.849	449.9	1.766	1.223	143.9	84.535	449.1	1.763	1.239	142.8	80
85	76.685	456.7	1.787	1.186	148.1	79.105	456.0	1.783	1.197	147.2	81.615	455.3	1.780	1.210	146.2	85
90	74.371	462.6	1.803	1.167	151.0	76.664	461.9	1.800	1.177	150.2	79.023	461.2	1.796	1.188	149.4	90
95	72.270	468.4	1.819	1.154	153.8	74.448	467.8	1.816	1.162	153.1	76.691	467.1	1.813	1.171	152.3	95
100	70.371	474.1	1.834	1.143	156.4	72.434	473.5	1.831	1.150	155.7	74.579	473.0	1.828	1.158	155.0	100
105	68.605	479.8	1.850	1.135	158.9	70.605	479.3	1.847	1.141	158.3	72.651	478.7	1.844	1.148	157.6	105
110	66.981	485.4	1.864	1.129	161.3	68.887	484.9	1.862	1.134	160.7	70.855	484.4	1.859	1.140	160.1	110
115	65.450	491.1	1.879	1.124	163.[illegible]	67.303	490.5	1.876	1.129	163.0	69.199	490.1	1.873	1.134	162.4	115
120	64.044	496.7	1.893	1.121	165.6	[illegible].825	496.2	1.891	1.126	165.2	67.653	495.9	1.888	1.130	164.7	120
125	62.709	502.3	1.908	1.119	167.9	64.435	501.9	1.905	1.123	167.4	66.215	501.4	1.902	1.127	166.8	125
130	61.451	507.9	1.922	1.118	169.9	63.138	507.5	1.919	1.122	169.4	64.856	507.1	1.916	1.126	168.9	130
135	60.264	513.5	1.935	1.118	171.9	61.904	513.1	1.933	1.121	171.4	63.576	512.7	1.930	1.125	170.9	135
140	59.147	519.1	1.949	1.119	173.8	60.733	518.7	1.946	1.122	173.4	62.373	518.3	1.944	1.125	172.9	140
145	58.077	524.7	1.962	1.120	175.6	59.631	524.3	1.960	1.123	175.2	61.217	523.9	1.957	1.126	174.8	145
150	57.062	530.3	1.976	1.122	177.5	58.577	529.9	1.973	1.124	177.1	60.123	529.6	1.971	1.127	176.7	150
155	56.093	535.9	1.989	1.124	179.2	57.577	535.5	1.986	1.126	178.8	59.085	535.2	1.984	1.129	178.5	155
160	55.172	541.5	2.002	1.126	180.9	56.617	541.2	1.999	1.129	180.6	58.093	540.9	1.997	1.131	180.2	160
165	54.281	547.1	2.015	1.129	182.6	55.703	546.8	2.012	1.131	182.3	57.140	546.5	2.010	1.134	181.9	165
170	53.438	552.8	2.028	1.132	184.3	54.829	552.5	2.025	1.134	183.9	56.234	552.2	2.023	1.136	183.6	170
175	52.618	558.5	2.040	1.136	185.9	53.977	558.2	2.038	1.138	185.6	55.359	557.9	2.036	1.140	185.2	175
180	51.829	564.2	2.053	1.140	187.4	53.155	563.9	2.051	[illegible]	187.1	54.516	563.6	2.048	1.143	186.8	180
185	51.079	569.9	2.066	1.143	189.0	52.383	569.6	2.063	1.145	188.7	53.714	569.3	2.061	1.147	188.4	185

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t]=°C [ρ]= kg/m³ [h]=kJ/kg [s]= kJ / (kg·K) [cp]= kJ / (kg·K) [c]=m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=18.91 bar (ts=65°C)					ps=19.34 bar (ts=66°C)					ps=19.79 bar (ts=67°C)					
65	100.28	428.3	1.701	1.450	128.7	-	-	-	-	-	-	-	-	-	-	65
70	95.14	435.3	1.721	1.359	133.6	98.70	434.2	1.717	1.391	132.2	102.48	433.1	1.712	1.427	130.6	70
75	90.92	441.9	1.741	1.299	137.9	94.13	441.0	1.737	1.322	136.7	97.49	440.0	1.732	1.347	135.3	75
80	87.34	448.2	1.759	1.255	141.8	90.24	447.5	1.755	1.273	140.6	93.34	446.6	1.751	1.292	139.5	80
85	84.24	454.5	1.776	1.225	145.3	86.97	453.7	1.773	1.237	144.2	89.79	452.9	1.769	1.253	143.2	85
90	81.43	460.6	1.793	1.199	148.5	83.93	459.9	1.790	1.210	147.5	86.69	459.1	1.786	1.223	146.6	90
95	78.83	466.5	1.809	[illegible]	151.4	81.44	465.6	1.806	1.190	150.6	83.93	465.2	1.803	1.203	149.7	95
100	76.81	472.4	1.825	1.166	154.2	79.58	471.3	1.822	1.174	153.5	81.46	471.1	1.819	1.182	152.7	100
105	74.76	478.2	1.841	1.155	156.9	76.95	477.6	1.838	1.162	156.2	79.20	477.0	1.834	1.172	155.4	105
110	72.83	483.9	1.856	1.146	159.4	74.98	483.4	1.853	1.153	158.7	77.13	482.8	1.850	1.159	158.1	110
115	71.17	489.5	1.870	1.140	161.8	73.17	489.1	1.868	1.145	161.2	75.24	488.6	1.865	1.151	160.5	115
120	69.54	495.3	1.885	1.135	164.1	71.50	494.9	1.882	1.140	163.5	73.48	494.2	1.879	1.145	162.9	120
125	68.04	501.0	1.899	1.132	166.3	69.92	500.5	1.897	1.136	165.7	71.85	500.1	1.894	1.141	165.2	125
130	66.62	506.6	1.914	1.130	168.4	68.45	506.2	1.911	1.134	167.9	70.31	505.8	1.906	1.138	167.4	130
135	65.23	512.3	1.927	1.129	170.5	67.05	511.9	1.925	1.132	170.0	68.57	511.4	1.922	1.135	169.5	135
140	64.04	517.9	1.941	1.128	172.4	65.75	517.5	1.939	1.132	172.0	67.51	517.1	1.935	1.135	171.5	140
145	62.84	523.6	1.955	1.129	174.4	64.51	523.2	1.952	1.132	173.9	66.23	522.8	1.950	1.135	173.5	145
150	61.72	523.2	1.968	1.130	176.2	63.34	528.9	1.966	1.133	175.8	65.01	528.5	1.963	1.136	175.4	150
155	60.64	534.9	1.981	1.131	178.1	62.22	534.5	1.979	1.134	177.7	63.84	534.2	1.976	1.137	177.3	155
160	59.61	540.5	1.995	1.133	179.8	61.15	540.2	1.992	1.136	179.5	62.75	539.8	1.990	1.138	179.1	160
165	58.62	545.2	2.008	1.136	181.6	60.14	545.9	2.005	1.138	181.2	61.69	545.5	2.003	1.140	180.8	165
170	57.69	551.9	2.020	1.139	183.3	59.17	551.6	2.018	1.141	182.9	60.68	551.2	2.016	1.143	182.6	170
175	56.78	557.6	2.033	1.142	184.9	58.23	557.3	2.031	1.144	184.6	59.72	557.0	2.029	1.146	184.2	175
180	55.91	563.3	2.046	1.145	186.5	57.34	563.0	2.044	1.147	185.2	58.79	562.7	2.041	1.149	185.9	180
185	55.08	569.0	2.059	1.148	188.1	56.49	568.7	2.055	1.150	187.8	57.90	568.4	2.054	1.152	187.5	185
	ps=20.24 bar (ts=68°C)					ps=20.70 bar (ts=69°C)					ps=21.17 bar (ts=70°C)					
70	106.51	431.8	1.708	1.468	129.0	110.81	430.5	1.702	1.516	127.3	115.44	429.1	1.697	1.572	125.4	70
75	101.04	438.9	1.728	1.376	134.0	104.79	437.8	1.724	1.408	132.5	108.76	436.6	1.719	1.444	131.0	75
80	95.55	445.6	1.747	1.314	138.3	99.91	444.7	1.743	1.337	137.0	103.45	443.6	1.739	1.363	135.7	80
85	92.74	452.1	1.765	1.269	142.1	95.82	451.2	1.762	1.287	141.0	99.04	450.3	1.758	1.307	139.8	85
90	89.44	458.3	1.783	1.236	145.5	92.28	457.6	1.779	1.251	144.6	95.27	456.7	1.775	1.265	143.6	90
95	86.52	464.5	1.799	1.212	148.9	89.20	463.7	1.796	1.224	147.9	91.97	463.0	1.793	1.235	147.0	95
100	83.90	470.5	1.816	1.193	151.9	86.42	469.8	1.812	1.203	151.0	89.04	469.1	1.809	1.213	150.2	100
105	81.52	476.4	1.831	1.178	154.7	83.93	475.8	1.828	1.185	153.9	86.41	475.1	1.825	1.195	153.1	105
110	79.37	482.3	1.847	1.166	157.4	81.66	481.7	1.844	1.174	156.6	84.02	481.1	1.841	1.182	155.9	110
115	77.38	488.1	1.862	1.158	159.9	79.57	487.5	1.859	1.164	159.2	81.84	487.0	1.856	1.171	158.5	115
120	75.54	493.8	1.877	1.151	162.3	77.65	493.3	1.874	1.157	161.7	79.82	492.8	1.871	1.163	161.0	120
125	73.82	499.6	1.891	1.146	164.6	75.85	499.1	1.888	1.151	164.0	77.95	498.6	1.886	1.157	163.4	125
130	72.23	505.3	1.905	1.143	166.8	74.20	504.8	1.903	1.147	166.3	76.21	504.4	1.900	1.152	165.7	130
135	70.73	511.0	1.919	1.140	169.0	72.64	510.5	1.917	1.144	168.4	74.59	510.1	1.914	1.149	167.9	135
140	69.31	516.7	1.933	1.139	171.0	71.17	516.3	1.931	1.143	170.5	73.05	515.8	1.928	1.147	170.0	140
145	67.98	522.4	1.947	1.138	173.0	69.78	522.0	1.944	1.142	172.5	71.61	521.6	1.942	1.145	172.1	145
150	66.72	528.1	1.961	1.139	175.0	68.47	527.7	1.958	1.142	174.5	70.25	527.3	1.955	1.145	174.1	150
155	65.51	533.8	1.974	1.140	176.9	67.22	533.4	1.971	1.143	176.4	68.95	533.0	1.969	1.147	176.0	155
160	64.37	539.5	1.987	1.141	178.7	66.03	539.1	1.985	1.144	178.3	67.72	538.8	1.982	1.146	177.9	160
165	63.23	545.2	2.000	1.143	180.5	64.90	544.6	1.997	1.145	180.1	66.56	544.5	1.995	1.148	179.7	165
170	62.23	550.9	2.013	1.145	182.2	63.82	550.6	2.011	1.147	181.8	65.44	550.2	2.008	1.150	181.5	170
175	61.23	556.6	2.026	1.148	183.9	62.79	556.3	2.024	1.150	183.5	64.37	556.0	2.021	1.152	183.2	175
180	60.28	562.4	2.039	1.151	185.6	61.80	562.1	2.037	1.153	185.2	63.35	561.8	2.034	1.155	184.9	180
185	59.36	568.2	2.052	1.154	187.2	60.85	567.8	2.049	1.156	186.9	62.37	567.5	2.047	1.158	186.6	185
190	58.47	573.9	2.064	1.157	188.8	59.93	573.6	2.062	1.159	188.5	61.42	573.3	2.059	1.161	188.2	190
	ps=21.65 bar (ts=71°C)					ps=22.14 bar (ts=72°C)					ps=22.63 bar (ts=73°C)					
75	112.99	435.4	1.714	1.485	129.4	117.52	434.1	1.709	1.533	127.6	122.38	432.7	1.704	1.590	125.8	75
80	107.18	442.6	1.735	1.392	134.3	111.12	441.5	1.730	1.424	132.9	115.23	440.3	1.726	1.460	131.3	80
85	102.41	449.4	1.754	1.328	138.6	105.94	448.4	1.750	1.352	137.4	109.66	447.3	1.745	1.378	136.1	85
90	98.38	455.9	1.772	1.283	142.5	101.58	455.0	1.768	1.301	141.4	104.98	454.1	1.764	1.321	140.2	90
95	94.85	462.2	1.789	1.250	146.0	97.85	461.4	1.786	1.264	145.0	100.95	460.6	1.782	1.280	144.0	95
100	91.75	468.4	1.806	1.224	149.3	94.55	467.7	1.802	1.236	148.4	97.47	466.9	1.799	1.249	147.4	100
105	88.98	474.5	1.822	1.205	152.3	91.63	473.8	1.819	1.215	151.5	94.36	473.1	1.815	1.226	150.6	105
110	86.46	480.5	1.838	1.190	155.1	88.98	479.9	1.835	1.198	154.4	91.57	479.2	1.831	1.208	153.6	110
115	84.16	486.4	1.853	1.178	157.8	86.57	485.8	1.850	1.186	157.1	89.04	485.2	1.847	1.193	156.4	115
120	82.06	492.2	1.868	1.169	160.4	84.35	491.7	1.865	1.176	159.7	86.73	491.1	1.852	1.182	159.0	120
125	80.10	498.1	1.883	1.162	162.8	82.32	497.5	1.880	1.168	162.2	84.59	497.0	1.877	1.174	161.5	125
130	78.29	503.9	1.897	1.157	165.1	80.42	503.4	1.894	1.162	164.5	82.60	502.8	1.892	1.168	163.9	130
135	76.59	509.6	1.911	1.153	167.4	78.65	509.2	1.909	1.158	166.8	80.76	508.7	1.906	1.163	166.2	135
140	74.99	515.4	1.925	1.151	169.5	76.99	514.9	1.923	1.155	169.0	79.04	514.5	1.920	1.159	168.5	140
145	73.50	521.1	1.939	1.149	171.6	75.43	520.7	1.937	1.153	171.1	77.42	520.3	1.934	1.157	170.6	145
150	72.09	526.9	1.953	1.149	173.6	73.96	526.5	1.950	1.152	173.1	75.89	526.0	1.948	1.156	172.6	150
155	70.74	532.6	1.966	1.149	175.5	72.57	532.2	1.964	1.152	175.1	74.44	531.8	1.961	1.155	174.6	155
160	69.47	538.4	1.980	1.149	177.4	71.25	538.0	1.977	1.152	177.0	73.07	537.6	1.975	1.155	176.6	160
165	68.26	544.1	1.993	1.151	179.3	69.99	543.8	1.991	1.153	178.9	71.77	543.4	1.988	1.156	178.5	165
170	67.10	549.9	2.006	1.152	181.1	68.80	549.5	2.004	1.155	180.7	70.53	549.2	2.001	1.158	180.3	170
175	65.99	555.7	2.019	1.154	182.8	67.65	555.3	2.017	1.157	182.5	69.35	555.0	2.014	1.159	182.1	175
180	64.94	561.4	2.032	1.157	184.5	66.56	561.1	2.029	1.159	184.2	68.22	560.8	2.027	1.161	183.8	180
185	63.92	567.2	2.045	1.160	186.2	65.51	566.9	2.042	1.162	185.9	67.14	566.6	2.040	1.164	185.6	185
190	62.95	573.0	2.057	1.163	187.9	64.51	572.7	2.055	1.165	187.5	66.10	572.4	2.052	1.167	187.2	190
195	62.01	578.8	[illegible]	1.166	189.5	63.54	578.5	2.067	1.168	189.2	65.10	578.2	2.065	1.170	188.9	195

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

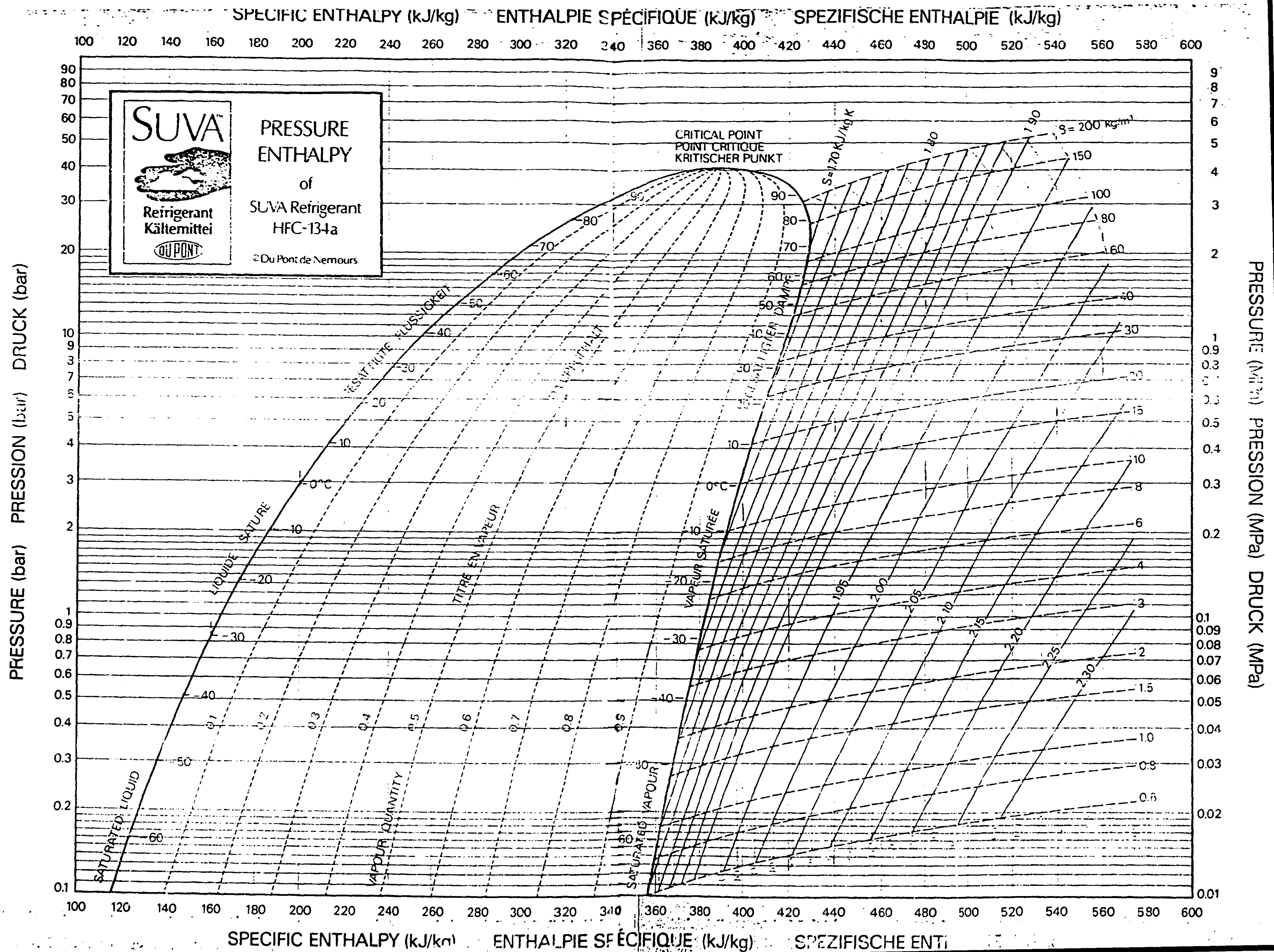
[t]=°C [ρ]= kg·m⁻³ [h]=kJ/kg [s]= kJ / (kg·K) [cp]= kJ / (kg·K) [c]=m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=28.05 bar (ts=83°C)					ps=28.65 bar (ts=84°C)					ps=29.25 bar (ts=85°C)					
85	163.46	432.8	1.694	1.999	118.6	172.03	430.6	1.686	2.155	116.1	181.93	428.1	1.678	2.390	113.3	85
90	150.70	442.0	1.719	1.698	125.7	157.19	440.3	1.713	1.774	123.8	164.28	438.5	1.707	1.868	121.7	90
95	141.50	450.0	1.741	1.544	131.4	145.90	448.7	1.732	1.591	129.8	152.66	447.2	1.731	1.644	[illegible]	95
100	134.27	457.5	1.761	1.449	135.2	138.99	456.3	1.757	1.481	134.9	143.99	455.1	1.752	1.516	133.5	100
105	128.31	464.6	1.780	1.393	140.5	132.55	463.5	1.776	1.407	139.4	137.01	462.4	1.772	1.433	138.1	105
110	123.25	471.4	1.798	1.335	144.4	127.13	470.4	1.794	1.355	143.4	131.19	469.5	1.790	1.374	142.3	110
115	118.85	478.0	1.815	1.301	148.0	122.45	477.1	1.811	1.316	147.0	126.22	476.2	1.808	1.332	146.0	115
120	114.96	484.4	1.831	1.274	151.2	118.33	483.5	1.828	1.286	150.4	121.53	482.8	1.825	1.299	149.5	120
125	111.47	490.7	1.847	1.253	154.2	114.66	490.0	1.844	1.263	153.5	117.95	489.2	1.841	1.274	152.7	125
130	108.32	496.9	1.862	1.237	157.2	111.34	496.2	1.860	1.245	156.5	114.47	495.5	1.857	1.255	155.7	130
135	105.45	503.1	1.878	1.224	159.9	108.33	502.4	1.875	1.232	159.2	111.30	501.8	1.872	1.240	158.5	135
140	102.80	509.2	1.893	1.214	162.5	105.56	508.6	1.890	1.221	161.9	108.40	507.9	1.887	1.228	161.2	140
145	100.35	515.2	1.907	1.206	165.0	103.00	514.6	1.905	1.212	164.4	105.73	514.1	1.902	1.218	163.8	145
150	98.08	521.2	1.922	1.200	167.4	100.63	520.7	1.919	1.205	166.8	103.26	520.1	1.915	1.211	166.2	150
155	95.95	527.2	1.936	1.195	169.6	98.42	526.7	1.933	1.200	169.1	100.95	526.2	1.930	1.205	168.5	155
160	93.96	533.2	1.950	1.192	171.8	96.34	532.7	1.947	1.196	171.3	98.79	532.2	1.944	1.201	170.5	160
165	92.08	539.1	1.963	1.190	174.0	94.39	538.7	1.961	1.194	173.5	96.77	538.2	1.958	1.198	173.0	165
170	90.31	545.1	1.977	1.189	176.0	92.56	544.6	1.974	1.192	175.6	94.86	544.2	1.972	1.196	175.1	170
175	88.63	551.0	1.990	1.188	178.0	90.82	550.6	1.988	1.191	177.6	93.06	550.1	1.985	1.195	177.1	175
180	87.04	557.0	2.003	1.188	180.0	89.17	556.5	2.001	1.191	179.5	91.35	556.1	1.998	1.194	179.1	180
185	85.52	562.9	2.016	1.189	181.8	87.60	562.5	2.014	1.192	181.4	89.72	562.1	2.011	1.195	181.0	185
190	84.08	568.9	2.029	1.190	183.7	86.10	568.5	2.027	1.193	183.3	88.18	568.1	2.024	1.195	182.9	190
195	82.70	574.8	2.042	1.192	185.5	84.68	574.4	2.040	1.194	185.1	86.70	574.0	2.037	1.197	184.7	195
200	81.37	580.8	2.055	1.193	187.2	83.31	580.4	2.052	1.196	186.9	85.29	580.0	2.050	1.198	186.5	200
205	80.11	586.7	2.067	1.195	188.9	82.00	586.4	2.065	1.198	188.6	83.94	586.0	2.063	1.200	188.2	205
	ps=29.87 bar (ts=86°C)					ps=30.49 bar (ts=87°C)					ps=31.13 bar (ts=88°C)					
90	172.11	436.5	1.701	1.955	119.6	180.89	434.3	1.694	2.139	117.2	190.93	431.9	1.686	2.348	114.6	90
95	158.90	445.7	1.726	1.707	126.4	165.62	444.0	1.720	1.780	124.6	172.94	442.2	1.714	1.869	122.7	95
100	149.28	453.8	1.748	1.556	132.1	154.90	452.4	1.743	1.601	130.6	160.91	451.0	1.738	1.653	129.0	100
105	141.69	461.3	1.768	1.461	136.9	146.62	460.1	1.763	1.492	135.6	151.82	458.9	1.759	1.527	134.2	105
110	135.43	468.4	1.786	1.396	141.2	139.86	467.4	1.782	1.419	140.0	144.51	466.3	1.778	1.445	138.8	110
115	130.10	475.3	1.804	1.349	145.0	134.16	474.4	1.801	1.367	144.0	138.40	473.4	1.797	1.387	142.9	115
120	125.46	482.0	1.821	1.313	148.6	129.23	481.1	1.818	1.328	147.6	133.15	480.2	1.814	1.344	146.7	120
125	121.36	488.4	1.838	1.286	151.8	124.89	487.6	1.834	1.298	151.0	128.55	486.8	1.831	1.311	150.1	125
130	117.69	494.8	1.854	1.265	154.9	121.02	494.1	1.850	1.275	154.1	124.45	493.3	1.847	1.286	153.3	130
135	114.36	501.1	1.869	1.248	157.8	117.52	500.4	1.866	1.257	157.1	120.79	499.7	1.863	1.266	156.3	135
140	111.33	507.3	1.884	1.235	160.5	114.34	506.7	1.881	1.243	159.8	117.45	506.0	1.878	1.251	159.1	140
145	108.53	513.5	1.899	1.225	163.1	111.42	512.8	1.896	1.232	162.5	114.39	512.2	1.893	1.239	161.8	145
150	105.95	519.6	1.913	1.217	165.6	108.72	519.0	1.911	1.223	165.0	111.58	518.4	1.908	1.229	164.4	150
155	103.55	525.6	1.928	1.210	168.0	106.22	525.1	1.925	1.216	167.4	108.97	524.5	1.922	1.222	166.8	155
160	101.31	531.7	1.942	1.206	170.3	103.89	531.1	1.939	1.211	169.7	106.53	530.6	1.936	1.216	169.2	160
165	99.20	537.7	1.956	1.202	172.5	101.70	537.2	1.953	1.207	172.0	104.25	536.7	1.950	1.211	171.4	165
170	97.22	543.7	1.969	1.200	174.6	99.64	543.2	1.967	1.204	174.1	102.12	542.7	1.964	1.208	173.6	170
175	95.35	549.7	1.983	1.198	176.7	97.70	549.2	1.980	1.202	176.2	100.11	548.7	1.978	1.205	175.7	175
180	93.58	555.7	1.996	1.196	178.7	95.87	555.2	1.993	1.201	178.2	98.21	554.8	1.991	1.205	177.7	180
185	91.90	561.7	2.009	1.195	180.6	94.12	561.2	2.007	1.201	180.2	96.40	560.8	2.004	1.204	179.6	185
190	90.30	567.7	2.022	1.195	182.5	92.47	567.2	2.020	1.201	182.1	94.69	566.8	2.017	1.204	181.7	190
195	88.77	573.6	2.035	1.195	184.4	90.89	573.2	2.033	1.202	184.0	93.05	572.8	2.030	1.205	183.6	195
200	87.32	579.6	2.048	1.201	186.2	89.39	579.3	2.045	1.203	185.8	91.50	578.9	2.043	1.206	185.4	200
205	85.92	585.7	2.060	1.203	187.9	87.95	585.3	2.058	1.205	187.6	93.02	584.9	2.056	1.207	187.2	205
210	84.59	591.7	2.073	1.205	189.6	86.57	591.3	2.071	1.207	189.3	88.59	590.9	2.068	1.209	189.0	210
	ps=31.77 bar (ts=89°C)					ps=32.43 bar (ts=90°C)					ps=33.10 bar (ts=91°C)					
90	202.66	429.0	1.677	2.655	111.7	217.15	425.6	1.667	3.167	108.4	-	-	-	-	-	90
95	180.97	440.3	1.708	1.979	120.7	189.92	438.1	1.701	2.118	118.5	200.03	435.7	1.694	2.302	116.1	95
100	167.34	449.4	1.733	1.713	127.3	174.29	447.8	1.727	1.784	125.6	181.83	446.0	1.721	1.867	123.8	100
105	157.32	457.6	1.754	1.567	132.8	163.17	456.2	1.750	1.611	131.4	169.41	454.7	1.745	1.661	129.9	105
110	149.39	465.2	1.774	1.473	137.6	154.52	464.0	1.770	1.504	136.3	159.94	462.7	1.766	1.538	135.0	110
115	142.82	472.4	1.793	1.408	141.8	147.45	471.3	1.789	1.431	140.7	152.30	470.2	1.785	1.456	139.6	115
120	137.22	479.3	1.811	1.361	145.7	141.46	478.3	1.807	1.379	144.7	145.89	477.3	1.803	1.398	143.6	120
125	132.34	486.0	1.828	1.325	149.2	136.28	485.1	1.824	1.340	148.3	140.37	484.2	1.821	1.355	147.3	125
130	128.02	492.5	1.844	1.298	152.5	131.71	491.7	1.841	1.310	151.6	135.54	490.9	1.837	1.323	150.8	130
135	124.15	499.0	1.860	1.276	155.5	127.64	498.2	1.857	1.287	154.8	131.24	497.4	1.854	1.298	154.0	135
140	120.65	505.3	1.875	1.259	158.4	123.95	504.6	1.872	1.268	157.7	127.37	503.9	1.869	1.278	157.0	140
145	117.45	511.6	1.890	1.246	161.2	120.60	510.9	1.887	1.254	160.5	123.85	510.2	1.885	1.262	159.8	145
150	114.51	517.8	1.905	1.236	163.8	117.52	517.1	1.902	1.242	163.1	120.63	516.5	1.899	1.250	162.5	150
155	111.78	523.9	1.920	1.227	166.2	114.68	523.3	1.917	1.233	165.6	117.67	522.7	1.914	1.240	165.0	155
160	109.25	530.0	1.934	1.221	168.6	112.04	529.5	1.931	1.226	168.1	114.92	528.9	1.928	1.232	167.5	160
165	106.88	536.1	1.948	1.216	170.9	109.58	535.6	1.945	1.221	170.4	112.35	535.0	1.943	1.226	169.8	165
170	104.66	542.2	1.962	1.212	173.1	107.28	541.7	1.959	1.217	172.6	109.96	541.2	1.956	1.222	172.1	170
175	102.58	548.3	1.975	1.210	175.3	105.11	547.8	1.973	1.214	174.8	107.70	547.3	1.970	1.218	174.3	175
180	100.60	554.3	1.989	1.208	177.3	103.06	553.8	1.986	1.212	176.9	105.58	553.3	1.984	1.216	176.4	180
185	98.74	560.3	2.002	1.207	179.3	101.13	559.9	1.999	1.211	178.9	103.58	559.4	1.997	1.214	178.5	185
190	96.96	566.4	2.015	1.207	181.3	99.29	565.9	2.012	1.210	180.9	101.68	565.5	2.010	1.214	180.5	190
195	95.28	572.4	2.028	1.208	183.2	97.55	572.0	2.025	1.211	182.8	99.87	571.6	2.023	1.214	182.4	195
200	93.67	578.5	2.041	1.209	185.1	95.88	578.0	2.038	1.211	184.7	98.15	577.6	2.036	1.214	184.3	200
205	92.13	584.5	2.053	1.210	186.9	94.30	584.1	2.051	1.212	186.5	96.51	583.7	2.049	1.215	186.1	205
210	90.66	590.6	2.066	1.212	188.6	92.78	590.2	2.064	1.214	188.3	94.95	589.8	2.061	1.216	187.9	210

TABLE II: SUPERHEATED VAPOUR PROPERTIES SUVA HFC - 134a

[t] = °C [ρ] = kg/m³ [h] = kJ/kg [s] = kJ/(kg·K) [cp] = kJ/(kg·K) [c] = m/s Saturation temperature in brackets

t	ρ	h	s	cp	c	ρ	h	s	cp	c	ρ	h	s	cp	c	t
	ps=23.13 bar (ts=74°C)					ps=23.64 bar (ts=75°C)					ps=24.16 bar (ts=76°C)					
75	127.64	431.1	1.698	1.657	123.9	133.37	429.5	1.692	1.739	121.8	-	-	-	-	-	75
80	119.73	439.0	1.721	1.502	128.8	124.47	437.7	1.716	1.550	129.1	129.57	436.2	1.711	1.625	126.3	80
85	113.57	446.3	1.741	1.407	134.7	117.73	445.1	1.737	1.433	133.3	122.05	443.9	1.732	1.476	131.8	85
90	108.50	453.1	1.760	1.343	139.0	112.21	452.1	1.756	1.366	137.8	116.11	451.1	1.752	1.393	136.5	90
95	104.23	459.7	1.778	1.297	142.9	107.62	458.8	1.774	1.315	141.8	111.14	457.9	1.771	1.335	140.7	95
100	100.53	466.1	1.795	1.263	146.5	103.64	465.3	1.792	1.276	145.5	106.92	464.4	1.788	1.293	144.4	100
105	97.27	472.4	1.812	1.237	149.7	100.16	471.6	1.809	1.249	148.8	103.19	470.8	1.806	1.262	147.9	105
110	94.25	478.5	1.829	1.217	152.8	97.04	477.8	1.825	1.227	151.9	99.91	477.1	1.822	1.238	151.1	110
115	91.53	484.5	1.844	1.202	155.6	94.22	483.9	1.841	1.210	154.9	96.95	483.2	1.838	1.220	154.1	115
120	89.15	490.5	1.859	1.190	158.3	91.65	489.9	1.856	1.197	157.6	94.27	489.3	1.853	1.205	156.9	120
125	86.93	496.4	1.874	1.180	160.9	89.33	495.9	1.871	1.187	160.2	91.82	495.3	1.868	1.194	159.5	125
130	84.85	502.3	1.889	1.172	163.3	87.18	501.8	1.886	1.179	162.7	89.56	501.2	1.883	1.185	162.1	130
135	82.93	508.2	1.903	1.168	165.7	85.17	507.7	1.901	1.173	165.1	87.46	507.1	1.898	1.178	164.5	135
140	81.14	514.0	1.917	1.164	167.9	83.29	513.5	1.915	1.168	167.4	85.51	513.0	1.912	1.173	166.8	140
145	79.45	519.8	1.931	1.161	170.1	81.54	519.3	1.929	1.165	169.5	83.69	518.9	1.925	1.170	169.0	145
150	77.85	525.6	1.945	1.159	172.2	79.89	525.2	1.943	1.163	171.7	81.96	524.7	1.940	1.167	171.2	150
155	76.36	531.4	1.959	1.159	174.2	78.33	531.0	1.956	1.162	173.7	80.34	530.5	1.954	1.165	173.2	155
160	74.94	537.2	1.972	1.159	176.1	76.66	536.8	1.970	1.162	175.7	78.81	536.4	1.967	1.165	175.2	160
165	73.59	543.0	1.986	1.159	178.1	75.46	542.5	1.983	1.162	177.6	77.37	542.2	1.981	1.165	177.2	165
170	72.31	548.8	1.999	1.160	179.9	74.13	548.4	1.996	1.163	179.5	75.99	548.0	1.994	1.166	179.1	170
175	71.09	554.6	2.012	1.162	181.7	72.86	554.2	2.009	1.164	181.3	74.68	553.9	2.007	1.167	180.9	175
180	69.92	560.4	2.025	1.164	183.5	71.65	560.1	2.022	1.166	183.1	73.43	559.7	2.020	1.169	182.7	180
185	68.80	566.2	2.037	1.166	185.2	70.49	565.9	2.035	1.169	184.9	72.23	565.5	2.033	1.171	184.5	185
190	67.72	572.1	2.050	1.169	186.9	69.38	571.7	2.048	1.171	186.6	71.08	571.4	2.046	1.173	186.2	190
195	66.69	577.9	2.063	1.172	188.5	68.32	577.6	2.060	1.174	188.2	69.99	577.3	2.058	1.176	187.9	195
	ps=24.69 bar (ts=77°C)					ps=25.23 bar (ts=78°C)					ps=25.77 bar (ts=79°C)					
80	135.07	434.7	1.705	1.673	124.4	141.07	433.0	1.699	1.754	122.3	147.66	431.2	1.693	1.855	120.1	80
85	126.73	442.6	1.727	1.517	130.2	131.69	441.3	1.723	1.565	128.6	137.02	439.9	1.717	1.620	126.8	85
90	120.21	450.0	1.748	1.421	135.2	124.54	448.8	1.743	1.454	133.8	129.12	447.5	1.739	1.493	132.3	90
95	114.87	456.9	1.767	1.357	139.5	118.74	455.9	1.763	1.380	138.3	122.83	454.8	1.759	1.407	137.0	95
100	110.32	463.6	1.785	1.310	143.4	113.86	462.7	1.781	1.329	142.3	117.59	461.7	1.777	1.349	141.2	100
105	106.38	470.0	1.802	1.276	145.9	109.65	469.2	1.799	1.291	145.9	113.09	468.3	1.795	1.306	144.9	105
110	102.88	476.3	1.818	1.250	150.2	105.97	475.6	1.815	1.262	149.3	109.16	474.8	1.812	1.275	148.4	110
115	99.77	482.5	1.835	1.229	153.3	102.69	481.8	1.831	1.240	152.4	105.69	481.1	1.828	1.250	151.5	115
120	96.94	488.5	1.850	1.213	156.1	99.71	488.0	1.847	1.222	155.4	102.56	487.3	1.844	1.232	154.6	120
125	94.37	494.7	1.865	1.201	158.8	97.01	494.1	1.862	1.209	158.1	99.72	493.4	1.859	1.217	157.4	125
130	92.01	500.7	1.880	1.192	161.4	94.53	500.1	1.877	1.198	160.7	97.12	499.5	1.875	1.205	160.1	130
135	89.82	506.6	1.895	1.184	163.9	92.24	506.0	1.892	1.190	163.2	94.73	505.5	1.889	1.196	162.6	135
140	87.78	512.5	1.909	1.179	165.2	90.11	512.0	1.907	1.184	165.5	92.51	511.4	1.904	1.189	165.0	140
145	85.88	518.4	1.924	1.174	168.5	88.13	517.9	1.921	1.179	167.9	90.45	517.4	1.918	1.184	167.4	145
150	84.09	524.2	1.937	1.172	170.6	85.27	523.8	1.935	1.176	170.1	88.51	523.3	1.932	1.180	169.5	150
155	82.41	530.1	1.951	1.170	172.7	84.53	529.6	1.949	1.174	172.2	86.70	529.2	1.946	1.178	171.7	155
160	80.82	535.9	1.965	1.169	174.8	82.88	535.5	1.962	1.172	174.3	84.99	535.1	1.960	1.175	173.8	160
165	79.32	541.5	1.978	1.169	176.8	81.32	541.4	1.976	1.172	176.3	83.37	540.9	1.973	1.175	175.9	165
170	77.89	547.6	1.991	1.169	178.7	79.84	547.2	1.989	1.172	178.2	81.84	546.8	1.987	1.175	177.8	170
175	76.53	553.5	2.005	1.170	180.5	78.44	553.1	2.002	1.173	180.1	80.35	552.7	2.000	1.176	179.7	175
180	75.24	559.3	2.018	1.171	182.4	77.10	559.0	2.015	1.174	182.0	78.99	558.6	2.013	1.177	181.5	180
185	74.00	565.2	2.030	1.173	184.1	75.82	564.8	2.028	1.176	183.8	77.67	564.5	2.026	1.179	183.4	185
190	72.82	571.1	2.043	1.175	185.9	74.59	570.7	2.041	1.177	185.5	76.41	570.4	2.039	1.180	185.2	190
195	71.68	576.9	2.056	1.178	187.6	73.42	576.6	2.054	1.180	187.2	75.19	576.3	2.051	1.182	186.9	195
200	70.59	582.8	2.065	1.181	189.2	72.29	582.5	2.066	1.183	188.9	74.03	582.2	2.064	1.185	188.6	200
	ps=26.33 bar (ts=80°C)					ps=26.89 bar (ts=81°C)					ps=27.47 bar (ts=82°C)					
80	155.01	429.2	1.686	1.985	117.7	-	-	-	-	-	-	-	-	-	-	80
85	142.76	438.3	1.712	1.686	125.0	149.01	436.6	1.706	1.766	123.0	155.86	434.8	1.700	1.864	120.9	85
90	133.98	446.3	1.734	1.531	130.8	139.17	445.0	1.729	1.579	129.1	144.72	443.5	1.724	1.633	127.4	90
95	127.12	453.7	1.754	1.436	135.7	131.64	452.6	1.750	1.468	134.3	136.42	451.3	1.746	1.504	132.9	95
100	121.46	460.7	1.773	1.370	140.0	125.52	459.7	1.769	1.394	138.8	129.77	458.5	1.765	1.420	137.5	100
105	116.65	467.5	1.791	1.323	143.9	120.37	466.5	1.787	1.342	142.8	124.25	465.6	1.784	1.362	141.7	105
110	112.50	474.0	1.808	1.289	147.4	115.93	473.1	1.805	1.303	146.5	119.52	472.3	1.801	1.319	145.5	110
115	108.80	480.4	1.825	1.262	150.7	112.03	479.6	1.822	1.274	149.8	115.38	478.8	1.818	1.287	148.9	115
120	105.50	486.6	1.841	1.241	153.8	108.55	485.9	1.838	1.252	152.9	111.70	485.2	1.835	1.262	152.1	120
125	102.52	492.8	1.856	1.225	156.6	105.41	492.1	1.853	1.234	155.9	108.39	491.4	1.850	1.243	155.1	125
130	99.80	498.9	1.872	1.213	159.4	102.55	498.2	1.869	1.220	158.7	105.39	497.6	1.865	1.228	157.9	130
135	97.29	504.9	1.887	1.203	162.0	99.93	504.3	1.884	1.209	161.3	102.65	503.7	1.881	1.216	160.6	135
140	94.98	510.9	1.901	1.195	164.4	97.51	510.3	1.898	1.201	163.8	100.12	509.8	1.896	1.207	163.2	140
145	92.82	516.9	1.915	1.189	166.8	95.27	516.3	1.913	1.195	166.2	97.77	515.8	1.910	1.200	165.6	145
150	90.81	522.8	1.930	1.185	169.1	93.17	522.3	1.927	1.190	168.5	95.59	521.8	1.924	1.195	167.9	150
155	88.92	528.7	1.943	1.182	171.2	91.21	528.2	1.941	1.186	170.7	93.55	527.7	1.938	1.191	170.2	155
160	87.15	534.6	1.957	1.180	173.4	89.36	534.1	1.955	1.184	172.9	91.63	533.7	1.952	1.188	172.4	160
165	85.47	540.5	1.971	1.179	175.4	87.62	540.1	1.968	1.182	174.9	89.82	539.6	1.966	1.186	174.5	165
170	83.88	546.4	1.984	1.178	177.4	85.97	546.0	1.982	1.182	176.9	88.11	545.5	1.979	1.185	176.5	170
175	82.37	552.3	1.997	1.178	179.3	84.41	551.9	1.995	1.182	178.9	86.49	551.5	1.992	1.185	178.5	175
180	80.94	558.2	2.010	1.179	181.2	82.92	557.8	2.008	1.182	180.8	84.96	557.4	2.006	1.185	180.4	180
185	79.57	564.1	2.023	1.181	183.0	81.51	563.7	2.021	1.183	182.6	83.49	563.3	2.019	1.186	182.2	185
190	78.26	570.0	2.036	1.182	184.8	80.16	569.6	2.034	1.185	184.4	82.09	569.2	2.031	1.187	184.1	190
195	77.01	575.9	2.049	1.184	186.5	78.86	575.5	2.047	1.187	186.2	80.76	575.2	2.044	1.189	185.8	195
200	75.8	581.8	2.061	1.187	188.2	77.62	581.5	2.059	1.189	187.9	79.48	581.1	2.057	1.191	187.6	200


SPECIFIC ENTHALPY (kJ/kg)
ENTHALPIE SPÉCIFIQUE (kJ/kg)
SPEZIFISCHE ENTHALPIE (kJ/kg)
SUVA
Refrigerant
Kältemittei
DU PONT
PRESSURE ENTHALPY
of
SUVA Refrigerant
HFC-134a
© Du Pont de Nemours
CRITICAL POINT
POINT CRITIQUE
KRITISCHER PUNKT
S=1.70 kJ/kg K
1.80
1.90
1.95
2.00
2.05
2.10
2.15
2.20
2.25
2.30
S = 200 kg/m³
150
100
80
60
40
30
20
15
10
8
6
4
3
2
1.5
1.0
0.8
0.6
PRESSURE (bar)
PRESSION (bar)
DRUCK (bar)
PRESSURE (MPa)
PRESSION (MPa)
DRUCK (MPa)
SATURATED LIQUID
LIQUIDE SATURÉ
GESÄTTIGTE FLÜSSIGKEIT
VAPOUR QUANTITY
TITRE EN VAPEUR
DAMPFGEHALT
SATURATED VAPOUR
VAPEUR SATURÉE
GESÄTTIGTER DAMPF
0°C

R134a application guide lines

Americold

UH

VOE

ZEM

ZANUSSI
ELETTROMECCANICA
TIANJIN
COMPRESSOR
COMPANY

Introduction

The replacement of R 12 refrigerant involves the revision of material and operating procedures presently used, often based on experience, all designed to achieve high system performance and reliability.

The following notes are written, not as an exhaustive application manual, but as a foundation to good practice to be used as a check to identify and create production process compatibility.

Compressor

Only R 134a refrigerant must be used.

R 134a compressors are filled with a synthetic ester oil because the new refrigerant is not compatible with the lubricants presently used in R 12 compressors.

Ester oil must not be mixed nor refilled with any other lubricant. Ester oil is more hygroscopic than the lubricants presently used. Under no circumstances can the compressor be left with open pipes for more than 15 minutes.

When the pipes are open, immediately prior to coupling into the system, they should be protected from any source of forced air circulation.

Our production system limits water content in the compressor, before charging with oil, to a maximum of 100 mg. The water content of the ester oil is held to a maximum of 60 ppm.

Ester oil can cause irritation and contact with eyes and skin is to be avoided. Ensure adequate ventilation of the work area at all times.

For given operating conditions the discharge temperature of R 134a is about 10°C lower than R 12 which, because ester oil has a better thermal stability than the mineral oil, means that these factors give a better protection against the valve coking.

Refrigerating circuit

Tests on existing appliances have shown that the basic design of condenser and evaporator can be maintained.

There will be occasions where a larger condenser is advisable to reduce a discharge pressure peak caused by slightly higher load during pull down.

A modification in capillary length, usually an increase in length, is sometimes advisable as some appliances benefit from a reduction in capillary flow rate.

The optimum refrigerant charge for R 134a is usually 10-20% lower than R 12.

A longer pressure equalization time is usually required.

The dryers used in R 12 systems are not compatible with R 134a. a suitable dryer (3 Å molecular sieve) is required (XH - 7 type or equivalent).

The dryer size has to be checked against the higher hygroscopicity of ester oil.

Ester oil has a satisfactory mixability with R 134a but not as good as that between mineral oil and R 12. For this reason the potential oil accumulation within the system has to be evaluated. For instance, the use of parallel channels in the evaporator should be reduced where ever possible.

Oil retention pockets and oversized cross sections, reducing fluid flow speed, have to be avoided.

Compatibility

The use of any products containing chlorine in the refrigerating circuit production process must be avoided.

The use of chlorinated solvents to wash system components is not allowed. The retrofit of R 134a compressors into R 12 systems is not allowed because it is impossible to avoid contamination between the different oils and refrigerants even after repeated flushing and vacuum procedures. Both the new refrigerant and ester oil make more severe demands on the purity requirements for the refrigerating circuit as far as soluble substances are concerned.

DIN 8964 allows up to 40 mg/m² of soluble substances on inner surfaces. In R 134a systems these substances can only be mineral oils with pour point compatible with the evaporating temperature.

Any grease, wax, paraffin, and generally, high viscosity substances must be avoided because their presence risks clogging the capillary tube.

The maximum water content of system components must be according to din norm 8964 (max 50 mg/m²).

Note: water is more critical to R 134a system reliability than with R 12 systems since it reduces the chemical stability of ester oil.

The reaction (hydrolysis) between ester and water produces alcohol and acid.

Metals commonly used, as copper, aluminium, steel, cast iron and brass, are compatible with R 134a and ester oil.

Elastomer compatibility must be checked. Some elastomers, for example viton (fluorocarbons), will exhibit, in the presence of R 134a and ester oil, swelling and/or reduction of tensile strength.

Contamination caused by the use of brazing flux must be avoided.

Brazing flux dissolved in water should not be used because of the potential risk of introducing water into the circuit.

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Production process

The vacuum procedures and limits used presently can be maintained. Any contamination caused by vacuum pump oil vapour backflow must be avoided, preferably by using a vapour trap, unless compatible lubrificants are used in the pump.

In order to prevent any form of contamination the vacuum and filling stations must be dedicated to R 134a.

Since the R 134a molecule is smaller than the R 12 molecule it is essential to recognise that all brazing processes and leak tests need to maintain a high level of integrity.

Most of the leak detectors presently used detect the presence of chlorine. Since R 134a does not contain chlorine this method can no longer be used. A list of suitable leak detectors is available on request.

Please note that halogen detectors can give false indications because of the presence of CFC's coming from the foam or from other production lines. It is imperative that production, service and maintenance engineers recognise that mineral oils must not be used anywhere within the refrigerating circuit production process. For example, when enlarging tube ends a compatible lubricant (ester oil) must be used.

AZMAYESH INDUSTRIAL FACTORIES CO.

PROJECT NO. MP/IRA/94/403

UNIDO,s CONTRACT NO. 94/097

PROGRESS REPORT # 1

PREPARED BY: A. BAHMANI

Date: February 1995

کارخانجات صنعتی آزمایش	موضوع AZMAYESH INDUSTRIAL FACTORIES COMPANY	نوع نشریه :
طرح و برنامه		شماره نشریه : 94 - 097

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SECTION I

REFRIGERATOR LOAD CALCLATION

THE GOVERNING LAW AND EQUATION FOR HERMETIC DOMESTIC REFRIFERATORS ARE AS FOLLOWS .

A . Heat gain through door and cabinet by conduction (Refrigerator compartment) .

$$Q_{TR} = U_{TR} * A_{TR} * \Delta T_R$$

WHERE

QTR = Total heat gain by conduction in Refrigerator Compartment

UTR = Total coeficient of heat transmission .

ΔTR = Temperature difference between Ambient temperature and Refrigerator Compartment .

$$U_R = \frac{1}{x_1/K_1 + x_2/K_2 + x_3/K_3 + \dots\dots}$$

x_1= Carbon steel thickness
x_2= Foam thickness (Average)
x_3= Inner liner ABS thickness

K_1= steel thermal conductivity
K_2= Foam thermal cinductivity
K_3= Plastic thermal conductivity

A_{tR} = Total heat gain surface through Refrigeration Section .

$$A_{TR} = A_1 + A_2 + A_3 + A_4 + A_5$$

$$\Delta_{tR} = (t_a - t_r)$$

$t_a = 43\,^\circ C$ $\quad$ $t_r = 5 +- 2\,^\circ C$

B . Heat gain through Evaporator compartment by conduction .

$$Q_{TE} = U_{TE} * A_{TE} * D_{TE}$$

Where

Q_{TE} = Total heat gain by conduction in Evaporator compartment .

U_{TE} = Total Coeficient of Heat Transmission .

Δ_{TR} = Temperature difference between Ambient temperatureand Evaporator compartment.

$$U_{TE} = \frac{1}{x_1/K_1 + x_2/K_3 + x_3/k_3 + x_4/K_4 + x_5/K_5}$$

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

X1 = Carbon steel thickness

X2 = Foam thickness

X3 = Inner liner ABS thickness

X4 = Air thickness between Evaporator and Refrigerator wall

X5 = Evaporator thickness .

K_1 = Steel Thermal conductivity .

K_2 = Foam Thermal conductivity.

K_3 = Plastic Thermal conductivity.

K_4 = Air Thermal conductivity .

K_5 = Evaporator (Aluminium) Thermal conductivity .

$\Delta t_{E_2} = t_{a_{max}} - t_E$ $\quad t_{a_{max}} = 43\ ^\circ C$ class T $\quad t_E = -12\ ^\circ C$

Note : The designed ambient temperature as per ISO 7371 Para. 16.11 have been considered in refrigeration load calculation .

$\Delta t_{E_2} = t_R - t_E$ $\quad t_R = 5 +- 2\ ^\circ C$ $\quad t_E = -12\ ^\circ C$

$At_{E_1} = A1 + A2$ $\quad A_{E_2}$ $\quad A_{E_3}$

$Q_{E_1} = U_{E1} * A_{E_1} * (t_A - t_E)$

$Q_{E_2} = U_{E2} * A_{E_2} * (t_A - t_E)$

$Q_{E_3} = U_{E3} * A_{E_3} * (t_R - t_E)$

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SECTION II

PRODUCT LOAD CALCULATION

$Q_{TP} = (W*C*D_{tR}) + (W*C_i*\Delta t_f) + (W*h_{if}) + Q_{TBF}$

$\Delta t_R = (t_1 - t_2)$ $\Delta t_f = (t_1 - t_F)$

$Q_{TP} = Q_{TPR} + Q_{TPf} + Q_{TBF} + Q_{TL}$

$Q_{TBF} = W*C_i(t_f - t_3)$

WHERE

Q_{TP} = Total product heat removal .

Q_{TR} = Product heat removal above freezing point .

Q_{TPF} = Product heat remval below freezing point .

Q_{TL} = Product heat removal by Latent Heat of Fusion .

W = Weight of product .

C = Specific heat above freezing .

t_1 = Initial temperature above freezing .

t_2 = Lower temperature above freezing .

t_3 = Final temperature below freezing .

t_f = Freezing temperature .

h_{if} = Latent heat of fusion .

C_i = Specific heat below freezing

$$\text{BTU per 24 hrs} = \frac{\text{Product load x 24}}{\text{Hrs required for product load}}$$

$$Q_{GT} = Q_{TR} + Q_{TE} + \Sigma Q_{PR} + \Sigma Q_{PF} + \Sigma Q_{LF} + \Sigma Q_F$$

WHERE

Q_{GT} = Grand total heat gain per 24 Hrs .

Q_{TR} = Heat gain through Refrigerator compartment .

Q_{TE} = Heat gain through Evaporator compartment .

ΣQ_{PR} = Total heat removed from products above freezing point .

ΣQ_{PF} = Total heat removed below freezing point .

ΣQ_{LF} = Total heat removed by Latent heat of Fusion .

ΣQ_F = Total heat removed at Freezing point .

$$\text{BTU per 24 Hrs.} = \frac{Q_{GT}}{16} = \frac{\text{BTU/ hr}}{3.4192} = \text{Watt/hr}$$

TABLE 1

PRODUCT NAME	LATENT HEAT BTU / lb	AVERAGE FREEZING POINT F	SPECIFIC HEAT (C) BTU / lb F	
			ABOVE FREEZING	BELOW FREEZING
WATER	. 143.5	32.018	0.999	1
VEGETABLE (MIXED)	130	30	0.90	0.45
BEEF	79	29	0.77	0.40
CUT MEET	95	29	0.72	0.40
LAMB	83.5	29	0.67	0.30
BUTTER	15	30	0.64	0.34
CHEESE	86	18	0.70	0.40
LETTUSE	136	31.2	0.96	0.48
LIMES	122	29	0.89	0.46
DATE	112	27.1	0.82	0.43
COT FISH	95	28	0.90	0.49
EGGS	100	27	0.76	0.40
APPLES	121	28.4	0.86	0.45
WATERMELONS	132	29.2	0.97	0.48
PEACHES	124	29.4	0.90	0.46
ORANGES	124	28	0.90	0.46
GRAPEFRUIT	126	28.4	0.91	0.46
PEARS	118	28.5	0.86	0.45
MASHROOMS	130	30.2	0.93	0.47
MILK	4.3-14	31	0.93	0.49

SECTION III

REFRIGERATOR SYSTEM CONDITION

A. Compressor Condition

1. Inlet Pressure
2. Outlet Pressure
3. Inlet Temperature
4. Outlet Temperature
5. Inlet Entholpy
6. Outlet Entholpy

B. Condenssor Condition

1. Inlet Pressure
2. Outlet pressure
3. Inlet Temperature
4. Outlet Temperature
5. Inlet Entholpy
6. Outlet Entholpy
7. Entholpy Defference Sub-cool
8. Entholpy defference

C. Capillary Tube Condition

1. Inlet temperature
2. outlet Temperature
3. Specific Volume

D. Evaporator Condition

1. Evaporator Condition

2 . Evaporator Outlet Temperature
3 . Evaporatore Pressure
4 . Entholpy at - 25 C
5 . Entholpy at 32 C

E . COP = Coeficient of compressor

$$COP = q_2 / W = (h_2 - h_1)/(h_2 - h_s)$$

$q_1 = h_2 - h_1$
$q_2 = h_1 - h_s$

$W = h_2 - h_s$

D . For a typical Compressor capacity of 87 watts , the following figures are found from HFC -134a Refrigerant , Pressure - Entholpy Diagram .

1 - Evaporating pressure at - 25 C	1.067	BAR
2 - Condensing pressure at + 55 C	14.912	BAR
3 - Entholpy h_2 , at -25 C / 32 C	431	kj/kg
4 - Entholpy h_1 , at 55 C liquid	279	kj/kg
5 - Entholpy difference $h_2 - h_1$	152	kj/kg
6 - Compressor Capacity	87	Watts
7 - Mass flow	2.06	kg/h
8 - Gas temperature (outlet)	84	C
9 - Specific volume	0.28	m^3/kg
10- Volume flow (inlet)	0.57	m^3/kg
11- Inlet Capillary tube temp.	55	C

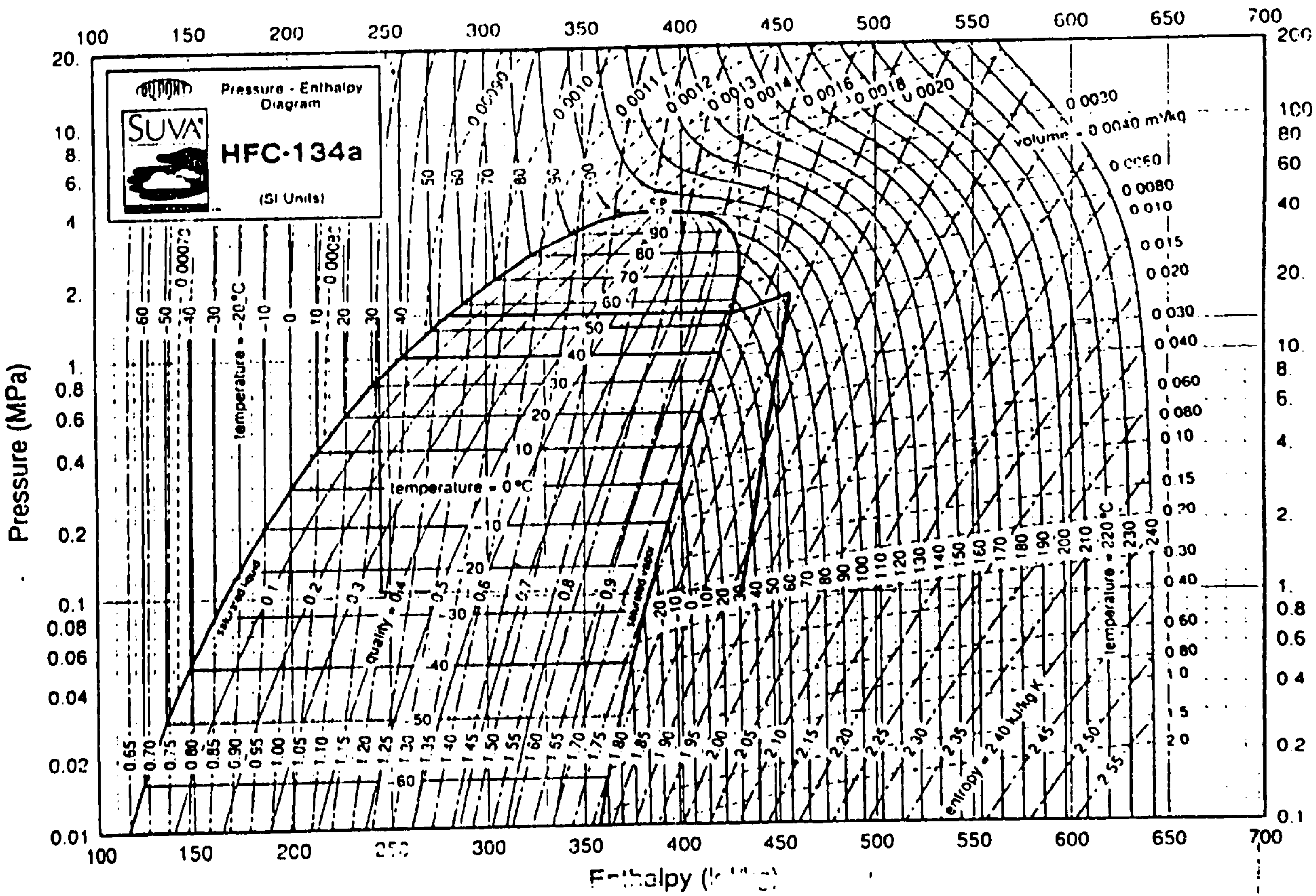


Figure [illegible]: Pressure-Enthalpy Diagram for HFC-134a (SI Units)

11- Inlet Capillary tube temp.	55	C
12- Specific volume	0.927	dm^3/kg
13- Volume flow	1.91	dm^3/h
14 - Entholpy h_1 , at 55 C liquid	279	kj/kg
15- Entholpy h_5 , at 32 C liquid	244	kj/kg
16- Entholpy difference (h_1 - h_5)	35	kj/kg
17- Capacity with Sub-Cooling at 32 C = Mass flow X (h_2 - h_5)	385.2	kj/h
18- Capacity whitout Sob-Cooling = Massflow X (h_2 - h_1)	313.1	kj/h

19- Performance relation = (h_4 - h_5) / (h_2 - h_5)

SECTION IV

EQUIPMENT SELECTION

The calculated hourly load is used as a quide in selection equipment . However the Compressor Sizes are limited to comparatively large increments .The compressor selection must be guided by the calculated load . and the actual selection of compressor may change the calculation time up or down . The evaporator should be selected to ballance The selected compressor capacity , and not the original calculated load .

The compressor operating time is suggested to be 16 Hours daily . Nevertheless Manufacturers recommendation will be considered during Equipment Selection .

The size of Evaporator and Condenser can be the same as those used for R-12 Refrigerant . sometimes , 10 - 15 % increase of condenser size is recommended . In our case we donot intend to increase the size of our condenser at the first step of our test and redesign of our Models . But , in Laboratory test we try to take it into our consideration .

Tne refrigerant charge size of R134a refrigerant system is about 10 - 20 % less than that of R12 system . The exact charge size is determined through laboratory test .

10 - 15 % increase of Capillary tube in laboratory test for checking the performance of Refrigeration Cycle will be accomplished .

Drier volume is 1.2 times of conventional type . for better Humidity absorbtion . so Driers Model XH7 or XH9 will be incorporated in our refrigeration system . the simillar type of Driers will be used as necessary .

Maximum acceptable moisture is 50 - 150 mg. Evacuation of 0.01 mm Hg. is recommended .

SECTION V

REFRIGERATOR UNIT GOVERNING EQUATIONS AND RELATIONS

1. Governing Equations.

1. $W = Fnc_1(T_7, T_2)$

2. $P = Fnc_2(T_7, T_2)$

3. $Q_{comp.} = Fnc_3(T_7, T_2)$

4. $Qps = Fnc_4(T_7, T_2)$

5. $Q_{cond} = Fnc_6(T_2, T_7)$ *

6. $Q_{cond} = W \cdot dh_{cond.}$

7. $Q_{evap} = Fnc_6(T_{ms}, T_7)$

8. $Q_{evap} + P = Q_{pc} + Q_{cond} + Q_{comp}$

WHERE

W = Compressor mass flow rate

P = Compressor power Consumption

Q_{comp} = Compressor heat rejection

Q_{pc} = Precooler heat rejection

Q_{cond} = Condenser heat rejection .

Q_{evap} = System refrigeration capacity .

dh_{cond} = Refrigerant Enthalpy change through condenser .

T_2 = Condenser mid-point temperature .

T_7 = Evaporator inlet temperature .

T_a = Ambient room temperature .

T_{ma} = Cabinet air temperature entring evaporatpr . **

* Superheat subcooling heat rejection are measured to be a single - valued function of T2 and Ta .

** Freezer and fresh food air are mixed in the return duct for a single evaporator configuration and a mixed -air temperature is calculated .

2. Upright Natural Convection Wire and Tube Condenser , Governing relations

a . $h_{eff}A = \eta_w . h_w . A_w . + h_t . A_t =$

$$\eta_w . h_{ncw} . A_w + \eta_w . A_w . F_w . [4\, \sigma\, \varepsilon\, (T_m)^{3}] + h_{nct} . A_t + A_t . F_t . [4\, \sigma\, \varepsilon\, (T_m)^{3}]$$

b . $$h_{ncw} = \frac{2\,(k_a / D_w)}{\ln [\, 1+4\,(L / Dw)(1 / N_{gr})^{.25}\,]}$$

h_{ncw} = Natural Convection Wire Heat Transfer Coeficient .

ηw = Wire Fin Efficiency .

k_a = Thermal Conduction of Air .

N_{gr} = Grashof Number = ($1.72 \times 10^{8} \times L^{3}$) .

L = Distance between Tubes .

A_w = Wire Surface Area .

F_w = Wire Radiation Configuration Factor = 0.85

4σ = Stephen Boltsman Coeficient = 0.68×10^{-3} BTU / Hr Ft^2 R^4

Tm = (Mean Wire Temperature R) ^3

c . $$h_{nct} = \frac{2\,(K_a / D_t)}{\ln [\, 1 + 5 / N_{gr}\, 0.025\,]}$$

h_{nct} = Natural convection Tube Heat Transfer Coefficient

D_t = Tube Diamiter

N_{gr} = Grashof Number + (1.72 x 10^3 x D_t^3)

A_t = Tube Radiation Configuration Factor

T_{tm} ^3 = (Mean Tube Temperature R)^3

3 . NATURAL CONVECTION EVAPORATOR GOVERNING RELATIONS .

$$Q_{evap} = h_{eff} \times A (T_2 - T_7)$$

heff = Effective Heat Transfer Coefficient

A = Surface Area

T2 = Compartment air Temperature

(Typically 5 F for Freezer and 38 F for refrigerator Compartment)

T7 = Evaporator Temperature

4 . VERTICAL PLATE NATURAL CONVECTION EVAPORATOR

Overall Heat Teransfer Coeficient =

$$UA = \eta [h + 4 \sigma \varepsilon (Tm)^3] . A$$

η = Plate fin effectiveness $:: \dfrac{\tan . h . m . l}{m . l}$

m = (2h / kg)^.5

g = Plate thickness

k = Plate conductivity

l = Tube spacing

h = Plate natural convection heat transfer coeficient .

$$h = 0.29 (\Delta T / L)^{0.24}$$

L = Plate hieght

$4 \sigma \varepsilon (T_m)^3$ = Radiation Coefficient

T_m = Mean temperature of plate

A = Surface area of plate

5 . COMPRESSOR HOUSING HEAT DISSIPATION

$Q_{comp} = U . A . \Delta T$

$U = h + 4 \sigma . \varepsilon (T)^3 = 1.44$

$h = 0.19 (\Delta T)^{1/3}$

ΔT = Temperature difference between shell and local ambient air

$4 \sigma \varepsilon (T)^3$ = Radiation Coefficient

A = Shell surface area

SECTION VI

REFRIGERATOR MODEL AR06 REFRIGERATION LOAD CALCULATION

A. Heat gain by conduction

1. Total heat gain by conduction in refrigerator compartment.

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot \Delta t_R$$

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot (T_a - T_r)$$

$$U_{TR_{ave}} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft . F

k_3 = PLastic thermal conductivity = 0.09 BTU / HR .ft . F

$$A_{TR} = A_1 + A_2 + A_3 + A_4 + A_5$$

$$A1 = A2 \quad \& \quad A3 = A4$$

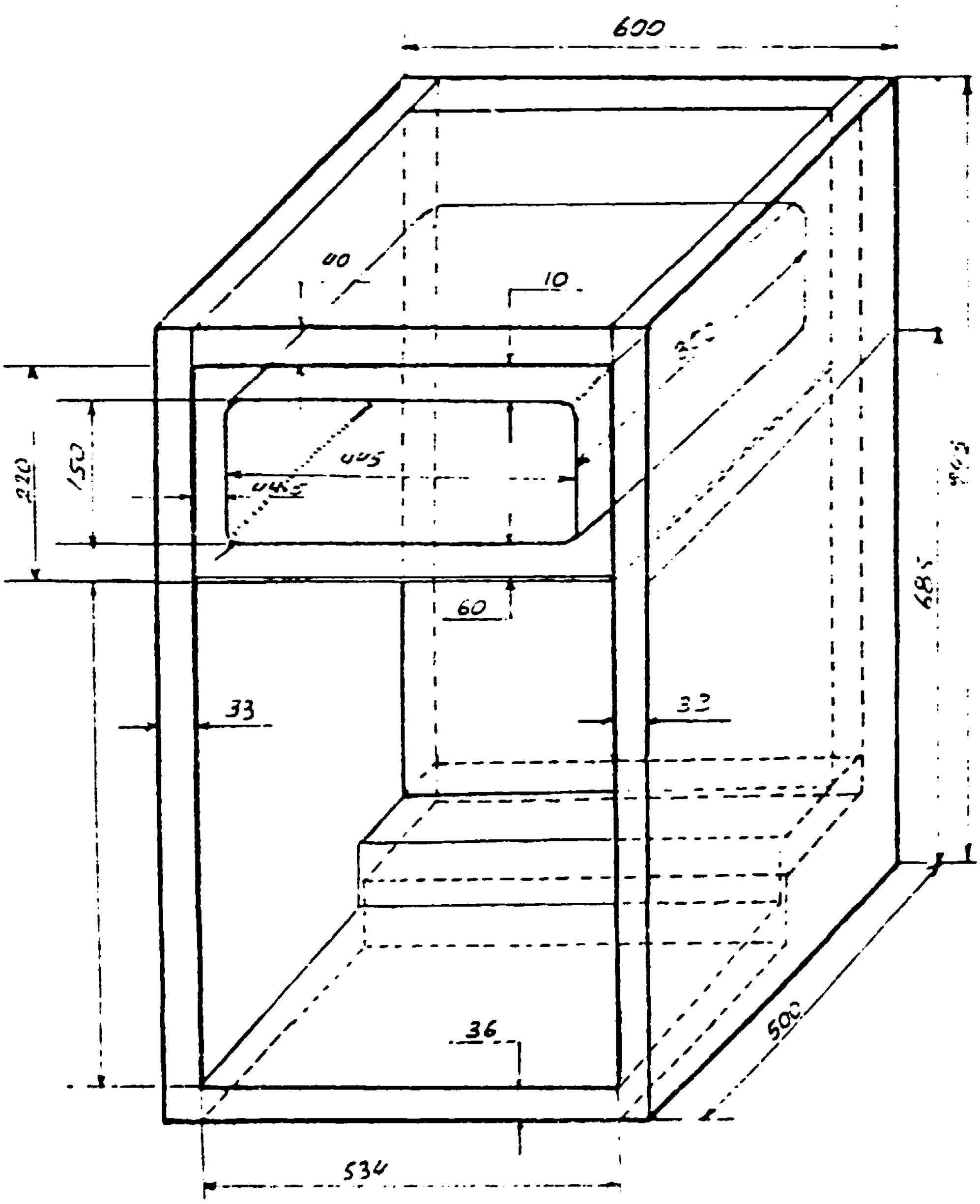
کارخانجات صنعتی آزمایش

طرح و برنامه

موضوع :

نوع نشریه :

شماره نشریه :



AR06 MODEL DIMENSIONS

تاریخ انتشار :

تاریخ و شماره تغییرات :

$A_{TR} = 2A_1 + 2A_3 + A_5$

$A_{TR} = 2(500 \times 685) + 2(534 \times 635) + (500 \times 534)$

$A_{TR} = 685000 + 731580 + 267000 = 1683580$ sq.mm = 18.123 sq.ft

$$U_{TR} = \frac{1}{0.000063 + 11.001 + 0.0729} = \frac{1}{11.07395189}$$

$U_{TR} = 0.090$ BTU / Hr . F . sq.ft

$t_{amax} = 43$ C = 109.4 F

$t_r = 5+-2$ C = 41 +- 4 F

$(t_a - t_r) = 109.4 - 41 = 68.4$ F

$Q_{TR} = 0.090 \times 18.123 \times 68.4 = 111.56$ BTU / Hr

$Q_{TR} =$ **111.56** BTU / Hr

2 . Total heat gain by conduction in Evaporator compartment .

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$$Q_{TE} = U_{TE} \cdot A_{TE} \cdot \Delta t_E$$

$$Q_{TE} = U_{TE} \cdot A_{TE} \cdot (T_a - T_E)$$

$T_a = 109.4$ F

$T_E = 10.4$ F

$$U_{TE1ave} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3 + x_4 / k_4 + x_5 / k_5}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

x_4 = Air thickness betwwn Ref. wall and Evaporator = 44.5 mm = 0.146 ft

x_5 = Evaporator thickness = 1.5 mm = 0.005 ft

x_{4u} = Upper Evaporator air thickness =10 mm = 0.033 Ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft .

k_3 = Plastic thermal conductivity = 0.09 BTU / HR . ft . F

k_4 = Thermal conductivity for air at Atmospheric pressure and 10.4 F

k_4 = 0.0135 BTU / Hr . Ft F

k_5 = Thermal conductivity for Aluminium = 117 BTU / Hr. Ft F

A_1 = 500 x 534 = 267000 sq.mm = 2.874 sq.Ft

x_1 / k_1 = 0.000063

x_2 / k_2 = 0.123 /0.0104 = 11.798

x_3 / k_3 = 0.0729

x_4 / k_4 = 0.033 /0.0135 = 2.44

x_5 / k_5 = 0.005 / 117 = 0.00004

$$UTE1 = \frac{1}{0.000063+11.798+0.0729+2.44+0.00004} = \frac{1}{14.311408}$$

U_{TE1} = 0.0698 BTU / Hr . sq.ft. F

$t_{a\,max}$ = 43 C = 109.4 F Room Temp.

t_{E1} = 10.4 F

$\Delta T_{E1} = (t_a - t_E)$ = 109.4 - 10.4 = 99 F

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$$Q_{E1} = U_1 . A_1 . \Delta T_1$$

$$Q_{E1} = 0.0698 \times 2.874 \times 99 = 19.88 \text{ BTU / Hr}$$

$$Q_{E2} = U_{E2} . A_{E2} . \Delta T_2$$

$A_{E2} = A_{E1} = 2.874$ sq. Ft

$$U_{TE2} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

$x_1 / k_1 = 0.016 / 0.09 = 0.1778$

$x_2 / k_2 = 0.18 / 0.0135 = 13.366$

$x_3 / k_3 = 0.00004$

$$U_{TE2} = \frac{1}{0.1778 + 13.366 + 0.00004}$$

$U_{TE2} = 0.0738$ BTU / Hr . sq.Ft .F

$\Delta T_{E2} = T_R - T_E = 41 - 10.4 = 30.6$ F

$$Q_{E2} = 0.0738 \times 2.874 \times 30.6 = 6.493 \text{ BTU / Hr}$$

$$Q_{E3} = U_{E3} . A_{E3T} . \Delta T_3$$

$$U_{TE3} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5}$$

$x_1 / k_1 = 0.000063$

$x_2 / k_2 = 0.1145 / 0.0104 = 11.001$

$x_3 / k_3 = 0.0656 / 0.09 = 0.0729$

$x_4 / k_4 = 0.146 / 0.0135 = 10.814$

$x_5 / k_5 = 0.0049 / 117 = 0.00004$

$$U_{TE3} = \frac{1}{0.000063+11.001+0.0729+10.814+0.00004}$$

$U_{TE3} = 0.044$ BTU / Hr . sq.Ft . F

$A_{E3T} = 2A_{E3} + 2A_{E4}$

$A_{E3} = 220 \times 500 = 110000$ sq.mm = 1.184 sq.ft

$A_{E4} = 220 \times 534 = 117480$ sq.mm = 1.264 sq ft

$A_{E3T} = 2 (1.184 + 1.264) = 4.897$ sq.ft

$\Delta T_{E3} = T_i - T_E = 109.4 - 10.4 = 99$ F

$Q_{E3} = 0.044 \times 4.897 \times 99 = 21.332$ BTU / Hr

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$Q_{TE} = 19.881+6.493+21.332 = 47.7$ BTU / Hr

B . PRODUCT LOAD CALCULATION

$Q_{PT} = \Sigma Q_{PR} + \Sigma Q_{PF} + \Sigma Q_{LF} + \Sigma Q_F$

1. ΣQ_{PR} = Heat removed from products above freezing point

$Q_{PR} = W_P . C_P . \Delta t_R = W_P . C_P . (t_1 - t_2)$

WHERE

1 . t_1 = For red and white fresh meet (Ave.) = 82.4 F

2 . t_1 = For butter and cheese (Ave.) = 50 F

3 . t_1 = For mixed vegetables (Ave.) = 59 F

4 . t_1 = For fruits of any kind (Ave.) = 59 F

5 . t_1 = For water = 50 F

6 . t_2 = For all above products = (Ave.) 41 F

Δt_{R1-1} = 41.4 F

Δt_{R1-2} = 9 F

Δt_{R1-3} = 18 F

Δt_{R1-4} = 18 F

Δt_{R1-5} = 9 F

Average sum of " C " Specific heat for items 1 through 5 from " Table 1 " are as follows .

"C_1" = 0.72 BTU / lb . F

"C_2" = 0.67 BTU / lb . F

"C_3" = 0.93 BTU / lb . F

"C_4" = 0.9 BTU / lb . F

"C_5" = 0.999 BTU / lb . F

"C_M" = For milk = 0.93 BTU / lb . F

Average Product Weight per Pound .

W_1 = 5 lb Meet and Fish

W_2 = 2 lb Butter and cheese

W_3 = 4 lb Vegetable (mixed) and lettuce

W_4 = 4 lb Fruit of any kind

W_5 = 4 lb Water

W_6 = 4 lb Milk

$Q_{PR1} = 5 \times 0.72 \times (82.4 - 41) = 149$ BTU

$Q_{PR2} = 2 \times 0.67 \times (50 - 41) = 12$ BTU

$Q_{PR3} = 4 \times 0.93 \times (59 - 41) = 66.96$ BTU

$Q_{PR4} = 4 \times 0.90 \times (59 - 41) = 64.8$ BTU

$Q_{PR5} = 4 \times 0.999 \times (50 - 41) = 35.96$ BTU

$Q_{PR6} = 4 \times 0.93 \times (50 - 41) = 33.48$ BTU

$$Q_{PR} = Q_{PR1} + Q_{PR2} + Q_{PR3} + Q_{PR4} + Q_{PR5} + Q_{PR6}$$

$$Q_{PR} = 149 + 12 + 66.96 + 64.8 + 35.96 + 33.48$$

$$Q_{PR} = 362.2 \text{ BTU}$$

2 . ΣQ_{PF1} = Heat removed from products to freeze product from initial temperature to freezing point .

$$Q_{PF1} = W \times C \times \Delta t$$

1 - Fish 2 lbs

2- Meet 5 lbs

3 - Water 5 lbs

$$\Delta t = (t_{Pi} - t_{PF})$$

4 - Δt_{1fish} = 50 - 28 = 22 F "C" = 0.9 BTU / lb F

5 - Δt_{1meet} = 82.4 - 29 = 53.4 F "C" = 0.72 BTU / lb F

6 - Δt_{1water} = 50 - 32 = 18 F "C" = 0.999 BTU / lb F

7 - $Q_{PF1fish}$ = 2 x 0.9 x 22 = 36.6 BTU

8 - $Q_{PF1meet}$ = 5 x 0.72 x 53.4 = 195.24 BTU

9 - $Q_{PF1water}$ = 5 x 0.999 x 18 = 89.91 BTU

$\Sigma Q_{PF1} = Q_{PF1\,fish} + Q_{PF1meet} + Q_{PF1water}$ = 39.6 + 195.24 + 89.91 = 324.75 BTU

$$\Sigma Q_{PF1} = 324.75 \text{ BTU}$$

3 - ΣQ_{PF2} = Heat removed from freezing point to final temerature below freezing.

$$Q_{PF2} = W \times C_i \times (t_f - t_3)$$

1 - Fish 2 lbs

2- Meet 5 lbs

3 - Ice 5 lbs

4 - $\Delta t_{1fish} = 28 - 10.4 = 17.6$ F "C_{ifish}" = 0.49 BTU / lb F

5 - $\Delta t_{1meet} = 29 - 10.4 = 18.6$ F "C_{imeet}" = 0.42 BTU / lb F

6 - $\Delta t_{1ice} = 32 - 10.4 = 21.6$ F "C_{iice}" = 1 BTU / lb F

7 - $Q_{PF2fish} = 2 \times 0.49 \times 17.6 = 17.248$ BTU

8 - $Q_{PF2meet} = 5 \times 0.42 \times 18.6 = 39.06$ BTU

9 - $Q_{PF2ice} = 5 \times 1 \times 21.6 = 108$ BTU

$\Sigma Q_{PF2} = Q_{PF2\,fish} + Q_{PF2meet} + Q_{PF2ice} = 17.248 + 39.06 + 108 = 164.31$ BTU

$$\Sigma Q_{PF2} = 164.31 \text{ BTU}$$

4 - ΣQLF = Heat removal to freeze product

$$Q_{LF} = W \times h_{if}$$

WHERE

1 - Weight of product per pound

2 - Latent heat per BTU / lb

3 - Fish 2 lbs

4 - Meet 5 lbs

5 - Ice 5 lbs

$Q_{LF_{fis}} = 2 \times 95 = 190$ BTU

$Q_{LF_{meet}} = 5 \times 85.8 = 429.1\ 6$ BTU

$Q_{LF_{ice}} = 5 \times 143.5 = 717.5$ BTU

$$Q_{LF} = Q_{LF_{fish}} + Q_{LF_{meet}} + Q_{LF_{ice}}$$

$$Q_{LF} = 190.66 + 429.16 + 717.5 = 1336.66 \text{ BTU}$$

$$Q_{LF} = 1336.66 \text{ BTU}$$

$$\Sigma Q_{PT} = 362.2 + 324.75 + 164.31 + 1336.66 = 2187.92 \text{ BTU}$$

$$Q_{PT} = 2187.92 \text{ BTU}$$

C . Total heat gain through Refrigerator and Evaporator and Products are calculated as follows .

$$Q_T = Q_{TR} + Q_{TE} + Q_{TP} = Q_{TC} + Q_{TP}$$

$Q_{TR} = 111.56$ BTU / Hr .

$Q_{TE} = 47.7$ BTU / Hr

$Q_{TC} = Q_{TR} + Q_{TE} = 111.56 + 47.7 = 159.26$ BTU / Hr

$Q_{Tp} = 2187.92$ BTU per 24 hours

Note . Desired Compressor Operating Time = 16 Hours Daily

Q_{Tp} / Hr = 2187.92 / 16 = 136.745 BTU / Hr

$Q_T = 159.26 + 136.745 = 296$ BTU / Hr

$Q_{GT} = Q_T + 10\% \, Q_T = 296 + 29.6 = 326.6$ BTU / Hr

$Q_{GT} = 325.6$ BTU / Hr

$Q_{GT} = 325.6 \times 0.2931 = 95.43$ Watts

$$Q_{GT} = 95.43 \text{ Watts / Hr}$$

D . Compressor selection for **Model AR06**

The compressor selection for Model AR06 is based on avaible or existing Compressor Models in Iranian Market at present which are as follows . Compressor power is to be 1/8 Hp . in all compressor types from different manufacturers .

Manufacturer Name	Model	Capacity .Watts
DANFUS	TL5G	115
NECCHI	ETR4H	89
ASPERA	BP1084Z	103
GOLD STAR	NF 45	103
SICOM	AZ133YS	95

From the above figures the nearest possible Compressor Capacity which are compatible to our Energy Requirements for Model AR06 , could be either comp. Model AZ133YS from SICOM with 95 Watts Capacity .or Model ETR4H from NECCHI with comp. capacity of 89 watts . the other Compressor models could be considered as alternatives due to the Laboratory test analysis .

Note 1 . 10 % additional load has been considered for Fridge air replacement and infiltration during the day .

Note 2 . For other equipment selection such as condenser . evaporator and drier refer to **Section IV** .

Capillary tube inner diameter = 0.78 mm
Refrigeration System internal Volume :
Capillary tube length = 440 cm
Evaporator Surface : 3510 cm^2, Volume : 35.8 lit
Total Volume :

SECTION VII

REFRIGERATOR MODEL AR08 REFRIGERATION LOAD CALCULATION

A . Heat gain by conduction

1 . Total heat gain by conduction in refrigerator compartment .

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot \Delta t_R$$

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot (T_a - T_r)$$

$$U_{TR_{ave}} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft . F

k_3 = PLastic thermal conductivity = 0.09 BTU / HR .ft . F

$$A_{TR} = A_1 + A_2 + A_3 + A_4 + A_5$$

$$A1 = A2 \quad \& \quad A3 = A4$$

$A_{TR} = 2A_1 + 2A_3 + A_5$

$A_{TR} = 2(500 \times 871) + 2(534 \times 871) + (500 \times 534)$

$A_{TR} = 871000 + 930228 + 267000 = 2068228$ sq.mm = 22.262 sq.ft

$$U_{TR} = \frac{1}{0.000063 + 11.001 + 0.0729} = \frac{1}{11.07395189}$$

$U_{TR} = 0.090$ BTU / Hr . F . sq.ft

$t_{a\,max} = 43$ C = 109.4 F

$t_r = 5 \pm 2$ C = 41 ± 4 F

$(t_a - t_r) = 109.4 - 41 = 68.4$ F

$Q_{TR} = 0.090 \times 22.262 \times 68.4 = 137.046$ BTU / Hr

Q_{TR} = 137.046 BTU / Hr

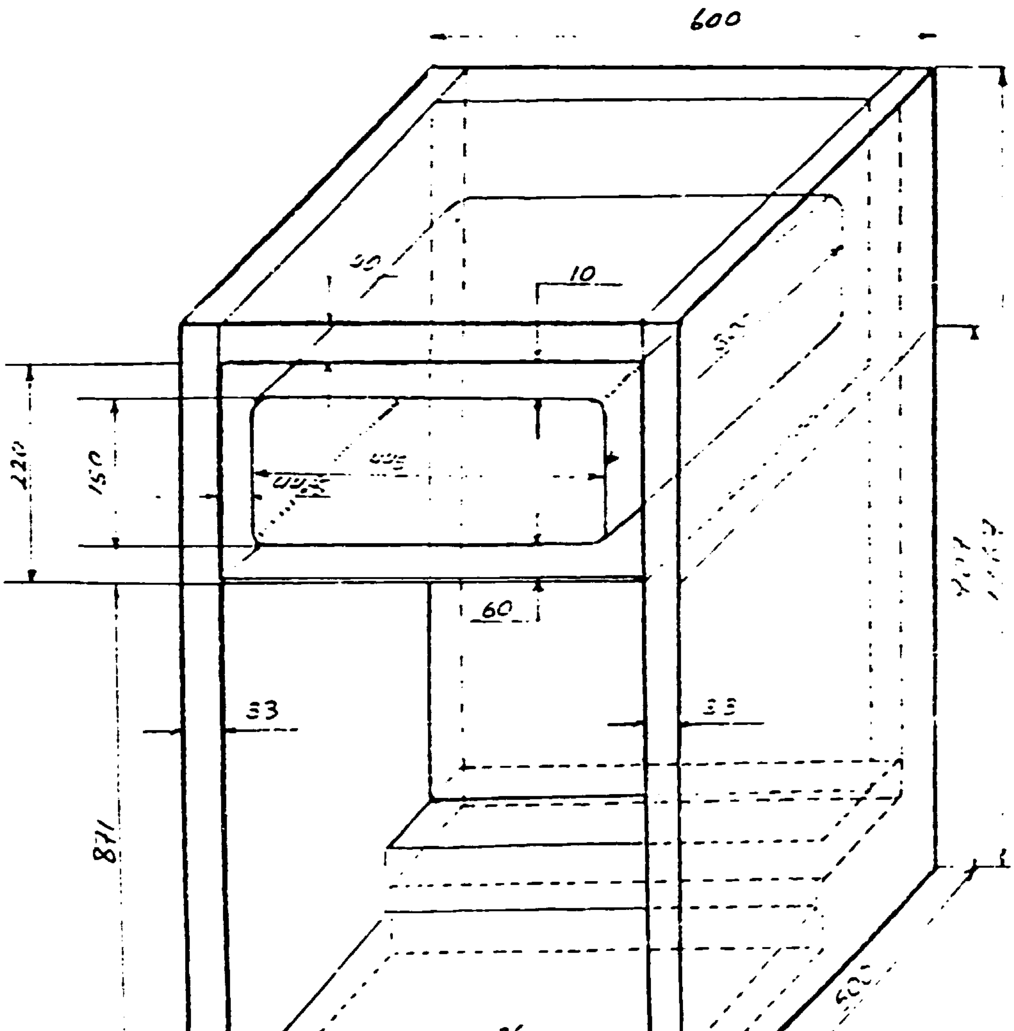
کارخانجات صنعتی آزمایش

شــــرح و بــــرنامه

موضوع :

نوع نشریه :

شماره نشریه :



AR08 MODEL DIMENSIONS

تاریخ و شمـــــاره تغییرات :

تاریخ انتشـــــار :

2 . Total heat gain by conduction in Evaporator compartment .

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$$Q_{TE} = U_{TE} \,.\, A_{TE} \,.\, \Delta t_E$$

$$Q_{TE} = U_{TE} \,.\, A_{TE} \,.\, (T_a - T_E)$$

T_a = 109.4 F

T_E = 10.4 F

$$U_{TE1ave} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

x_4 = Air thickness betwwn Ref. wall and Evaporator = 44.5 mm = 0.146 ft

x_5 = Evaporator thickness = 1.5 mm = 0.005 ft

x_{4u} = Upper Evaporator air thickness = 10 mm = 0.033 Ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft .

k_3 = Plastic thermal conductivity = 0.09 BTU / HR .ft . F

k_4 = Thermal conductivity for air at Atmospheric pressure and 10.4 F

k_4 = 0.0135 BTU / Hr . Ft F

k_5 = Thermal conductivity for Aluminium = 117 BTU / Hr. Ft F

A_1 = 500 x 534 = 267000 sq.mm = 2.874 sq.Ft

x_1 / k_1 = 0.000063

x_2 / k_2 = 0.123 / 0.0104 = 11.798

x_3 / k_3 = 0.0729

x_4 / k_4 = 0.033 / 0.0135 = 2.44

x_5 / k_5 = 0.005 / 117 = 0.00004

$$U_{TE1} = \frac{1}{0.000063+11.798+0.0729+2.44+0.00004} = \frac{1}{14.311408}$$

U_{TE1} = 0.0698 BTU / Hr . sq.ft. F

$t_{a\,max}$ = 43 C = 109.4 F Room Temp.

t_{E1} = 10.4 F

ΔT_{E1} = (t_a - t_E) = 109.4 - 10.4 = 99 F

$$Q_{E1} = U_1 . A_1 . \Delta T_1$$

$$Q_{E1} = 0.0698 \times 2.874 \times 99 = \mathbf{19.88} \ \text{BTU / Hr}$$

$$Q_{E2} = U_{E2} . A_{E2} . \Delta T_2$$

$AE2 = AE1 = 2.874$ sq. Ft

$$U_{TE2} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

$x_1 / k_1 = 0.016 / 0.09 = 0.1778$

$x_2 / k_2 = 0.18 / 0.0135 = 13.366$

$x_3 / k_3 = 0.00004$

$$U_{TE2} = \frac{1}{0.1778 + 13.366 + 0.00004}$$

$U_{TE2} = 0.0738$ BTU / Hr . sq.Ft .F

$\Delta T_{E2} = T_R - T_E = 41 - 10.4 = 30.6$ F

$$Q_{E2} = 0.0738 \times 2.874 \times 30.6 = \mathbf{6.493} \ \text{BTU / Hr}$$

$$Q_{E3} = U_{E3} . A_{E3T} . \Delta T_3$$

$$Q_{E1} = U_1 . A_1 . \Delta T_1$$

$$Q_{E1} = 0.0698 \times 2.874 \times 99 = \mathbf{19.88} \text{ BTU / Hr}$$

$$Q_{E2} = U_{E2} . A_{E2} . \Delta T_2$$

$AE2 = AE1 = 2.874$ sq. Ft

$$U_{TE2} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

$x_1 / k_1 = 0.016 / 0.09 = 0.1778$

$x_2 / k_2 = 0.18 / 0.0135 = 13.366$

$x_3 / k_3 = 0.00004$

$$U_{TE2} = \frac{1}{0.1778 + 13.366 + 0.00004}$$

$U_{TE2} = 0.0738$ BTU / Hr . sq.Ft .F

$\Delta T_{E2} = T_R - T_E = 41 - 10.4 = 30.6$ F

$$Q_{E2} = 0.0738 \times 2.874 \times 30.6 = \mathbf{6.493} \text{ BTU / Hr}$$

$$Q_{E3} = U_{E3} . A_{E3T} . \Delta T_3$$

$$U_{TE3} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5}$$

$x_1/k_1 = 0.000063$

$x_2/k_2 = 0.1145/0.0104 = 11.001$

$x_3/k_3 = 0.0656/0.09 = 0.0729$

$x_4/k_4 = 0.146/0.0135 = 10.814$

$x_5/k_5 = 0.0049/117 = 0.00004$

$$U_{TE3} = \frac{1}{0.000063+11.001+0.0729+10.814+0.00004}$$

$U_{TE3} = 0.044$ BTU / Hr . sq.Ft . F

$A_{E3T} = 2A_{E3} + 2A_{E4}$

$A_{E3} = 220 \times 500 = 110000$ sq.mm = 1.184 sq.ft

$A_{E4} = 220 \times 534 = 117480$ sq.mm = 1.264 sq.ft

$A_{E3T} = 2(1.184 + 1.264) = 4.897$ sq.ft

$\Delta T_{E3} = T_a - T_E = 109.4 - 10.4 = 99$ F

$Q_{E3} = 0.044 \times 4.897 \times 99 = 21.332$ BTU / Hr

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$Q_{TE} = 19.881+6.493+21.332 = 47.7$ BTU / Hr

B . PRODUCT LOAD CALCULATION

$Q_{PT} = \Sigma Q_{PR} + \Sigma Q_{PF} + \Sigma Q_{LF} + \Sigma Q_F$

1. ΣQ_{PR} = Heat removed from products above freezing point

$Q_{PR} = W_P \cdot C_P \cdot \Delta t_R = W_P \cdot C_P \cdot (t_1 - t_2)$

WHERE

1 . t_1 = For red and white fresh meet (Ave.) = 82.4 F

2 . t_1 = For butter and cheese (Ave.) = 50 F

3 . t_1 = For mixed vegetables (Ave.) = 59 F

4 . t_1 = For fruits of any kind (Ave.) = 59 F

5 . t_1 = For water = 50 F

6 . t_1 = For bread = 75 F

7 . t_2 = For all above products = (Ave.) 41 F

$\Delta t_{R1\text{-}1}$ = 41.4 F

$\Delta t_{R1\text{-}2}$ = 9 F

$\Delta t_{R1\text{-}3}$ = 18 F

$\Delta t_{R1\text{-}4}$ = 18 F

$\Delta t_{R1\text{-}5}$ = 9 F

Δt_{R1-6} = 34 F

Average sum of " C " specific heat for above products from Table 1 are as follows .

" C_1 " = 0.72 BTU / lb . F

" C_2 " = 0.67 BTU / lb ..F

" C_3 " = 0.93 BTU / lb . F

" C_4 " = 0.9 BTU / lb . F

" C_5 " = 0.999 BTU / lb . F

" C_6 " = 0.70 BTU / lb . F

" C_7 " = For milk = 0.93 BTU / lb . F

Average Product Weight per Pound .

W_1 = 5 lb Meet and Fish

W_2 = 2 lb Butter and cheese

W_3 = 4 lb Vegetable (mixed) and lettuce

W_4 = 4 lb Fruit of any kind

W_5 = 4 lb Water

W_6 = 2 lb Bread

W_7 = 4 lb Milk

Q_{PR1} = 5 x 0.72 x (82.4 -41) = 149 BTU

Q_{PR2} = 2 x 0.67 x (50 -41) = 12 BTU

Q_{PR3} = 4 x 0.93 x (59 -41) = 66.96 BTU

$Q_{PR4} = 4 \times 0.90 \times (59 - 41) = 64.8$ BTU

$Q_{PR5} = 4 \times 0.999 \times (50 - 41) = 35.96$ BTU

$Q_{PR6} = 2 \times 0.70 \times (75 - 41) = 47.6$ BTU

$Q_{PR7} = 4 \times 0.93 \times (50 - 41) = 33.48$ BTU

$Q_{PR} = Q_{PR1} + Q_{PR2} + Q_{PR3} + Q_{PR4} + Q_{PR5} + Q_{PR6} + Q_{PR7}$

$Q_{PR} = 178.85 + 12.06 + 66.96 + 129.6 + 71.93 + 47.6 + 33.48$

$Q_{PR} = 540.48$ BTU

2 . ΣQ_{PF1} = Heat removed from products to freeze product from initial temperature to freezing point above freezin point .

$$Q_{PF1} = W \times C \times \Delta t$$

Weight of products are as follows

1 - Fish 2 lbs

2- Meet 5 lbs

3 - Water 5 lbs

$$\Delta t = (t_{pi} - t_{pF})$$

4 - Δt_{1fish} = 50 - 28 = 22 F "C" = 0.9 BTU / lb F

5 - Δt_{1meet} = 82.4 - 29 = 53.4 F "C" = 0.72 BTU / lb F

6 - Δt_{1water} = 50 - 32 = 18 F "C" = 0.999 BTU / lb F

7 - Q_{Ffish} = 2 x 0.9 x 22 = 39.6 BTU

8 - Q_{Fmeet} = 5 x 0.72 x 53.4 = 195.24 BTU

9 - Q_{Fwater} = 5 x 0.999 x 18 = 89.91 BTU

$\Sigma Q_{PF1} = Q_{PF1\,fish} + Q_{PF1\,meet} + Q_{PF1\,water}$ = 39.6 + 195.24 + 89.91 = 324.75 BTU

$$\Sigma Q_{PF1} = 324.75 \text{ BTU}$$

3 - ΣQ_{PF2} = Heat removed from freezing point to final temerature below freezing .

$$Q_{PF2} = W \times C_i \times (t_f - t_3)$$

1 - Fish 2 lbs

2- Meet 5 lbs

3 - Ice 5 lbs

4 - $\Delta t_{1fish} = 28 - 10.4 = 17.6$ F " C_{ifish} " = 0.49 BTU / lb F

5 - $\Delta t_{1meet} = 29 - 10.4 = 18.6$ F " C_{imeet} " = 0.42 BTU / lb F

6 - $\Delta t_{1ice} = 32 - 10.4 = 21.6$ F " C_{iice}" = 1 BTU / lb F

7 - $Q_{PF2fish} = 2 \times 0.49 \times 17.6 = 17.248$ BTU

8 - $Q_{PF2meet} = 5 \times 0.42 \times 18.6 = 39.06$ BTU

9 - $Q_{PF2ice} = 5 \times 1 \times 21.6 = 108$ BTU

$\Sigma Q_{PF2} = Q_{PF2\,fish} + Q_{PF2meet} + Q_{PF2ice} = 17.248 + 39.06 + 108 = 164.31$ BTU

$$\Sigma Q_{PF2} = 164.31 \text{ BTU}$$

4 - ΣQ_{LF} = Heat removal to freeze product

$$Q_{LF} = W \times h_{if}$$

WHERE

Q_{LF} = Heat removal by latent heat

W = Weight of product

h_{if} = Latent heat per BTU / lb

1 - Weight of product per pound

2 - Latent heat per BTU / lb

3 - Fish 2 lbs

4 - Meet 5 lbs

5 - Ice 5 lbs

$Q_{LF_{fis}}$ = 2 x 95 = 190 BTU

$Q_{LF_{meet}}$ = 5 x 85.8 = 429.1 6 BTU

$Q_{LF_{ice}}$ = 5 x 143.5 = 717.5 BTU

$$Q_{LF} = Q_{LF_{fish}} + Q_{LF_{meet}} + Q_{LF_{ice}}$$

$$Q_{LF} = 190.66 + 429.16 + 717.5 = 1336.66 \text{ BTU}$$

$$Q_{LF} = 1336.66 \text{ BTU}$$

$$\Sigma Q_{PT} = 540.48 + 324.75 + 164.31 + 1336.66 = 2187.92 \text{ BTU}$$

$$Q_{PT} = 2366.2 \text{ BTU in 24 hours}$$

$$Q_{PT_{hr}} = 2366.2 / 16 = 147.9 \text{ btu / Hr.}$$

Note . Compressor operating time = 16 hours daily

C . Total heat gain through Refrigerator and Evaporator and Products are calculated as follows .

$$Q_T = Q_{TR} + Q_{TE} + Q_{TP} = Q_{TC} + Q_{TP}$$

Where

Q_{TC} = Total heat gain by conduction

Q_{TR} = Total heat remoned from products

Q_{TR} = 137.046 BTU / Hr

Q_{TE} = 47.7 BTU / Hr

$Q_{TC} = Q_{TR} + Q_{TE}$ = 137.046 + 47.7 = 184.746 BTU / Hr

Q_{Tp} = 2366.2 BTU per 24 hours

Note . Desired Compressor Operating Time = 16 Hours Daily

Q_{Tp} / Hr = 2366.2 / 16 = 147.9 BTU / Hr

Q_T = 184.746 + 147.9 = 332.65 BTU / Hr

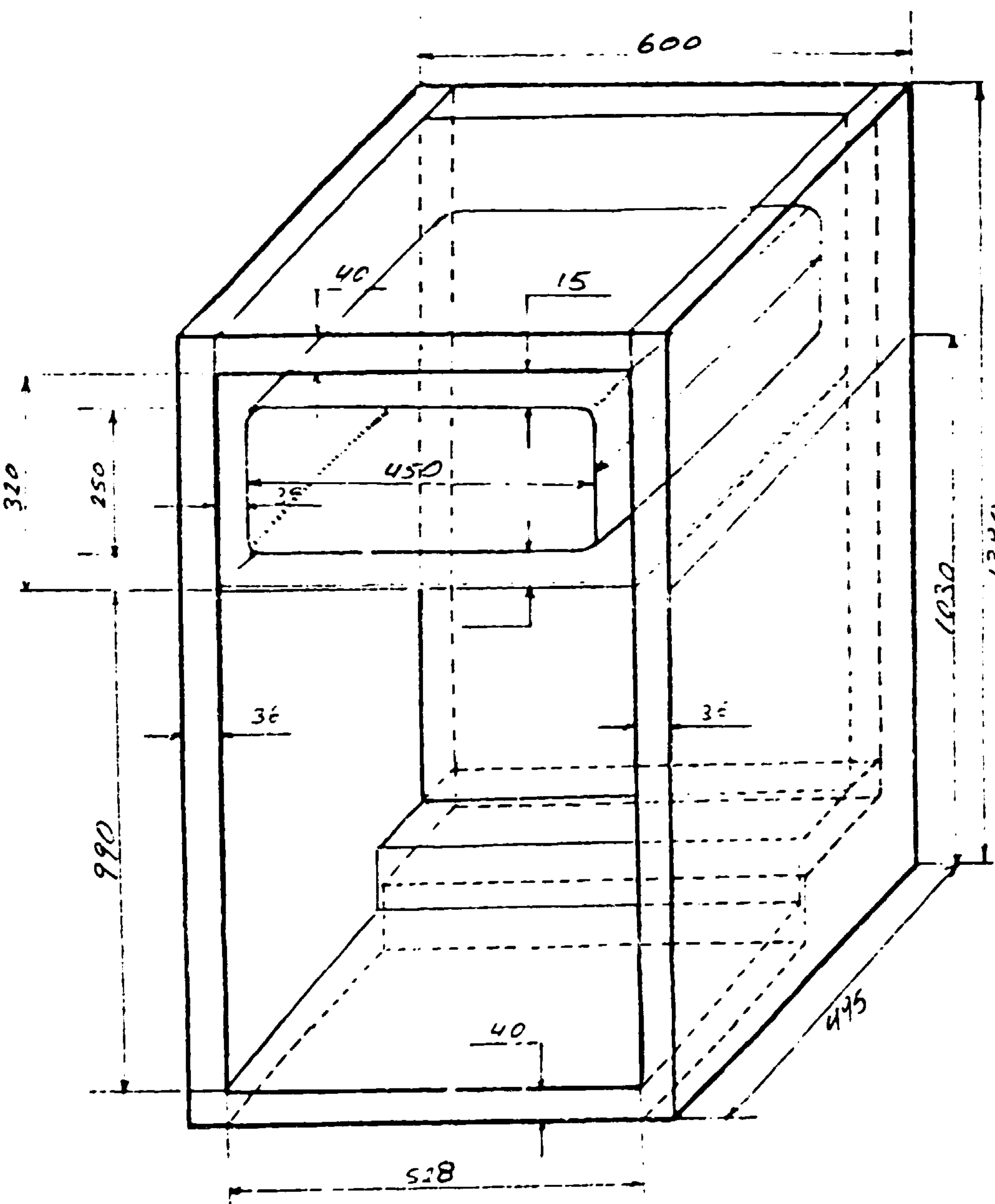
$$Q_{GT} = Q_T + 10\% \, Q_T = 332.65 + 33.26 = 365.91 \text{ BTU / Hr}$$

$$Q_{GT} = 365.91 \text{ BTU / Hr}$$

$$Q_{GT} = 365.91 \times 0.2931 = 107.25 \text{ Watts}$$

$$Q_{GT} = 107.25 \text{ Watts / Hr}$$

نوع نشریه :	موضوع :	کارخانجات صنعتی آزمایش
شماره نشریه :		خـــــرج و بـــــرنامه



MODEL ARIO

تاریخ انتشـــــــار : ۸ـ	تاریخ وشمـــــاره تغییرات :

D . Compressor selection for **Model AR08**

The compressor selection for Model AR08 is based on avaible or existing Compressor Models in Iranian Market at present which are as follows , Compressor power is to be 1/8 Hp , in all compressor types from different manufacturers .

Manufacturer Name	Model	Capacity ,Watts
DANFUS	TL5G	115
NECCHI	ETR4H	89
ASPERA	BP1084Z	103
GOLD STAR	NF 45	103
SICOM	AZ133YS	95

From the above figures the nearest possible Compressor Capacity which are compatible to our Energy Requirements for Model AR08 , could be either comp. Model TL5G from DANFUS with 115 Watts Capacity .or Model NF 45 from GOLD STAR with comp. capacity of 103 watts , the other Compressor models could be considered as alternatives due to the Laboratory test analysis .

Note 1 . 10 % additional load has been considered for Fridge air replacement and infiltration during the day .

Note 2 . For other equipment selection such as condenser . evaporator and drier refer to **Section IV** .

SECTION VIII

REFRIGERATOR MODEL AR10 REFRIGERATION LOAD CALCULATION

A . Heat gain by conduction .

1 . Total heat gain by conduction in refrigerator compartment .

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot \Delta t_R$$

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot (T_a - T_r)$$

$$U_{TR_{ave}} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft . F

k_3 = PLastic thermal conductivity = 0.09 BTU / HR .ft F

$$A_{TR} = A_1 + A_2 + A_3 + A_4 + A_5$$

$$A1 = A2 \quad \& \quad A3 = A4$$

$$A_{TR} = 2A_1 + 2A_3 + A_5$$

$$A_{TR} = 2(500 \times 990) + 2(534 \times 990) + (495 \times 990)$$

$$A_{TR} = 1029600 + 980100 + 257400 = 2267100 \text{ sq.mm} = 24.4 \text{ sq.ft}$$

$$U_{TR} = \frac{1}{0.000063 + 11.001 + 0.0729} = \frac{1}{11.07395189}$$

$$U_{TR} = 0.090 \text{ BTU / Hr . F . sq.ft}$$

$$t_{amax} = 43 \text{ C} = 109.4 \text{ F}$$

$$t_r = 5+-2 \text{ C} = 41 +- 4 \text{ F}$$

$$(t_a - t_r) = 109.4 - 41 = 68.4 \text{ F}$$

$$Q_{TR} = 0.090 \times 24.4 \times 68.4 = 150.22 \text{ BTU / Hr}$$

$$Q_{TR} = \mathbf{150.22} \text{ BTU / Hr}$$

2 . Total heat gain by conduction in Evaporator compartment .

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$$Q_{TE} = U_{TE} \cdot A_{TE} \cdot \Delta t_E$$

$$Q_{TE} = U_{TE} \cdot A_{TE} \cdot (T_a - T_E)$$

$T_a = 109.4$ F

$T_E = 10.4$ F

$$U_{TE1ave} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3 + x_4 / k_4 + x_5 / k_5}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

x_4 = Air thickness betwwn Ref. wall and Evaporator = 44.5 mm = 0.146 ft

x_5 = Evaporator thickness = 1.5 mm = 0.005 ft

x_{4u} = Upper Evaporator air thickness = 10 mm = 0.033 Ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft .

k_3 = Plastic thermal conductivity = 0.09 BTU / HR .ft . F

k_4 = Thermal conductivity for air at Atmospheric pressure and 10.4 F

k_4 = 0.0135 BTU / Hr . Ft F

k_5 = Thermal conductivity for Aluminium = 117 BTU / Hr. Ft F

A_1 = 528 x 465 = 261350 sq.mm = 2.81 sq.Ft

x_1 / k_1 = 0.000063

x_2 / k_2 = 0.123 / 0.0104 = 11.798

x_3 / k_3 = 0.0729

x_4 / k_4 = 0.033 / 0.0135 = 2.44

x_5 / k_5 = 0.005 / 117 = 0.00004

$$UTE1 = \frac{1}{0.000063+11.798+0.0729+2.44+0.00004} = \frac{1}{14.311}$$

$$U_{TE1} = 0.064 \text{ BTU / Hr . sq.ft. F}$$

$t_{a\,max}$ = 43 C = 109.4 F Room Temp.

t_{E1} = 10.4 F

ΔT_{E1} = (t_a - t_E) = 109.4 - 10.4 = 99 F

$$Q_{E1} = U_1 . A_1 . \Delta T_1$$

$$Q_{E1} = 0.064 \times 2.81 \times 99 = 17.8 \text{ BTU / Hr}$$

$$Q_{E2} = U_{E2} . A_{E2} . \Delta T_2$$

$A_{E2} = A_{E1} = 2.81$ sq. Ft

$$U_{TE2} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

$x_1 / k_1 = 0.016 / 0.09 = 0.1778$

$x_2 / k_2 = 0.213 / 0.0134 = 15.91$

$x_3 / k_3 = 0.00004$

$$U_{TE2} = \frac{1}{0.1778 + 15.91 + 0.00004}$$

$U_{TE2} = 0.062$ BTU / Hr . sq.Ft .F

$\Delta T_{E2} = T_R - T_E = 41 - 10.4 = 30.6$ F

$$Q_{E2} = 0.064 \times 2.81 \times 30.6 = 5.3 \text{ BTU / Hr}$$

$$Q_{E3} = U_{E3} . A_{E3T} . \Delta T_3$$

$$U_{TE3} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5}$$

$x_1 / k_1 = 0.000063$

$x_2 / k_2 = 0.1145 / 0.0104 = 11.798$

$x_3 / k_3 = 0.0656 / 0.09 = 0.0729$

$x_4 / k_4 = 0.146 / 0.0135 = 10.814$

$x_5 / k_5 = 0.0049 / 117 = 0.00004$

$$U_{TE3} = \frac{1}{0.000063+11.798+0.0729+10.814+0.00004}$$

$U_{TE3} = 0.044$ BTU / Hr . sq.Ft . F

$A_{E3T} = 2A_{E3} + 2A_{E4}$

$A_{E3} = 250 \times 495 = 123750$ sq.mm = 1.33 sq.ft

$A_{E4} = 250 \times 528 = 132000$ sq.mm = 1.42 sq.ft

$A_{E3T} = 2 (1.33 + 1.42) = 5.5$ sq.ft

$\Delta T_{E3} = T_a - T_E = 109.4 - 10.4 = 99$ F

$Q_{E3} = 0.044 \times 5.5 \times 99 =$ **23.98** BTU / Hr

$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$

$Q_{TE} = 19.17+5.27+23.98 =$ **48.42** BTU / Hr

B . PRODUCT LOAD CALCULATION

$Q_{PT} = \Sigma Q_{PR} + \Sigma Q_{PF} + \Sigma Q_{LF} + \Sigma Q_F$

1. ΣQ_{PR} = Heat removed from products above freezing point

$Q_{PR} = W_P \cdot C_P \cdot \Delta t_R = W_P \cdot C_P \cdot (t_1 - t_2)$

WHERE

1 . t_1 = For red and white fresh meet (Ave.) = 82.4 F

2 . t_1 = For butter and cheese (Ave.) = 50 F

3 . t_1 = For mixed vegetables (Ave.) = 59 F

4 . t_1 = For fruits of any kind (Ave.) = 59 F

5 . t_1 = For water = 50 F

6 . t_1 = For bread = 75 F

7 . t_2 = For all above products = (Ave.) 41 F

$\Delta t_{R1\cdot1}$ = 41.4 F

$\Delta t_{R1\cdot2}$ = 9 F

$\Delta t_{R1\cdot3}$ = 18 F

$\Delta t_{R1\cdot4}$ = 18 F

$\Delta t_{R1\cdot5}$ = 9 F

$\Delta t_{R1-6} = 34$ F

Average sum of " C " specific heat for above products from Table 1 are as follows .

"C_1" = 0.72 BTU / lb . F

"C_2" = 0.67 BTU / lb . F

"C_3" = 0.93 BTU / lb . F

"C_4" = 0.9 BTU / lb . F

"C_5" = 0.999 BTU / lb . F

"C_6" = 0.70 BTU / lb . F

"C_7" = For milk = 0.93 BTU / lb . F

Average Product Weight per Pound .

W_1 = 8 lb Meet and Fish

W_2 = 2 lb Butter and cheese

W_3 = 6 lb Vegetable (mixed) and lettuce

W_4 = 12 lb Fruit of any kind

W_5 = 10 lb Water

W_6 = 5 lb Bread

W_7 = 6 lb Milk

$Q_{PR1} = 8 \times 0.72 \times (82.4 - 41) = 238.4$ BTU

$Q_{PR2} = 2 \times 0.67 \times (50 - 41) = 12$ BTU

$Q_{PR3} = 6 \times 0.93 \times (59 - 41) = 100.44$ BTU

$Q_{PR4} = 12 \times 0.90 \times (59 - 41) = 194.4$ BTU

$Q_{PR5} = 10 \times 0.999 \times (50 - 41) = 89.91$ BTU

$Q_{PR6} = 5 \times 0.70 \times (75 - 41) = 11.9$ BTU

$Q_{PR7} = 6 \times 0.93 \times (50 - 41) = 50.22$ BTU

$$Q_{PR} = Q_{PR1} + Q_{PR2} + Q_{PR3} + Q_{PR4} + Q_{PR5} + Q_{PR6} + Q_{PR7}$$

$$Q_{PR} = 238.4 + 12.06 + 100.44 + 194.4 + 89.91 + 11.9 + 50.22$$

$$Q_{PR} = 697.3 \text{ BTU}$$

2 . ΣQ_{PF1} = Heat removed from products to freeze product from initial temperature to freezing point above freezin point .

$$Q_{PF1} = W \times C \times \Delta t$$

Weight of products are as follows

1 - Fish 4 lbs

2- Meet 7 lbs

3 - Water 5 lbs

$$\Delta t = (t_{pi} - t_{pF})$$

4 - $\Delta t_{1fish} = 50 - 28 = 22$ F "C" = 0.9 BTU / lb F

5 - $\Delta t_{1meet} = 82.4 - 29 = 53.4$ F "C" = 0.72 BTU / lb F

6 - $\Delta t_{1water} = 50 - 32 = 18$ F "C" = 0.999 BTU / lb F

7 - $Q_{PF1fish} = 4 \times 0.9 \times 22 = 79.2$ BTU

8 - $Q_{PF1meet} = 7 \times 0.72 \times 53.4 = 269.14$ BTU

9 - $Q_{PF1water} = 5 \times 0.999 \times 18 = 89.91$ BTU

$\Sigma Q_{PF1} = Q_{PF1\,fish} + Q_{PF1meet} + Q_{PF1water} = 79.2 + 269.14 + 89.91 = 438.34$ BTU

$$\Sigma Q_{PF1} = 438.34 \text{ BTU}$$

3 - ΣQ_{PF2} = Heat removed from freezing point to final temerature below freezing .

$$Q_{PF2} = W \times C_i \times (t_f - t_3)$$

1 - Fish 4 lbs

2- Meet 7 lbs

3 - Ice 5 lbs

4 - $\Delta t_{1fish} = 28 - 10.4 = 17.6$ F "C_{ifish}" = 0.49 BTU / lb F

5 - $\Delta t_{1meet} = 29 - 10.4 = 18.6$ F "C_{imeet}" = 0.42 BTU / lb F

6 - $\Delta t_{1ice} = 32 - 10.4 = 21.6$ F "$C_{i\,ice}$" = 1 BTU / lb F

7 - $Q_{PF2fish} = 4 \times 0.49 \times 17.6 = 34.5$ BTU

8 - $Q_{PF2meet} = 7 \times 0.42 \times 18.6 = 54.68$ BTU

9 - $Q_{PF2ice} = 5 \times 1 \times 21.6 = 108$ BTU

$\Sigma Q_{PF2} = Q_{PF2\,fish} + Q_{PF2meet} + Q_{PF2ice} = 34.5 + 54.68 + 108 = 197.18$ BTU

$$\Sigma Q_{PF2} = 197.18 \text{ BTU}$$

4 - ΣQ_{LF} = Heat removal to freeze product

$$Q_{LF} = W \times h_{if}$$

WHERE

Q_{LF} = Heat removal by latent heat

W = Weight of product

h_{if} = Latent heat per BTU / lb

1 - Weight of product per pound

2 - Latent heat per BTU / lb

3 - Fish 5 lbs

4 - Meet 7 lbs

5 - Ice 5 lbs

$Q_{LF_{fish}} = 5 \times 95 = 380$ BTU

$Q_{LF_{meet}} = 7 \times 85.8 = 600.6$ BTU

$Q_{LF_{ice}} = 5 \times 143.5 = 717.5$ BTU

$$Q_{LF} = Q_{LF_{fish}} + Q_{LF_{meet}} + Q_{LF_{ice}}$$

$$Q_{LF} = 380 + 600.6 + 717.5 = 1698.1 \text{ BTU}$$

$$Q_{LF} = 1698.1 \text{ BTU}$$

$$\Sigma Q_{PT} = 697.3 + 438.34 + 197.18 + 1698.1 = 3030.94 \text{ BTU}$$

$$Q_{PT} = 3030.94 \text{ BTU in 24 hours}$$

$$Q_{PT_{hr}} = 3030.94 / 16 = 189.43 \text{ BTU / Hr.}$$

Note . Compressor operating time = 16 hours daily

C . Total heat gain through Refrigerator and Evaporator and heat removed from Products are calculated as follows .

$$Q_T = Q_{TR} + Q_{TE} + Q_{TP} = Q_{TC} + Q_{TP}$$

Where

Q_{TC} = Total heat gain by conduction

Q_{TR} = Total heat remoned from products

Q_{TR} = 150.2 BTU / Hr

Q_{TE} = 48.42 BTU / Hr

$Q_{TC} = Q_{TR} + Q_{TE}$ = 150.2 + 48.42 = 198.62 BTU / Hr

Q_{Tp} = 3030.94 BTU per 24 hours

Note . Desired Compressor Operating Time = 16 Hours Daily

Q_{Tp} / Hr = 3030.94 / 16 = 189.43 BTU / Hr

Q_T = 198.62 + 189.43 = 388.1 BTU / Hr

$Q_{GT} = Q_T + 10\,\%\,Q_T$ = 388.1 + 38.81 = 426.91 BTU / Hr

Q_{GT} = 426.91 BTU / Hr

Q_{GT} = 426.91 x 0.2931 = 125.12 Watts

Q_{GT} = 125.12 Watts / Hr

D. Compressor selection for **Model AR10**

The compressor selection for Model AR10 is based on avaible or existing Compressor Models in Iranian Market at present which are as follows, Compressor power is to be 1/6 Hp, in all compressor types from different manufacturers.

Manufacturer Name	Model	Capacity ,Watts
DANFUS	TLS5F	130
NECCHI	ETR5.5H	123
ASPERA	BP1111Z	125
GOLD STAR	NF 52	135
SICOM	AZ1345YS	120

From the above figures the nearest possible Compressor Capacity which are compatible to our Energy Requirements for Model AR10, could be either comp. Model TLS5F from DANFUS with 130 Watts Capacity ,or Model BP1111z from ASPERA with comp. capacity of 125 watts or compressor Model NF 52 from GOLD STAR, the other Compressor models could be considered as alternatives due to the Laboratory test analysis.

Note 1. 10 % additional load has been considered for Fridge air replacement and infiltration during the day.

Note 2. For other equipment selection such as condenser, evaporator and drier refer to **Section IV**.

SECTION IX

REFRIGERATOR MODEL AR12 REFRIGERATION LOAD CALCULATION

A . Heat gain by conduction

1 . Total heat gain by conduction in refrigerator compartment .

$$Q_{TA} = U_{TR} . A_{TR} . \Delta t_R$$

$$Q_{TA} = U_{TR} . A_{TR} . (T_a - T_r)$$

$$U_{TR_{ave}} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

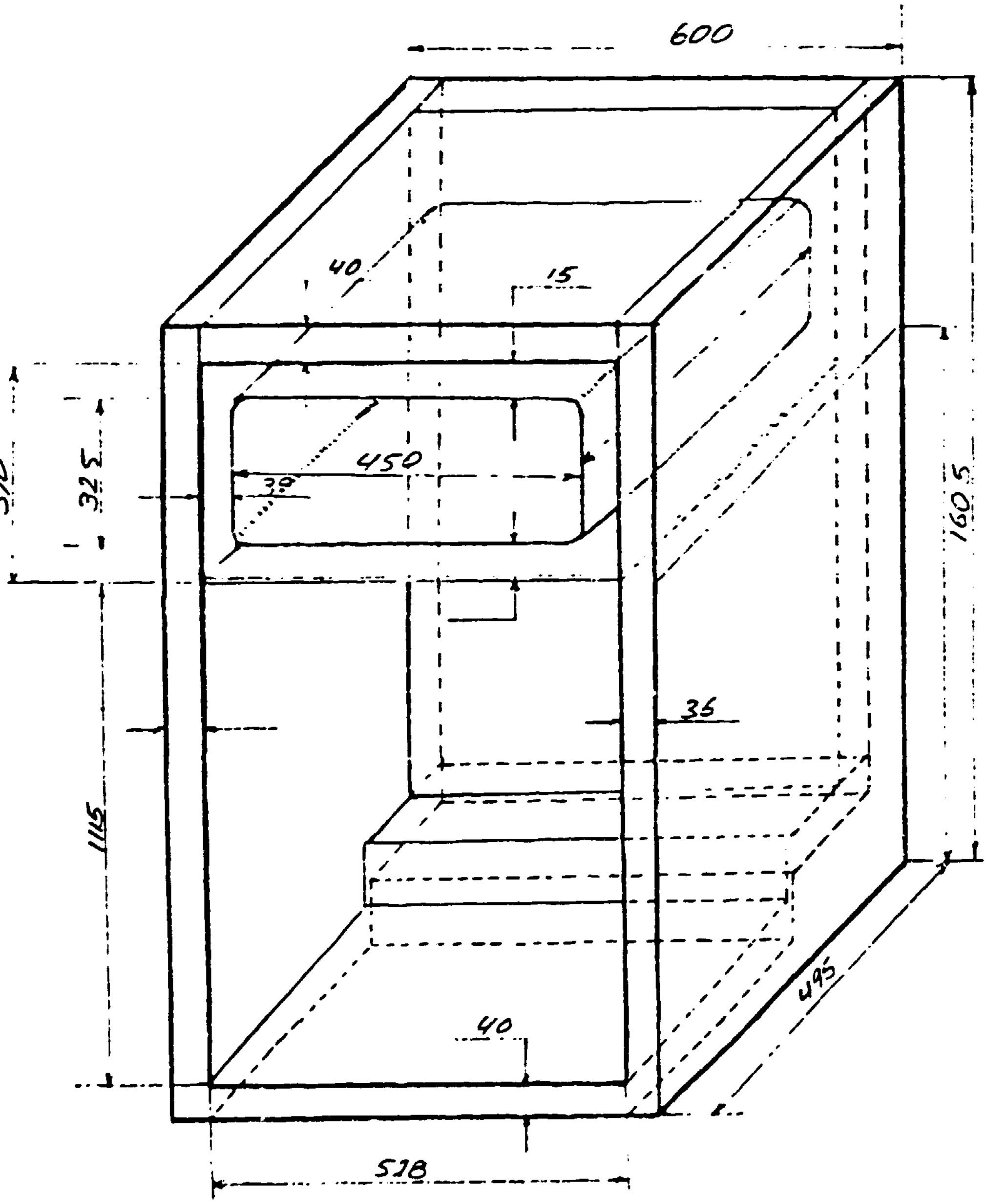
k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft . F

k_3 = PLastic thermal conductivity = 0.09 BTU / HR .ft . F

$$A_{TR} = A_1 + A_2 + A_3 + A_4 + A_5$$

$$A1 = A2 \quad \& \quad A3 = A4$$

نوع نشریه :	موضوع :	کارخانجات صنعتی آزمایش
شماره نشریه :		خدمات و برنامه



MODEL AR12

تاریخ انتشار :	تاریخ وشماره سیرات :

$A_{TR} = 2A_1 + 2A_3 + A_5$

$A_{TR} = 2(528 \times 1115) + 2(495 \times 1115) + (528 \times 495)$

$A_{TR} = 1177440 + 1103850 + 261360 = 2542650$ sq.mm = 27.37 sq.ft

$$U_{TR} = \frac{1}{0.000063 + 11.001 + 0.0729} = \frac{1}{11.07395189}$$

$U_{TR} = 0.090$ BTU / Hr . F . sq.ft

$t_{amax} = 43$ C = 109.4 F

$t_r = 5 \pm 2$ C = 41 $\pm$ 4 F

$(t_a - t_r) = 109.4 - 41 = 68.4$ F

$Q_{TR} = 0.090 \times 27.37 \times 68.4 = 168.48$ BTU / Hr

$Q_{TR} =$ **168.48** BTU / Hr

2 . Total heat gain by conduction in Evaporator compartment .

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$$Q_{TE} = U_{TE} \,.\, A_{TE} \,.\, \Delta t_E$$

$$Q_{TE} = U_{TE} \,.\, A_{TE} \,.\, (T_a - T_E)$$

$T_a = 109.4$ F

$T_E = 10.4$ F

$$U_{TE1ave} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 35 mm (average) = 0.1145 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

x_4 = Air thickness betwwn Ref. wall and Evaporator = 44.5 mm = 0.146 ft

x_5 = Evaporator thickness = 1.5 mm = 0.005 ft

x_{4u} = Upper Evaporator air thickness = 10 mm = 0.033 Ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft .

k_3 = Plastic thermal conductivity = 0.09 BTU / HR .ft . F

k_4 = Thermal conductivity for air at Atmospheric pressure and 10.4 F

k_4 = 0.0135 BTU / Hr . Ft F

k_5 = Thermal conductivity for Aluminium = 117 BTU / Hr. Ft F

A_1 = 528 x 465 = 261350 sq.mm = 2.81 sq.Ft

$x_1 / k_1 = 0.000063$

$x_2 / k_2 = 0.123 / 0.0104 = 11.798$

$x_3 / k_3 = 0.0729$

$x_4 / k_4 = 0.0492 / 0.0135 = 3.645$

$x_5 / k_5 = 0.005 / 117 = 0.00004$

$$UTE1 = \frac{1}{0.000063+11.798+0.0729+3.645+0.00004} = \frac{1}{15.51}$$

U_{TE1} = 0.064 BTU / Hr . sq.ft. F

$t_{a\,max}$ = 43 C = 109.4 F Room Temp.

t_{E1} = 10.4 F

$\Delta T_{E1} = (t_a - t_E) = 109.4 - 10.4 = 99$ F

$$Q_{E1} = U_1 . A_1 . \Delta T_1$$

$$Q_{E1} = 0.064 \text{ x } 2.81 \text{ x } 99 = \mathbf{17.8} \text{ BTU / Hr}$$

$$Q_{E2} = U_{E2} . A_{E2} . \Delta T_2$$

$AE2 = AE1 = 2.81$ sq. Ft

$$U_{TE2} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

$x_1 / k_1 = 0.016 / 0.09 = 0.1778$

$x_2 / k_2 = 0.213 / 0.0134 = 15.91$

$x_3 / k_3 = 0.00004$

$$U_{TE2} = \frac{1}{0.1778 + 15.91 + 0.00004}$$

$U_{TE2} = 0.062$ BTU / Hr . sq.Ft .F

$\Delta T_{E2} = T_R - T_E = 41 - 10.4 = 30.6$ F

$$Q_{E2} = 0.064 \text{ x } 2.81 \text{ x} 30.6 = 5.3 \text{ BTU / Hr}$$

$$Q_{E3} = U_{E3} . A_{E3T} . \Delta T_3$$

$$U_{TE3} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5}$$

$x_1/k_1 = 0.000063$

$x_2/k_2 = 0.1145/0.0104 = 11.798$

$x_3/k_3 = 0.0656/0.09 = 0.0729$

$x_4/k_4 = 0.146/0.0135 = 10.814$

$x_5/k_5 = 0.0049/117 = 0.00004$

$$U_{TE3} = \frac{1}{0.000063+11.798+0.0729+10.814+0.00004}$$

$U_{TE3} = 0.044$ BTU / Hr . sq.Ft . F

$A_{E3T} = 2A_{E3} + 2A_{E4}$

$A_{E3} = 325 \times 495 = 160875$ sq.mm = 1.73 sq.ft

$A_{E4} = 325 \times 528 = 171600$ sq.mm = 1.85 sq.ft

$A_{E3T} = 2(1.73 + 1.85) = 7.16$ sq.ft

$\Delta T_{E3} = T_3 - T_E = 109.4 - 10.4 = 99$ F

$Q_{E3} = 0.044 \times 7.16 \times 99 =$ **31.18** BTU / Hr

$$Q_{TE} = Q_{E1} + Q_{E2} + Q_{E3}$$

$Q_{TE} = 17.8+5.33+31.18 =$ **54.31** BTU / Hr

B . PRODUCT LOAD CALCULATION FORMODEL AR12

$Q_{PT} = \Sigma Q_{PR} + \Sigma Q_{PF} + \Sigma Q_{LF} + \Sigma Q_{F}$

1. ΣQ_{PR} = Heat removed from products above freezing point

$Q_{PR} = W_P . C_P . \Delta t_R = W_P . C_P . (t_1 - t_2)$

WHERE

1 . t_1 = For red and white fresh meet (Ave.) = 82.4 F

2 . t_1 = For butter and cheese (Ave.) = 50 F

3 . t_1 = For mixed vegetables (Ave.) = 59 F

4 . t_1 = For fruits of any kind (Ave.) = 59 F

5 . t_1 = For water = 50 F

6 . t_1 = For bread = 75 F

7 . t_2 = For all above products = (Ave.) 41 F

Δt_{R1-1} = 41.4 F

Δt_{R1-2} = 9 F

Δt_{R1-3} = 18 F

Δt_{R1-4} = 18 F

Δt_{R1-5} = 9 F

$\Delta t_{R1-6} = 34$ F

Average sum of " C " specific heat for above products from Table 1 are as follows .

" C_1 " = 0.72 BTU / lb . F

" C_2 " = 0.67 BTU / lb ..F

" C_3 " = 0.93 BTU / lb . F

" C_4 " = 0.9 BTU / lb . F

" C_5 " = 0.999 BTU / lb . F

" C_6 " = 0.70 BTU / lb . F

" C_7 " = For milk = 0.93 BTU / lb . F

Average Product Weight per Pound .

W_1 = 10 lb Meet and Fish

W_2 = 4 lb Butter and cheese

W_3 = 10 lb Vegetable (mixed) and lettuce

W_4 = 16 lb Fruit of any kind

W_5 = 10 lb Water

W_6 = 6 lb Bread

W_7 = 8 lb Milk

$Q_{PR1} = 10 \times 0.72 \times (82.4 - 41) = 298$ BTU

$Q_{PR2} = 4 \times 0.67 \times (50 - 41) = 24.1$ BTU

$Q_{PR3} = 10 \times 0.93 \times (59 - 41) = 167.4$ BTU

$$Q_{PR4} = 16 \times 0.90 \times (59 - 41) = 259.2 \text{ BTU}$$

$$Q_{PR5} = 10 \times 0.999 \times (50 - 41) = 89.91 \text{ BTU}$$

$$Q_{PR6} = 6 \times 0.70 \times (75 - 41) = 142.8 \text{ BTU}$$

$$Q_{PR7} = 8 \times 0.93 \times (50 - 41) = 67 \text{ BTU}$$

$$Q_{PR} = Q_{PR1} + Q_{PR2} + Q_{PR3} + Q_{PR4} + Q_{PR5} + Q_{PR6} + Q_{PR7}$$

$$Q_{PR} = 298 + 24.1 + 167.4 + 259.2 + 89.91 + 142.8 + 67$$

$$Q_{PR} = 1048.5 \text{ BTU}$$

2 . ΣQ_{PF1} = Heat removed from products to freeze product from initial temperature to freezing point above freezin point .

$$Q_{PF1} = W \times C \times \Delta t$$

Weight of products are as follows

1 - Fish 6 lbs

2 - Water 12 lbs

3 - Meet 10 lbs

$$\Delta t = (t_{pi} - t_{pF})$$

4 - $\Delta t_{1fish} = 50 - 28 = 22$ F "C" = 0.9 BTU / lb F

5 - $\Delta t_{1meet} = 82.4 - 29 = 53.4$ F "C" = 0.72 BTU / lb F

6 - $\Delta t_{1water} = 50 - 32 = 18$ F "C" = 0.999 BTU / lb F

9 - $Q_{PF1fish} = 6 \times 0.9 \times 22 = 118.8$ BTU

10 - $Q_{PF1meet} = 12 \times 0.72 \times 53.4 = 461.3$ BTU

11 - $Q_{PF1water} = 5 \times 0.999 \times 18 = 90$ BTU

$$\Sigma Q_{PF1} = Q_{PF1\,fish} + Q_{PF1\,meet} + Q_{PF1\,water}$$

$$\Sigma Q_{PF1} = 118.8 + 461.3 + 90$$

$$\Sigma Q_{PF1} = 670.1 \text{ BTU}$$

3 - ΣQ_{PF2} = Heat removed from freezing point to final temerature below freezing .

$$Q_{PF2} = W \times C_i \times (t_f - t_3)$$

1 - Fish 6 lbs

2- Meet 12 lbs

3 - Ice 5 lbs

4 - Δt_{1fish} = 28 - 10.4 = 17.6 F "C_{ifish}" = 0.49 BTU / lb F

5 - Δt_{1meet} = 29 - 10.4 = 18.6 F "C_{imeet}" = 0.42 BTU / lb F

6 - Δt_{1ice} = 32 - 10.4 = 21.6 F "C_{ice}" = 1 BTU / lb F

7- $Q_{PF2fish}$ = 6 x 0.49 x 17.6 = 51.7 BTU

8 - $Q_{PF2meet}$ = 12 x 0.42 x 18.6 = 93.7 BTU

9 - Q_{PF2ice} = 5 x 1 x 21.6 = 108 BTU

$\Sigma Q_{PF2} = Q_{PF2fish} + Q_{PF2meet} + Q_{PF2ice} = 51.7 + 93.7i + 108 = 253.4$ BTU

$$\Sigma Q_{PF} = 253.4 \text{ BTU}$$

4 - ΣQ_{LF} = Heat removal to freeze product

$$Q_{LF} = W \times h_{if}$$

WHERE

Q_{LF} = Heat removal by latent heat

W = Weight of product

h_{if} = Latent heat per BTU / lb

1 - Weight of product per pound

2 - Latent heat per BTU / lb

3 - Fish 6 lbs

4 - Meet 12 lbs

5 - Ice 5 lbs

$Q_{LFfis} = 6 \times 95 = 570$ BTU

$Q_{LFmeet} = 12 \times 85.8 = 1029$ BTU

$$Q_{LF_{ice}} = 5 \times 143.5 = 717.5 \text{ BTU}$$

$$Q_{LF} = Q_{LF_{fish}} + Q_{LF_{meet}} + Q_{LF_{ice}}$$

$$Q_{LF} = 570 + 1029 + 717.5 = 2316.5 \text{ BTU}$$

$$Q_{LF} = 2316.5 \text{ BTU}$$

$$\Sigma Q_{PT} = 1048.5 + 670.1 + 253.4 + 2316.5 = 4288.5 \text{ BTU}$$

$$Q_{PT} = 4288.5 \text{ BTU in 24 hours}$$

$$Q_{PT_{hr}} = 4288.5 / 16 = 268 \text{ BTU / Hr.}$$

Note . Compressor operating time = 16 hours daily

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C . Total heat gain through Refrigerator and Evaporator and heat removed from Products are calculated as follows .

$$Q_T = Q_{TR} + Q_{TE} + Q_{TP} = Q_{TC} + Q_{TP}$$

Where

Q_{TC} = Total heat gain by conduction

Q_{TR} = Total heat remoned from products

Q_{TR} = 168.48 BTU / Hr

Q_{TE} = 54.31 BTU / Hr

$Q_{TC} = Q_{TR} + Q_{TE} = 168.48 + 54.31 = 222.79$ BTU / Hr

Q_{Tp} = 4288.5 BTU per 24 hours

Note . Desired Compressor Operating Time = 16 Hours Daily

Q_{Tp} / Hr = 4288.5 / 16 = 268 BTU / Hr

$Q_T = 222.79 + 268 = 490.79$ BTU / Hr

$$Q_{GT} = Q_T + 10\,\%\, Q_T = 490.79 + 49.08 = 540.59 \text{ BTU / Hr}$$

$$Q_{GT} = 540.59 \text{ BTU / Hr}$$

$$Q_{GT} = 540.59 \times 0.2931 = 158.45 \text{ Watts}$$

$$Q_{GT} = 158.45 \text{ Watts / Hr}$$

D. Compressor selection for **Model AR12**

The compressor selection for Model AR12 is based on avaible or existing Compressor Models in iranian Market at present which are as follows. Compressor power is to be 1/5 Hp, in all compressor types from different manufacturers.

Manufacturer Name	Model	Capacity .Watts
DANFUS	-------	----
NECCHI	ESC 8H	170
ASPERA	BP1112Z	152
GOLD STAR	NF 62	156
SICOM	AE1360YS	158

From the above figures the nearest possible Compressor Capacity which are compatible to our Energy Requirements for Model AR12, could be either comp. Model AE1360YS from SICOM with comp. capacity of 158 watts or compressor Modl NF 62 from GOLD STAR, 156 Watts, the other Compressor models could be considered as alternatives due to the Laboratory test analysis.

Note 1. 10 % additional load has been considered for Fridge air replacement and infiltration during the day.

Note 2. For other equipment selection such as condenser, evaporator and drier refer to **Section IV**.

SECTION X

REFRIGERATOR AND FREEZER MODEL ARF2 LOAD CALCULATION

A . Heat gain by conduction .

1 . Total heat gain by conduction in refrigerator compartment .

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot \Delta t_R$$

$$Q_{TA} = U_{TR} \cdot A_{TR} \cdot (T_a - T_r)$$

$$U_{TR_{ave}} = \frac{1}{x_1/k_1 + x_2/k_2 + x_3/k_3}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_{2-1} = Foam thickness (ave.) for fridge = 35 mm (average) = 0.1145 ft (ave.)

x_{2-2} = Foam thickness (Ave.) for freezer = 53 mm (Ave.) = 0.173 ft (Ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 ft

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft . F

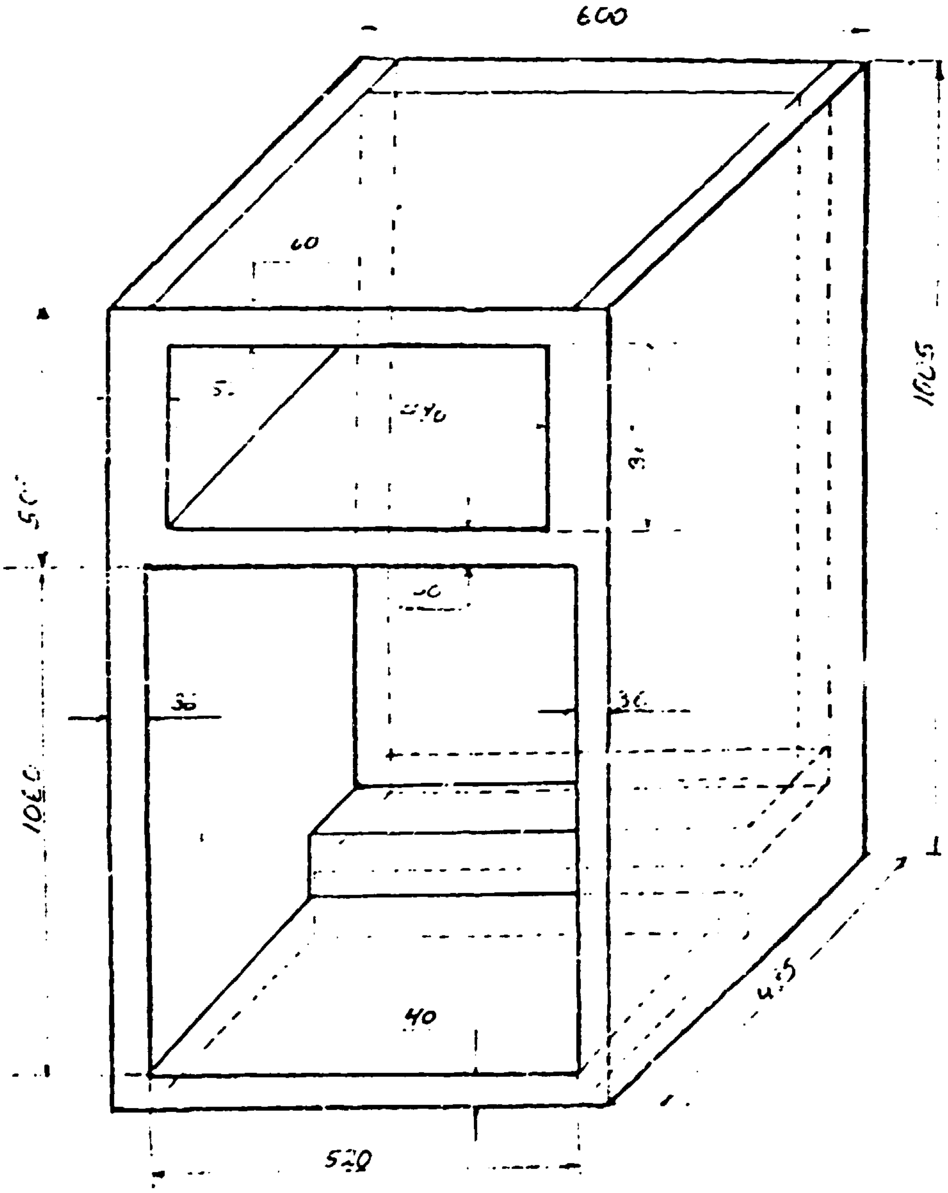
k_3 = PLastic thermal conductivity = 0.09 BTU / HR .ft . F

a-1 Heat gain by conduction through Fridge compartment .

$$A_{TR} = A_1 + A_2 + A_3 + A_4 + A_5$$

$$A1 = A2 \quad \& \quad A3 = A4$$

شرکت مخابرات ایران	موضوع :	نوع نشریه :
دفتر تدوین و برنامه		شماره نشریه :



ARF2

تاریخ و شماره تغییرات :	تاریخ انتشار :

A1 = A2 & A3 = A4

$A_{TR} = 2A_1 + 2A_3 + A_5$

$A_{TR} = 2(1060 \times 495) + 2(520 \times 1060) + (520 \times 495)$

$A_{TR} = 524700 + 551200 + 257400 = 2409161.6$ sq.mm = 25.932 sq.ft

$$U_{TR} = \frac{1}{0.000063 + 11.001 + 0.0729} = \frac{1}{11.07395189}$$

$U_{TR} = 0.090$ BTU / Hr . F . sq.ft

$t_{amax} = 43$ C = 109.4 F

$t_r = 5 \pm 2$ C = 41 +- 4 F

$(t_a - t_r) = 109.4 - 41 = 68.4$ F

$Q_{TR} = 0.090 \times 25.932 \times 68.4 = 159.64$ BTU / Hr

Q_{TR} = 159.64 BTU / Hr

a-2 . Total heat gain by conduction in Freezer compartment .

$$Q_{TF} = Q_{F1} + Q_{F2} + Q_{F3}$$

$$Q_{TF} = U_{TF} \cdot A_{TF} \cdot \Delta t_F$$

$$Q_{TF} = U_{TF} \cdot A_{TF} \cdot (T_a - T_F)$$

$T_a = 109.4$ F

$T_F = 0.4$ F

$\Delta t_F = 109.4 - 0.4 = 109$ F

$$U_{TFave} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

x_1 = Carbon steel thickness = 0.6 mm = 0.00197 ft.

x_2 = Foam thickness (ave.) = 53 mm (average) = 0.174 ft (ave.)

x_3 = Inner liner ABS thickness = 2 mm = 0.00656 f

k_1 = Steel thermal conductivity = 31.2 BTU / Hr . ft . F

k_2 = Foam thermal conductivity = 0.0104 BTU / Hr . ft .

k_3 = Plastic thermal conductivity = 0.09 BTU / HR . ft F

$A_{F1} = A_1 + A_2 + A_3 + A_4$

$A_{F1} = A_1 + A_2 + A_3 + A_4$

$A_1 = A_2$ & $A_3 = A_4$

$A_1 = 360 \times 495 = 178560$ sq.mm = 1.92 sq.Ft

$A_3 = 505 \times 495 = 249975$ sq.mm = 2.69 sq.FT

$x_1 / k_1 = 0.000063$

$x_2 / k_2 = 0.174 / 0.0104 = 16.72$

$x_3 / k_3 = 0.0729$

$$U_{TE1} = \frac{1}{0.000063 + 16.72 + 0.0729} = \frac{1}{16.792963}$$

$$U_{TE1} = 0.059 \text{ BTU / Hr . sq.ft. F}$$

$t_{a\,max} = 43$ C = 109.4 F Room Temp.

$t_{F1} = 0.4$ F

$\Delta T_{F1} = (t_a - t_F) = 109.4 - 0.4 = 109$ F

$$Q_{F1} = U_1 . A_1 . \Delta T_1$$

$$Q_{F1} = 0.059 \times 9.22 \times 109 = 59.3 \text{ BTU / Hr}$$

$$Q_{F2} = U_{F2} . A_{F2} . \Delta T_2$$

$A_{F2} = A_{F1} = 228160 sq.mm = 2.456 sq. Ft$

$$U_{TF2} = \frac{1}{x_1 / k_1 + x_2 / k_2 + x_3 / k_3}$$

$x_1 / k_1 = 0.000063$

$x_2 / k_2 = 18.93$

$x_3 / k_3 = 0.0729$

$$U_{TF2} = \frac{1}{0.000063 + 18.93 + 0.0729}$$

$U_{TF2} = 0.052$ BTU / Hr . sq.Ft .F

$\Delta T_{F2} = T_R - T_F = 41 - 0.4 = 40.6$ F

$Q_{F2} = 0.052 \times 2.456 \times 40.6 = 13.92$ BTU / Hr

$$Q_{F3} = U_{F3} . A_{F3T} . \Delta T_3$$

$U_{F3} = U_{F2}$

$U_{F3} = 0.052$ BTU / Hr sq.ft . F

$U_{TF3} = 0.052$ BTU / Hr . sq.Ft . F

$A_{F3} = A_{F2}$

$A_{F3} = 2.456$ sq. FT

$\Delta T_{FR} = T_R - T_F = 41 - 0.4 = 40.6$ F

$Q_{F3} = 0.052 \times 2.456 \times 40.6 = 5.185$ BTU/Hr

$$Q_{TF} = Q_{F1} + Q_{F2} + Q_{F3}$$

$Q_{TF} = 59.3+13.92+5.185 = 78.4$ BTU/Hr

B. PRODUCT LOAD CALCULATION FOR MODEL ARF2

$Q_{PT} = \Sigma Q_{PR} + \Sigma Q_{PF} + \Sigma Q_{LF} + \Sigma Q_{F}$

1. ΣQ_{PR} = Heat removed from products above freezing point

$Q_{PR} = W_P . C_P . \Delta t_R = W_P . C_P . (t_1 - t_2)$

WHERE

1 . t_1 = For red and white fresh meet (Ave.) = 82.4 F

2 . t_1 = For butter and cheese (Ave.) = 50 F

3 . t_1 = For mixed vegetables (Ave.) = 59 F

4 . t_1 = For fruits of any kind (Ave.) = 59 F

5 . t_1 = For water = 50 F

6 . t_1 = For bread = 75 F

7 . t_2 = For all above products = (Ave.) 41 F

Δt_{R1-1} = 41.4 F

Δt_{R1-2} = 9 F

Δt_{R1-3} = 18 F

Δt_{R1-4} = 18 F

Δt_{R1-5} = 9 F

$\Delta t_{R1-6} = 34$ F

Average sum of " C " specific heat for above products from Table 1 are as follows .

" C_1 " = 0.72 BTU / lb . F

" C_2 " = 0.67 BTU / lb . F

" C_3 " = 0.93 BTU / lb . F

" C_4 " = 0.9 BTU / lb . F

" C_5 " = 0.999 BTU / lb . F

" C_6 " = 0.70 BTU / lb . F

" C_7 " = For milk = 0.93 BTU / lb . F

Average Product Weight per Pound .

W_1 = 10 lb Meet and Fish

W_2 = 4 lb Butter and cheese

W_3 = 10 lb Vegetable (mixed) and lettuce

W_4 = 16 lb Fruit of any kind

W_5 = 10 lb Water

W_6 = 6 lb Bread

W_7 = 8 lb Milk

$Q_{PR1} = 10 \times 0.72 \times (82.4 - 41) = 298$ BTU

$Q_{PR2} = 4 \times 0.67 \times (50 - 41) = 24.1$ BTU

$Q_{PR3} = 10 \times 0.93 \times (59 - 41) = 167.4$ BTU

$$Q_{PR4} = 16 \times 0.90 \times (59 - 41) = 259.2 \text{ BTU}$$

$$Q_{PR5} = 10 \times 0.999 \times (50 - 41) = 89.91 \text{ BTU}$$

$$Q_{PR6} = 6 \times 0.70 \times (75 - 41) = 142.8 \text{ BTU}$$

$$Q_{PR7} = 8 \times 0.93 \times (50 - 41) = 67 \text{ BTU}$$

$$Q_{PR} = Q_{PR1} + Q_{PR2} + Q_{PR3} + Q_{PR4} + Q_{PR5} + Q_{PR6} + Q_{PR7}$$

$$Q_{PR} = 298 + 24.1 + 167.4 + 259.2 + 89.91 + 142.8 + 67$$

$$Q_{PR} = 1048.5 \text{ BTU}$$

2 . ΣQ_{PF1} = Heat removed from products to freeze product from initial temperature to freezing point above freezin point .

$$Q_{PF1} = W \times C \times \Delta t$$

Weight of products are as follows

1 - Fish 6 lbs

2- Vegetables 8 lbs

3 - Water 8 lbs

4 - Meet 10 lbs

$$\Delta t = (t_{pi} - t_{pF})$$

5 - Δt_{1fish} = 50 - 28 = 22 F "C" = 0.9 BTU / lb F

6 - Δt_{1meet} = 82.4 - 29 = 53.4 F "C" = 0.72 BTU / lb F

7 - Δt_{1water} = 50 -3 2 = 18 F "C" = 0.999 BTU / lb F

8 - $\Delta t_{1Veg.}$ = 59 - 30 = 29 F "C" = 0.93 BTU / lb F

9 - $Q_{PF1fish}$ = 6 x 0.9 x 22 = 118.8 BTU

10 - $Q_{PF1meet}$ = 10 x 0.72 x 53.4 = 384.48 BTU

11 - $Q_{PF1water}$ = 8 x 0.999 x 18 = 143.85 BTU

12 - $Q_{PF1veg.}$ = 8 x 0.93 x 29 = 215.76 BTU

$$\Sigma Q_{PF1} = Q_{PF1\,fish} + Q_{PF1\,meet} + Q_{PF1\,water} + Q_{PF1\,veg.}$$

$$\Sigma Q_{PF1} = 118.8 + 215.76 + 384.48 + 143.85$$

$$\Sigma Q_{PF1} = 826.9 \text{ BTU}$$

3 - ΣQ_{PF2} = Heat removed from freezing point to final temerature below freezing .

$$Q_{PF2} = W \times C_i \times (t_f - t_3)$$

1 - Fish 6 lbs

2- Meet 10 lbs

3 - Ice 8 lbs

4 - Vegetable 8 lbs

5 - $\Delta t2_{fish}$ = 28 - 10.4 = 17.6 F " $C_{i\,fish}$ " = 0.49 BTU / lb F

6 - $\Delta t2_{meet}$ = 29 - 10.4 = 18.6 F " $C_{i\,meet}$ " = 0.42 BTU / lb F

7 - $\Delta t2_{ice}$ = 32 - 10.4 = 21.6 F " $C_{i\,ice}$" = 1 BTU / lb F

8 - Δt_{2veg} = 30 - 0.4 = 29.6 F " $C_{i\,veg}$ " = 0.45 BTU / lb

9- $Q_{PF2fish} = 6 \times 0.49 \times 27.6 =$ 81.14 BTU

8 - $Q_{PF2meet} = 10 \times 0.40 \times 28.6 =$ 114.4 BTU

9 - $Q_{PF2ice} = 8 \times 1 \times 31.6 = 251.2$ BTU

10 - $Q_{PF2veg} = 8 \times 0.45 \times 29.6 = 106.56$ BTU

$$\Sigma Q_{PF2} = Q_{PF2fish} + Q_{PF2meet} + Q_{PF2ice} + Q_{PF2veg}$$

$$\Sigma Q_{PF2} = 81.14 + 114.4 + 251.2 + 106.56$$

$$\Sigma Q_{PF} = 553.3 \text{ BTU}$$

4 - ΣQ_{LF} = Heat removal to freeze product

$$Q_{LF} = W \times h_{if}$$

WHERE

Q_{LF} = Heat removal by latent heat

W = Weight of product

h_{if} = Latent heat per BTU / lb

1 - Weight of product per pound

2 - Latent heat per BTU / lb

4 - Meet 10 lbs

5 - Ice 8 lbs

6 - Vegetable 8

$QLF_{fis} = 6 \times 95 = 570$ BTU

$QLF_{meet} = 10 \times 85.8 = 858$ BTU

$QLF_{ice} = 8 \times 143.5 = 1148$ BTU

$QLF_{ice} = 8 \times 130 = 1040$ BTU

$$QLF = QLF_{fish} + QLF_{meet} + QLF_{ice} + QLF_{veg}$$

$$QLF = 570 + 858 + 1148 + 1040 = 3796 \text{ BTU}$$

$$QLF = 3796 \text{ BTU}$$

$$\Sigma Q_{PT} = 1048.5 + 862.9 + 553.3 + 3796 = 6361 \text{ BTU}$$

$$Q_{PT} = 6361 \text{ BTU in 24 hours}$$

$$Q_{PT_{hr}} = 6361 / 16 = 397.56 \text{ BTU / Hr.}$$

Note . Compressor operating time = 16 hours daily

C . Total heat gain through Refrigerator and Evaporator and heat removed from Products are calculated as follows .

$$Q_T = Q_{TR} + Q_{TE} + Q_{TP} = Q_{TC} + Q_{TP}$$

Where

Q_{TC} = Total heat gain by conduction

Q_{TR} = Total heat remoned from products

Q_{TR} = 159.64 BTU / Hr

Q_{TF} = 78.4 BTU / Hr

$Q_{TC} = Q_{TR} + Q_{TF}$ = 159.64+ 78.4 = 238.04 BTU / Hr

Q_{Tp} = 6361 BTU per 24 hours

Note . Desired Compressor Operating Time = 16 Hours Daily

Q_{Tp} / Hr = 6361 / 16 = 396.56 BTU / Hr

Q_T = 238.04 + 397.56 = 635.6 BTU / Hr

$Q_{GT} = Q_T + 10\%\, Q_T$ = 635.6 + 63.56 = 699.16 BTU / Hr

Q_{GT} = 699.16 BTU / Hr

Q_{GT} = 699.16 x 0.2931 = 204.92 Watts

Q_{GT} = 204.92 Watts / Hr

D . Compressor selection for **Model ARF2**

The compressor selection for Model ARF2 is based on avaible or existing Compressor Models in Iranian Market at present which are as follows , Compressor power is to be 1/5 Hp , in all compressor types from different manufacturers .

Manufacturer Name	Model	Capacity ,Watts
DANFUS	-------	----
NECCHI	ESC 9HK	203
ASPERA	BP1116Z	207
GOLD STAR	VF 75	205
SICOM	AE1370YS	186

From the above figures the nearest possible Compressor Capacity which are compatible to our Energy Requirements for Model ARF2 , could be either comp. Model ESC 9HK from NECCHI with comp. capacity of 203 watts or compressor Modl BK1116z from ASPERA, 207 Watts , the other Compressor models could be considered as alternatives due to the Laboratory test analysis .

Note 1 . 10 % additional load has been considered for Fridge air replacement and infiltration during the day .

Note 2 . For other equipment selection such as condenser , evaporator and drier refer to Section IV .

AZMAYESH INDUSTRIAL FACTORIES CO.

PROJECT NO. MP/IRA/94/403

UNIDO,s CONTRACT NO. 94/097

PROGRESS REPORT # 2

PREPARED BY: A. BAHMANI

EDITED AND APPROVED BY: N. IMANI

Date: May 1995

TABLE OF CONTENTS

III

8 - Preparation of " Optimization Method " for selecting suitable components like compressor , condenser , capillary tube , Refrigerant weight and Insulation type and material .

9 - A summery about preparation and accomplishment of trial test and documentaion regarding selection of some component for our prototypes .

CHAPTER 1

PRODUCT SPECIFICATION

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

PROGRESS REPORT # 2

PROTOTYPE TEST RESULTS ANALYSIS

With respect to contract No. 94/097 with UNIDO Para 2.09 a, Azmayesh company is hounered here with to present the second progress report regarding making prototypes as well as accomplishing necessary modifications and optimization with regard to energy consumption.

This report contains the Analyisis of 5 Azmayesh Refrigerator and Ref-Freezer Models **AR06 , AR08 , AR10 ,AR12 and ARF2** , R134a prototypes performance test in comparison with application refrigerant R12 , in order to reach a reasonable result for selecting R134a refrigerant as well as trying all possible ways of opitimizing the refrigeration system for obtainging the required energy consumption .

This report will discuss the following subjects .

1 - Products specifications

2 - Working performance characteristics of 5 Models of Azmayesh Refrigerator and Ref-Freezers

3 - Determination of Constant " C " in order to determine actual heat resistance coeficient factor and also actual sum of heat transfer in **WATT** .

4 - Selection of HFC 134a compatible components like compressor and drier . It should be noticed that through our experiences ,evaporator , condenser and capillary tube will not be changed , but a modification on refrigerator water drainage tray under freezer compartment will be accomplished .

5 - Reviewing , Analyzing , Evaluating and Comparing test results of Refrigerator and Ref - Rreezer models AR06 , AR08 , AR10 , AR12 and ARF2 .

6 - Preparation of " Storage Tempreature Test Procedure " in accordance with , ISO 7371 , ISO 8187 and DIN 8950 for Calssification Code " T " under ambient temperature 43 , 32 and 18 degree centigrade .

7 - Preparation of " Energy Consumption Test Procedure " under ambient temperature of 18 degree centigrade in accordance with ISO 7173 , and ISO 8187 .

MODEL AR06 TECHNICAL SPECIFICATION

STAR CODE	TWO STAR
EGG SHELVES / NUMBER OF EGGS	1 / 9
BUTTER AND CHEESE COMPARTMENT	1
BOTTLE SHELVES / NUMBER OF BOTTLE	1 / 4
VARIABLE HEIGHT STAGE	2
MEAT TRAY	1
FRUIT COMPARTMENT	1
VOLUME LIT .	180
COOLING WATT CAPACITY WATT	95
ENERGY CONSUMPTION KW / 24 HRS.	1.3
COMPRESSOR SIZE (C Cm.)	4.3
EVAPORATOR TYPE	ROLLBOND
VOLTAGE RANGE	165-230VOLT
DIMENSION	98 X 60 X59
NET WEIGHT Kg .	42

KM 12 ... - ALI ROAD P.O. BOX 11365 - 4773 TEHRAN , IRAN , TEL. 98 21 777107 , FAX 98 21 777105

MODEL AR08 TECHNICAL SPECIFICATION

STAR CODE	TWO STAR
EGG SHELVES / NUMBER OF EGGS	1 / 9
BUTTER AND CHEESE COMPARTMENT	1
BOTTLE SHELVES / NUMBER OF BOTTLE	2 / 10
VARIABLE HEIGHT STAGE	3
MEAT TRAY	1
FRUIT COMPARTMENT	1
VOLUME LIT .	230
COOLING WATT CAPACITY WATT	108
ENERGY CONSUMPTION KW / 24 HRS.	1.5
COMPRESSOR SIZE (C.Cm.)	4.3
EVAPORATOR TYPE	ROLLBOND
VOLTAGE RANGE	165-230VOLT
DIMENSION	119 X 60 X 59
NET WEIGHT Kg .	45

MODEL AR10 TECHNICAL SPECIFICATION

STAR CODE	TWO STAR
EGG SHELVES / NUMBER OF EGGS	2 / 18
BUTTER AND CHEESE COMPARTMENT	2
BOTTLE SHELVES / NUMBER OF BOTTLE	2 / 10
VARIABLE HEIGHT STAGE	3
MEAT TRAY	1
FRUIT COMPARTMENT	1
VOLUME LIT.	280
COOLING WATT CAPACITY WATT	125
ENERGY CONSUMPTION KW / 24 HRS.	1.85
COMPRESSOR SIZE (C.Cm.)	5.2
EVAPORATOR TYPE	ROLLBOND
VOLTAGE RANGE	165-230VOLT
DIMENSION	141 X 60 X 59
NET WEIGHT Kg.	57.2

MODEL AR12 TECHNICAL SPECIFICATION

STAR CODE	TWO STAR
EGG SHELVES / NUMBER OF EGGS	2 / 18
BUTTER AND CHEESE COMPARTMENT	2
BOTTLE SHELVES / NUMBER OF BOTTLE	2 / 10
VARIABLE HEIGHT STAGE	3
MEAT TRAY	1
FRUIT COMPARTMENT	1
VOLUME LIT.	340
COOLING WATT CAPACITY WATT	158
ENERGY CONSUMPTION KW / 24 HRS.	2.25
COMPRESSOR SIZE (C.Cm.)	6.6
EVAPORATOR TYPE	ROLLBOND
VOLTAGE RANGE	165-230 VOLT
DIMENSION	164 X 60 X 59
NET WEIGHT Kg.	60

KM. 12, ABR - A... ROAD P.O. BOX 13385 - 4773 TEHRAN, IRAN, TEL. 00 21 777107, FAX 00 21 777105

MODEL ARF2 TECHNICAL SPECIFICATION

STAR CODE	THREE STAR
EGG SHELVES / NUMBER OF EGGS	1 / 9
BUTTER AND CHEESE COMPARTMENT	1
BOTTLE SHELVES / NUMBER OF BOTTLE	2 / 10
VARIABLE HEIGHT STAGE	3
FRUIT COMPARTMENT	1
TOTALVOLUME LIT.	310
FREEZER VOLUME LIT.	78
COOLING WATT CAPACITY WATT	205
ENERGY CONSUMPTION KW / 24 HRS.	3
NUMBER OF EVAPORATOT	2
EVAPORATOR TYPE	ROLLBOND/TUBE
VOLTAGE RANGE	165-230 VOLT
DIMENSION	164 X 60 X 59
NET WEIGHT Kg.	61

CHAPTER 2

WORKING PERFORMANCE

CHARACTERISTIC

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

WORKING PERFORMANCE CHARACTERISTICS
MODEL AR06

REFRIGERANT	R12
THERMOSTAT TYPE	PUSH BOTTON DEFROST
COOLING CAPACITY	95 WATT
AMBIENT TEMPERATURE	43 C
ENERGY CONSUMPTION Kw 24 / Hrs	1.3
THERMOSTAT ON POSITION TIME	6'50"
THERMOSTAT OFF POSITION	4' 50"
FREEZER MEAN TEMPERATURE	-12 C
CABINET MEAN TEMPERATURE	+ 5 C
CELLAR MEAN TEMPERATURE	+ 10 C
EVAPORATING TEMPERATURE	- 18 C
SUCTION TEMPERATURE	+ 45 C
CONDENSER INLET TEMPERATURE	+ 65 C
CONDENSER OUTLET TEMPERATURE	+ 51 C
COMPRESSOR SHELL	+ 65 C
SUB-COOLING TEMPERATURE	+ 32 C
REFRIGERANT WEIGHT	110 Gr.
ICE MAKING CAPACITY	2 Kg / Hr
COMPRESSOR RUNNING TIME	LESS THAN 75 %

WORKING PERFORMANCE CHRACTERISTICS
MODEL AR08

REFRIGERANT	R12
THERMOSTAT TYPE	PUSH BOTTON DEFROST
COOLING CAPACITY	108 WATT
AMBIENT TEMPERATURE	43 C
ENERGY CONSUMPTION Kwatt / 24 Hrs	1.5
THERMOSTAT ON POSITION TIME	6'50"
THERMOSTAT OFF POSITION	4' 50"
FREEZER MEAN TEMPERATURE	-12 C
CABINET MEAN TEMPERATURE	+ 5 C
CELLAR MEAN TEMPERATURE	+ 10 C
EVAPORATING TEMPERATURE	- 18 C
SUCTION TEMPERATURE	+ 45 C
CONDENSER INLET TEMPERATURE	+ 65 C
CONDENSER OUTLET TEMPERATURE	+ 51 C
COMPRESSOR SHELL	+ 65 C
SUB-COOLING TEMPERATURE	+ 32 C
REFRIGERANT WEIGHT	110 Gr.
ICE MAKING CAPACITY	2 Kg / Hr
COMPRESSOR RUNNING TIME	LESS THAN 75 %

WORKING PERFORMANCE CHARACTERISTICS
MODEL AR10

REFRIGERANT	R12
THERMOSTAT TYPE	PUSH BOTTONDEFROST
COOLING CAPACITY	125 WATT
AMBIENT TEMPERATURE	32 C
ENERGY CONSUMPTION Kwatt 24 / Hrs	1.85
THERMOSTAT ON POSITION TIME	3'
THERMOSTAT OFF POSITION	5' 30"
FREEZER MEAN TEMPERATURE	-10 C
CABINET MEAN TEMPERATURE	+ 2.5 C
CELLAR MEAN TEMPERATURE	+ 6 C
EVAPORATING TEMPERATURE	- 21 C
SUCTION TEMPERATURE	+ 32 C
CONDENSER INLET TEMPERATURE	+ 48 C
CONDENSER OUTLET TEMPERATURE	+ 38 C
COMPRESSOR SHELL	+ 58 C
SUB-COOLING TEMPERATURE	+ 32 C
REFRIGERANT WEIGHT	140 Gr.
ICE MAKING CAPACITY	1 Kg / Hr
COMPRESSOR RUNNING TIME	LESS THAN 75 %

WORKING PERFORMANCE CHRACTERISTICS
MODEL AR12

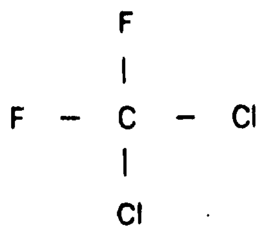
REFRIGERANT	R12
THERMOSTAT TYPE	PUSH BOTTON DEFROST
COOLING CAPACITY	158 WATT
AMBIENT TEMPERATURE	32 C
ENERGY CONSUMPTION Kwatt / 24 Hrs	2.25
THERMOSTAT ON POSITION TIME	2'50"
THERMOSTAT OFF POSITION	4' 50"
FREEZER MEAN TEMPERATURE	-12 C
CABINET MEAN TEMPERATURE	+4.25 C
CELLAR MEAN TEMPERATURE	+7 C
EVAPORATING TEMPERATURE	- 18 C
SUCTION TEMPERATURE	+ 33 C
CONDENSER INLET TEMPERATURE	+ 50 C
CONDENSER OUTLET TEMPERATURE	+ 40 C
COMPRESSOR SHELL	+ 64 C
SUB-COOLING TEMPERATURE	+ 32 C
REFRIGERANT WEIGHT	150 Gr.
ICE MAKING CAPACITY	1 Kg / Hr
COMPRESSOR RUNNING TIME	LESS THAN 75 %

WORKING PERFORMANCE CHARACTERISTICS
MODEL ARF2

REFRIGERANT	R12
THERMOSTAT TYPE	PUSH BOTTON DEFROST
COOLING CAPACITY	204 WATT
AMBIENT TEMPERATURE	32 C
ENERGY CONSUMPTION Kwatt / 24 Hrs	3
THERMOSTAT ON POSITION TIME	18'
THERMOSTAT OFF POSITION	16'
FREEZER MEAN TEMPERATURE	- 24 C
CABINET MEAN TEMPERATURE	+ 3 C
CELLAR MEAN TEMPERATURE	+ 4 C
EVAPORATING TEMPERATURE	- 27 C
SUCTION TEMPERATURE	+ 33 C
CONDENSER INLET TEMPERATURE	+ 55 C
CONDENSER OUTLET TEMPERATURE	+ 42 C
COMPRESSOR SHELL	+ 59 C
SUB-COOLING TEMPERATURE	+ 32 C
REFRIGERANT WEIGHT	220 Gr.
ICE MAKING CAPACITY	1 Kg / Hr
COMPRESSOR RUNNING TIME	LESS THAN 75 %

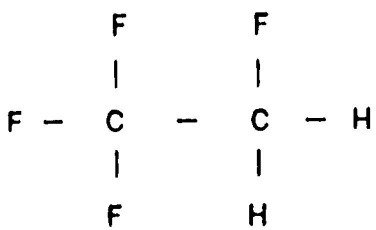
HFC 134a CHARACTERISTICS

CFC 12	CCl_2F_2



Cl → H

HFC 134a	CH_2FCF_3



HFC134a has no chlorine.	◆ **ODP(Ozone Depletion Potential) is Zero.** ◆ **Poor miscibility with existing oil. (Mineral/Alkyl benzene)** ◆ **Ester-base oil is necessary.** ⇩ ● High Hygroscopicity ● Chemical Reaction ◆ **No metal chloride coat formation on bearing metal surfaces.** ⇩ ● Poor Lubricity
HFC134a's specific volume of gas phase is greater than CFC12's.	◆ **Mass flow rate is reduced.** ⇩ ● Poor Cooling Capacity

CHAPTER 3

DETERMINATION OF

CONSTANT " C "

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

Determination of Constant " C "

One of the most important means to reduce the energy consumption and refrigeration system optimization is determination of actual Constant " **C** " , constant C figure has 2 parameters :

a . Insulation Material
b . Watt energy

1 - Finding the Insulation Material Thermal Conductivity

Finding the insulation Matreial Thermal Conductivity is actually impractical because of the mixture of three different types of chemical substances . So this measurement should be performed either repeativly by Measuring Devices through sampling procedures or determination of Constant " C " by achiving steps 3 through 9 , We blieve that determination of " C " constant in our factory is not repeativly practical , because we have an accurate measuring device which could easyly measure the actual foam constant" K " factor, but for determination of WATT energy required to be transfered and also calculating exact sum of area of cooling and freezing compartment which transfer heat .

2 - Assumption of WATT energy

For energy transfered by heat in WATT , we measure constant "C " by accomplishing steps 3 through 9 as follows .

3 - Determination of the Cabinet Constant " C "

3 - 1 The refrigerator is kept in test room at (t_a) .

3 - 2 Installation of electrical heater of (P) inside the refrigerator cabinet for getting inside temperature (t_i)

3 - 3 The defference ($t_i - t_a$) should be equal - 20 k

$$\textbf{Cabinet Constant " C "} = \frac{P}{(t_i - t_a)}$$

P in Watt

($t_i - t_a$) in k

3 - 4 For model AR08 Refrigerator

P = 20 Watt

t_i = 37.86 C

t_a = 25.43 C

$$C = \frac{p}{(t_i - t_a)} = \frac{20 \text{ watt}}{36.86-25.43} = 1.61 \text{ W/k}$$

" C " = 1.61 W / K

3 - 5 the cabinet constant C of refrigerator Model AR08 is 1.61 W / K

3 - 6 The practical overall Heat Transfer Coefficient (K) can be found from " C " as follows :

K = C / A Units for C in W/K and A in square inch .

A = Effective Heat Transmission Area

3 - 7 Simple derivation for seperate cabinet constant of freezer compartment and refrigerator compartment (cooling compartment) enclosing cellar compartment can be found as follows :

CHAPTER 4

SELECTION OF R134

COMPATIBLE COMPONENTS

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

SELECTION OF R134a COMPATIBLE COMPONENTS

The theorical assessment of refrigerator cycle for use of refrigerant R134a will only lead us to select major components like compressor, which we essentialy rely on Compressor Manufacturer Technical Data and Specifications. The selection of other components like Capillary tube, Evaporator, Condenser will be discussed in the following paragraphs.

1 - Compressor

The compressor is the heart of refrigeration system. The compressor insufficiencies are motor losses, suction gas heating, bearing losses, suction and discharge port pressure drops, and non-isothermal compression. A direct means of reducing compressor losses is to improve the electric motor efficiency, lubricants and reduce suction gas heating which is beyond the scope of our progress report. The amount of most of these losses are related to the pressure ratio across the compressor.

In our case , the consept is using refrigerant R134a , we are not much flexible in designing and selecting compressors , so we are seriously depend on Manufacturer Compressor Capability , Capacity , Compatibilty , Efficiency and Energy consumption ratio , which for each manufacturer the above factors are largely different . For instance , the factor for converting DANFOSS Compressor characteristics from CECOMAF Standard to ASHRAE Standard (with consideration of sub - cooling incoporation) , we have to multiply Watt Capacity in CECOMAF condition by Constant value of 1.231 plus consideration of almost 4.1 Watt / Degree for - 23.3 C evaporating temperature . This condition for ZANUSSI compressor is completly different , it means that for converting CECOMAF Standard to ASHRAE Standards we have to use Constant factor 1.18 or less .

Therefore these facts tell us , not to rely only on COPMRESSOR MANUFACTURER technical specifications but rely mostly on our Laboratory test results as well as those figures that could lead us to select a suitable compressor .

Table 1 shows the variety of compressor selection and Watt capacity . More than ten major Compressor manufacturers and suppliers (listed below)are supplying so many defferent kinds of Compressors with different prices and characteristics as well as two domestic large Compressor Manufacturers which shall produce more than two milion units per year in the near future .

In order to have better understanding about **Hermetic Compressors** using ESTER OIL and **Refrigerant R134a** it will be very usefull to enclose an analytical investigation report prepared by GOLD STAR Co . in this regard .

The following Compressor Manufacturers are offering their products to Iranian household Refrigerator manufacturer .

COMPRESSOR MANUFACTURER

1 - MATSUSHITA (NATIONAL)
2 - ZANUSSI (ELECTROLUX)
3 - DANFOSS
4 - NECCHI
5 - GOLDSTAR

6 - SAMSUNG

7 - ASPERA

8 - ELECTROLUX

9 - SICOM

10-TECUMSEH

According to the above discussion the following parameters are considered :

1 - Our refrigerator cooling capacities are as follows

AR06	95 WATT
AR08	108 WATT
AR10	125 WATT
AR12	158 WATT
ARF2	205 WATT

2 - ASHRAE TEST STANDARD

Evaporating temp. = - 23.3

Condensing temp. = + 55

Sub - Cooling temp. = +32 C

Suction temp. = +32 C

Ambient temp. = +32 C

3 - Minimum Compressor power ratio.

4 - Laboratory Performance test approval.

5 - Reasonable and price.

6 - Compatibility of compressor with our refrigeration system components.

2 - Evaporator and condenser

Efficiency losses in evaporator and condenser are associated with finite temperature differences between the refrigerator and air, with pressure drop, and with reduction in heat transfer due to oil circulation with refrigerants. Maximization of heat transfer along with minimization of pressure drop is largely a matter of performance - cost tradeoffs.

designing compact evaporators and condenser could be an art, specially with the space constraints imposed due to Refrigerator and Freezer volume and standard size .

In our R12 into R134a Models conversion programme , through laboratory tests and also recommendation from most large refrigerator and houshold manufacturer and also restriction imposed due to design of refrigerators , we did not consider any changes or modifications on evapoarator and condenser , Azmayesh Co . has planned to change its tube and plate type of condenser and rollbond type of evaporator into wire tube evaporator and condenser in the near future after investigation of their efficiency on our products and engineering assessment and research .

But up to now , we found it unnecessary to change evaporator and condenser design .

3 - Capilary tube

The refrigerant expansion in a capillary tube is a non-reversible process . It has a potential for work , but requires a mechanism such as a miniature turbine to extract work . Such a mechanism will unlikly to be implemented due to the cost consideration .

AZMAYESH NON CFC REFRIGERATOR TRIAL PRODUCTION COMPRESSOR SELECTION FORM

R134a COMPRESSOR MODELS

MANUFACTURER																	
ZANUSSI			DANFOSS			NECCHI			GOLDSTAR			MATSUSHITA			ASPERA		
MODEL	WATT POWER	QTY	MODEL	WATT POWER	QTY	MODEL	WATT POWER	QTY	MODEL	WATT POWER	QTY	MODEL	WATT POWER	QTY	MODEL	WATT POWER	QTY
REF MODEL AR06			REF MODEL AR06			REF MODEL AR06			REF MODEL AR06			REF MODEL AR06			REF MODEL AR06		
GL40AH OR GL40AA	95 94		TL4G	85					VS36LAEG	84		S48C10KAX0	95		BP1048Z22	108	
REF MODEL AR08			REF MODEL AR08			REF MODEL AR08			REF MODEL AR08			REF MODEL AR08			REF. MODEL AR08		
GL45AH OR GL45AA	113 112		TL5G	106		ESC511	107		NR45LAEG	108		S48C13KAX5 OR QA51C11RAX5	110		BP1048Z22	108	
REF MODEL AR10			REF MODEL AR10			REF MODEL AR10			REF. MODEL AR10			REF. MODEL AR10			REF. MODEL AR10		
GL50AH OR GL50AA	129 128		TLS5F	128					NR58LAEG	124		QA57C13RAX5	122		BP1111Z	125	
REF MODEL AR12			REF MODEL AR12			REF MODEL AR12			REF. MODEL AR12			REF. MODEL AR12			REF MODEL AR12		
GL60AH OR GL60AA	155 154		TLS7F	167		ESC8H	172		NR62LAEG	156		QA77C18RAX5 D66C15RAX5	151		B1116Z	158	
REF MODEL ARF2			REF MODEL ARF2			REF MODEL ARF2			REF MODEL ARF2			REF. MODEL ARF2			REF MODEL ARF2		
GL80AH OR GL80AA	204 201		FR10G	189		ESC9H	214		V75LAEG	194		QA91C20RAX D91C21RAX5	227		B1118Z	204	

TEST CONDITION ASHRAE, EVAP. TEMP. = 23.3 C, AMB. TEMP. = 32 C, COND. TEMP. = 54 OR 55 C, SUCTION TEMP. 32 C, SUBCOOLING TEMP. 32 C

TABLE 1

The insertion of capillary tube into the suction line will creat a better heat transfer in order to get Sub-Cooling temperature of 32 degree centigrade .

For determination of length of capillary tube we tested our prototypes in two conditions .

a) With reducing 10% weight of refrigerant without changing the changing length of capillary tube .

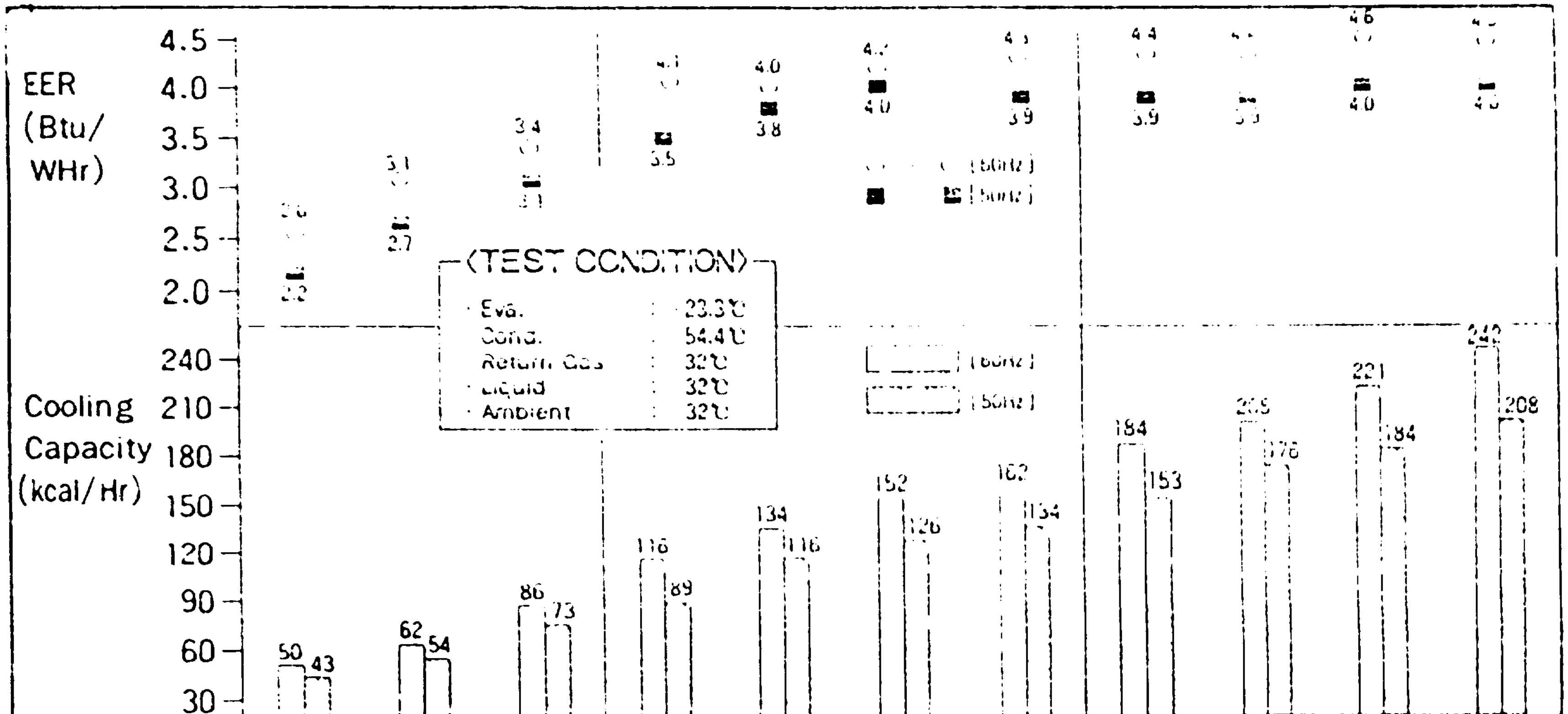
b) With reducing 10% weight of refrigerant and also increasing 10% length of capillary tube .

The results of laboratory tests show that there is not much difference between these two conditions , but the correct amount of refrigerant will guide us to an optimized condition .For this reason we are not going to increase the length of capillary tube unless in optimizing programme if we could see a remarkable energy saving and also compressor selection consideration .

so the optimization programme in this regard will need a long term period programme which Azmayesh Co . is planning to achive

COMPRESSOR PERFORMANCE

■ NEW FREON COMPRESSOR PERFORMANCE (STANDARD VERSION)



MODEL	VSF 24	VSF 28	VSF 36	NF 45	NF 52	NF * 57	NF 62	VF * 69	VF 75	VF * 80	VF * 88
Displacement (cm³/rev.)	2.42	2.84	3.58	4.50	5.20	5.73	6.22	6.90	7.46	8.10	8.83

Note : * Under development ┌ Sample available from Jan, 1994
└ Production available from July, 1994

■ COMPRESSOR LIFE TEST STATUS

TEST		TEST CONDITIONS		RESULTS					
				OIL		MOTOR		COMPRESSION PARTS	
		CFC 12/MINERAL	HFC 134a/ESTER	COLOR	T.A.N	HI POT	INSULATION	VALVES	WEAR
HI LOAD TEST		Ps/Pd=1/24(Kg/㎠G) Ambient 43℃ Duration 48 Hrs	1/27(Kg/㎠G) 43℃ 168 Hrs	L 0.5 ~1.5	0.01 ~0.05	O.K	O.K	No Sludge (Build-up)	· Limit: 10μ · Actual wear : 0~6μ
LIFE TEST	Continuous Run	Ps/Pd=1/15(Kg/㎠G) Ambient 43℃ Duration 2,200 Hrs	1/17(Kg/㎠G) 43℃ 2,200 Hrs / 4,400 Hrs	L 0.5 ~1.5	0.10 ~0.04	O.K	O.K	No Sludge (Build-up)	· Limit: 10μ · Actual wear : 0~5μ
	On/Off	Ps/Pd=1/15(Kg/㎠G) Ambient 43℃ On 5 min./Off 5min. Duration 30,000 Cycles	1/17(Kg/㎠G) 43℃ 5 min./5 min. 30,000 Cycles	L 0.5 ~1.5	0.01 ~0.05	O.K	O.K	No Sludge (Build-up)	· Limit: 10μ · Actual wear : 0~6μ

◆ **Actual wear with HFC 134a/Ester application shows the same wear level compared to CFC12's.**

REFRIGERATOR LIFE TEST STATUS

TEST PLACE	TEST CONDITIONS	QUANTITY (unit)	TEST PERIOD	RESULTS
TEST ROOM	● **Ambient** **15℃/43℃** **(Night/Day)** ● **Cycling Run** ● **Auto Defrost**	Around 100 units	March. '90 ~Dec. '92	● **No capillary blockage** ● **Capi-tube flow rate decrease : 4%~8%** **⇒ Considered allowable** ● **Compressor analysis showed reliable results**
		120 units	May. '93 ~	● **No problem has been found**
FIELD	● **Home Use**	Around 200 units	May. '92 ~	● **No claim has been received**
		Around 3,000 units	May. '93 ~	● **No claim has been received**

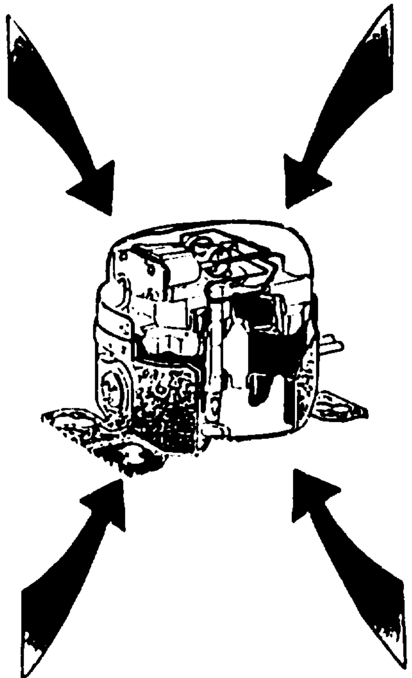
TECHNICAL TASKS
FOR HFC 134a/ESTER COMPRESSOR DEVLOPMENT

◆ HFC 134a's specific volume increase
⇒ 37% increase compared to CFC12's.
(−30℃/GAS)

Effect	· Cooling capacity reduced by around 15%
Counter-measure	· Gas passage improvement · Displacement increase · Motor torque optimization

◆ HFC 134a has no chlorine.
◆ HFC 134a has higher compression ratio.
⇒ 26% increase compared to CFC12's.
(Eva. −23.3℃/Cond. 54.4℃)

Effect	· Wear increase · Noise/Vibration increase
Counter-measure	· Anti-Wear coat for bearing surfaces · Wear mechanism improvement · Higher viscosity oil [15→22Cst, 22→32Cst] · Muffler/Suspension improvement



◆ Chlorinated detergent regulation
1.1.1-TCE
CFC 113

Effect	· Impurties may increase if there's no adequate substitues
Counter-measure	· Powerful substitues development · Washing system improvement

◆ Ester oil has high hygroscopicity.
⇒ Moisture absorption leads to acid formation in oil and deteriorates metals and organic materials.

Effect	· Sludge(Metallic soap) and extractions results in capillary tube blockage
Counter-measure	· Powerful dehydration system · Process control(Moisture prevention) · Special dryer should be needed · Charging machines should be for Ester only

NEW OIL

◆ TYPE : Polyol Ester

◆ MAKER

- KYODO OIL — JAPAN(Approved)
- SUN OIL — JAPAN(Approved)
- ICI — U.K(Under Testing)
- LUBRIZOHL — U.S.A(Under Testing)

◆ VISCOSITY RANGE

10/15/22/32 Cst @ 40℃

◆ CHARACTERISTICS(KYODO)

- Color : L 0.5(ASTM)
- T. A. N : 0.01(mgKOH/g)
- Pour Point : −50℃ below
- Phase Separation : −43℃ below
- Resistivity : 10^{9} (Ω·cm @25℃)
- Additives : Oxidation Inhibitor
  Acid Scavenger

〈HYGROSCOPICITY〉

ITEM \ OIL		ESTER OIL	MINERAL OIL
SATURATED WATER CONTENTS AT 25℃ (ppm)		1500	53
HYGROSCOPIC TEST WATER CONTENTS (ppm)	0 min.	23	21
	10 min.	56	25
	30 min.	165	30
	1 hr.	198	43
	2 hr.	296	47
	4 hr.	479	49
	8 hr.	744	50
	24 hr.	1007	52

ESTER OIL CHARACTERISTICS

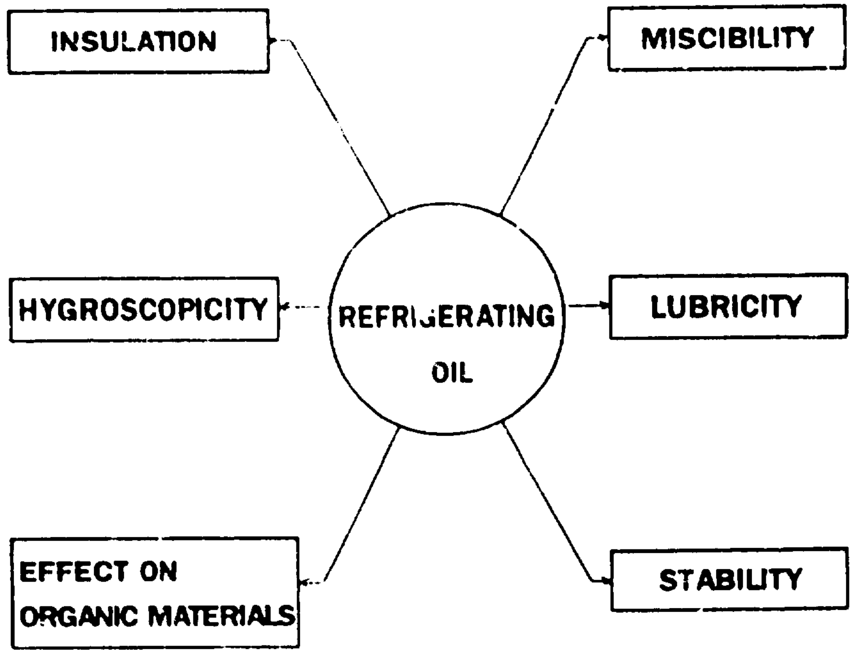
■ TARGETS OF NEW OILS FOR HFC 134a

TARGET (left)

Resistivity
$\rho \geq 10^{13}$ ($\Omega \cdot cm$)

As low as possible

As small as possible



TARGET (right)

Miscible range below −40℃

Falex Test: Wear better than R−12/Mineral

Chemical Stability:
Stable at Sealed Glass Tube Test
@ 175℃ × 14 Days (ASTM)

Hydrolytic Stability:
Stable at Bomb Test
@ 175℃ × 14 Days

COMPRESSOR LIFE TEST RESULTS

RELIABILITY DESIGN POINTS

DESCRIPTIONS	SPECIFICATION		IMPROVEMENT POINTS
	CONVENTIONAL (CFC 12)	IMPROVED (HFC 134a)	
1. Refrigerating Oil	Mineral	Ester (+ Additives)	· Compatible to HFC134a application
2. Motor Insulations — Insulation film — Sleeve(plastic) — Winding Coat	· PET · PBT · Enamel Coat + Paraffinic Wax	· Improved PET · Improved PBT · No Wax (Self Lubricating Wire)	· Lower oligomer extraction/Higher thermal resistivity · Lower oligomer extraction · Lower sludge formation
3. Material (Bearing Parts)	· Mild Steel	· Hi-carbon Steel · Surface Coat	· Higher wear resisitivity
4. Parts Cleaning	· Alkaline Wash · 1,1,1-TCE Degrease	· Improved Alkaline Wash	· Substitute for chlorine detergent · Higher parts cleanness level
5. Dehydration	· Drying System (Open shell status)	· Evacuation System	· More effective moisture removal

CHAPTER 5

EVALUATION OF PROTOTYPES

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

EVALUATION OF PROTOTYPES

1 - In this chapter we are going to Review , Analyze , Evaluate and compare breifly test results of refrigerator and ref-freezer Models AR06 , AR08 , AR10 , AR12 and ARF2 using refrigerant R134a in their refrigeration cycle , in comparison with previous R12 test reults .

2 - Azmayesh Industrial Factories Company is using Iranian Test Standards for its laboratory test procedure , so far . It seems that it would almost impractical to compare two different standards in defferent conditions , so it is reasonable to consider only some important data from our previous test results to compare with R134a .

3 - To compare the application of refrigerant R12 and R134a we basicly consider the performance of the refrigerator at the same ambient temperature usually 32 degree centigrade or 43 degree centigrade , since we perfom our laboratory test in 47 degree centigrade to comptly with Iranian standards , for some Models we have compared 43 and 47 degree centigrade .

4 - In this evaluation we are not going to discuss the advantage and disadvantage of use of refrigerant R134a , because these evaluation has been done previously by most famous and large Compressor and Refrigerator Manufacturer such as Danfoss , Goldstar , Leibherr , AEG and etc.

5 - Our laboratory test results show that at almost the same test condition we can get the following results . In this review we have neglected the compressor defferent manufacturer . The compressor effects in this regard have discussed by manufacturer in their respective reports to their customers .

MODELS AR06 and AR08

Description		R134a	R12
Freezer Mean Temperature	C	- 20	- 12
Freezer Bulb Temperature	C	- 22	- 18
Refrigerator Compartment Mean Temp .	C	+ 3	+ 5
Suction Temperature	C	+ 45	+ 45
Condenser Inlet Temperature	C	+ 65	+ 65
Condenser Outlet Temperature	C	+ 50	+ 51
Compressor Running Time	%	65 %	52 %
Ambient Temperature	C	43	43

NOTE : For Models AR06 and AR08 we use the same Refrigeration system

MODEL AR10

Description		R134a	R12
Freezer Mean Temperature	C	- 13	- 12
Freezer Bulb Temperature	C	- 22	- 19
Refrigerator Compartment Mean Temp.	C	+ 6	+ 3.6
Suction Temperature	C	+ 45	+ 44
Condenser Inlet Temperature	C	+ 75	+ 62
Condenser Outlet Temperature	C	+ 50	+ 44
Compressor Running Time	%	56 %	55 %
Ambient Temperature	C	43	43

MODEL AR12

Description		R134a	R12
Freezer Mean Temperature	C	- 18	- 12
Freezer Bulb Temperature	C	- 24	- 18
Refrigerator Compartment Mean Temp.	C	+ 4	+ 4.3
Suction Temperature	C	+ 34	+ 33
Condenser Inlet Temperature	C	+ 65	+ 65
Condenser Outlet Temperature	C	+ 53	+ 50
Compressor Running Time	%	41 %	37 %
Ambient Temperature	C	32	3

MODEL ARF2

Description		R134a	R12
Freezer Mean Temperature	C	- 15	- 23
Freezer Bulb Temperature	C	- 11	- 27
Refrigerator Compartment Mean Temp .	C	+ 1	+ 3
Suction Temperature	C	+ 45	+ 39
Condenser Inlet Temperature	C	+ 90	+ 61
Condenser Outlet Temperature	C	+ 50	+ 48
Compressor Running Time	%	74 %	% 72
Ambient Temperature	C	43	47

5 -1- From the test results figure of our refrigerator , we find out that the Freezer mean temperature for R134a is better than R12 and condenser outlet and inlet temperature are almost the same , it means that it is not necessary to modify our evaporator and condenser assembly .

6 - Compressor running time is also acceptable because they are below 80% and comparing with R12 it is sometimes much less . So , we conclude that R134a compressor types are more efficient than R12 compressor on our refrigerators .

7 - Suction temperature is almost the same and it means that our Refrigeration cycle is suitable for R134a .

8 - The evaporating temperature varys from -22 to -24 degree centigrade using **R134a** refrigerant , these figures show that our test condition could be **ASHRAE** Standard and by Optimizing the refrigerant weight and suitable air distribution in fresh food compartment we can easyly get -23.3 degree centigrade evaporating temperature .

9 - The suction temperature is around 33 degree C for 32 degree C ambient temperature and 43 to 45 degree C for 43 C ambient temperature , these two figures are acceptable it shows that our test condition comply with **ASHRAE** standard .

10 - As previously mentioned , through these test and evaluation we found out that our products has a minor problem in distributing cold air inside fresh food compartment , in order to get a unified and stable air temperature we have modified our water drain tray under evaporator compartment to get mean temperature of + 5 "C " in fresh food compartment .

This deffect has no relation with selection of refrigerant R134a and design failure of internal part existed before even with R12 .

AZMAYESH INDUSTRIAL FACTORIES CO.

R12 PROTOTYPE TEST SHEET

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FORM NO. 0001 DATE APRIL 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR06
SERIAL NUMBER :	PROTOTYPE NUMBER : NON
CLASSIFICATION TEST CONDITION ' T '	AMBIENT TEMPERATURE 43 C
COMPRESSOR NAME : ZANUSSI	MODEL : G45AW
WATT . CAPACITY : 95 WATT	POWER CONSUMPTION . WATT 24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 110
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 180

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON °C	OFF °C
Freezer Air Temp. t_1 c		
Freezer Air Temp . t_2 c		
Freezer Air Temp . t_3 c		
Freezer Mean Temp t_{m1}	-11	-13
Freezer Bulb Temp . t_4	-12	-18
Refrigerator Comp. Temp . t_5	0	0
Refrigerator Comp. Temp. t_6	+5	+5
Refrigerator Co	+10	+10
Refrigerator Comp. Mean Temp t_{m2}	+5	+5
Crisper Comp. Temp . t_8	+10	+10
Compressor Shell Temp.	64	65
Condenser Inlet Temp	47	65
Condenser Outlet Temp .	45	51
Suction Temp.	43	45

REMARKS

COMPRESSOR OPERATING TIME 52 %

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R12 PROTOTYPE TEST SHEET

PAGE 5-10

FORM NO. 0002

DATE : APRIL 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR08
SERIAL NUMBER :	PROTOTYPE NUMBER : NON
CLASSIFICATION/TEST CONDITION " T "	AMBIENT TEMPERATURE : 43 C
COMPRESSOR NAME : ZANUSSI	MODEL : G45AW
WATT . CAPACITY : 108 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	REFRIGERANT WEIGHT GR 110
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 230

THERMOSTAT TYPE	THERMOSTAT SETTING			
	ON	NO.	OFF	NO
Freezer Air Temp. t_1 c				
Freezer Air Temp . t_2 c				
Freezer Air Temp . t_3 c				
Freezer Mean Temp . t_{m1}	-11		-13	
Freezer Bulb Temp . t_4	-12		-18	
Refrigerator Comp. Temp . t_5	0		0	
Refrigerator Comp. Temp. t_6	+5		+5	
Refrigerator Co	+10		+10	
Refrigerator Comp. Mean Temp . t_{m2}	+5		+5	
Crisper Comp. Temp . t_8	+10		+10	
Compressor Shell Temp.	64		65	
Condenser Inlet Temp	47		65	
Condenser Outlet Temp .	45		51	
Suction Temp.	43		5	

REMARKS

COMPRESSOR OPERATING TIME 52 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R12 PROTOTYPE TEST SHEET

FORM NO 0003 DATE APRIL 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARIO
SERIAL NUMBER :	PROTOTYPE NUMBER : NON
CLASSIFICATION, TEST CONDITION " N "	AMBIENT TEMPERATURE : 32 C
COMPRESSOR NAME : MATSUSHITA	MODEL : FN51Q11G
WATT. CAPACITY : 125 WATT	POWER CONSUMPTION . WATT 24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 140
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT .285

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NO	OFF NO
Freezer Air Temp. t_1 c		
Freezer Air Temp . t_2 c		
Freezer Air Temp . t_3 c		
Freezer Mean Temp . t_{m1}	-6	-10
Freezer Bulb Temp . t_4	-17	-21
Refrigerator Comp. Temp . t_5	[illegible]	-1
Refrigerator Comp. Temp. t_6	+2	+2
Refrigerator Co	+6	+6
Refrigerator Comp. Mean Temp t_{m2}	2.5	+2.5
Crisper Comp. Temp . t_8	+6	+6
Compressor Shell Temp.	55	58
Condenser Inlet Temp .	36	48
Condenser Outlet Temp .	34	38
Suction Temp.	30	32

REMARKS COMPRESSOR OPERAYING TIME 35 %

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R12 PROTOTYPE TEST SHEET

FORM NO. 0004 DATE : APRIL 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR12
SERIAL NUMBER :	PROTOTYPE NUMBER : NON
CLASSIFICATION/TEST CONDITION " N "	AMBIENT TEMPERATURE : 32 C
COMPRESSOR NAME : MATSUSHITA	MODEL : FN51Q11G
WATT . CAPACITY : 158 WATT	POWER CONSUMPTION . WATT 24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 150
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT .340

THERMOSTAT TYPE	THERMOSTAT SETTING	
	[illegible]	[illegible]
Freezer Air Temp. t1 :		
Freezer Air Temp . t2 c		
Freezer Air Temp . t3 c		
Freezer Mean Temp . t m1	-12	-12
Freezer Bulb Temp . t4	-15	-18
Refrigerator Comp. Temp . t5	+1	+1
Refrigerator Comp. Temp. t6	+5	+5
Refrigerator Co	+7	+7
Refrigerator Comp Mean Temp t m2	4.3	+4.3
Crisper Comp. Temp . t8	+7	+7
Compressor Shell Temp.	60	64
Condenser Inlet Temp .	40	50
Condenser Outlet Temp .	30	40
Suction Temp.	33	33

REMARKS COMPRESSOR OPERAYING TIME 37 %

AZMAYESH INDUSTRIAL FACTORIES CO .

R12 PROTOTYPE TEST SHEET

FORM NO. 0005

DATE : APRIL 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARF2
SERIAL NUMBER :	PROTOTYPE NUMBER : NON
CLASSIFICATION/TEST CONDITION " N "	AMBIENT TEMPERATURE : 32 C
COMPRESSOR NAME : MATSUSHITA	MODEL : FN77G1BG
WATT . CAPACITY : 205 WATT	POWER CONSUMPTION . WATT / 24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR. 220
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT .310

THERMOSTAT TYPE	THERMOSTAT SETTING ON NO	OFF NC
Freezer Air Temp. t_1 c		
Freezer Air Temp . t_2 c		
Freezer Air Temp . t_3 c		
Freezer Mean Temp . t_{m1}	-18	-24
Freezer Bulb Temp . t_4	-20	-27
Refrigerator Comp. Temp . t_5		
Refrigerator Comp. Temp. t_6	+1	+1
Refrigerator Co	+4	+4
Refrigerator Comp. Mean Temp . t_{m2}	4.3	+4.3
Crisper Comp. Temp . t_8	+7	+7
Compressor Shell Temp.	53	50
Condenser Inlet Temp .	35	55
Condenser Outlet Temp .	34	42
Suction Temp.	23	33

REMARKS COMPRESSOR OPERAYING TIME 53 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-14

FORM NO. ______ DATE 3 Sep 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR06
SERIAL NUMBER --	PROTOTYPE NUMBER R6-01
CLASSIFICATION/TEST CONDITION --	AMBIENT TEMPERATURE 18 c
COMPRESSOR NAME Goldstar	MODEL NR45 LAEG
WATT. CAPACITY 95	POWER CONSUMPTION. WATT 24 Hrs --
VOLT 220 AMPER -- HRTZ 50	REFRIGERANT WEIGHT GR 110
INSULATION TYPE C.F.C.R FCQM	REF. INSIDE VOLUME LIT. 180

THERMOSTAT TYPE	THERMOSTAT SETTING			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-10		-15	
Freezer Air Temp. t_2	-11		-16	
Freezer Air Temp. t_3	-12		-16	
Freezer Mean Temp. t_{m1}	-11		-16	
Freezer Bulb Temp. t_4	-19		-20	
Refrigerator Comp. Temp. t_5	-2		-3	
Refrigerator Comp. Temp. t_6	2		1	
Refrigerator Comp. Temp t_7	4		2	
Refrigerator Comp. Mean Temp. t_{m2}	1		0	
Crisper Comp. Temp. t_8	+4		+4	
Compressor Shell Temp.	20		30	
Condenser Inlet Temp.	20		28	
Condenser Outlet Temp.	19		22	
Suction Temp.	-19		20	

REMARKS Working percentage = 25%

AZMAYESH INDUSTRIAL FACTORIES CO .

R134a PROTOTYPE TEST SHEET

5-15

FORM NO. ______ DATE . 3. Sep. 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR06
SERIAL NUMBER --	PROTOTYPE NUMBER R6-07
CLASSIFICATION TEST CONDITION Moderate	AMBIENT TEMPERATURE 32 c
COMPRESSOR NAME Goldstar	MODEL NR 45 LAEG
WATT. CAPACITY 95	POWER CONSUMPTION . WATT 24 Hrs
VOLT 220 AMPER -- HRTZ. 50	RIFRIGERANT WEIGHT GR 110
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 180

THERMOSTAT TYPE	[illegible]			
	ON	[illegible]	OFF	[illegible]
Freezer Air Temp. t_1	-11		-15	
Freezer Air Temp. t_2	-12		-16	
Freezer Air Temp. t_3	-13		-16	
Freezer Mean Temp. t_{m1}	-12		-16	
Freezer Bulb Temp. t_4	-15		-21	
Refrigerator Comp. Temp. t_5	+4		+3	
Refrigerator Comp. Temp. t_6	+5		+4	
Refrigerator Comp. Temp t_7	+6		+5	
Refrigerator Comp. Mean Temp. t_{m2}	+5		+4	
Crisper Comp. Temp. t_8	+5		+5	
Compressor Shell Temp.	35		60	
Condenser Inlet Temp.	54		50	
Condenser Outlet Temp.	33		42	
Suction Temp.	32		33	

REMARKS Working percentage = 33%

AZMAYESH INDUSTRIAL FACTORIES CO .

R134a PROTOTYPE TEST SHEET

5-16

FORM NO. ________ DATE 3. Sep. 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR06
SERIAL NUMBER -	PROTOTYPE NUMBER R6-01
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43 c
COMPRESSOR NAME Goldstar	MODEL NR 45 LAEG
WATT. CAPACITY 95	POWER CONSUMPTION . WATT. 24 Hrs
VOLT 220 AMPER -- HRTZ. 50	REFRIGERANT WEIGHT GR 110
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 180

THERMOSTAT TYPE	THERMOSTAT SETTING ON	NO	OFF	NO
Freezer Air Temp. t_1	-10		-15	
Freezer Air Temp. t_2	-11		-16	
Freezer Air Temp. t_3	-9		-14	
Freezer Mean Temp. t_{m1}	-10		-15	
Freezer Bulb Temp. t_4	-14		-20	
Refrigerator Comp. Temp. t_5	-1		-1	
Refrigerator Comp. Temp. t_6	+8		+3	
Refrigerator Comp. Temp t_7	+8		+7	
Refrigerator Comp. Mean Temp. t_{m2}	+6		+5	
Crisper Comp. Temp. t_8	+8		+8	
Compressor Shell Temp.	60		73	
Condenser Inlet Temp.	45		70	
Condenser Outlet Temp.	44		60	
Suction Temp.	43		44	

REMARKS Working percentage = 75%

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-17

Date - 4 Sep 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARO 6
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R6-02
CLASSIFICATION/TEST CONDITION 'T'	AMBIENT TEMPERATURE : 43 °C
COMPRESSOR NAME : Goldstar	MODEL : NR 45 LAEG
WATT. CAPACITY : WATT 95	POWER CONSUMPTION. WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	RIFRIGERANT WEIGHT GR 100
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 180

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NO.	OFF NO
Freezer Air Temp. t_1 c	-10	-15
Freezer Air Temp. t_2 c	-11	-16
Freezer Air Temp. t_3 c	-9	-13
Freezer Mean Temp. t_m	-11	-16
Freezer Bulb Temp. t_4	-14	-22
Refrigerator Comp. Temp. t_5	+1	+1
Refrigerator Comp. Temp. t_6	+8	+8
Refrigerator Comp. t_7	+8	+8
Refrigerator Comp. Mean Temp. t_{m2}	+7	+5
Crisper Comp. Temp. t_8	+8	+8
Compressor Shell Temp.	60	73
Condenser Inlet Temp.	45	70
Condenser Outlet Temp.	44	60
Suction Temp.	43	44

REMARKS COMPRESSOR OPERAYING TIME % 75

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-18

Date: 4 Sep 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR06
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R6-03
CLASSIFICATION TEST CONDITION 'T'	AMBIENT TEMPERATURE : 43 °C
COMPRESSOR NAME : Necchi	MODEL : ESC4H
WATT . CAPACITY : 95 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 180

THERMOSTAT TYPE	THERMOSTAT SETTING ON NC	OFF NC
Freezer Air Temp. t_1 c	-10	-17
Freezer Air Temp . t_2 c	-12	-18
Freezer Air Temp . t_3 c	-10	-14
Freezer Mean Temp . t_{m1}	11	-16
Freezer Bulb Temp . t_4	-15	-24
Refrigerator Comp. Temp . t_5	+8	+9
Refrigerator Comp. Temp. t_6	+8	+8
Refrigerator Comp. t_7	+7	+6
Refrigerator Comp. Mean Temp . t_{m2}	+7	+5
Crisper Comp. Temp . t_8	+8	+8
Compressor Shell Temp.	65	80
Condenser Inlet Temp .	50	75
Condenser Outlet Temp .	45	60
Suction Temp.	43	50

REMARKS COMPRESSOR OPERAYING TIME % 70

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-19

Date 4 Sep 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR06
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R6-04
CLASSIFICATION/TEST CONDITION 'T'	AMBIENT TEMPERATURE : 43 °C
COMPRESSOR NAME : Danfoss	MODEL : TL4G
WATT . CAPACITY : 95 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 180

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NC	ON NC
Freezer Air Temp. t_1 c	-9	-15
Freezer Air Temp . t_2 c	-11	-16
Freezer Air Temp . t_3 c	-10	-13
Freezer Mean Temp . t_{m1}	-10	-15
Freezer Bulb Temp . t_4	-15	-22
Refrigerator Comp. Temp . t_5	+8	+8
Refrigerator Comp. Temp. t_6	+8	+8
Refrigerator Comp. t_7	+7	+6
Refrigerator Comp. Mean Temp . t_{m2}	+7	+5
Crisper Comp. Temp . t_8	+8	+8
Compressor Shell Temp.	60	75
Condenser Inlet Temp .	55	65
Condenser Outlet Temp .	50	65
Suction Temp.	30	45

REMARKS COMPRESSOR OPERAYING TIME % 65

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-20

FORM NO. ______ DATE ______

DESCRIPTION	DESCRIPTION
PRODUCT NAME AR	MODEL AR08
SERIAL NUMBER --	PROTOTYPE NUMBER R8-1
CLASSIFICATION TEST CONDITION --	AMBIENT TEMPERATURE 18 c
COMPRESSOR NAME Aspera	MODEL Ep 1048 Z 22
WATT. CAPACITY 103	POWER CONSUMPTION. WATT 24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE C.F.C Foam	REF. INSIDE VOLUME LIT. 220

THERMOSTAT TYPE	THERMOSTAT SETTING ON	NO.	OFF	NO.
Freezer Air Temp. t_1	-12		-15	
Freezer Air Temp. t_2	-13		-16	
Freezer Air Temp. t_3	-12		-15	
Freezer Mean Temp. t_{m1}	-12		-15	
Freezer Bulb Temp. t_4	-15		-21	
Refrigerator Comp. Temp. t_5	-1		-1	
Refrigerator Comp. Temp. t_6	2		1	
Refrigerator Comp. Temp t_7	+3		+2	
Refrigerator Comp. Mean Temp. t_{m2}	+1		+1	
Crisper Comp. Temp. t_8	+4		+4	
Compressor Shell Temp.	40		44	
Condenser Inlet Temp.	23		37	
Condenser Outlet Temp.	+19		23	
Suction Temp.	+18		19	

REMARKS Working Percentage = 19%

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-21

FORM NO. ______ DATE ______

DESCRIPTION	DESCRIPTION
PRODUCT NAME AR	MODEL A203
SERIAL NUMBER --	PROTOTYPE NUMBER R8-1
CLASSIFICATION TEST CONDITION	AMBIENT TEMPERATURE 32 C
COMPRESSOR NAME ASpera	MODEL 3P 1043 Z 22
WATT. CAPACITY 108	POWER CONSUMPTION. WATT 24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE C.F.C R. Foam	REF. INSIDE VOLUME LIT. 230

THERMOSTAT TYPE	THERMOSTAT SETTING ON	NO.	OFF	NO.
Freezer Air Temp. t_1	-12		-15	
Freezer Air Temp. t_2	-13		-16	
Freezer Air Temp. t_3	-12		-15	
Freezer Mean Temp. t_{m1}	-12		-15	
Freezer Bulb Temp. t_4	-15		-21	
Refrigerator Comp. Temp. t_5	-2		-3	
Refrigerator Comp. Temp. t_6	+2		+1	
Refrigerator Comp. Temp t_7	+3		+2	
Refrigerator Comp. Mean Temp. t_{m2}	+1		0	
Crisper Comp. Temp. t_8	+4		+3	
Compressor Shell Temp.	55		60	
Condenser Inlet Temp.	50		45	
Condenser Outlet Temp.	+19		30	
Suction Temp.	18		19	

REMARKS Working percentage = 30%

AZMAYESH INDUSTRIAL FACTORIES CO

R134a PROTOTYPE TEST SHEET

FORM NO. 0018 DATE May 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR08
SERIAL NUMBER NON	PROTOTYPE NUMBER R8—1
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Aspera	MODEL BP 1048 Z 22
WATT. CAPACITY 108	POWER CONSUMPTION. WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 230

THERMOSTAT TYPE	[illegible]			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-10		-20	
Freezer Air Temp. t_2	-11		-21	
Freezer Air Temp. t_3	-10		-20	
Freezer Mean Temp. t_{m1}	-10		-20	
Freezer Bulb Temp. t_4	-14		-22	
Refrigerator Comp. Temp. t_5	+3		+2	
Refrigerator Comp. Temp. t_6	+4		+3	
Refrigerator Comp. Temp t_7	+5		+4	
Refrigerator Comp. Mean Temp. t_{m2}	+4		+3	
Crisper Comp. Temp. t_8	+7		+6	
Compressor Shell Temp.	70		75	
Condenser Inlet Temp.	45		65	
Condenser Outlet Temp.	45		50	
Suction Temp.	44		45	

REMARKS Working percentage ≠ 65 %

AZMAYESH INDUSTRIAL FACTORIES CO .

R134a PROTOTYPE TEST SHEET

5-23

Date 10 May 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR08
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R8-02
CLASSIFICATION TEST CONDITION ·T·	AMBIENT TEMPERATURE : 43 °C
COMPRESSOR NAME : Zanussi	MODEL : GL 45 AA
WATT . CAPACITY : 108 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 230

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NC	OFF NC
Freezer Air Temp. t_1 c	-10	-20
Freezer Air Temp . t_2 c	-11	-22
Freezer Air Temp . t_3 c	-10	-21
Freezer Mean Temp . t_{m1}	-10	-21
Freezer Bulb Temp . t_4	-14	-24
Refrigerator Comp. Temp . t_5	+3	+2
Refrigerator Comp. Temp. t_6	+5	+3
Refrigerator Comp. t_7	+5	+4
Refrigerator Comp. Mean Temp . t_{m2}	+8	+5
Crisper Comp. Temp . t_8	+7	+6
Compressor Shell Temp.	75	80
Condenser Inlet Temp .	45	67
Condenser Outlet Temp .	45	50
Suction Temp.	40	45

REMARKS COMPRESSOR OPERAYING TIME % 65

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-29

Date: 10 May 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR08
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R8-03
CLASSIFICATION/TEST CONDITION " T"	AMBIENT TEMPERATURE : 43°C
COMPRESSOR NAME : Necchi	MODEL : ESC5H
WATT . CAPACITY : 108 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	REFRIGERANT WEIGHT GR 110
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 230

THERMOSTAT TYPE	THERMOSTAT SETTING ON NO.	OFF NO.
Freezer Air Temp. t1 c	-10	-18
Freezer Air Temp. t2 c	-11	-17
Freezer Air Temp. t3 c	-10	-19
Freezer Mean Temp. tm1	-10	-18
Freezer Bulb Temp. t4	-15	-22
Refrigerator Comp. Temp. t5	+4	+3
Refrigerator Comp. Temp. t6	+6	+3
Refrigerator Comp. t7	+5	+6
Refrigerator Comp. Mean Temp. tm2	+5	+4
Crisper Comp. Temp. t8	+8	+7
Compressor Shell Temp.	70	80
Condenser Inlet Temp.	50	65
Condenser Outlet Temp.	45	50
Suction Temp.	40	45

REMARKS

COMPRESSOR OPERAYING TIME % 60

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-25

Date: 10 May 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR08
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R8-04
CLASSIFICATION TEST CONDITION "T"	AMBIENT TEMPERATURE : 43 °C
COMPRESSOR NAME : Danfoss	MODEL : TL5G
WATT . CAPACITY : 108 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 100
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 230

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NC.	OFF NC
Freezer Air Temp. t1 c	-11	-20
Freezer Air Temp . t2 c	-12	-22
Freezer Air Temp . t3 c	-10	-21
Freezer Mean Temp . tm1	-11	-21
Freezer Bulb Temp . t4	-15	-25
Refrigerator Comp. Temp . t5	+5	+3
Refrigerator Comp. Temp. t6	+6	+4
Refrigerator Comp t7	+7	+3
Refrigerator Comp. Mean Temp . tm2	+6	+3
Crisper Comp. Temp . t8	+8	+8
Compressor Shell Temp.	65	80
Condenser Inlet Temp .	55	65
Condenser Outlet Temp .	40	45
Suction Temp.	40	45

REMARKS COMPRESSOR OPERAYING TIME % 65

AZMAYESH INDUSTRIAL FACTORIES CO .

R134a PROTOTYPE TEST SHEET

5-25

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR10
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R10-1
CLASSIFICATION/TEST CONDITION "N"	AMBIENT TEMPERATURE : 18 °C
COMPRESSOR NAME : Goldstar	MODEL : NR58 LAEG
WATT . CAPACITY : 125 WATT	POWER CONSUMPTION . WATT/24 Hr.
VOLT 220 AMPER HRTZ 50	RIFRIGERANT WEIGHT GR 125
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 285

THERMOSTAT TYPE	THERMOSTAT SETTING ON	OFF
Freezer Air Temp. t1 c	-12	-16
Freezer Air Temp . t2 c	-13	-16
Freezer Air Temp . t3 c	-12	-16
Freezer Mean Temp . tm1	-12	-16
Freezer Bulb Temp . t4	-16	-23
Refrigerator Comp. Temp . t5	-1	-1
Refrigerator Comp. Temp. t6	+2	+1
Refrigerator Co	+3	+2
Refrigerator Comp. Mean Temp . tm2	+1	+1
Crisper Comp. Temp . t8	+4	+4
Compressor Shell Temp.	40	45
Condenser inlet Temp .	24	38
Condenser Outlet Temp .	+18	25
Suction Temp.	+18	20

REMARKS COMPRESSOR OPERAYING TIME % 20

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-27

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR10
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R10 -1
CLASSIFICATION TEST CONDITION ·N·	AMBIENT TEMPERATURE : 32°C
COMPRESSOR NAME : GoldStar	MODEL : NR58LAEG
WATT . CAPACITY : 125 WATT	POWER CONSUMPTION . WATT. 24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 125
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 285

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NC	OFF NC
Freezer Air Temp. t1 c	-11	-15
Freezer Air Temp . t2 c	-12	-17
Freezer Air Temp . t3 c	-13	-16
Freezer Mean Temp . tm1	-12	-16
Freezer Bulb Temp . t4	-15	-23
Refrigerator Comp. Temp . t5	+2	+2
Refrigerator Comp. Temp. t6	+3	+1
Refrigerator Comp t7	+4	+2
Refrigerator Comp. Mean Temp . tm2	+3	+2
Crisper Comp. Temp . t8	+4	+3
Compressor Shell Temp.	55	60
Condenser Inlet Temp	35	45
Condenser Outlet Temp .	20	30
Suction Temp.	25	26

REMARKS COMPRESSOR OPERAYING TIME %34

AZMAYESH INDUSTRIAL FACTORIES CO .

R134a PROTOTYPE TEST SHEET

PAGE 5 - 28

FORM NO. 0016

DATE MAY 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR10
SERIAL NUMBER NON	PROTOTYPE NUMBER R10-1
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43 c
COMPRESSOR NAME Goldstar	MODEL NR 58 LAE G
WATT. CAPACITY 125	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR. 125
INSULATION TYPE C.F.C. FOAM	REF. INSIDE VOLUME LIT. 285

THERMOSTAT TYPE	ON	NO.	OFF	NO.
Freezer Air Temp. t_1	-13		-20	
Freezer Air Temp. t_2	-12		-19	
Freezer Air Temp. t_3	-13		-20	
Freezer Mean Temp. t_{m1}	-13		-20	
Freezer Bulb Temp. t_4	-16		-23	
Refrigerator Comp. Temp. t_5	+3		+2	
Refrigerator Comp. Temp. t_6	+5		+4	
Refrigerator Comp. Temp t_7	+7		+6	
Refrigerator Comp. Mean Temp. t_{m2}	+5		+4	
Crisper Comp. Temp. t_8	+7		+6	
Compressor Shell Temp.	80		85	
Condenser Inlet Temp.	45		60	
Condenser Outlet Temp.	45		98	
Suction Temp.	44		45	

REMARKS Working percentage = 65 %

AZMAYESH INDUSTRIAL FACTORIES CO .

R134a PROTOTYPE TEST SHEET PAGE 5-29

FORM NO. 0017 DATE MAY 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR10
SERIAL NUMBER NON	PROTOTYPE NUMBER NO - 2
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Aspera	MODEL BP 1111 Z
WATT. CAPACITY 125	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 125
INSULATION TYPE C.F.C.R - FOAM	REF. INSIDE VOLUME LIT. 285

THERMOSTAT TYPE	[illegible]	[illegible]
Freezer Air Temp. t_1	-9	-13
Freezer Air Temp. t_2	-10	-12
Freezer Air Temp. t_3	-8	-12
Freezer Mean Temp. t_{m1}	-9	-13
Freezer Bulb Temp. t_4	-16	-22
Refrigerator Comp. Temp. t_5	+6	+6
Refrigerator Comp. Temp. t_6	+5	+5
Refrigerator Comp. Temp t_7	+7	+7
Refrigerator Comp. Mean Temp. t_{m2}	+6	+6
Crisper Comp. Temp. t_8	+7	+7
Compressor Shell Temp.	80	86
Condenser Inlet Temp.	47	77
Condenser Outlet Temp.	46	50
Suction Temp.	44	45

REMARKS Working percentage = 56 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-30

Date: 15 May 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR10
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R10-03
CLASSIFICATION/TEST CONDITION "T"	AMBIENT TEMPERATURE : 43°C
COMPRESSOR NAME : Zanussi	MODEL : GL 60 AA
WATT . CAPACITY : 125 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 125
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 285

THERMOSTAT TYPE	THERMOSTAT SETTING ON NC.	OFF NC
Freezer Air Temp. t_1 c	-14	-18
Freezer Air Temp . t_2 c	-12	-19
Freezer Air Temp . t_3 c	-11	-20
Freezer Mean Temp . t_m	-12	-19
Freezer Bulb Temp . t_4	-16	-23
Refrigerator Comp. Temp . t_5	+3	+2
Refrigerator Comp. Temp. t_6	+6	+5
Refrigerator Comp t_7	+6	+4
Refrigerator Comp. Mean Temp . t_{mr}	+5	+4
Crisper Comp. Temp . t_8	+8	+7
Compressor Shell Temp.	80	85
Condenser Inlet Temp .	50	65
Condenser Outlet Temp .	40	50
Suction Temp.	40	45

REMARKS COMPRESSOR OPERAYING TIME % 60

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-31

Date: 15 May 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR10
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R10-04
CLASSIFICATION/TEST CONDITION 'T'	AMBIENT TEMPERATURE : 43°C
COMPRESSOR NAME : Danfoss	MODEL : FR 7.5G
WATT . CAPACITY : 125 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	RIFRIGERANT WEIGHT GR 125
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 285

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NO.	ON NO
Freezer Air Temp. t_1 c	-14	-16
Freezer Air Temp . t_2 c	-12	-18
Freezer Air Temp . t_3 c	-10	-17
Freezer Mean Temp . t_{m1}	-12	-17
Freezer Bulb Temp . t_4	-19	-22
Refrigerator Comp. Temp . t_5	+4	+3
Refrigerator Comp. Temp. t_6	+6	+5
Refrigerator Comp t_7	+5	+5
Refrigerator Comp. Mean Temp . t_{m2}	+5	+4
Crisper Comp. Temp . t_8	+9	+9
Compressor Shell Temp.	80	85
Condenser Inlet Temp .	50	60
Condenser Outlet Temp .	40	49
Suction Temp.	38	45

REMARKS COMPRESSOR OPERAYING TIME % 70

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET — *PAGE 5 - 32*

FORM NO. *0009* DATE *APRIL 95*

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR12
SERIAL NUMBER *NON*	PROTOTYPE NUMBER *R12-2*
CLASSIFICATION/TEST CONDITION --	AMBIENT TEMPERATURE 18 c
COMPRESSOR NAME Danfoss	MODEL FR 8.5 G
WATT. CAPACITY 158	POWER CONSUMPTION . WATT/24 Hrs --
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 150
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME T. 340

THERMOSTAT TYPE	[illegible]			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-13		-14	
Freezer Air Temp. t_2	-14		-15	
Freezer Air Temp. t_3	-13		-14	
Freezer Mean Temp. t_{m1}	-13		-14	
Freezer Bulb Temp. t_4	-15		-20	
Refrigerator Comp. Temp. t_5	+2		+1	
Refrigerator Comp. Temp. t_6	+2		+1	
Refrigerator Comp. Temp t_7	+3		+2	
Refrigerator Comp. Mean Temp. t_{m2}	+2		+1	
Crisper Comp. Temp. t_8	5		4	
Compressor Shell Temp.	30		35	
Condenser Inlet Temp.	22		32	
Condenser Outlet Temp.	20		22	
Suction Temp.	18		19	

REMARKS Working percentage = 17 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

FORM NO. 2015 DATE May 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-4
CLASSIFICATION TEST CONDITION	AMBIENT TEMPERATURE 18 c
COMPRESSOR NAME Aspera	MODEL B 1116 Z
WATT. CAPACITY 138	POWER CONSUMPTION. WATT. 24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 135
INSULATION TYPE C.F.C.R - FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	[illegible]			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-14		-17	
Freezer Air Temp. t_2	-15		-18	
Freezer Air Temp. t_3	-14		-17	
Freezer Mean Temp. t_{m1}	-4		-17	
Freezer Bulb Temp. t_4	-17		-24	
Refrigerator Comp. Temp. t_5	1		0	
Refrigerator Comp. Temp. t_6	2		1	
Refrigerator Comp. Temp t_7	3		2	
Refrigerator Comp. Mean Temp. t_{m2}	2		1	
Crisper Comp. Temp. t_8	5		5	
Compressor Shell Temp.	26		32	
Condenser Inlet Temp.	21		27	
Condenser Outlet Temp.	20		22	
Suction Temp.	18		19	

REMARKS Working percentage = 20 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

FORM NO. 0011 DATE APRIL 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-2
CLASSIFICATION/TEST CONDITION Moderate	AMBIENT TEMPERATURE 32 c
COMPRESSOR NAME Danfoss	MODEL FR 8.5 G
WATT. CAPACITY 158	POWER CONSUMPTION. WATT/24 Hrs --
VOLT 220 AMPER - HRTZ. 50	REFRIGERANT WEIGHT GR 150
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING			
	ON	NO.	OFF	NO.
Freezer Air Temp. t_1	-15		-16	
Freezer Air Temp. t_2	-14		-14	
Freezer Air Temp. t_3	-14		-15	
Freezer Mean Temp. t_{m1}	-14		-15	
Freezer Bulb Temp. t_4	-15		-20	
Refrigerator Comp. Temp. t_5	+4		+3	
Refrigerator Comp. Temp. t_6	+5		+4	
Refrigerator Comp. Temp t_7	+6		+5	
Refrigerator Comp. Mean Temp. t_{m2}	+5		+4	
Crisper Comp. Temp. t_8	6		5	
Compressor Shell Temp.	54		58	
Condenser Inlet Temp.	39		55	
Condenser Outlet Temp.	35		39	
Suction Temp.	32		33	

REMARKS Working percentage = 40 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET ——— PAGE 5 - 35

FORM NO. 0014 DATE MAY 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-4
CLASSIFICATION/TEST CONDITION Moderate	AMBIENT TEMPERATURE 32 c
COMPRESSOR NAME Aspera	MODEL B 1116 Z
WATT. CAPACITY 138	POWER CONSUMPTION. WATT 24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 135
INSULATION TYPE C.F.C.R - FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	[illegible]			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-14		-18	
Freezer Air Temp. t_2	-14		-18	
Freezer Air Temp. t_3	-15		-19	
Freezer Mean Temp. t_{m1}	-14		-18	
Freezer Bulb Temp. t_4	-17		-24	
Refrigerator Comp. Temp. t_5	+2		+2	
Refrigerator Comp. Temp. t_6	+4		+4	
Refrigerator Comp. Temp t_7	+6		+6	
Refrigerator Comp. Mean Temp. t_{m2}	+4		+4	
Crisper Comp. Temp. t_8	+7		+7	
Compressor Shell Temp.	56		64	
Condenser Inlet Temp.	37		53	
Condenser Outlet Temp.	33		38	
Suction Temp.	33		34	

REMARKS Working percentage = 41 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET PAGE 5-36

FORM NO. 0008 DATE APRIL 25

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-1
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Goldstar	MODEL NR 62 LAE G
WATT. CAPACITY 158	POWER CONSUMPTION, WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 135
INSULATION TYPE C.F.C.R - FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING			
	ON	NC	OFF	NC
Freezer Air Temp. t_1	-7		-9	
Freezer Air Temp. t_2	-8		-10	
Freezer Air Temp. t_3	-9		-11	
Freezer Mean Temp. t_{m1}	-8		-10	
Freezer Bulb Temp. t_4	-13		-18	
Refrigerator Comp. Temp. t_5	+4		+4	
Refrigerator Comp. Temp. t_6	+5		+5	
Refrigerator Comp. Temp t_7	+6		+6	
Refrigerator Comp. Mean Temp. t_{m2}	+5		+5	
Crisper Comp. Temp. t_8	10		10	
Compressor Shell Temp.	73		78	
Condenser Inlet Temp.	50		76	
Condenser Outlet Temp.	45		51	
Suction Temp.	44		45	

REMARKS Working Percentage = 55 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET — PAGE 5-37

FORM NO. 00 DATE APRIL 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R	MODEL AR 12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-2
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Danfoss	MODEL FR 8.5 G
WATT. CAPACITY 158	POWER CONSUMPTION . WATT. 24 Hrs
VOLT 220 AMPER -- HRTZ. 50	REFRIGERANT WEIGHT GR. 150
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	ON	NO	OFF	NO
Freezer Air Temp. t_1	-15		-16	
Freezer Air Temp. t_2	-13		-14	
Freezer Air Temp. t_3	-14		-15	
Freezer Mean Temp. t_{m1}	-14		-15	
Freezer Bulb Temp. t_4	-16		-20	
Refrigerator Comp. Temp. t_5	+7		+6	
Refrigerator Comp. Temp. t_6	+8		+7	
Refrigerator Comp. Temp t_7	+9		+8	
Refrigerator Comp. Mean Temp. t_{m2}	+8		+7	
Crisper Comp. Temp. t_8	+11		+10	
Compressor Shell Temp.	75		80	
Condenser Inlet Temp.	52		70	
Condenser Outlet Temp.	45		50	
Suction Temp.	43		44	

REMARKS Working percentage = 64 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

PAGE 5-38

FORM NO. 0019

DATE : APRIL 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : AR12
SERIAL NUMBER : NON	PROTOTYPE NUMBER : R12 - 2
CLASSIFICATION/TEST CONDITION 'N'	AMBIENT TEMPERATURE : 43 C
COMPRESSOR NAME : DANFOSS	MODEL : FR 8.5 G
WATT. CAPACITY : 158 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR. 130
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NO	OFF NO
Freezer Air Temp. t_1 c		
Freezer Air Temp. t_2 c		
Freezer Air Temp. t_3 c		
Freezer Mean Temp. t_{m1}	-10	-14
Freezer Bulb Temp. t_4	-15	-20
Refrigerator Comp. Temp. t_5	1	0
Refrigerator Comp. Temp. t_6	8	7
Refrigerator Comp. Temp. t_7	8	8
Refrigerator Comp. Mean Temp. t_{m2}	5.6	5
Crisper Comp. Temp. t_8	13	12
Compressor Shell Temp.	80	85
Condenser Inlet Temp.	55	72
Condenser Outlet Temp.	45	55
Suction Temp.	43	44

REMARKS COMPRESSOR OPERAYING TIME 68%

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

FORM NO. 0012 DATE MAY 1995

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R.	MODEL AR12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-3
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Tecamseh	MODEL AE 360 KS 561
WATT. CAPACITY 158	POWER CONSUMPTION. WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 130
INSULATION TYPE C.F.C.R - FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-15		-21	
Freezer Air Temp. t_2	-16		-23	
Freezer Air Temp. t_3	-14		-22	
Freezer Mean Temp. t_{m1}	-15		-22	
Freezer Bulb Temp. t_4	-15		-22	
Refrigerator Comp. Temp. t_5	+4		+3	
Refrigerator Comp. Temp. t_6	+6		+5	
Refrigerator Comp. Temp t_7	+8		+7	
Refrigerator Comp. Mean Temp. t_{m2}	6		+5	
Crisper Comp. Temp. t_8	+8		+6	
Compressor Shell Temp.	52		73	
Condenser Inlet Temp.	50		68	
Condenser Outlet Temp.	46		55	
Suction Temp.	44		45	

REMARKS Working percentage = 60 %

AZMAYESH INDUSTRIAL FACTORIES CO .

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R134a PROTOTYPE TEST SHEET

FORM NO. 0013

DATE MAY 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R.	MODEL AR12
SERIAL NUMBER NON	PROTOTYPE NUMBER R12-4
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Aspera	MODEL B 1116 Z
WATT . CAPACITY 158	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 135
INSULATION TYPE C.F.C.R - FOAM	REF. INSIDE VOLUME LIT . 340

THERMOSTAT TYPE	[illegible]			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-17		-23	
Freezer Air Temp . t_2	-16		-24	
Freezer Air Temp . t_3	-18		-25	
Freezer Mean Temp . t_{m1}	-17		-24	
Freezer Bulb Temp . t_4	-17		-24	
Refrigerator Comp. Temp . t_5	+7		+6	
Refrigerator Comp. Temp. t_6	+8		+7	
Refrigerator Comp. Temp t_7	+6		+4	
Refrigerator Comp. Mean Temp . t_{m2}	+7		+6	
Crisper Comp. Temp . t_8	13		13	
Compressor Shell Temp.	70		80	
Condenser Inlet Temp .	50		75	
Condenser Outlet Temp .	48		55	
Suction Temp.	47		48	

REMARKS

Working percentage = 61 %

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-91

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARFZ
SERIAL NUMBER : NON	PROTOTYPE NUMBER : RFZ-1
CLASSIFICATION/TEST CONDITION ·N·	AMBIENT TEMPERATURE : 18°C
COMPRESSOR NAME : Aspera	MODEL : B 1118Z
WATT . CAPACITY : 204 WATT	POWER CONSUMPTION . WATT. 24 Hr
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 180
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NC	OFF NC
Freezer Air Temp. t1 c	-15	-21
Freezer Air Temp. t2 c	-16	-20
Freezer Air Temp. t3 c	-14	-20
Freezer Mean Temp. tm1	-15	-20
Freezer Bulb Temp. t4	-17	-24
Refrigerator Comp. Temp. t5	+5	+4
Refrigerator Comp. Temp. t6	+4	+3
Refrigerator Comp t7	+4	+3
Refrigerator Comp. Mean Temp. tm2	+4	+3
Crisper Comp. Temp. t8	+8	+6
Compressor Shell Temp.	55	65
Condenser Inlet Temp.	37	55
Condenser Outlet Temp.	32	38
Suction Temp.	33	34

REMARKS COMPRESSOR OPERAYING TIME % 25

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-42

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARF2
SERIAL NUMBER : NON	PROTOTYPE NUMBER : RF2-1
CLASSIFICATION TEST CONDITION "N"	AMBIENT TEMPERATURE : 32°C
COMPRESSOR NAME : Aspera	MODEL : B 1118 Z
WATT . CAPACITY : 204 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 180
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON NC	OFF NC
Freezer Air Temp. t_1 c	-15	-18
Freezer Air Temp . t_2 c	-14	-19
Freezer Air Temp . t_3 c	-13	-18
Freezer Mean Temp . t_{m1}	-14	-18
Freezer Bulb Temp . t_4	-18	-23
Refrigerator Comp. Temp . t_5	+6	+4
Refrigerator Comp. Temp. t_6	+5	+3
Refrigerator Comp t_7	+5	+3
Refrigerator Comp. Mean Temp . t_{m2}	+5	+3
Crisper Comp. Temp . t_8	+8	+8
Compressor Shell Temp.	55	60
Condenser Inlet Temp .	37	45
Condenser Outlet Temp .	32	38
Suction Temp.	32	34

REMARKS COMPRESSOR OPERAYING TIME % 45

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

FORM NO. 0006 DATE APRIL 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R.F.	MODEL ARF2
SERIAL NUMBER NON	PROTOTYPE NUMBER RF2-1
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Aspera	MODEL B 1113 Z
WATT. CAPACITY 204	POWER CONSUMPTION. WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 150
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING			
	ON	°C	OFF	°C
Freezer Air Temp. t_1	-6		-15	
Freezer Air Temp. t_2	-7		-14	
Freezer Air Temp. t_3	-6		-15	
Freezer Mean Temp. t_{m1}	-6		-15	
Freezer Bulb Temp. t_4	+4		-11	
Refrigerator Comp. Temp. t_5	+5		+0	
Refrigerator Comp. Temp. t_6	+6		+1	
Refrigerator Comp. Temp t_7	+7		+2	
Refrigerator Comp. Mean Temp. t_{m2}	+6		+1	
Crisper Comp. Temp. t_8	+5		+7	
Compressor Shell Temp.	75		85	
Condenser Inlet Temp.	50		90	
Condenser Outlet Temp.	45		50	
Suction Temp.	44		45	

REMARKS Working percentage = 74%

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET — PAGE 5.44

FORM NO. 0007 DATE APRIL 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME A.R.F	MODEL AFR2
SERIAL NUMBER NON	PROTOTYPE NUMBER RF2-2
CLASSIFICATION/TEST CONDITION Tropical	AMBIENT TEMPERATURE 43
COMPRESSOR NAME Goldstor	MODEL V75 LAEG
WATT. CAPACITY 204	POWER CONSUMPTION. WATT/24 Hrs
VOLT 220 AMPER HRTZ. 50	RIFRIGERANT WEIGHT GR 210
INSULATION TYPE C.F.C.R FOAM	REF. INSIDE VOLUME LIT. 300

THERMOSTAT TYPE	[illegible]			
	ON	NO	OFF	NO
Freezer Air Temp. t_1	-8		-15	
Freezer Air Temp. t_2	-7		-15	
Freezer Air Temp. t_3	-7		-14	
Freezer Mean Temp. t_{m1}	-7		-15	
Freezer Bulb Temp. t_4	+3		-12	
Refrigerator Comp. Temp. t_5	+6		+3	
Refrigerator Comp. Temp. t_6	+7		+2	
Refrigerator Comp. Temp t_7	+5		+4	
Refrigerator Comp. Mean Temp. t_{m2}	+6		+3	
Crisper Comp. Temp. t_8	+6		+3	
Compressor Shell Temp.	50		92	
Condenser Inlet Temp.	50		90	
Condenser Outlet Temp.	48		60	
Suction Temp.	44		45	

REMARKS Working percentage = 88%

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET 5-45

Date 11 June 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARF2
SERIAL NUMBER : NON	PROTOTYPE NUMBER : RF-03
CLASSIFICATION TEST CONDITION "T"	AMBIENT TEMPERATURE : 43°C
COMPRESSOR NAME : Zanussi	MODEL : GL 80 AA
WATT . CAPACITY : 204 WATT	POWER CONSUMPTION . WATT/24 Hrs
VOLT 220 AMPER HRTZ 50	REFRIGERANT WEIGHT GR 200
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT. 340

THERMOSTAT TYPE	THERMOSTAT SETTING ON NC.	OFF NC
Freezer Air Temp. t_1 c	-5	-17
Freezer Air Temp. t_2 c	-8	-19
Freezer Air Temp. t_3 c	-7	-20
Freezer Mean Temp. t_m	-7	-18
Freezer Bulb Temp. t_4	-15	-24
Refrigerator Comp. Temp. t_5	+5	+3
Refrigerator Comp. Temp. t_6	+2	+6
Refrigerator Comp t_7	+8	+6
Refrigerator Comp. Mean Temp. t_{mr}	+7	+5
Crisper Comp. Temp. t_8	+6	+5
Compressor Shell Temp.	70	85
Condenser Inlet Temp.	50	85
Condenser Outlet Temp.	45	50
Suction Temp.	32	43

REMARKS COMPRESSOR OPERAYING TIME % 75

AZMAYESH INDUSTRIAL FACTORIES CO.

R134a PROTOTYPE TEST SHEET

5-46

Date 12 June 95

DESCRIPTION	DESCRIPTION
PRODUCT NAME : REFRIGERATOR	MODEL : ARF2
SERIAL NUMBER : NON	PROTOTYPE NUMBER : RF-04
CLASSIFICATION TEST CONDITION "T"	AMBIENT TEMPERATURE : 43°C
COMPRESSOR NAME : Necchi	MODEL : ESC9H
WATT . CAPACITY : 204 WATT	POWER CONSUMPTION . WATT / 24 Hrs
VOLT 220 AMPER HRTZ. 50	REFRIGERANT WEIGHT GR 200
INSULATION TYPE : POLYURITHINE	REF. INSIDE VOLUME LIT . 340

THERMOSTAT TYPE	THERMOSTAT SETTING	
	ON [illegible]	OFF [illegible]
Freezer Air Temp. t1 c	-6	-18
Freezer Air Temp. t2 c	-7	-19
Freezer Air Temp. t3 c	-8	-21
Freezer Mean Temp. tm1	-7	-20
Freezer Bulb Temp. t4	-16	-23
Refrigerator Comp. Temp. t5	+6	+4
Refrigerator Comp. Temp. t6	+4	+4
Refrigerator Co	+7	+5
Refrigerator Comp. Mean Temp. tm2	+6	+4
Crisper Comp. Temp. t8	+8	+7
Compressor Shell Temp.	75	85
Condenser Inlet Temp.	55	80
Condenser Outlet Temp.	43	50
Suction Temp.	38	45

REMARKS COMPRESSOR OPERAYING TIME % 70

CHAPTER 6

TEMPERATURE TEST PROCEDURE

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

Azmayesh Refrigerators and Ref - Freezers Storage Temperature Test Procedure

Model : AR06 . AR 08 . AR10, AR12, and ARF2

Refrigerant : R134a classification T

Publication NO. : ALAB-95-PO1

Revision No. :

Date of Issue : April-1995

Change No. : 0

1- Subject : This procedure explains the methods of laboratory test in **Azmayesh Industrial Factories Company** laboratory department in desired conditions for determination of product storage temperature.

2 - Scope : This procedure describes the methods of laboratory test for

Azmayesh Refrigerator and Refrigerator- Freezer Model AR06 ,AR08 , AR10 , AR12, and ARF2

3 - Reference : ISO 7371 , ISO 8187, DIN 8950 .

4 - Instruction :

4 -1- This procedure shall comply with the above mentioned standards

4 -2- Prepration of hot room .

4 -2-1-The hot room Air tempereture should be kept steady and equal within the hot room space .

4 -2-2-Maximum 4 Appliances could be put in hot room at the same time for the purpose of test .

4 -2-3- All other objects which are not to be used for test shall be evacuated .

4-2-4- Reletive humidity of hot room shall be adjusted in accordence with desired calssification test (T) tropical .

4-2-5- All Record and temperature sensors shall be checked perior to test run

4-2-6- Assure that all Recorders are properly checked and calibrated .

4-2-7- Assure that all measuring Instruments are properly fitted and calibrated .

4-2-8- Check all measuring devices for calibration due date

4-2-9- Check hot room for cleanness and free of any obstruction during test .

4-2-10- Check for equality of temperature of hot room before starting the appliances for preformance test .

4-2-11- Consider and make sure that all pre-caution set-forth by compressor manufactures are applied to appliances prior and after the test .

4-3- Prepration of the appliance .

4-3-1 Each appliance shall be placed on a wooden Slide top platform in dull black colour , open for free air circulation under the platform , the top of the platform shall be 30 centimeter above the test room . floor and shall extend at least 30 centimeter but not more than 0.6 m . beyond all sides of the appliance except at the rear where it shall extend to the vertical partitiom.

4-3-2 Circulation of air about the appliance shall be restricted by surrounding the appliance by three vertical partitions , painted dull black.

4-3-3 One vertical partition shall be placed parallel the rear of the appliance , against the stops or at the distance of 5 centimeter from condenser tube vertical surface .

4-3-4- Two vertical partitions shall be placed parallel to the side of cabinet and shall be fixed on the platform 0.3 m. from the sides of the cabinet

4-3-5 The two side partitions shall be 0.3 m. wide.

4-3-6-The vertical partitions shall present no discontiruity they shall be such a height that they extend at least 0.3 m. above the top of the appliance .

4-3-7- The appliance shall be placed or shielded as to prevent direct radiation to or from the space cooling or heating equipment in the test room.

4-3-8- The appliance shall be placed far enough away from all other objects in the test room to eliminatate any possibillity of any point in the space in which it is situated being at a temperature other than ambient .

4-3-9- Air tempereture in test room shall be such that the specified ambient temrerature are obtained within the limits of the specified tolerances.

4-3-10- Avoid from Air current fvelocity above 0.25m/s in test room.

4-3-11- The air circulation in the test room shall not interfere with the normal air circulation created by the appliance .

5- Test Procedure for Storage Temperature .

5-1- The evaporator shall be defrosted if necessary and the internall walls and components of the appliance dried.

5-2- All doors and means of access shall kept closed during tests.

5-3- The appliance shall be fully operational and in service , and shall be operationally checked by Q.C department prior to test run .

5-3-1 All internal fittings such as ice trays shall be put into position , except **Model ARF2** .

5-4- Thermostat position shall be in normal setting or between 3 or 4 grade.

5-5- The empty appliance shall be operated at least for 24 hrs. to reach equilibrium.

5-6- The food freezer compartment and frozen food storage compartment shall be equipped with test packages.

6- Class (T) Temperature Condition.

6-1- Storage temperature **18 degree** C **and 43 degreeC** .

6-2- Energy consumption **32 degreeC** .

6-3 The temperature at each measurement point shall be kept constant within + - 5 degree k of the nominal ambient temperature both during the periods required for obtaining stable operating condition and during the tests .

7- Humidity

Relative humidity shall be kept between 45% and 75%

8- Test packages

8-1 The tests shall be carried out with test packages loaded in the form of parrallelepipeds.

8-2- Test packages shall be prepared in accordance with ISO 8187 para 8.2.

9- Measuring procedure .

9 - 1 - Temperature shall be measured with temperature probe , the

sensors of which are inserted in test packages .

9 - 2 - The accuracy of measuring Instrument shall be within +-0.3 K

9 - 4 - The temperature t_1,t_2,t_3 and t_{c1},t_{c2} shall be measured in copper or brass cylinders suspended and located at temperature sensing point as shown in figure 1 half way between the rear internal wall of the appliance and the internal wall of close door .

9-5-The mean Internal temperatures ,t_m and t_{cm} shall then be calculated as an average of the mean temperatures of t_1,t_2,t_3 and $t_{c1}$and t_{c2}

9-10- The sensors surfaces shall be separeted from any heat conducting surface by at least 25mm of air space .

10- Test period

The test period.shall be at least 24hr after stable. operating conditions have been attained.

11- Storage plan

11-1 The food freezer compartment shall be filled with as many test package as they can hold.

11-2 The test package temperature shall have been previously brought to approximately equal to the classification temperature of the compartment.

11-3- Test packages having a base of **100 x 200** mm shall be made using 1kg package **(50x100x200)**mm laid flat

11-4- Free air spaces of 15mm minimum as far as possible equal shall be left between adjacent stacks of test packages.

11-5 Door shelves and compartments shall be loaded with as many packages as possible, free air spaces shall be maintained between the packages and the inner surface of the door.

12- Temperature measurement .

12-1- For ambient temperature of 43 degree C for class (T) test . The thermostat shall be adjusted , as necessary , to position which to get storage temperatures as follows , after stable operating conditions have been attained .

Note : For stable condition Reffer to para 3.4.8 I.S.O 8187

12-2- Appliance shall be capable of maintaining simultaneously ,the required storage temperature in the different compartments as follows.

12-3- The temperature of -12 **degree** C for Models AR06 , AR08 , AR10 and AR12 and **-18 degree** C for Model ARF2 shall be maintained in the Evaporator and Freezer Compartment.

12-4- For class T stroage temperature in ambient temperature **+18 degree** C to **43 degree C** for Model **AR06 . AR08 . AR10 , AR12** and **ARF2** in fresh food compartment the t_1, t_2 , t_3 shall be between 0 degree C and +10 degree C and tm max should be +5 ,+ - 0.5 degree C

12-5- t_{cm} in cellar compartment for class T should be between + 8 degree C and +14 degree C .

12- 6- t_m in freezer compartment shall be -12 degree C for Models AR06 , AR08 , AR10 , AR12 and ARF2 .

12- 7 t_m in Freezer Compartment for Model ARF2 shall be - 18 C +- 0.5

12- 8 For temperature measurement , the stable operating condition are deemed to be reached when the temperature at all coressponding points during successive operating cycle agree within +- 0.5 C and no marked trend from the mean temperature happen during aperiod of 24 Hrs .

13 - Percentage running time "R "

The percentage running time shall not exceed **80%**

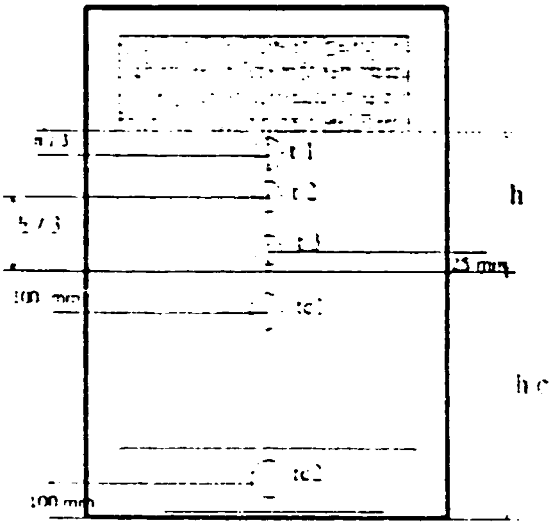

Figure 1

CHAPTER 7

ENERGY CONSUMPTION TEST PROCEDURE

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

Azmayesh refrigeration and Ref - Freezer Energy Consumption Test Procedure

Model : AR06 , AR08 , AR10 , AR12 and ARF2

Refrigerant : R134a

Classification : " T "

Publication No . : ALAB - 95 - P02

Revision No . :

Change No . : 0

Date of Issue : April 1995

1 - Subject :

This procedure describes the methods of checking the energy consumption of Azmayesh Products under specified test condition .

2 - Scope :

This procedure describes the methods of laboratory test for determination of energy comsumption of Azmayesh products Model AR06 , AR08 , AR10 , AR12 and ARF2 .

5 - 3 - 2 In the case of cyclic operation , the initial and final values shall be read inmidiately after the thermostat cuts out .

5 - 3 - 3 The measurement of energy consumption shall be carried out under storage conditions , as follows .

5 - 3 - 3 - 1 The energy consumption corresponds to the temperature t_m =+ 5 **degree** C and ambient temperature of 32 **degree** C .

5 - 3 - 3 - 2 The energy consumption could also be corresponding to one of the following temperature condition .

a) Either t_m = + 5 degree C , with t_1 , t_2 , and t_3 between 0 degree C and + 10 degree C and simultaneously the maximum temperature of warmest test packages colder or equal to - 12 degree C for Models AR06 , AR08 , AR10 , AR12 and - 18 degree for ARF2 OR ,

b) The maximum temperature of the warmest test equal to - 12 degree C for Model AR06 , AR08 , AR10 and AR12 and - 18 degree C

3 - References

ISO 7371 , ISO 8187 and DIN 8950

4 - Instruction :

This procedure shall comply with above mentioned Standards and Publication No . ALAB - 95 - P01 as necessary .

5 - Precedure

5 - 1 Ambient temperature

32 degree C for class " T "

5 - 2 Appliance shall be prepared in accordance with Azmayesh Publication No . ALAB - 95 - P01 Dated April 1995 , Para . 4 - 2 through 4 - 3 .

5 - 3 Measurement

5 - 3 - 1 The value of the energy consumption shall be calculated and measured for a period of exactly 24 Hrs .

ARF2 and simultaneously tm between 0 degree C and + 5 degree C with t1 , t2 and t3 between 0 and 10 degree C .

5 - 3 - 3 - 3 The energy consumption may be obtained by interpolation from results , one giving a temperature above and one below the specified temperature t_m = + 5 degree C for condition a) above or one giving a temperature above and one below classification temperature of freezing compartment - 12 degree C for Models AR08 , AR08 , AR10 and AR12 and - 18 degree C for Model ARF2 .

5 - 3 - 3 - 4 The temperature deviation above and below = 5 degree C in condition a) or above and below the classification temperature in condition
b) snall be within limits of +- 2 K .

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CHAPTER 8

OPTIMIZATION METHOD

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

Azmayesh Refrigerators and Ref-Freezer Optimization Method

Models : AR06 . AR08 . AR10 . AR12 and ARF2

Refrigerant : R134a

Publication No . ALAB - 95 - P03

Date of Issue : APRIL 1995

Change No . : 0

1 - Subject : Refrigerator and Ref - Freezer optimization method .

2 - purpose : To have a standard method of product optimization for high efficiency low- energy consumtion and proper equipment selection with company's policy consideration .

3 - Scope : This publication describes the method of refrigeration system optimization for Azmayesh Refrigerator and Ref - Freezer and also Freezer for defined Models .

4 - Refrigeration System Optimization .

4 -1- Since We are limited in the number of Refrigeration System Modules and factors we devide , these Modules into two Systems

a) Variable components: like , Refrigerant , Capillary tube, Drier, compressor and Insulation

b) Non-Variable components: like Door,cabinet, Evaporator,and Condeser

Note : Evaporator and condenser are considered as Non-Variable components due to the Engineering and economical situation which we are not prepared to change them , unless , Such a modification could affect largely on Refrigeration System and limit our Variable components Selection .

4 - 1 - 1 Variable Components

Refrigerant

Since Refrigerant **R12** is to be phased - out from our production line and Refrigerant R134a has been Selected as an production line and Refrigerrant **R134a** has been Selected as an **ODP Zero** Refrigerant we discuss **R134a** in this regards. Due to the higher potential of **R134a** in a refrigerant cycle . It seems that at least **10%** decrease of refrigerant weight in comparison with **R12** could give us the same cooling capacity , but through our labratory test we found out that only 80% of Refrigerator can correspond to the reduction of Refrigerant weight because of different models of compressors from different manufacturer. therfore for optimization of refregerant it is reasonable to check the weight of Refrigrant and come to the correct amount of weight whenever we change our compressor unit Due to the Market and Design and Economical Restrictions so we should take it into our consideration that . printing gas weight in our **Serial Number** plugs must be accomplished just after the unit production by declaretion of labratory and not using preprinted Metal tags on the units .

Capillary tubes

Through our labratory test we found out that increase and decrease of capillary tube could be a mean of optimization programme in some casebut not all the time , and that is when we need to reach the Standard test condition , under **ASHRAE** standard , just when we want to adjust the Evaporating tempreture and also Subcooling temprature . In case of **R134a** refrigrant , at the first step we tried to increase the length of capillary length in order to have the better Evaporating temperature , and then we chose the same length as it was before . we found out that there is not much defference between two conditions , so we recommend not to increase the length of capillary tube only in case of using Compressor either with higher cooling capacity than it is required or the amount of refrigerant gas can not be regulated by the weight properly .

Compressor

To our idea Compressor Unit is the most effective Variable component that could affect the efficiency of Refrigeration System . So it is very important to choose the correct and proper compressor in order to achive the desired test condition , the following factor could be main steps for a correct compressor selection in order to optimize Refrigeration system and also make all Refrigeration modules compatible to each other .

It should be noticed that compressor selection is only the theoritical step of optimization programme and final selection must be achived after compressor laboratory operational and conformance test .

1 - Cooling Capacity

For a proper and favarable compressor selection we have to know our cooling Requirment first , in order to know our requirement we should know the cooling capacity of appliance that is under our optimization programme , it is very important because wrong cooling capacity leads us to select the wrong compressor.

2 - System Condition

The condition which we have calculated for our Refrigeration load is important too , the test condition which we have been considered for example There is a slight defference between **ASHRAE** standard and **CECOMAF** standard and that is higher evaporating temperature and higher Sub-cooling tempreture for **CECOMAF** standard , so in this case we will need more cooling capacity . For example , for our Refrigerator Model **AR08** with a cooling Requirement of **93 Kcal/hr** in **ASHRAE** standard condition we should choose Zanussi compressor Model **GL45AA** with cooling capacity of **92 Kcal/hr** but at the same condition for **CECOMAF** standard we have to select Zanussi Compressor Model GL5DAA the reason for this defference is the difference between **COP** of compressor in two standard condition which for Model **GL45AA** the **COP** in **ASHRAE** condition is 1.08 and in **CECOMAF** is 0.83 , in using an efficient Sub- cooling system by using almost 90 cm of Evaporator Return line for cooling the capillary outlet tube we have to select ASHRAE standard condition with Sub- cooling temperature , which in this standard test condition is 32 degree Centigrade .

3 - Evaporating Tempreature

Evaporating temperature is one of the most important factor in determining the desired condition , for example in order to reach - **12** degree centigrade of test package inside evaporator compartment we have to know what evaporating temperature we need ?

If we expect -25 degree centigrade with Sub- Cooling system , then we have to select a compressor with higher cooling capacity and better COP . Since most of compressors in among our sources uses -23.3 degree centigrade evaporating tempreture , test condition , we consider this figure as an aim to reach and select an optimized compressor and then we try to adjust the amount of refrigerant weight and also perform minor modification in designing of cabinet in order to keep -12 degree centigrade or -23.3 evaporating temperature in Freezer compartment .

4 - System Sizing

This subject could be considered as a guide to select proper compressor ,The following items are important subjects that could be taken into our consideration .

a - Condenser sizing , (condensing temperature)
b - Heat exchanger suction gas / liquid (superheat suction gas)
c - Evaporator sizing . (evaporating temperature , suction gas temp.)

5 - Drier

Filter drier does not have such a remarkable affect in our Refrigeration System , unless proper selection and humidity absorbtion potential , which should be considered In case of R 134a refrigerant Drier XH7 & XH9 with a higher humidity absorbtion potential are recommended .

6 - Insullation:

Type of Insullation could affect the rate of energy consumtion . Since changing Insulation type is not a repeatative activity in optimization programme we would rather to take this subject in energy consumption programme .

4 -1-2 Non- Variable Components .

1 - Door and Cabinet

As a matter of optimization device we can not consider th interchangeability of Refrigerator and Freezer Cabinetand door . unless minor modifications that are practicaly possible , such as designing or changing small parts to keep inside temperature stable and in this step, we found out that we have a problem in distributing air properly inside evaporator compartment and food compartment, so we planned to reinforce and seal the water drain tray under evaporator section in order to keep -12 degree centigrade air temperature in evaporator section constant.

2- Evaporator and Condenser

Evaporator and Condenser are of those component which could hardly be modified especially Evaporator because our Evaporator is Roll Bond type and we could not simply modify it, although in laboratory test we found out it is not necessary to modify our evaporator.

The condenser is not considered as a component to affect largely our refrigeration system, becausse we found out that we can get temperature 32 degree centigrade in condenser outlet tube easyly and the temperature defferance of one third of condenser tube and midel of filter drier is not more than 5 degree centigrade.

CHAPTER 9

PREPARATION OF TRIAL EQUIPMENTS

AZMAYESH INDUSTRIAL FACTORIES COMPANY

MAY 1995

PREPARATION OF TRIAL EQUIPMENT

1 - Due to the contract No. 94 / 097 with UNIDO we have to prepare 4 prototypes for each Model . Taking into our consideration that for each Model we have to perform three condition tests as follows

a) 43 C Cyclic run test
b) 32 C Cyclic run test
c) 18 C Cyclic run test

The above mentioned tests are principaly performed in order to check the performance of each refrigerator model in new condition using refrigerant R134a and comparing them with R12 refrigerant .

Determination of energy consumption is another objective in this project that we have to accomplish it through testing defferent kind of Compressor Models .

As we mentioned in Selection of R134a Compatible Components Chapter , we actualy deal with many defferent kinds of compressors which could affect our Energy consumption ratio , for this reason we which could affect our Energy consumption ratio, for this reason we have to consider the testing results of these numerous kind of compressor performance in our Optimizing Programme.

The following compressor models have been test in our laboratory so far for determination of R134a refrigeration cycle performance.

Compressor Model	Manufacturer
BP 1048 Z 22	ASPERA
B 1118 Z	ASPERA
B 1116 Z	ASPERA
BP 1111 Z	ASPERA
FR 8.5 G	DANFOSS
V 75 LAEG	GOLDSTAR
NR 62 LAEG	GOLDSTAR
NR 58 LAEG	GOLDSTAR
AE 360 KS 561	TECAMSEH

At the time of preparing this report some more compressor models from Danfoss , Matsushita and Necchi were going to be tested for determination of performance characteristics and energy consumption .

2 - Field Test

Through defferent catalogues and technical informations and specifications available in our company we prepared a spread sheet to select at least 30 defferent Compressor Model from 6 Manufactrurer .

From these Compressor Models after appropriate test in our laboratory we are going to install following Compressors on our Refrigerator Units for a quantity of 50 to 100 Units for the purpose of field test , then we are going to collect all external failure which could happen during field test evaluation and try to achive necessary modification and also suitable component selection . In this respect we are planning to train our servicemen all around Iran in order to give us correct and desireable technical information regarding technical , design and manufacturing deffects .