The Use of R-407C as a Replacement for R-134a in a Chest Freezer

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DEDICATION

To the soul of my father,

To my mother,

To my brother and sisters,

I dedicate this work…

With

Love and Respect

Ahmad

ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude to my supervisor Professor Mahmoud Hammad for his valuable guidance support and encouragement.

Special thanks to the mechanical engineering department instructors and employees, for the greatest help all over the way.

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NOMENCLATURE

COP	Coefficient of performance
P	Pressure (kpa)
h	Specific enthalpy (kJ/kg)
$\dot{m}$	Mass flow rate (g/s)
T	Temperature (°C)
Cp	Specific heat (kJ/kg.K)
M	Mass (kg)
q_{ref}	Refrigerating effect (kJ/kg)
Q_{ref}	Refrigeration capacity (Watt)
W	Power consumption (Watt)
w	Compression work (kJ/kg)
t	Time (sec)

SUBSCRIPTS

a	Ambient
c	Condenser
e	Evaporator
co	Container
w	Water load
air	Air inside the freezer zone

ABREVIATIONS

ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CFC	Chlorofluorocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HC	Hydrocarbon
NBP	Normal Boiling Point
GWP	Global Warming Potential
ODP	Ozone Depletion Potential

ABSTRACT

The Use of R-407C as a Replacement to R-134a in a Chest Freezer

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The refrigerant R-407C, which is a new blend of (52% R-134a, 25% R-125 and 23% R-32) was used and tested in a locally manufactured chest freezer as a replacement to R-134a. The proposed refrigerant have the advantages of being locally available, zero ozone depletion potential, low global warming potential, high latent heat of vaporization, in addition to its reasonable properties when compare to R-134a.

The freezer was charged with three different quantities (150, 200, and 250)g of R-407C, then the best amount of R-407C, which gives the optimum coefficient of performance was optioned. The performance of the best charge quantity is compared with that for R-134a

This research shows that the best charge quantity of R-407C, which gives the optimum COP is 210g, where the COP in that case equals to 3.0 at Tc = 39 °C, Te = -15.1 °C, and Ta = 22.5 °C, which is lower than that for R-134a by 32.13% at the same conditions. And at the same pervious conditions, the electrical power consumption for R-407C is higher than that for R-134a by 48.48%.

The results show that R-407C blend (52% R-134a, 25% R-125 and 23% R-32) is not a good replacement to R-134a in chest freezers designed for R-134a, since it does not give a good refrigerating effect, exhibits a high work of compression (low COP), and consumes higher electrical power comparable with R-134a.

Chapter One

INTRODUCTION

Refrigerants are the working fluids in refrigeration, air-conditioning, and heat pumping systems. They absorb heat from one area and reject it into another, usually through evaporation and condensation, respectively. These phase changes occur both in absorption and mechanical vapor compression systems, but they do not occur in systems operating on a gas cycle using a fluid such as air. The design of the refrigeration equipment depends strongly on the properties of the selected refrigerant.

Domestic refrigerators and freezers are the most worldwide used home appliances that work with refrigerants. Therefore, the phasing out of chlorofluorocarbons (CFCs) refrigerants will cause heavy effect on these appliances.

1.1 Refrigerants and Environmental Aspects

Two aspects of refrigerant effect have recently been much discussed in relation to environmental issues. The first concerns the ozone layer depletion by chlorofluorocarbons (CFCs) and the second relates to global warming.

Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are currently used extensively in air-conditioning and refrigeration. They possess most of the characteristics required, such as thermal and chemical stability, thermodynamics suitability, non-toxicity, non-flammability, low cost, etc., but have a damaging effect on the stratospheric ozone layer. Because of this damage an international agreement (Montreal Protocol) was signed in September 16, 1987, and since that date scientists began a hard work to find a suitable replacement for (CFCs) and (HCFCs).

1.2 Alternative Refrigerants

Since the phasing out of (CFCs) is essential and only a matter of time, it is a vital matter to find environmental safe alternatives that could replace these refrigerants. Efforts were directed towards finding new refrigerants that possess suitable properties to replace (CFCs), and at the

same time don't contain chlorine atoms, which acts to deplete the ozone layer.

Hydrofiuorecarbon (HFC) refrigerants like (HFC-134a) were tested and succeeded as an alternative refrigerant for CFC-12 in domestic refrigerators but the researchers concluded that for R-134a the compressor volume must be increased compared with R-12 and so the power consumed will increase for the same cooling capacity.

Hydrocarbons (HCs) offer acceptable alternative refrigerants to the (CFCs), since they have good thermodynamically properties and they are universally available at low prices, and they don't contain chlorine atoms so there is no ozone depletion potential, and the global warming potential is very low. The only disadvantage of using (HCs) as a refrigerant is their flammability.

Requirements for replacement refrigerants include satisfactory performance within the refrigeration system (possibly better than CFCs) and harmless behavior both for animals and the environment outside it, in addition to a low or preferably zero Ozone Depletion Potential (ODP) and relatively low Global Warming Potential (GWP).

A suitable refrigerant must provide acceptable environmental properties, in conjunction with the following requirements, which are very important for its use:

1- Suitable physical and thermodynamic properties.

2- High chemical and thermal stability.

3- Good miscibility with lubricants.

4- Compatibility with materials.

5- Low toxicity.

6- Low flammability.

Recently a new blend of refrigerants R-407C, which is a mixture of (52% R-134a, 25% R-125 and 23% R-32), was used as a replacement for R-22 in air conditioning systems, and shows a good performance, in addition to zero ozone depletion potential.

1.3 Importance of this work

Refrigeration has become essential to many activities, including storage, transport and distribution of food, conservation of medical products and various industrial processes.

The aim of this research is to test a locally manufactured chest freezer using R-407C as an alternative to R-134a without changing or modifying the used freezer components.

In this research, a study will be carried out for the performance of the new blend of refrigerants R-407C which is a mixture of (52% R-134a, 25% R-125 and 23% R-32) as a replacement for R-134a in the chest freezer.

The thermodynamics properties and the performance curves of R-407C will be compared with those for refrigerant R-134a.

Chapter Two

LITERATURE SURVY

The depletion of ozone layer, the warming of the earth and many other destructive effects of the CFCs, HCFCs and halons led to the held of Montreal conference in 1987, which requested the totally phase out of their usage. Governmental organization, scientists and researchers all over the world, raced for finding alternatives to replace the harmful CFCs, HCFCs, and halons with minimum design changes of the existing units.

Several works concentrated on different alternatives for R-12. Hydrocarbons (HCs) and their mixtures were used and they are still under research, the fluids HFC134a, HFC152a, and the non-azeotropic mixtures HFC134a/HFC152a, CFC114/HCFC22/HCF152a, etc. were used as the potential alternatives to R-12 in domestic refrigeration, but all those researches were facing some problems; the Hydrocarbons for example are flammable, and HFC134a needs more power than R-12 to produce the same refrigeration capacity.

Many papers had been published within the last few years concerning physical and thermodynamic properties, system performance (refrigeration capacity and performance) and environmental effect for different alternative refrigerants such as, R-134a as a replacement to R-12 in domestic refrigerators, and R-407C as a replacement to R-22 in air conditioning.

In this chapter, the previous work and the later efforts concerning the proposed area of study will be presented.

The earliest screening by Midgley concluded that potential refrigerants should be made from some combinations of carbon, hydrogen, nitrogen, oxygen, sulfur, fluorine, chlorine and bromine. Since some toxicity and stability problems were associated with nitrogen and sulfur compounds, these were eliminated. Ultimately CFCs were selected. Currently, CFC12, which has an ODP of 1.0, is used extensively in refrigeration.

Atwood, (1991) invited scientists to look for a suitable alternative refrigerant for each application individually since it is extremely difficult to find an alternative for some refrigerants suitable for all applications.

McLinden and Didion, (1992) used various constraints and eliminated chlorine and bromine due to their active participation in ozone layer depletion, concluded that the potential refrigerants should consist of the elements carbon, hydrogen, oxygen and fluorine, such as R-134a, R-32 and R-152a or any blend that consists of these refrigerants such as R-407C and R-410a.

Preisegger and Henrici, (1992) summarized the requirements for a suitable replacement for R-12 by R-134a. They described the chemical properties, the material compatibility, and the thermodynamic properties of R-134a and gave some explanations of installing closed product cycles for CFCs and their substitutes. They mentioned special requirements for suitable compressor lubricants. They also compared some thermodynamic properties such as the isentropic component, the speed of sound in refrigerant vapor, COP, specific heat capacity, thermal conductivity and viscosity of R-134a with that of R-12 and they proved that R-134a is acceptable alternative for R-12.

Eckels and Pate, (1990) made an experimental comparison of evaporation and condensation heat transfer coefficient for R-134a and R-12. They measured the heat transfer coefficients in a horizontal smooth tube with an inner diameter of 8.0 mm and a length of 3.67m. In single-

phase flow, heat transfer coefficients for R-134a were 33% higher when compared to those of R-12. For evaporation at similar mass fluxes, heat transfer coefficients for R-134a were 35% to 45% higher than those of R-12. For condensation at similar mass fluxes, heat transfer coefficients for R-134a were 25% to 35% higher than those of R-12.

Bansal, (1992) made an experimental study of HFC-134a on an industrial heat pump showed that HFC-134a has some disadvantages. For example, in order to replace R-12 with R-134a in a heat pump system, cleaning a heat pump system is cumbersome and can be quit expensive. In addition, R-134a can't offer the full operating range of R-12, particularly beyond 70°C.

Spartz, (1993) investigated alternative refrigerants for R-22 chillers. All its alternatives are based on HCF refrigerant mixtures. He summarized the results of his research as that there are already some promising candidates to replace R- 22 in chillers, although much work is still to be done. The R-32/R-125/R-134a mixture, R-134a and R-32/R-125/ azeotrope are possible alternatives.

Luzzatto, (1994) presented the efforts carried out in Delchi Carrier, vinasanta plant on application of R-134a and R-407C as substitution for R-22 on portable room air conditioning system. They showed that for R-134a, the compressor displacement should be 50% higher than that for R-22, and the lubricant oil, the expansion device and filter should be changed while by using R-407C the (COP) reaches 91% of that for R-22 system without any modification. They provided a cost comparison between systems using R-134a and R-407C, they concluded that the system cost will increase by 2% and 7% by using R-407C and R-134a respectively, higher than the system working on R-22.

Habash, (1994) concluded that the propane/butane mixture is an attractive substitute for R-12 in domestic refrigeration systems, but have a disadvantage that is this mixture is flammable.

The Association of European Refrigeration Compressor Manufactures (ASERCOM), (1997) conducted several experiments on the use of R-407C to replace R-22. They concluded that the advantages of R-407C as non-flammable, non-toxic, available in the market, has lower discharge temperature than R-22 and a large subcooling effect.

Zoubi, (1998) concluded that refrigerant R-134a has no side effects nor any disadvantages were noticed during the period of operation, such as compressor overheating or frost accumulation.

German Compressor Manufacturing Company BITZER, (1999) showed that R-407C is preferred over other available alternatives for R-22.

German Compressor Manufacturing Company BITZER, (2000) demonstrated that R-134a has similar thermodynamics properties to R-12, and it is already available in sufficient quantities as an alternative for R-12, but it requires a large compressors displacement for different specific refrigeration capacity.

Garofono, (1994) built a theoretical model to predict the performance of a refrigerant cycle operating with R-22, R-134a, and azeotropic blend R-407C [R-32/R-125/R-134a (23%/ 25%/ 52%)]. The theoretical prediction compared with experimental result recorded during test on small chiller heat pump version. They found from the theoretical model that the compression ratio is 3.6 for R-22, while 3.96 for R-407C. They found also, that the percentage of (COP) and refrigerant charge

amount of R-407C comparing with that of R-22 reached 90% and 98% receptively.

Xiao Feng, (1994) discussed some potential alternatives for HCFC22 such as HFC134a, propane, HFC32/HFC125, HFC33/HFC125a, HFC125/HFC143a/HFC134a, and HFC152a/HFC134a/HFC32 by calculating their (COP) and the capacities. They concluded that for HFC134a and propane the compressor volume must be increased compared with HCFC22 for the same cooling capacity.

Makahleh, (2001) Concluded that R-407C is a good replacement to R-22 in air conditioner Split Unit.

The previous work concentrated in finding suitable alternatives for R-12 and for R-22, mainly discussing the physical and thermodynamic properties of the alternative R-134a and R-407C. It also concentrated on mathematical modeling and performance of chillers and heat pumps. So, this work will be concentrated on experimental performance of a chest freezer.

The aim of this research is to test a locally manufactured chest freezer using R-407C as an alternative to R-134a without changing or modifying the used freezer components, and a study will be carried out for the performance of the new blend of refrigerants R-407C which is a mixture of (52% R-134a, 25% R-125 and 23% R-32) as a replacement for R-134a in a domestic refrigerator. The thermodynamics properties and the performance curves of R-407C will be compared with those for refrigerant R-134a.

Chapter Three

COMPARATIVE STUDY

R-134a vs. R-407C

3.1 General Background

R-134a has been introduced as a replacement for R-12 in many applications, after that, R-407C has been introduced as a replacement for R-22 in air conditioning systems. (CFCs) and (HCFCs) which were developed over 70 years ago, have many unique properties. They are low in toxicity, nonflammable, non-corrosive, and compatible with other materials. In addition, they offer the thermodynamic and physical properties that make them ideal for a variety of uses.

The fluid used for energy exchanges in a refrigerating system is called the refrigerant. The refrigerant usually absorbs heat while undergoing a phase change (in the evaporator) and then is compressed to a higher pressure and a higher temperature, allowing it to transfer that energy (in the condenser) directly or indirectly to the atmosphere or to a medium being purposefully heated.

A method of referring to refrigerant by number was developed and registered by Dupont in 1956. The American Society of Heating,

Refrigeration, and Air-conditioning Engineers (ASHRAE) adopted the method in 1960.

3.2 Comparative Study

When selecting a refrigerant for a specific application, the properties of this refrigerant have to satisfy a number of application requirements in order to be suitable for that application. These requirements that must be satisfied by the refrigerant may be classified as thermodynamically, physical, and chemical requirements, in addition to other factors as cost and availability. Each refrigerant has its own specific properties and characteristics, which must be known well before deciding if a refrigerant is suitable for an application, or not. Also, these properties and characteristics form a good basis for comparisons among different refrigerants.

This chapter presents an over view of a substitute refrigerant R-407C which is azeotropic mixture of (52% R-134a, 25% R-125 and 23% R-32) which could replace R-134a by studying their theromdynamical, physical, and chemical properties and other requirements. This study will give an indication and a conclusion of the properties of R-407C and whether it meat the requirements which are

important for their use in a chest freezer or not, R-407C would be a suitable alternative because it is environmentally accepted.

3.3 Thermodynamic Properties

Thermodynamic properties are the most important properties in selecting refrigerants for any application. A refrigerant is not useful for an application unless its properties fulfill the thermodynamic requirements for that application. The thermodynamic properties of R-134a and R-407C are listed in table 3.1.

Table 3.1 Thermodynamic properties of refrigerants

Properties	R-134a	R-407C
Boiling point (°C)	-26.16	-44
Critical temp. (°C)	101.1	87
Critical pressure (Mpa)	4.1	4.62
Temperature glide	0.0	7.4
Latent heat of vaporization (kJ/kg)	217.1	245.4

*At one atmospheric pressure.

3.3.1 Freezing point

Low freezing temperature of the refrigerant is required because the refrigerant must not solidify during normal operating conditions.

3.3.2 Boiling point

Low boiling temperature at atmospheric pressure (Normal Boiling point) of the refrigerant is required for an efficient refrigerant. Otherwise it is required to operate the compressor at high vacuums, which reduces the capacity of the system.

As shown in table 3.1, R-407C has lower boiling point than R-134a, which is preferable.

3.3.3 Critical temperature and pressure

The critical temperature of the refrigerant should be higher than its temperature in the condenser for easy condensation of the vapor refrigerant, because we cannot get a good condensation for the refrigerant above its critical temperature regardless the amount of the applied pressure.

As shown in table 3.1, the critical temperature of R-407C is lower than R-134a but still enough above the temperature occurring in the condenser. Also the critical pressures for the tow refrigerant are much higher than any pressure in the system.

3.3.4 Latent heat of vaporization

The latent heat of vaporization (kJ/kg) is the amount of heat in kJ that is required to vaporize one Kg of the liquid at atmospheric pressure, the liquid to be at its boiling point when the operation begins.

One of the required thermodynamic characteristics of general importance is high latent heat of vaporization. This means a large refrigerating effect per unit mass of the refrigerant circulated, which must absorb heat exactly equal to its latent of vaporization. Thus, if a refrigerant with a high latent heat of vaporization is used, lower refrigerant charge mass and/or smaller compressor, condenser, and evaporator can be used.

As shown in table 3.1, the latent heat of vaporization for R-407C is comparatively higher than that for R-134a this means a lower quantity of R-407C can be used than that R-134a because the refrigerant with a high latent heat (R-407C) will absorb more heat per kg of its quantity than the refrigerant with a lower latent heat of vaporization (R-134a).

3.3.5 Evaporation and condensing pressure

The range of the operating pressure is one of the major considerations in the selection of refrigerant for the economical working of the refrigerant system.

Pressure in the evaporator and condenser should be positive and above atmospheric to prevent air from leaking into the refrigeration system. Also the pressure should not be too high above atmospheric because otherwise expensive piping and equipment will be required.

Low compression ratio result in low power consumption. Therefore, the refrigerant with the lowest compression ratio (condenser to evaporator pressure ratio) is desirable.

3.3.6 Coefficient of performance

A high coefficient of performance is desirable because it indicates that a given amount of refrigeration requires only a small amount of work is needed. In other words, it is a measure of the cycle efficiency.

3.3.7 Compressor discharge temperature

Low discharge temperature gives a long life and less maintenance for the compressor because it reduces the possibility of overheating of the compressor.

3.3.8 Temperature glide

Temperature glide is the difference between the bubble and dew point temperatures for azeotropic refrigerant blends, this difference will affect on the performance of the condenser and the evaporator.

3.4 Physical and Chemical Properties

3.4.1 Specific heat of liquid and vapor

The specific heat is the quantity of heat required to raise 1g of a substance 1°C. Low specific heat of liquid and high specific heat of vapor are both desirable because they increase the refrigerating effect per kg of the refrigerant. Low specific heat of liquid tends to increase the subcooling of liquid, and high specific heat of vapor tends to decrease the superheating of vapor. As shown in table 3.2, R-407C has higher vapor and liquid specific heats than R-134a.

Table 3.2 Physical and Chemical properties of refrigerants

Refrigerant	R-134a	R-407C
Chemical formula	CH_2FCF_3 (100)%	$CH_2F_2/CHF_2CF_3/CH_2FCF_3$ (23/25/52)%
Specific heat of liquid (kJ/kg.K)	0.93	(0.997)
Specific heat of vapor (kJ/kg.K)	1.367	1.426
Ozone depletion potential	0.0	(0.0)
Global warming potential	1300	1610
Toxicity (ppm)	1000	1000
Flammability	–	–
Lubricant	Polyol ester	Polyol ester

3.4.2. Viscosity

The viscosity is a measure of flowing quality. It is desirable to use refrigerants with low viscosities in both liquid and vapor states for higher heat transfer in the evaporator and condenser, low pumping power and small pressure drops during flow.

3.4.3 Thermal conductivity

A high thermal conductivity of refrigerant in both liquid and vapor state is desirable for more efficient heat transfer in the evaporator and the condenser.

3.4.4 Miscibility with oil

Lubricants are an essential component of a refrigeration system. A refrigeration compressor requires lubrication like any mechanical equipment; oil is necessary to lubricate the bearings and the pistons in the case of reciprocating compressors. The oil helps to absorb and carry away the heat generate by the working of the compressor.

Miscibility of the oil and the refrigerant is the ability of the refrigerant to mix with the oil. Therefore, it is an important characteristic in the selection of any refrigerant, so the refrigerant must be completely

Water a most undesirable contaminant in refrigeration system because it may cause rusting corrosion, refrigerant decomposition, value damage, and general deterioration of the system, so non-soluble refrigerants in water are preferred. The solubility of water in both R-134a and R-407C is low.

3.4.8 Ozone depletion potential and global warming

The environmental consequences of a refrigerant that leaks from a system must also be considered. Because of their great stability, fully halogenated compounds, such as chloroflurocarbons (CFCs), persist in the atmosphere for many years and eventually diffuse into the stratosphere. The molecules of CFCs, such as R-11 and R-12, contain only carbon and the halogens chlorine and fluorine. Once in the upper atmosphere, CFC molecules break down and release chlorine, which destroys ozone (ozone depletion). In the lower atmosphere, these molecules absorb infrared radiation, which may contribute to the warming of the earth. Both R-134a and R-407C have low global warming potential, and zero ozone depletion potential.

3.5 Cost

The cost factor is not critical in deciding which refrigerant to use especially if the alternative refrigerant. (R-407C) provides acceptable environmental properties and the amount of charge required to charge the compressor of the freezer is small about (0.2kg). Table 3.3 shows the cost of R-134a and R-407C.

Table 3.3 Refrigerants costs

Refrigerant	Estimated Cost (JD/kg)
R-134a	5.0
R-407C	35.0

3.6 Availability

The availability of the refrigerant used in the refrigeration application is an important factor. Both R-134a and R-407C are available in our local markets.

Chapter Four

EXPERIMENTAL WORK PROCEDURE

4.1 Introduction

The object of this research is to study the performance of a chest freezer by replacing R-134a by R-407C. In this research, a locally manufactured chest freezer unit will be used to test the performance of the two refrigerants.

4.2 Freezer Unit Specification

The freezer used in this research is a simple chest freezer that contains a frozen food storage compartment, and it does not include defrosting devises or forced air circulation. The specifications of the freezer denoted by the manufacture are listed in table 4.1.

Table 4.1 Specification of the freezer used in this research

Trade mark	ABDIN
Manufacturer	Abdin Industrial EST.
Gross Capacity	200 L
Freezer storage capacity	200 L
Refrigerant R-134a charge mass	220 g
Power rating	186 Watt
Motor power	179 Watt
Nominal current and voltage	1.5 A (230 volts)
Compressor design	Reciprocating (hermetically-sealed)
Compressor displacement size	12 cc
Capillary tube diameter	0.8 mm
Capillary tube length	3.15 m
Lubricant	Polyol ester oil

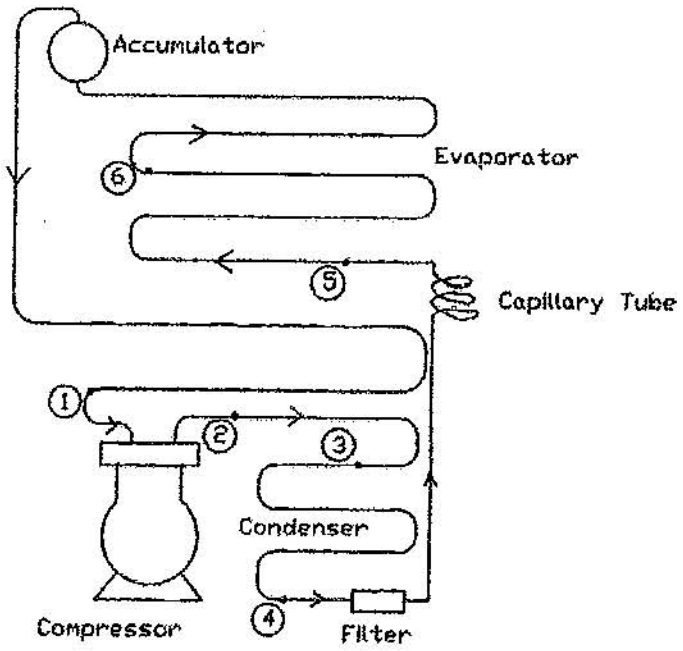

Figure (4.1): Freezer system schematic diagram

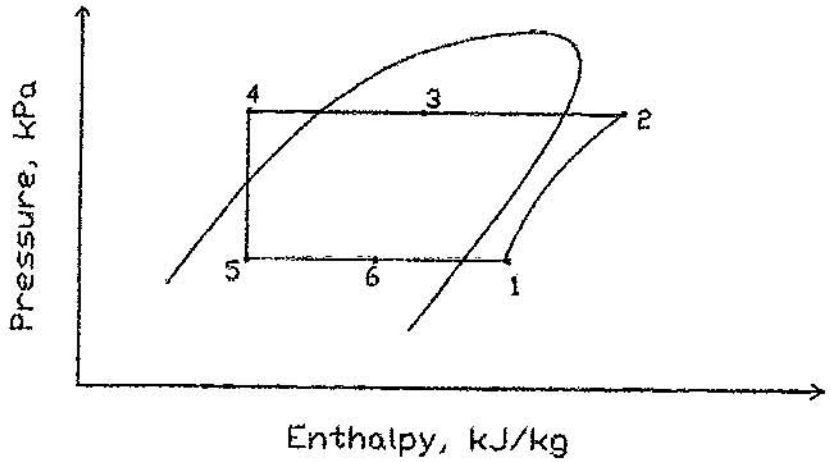

Figure (4.2): p-h diagram of the freezer system

4.3 Measuring Devices and Procedure

The variables that were measured during the experiments are temperature, pressure, power consumption, and time interval.

4.3.1 Temperature measurement

The temperature will be measured by thermocouples, which will be connected, to a microprocessor. The thermocouples will be fixed in certain points in the system by a tape, then it will be insulated to obtain a good results. These points (as shown in Figures 4.1 and 4.2) are:

1- Suction of the compressor, T_1

2- Discharge of the compressor, T_2

3- Midpoint of the condenser, T_3

4- Outlet of the condenser, T_4

5- Inlet of the evaporator, T_5

6- Midpoint of the evaporator, T_6

7- Inside the water load, T_7

8- The external surface of the container, T_8

9- Space (air) temperature, freezer compartment, T_9

10- The ambient temperature, T_{10}

4.3.2 Pressure measurement

Two pressure gauges will be used, one on the suction line of the compressor, which is low pressure gauge, and the other on the discharge line which is a high pressure gauge.

4.3.3 Actual electric power consumption measurement

The actual electric power consumed by the motor-compressor unit will be measured by a single-phase watt-hour meter.

4.3.4 Time

Measuring time intervals is important for calculating the rate of heat removal from the load (refrigeration capacity).

4.4 Experimental Work Procedure

Since the same freezer unit is used in the tests of the two refrigerants, the work was divided into two parts; the first part of the tests on R-134a and the second one for the tests on R-407C. Each part experiments was performed as follows:

4.4.1 First part

In this part the freezer was operated with its original refrigerant R-134a. Two types of tests were done, which are:

A- Evaporation temperature (Te) variation test

In order to perform this experiment, a simulated load which consists of a steel container of known specific heat and mass (0.85 kg of steel) filled with a specified quantity of hot water (12 liter of water at average temperature 80°C) was placed in the freezer compartment. After connecting thermocouple 7 and 8 to the load, it was placed in the freezer compartment. This will cause a rapid increase of Te to a maximum value. Then, it decreases slowly until it reaches its low limit.

During the period of Te variation, temperatures at the ten locations and time intervals were recorded. Assuming actual vapor compression refrigeration cycles the state at each point in the system can be determined using the temperature and pressure readings and R-134a tables.

4.4.2 Second part

In this part, tests were performed on R-407C. First, the freezer was evacuated from R-134a and then charged with R-407C and operated on it for 24 hours. After that, it was evacuated again to ensure that no R-134a traces are left in the system, and then charged with a specified quantity R-407C.

The freezer was first charged with 150g of R-407C, then Te variation test was performed and all calculations were completed to get the COP. After that, R-407C refrigerant was increased in steps of 50g until reaching a charge of 250g. The same experiments were performed for each of the three R-407C charge quantities (i.e. 150, 200 and 250)g.

The objective of doing all these experiments is to determine which charge quantity gives the best system performance and compare it with the performance of R-134a. Finally, the same experiments described above in tests A, B, and C were performed again using the best quantity of R-407C.

Chapter Five

MATHEMATICAL ANALYSIS

5.1 Introduction

In this chapter a complete mathematical analysis will de performed, and various parameters will be calculated using the data readings collected. The calculations are based on actual vapor compression cycle.

5.1.1 Theoretical vapor compression cycle

The vapor compression cycle is the most widely used refrigeration cycle in practice. The vapor processes, which comprise the theoretical vapor compression cycle, are:

1- Isentropic compression from saturated vapor at low pressure to superheated vapor at high pressure.

2- Rejection of heat at constant pressure and condensation to saturated liquid.

3- Irreversible expansion at constant enthalpy from saturated liquid at high pressure to saturated mixture at low pressure.

4- Addition of heat at constant pressure and evaporation to saturated vapor.

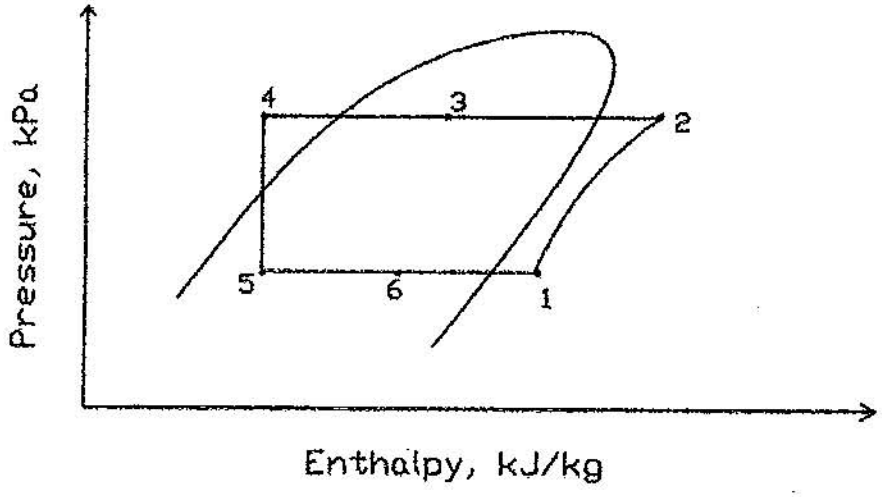

Figure (5.1): p-h diagram of the freezer system

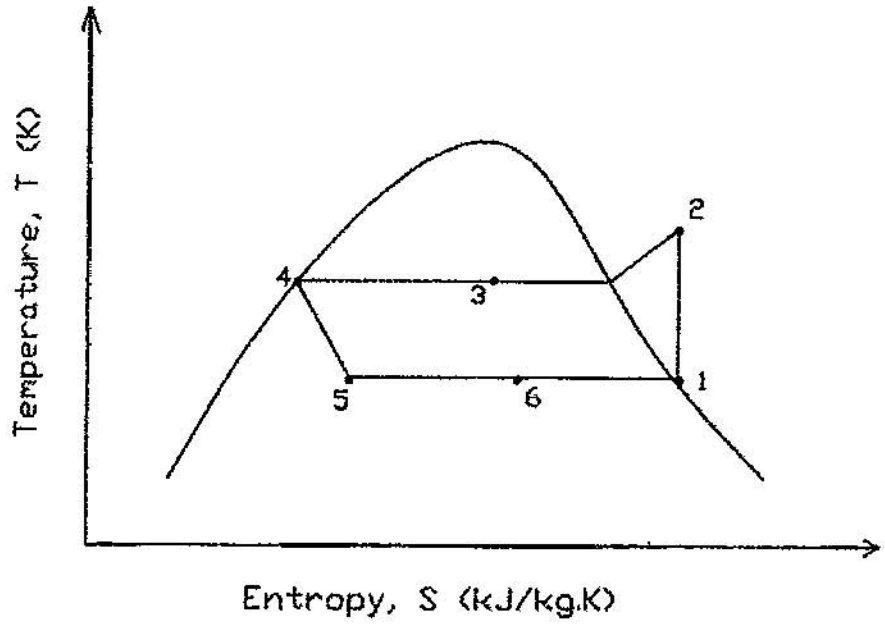

Figure (5.2): The standard T-S diagram

5.3 Mathematical Calculation

After collecting the data readings, set of the performance parameters of the refrigeration system were calculated by using the equations and methods, which will be discussed in this chapter.

5.3.1 Refrigerating effect

The refrigeration effect is the quantity of heat absorbed from the refrigerated space (freezer compartment) by the evaporator in kJ per kg of circulated refrigerant.

The net refrigerating effect depends upon the temperature at which the liquid is vaporized in the evaporator and the temperature of the liquid approaching the capillary tube. The mathematical formula is given by:

$$q_{ref} = (h_1 - h_5) \qquad (5.1)$$

Where,

q_{ref} : Refrigerating effect (kJ/kg).

h_1 : Is the enthalpy of the superheated vapor at the outlet of the evaporator as shown in Fig. 5.1 (kJ/kg).

h_5 : Is the enthalpy of the two phase liquid vapor mixture which enters the evaporator as shown in Fig. 5.1 (kJ/kg).

5.3.2 Refrigeration capacity

The refrigeration capacity is the rate of heat removal in kW from the refrigerated compartment by the evaporator. It is calculated by multiplying the refrigerating effect by the mass flow rate of the refrigerant in the evaporator, thus

$$Q_{ref} = m^{\bullet} q_{ref} = m^{\bullet} (h_1 - h_5) \qquad (5.2)$$

Where, Q_{ref} is the refrigeration capacity in kW and $m^{\bullet}$ is the refrigerant mass flow rate in (kg/s).

5.3.3 Mass flow rate of the refrigerant

The mass flow rate of the refrigerant is the mass of that refrigerant which must be circulated per second for any operating condition. It is given by:

$$m^{\bullet} = Q_{ref} / q_{ref} \qquad (5.3)$$

Where, $m^{\bullet}$ is the refrigerant mass flow rate in kg/s, and Q_{ref} is the refrigeration capacity in kW, which is calculated by measuring the rate of heat removed by evaporator from a simulated load (which consists of

metal container filled with hot water) in the freezer, using the following equation:

$$Q_{ref} = (M_w Cp_w \Delta T_w + M_{co} Cp_{co} \Delta T_{co} + M_{air} Cp_{air} \Delta T_{air}) / \Delta t \qquad (5.4)$$

Where,

M_w, M_{co}, and M_{air} are the masses of the water, container, and air inside the freezer in (kg).

Cp_w, Cp_{co}, and Cp_{air} are the specific heats of the water, container, and air inside the freezer in (kJ/kg.K).

ΔT_w, ΔT_{co}, and ΔT_{air} are the temperature differences of water container, and air inside the freezer, during the time period Δt (in seconds).

5.3.4 Work of compression

Compression work is the work consumed by the compressor in (kJ/kg) to compress one kilogram of the vapor from the inlet to the outlet, and it is given by:

$$w = (h_2 - h_1) \qquad (5.5)$$

Where,

w : Compression work (kJ/kg).

h_1 : Is the enthalpy of the superheated vapor at the inlet of the compressor as shown in Fig. 5.1 (kJ/kg).

h_2 : Is the enthalpy of the superheated vapor at the outlet of the compressor as shown in Fig. 5.1 (kJ/kg).

5.3.5 Theoretical power consumption

The power required by the compressor is the product of the mass flow rate of the refrigerant and the increase in enthalpy during the compression (the compression work).

$$W = m^{\bullet} w = (h_2 - h_1) \qquad (5.6)$$

Where, W is the theoretical power in (kW)

5.3.6 Actual electrical power consumption

The actual electrical power consumption is the power consumed by the compressor in (Watt), which is measured using a single-phase watt-hour meter.

5.3.7 Coefficient of performance (COP)

The coefficient of performance of a refrigeration system is an expression of the efficiency of the system. It can be obtained by dividing the refrigeration capacity over the power consumption, and it is given by:

$$COP = Q_{ref} / W = (h_1 - h_5)/(h_2 - h_1) \qquad (5.7)$$

5.4 Sample Calculation

A sample calculation will be presented for the optimum charge (210g) of R-407C, using one set of readings from the data tables in Appendix A, the readings are listed in table 5.1.

Table 5.1 Sample data readings for R-407C

Readings (units)	Measured values
Suction pressure (kpa)	182
Discharge pressure (kpa)	2400
Inlet temperature to the compressor (°C)	12.5
Outlet temperature from the compressor (°C)	87.5
Condenser temperature (°C)	39.0
Outlet temperature from the condenser (°C)	32.5
Evaporator temperature (°C)	-4.7
Temperature difference of water (°C)	1.7
Temperature difference of container (°C)	1.8
Temperature difference of air (°C)	2.0
Time period during the difference (min)	5

For the two state points at the inlet and the outlet of the compressor. From the suction and discharge temperatures, in addition to the suction and discharge pressures, using superheated vapor-constant pressure tables for R-407C in Appendix D, the values of enthalpies h_1 and h_2 can be obtained. In the same manner, the value of the enthalpy leaving the condenser (h_4) can be obtained using saturation properties-

temperature tables for R-407C in Appendix D. Due to high throttling through the capillary tube a pressure drop will occur with constant enthalpy, so the value of enthalpy at the inlet of the evaporator equals to the value of enthalpy at the outlet of the condenser (i.e. $h_4 = h_5$).

Using equations (5.1) through (5.7), all system performance parameters can be obtained.

From equation (5.4), and for:

$$M_w = 12kg,\ M_{co} = 0.85kg,\ \text{and}\ M_{air} = 0.2kg$$

Q_{ref}=(12*4.186*1.7+0.85*0.45*1.8+0.2*1.035*2.0)/(5*60)

$= 0.288$ kW $= 288$ Watt

$q_{ref} = (h_1 - h_5) = 428.3 - 250.7 = 177.6$ kJ/kg

$\dot{m} = Q_{ref} / q_{ref} = 288 / 177.6 = 1.61*10^{-3}$ kg/s $= 1.61$ g/s

$w = (h_2 - h_1) = 469 - 428.3 = 40.7$ kJ/kg

$COP = q_{ref} / w = 177.6 / 40.7 = 4.36$

The tabulated results are listed in table 5.2

Table 5.2 Results of sample calculation for R-407C

Properties (units)	Calculated values
The suction vapor enthalpy (kJ/kg)	428.3
The discharge vapor enthalpy (kJ/kg)	469
Enthalpy at the inlet of the evaporator (kJ/kg)	250.7
The refrigeration effect (kJ/kg)	177.6
The compression work (kJ/kg)	40.7
The coefficient of performance (COP)	4.36
The refrigeration capacity (Watt)	288
The mass flowrate of the refrigerant (g/s)	1.61

Chapter Six

RESULTS AND DISCUSSION

6.1 Introduction

Each of the four components of a vapor-compression system - the compressor, the condenser, the expansion device (capillary tube), and the evaporator - has its own peculiar behavior, at the same time, each component is influenced by condition imposed by the other members of the quarter.

First a comparison should be made between the performance of the different charge quantities of R-407C to find out the best quantity to be charged in the used chest freezer without making any changes or replacements in the freezer system.

Then, the performance of the best-suited charge of R-407C should be compared to that of R-134a to prove if R-407C is a possible alternative replacement to the R-134a refrigerant or not. The aim of this chapter is to compare the performance curves for both R-407C and R-134a with respect to the condensing and evaporating temperatures.

6.2 System Performance versus Charge Quantity

As stated in chapter 4, three different R-407C charge quantities were charged in the used chest freezer to find out which quantity gives the best performance starting with the 150 g charge until reaching the charge of 250 g in steps of 50 g.

Figure 6.1 shows the variation of the coefficient of performance with the evaporating temperature for three different selected charge quantities at 39 °C condensing temperature. From this figure, it is noticed that the COP of 150g, 200g, and 250g charge are very close to each other with higher values for 200g charge.

Variation of the coefficient of performance with the charge quantity for refrigerant R-407C is presented in Figure 6.2, from that figure it is noticed that the COP increased as the charge increased until it reaches an optimum value, then it begins to decreased again. The optimum COP value was 2.75 and was reached at the 210g charge, which means that this charge is the most suitable one to work with the used chest freezer. The values of the coefficient of performance were calculated at the conditions stated in figure 6.2 (Te = -15.1 °C, Tc =39 °C, and Ta = 22.5 °C).

6.3 Variation with the Evaporating Temperatures (Te)

Variation of the performance parameters of the chest freezer with the evaporating temperatures are presented for an evaporating temperature range from -27 °C to -5 °C, at 39 °C condensing temperature (Tc) and 22.5 °C ambient temperature (Ta). The performance parameters studied are the refrigerating effect, compression work, coefficient of performance, refrigeration capacity, mass flow rate, theoretical power consumption, and actual electrical power consumption.

All Te variation test data and results are presented in Appendix A and the results of these testing are presented graphically in figures 6.3 to 6.9 for both R-134a and R-407C at optimum charge.

6.3.1 Refrigerating effect

Variation of the refrigerating effect with the evaporating temperatures is presented in Figure 6.3 for both R-134a and R-407C, for constant condensing temperature (Tc = 39 °C). It is shown that the refrigerating effect increases slightly with an increase in the evaporating temperature. The increase in due to the slightly higher enthalpy at higher evaporating temperatures while the enthalpy of the refrigerant entering the capillary tube remains constant. Also, it is clear that the refrigerating

effect for R-407C is lower than that for R-134a by 5% at Te = -15.1 °C and this ratio increases to 20% at Te= -27 °C for the same conditions (Tc and Ta), that is due to decreased in enthalpy difference across the evaporator.

6.3.2 Compression work

Figure 6.4 shows the variation of the compressor work with respect to the evaporating temperatures, as the evaporating temperature increases, at a constant condensing temperature, the work will decreased due to that the evaporating pressure and temperature will increase (and thus the suction enthalpy will increase) while keeping the discharge enthalpy constant, therefore, this will cause the work to be reduced as Te increases, since the work equal to the enthalpy difference through compressor. Also, from Figure 6.4 it is clear that the values of compression work for R-407C is higher than that for R-134a by 41.1% at Te=-15.1 °C and this ratio increases to 72% at Te= -27 °C for the same conditions (Tc and Ta).

6.3.3 Coefficient of performance

From Figure 6.5 it is noticed that as Te increased, at constant Tc, the coefficient of performance (COP) increases. Since the enthalpy difference across the evaporator will increased, and the enthalpy

difference across the compressor will decrease.

A high coefficient of performance is one of the most desirable requirements for any refrigeration unit because it is an indication of the high efficiency of the system.

It is also noticed that COP for R-407C is lower than that for R-134a by 32.13% at Te= -15.1 °C for the same conditions (Tc and Ta), since the refrigeration effect for R-047C is less than that for R-134a and the compression work for R-047C is greater than that for R-134a.

6.3.4 Refrigeration capacity

The refrigeration capacity was calculated by measuring the rate of heat removal in the freezer compartment. Variation of the refrigeration capacity with the evaporating temperature is presented in Figure 6.6, it is noticed that for constant condensing temperature, the refrigeration capacity increases with increasing the evaporating temperature.

Since refrigeration capacity equal to the mass flow rate multiplied by the enthalpy difference across the evaporator. Increasing Te will cause both mass-flow rate and enthalpy difference to be increased, therefore, increasing the evaporating temperature can increase the refrigeration capacity.

Figure 6.6 indicates that the refrigeration capacity for R-134a is higher than that for R-407C by 16.1% at Te= -15.1 °C for the same conditions (Tc and Ta).

6.3.5 Mass flow rate

Variation of the mass flow rate with the evaporating temperature for both R-407C and R-134a, at constant condensing temperature (Tc = 39 °C) is shown in Figure 6.7.

As shown in Figure 6.7, increasing the evaporating temperature, at a constant condensing temperature, will increase the mass rate of flow. Since the mass flow rate is proportional to the specific volume, as Te increases, the specific volume decreases, which cause the mass flow rate to increase for constant Tc, also Figure 6.7 indicates that the mass flow rate for R-134a is higher than that for R-407C by 15.3% at Te= -15.1 °C for the same conditions (Tc and Ta).

6.3.6 Theoretical power consumption

The curves of the theoretical power consumption for both R-407C and R-134a are plotted against Te at constant condensing temperature (Tc= 39 °C) are shown in Figure 6.8.

Theoretically, the power equals zero value at two points, where the evaporating temperature equals the condensing temperature and where the mass rate of flow is zero. Between the two extremes the power shows a peak value practically, most refrigeration system operate on the left side of the peak of the power curve, which appears clearly in Figure 6.8.

As shown in Figure 6.8, the power increases with increasing the evaporating temperature, since when Te increase, mass flow rate increases at a rate higher than the decreases rate of the enthalpy, which explains the increases in the theoretical compressor power.

Compressor power for R-407C is higher than that for R-134a by 20% at Te= -15.1 °C under the same conditions.

6.3.7 Actual electrical power consumption

The curves of the actual electrical power consumption for both R-407C and R-134a are plotted against Te at constant condensing temperature (Tc = 39 °C) are shown in Figure 6.9.

As shown in Figure 6.9, the power increases with increasing the evaporating temperature, until it reaches a peak point, then the power will decrease, since when Te increase, mass flow rate increases at a rate

higher than the decreases rate of the enthalpy, and then, mass flow rate increases at a rate lower than the decreases rate of the enthalpy.

Electrical power consumption for R-407C is higher than that for R-134a by 48.48% at Te= -15.1 °C under the same conditions.

6.4 Variation with the Condensing Temperature (Tc)

Variation of the performance parameters with the condensing temperatures are presented in two parts; first, at two values of Te (-15.1 °C, -20.6 °C) and Ta=22.5 °C for R-134a refrigerant, the second part, for two different refrigerants, R-134a and R-407C at Te = -15.1 °C.

All Tc variation test data and results are presented in Appendix B and the result of this testing are presented graphically in Figure 6.10 to 6.15.

6.4.1 Refrigerating effect

Figure 6.10 shows the refrigerant effect versus Tc, for R-134a at two values of constant evaporating temperature, the refrigerating effect decreases with increasing the condensing temperature because increasing Tc causes increases in the enthalpy of the refrigerant entering the

evaporator while keeping the one leaving the evaporator constant. This will cause a decrease in the refrigeration effect.

Also, it is shown that the refrigerant effect at (Te = -20.6 °C) is slightly lower than that at (Te = -15.1 °C).

Figure 6.11 shows the refrigerant effect versus Tc, for two refrigerants (R-407C and R-134a) at constant evaporating temperature (Te = -15.1 °C). Also, it is shown that the refrigerant effect for R-134a is higher than that for R-407C by 2% at Tc= 33 °C under the same conditions.

6.4.2 Compression work

The compression work is plotted against Tc for R-134a at two values of Te, as shown in Figure 6.12. As the condensing temperature increases, at a constant evaporating temperature, the work will increases due to that the discharge pressure and temperature (and thus the discharge enthalpy of the refrigerant) will increases while keeping the suction enthalpy constant. Therefore, this will cause the compression work to increase as Tc increases, since work equal to the enthalpy difference across the compressor.

Figures 6.18 and 6.19 show the evaporating temperature response to load during the operation period for R-134a and R-407C respectively. After placing the load, Te began to increase as a result of increasing the amount of heat that would be absorbed by the refrigerant from the load until it reached its highest value, and then it began slowly to decreases.

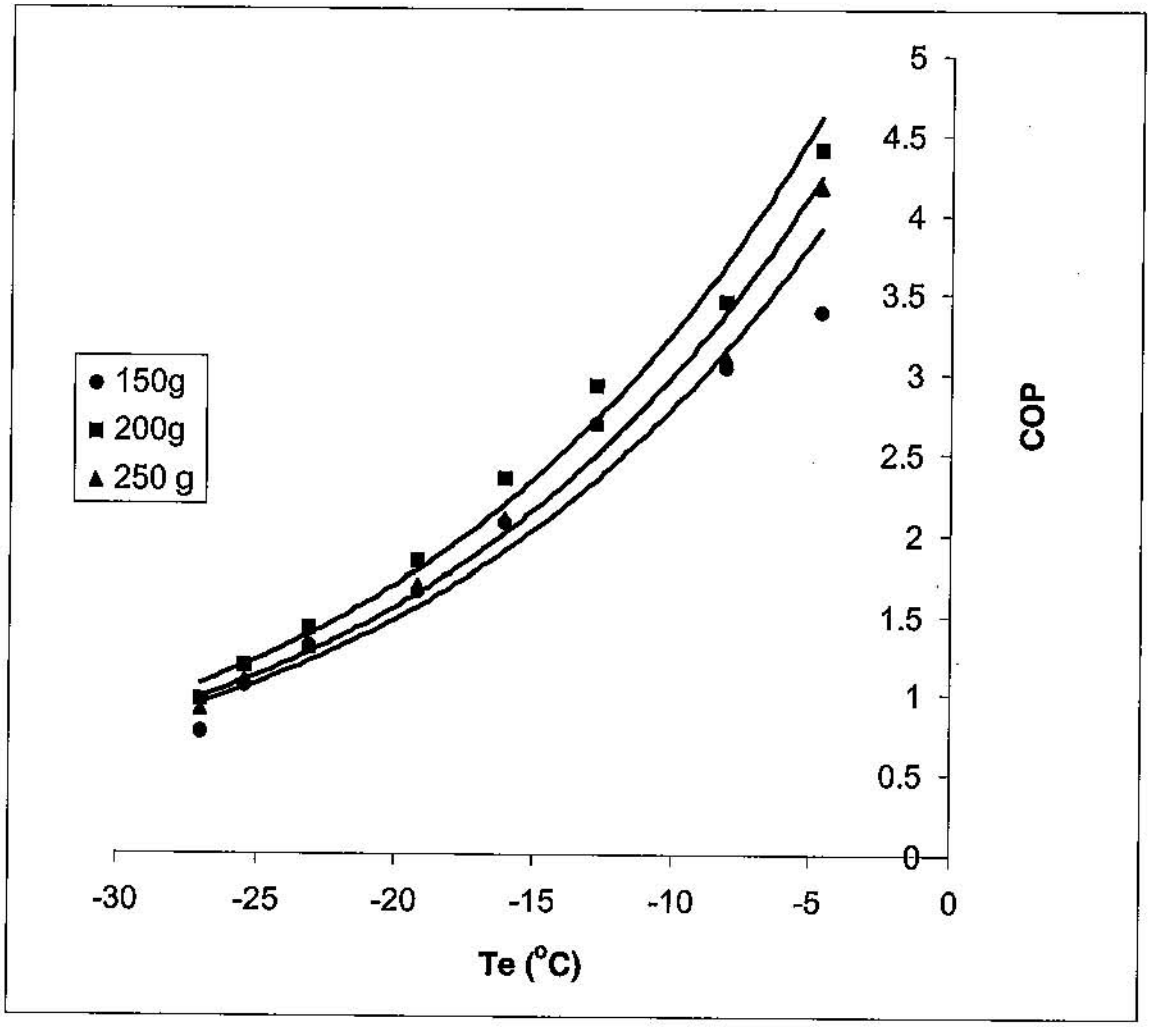

Figure 6.1 Coefficient of performance versus evaporating temperature for R-407C.

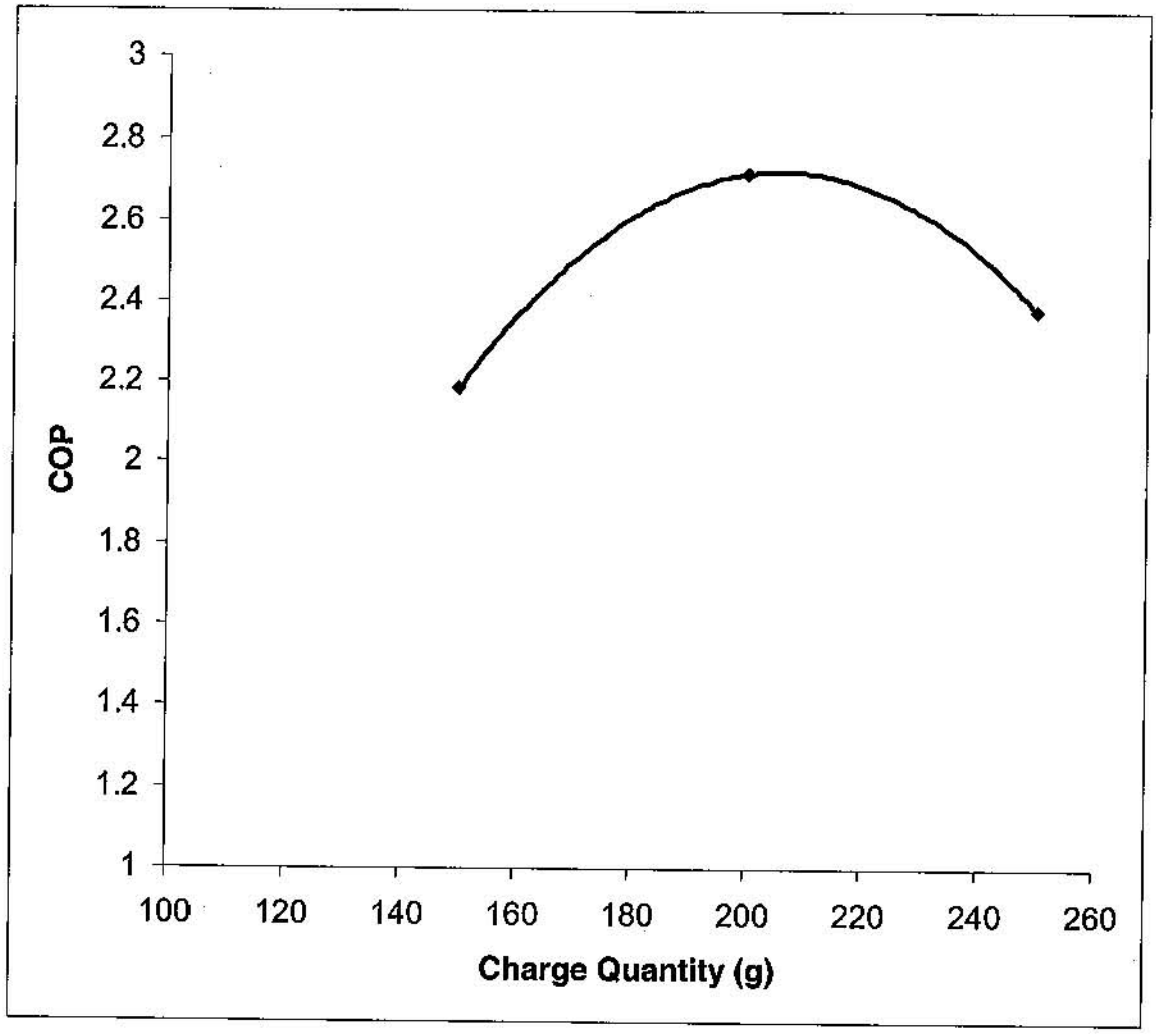

Figure 6.2 Coefficient of performance versus charge quantity.

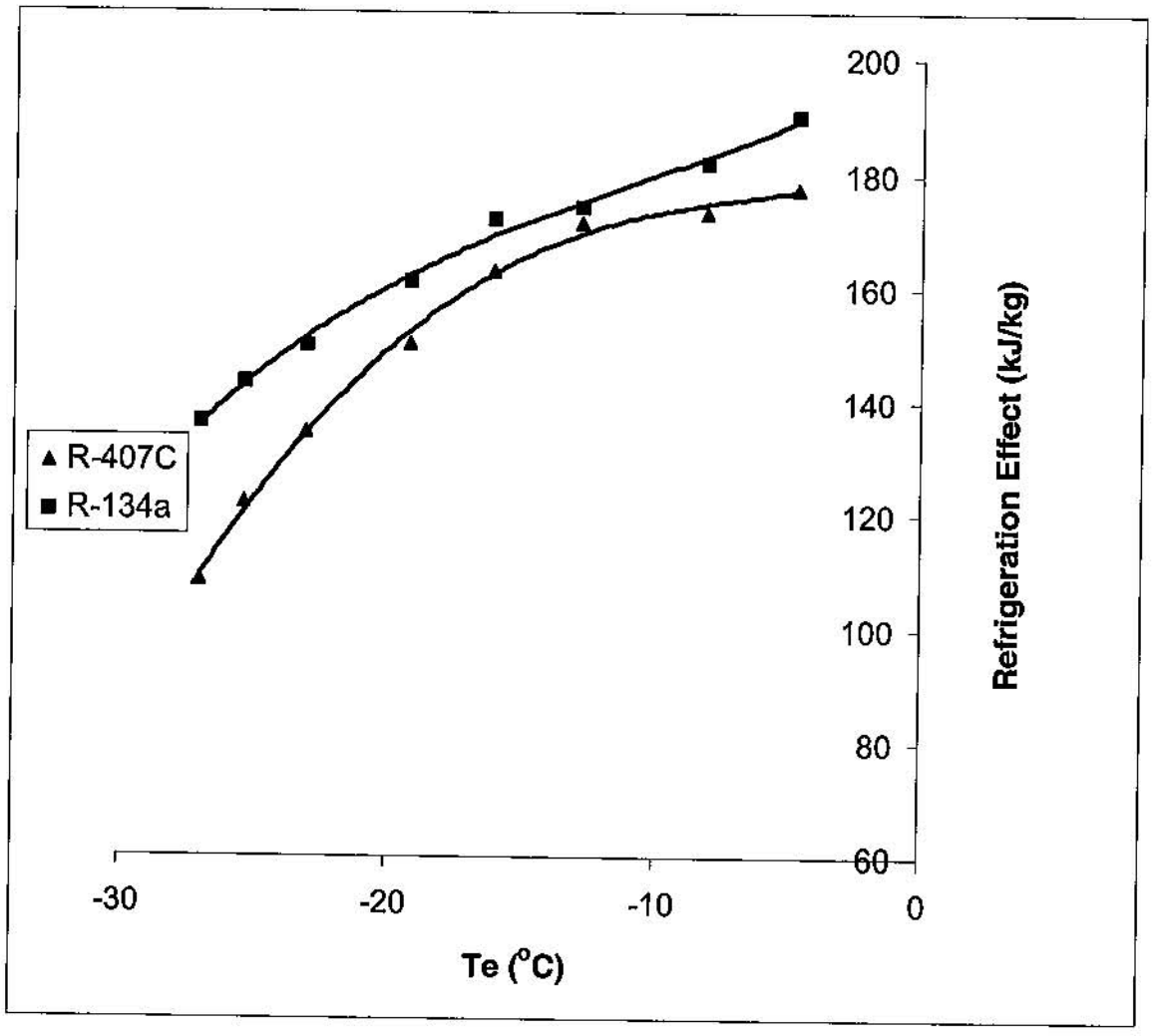

Figure 6.3 Refrigeration effect versus evaporating temperature.

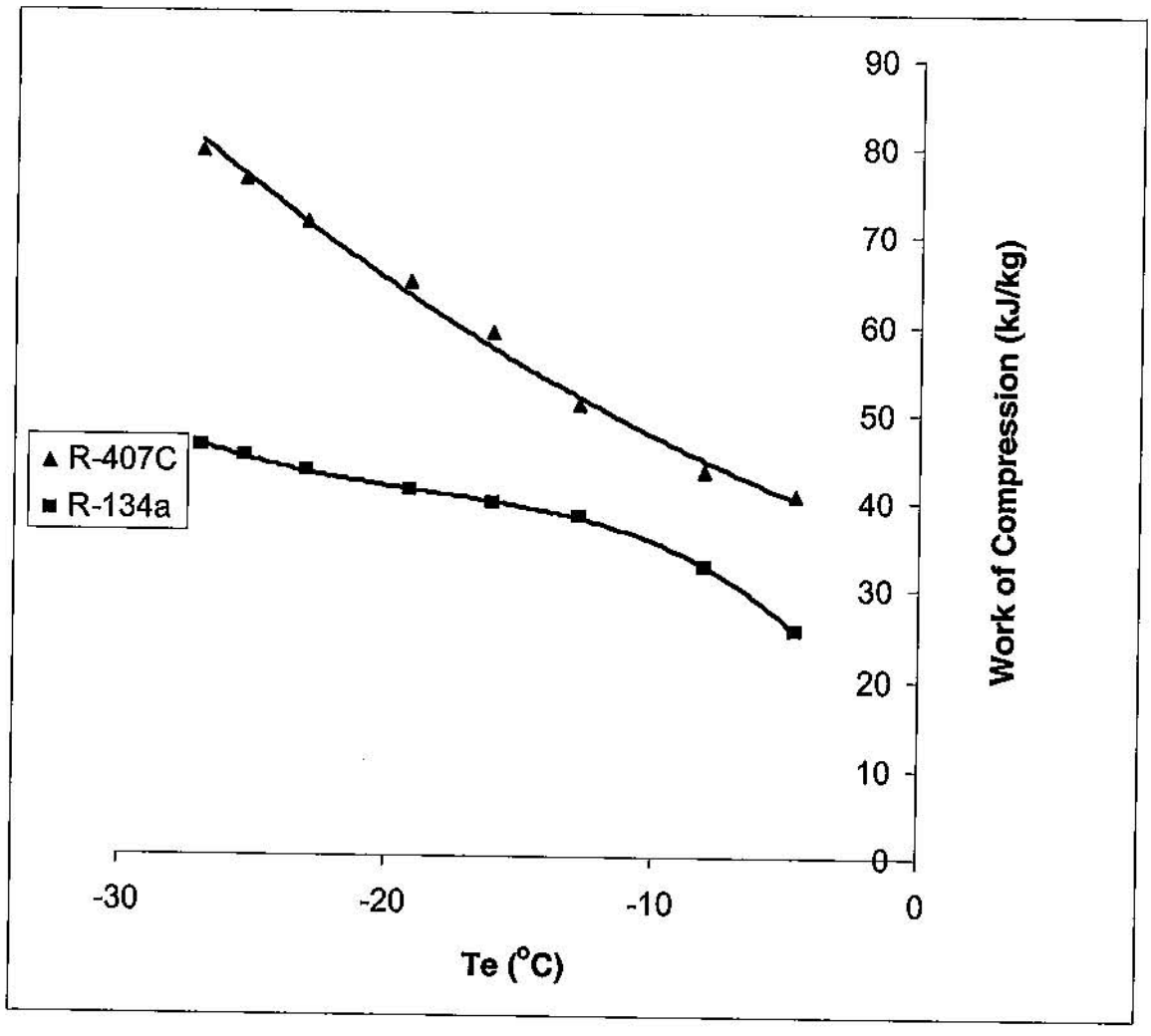

Figure 6.4 Work of compression versus evaporating temperature.

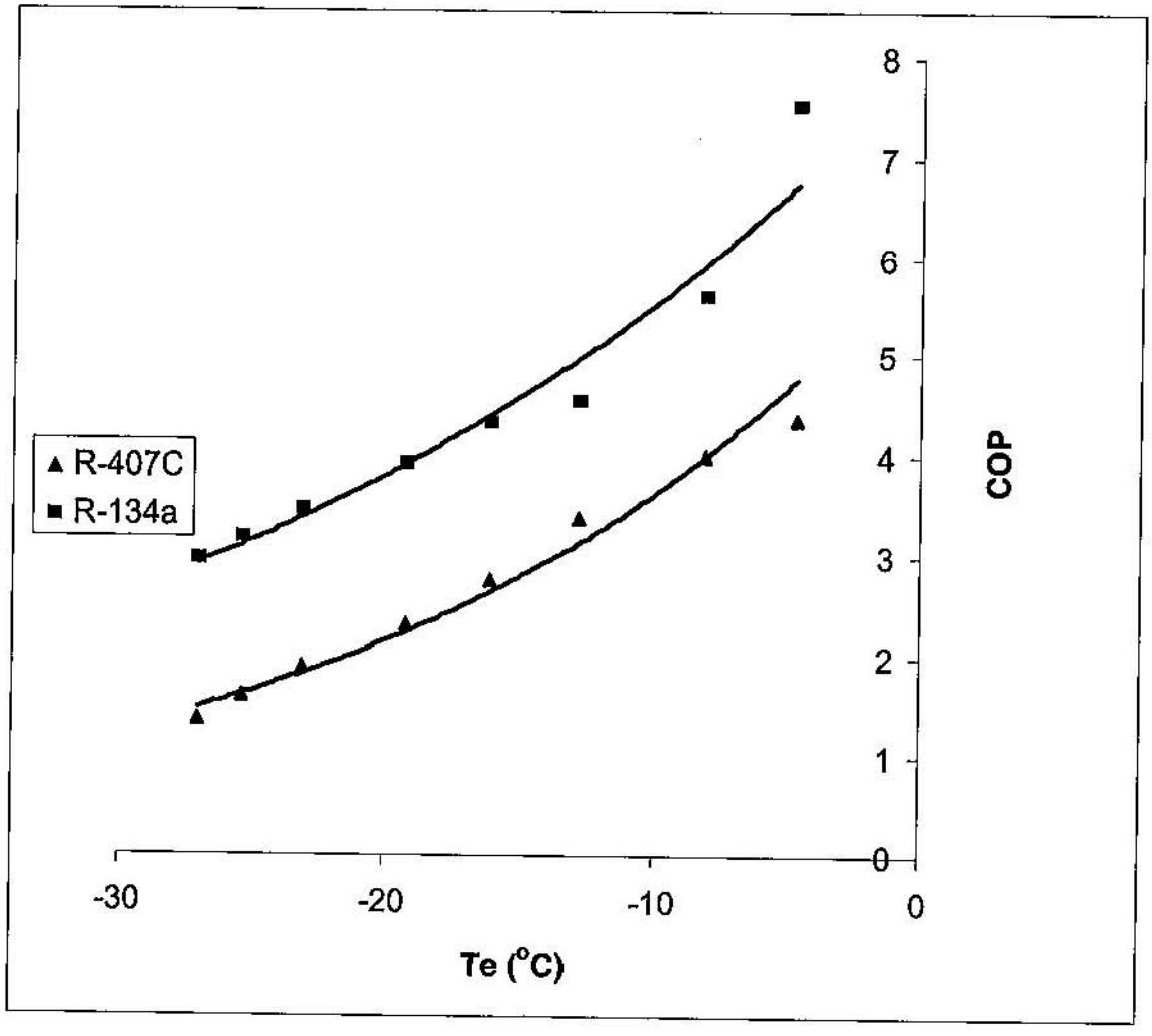

Figure 6.5 Coefficient of performance versus evaporating temperature.

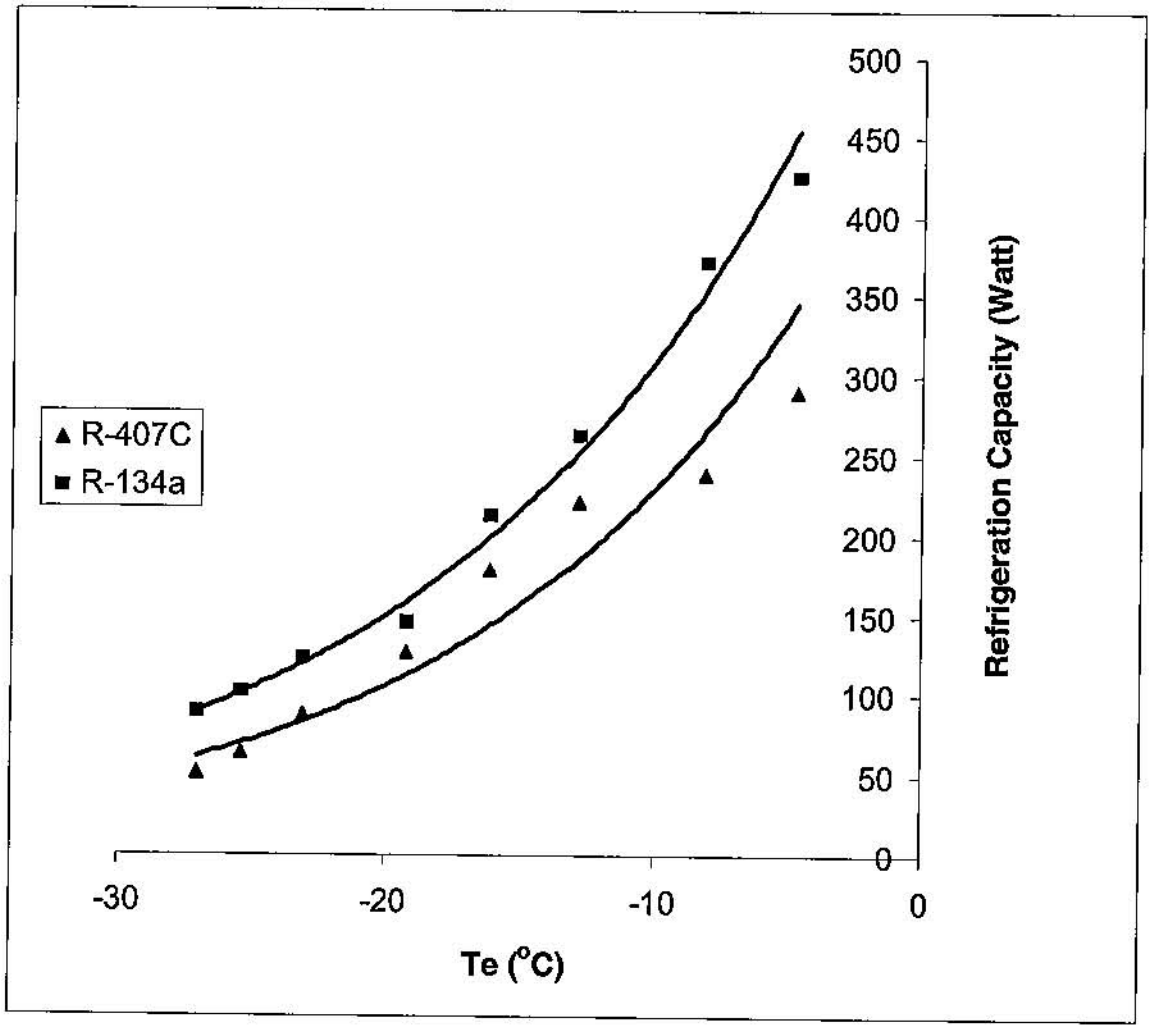

Figure 6.6 Refrigeration capacity versus evaporating temperature.

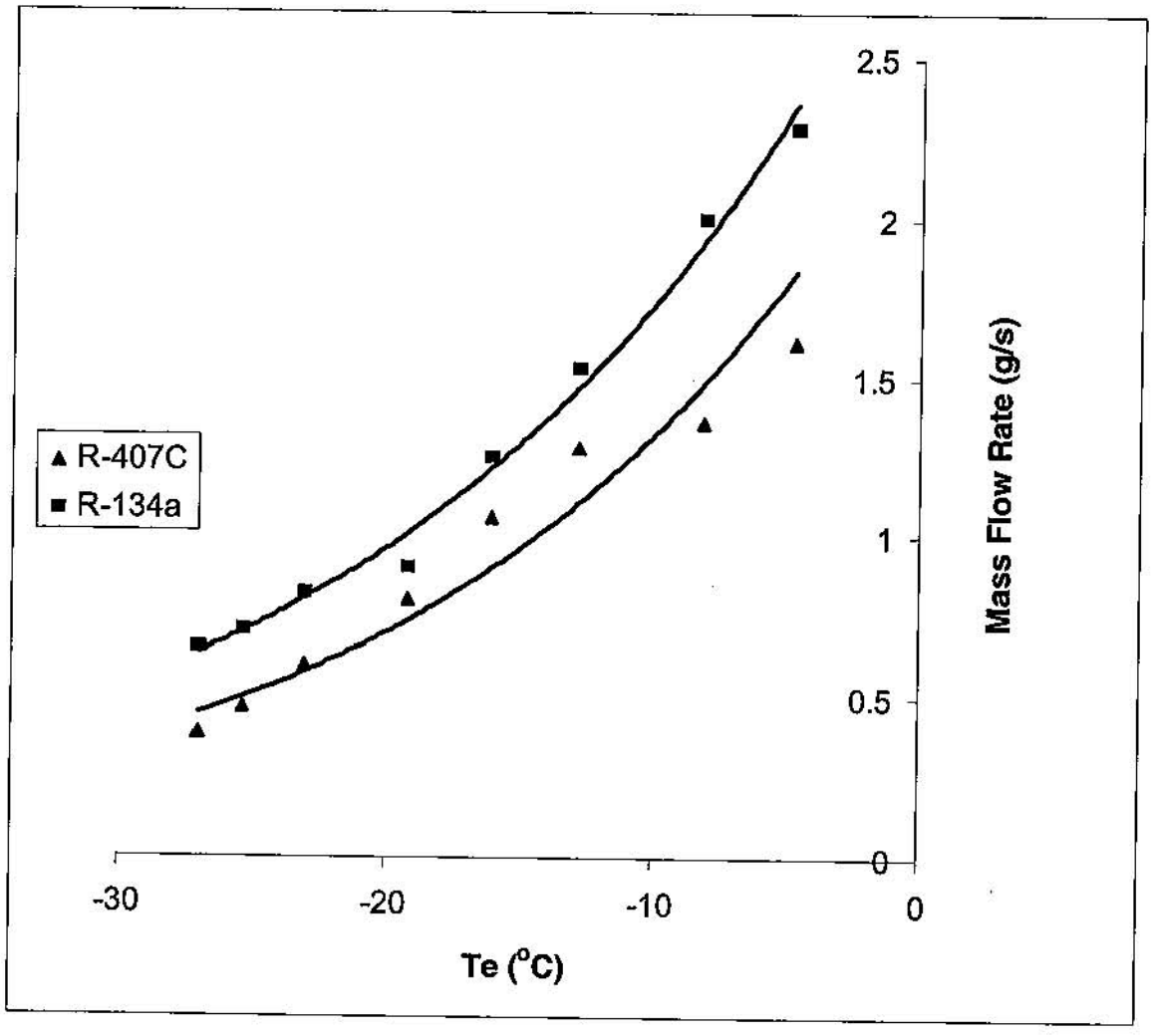

Figure 6.7 Mass flow rate versus evaporating temperature.

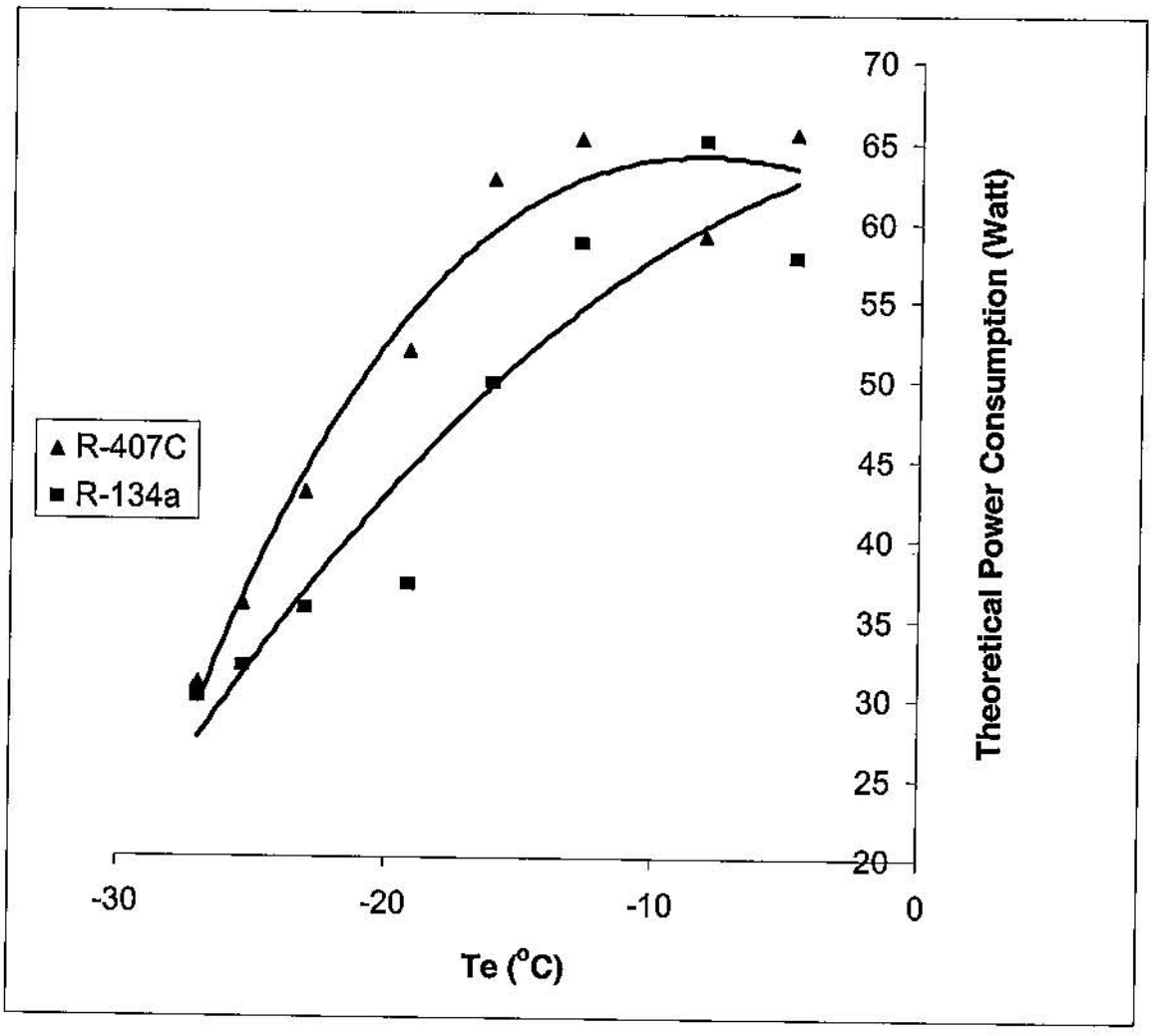

Figure 6.8 Theoretical power consumption versus evaporating temperature.

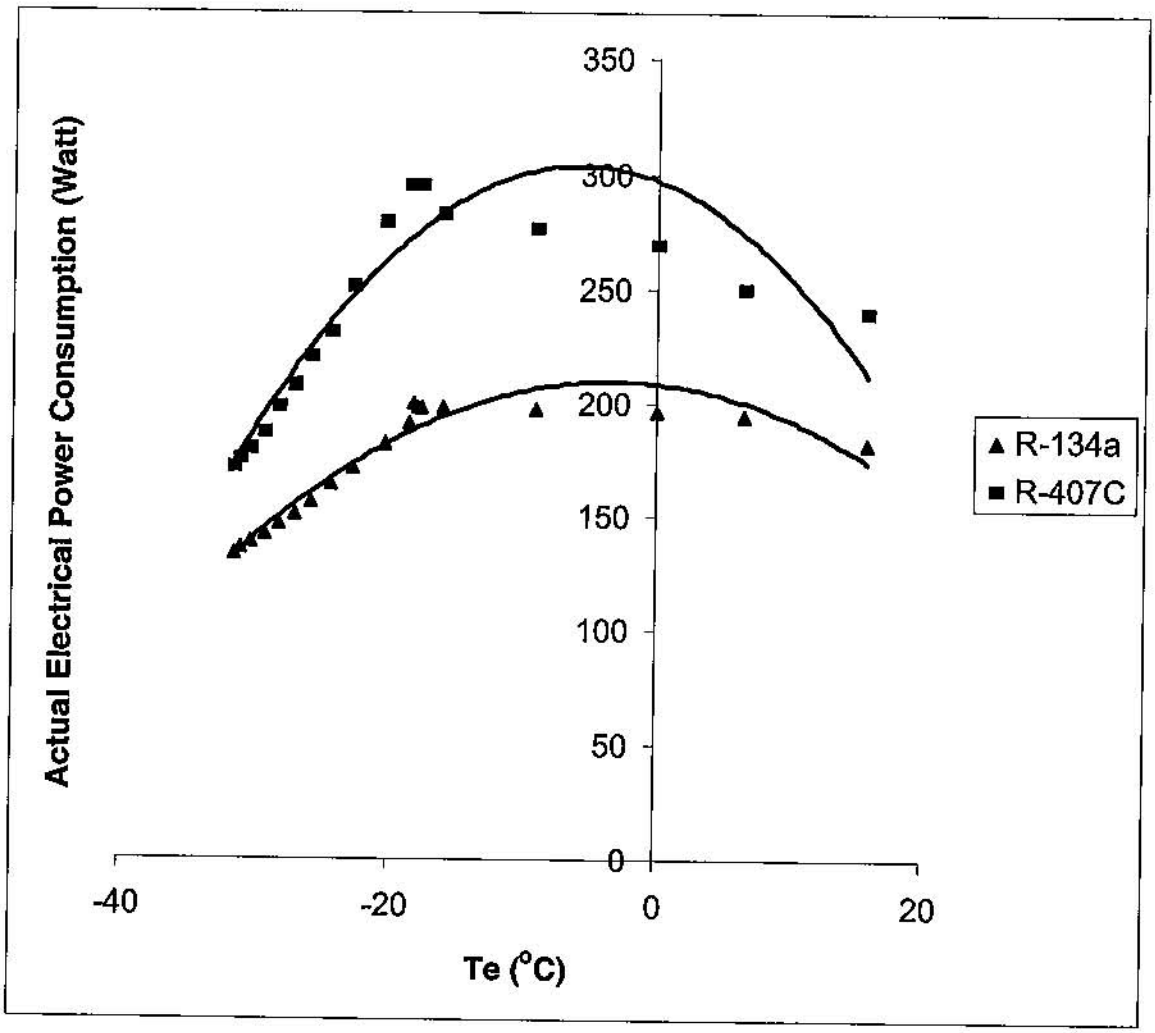

Figure 6.9 Actual electrical power consumption versus evaporating temperature.

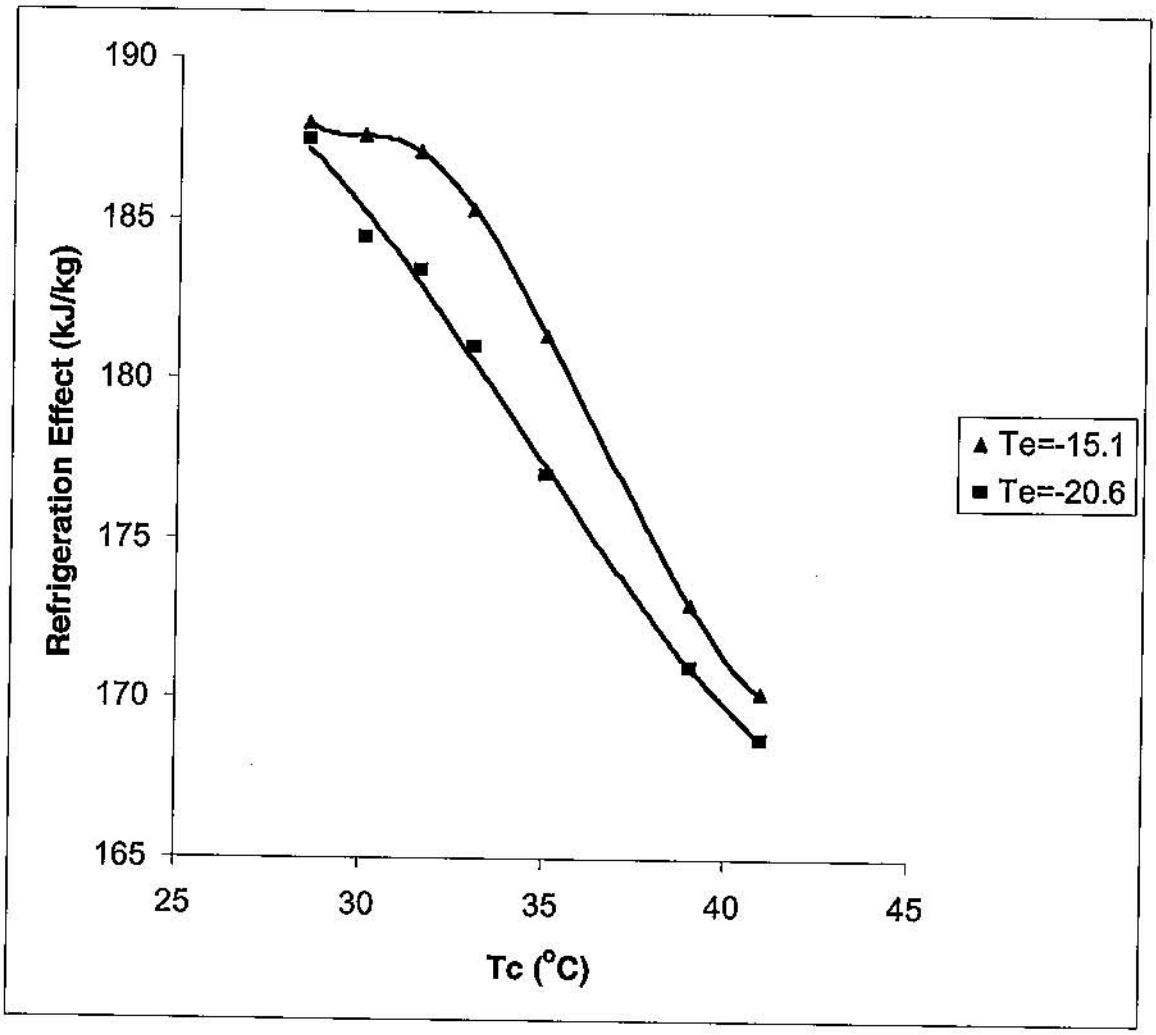

Figure 6.10 Refrigeration effect versus condensing temperature for R-134a.

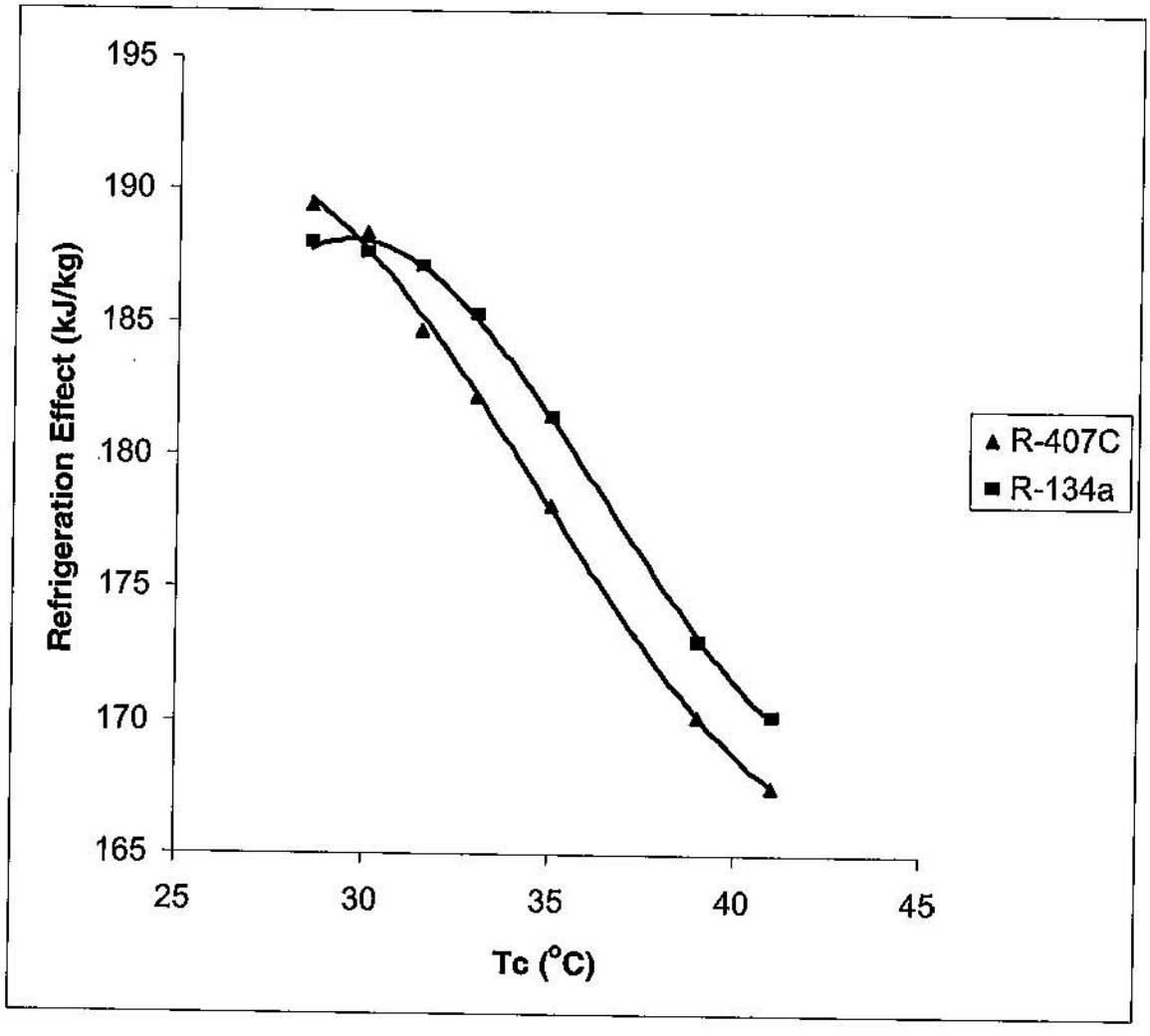

Figure 6.11 Refrigeration effect versus condensing temperature.

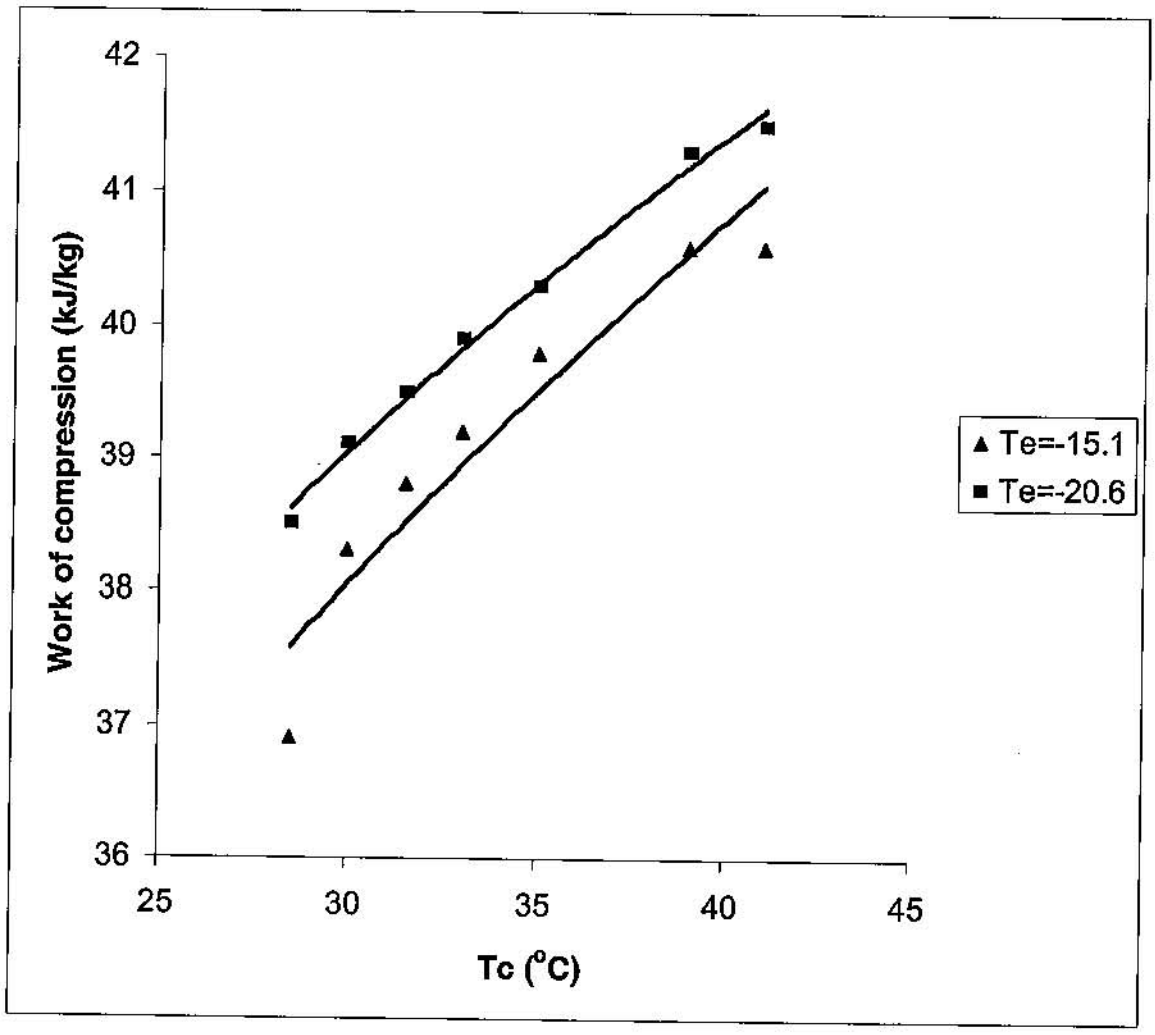

Figure 6.12 Work of compression versus condensing temperature for R-134a.

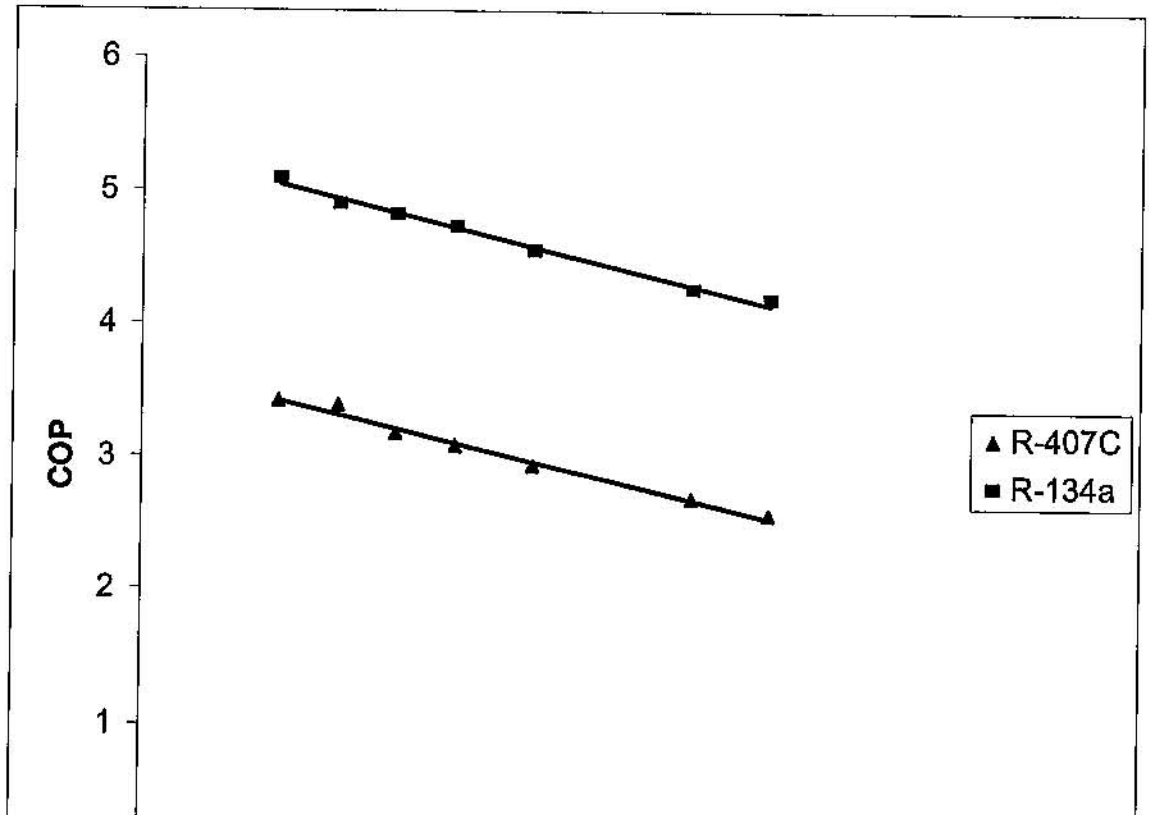

Figure 6.13 Work of compression versus condensing temperature.

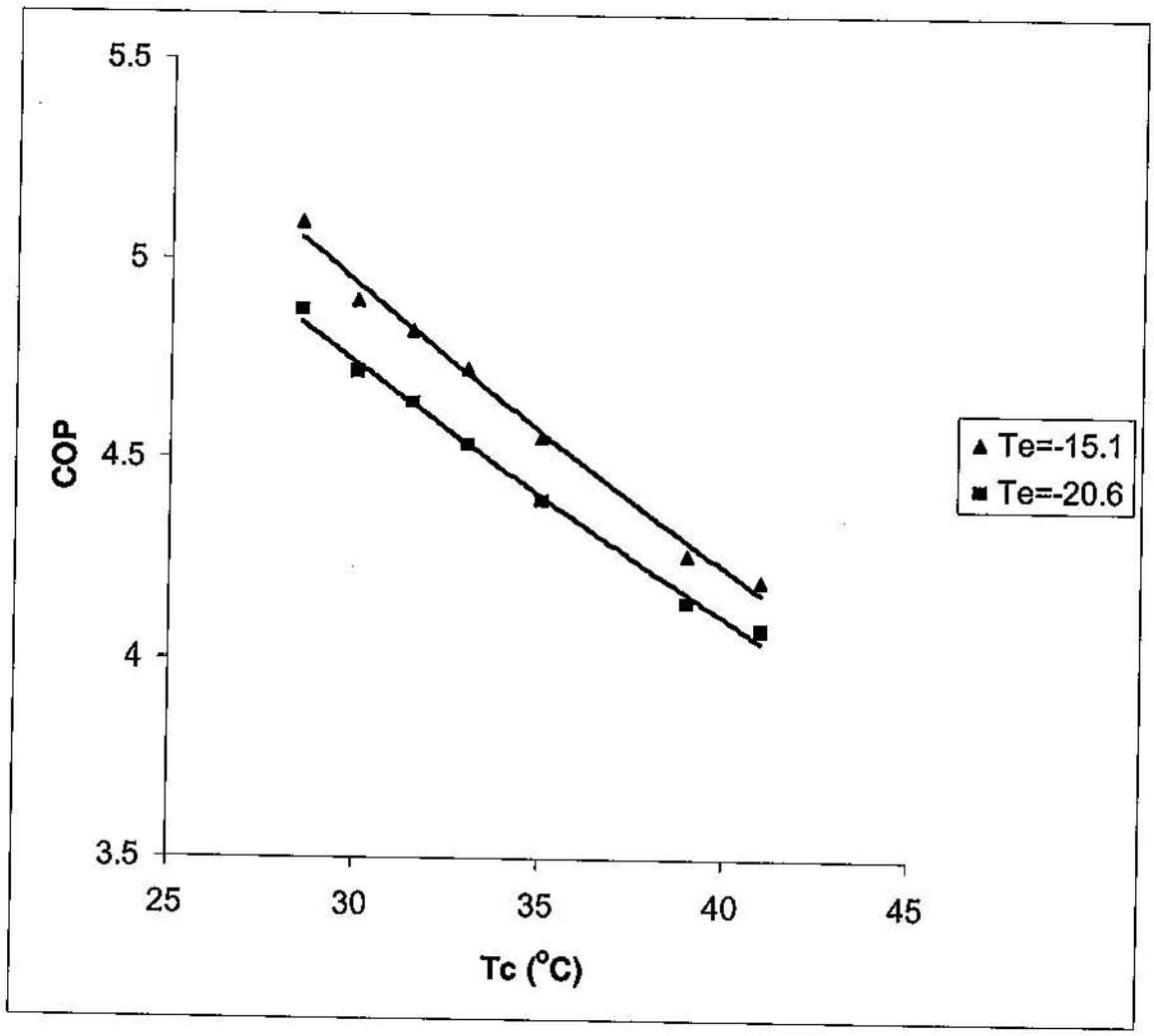

Figure 6.14 Coefficient of performance versus condensing temperature for R-134a.

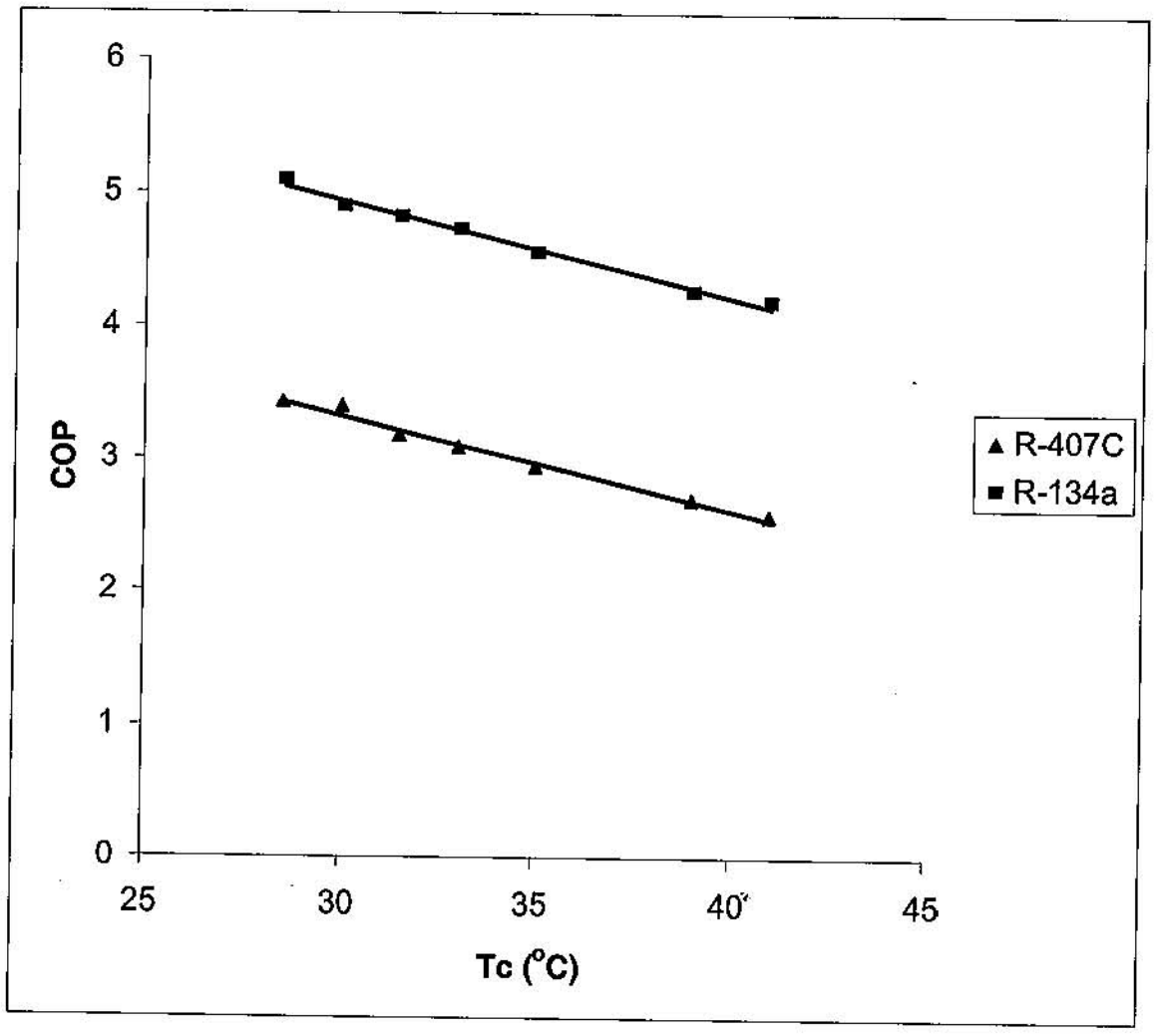

Figure 6.15 Coefficient of performance versus condensing temperature.

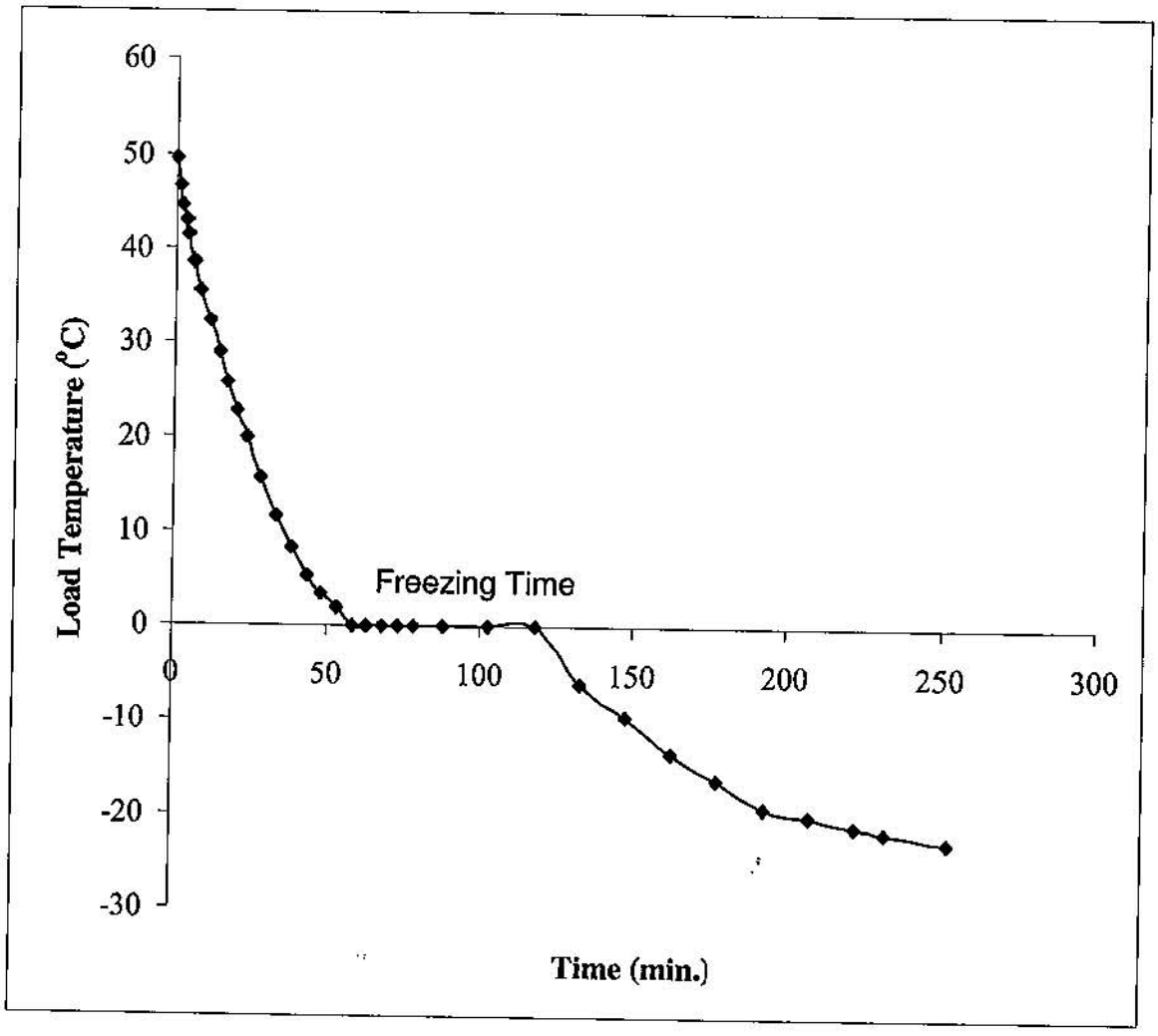

Figure 6.16 Load temperature versus time for R-134a.

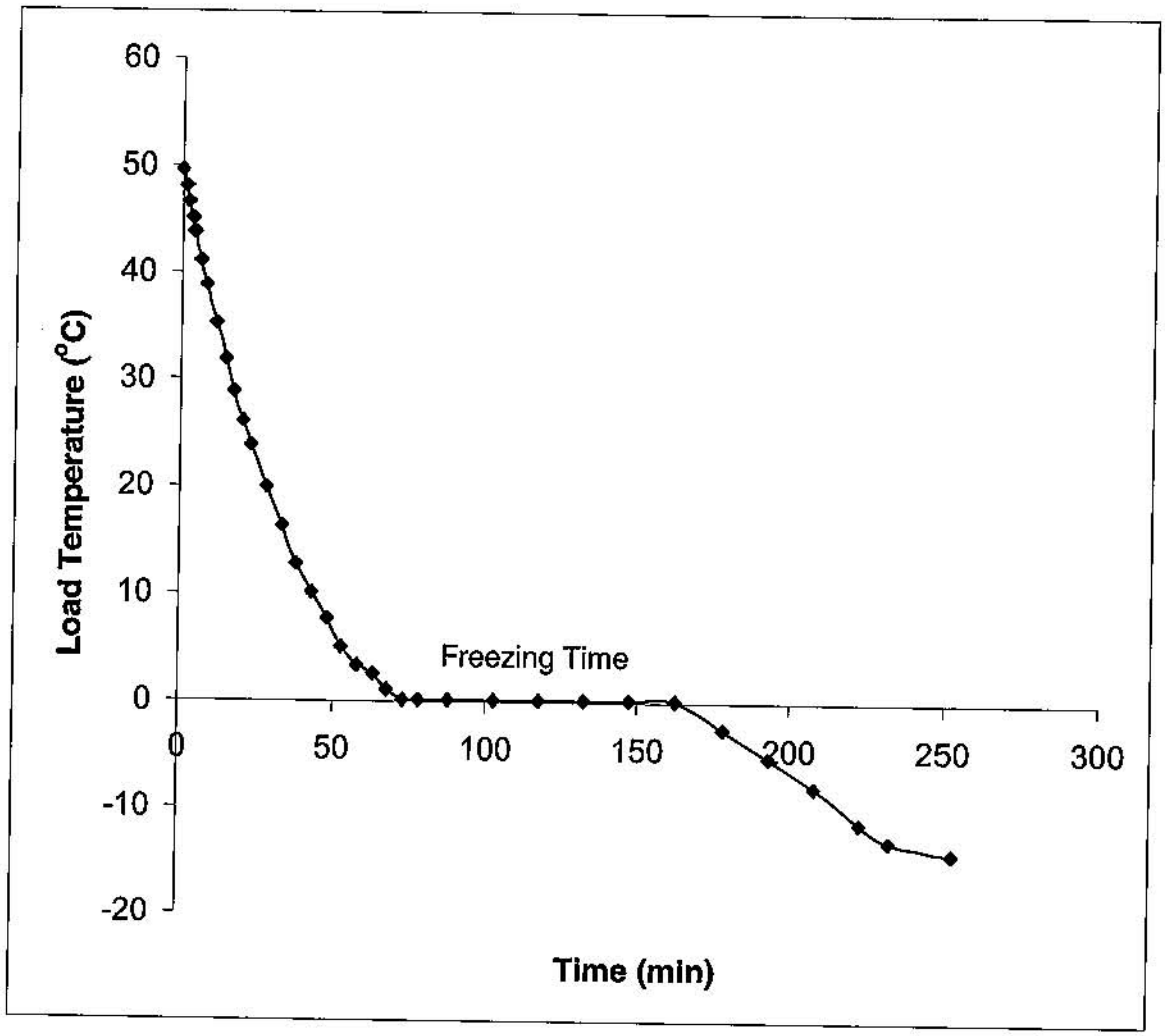

Figure 6.17 Load temperature versus time for R-407C.

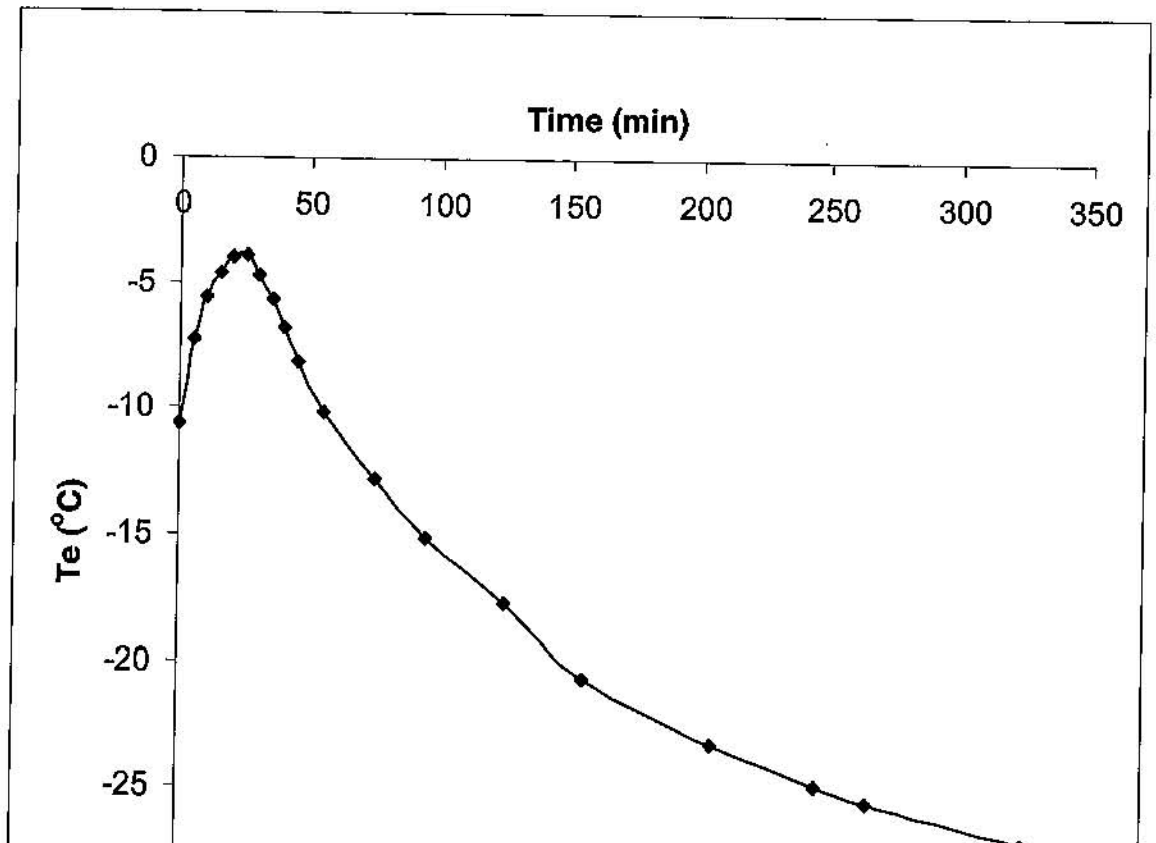

Figure 6.18 Evaporating temperature versus time for R-134a.

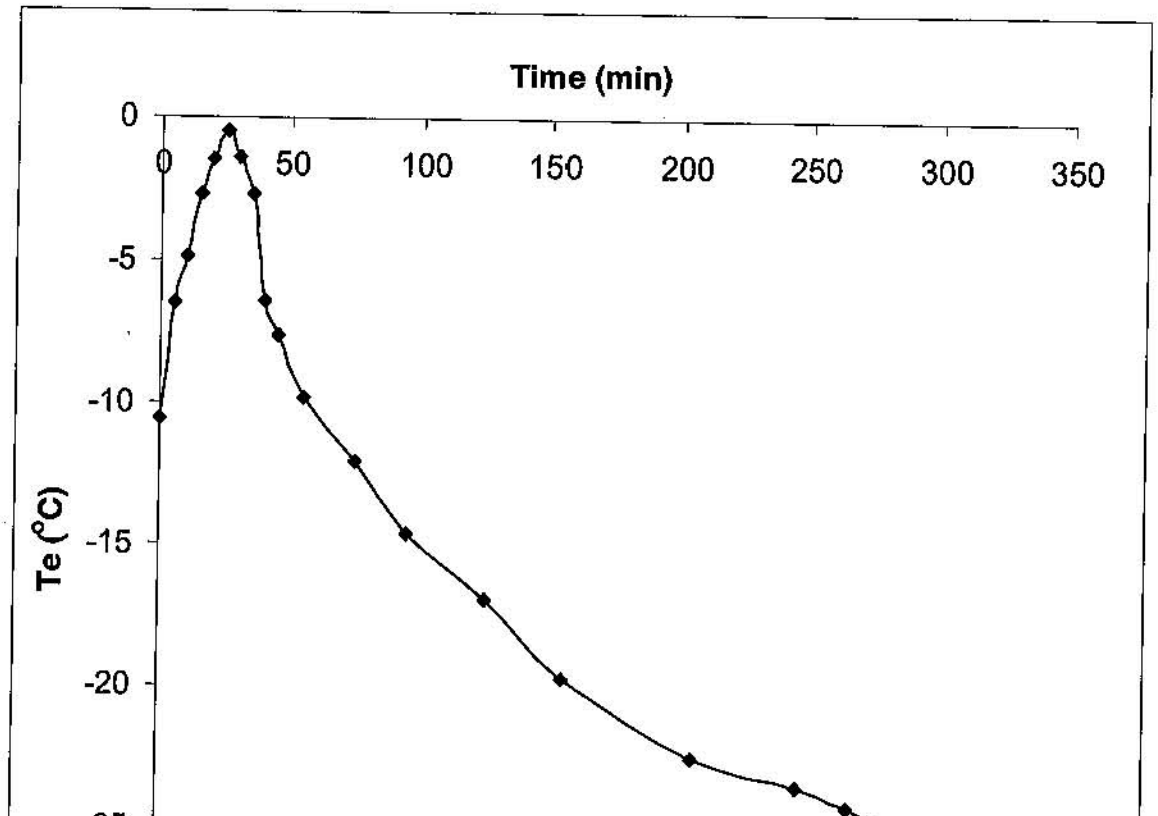

Figure 6.19 Evaporating temperature versus time for R-407C.

Chapter Seven

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This research covers an experimental study of the performance of a locally manufactured chest freezer using R-407C, which is a mixture of (52% R-134a, 25% R-125 and 23% R-32) as an alternative refrigerant to R-134a.

The performance of R-407C was tested, without changing or modifying the design of the used freezer, and compared with that of R-134a, the original refrigerant. The following conclusions were deduced:

1. The thermodynamical performance of refrigerant R-407C is not competent with that of refrigerant R-134a. Results showed evaporator temperatures for R-407C down to –32 °C and coefficients of performance around 1.35 (very low) at Te of –27 °C, Tc of 39 °C, and Ta of 22.5 °C. While for R-134a (original refrigerant), at the same conditions and evaporator temperatures down to –32 °C, the coefficient of performance was 2.96, which is higher than that

for R-407C by 54.4%, and capacity dropped from 89 Watt for R-134a down to 51 Watt for R-407C under the same conditions.

2. More energy required (about 50%) in the input power when using R-407C as alternative to R-134a in the chest freezer.

3. From the experimental results of the performance tests with R-407C as a substitute for R-134a it has been found that the best refrigerant charge mass required for R-407C was 95.45% of the mass used for R-134a.

4. Same evaporating temperature were reached for both R-407C and R-134a at the same condensing and ambient temperatures.

5. No design modifications or component replacements are required for the chest freezer in order to be fitted with R-407C.

6. Despite of the environmentally friendly nature of R-407C and its availability, safety, and other desirable characteristics, R-407C is not a suitable or acceptable alternative to R-134a in chest freezers.

7.2 Recommendations

1. According to the results of this research, refrigerant R-407C is not recommend as a suitable alternative to refrigerant R-134a in chest freezers and small freezing systems due to drop in capacity and COP.
2. More experimental researches and studies are recommended to be carried out on the R-407C for a wider range of working and environmental conditions (low condensing and ambient temperatures) in freezers and domestic refrigerators.
3. A changes or modifications in the chest freezer, specially in the compressor is recommended to reduce the input power of the compression, which is the essential problem that made R-407C to fall as an alternative refrigerant in freezers.
4. More research and studies are recommended on other promising and environmentally safe alternative refrigerants, which will be very useful for the industry when phasing out existing CFCs and HCFCs.

REFERENCES

Association of European Refrigeration Compressor Manufactures (ASERCOM), 1997. Substitution of R-22 in a new air conditioning system. Published by: ASERCOM 91, Berlin.

Atwood, and Theodor, 1991. Refrigerants of the future. ASHRAE Handbook of Fundamentals, Atlanta.

American Society of Heating, Refrigeration, and Air Conditioning Engineers, ASHRAE Handbook of fundamentals, Atlanta, 1993.

Bansal P., Dutto T., and Hivet B., 1992. Performance evaluation of environmentally benign refrigerants in heat pumps one. International journal of refrigeration V15: 340-348.

Bansal P., Dutto T., and Hivet B., 1992. Performance evaluation of environmentally benign refrigerants in heat pumps two. International journal of refrigeration V15: 349-359.

Carofano A., Fabberetti V. Theoretical comparison of refrigerant cycle for air conditioning system operating with R-22, R-134a, Blends and relative experiment test. Production of Refrigeration Science and Technology (CFC. THE Day After), VDI, Beriche NO.2, Pavoda, Italy, 267-274.

Eckels S. J., and Pate M. P., 1991. An Experimental Comparison of Evaporation and Condensation Heat Transfer Coefficients for HFC-134a and CFC-12, International journal of refrigeration V14: 70-77.

German Compressor Manufacturing Company (BITZER), 1999. Refrigerant Report 5. Published by BITZER Kuhlmachinebau Gmbh Germany.

German Compressor Manufacturing Company (BITZER), 2000. The future has already begun. Published by BITZER Kuhlmachinebau Gmbh Germany.

Habash A., 1994. "Performance Of Propane/Butane Mixture As A Refrigerant For Use In Domestic Refrigerators", M. Sc. Thesis, University of Jordan, Amman, Jordan.

Luzzatto D., Magni F., and Radaelli G., 1994. Alternative refrigerants; Application of R-22 alternatives in air conditioning equipment. Production of Refrigeration Science and Technology (CFC. THE Day After), VDI, Beriche NO.2, Pavoda, Italy, 307-314.

Makahleh F. M., 2001. "Performance Study Of Two A/C Split Unit Using R-407c", M. Sc. Thesis, University of Jordan, Amman, Jordan.

McLinden M. O., and Didion D. A. The search for alternative refrigerants. International journal of refrigeration V17:149-155.

Midgley T. Assessment of HFCs, fluorinated ethers and amine as alternatives to CFC12. International journal of refrigeration V16: 81-152.

Preisegger E., and Henrici R., 1992. R-134a: The First Step into a New Age of Refrigerants, International journal of refrigeration V15: 326-331.

Spartz M., 1993. Alternative refrigerants for R-22 chillers. ASHRAE journal of refrigeration, May 1993, pages 50-52.

Xiao Feng, Yong-Zhang Tu, and Li-Li Zhou, 1994. Study on the alternative refrigerants for HCFC-22. Production of Refrigeration Science and Technology (CFC. THE Day After), VDI, Beriche NO.2, Pavoda, Italy, 259-266.

APPENDICES

APPENDIX A : Data and Results (Te Variation Test)

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Superheated Properties for R-407C

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APPENDIX A

Data and Results Tables (Te variation Test)

Table (A.1) Refrigerant R-134a, Ta = 22.5 °C and Tc = 39 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_4 °C	T_6 °C	T_7 °C	T_8 °C	T_9 °C
214	2050	22.1	79	21.5	-4.7	77.6	79.2	35.8
207	1820	22.2	79	23.7	-5.7	75.3	76.5	34.3
203	1750	23	80.1	26.5	-6.8	73.2	74.5	32.4
200	1650	23.3	80.5	28	-8.1	71	72.2	30.4
187	1510	23.5	80.5	30.5	-10.1	67.3	68.3	27
180	1370	23.9	81	32.1	-11.8	63.9	64.9	23.5
173	1340	24.2	81.5	34.2	-12.8	60.8	61.8	21.4
166	1300	24.5	82.8	35	-14.1	58.1	59	18.8

 # Results

Te °C	w_{com} kJ/kg	q_{ref} kJ/kg	COP	Q_{ref} Watt	$\dot{m}$ g/s
-4.7	25.3	190	7.51	425	2.28
-5.7	28.7	187.1	6.52	390	2.14
-6.8	30.6	183.8	6.00	390	2.14
-8.1	32.5	182.1	5.60	370	2.08
-10.1	34.5	178.8	5.20	314	1.82
-11.8	36.9	176.7	4.79	289	1.67
-12.8	38.3	174.3	4.55	263	1.53
-14.1	38.8	173.6	4.42	230	1.33

Table (A.2) Refrigerant R-407C, Charge quantity 150g,

Ta = 22.5 °C and Tc = 39 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_4 °C	T_6 °C
193	3515	14	89	36	-4.7
182	3470	14.5	93.6	36	-5.7
175	3400	15.3	96	36.5	-6.8
175	2350	15.5	104.2	37	-8.1
161	2210	15.5	106	37.4	-10.1
158	2200	16	107.3	38	-11.8
150	2150	16.3	109.1	38.3	-12.8
142	2060	16.5	110	38.7	-14.1

 # Results

Tc °C	W_{com} kJ/kg	q_{ref} kJ/kg	COP
-4.7	51	173.1	3.39
-5.7	52.9	173.6	3.28
-6.8	54.4	173.3	3.18
-8.1	56.9	172.7	30.4
-10.1	60.7	172.1	2.83
-11.8	61.7	171.6	2.78
-12.8	63.7	171.4	2.69
-14.1	66	170.6	2.58

Table (A.3) Refrigerant R-407C, Charge quantity 200g,

Ta = 22.5 °C and Tc = 39 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_4 °C	T_6 °C
152	2380	13	88	33	-4.7
150	2350	13.5	91.1	33.5	-5.7
144	2350	14.3	93	34.5	-6.8
137	2300	14.7	97.5	36	-8.1
135	2230	15	100.4	36.5	-10.1
135	2200	15.2	101.9	37	-11.8
130	2110	15.7	104.3	38	-12.8
120	2000	16.5	105	38.5	-14.1

 # Results

Tc °C	W_{com} kJ/kg	q_{ref} kJ/kg	COP
-4.7	40.3	177.9	4.41
-5.7	43.6	177.4	4.07
-6.8	45.2	176.5	3.90
-8.1	50.5	174.4	3.45
-10.1	54.6	173.3	3.18
-11.8	56	173.2	3.09
-12.8	58.8	171.8	2.92
-14.1	60.5	171.6	2.84

Table (A.4) Refrigerant R-407C, Charge quantity 250g,

Ta = 22.5 °C and Tc = 39 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_4 °C	T_6 °C
173	2240	13	88	31	-4.7
170	2200	13	92.1	32.5	-5.7
167	2510	13.7	95	34	-6.8
160	2020	14	99.3	34	-8.1
158	1950	14	102.7	35.2	-10.1
155	1900	14.5	104.4	35.7	-11.8
150	1870	15	106.1	37	-12.8
148	1800	15.5	107.5	38	-14.1

 # Results

Te °C	W_{com} kJ/kg	q_{ref} kJ/kg	COP
-4.7	43.4	180.9	4.17
-5.7	47.8	178.3	3.73
-6.8	51.9	176.7	3.41
-8.1	56.9	176.9	3.11
-10.1	60	175.1	2.92
-11.8	62.8	174.6	2.78
-12.8	64.2	172.7	2.69
-14.1	65.9	171.3	2.60

Table (A.5) Refrigerant R-407C, Optimum charge = 210g,

Ta = 22.5 °C and Tc = 39 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_4 °C	T_6 °C	T_7 °C	T_8 °C	T_9 °C
182	2400	12.5	87.5	32.5	-4.7	88.7	85.5	39.2
180	2380	13	89	33	-5.7	89	83.8	37.7
176	2350	13	89	34.2	-6.8	80.5	82.2	36
176	2300	13.5	89.5	35.6	-8.1	79.1	80.7	35.9
170	2250	14.6	90	36	-10.1	76.8	77.8	31
168	2000	15	91	36.5	-11.8	73.6	75.1	27.9
165	1860	15.7	92.7	37.4	-12.8	71	72.5	25.3
160	1750	16	93.5	38.5	-14.1	68.6	70	22.8

 # Results

Tc °C	w_{com} kJ/kg	q_{ref} kJ/kg	COP	Q_{ref} Watt	$\dot{m}$ g/s
-4.7	40.7	177.6	4.36	288	1.61
-5.7	41.6	177.4	4.26	288	1.61
-6.8	42	175.6	4.18	255	1.44
-8.1	43.4	173.4	3.99	239	1.36
-10.1	44	173.9	3.95	238	1.36
-11.8	46.8	172.6	3.68	229	1.32
-12.8	50.9	171.5	3.37	221	1.28
-14.1	52.1	170.8	3.28	204	1.19

Table (A.6) Actual electrical power consumption for Refrigerant R-407C with optimum Charge = 210g, and for Refrigerant R-134a, Ta = 22.5 °C and Tc = 39 °C

 # Data

Te °C	Δt/2rev. (sec) R-134a	Δt/2rev. (sec) R-407C
15.9	46.0	35.1
6.6	43.1	33.6
0.0	42.8	31.2
-9	42.5	30.4
-16	42.3	29.7
-17.6	42.3	28.5
-18	42.3	28.5
-18.2	42.0	28.5
-18.6	44.0	28.5
-20.4	46.2	30.1
-22.7	48.9	33.5
-24.3	51.1	36.4
-25.8	53.5	38.2
-27.1	55.4	40.6
-28.3	57.2	42.3
-29.3	58.7	45.1
-30.3	60.4	46.7
-31	61.4	47.9
-31.5	62.6	48.9

Table (A.6) Continued

 # Results

Te °C	W (Watt) R-134a	W (Watt) R-407C
-15.9	182	239
-6.6	195	250
0.0	196	269
-9	197	276
-16	198	282
-17.6	198	294
-18	198	294
-18.2	200	294
-18.6	191	294
-20.4	182	279
-22.7	172	259
-24.5	164	230
-25.8	157	220
-27.1	151	207
-28.3	147	198
-29.3	143	186
-30.3	139	180
-31	137	175
-31.5	134	171

APPENDIX B

Data and Results Tables (Tc variation Test)

Table (B.1) Refrigerant R-134a, Ta = 22.5 °C and Te = -15.1 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_3 °C	T_4 °C
170	1370	23.6	80.9	28.5	24.5
178	1390	24.1	81.4	30	25
178	1390	24.6	82.8	31.5	25.5
179	1400	24.6	82.9	33	27
179	1400	24.8	82.9	35	30
179	1420	25	83.9	39	36
181	1435	25.6	84.5	41	38.2

 # Results

Tc °C	W_{com} kJ/kg	q_{ref} kJ/kg	COP
28.5	36.9	187.6	5.08
30	38.3	187.6	4.90
31.5	38.8	187.1	4.82
33	39.2	185.3	4.73
35	39.8	181.4	4.56
39	40.6	173	4.30
41	40.6	170.2	4.19

Table (B.2) Refrigerant R-134a, Ta = 22.5 °C and Te = -20.6 °C

 # Data

P_1 kpa	P_2 kpa	T_1 °C	T_2 °C	T_3 °C	T_4 °C
176	1300	24	82	28.5	25
176	1321	24.5	82.7	30	27.5
177	1321	25	83.1	31.5	28.3
177	1350	25.4	83.6	33	29
177	1370	26.1	84.9	35	31
178	1390	26.4	85.7	39	37
180	1400	26.8	86	44	40

 # Results

Te °C	W_{com} KJ/kg	Q_{ref} kJ/kg	COP
28.5	38.5	187.5	4.87
30	39.1	184.4	4.72
31.5	39.2	183.4	4.68
33	39.3	183.3	4.66
35	40.3	181.2	4.49
39	41.3	172.1	4.17
41	41.5	168.8	4.07

Table (B.3) Refrigerant R-407C, Optimum charge = 210g,

Ta = 22.5 °C and Te = -15.1 °C

 # Data

P_1 Kpa	P_2 Kpa	T_1 °C	T_2 °C	T_3 °C	T_4 °C
137	1400	13	90.5	28.5	26
145	1400	14.5	92.5	30	27.5
146	1450	15	95.3	31.5	29.6
152	1510	15	97	33	31.5
155	1550	15.5	99.3	35	34.2
155	1600	16	102.4	36	38.5
158	1630	16.5	104.8	41	40.5

 # Results

Tc °C	W_{com} KJ/kg	q_{ref} KJ/Kg	COP
28.5	55.3	189.4	3.42
30	55.6	188.4	3.39
31.5	58	184.7	3.18
33	58.9	182.2	3.00
35	60.7	178.1	2.93
39	63	170.2	2.70
41	65.2	167.6	2.57

APPENDIX C

Data Tables (Time variation Test)

Table (C.1) Variation of evaporating temperature for Refrigerant R-407C with optimum Charge = 210g, and for Refrigerant R-134a, Ta = 22.5 °C and Tc = 39 °C

 # Data

Time Sec	Te (°C) R-134a	Te (°C) R-407C
0	-10.6	-10.6
5	-7.3	-6.6
10	-5.6	-4.9
15	-4.6	-3.7
20	-4	-3.1
25	-3.9	-3.5
30	-4.7	-4.4
35	-5.7	-5.7
40	-6.8	-6.4
45	-8.1	-7.6
50	-10.1	-9.8
75	-12.8	-12.1
95	-15.1	-14.6
125	-17.6	-16.9
155	-20.6	-19.6
205	-23.1	-22.4
245	-24.7	-23.4
265	-25.4	-24.1
325	-27	-26.4

Table (C.3) Continued

Time sec	T_{load} (°C) R-134a	T_{load} (°C) R-134a
223	-21.1	-14.4
233	-21.8	-15.1
243	-22.8	-15.2

APPENDIX D

Table (D.1) Saturation Properties for R-407C

TEMP. °C	PRESSURE kPa		VOLUME m3/kg		DENSITY kg/m3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP. °C
	LIQUID pf	VAPOR pg	LIQUID vf	VAPOR vg	LIQUID 1/vf	VAPOR 1/vg	LIQUID hf	LATENT hfg	VAPOR hg	LIQUID sf	VAPOR sg	
-40	119.7	85.0	0.0007	0.2577	1378.9	3.880	146.6	242.9	389.5	0.7903	1.8487	-40
-39	125.3	89.3	0.0007	0.2460	1375.4	4.065	147.9	242.3	390.2	0.7957	1.8468	-39
-38	131.1	93.8	0.0007	0.2349	1371.9	4.257	149.1	241.7	390.8	0.8011	1.8449	-38
-37	137.1	98.5	0.0007	0.2244	1368.3	4.456	150.4	241.0	391.4	0.8064	1.8430	-37
-36	143.3	103.4	0.0007	0.2145	1364.8	4.662	151.7	240.4	392.1	0.8118	1.8412	-36
-35	149.8	108.5	0.0007	0.2051	1361.3	4.876	153.2	239.5	392.7	0.8184	1.8394	-35
-34	156.4	113.8	0.0007	0.1962	1357.7	5.098	154.5	238.8	393.4	0.8237	1.8377	-34
-33	163.3	119.2	0.0007	0.1877	1354.2	5.327	155.8	238.2	394.0	0.8290	1.8360	-33
-32	170.5	124.9	0.0007	0.1797	1350.6	5.564	157.1	237.6	394.6	0.8343	1.8343	-32
-31	177.8	130.8	0.0007	0.1721	1347.1	5.810	158.3	236.9	395.3	0.8396	1.8326	-31
-30	185.5	136.9	0.0007	0.1649	1343.5	6.064	159.6	236.3	395.9	0.8448	1.8310	-30
-29	193.3	143.2	0.0007	0.1580	1339.9	6.327	160.9	235.6	396.5	0.8501	1.8294	-29
-28	201.5	149.8	0.0007	0.1515	1336.3	6.599	162.2	234.9	397.2	0.8554	1.8278	-28
-27	209.9	156.5	0.0008	0.1453	1332.7	6.880	163.3	234.5	397.8	0.8596	1.8263	-27
-26	218.6	163.6	0.0008	0.1394	1329.2	7.171	164.4	234.0	398.4	0.8643	1.8248	-26
-25	227.6	170.9	0.0008	0.1338	1325.6	7.472	165.7	233.3	399.0	0.8696	1.8233	-25
-24	236.8	178.4	0.0008	0.1285	1322.0	7.782	167.1	232.6	399.7	0.8748	1.8218	-24
-23	246.3	186.2	0.0008	0.1234	1318.3	8.102	168.4	231.9	400.3	0.8801	1.8204	-23
-22	256.2	194.2	0.0008	0.1186	1314.7	8.433	169.7	231.2	400.9	0.8854	1.8189	-22
-21	266.3	202.6	0.0008	0.1140	1311.1	8.775	171.0	230.5	401.5	0.8907	1.8176	-21
-20	276.8	211.2	0.0008	0.1096	1307.5	9.127	172.4	229.7	402.1	0.8959	1.8162	-20
-19	287.5	220.1	0.0008	0.1054	1303.8	9.491	173.7	229.0	402.7	0.9012	1.8148	-19
-18	298.6	229.2	0.0008	0.1014	1300.2	9.866	175.1	228.3	403.4	0.9064	1.8135	-18
-17	310.0	238.7	0.0008	0.0975	1296.5	10.253	176.4	227.5	404.0	0.9117	1.8122	-17
-16	321.8	248.5	0.0008	0.0939	1292.9	10.651	177.8	226.8	404.6	0.9169	1.8109	-16
-15	333.8	258.6	0.0008	0.0904	1289.2	11.062	179.1	226.0	405.2	0.9221	1.8097	-15
-14	346.3	269.0	0.0008	0.0871	1285.5	11.486	180.5	225.3	405.8	0.9274	1.8084	-14
-13	359.0	279.7	0.0008	0.0839	1281.9	11.923	181.9	224.5	406.4	0.9326	1.8072	-13
-12	372.2	290.8	0.0008	0.0808	1278.2	12.372	183.2	223.7	407.0	0.9378	1.8060	-12
-11	385.7	302.2	0.0009	0.0779	1274.5	12.835	184.5	223.1	407.6	0.9425	1.8048	-11
-10	399.6	313.9	0.0008	0.0751	1270.8	13.313	185.9	222.3	408.2	0.9478	1.8037	-10
-9	413.8	326.0	0.0008	0.0724	1267.1	13.804	187.3	221.5	408.8	0.9530	1.8025	-9
-8	428.5	338.5	0.0008	0.0699	1263.3	14.311	188.7	220.7	409.3	0.9582	1.8014	-8
-7	443.6	351.3	0.0008	0.0674	1259.6	14.831	190.1	219.9	409.9	0.9635	1.8003	-7
-6	458.9	364.5	0.0009	0.0651	1255.9	15.368	191.5	219.0	410.5	0.9687	1.7992	-6
-5	474.8	378.1	0.0008	0.0628	1252.1	15.919	192.9	218.2	411.1	0.9739	1.7981	-5
-4	491.0	392.1	0.0009	0.0607	1248.4	16.487	194.3	217.4	411.7	0.9791	1.7970	-4
-3	507.7	406.5	0.0009	0.0586	1244.6	17.071	195.7	216.5	412.2	0.9843	1.7959	-3
-2	524.8	421.2	0.0008	0.0566	1240.8	17.671	197.1	215.7	412.8	0.9896	1.7949	-2
-1	542.3	436.4	0.0008	0.0547	1237.0	18.289	198.6	214.8	413.4	0.9948	1.7938	-1
0	560.3	452.0	0.0008	0.0528	1233.2	18.924	200.0	213.9	413.9	1.0000	1.7928	0
1	578.7	468.0	0.0008	0.0511	1229.4	19.577	201.4	213.0	414.5	1.0052	1.7918	1
2	597.6	484.5	0.0009	0.0494	1225.6	20.249	202.9	212.1	415.0	1.0104	1.7908	2
3	616.9	501.4	0.0008	0.0478	1221.8	20.939	204.3	211.2	415.6	1.0156	1.7898	3
4	636.7	518.7	0.0008	0.0462	1217.9	21.649	205.8	210.3	416.1	1.0209	1.7888	4
5	657.0	536.6	0.0008	0.0447	1214.1	22.378	207.3	209.4	416.6	1.0261	1.7879	5
6	677.8	554.8	0.0008	0.0432	1210.2	23.127	208.7	208.4	417.2	1.0313	1.7869	6
7	699.0	573.6	0.0008	0.0418	1206.3	23.898	210.2	207.5	417.7	1.0365	1.7859	7
8	720.8	592.8	0.0008	0.0405	1202.4	24.689	211.7	206.5	418.2	1.0418	1.7850	8
9	743.0	612.5	0.0008	0.0392	1198.5	25.502	213.2	205.6	418.8	1.0470	1.7841	9
10	765.8	632.8	0.0008	0.0380	1194.6	26.338	214.7	204.6	419.3	1.0522	1.7831	10
11	789.1	653.5	0.0008	0.0368	1190.7	27.196	216.2	203.6	419.8	1.0574	1.7822	11
12	812.9	674.7	0.0008	0.0356	1186.8	28.078	217.7	202.6	420.3	1.0627	1.7813	12
13	837.3	696.5	0.0008	0.0345	1182.8	28.984	219.2	201.6	420.8	1.0679	1.7804	13
14	862.2	718.8	0.0008	0.0334	1178.8	29.914	220.8	200.5	421.3	1.0732	1.7794	14
15	887.6	741.7	0.0009	0.0324	1174.8	30.870	222.3	199.5	421.8	1.0784	1.7785	15
16	913.6	765.1	0.0009	0.0314	1170.8	31.852	223.8	198.4	422.3	1.0837	1.7776	16

Table (D.1) Continued

TEMP. °C	PRESSURE kPa		VOLUME m3/kg		DENSITY kg/m3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP. °C
	LIQUID pf	VAPOR pg	LIQUID vf	VAPOR vg	LIQUID 1/vf	VAPOR 1/vg	LIQUID hf	LATENT hfg	VAPOR hg	LIQUID sf	VAPOR sg	
20	1023.4	864.4	0.0009	0.0277	1154.7	36.052	230.1	194.1	424.1	1.1047	1.7740	20
21	1052.3	890.7	0.0009	0.0269	1150.6	37.175	231.6	193.0	424.6	1.1100	1.7731	21
22	1081.8	917.6	0.0009	0.0261	1146.5	38.328	233.2	191.8	425.1	1.1153	1.7722	22
23	1112.0	945.1	0.0009	0.0253	1142.3	39.512	234.8	190.7	425.5	1.1206	1.7713	23
24	1142.7	973.3	0.0009	0.0246	1138.2	40.728	236.4	189.5	425.9	1.1259	1.7704	24
25	1174.1	1002.1	0.0009	0.0238	1134.0	41.977	238.0	188.3	426.4	1.1312	1.7695	25
26	1206.1	1031.5	0.0009	0.0231	1129.9	43.261	239.7	187.1	426.8	1.1366	1.7686	26
27	1238.8	1061.6	0.0009	0.0224	1125.6	44.579	241.3	185.9	427.2	1.1419	1.7677	27
28	1272.1	1092.3	0.0009	0.0218	1121.4	45.934	242.9	184.7	427.6	1.1473	1.7668	28
29	1306.0	1123.7	0.0009	0.0211	1117.2	47.325	244.6	183.4	428.0	1.1526	1.7659	29
30	1340.7	1155.9	0.0009	0.0205	1112.9	48.755	246.2	182.1	428.4	1.1580	1.7649	30
31	1376.0	1188.7	0.0009	0.0199	1108.6	50.225	247.9	180.8	428.7	1.1634	1.7640	31
32	1412.0	1222.2	0.0009	0.0193	1104.3	51.735	249.6	179.5	429.1	1.1688	1.7630	32
33	1448.7	1256.4	0.0009	0.0188	1099.9	53.287	251.3	178.2	429.5	1.1742	1.7621	33
34	1486.1	1291.4	0.0009	0.0182	1095.5	54.883	253.0	176.9	429.8	1.1796	1.7611	34
35	1524.2	1327.1	0.0009	0.0177	1091.1	56.523	254.7	175.5	430.2	1.1850	1.7602	35
36	1563.0	1363.5	0.0009	0.0172	1086.7	58.209	256.4	174.1	430.5	1.1905	1.7592	36
37	1602.5	1400.7	0.0009	0.0167	1082.2	59.943	258.1	172.7	430.8	1.1959	1.7582	37
38	1642.8	1438.7	0.0009	0.0162	1077.7	61.726	259.9	171.3	431.1	1.2014	1.7572	38
39	1683.8	1477.5	0.0009	0.0157	1073.2	63.561	261.6	169.8	431.4	1.2069	1.7562	39
40	1725.5	1517.0	0.0009	0.0153	1068.6	65.448	263.4	168.3	431.7	1.2125	1.7551	40
41	1768.0	1557.4	0.0009	0.0148	1064.0	67.390	265.2	166.8	432.0	1.2180	1.7541	41
42	1811.3	1598.6	0.0009	0.0144	1059.4	69.388	267.0	165.3	432.3	1.2236	1.7530	42
43	1855.3	1640.6	0.0009	0.0140	1054.7	71.446	268.8	163.7	432.5	1.2292	1.7519	43
44	1900.2	1683.5	0.0010	0.0136	1050.0	73.565	270.6	162.2	432.8	1.2348	1.7508	44
45	1945.8	1727.2	0.0010	0.0132	1045.2	75.747	272.5	160.5	433.0	1.2404	1.7497	45
46	1992.2	1771.7	0.0010	0.0128	1040.4	77.994	274.3	158.9	433.2	1.2461	1.7485	46
47	2039.4	1817.2	0.0010	0.0125	1035.5	80.311	276.2	157.2	433.4	1.2517	1.7474	47
48	2087.4	1863.5	0.0010	0.0121	1030.6	82.699	278.1	155.5	433.6	1.2575	1.7462	48
49	2136.2	1910.8	0.0010	0.0117	1025.7	85.161	280.0	153.8	433.8	1.2632	1.7449	49
50	2185.9	1959.0	0.0010	0.0114	1020.7	87.701	281.9	152.0	433.9	1.2690	1.7437	50
51	2236.4	2008.1	0.0010	0.0111	1015.6	90.321	283.8	150.2	434.1	1.2748	1.7424	51
52	2287.7	2058.1	0.0010	0.0107	1010.5	93.027	285.8	148.4	434.2	1.2806	1.7411	52
53	2339.9	2109.1	0.0010	0.0104	1005.3	95.820	287.7	146.5	434.3	1.2865	1.7397	53
54	2392.9	2161.1	0.0010	0.0101	1000.0	98.707	289.7	144.6	434.4	1.2924	1.7384	54
55	2446.8	2214.1	0.0010	0.0098	994.7	101.691	291.7	142.7	434.4	1.2984	1.7369	55
56	2501.6	2268.1	0.0010	0.0095	989.3	104.777	293.8	140.7	434.5	1.3044	1.7355	56
57	2557.3	2323.1	0.0010	0.0093	983.8	107.970	295.8	138.6	434.5	1.3105	1.7340	57
58	2613.8	2379.1	0.0010	0.0090	978.2	111.277	297.9	136.6	434.5	1.3166	1.7324	58
59	2671.2	2436.2	0.0010	0.0087	972.6	114.703	300.0	134.4	434.4	1.3227	1.7308	59
60	2729.5	2494.4	0.0010	0.0085	966.8	118.255	302.2	132.2	434.4	1.3289	1.7291	60
61	2788.7	2553.6	0.0010	0.0082	961.0	121.941	304.3	130.0	434.3	1.3352	1.7274	61
62	2848.8	2614.0	0.0010	0.0080	955.0	125.768	306.5	127.7	434.2	1.3415	1.7256	62
63	2909.9	2675.4	0.0011	0.0077	948.9	129.746	308.7	125.3	434.1	1.3479	1.7238	63
64	2971.8	2738.0	0.0011	0.0075	942.7	133.884	311.0	122.9	433.9	1.3544	1.7219	64
65	3034.7	2801.8	0.0011	0.0072	936.3	138.194	313.3	120.4	433.7	1.3609	1.7199	65
66	3098.5	2866.8	0.0011	0.0070	929.8	142.687	315.6	117.9	433.5	1.3675	1.7178	66
67	3163.2	2932.9	0.0011	0.0068	923.2	147.378	318.0	115.2	433.2	1.3743	1.7157	67
68	3228.8	3000.3	0.0011	0.0066	916.3	152.282	320.4	112.5	432.9	1.3811	1.7134	68
69	3295.4	3068.9	0.0011	0.0064	909.3	157.416	322.8	109.7	432.5	1.3880	1.7111	69
70	3362.9	3138.8	0.0011	0.0061	902.0	162.800	325.3	106.8	432.1	1.3950	1.7086	70
71	3431.3	3210.1	0.0011	0.0059	894.5	168.458	327.9	103.8	431.6	1.4022	1.7060	71
72	3500.6	3282.6	0.0011	0.0057	886.7	174.415	330.5	100.6	431.1	1.4095	1.7033	72
73	3570.8	3356.5	0.0011	0.0055	878.6	180.703	333.1	97.4	430.5	1.4169	1.7004	73
74	3642.0	3431.8	0.0011	0.0053	870.1	187.358	335.9	94.0	429.9	1.4246	1.6973	74
75	3714.0	3508.6	0.0012	0.0051	861.3	194.425	338.7	90.4	429.2	1.4324	1.6941	75
76	3786.9	3586.9	0.0012	0.0050	852.0	201.958	341.6	86.7	428.3	1.4404	1.6906	76
77	3860.6	3666.7	0.0012	0.0048	842.1	210.021	344.6	82.8	427.4	1.4487	1.6869	77
78	3935.2	3748.1	0.0012	0.0046	831.6	218.698	347.8	78.6	426.4	1.4573	1.6829	78
79	4010.5	3831.1	0.0012	0.0044	820.3	228.096	351.0	74.2	425.2	1.4663	1.6785	79

Table (D.2) Superheated Properties for R-407C

ABSOLUTE PRESSURE, kPa

TEMP. °C	90.0 (-38.90°C) V	H	S	100.0 (-36.70°C) V	H	S	101.325 (-36.40°C) V	H	S	110.0 (-34.70°C) V	H	S	TEMP. °C
	(0.2443)	(390.2)	(1.8465)	(0.2214)	(391.6)	(1.8425)	(0.2186)	(391.8)	(1.8420)	(0.2025)	(392.9)	(1.8389)	
-35	0.2486	393.1	1.8584	0.2231	392.9	1.8477	0.2201	392.8	1.8464	—	—	—	-35
-30	0.2542	396.7	1.8737	0.2281	396.6	1.8631	0.2251	396.5	1.8617	0.2068	396.4	1.8534	-30
-25	0.2598	400.5	1.8886	0.2332	400.3	1.8782	0.2301	400.3	1.8769	0.2114	400.1	1.8686	-25
-20	0.2654	404.2	1.9038	0.2382	404.0	1.8932	0.2351	404.0	1.8919	0.2160	403.9	1.8836	-20
-15	0.2710	408.0	1.9187	0.2433	407.9	1.9081	0.2400	407.8	1.9066	0.2206	407.7	1.8985	-15
-10	0.2765	411.9	1.9334	0.2483	411.7	1.9229	0.2450	411.7	1.9215	0.2252	411.5	1.9133	-10
-5	0.2821	415.7	1.9480	0.2533	415.6	1.9375	0.2499	415.6	1.9362	0.2298	415.4	1.9279	-5
0	0.2876	419.7	1.9625	0.2583	419.5	1.9520	0.2549	419.5	1.9507	0.2344	419.4	1.9424	0
5	0.2931	423.6	1.9769	0.2633	423.5	1.9664	0.2598	423.5	1.9651	0.2389	423.3	1.9568	5
10	0.2987	427.6	1.9911	0.2683	427.5	1.9807	0.2647	427.5	1.9793	0.2435	427.3	1.9711	10
15	0.3042	431.7	2.0053	0.2733	431.5	1.9948	0.2697	431.5	1.9935	0.2480	431.4	1.9853	15
20	0.3097	435.7	2.0193	0.2783	435.6	2.0089	0.2746	435.6	2.0076	0.2526	435.5	1.9994	20
25	0.3152	439.9	2.0333	0.2832	439.7	2.0228	0.2795	439.7	2.0215	0.2571	439.6	2.0134	25
30	0.3207	444.0	2.0471	0.2882	443.9	2.0367	0.2844	443.9	2.0354	0.2616	443.8	2.0272	30
35	0.3262	448.2	2.0609	0.2932	448.1	2.0505	0.2893	448.1	2.0492	0.2661	448.0	2.0410	35
40	0.3317	452.5	2.0745	0.2981	452.4	2.0641	0.2942	452.3	2.0628	0.2706	452.2	2.0547	40
45	0.3377	456.8	2.0881	0.3031	456.6	2.0777	0.2990	456.6	2.0764	0.2752	456.5	2.0683	45
50	0.3426	461.1	2.1016	0.3080	461.0	2.0912	0.3039	461.0	2.0899	0.2797	460.9	2.0818	50
55	0.3481	465.4	2.1150	0.3129	465.3	2.1046	0.3088	465.3	2.1033	0.2842	465.2	2.0952	55
60	0.3536	469.8	2.1283	0.3179	469.7	2.1179	0.3137	469.7	2.1166	0.2887	469.6	2.1085	60
65	0.3590	474.3	2.1415	0.3228	474.2	2.1312	0.3185	474.2	2.1299	0.2931	474.1	2.1218	65
70	0.3645	478.8	2.1547	0.3277	478.7	2.1443	0.3234	478.7	2.1430	0.2976	478.6	2.1349	70
75	0.3700	483.3	2.1678	0.3326	483.2	2.1574	0.3283	483.2	2.1561	0.3021	483.1	2.1480	75
80	0.3754	487.8	2.1808	0.3376	487.8	2.1704	0.3331	487.7	2.1691	0.3066	487.7	2.1610	80
85	0.3809	492.4	2.1937	0.3425	492.4	2.1834	0.3380	492.3	2.1821	0.3111	492.3	2.1740	85
90	0.3863	497.1	2.2066	0.3474	497.0	2.1962	0.3428	497.0	2.1949	0.3155	496.9	2.1869	90
95	0.3918	501.8	2.2193	0.3523	501.7	2.2090	0.3477	501.7	2.2077	0.3200	501.6	2.1996	95
100	0.3972	506.5	2.2321	0.3572	506.4	2.2217	0.3525	506.4	2.2204	0.3245	506.3	2.2124	100
105	0.4026	511.2	2.2447	0.3621	511.1	2.2344	0.3573	511.1	2.2331	0.3290	511.0	2.2250	105
110	0.4081	516.0	2.2573	0.3670	515.9	2.2470	0.3622	515.9	2.2457	0.3334	515.8	2.2376	110
115	0.4135	520.8	2.2698	0.3719	520.7	2.2595	0.3670	520.7	2.2582	0.3378	520.7	2.2501	115
120	—	—	—	—	—	—	—	—	—	0.3423	525.5	2.2626	120

TEMP. °C	120.0 (-32.9°C) V	H	S	130.0 (-31.1°C) V	H	S	140.0 (-29.5°C) V	H	S	150.0 (-28.0°C) V	H	S	TEMP. °C
	(0.1866)	(394.1)	(1.8357)	(0.1731)	(395.2)	(1.8328)	(0.1615)	(396.2)	(1.8302)	(0.1513)	(397.2)	(1.8278)	
-30	0.1890	396.2	1.8445	0.1740	396.0	1.8363	—	—	—	—	—	—	-30
-25	0.1933	399.9	1.8597	0.1779	399.8	1.8515	0.1648	399.6	1.8439	0.1534	399.4	1.8368	-25
-20	0.1975	403.7	1.8748	0.1819	403.5	1.8666	0.1684	403.4	1.8590	0.1568	403.2	1.8519	-20
-15	0.2018	407.5	1.8897	0.1858	407.4	1.8816	0.1721	407.2	1.8740	0.1602	407.0	1.8669	-15
-10	0.2060	411.4	1.9045	0.1897	411.2	1.8964	0.1757	411.1	1.8888	0.1637	410.9	1.8818	-10
-5	0.2102	415.3	1.9192	0.1936	415.1	1.9111	0.1794	415.0	1.9035	0.1671	414.8	1.8965	-5
0	0.2144	419.2	1.9337	0.1975	419.1	1.9256	0.1830	418.9	1.9181	0.1705	418.8	1.9111	0
5	0.2186	423.2	1.9481	0.2014	423.0	1.9400	0.1866	422.9	1.9326	0.1739	422.7	1.9256	5
10	0.2228	427.2	1.9624	0.2053	427.1	1.9544	0.1903	426.9	1.9469	0.1772	426.8	1.9399	10
15	0.2270	431.2	1.9766	0.2091	431.1	1.9686	0.1939	431.0	1.9611	0.1806	430.8	1.9541	15
20	0.2312	435.3	1.9907	0.2130	435.2	1.9827	0.1975	435.1	1.9752	0.1840	434.9	1.9683	20
25	0.2353	439.5	2.0047	0.2169	439.3	1.9967	0.2011	439.2	1.9892	0.1874	439.1	1.9823	25
30	0.2395	443.7	2.0186	0.2207	443.5	2.0106	0.2046	443.4	2.0031	0.1907	443.3	1.9962	30
35	0.2436	447.9	2.0323	0.2246	447.7	2.0244	0.2082	447.6	2.0169	0.1941	447.5	2.0100	35
40	0.2478	452.1	2.0460	0.2284	452.0	2.0381	0.2118	451.9	2.0307	0.1974	451.8	2.0237	40
45	0.2519	456.4	2.0596	0.2322	456.3	2.0517	0.2154	456.2	2.0443	0.2008	456.1	2.0374	45
50	0.2560	460.7	2.0731	0.2361	460.6	2.0652	0.2189	460.5	2.0578	0.2041	460.4	2.0509	50
55	0.2602	465.1	2.0866	0.2399	465.0	2.0786	0.2225	464.9	2.0712	0.2074	464.8	2.0644	55
60	0.2643	469.5	2.0999	0.2437	469.4	2.0920	0.2261	469.3	2.0846	0.2107	469.2	2.0777	60
65	0.2684	474.0	2.1132	0.2475	473.9	2.1052	0.2296	473.8	2.0979	0.2141	473.7	2.0910	65
70	0.2726	478.5	2.1263	0.2513	478.4	2.1184	0.2332	478.3	2.1111	0.2174	478.2	2.1042	70
75	0.2767	483.0	2.1394	0.2551	482.9	2.1315	0.2367	482.8	2.1242	0.2207	482.7	2.1173	75
80	0.2808	487.5	2.1525	0.2590	487.5	2.1446	0.2402	487.4	2.1372	0.2240	487.3	2.1304	80
85	0.2849	492.2	2.1654	0.2628	492.1	2.1575	0.2438	492.0	2.1502	0.2273	491.9	2.1433	85
90	0.2890	496.8	2.1783	0.2666	496.7	2.1704	0.2473	496.6	2.1631	0.2306	496.5	2.1562	90
95	0.2931	501.5	2.1911	0.2704	501.4	2.1832	0.2508	501.3	2.1759	0.2339	501.2	2.1690	95
100	0.2972	506.2	2.2038	0.2741	506.1	2.1959	0.2544	506.0	2.1886	0.2372	505.9	2.1818	100
105	0.3013	511.0	2.2165	0.2779	510.9	2.2086	0.2579	510.8	2.2013	0.2405	510.7	2.1945	105
110	0.3054	515.8	2.2291	0.2817	515.7	2.2212	0.2614	515.6	2.2139	0.2438	515.5	2.2071	110
115	0.3095	520.6	2.2416	0.2855	520.5	2.2337	0.2649	520.4	2.2264	0.2471	520.3	2.2196	115
120	0.3136	525.4	2.2540	0.2893	525.4	2.2462	0.2685	525.3	2.2389	0.2504	525.2	2.2321	120

Table (D.2) Continued

	ABSOLUTE PRESSURE, kPa												
	160.0			170.0			180.0			190.0			
IP.	(-26.50°C)			(-25.10°C)			(-23.80°C)			(-22.50°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.1424)	(398.1)	(1.8255)	(0.1345)	(399.0)	(1.8234)	(0.1274)	(399.8)	(1.8215)	(0.1211)	(400.6)	(1.8197)	
25	0.1434	399.2	1.8301	0.1346	399.0	1.8238	—	—	—	—	—	—	-25
20	0.1466	403.0	1.8453	0.1376	402.9	1.8390	0.1296	402.7	1.8330	0.1225	402.5	1.8274	-20
15	0.1498	406.9	1.8603	0.1407	406.7	1.8540	0.1325	406.5	1.8481	0.1252	406.4	1.8424	-15
10	0.1531	410.7	1.8752	0.1437	410.6	1.8689	0.1354	410.4	1.8630	0.1280	410.2	1.8574	-10
-5	0.1563	414.7	1.8899	0.1468	414.5	1.8837	0.1383	414.3	1.8778	0.1307	414.2	1.8722	-5
0	0.1595	418.6	1.9045	0.1498	418.5	1.8983	0.1412	418.3	1.8924	0.1335	418.1	1.8868	0
5	0.1627	422.6	1.9190	0.1528	422.4	1.9128	0.1440	422.3	1.9069	0.1362	422.2	1.9013	5
10	0.1658	426.6	1.9333	0.1558	426.5	1.9272	0.1469	426.3	1.9213	0.1389	426.2	1.9158	10
15	0.1690	430.7	1.9476	0.1588	430.6	1.9414	0.1497	430.4	1.9356	0.1416	430.3	1.9301	15
20	0.1722	434.8	1.9617	0.1618	434.7	1.9556	0.1526	434.5	1.9498	0.1443	434.4	1.9442	20
25	0.1754	439.0	1.9758	0.1648	438.8	1.9696	0.1554	438.7	1.9638	0.1470	438.6	1.9583	25
30	0.1785	443.1	1.9897	0.1678	443.0	1.9836	0.1582	442.9	1.9778	0.1497	442.8	1.9723	30
35	0.1817	447.4	2.0035	0.1707	447.2	1.9974	0.1610	447.1	1.9915	0.1523	447.0	1.9861	35
40	0.1848	451.6	2.0173	0.1737	451.5	2.0111	0.1638	451.4	2.0054	0.1550	451.3	1.9999	40
45	0.1880	455.9	2.0309	0.1767	455.8	2.0248	0.1666	455.7	2.0190	0.1577	455.6	2.0136	45
50	0.1911	460.3	2.0444	0.1796	460.2	2.0384	0.1694	460.1	2.0326	0.1603	459.9	2.0271	50
55	0.1942	464.7	2.0579	0.1826	464.6	2.0518	0.1722	464.4	2.0461	0.1630	464.3	2.0406	55
60	0.1974	469.1	2.0713	0.1855	469.0	2.0652	0.1750	468.9	2.0595	0.1656	468.8	2.0540	60
65	0.2005	473.6	2.0846	0.1885	473.4	2.0785	0.1778	473.3	2.0728	0.1683	473.2	2.0674	65
70	0.2036	478.1	2.0978	0.1914	477.9	2.0917	0.1806	477.8	2.0860	0.1709	477.7	2.0806	70
75	0.2067	482.6	2.1109	0.1944	482.5	2.1049	0.1834	482.4	2.0991	0.1736	482.3	2.0937	75
80	0.2098	487.2	2.1240	0.1973	487.1	2.1179	0.1862	487.0	2.1122	0.1762	486.9	2.1068	80
85	0.2129	491.8	2.1369	0.2002	491.7	2.1309	0.1889	491.6	2.1252	0.1788	491.5	2.1198	85
90	0.2160	496.4	2.1498	0.2032	496.3	2.1438	0.1917	496.2	2.1381	0.1815	496.2	2.1327	90
95	0.2191	501.1	2.1627	0.2061	501.0	2.1566	0.1945	500.9	2.1509	0.1841	500.8	2.1456	95
100	0.2222	505.8	2.1754	0.2090	505.8	2.1694	0.1972	505.7	2.1637	0.1867	505.6	2.1583	100
105	0.2253	510.6	2.1881	0.2119	510.5	2.1821	0.2000	510.4	2.1764	0.1893	510.3	2.1710	105
110	0.2284	515.4	2.2007	0.2148	515.3	2.1947	0.2028	515.2	2.1890	0.1920	515.2	2.1837	110
115	0.2315	520.2	2.2132	0.2178	520.2	2.2072	0.2055	520.1	2.2016	0.1946	520.0	2.1962	115
120	0.2346	525.1	2.2257	0.2207	525.0	2.2197	0.2083	525.0	2.2141	0.1972	524.9	2.2087	120
125	0.2377	530.0	2.2381	0.2236	530.0	2.2321	0.2110	529.9	2.2265	0.1998	529.8	2.2211	125
130	—	—	—	—	—	—	0.2138	534.8	2.2388	0.2024	534.7	2.2335	130

	200.0			210.0			220.0			230.0			
MP. C	(-21.30°C)			(-20.10°C)			(-18.00°C)			(-17.90°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.1154)	(401.3)	(1.8180)	(0.1101)	(402.0)	(1.8164)	(0.1054)	(402.7)	(1.8149)	(0.1010)	(403.4)	(1.8134)	
-20	0.1160	402.3	1.8220	0.1102	402.2	1.8168	—	—	—	—	—	—	-20
-15	0.1187	406.2	1.8371	0.1127	406.0	1.8319	0.1073	405.8	1.8270	0.1024	405.7	1.8223	-15
-10	0.1213	410.1	1.8520	0.1152	409.9	1.8469	0.1097	409.8	1.8420	0.1047	409.6	1.8373	-10
-5	0.1239	414.0	1.8668	0.1177	413.9	1.8617	0.1121	413.7	1.8568	0.1070	413.5	1.8522	-5
0	0.1265	418.0	1.8815	0.1202	417.8	1.8764	0.1145	417.7	1.8716	0.1093	417.5	1.8669	0
5	0.1291	422.0	1.8960	0.1227	421.9	1.8910	0.1169	421.7	1.8861	0.1116	421.6	1.8815	5
10	0.1317	426.1	1.9105	0.1252	425.9	1.9054	0.1193	425.8	1.9006	0.1139	425.6	1.8960	10
15	0.1343	430.1	1.9248	0.1276	430.0	1.9198	0.1216	429.9	1.9149	0.1161	429.7	1.9103	15
20	0.1368	434.3	1.9390	0.1301	434.1	1.9340	0.1240	434.0	1.9292	0.1184	433.9	1.9246	20
25	0.1394	438.4	1.9531	0.1326	438.3	1.9481	0.1263	438.2	1.9433	0.1206	438.0	1.9387	25
30	0.1420	442.6	1.9670	0.1350	442.5	1.9620	0.1287	442.4	1.9573	0.1229	442.2	1.9527	30
35	0.1445	446.9	1.9809	0.1374	446.7	1.9759	0.1310	446.6	1.9712	0.1251	446.5	1.9666	35
40	0.1471	451.2	1.9947	0.1399	451.0	1.9897	0.1333	450.9	1.9850	0.1273	450.8	1.9804	40
45	0.1496	455.5	2.0084	0.1423	455.4	2.0034	0.1356	455.2	1.9987	0.1296	455.1	1.9941	45
50	0.1521	459.8	2.0220	0.1447	459.7	2.0170	0.1380	459.6	2.0123	0.1318	459.5	2.0078	50
55	0.1547	464.2	2.0355	0.1471	464.1	2.0305	0.1403	464.0	2.0258	0.1340	463.9	2.0213	55
60	0.1572	468.7	2.0489	0.1495	468.5	2.0439	0.1426	468.4	2.0392	0.1362	468.3	2.0347	60
65	0.1597	473.1	2.0622	0.1519	473.0	2.0573	0.1449	472.9	2.0526	0.1384	472.8	2.0481	65
70	0.1622	477.6	2.0754	0.1543	477.5	2.0705	0.1472	477.4	2.0658	0.1406	477.3	2.0613	70
75	0.1647	482.2	2.0886	0.1567	482.1	2.0837	0.1495	482.0	2.0790	0.1428	481.9	2.0745	75
80	0.1672	486.8	2.1017	0.1591	486.7	2.0968	0.1518	486.6	2.0921	0.1450	486.5	2.0876	80
85	0.1697	491.4	2.1147	0.1615	491.3	2.1098	0.1540	491.2	2.1051	0.1472	491.1	2.1006	85
90	0.1723	496.1	2.1276	0.1639	496.0	2.1227	0.1563	495.9	2.1180	0.1494	495.8	2.1136	90
95	0.1748	500.8	2.1404	0.1663	500.7	2.1356	0.1586	500.6	2.1309	0.1516	500.5	2.1264	95
100	0.1772	505.5	2.1532	0.1687	505.4	2.1483	0.1609	505.3	2.1437	0.1538	505.2	2.1392	100
105	0.1797	510.3	2.1659	0.1711	510.2	2.1611	0.1632	510.1	2.1564	0.1560	510.0	2.1520	105
110	0.1822	515.1	2.1786	0.1734	515.0	2.1737	0.1654	514.9	2.1690	0.1581	514.8	2.1646	110
115	0.1847	519.9	2.1911	0.1758	519.8	2.1863	0.1677	519.7	2.1816	0.1603	519.7	2.1772	115
120	0.1872	524.8	2.2036	0.1782	524.7	2.1988	0.1700	524.6	2.1941	0.1625	524.6	2.1897	120
125	0.1897	529.7	2.2160	0.1805	529.6	2.2112	0.1722	529.6	2.2066	0.1646	529.5	2.2021	125
130	0.1922	534.7	2.2284	0.1829	534.6	2.2236	0.1745	534.5	2.2189	0.1668	534.4	2.2145	130
135	—	—	—	—	—	—	0.1768	539.5	2.2312	0.1690	539.4	2.2268	135

Table (D.2) Continued

TEMP. °C	ABSOLUTE PRESSURE, kPa												TEMP. °C
	240.0			250.0			260.0			270.0			
	(-16.90°C)			(-15.90°C)			(-14.90°C)			(-13.90°C)			
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0970)	(404.0)	(1.8121)	(0.0934)	(404.7)	(1.8108)	(0.0899)	(405.3)	(1.8095)	(0.0868)	(405.8)	(1.8083)	
-15	0.0978	405.5	1.8177	0.0937	405.3	1.8133	—	—	—	—	—	—	-15
-10	0.1001	409.4	1.8328	0.0959	409.3	1.8284	0.0920	409.1	1.8242	0.0883	408.9	1.8201	-10
-5	0.1023	413.4	1.8476	0.0980	413.2	1.8433	0.0940	413.1	1.8391	0.0903	412.9	1.8351	-5
0	0.1045	417.4	1.8624	0.1001	417.2	1.8581	0.0961	417.1	1.8539	0.0923	416.9	1.8499	0
5	0.1067	421.4	1.8770	0.1022	421.2	1.8727	0.0981	421.1	1.8686	0.0943	420.9	1.8646	5
10	0.1089	425.5	1.8915	0.1043	425.3	1.8872	0.1001	425.2	1.8831	0.0962	425.0	1.8791	10
15	0.1111	429.6	1.9059	0.1064	429.4	1.9016	0.1022	429.3	1.8975	0.0982	429.1	1.8935	15
20	0.1133	433.7	1.9201	0.1085	433.6	1.9159	0.1042	433.4	1.9118	0.1002	433.3	1.9078	20
25	0.1154	437.9	1.9343	0.1106	437.8	1.9300	0.1062	437.6	1.9260	0.1021	437.5	1.9220	25
30	0.1176	442.1	1.9483	0.1127	442.0	1.9441	0.1082	441.9	1.9400	0.1040	441.7	1.9361	30
35	0.1197	446.4	1.9622	0.1148	446.2	1.9580	0.1102	446.1	1.9540	0.1060	446.0	1.9500	35
40	0.1219	450.7	1.9761	0.1168	450.5	1.9719	0.1122	450.4	1.9678	0.1079	450.3	1.9639	40
45	0.1240	455.0	1.9898	0.1189	454.9	1.9856	0.1142	454.8	1.9815	0.1099	454.6	1.9777	45
50	0.1261	459.4	2.0034	0.1209	459.2	1.9992	0.1161	459.1	1.9952	0.1117	459.0	1.9913	50
55	0.1283	463.8	2.0169	0.1230	463.7	2.0128	0.1181	463.5	2.0088	0.1136	463.4	2.0049	55
60	0.1304	468.2	2.0304	0.1250	468.1	2.0262	0.1201	468.0	2.0222	0.1155	467.9	2.0183	60
65	0.1325	472.7	2.0437	0.1271	472.6	2.0396	0.1221	472.5	2.0356	0.1174	472.4	2.0317	65
70	0.1346	477.2	2.0570	0.1291	477.1	2.0529	0.1240	477.0	2.0489	0.1193	476.9	2.0450	70
75	0.1367	481.8	2.0702	0.1311	481.7	2.0661	0.1260	481.6	2.0621	0.1212	481.5	2.0582	75
80	0.1389	486.4	2.0833	0.1332	486.3	2.0792	0.1279	486.2	2.0752	0.1231	486.1	2.0714	80
85	0.1410	491.0	2.0963	0.1352	490.9	2.0922	0.1299	490.8	2.0882	0.1250	490.7	2.0844	85
90	0.1431	495.7	2.1093	0.1372	495.6	2.1052	0.1318	495.5	2.1012	0.1268	495.4	2.0974	90
95	0.1452	500.4	2.1222	0.1392	500.3	2.1180	0.1338	500.2	2.1141	0.1287	500.1	2.1103	95
100	0.1473	505.1	2.1350	0.1413	505.0	2.1309	0.1357	505.0	2.1269	0.1306	504.9	2.1231	100
105	0.1493	509.9	2.1477	0.1433	509.8	2.1436	0.1377	509.7	2.1396	0.1325	509.6	2.1358	105
110	0.1514	514.7	2.1603	0.1453	514.6	2.1562	0.1396	514.6	2.1523	0.1343	514.5	2.1485	110
115	0.1535	519.6	2.1729	0.1473	519.5	2.1688	0.1415	519.4	2.1649	0.1362	519.3	2.1611	115
120	0.1556	524.5	2.1854	0.1493	524.4	2.1814	0.1434	524.3	2.1774	0.1380	524.2	2.1736	120
125	0.1577	529.4	2.1979	0.1513	529.3	2.1938	0.1454	529.2	2.1899	0.1399	529.2	2.1861	125
130	0.1598	534.4	2.2103	0.1533	534.3	2.2062	0.1473	534.2	2.2023	0.1418	534.1	2.1985	130
135	0.1618	539.4	2.2226	0.1553	539.3	2.2185	0.1492	539.2	2.2146	0.1436	539.1	2.2108	135
140	—	—	—	—	—	—	0.1511	544.2	2.2269	0.1455	544.2	2.2231	140

TEMP. °C	280.0			290.0			300.0			310.0			TEMP. °C
	(-13.00°C)			(-12.10°C)			(-11.20°C)			(-10.30°C)			
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0838)	(406.4)	(1.8077)	(0.0810)	(406.9)	(1.8061)	(0.0785)	(407.5)	(1.8051)	(0.0760)	(408.0)	(1.8041)	
-10	0.0850	408.7	1.8162	0.0818	408.6	1.8124	0.0789	408.4	1.8087	0.0762	408.2	1.8051	-10
-5	0.0869	412.7	1.8312	0.0837	412.6	1.8274	0.0807	412.4	1.8237	0.0779	412.2	1.8201	-5
0	0.0888	416.7	1.8460	0.0856	416.6	1.8422	0.0825	416.4	1.8386	0.0797	416.3	1.8350	0
5	0.0907	420.8	1.8607	0.0874	420.6	1.8569	0.0843	420.5	1.8533	0.0814	420.3	1.8498	5
10	0.0926	424.9	1.8753	0.0893	424.7	1.8715	0.0861	424.6	1.8679	0.0832	424.4	1.8644	10
15	0.0945	429.0	1.8897	0.0911	428.9	1.8860	0.0879	428.7	1.8824	0.0849	428.6	1.8789	15
20	0.0964	433.2	1.9040	0.0929	433.0	1.9003	0.0897	432.9	1.8967	0.0866	432.7	1.8932	20
25	0.0983	437.4	1.9182	0.0947	437.2	1.9145	0.0914	437.1	1.9109	0.0883	437.0	1.9075	25
30	0.1002	441.6	1.9323	0.0965	441.5	1.9286	0.0932	441.3	1.9250	0.0900	441.2	1.9216	30
35	0.1020	445.9	1.9463	0.0984	445.7	1.9426	0.0949	445.6	1.9390	0.0917	445.5	1.9356	35
40	0.1039	450.2	1.9601	0.1002	450.0	1.9565	0.0967	449.9	1.9529	0.0934	449.8	1.9495	40
45	0.1057	454.5	1.9739	0.1020	454.4	1.9702	0.0984	454.3	1.9667	0.0951	454.2	1.9633	45
50	0.1076	458.9	1.9876	0.1037	458.8	1.9839	0.1002	458.7	1.9804	0.0968	458.5	1.9770	50
55	0.1094	463.3	2.0011	0.1055	463.2	1.9975	0.1019	463.1	1.9940	0.0985	463.0	1.9906	55
60	0.1113	467.8	2.0146	0.1073	467.7	2.0110	0.1036	467.6	2.0075	0.1001	467.4	2.0041	60
65	0.1131	472.3	2.0280	0.1091	472.2	2.0244	0.1053	472.1	2.0209	0.1018	471.9	2.0175	65
70	0.1149	476.8	2.0413	0.1108	476.7	2.0377	0.1070	476.6	2.0342	0.1035	476.5	2.0309	70
75	0.1168	481.4	2.0545	0.1126	481.3	2.0509	0.1088	481.2	2.0475	0.1051	481.2	2.0441	75
80	0.1186	486.0	2.0677	0.1144	485.9	2.0641	0.1105	485.8	2.0606	0.1068	485.7	2.0573	80
85	0.1204	490.6	2.0807	0.1161	490.5	2.0771	0.1122	490.4	2.0737	0.1084	490.3	2.0703	85
90	0.1222	495.3	2.0937	0.1179	495.2	2.0901	0.1139	495.1	2.0867	0.1101	495.0	2.0833	90
95	0.1240	500.0	2.1066	0.1196	499.9	2.1030	0.1156	499.8	2.0996	0.1117	499.7	2.0962	95
100	0.1258	504.8	2.1194	0.1214	504.7	2.1159	0.1173	504.6	2.1124	0.1134	504.5	2.1091	100
105	0.1276	509.6	2.1322	0.1231	509.5	2.1286	0.1189	509.4	2.1252	0.1150	509.3	2.1219	105
110	0.1294	514.4	2.1448	0.1249	514.3	2.1413	0.1206	514.2	2.1379	0.1167	514.1	2.1345	110
115	0.1312	519.2	2.1574	0.1266	519.2	2.1539	0.1223	519.1	2.1505	0.1183	519.0	2.1472	115
120	0.1330	524.1	2.1700	0.1284	524.1	2.1664	0.1240	524.0	2.1630	0.1199	523.9	2.1597	120
125	0.1348	529.1	2.1824	0.1301	529.0	2.1789	0.1257	528.9	2.1755	0.1216	528.8	2.1722	125
130	0.1366	534.0	2.1948	0.1318	534.0	2.1913	0.1274	533.9	2.1879	0.1233	533.8	2.1846	130

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

°P.	320.0 (-9.50°C)			330.0 (-8.70°C)			340.0 (-7.90°C)			350.0 (-7.10°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0738)	(408.5)	(1.8031)	(0.0716)	(408.9)	(1.8021)	(0.0696)	(409.4)	(1.8012)	(0.0677)	(409.9)	(1.8004)	
-5	0.0753	412.1	1.8166	0.0728	411.9	1.8132	0.0705	411.7	1.8099	0.0683	411.6	1.8067	-5
0	0.0770	416.1	1.8316	0.0745	415.9	1.8282	0.0722	415.8	1.8249	0.0699	415.6	1.8217	0
5	0.0787	420.2	1.8463	0.0762	420.0	1.8430	0.0738	419.9	1.8397	0.0715	419.7	1.8365	5
10	0.0804	424.3	1.8610	0.0778	424.1	1.8576	0.0754	424.0	1.8544	0.0731	423.8	1.8512	10
15	0.0821	428.4	1.8755	0.0794	428.3	1.8722	0.0770	428.1	1.8689	0.0746	428.0	1.8658	15
20	0.0838	432.6	1.8898	0.0811	432.5	1.8865	0.0786	432.3	1.8833	0.0762	432.2	1.8802	20
25	0.0854	436.8	1.9041	0.0827	436.7	1.9008	0.0801	436.5	1.8976	0.0777	436.4	1.8945	25
30	0.0871	441.1	1.9182	0.0843	440.9	1.9150	0.0817	440.8	1.9118	0.0792	440.7	1.9087	30
35	0.0887	445.4	1.9323	0.0859	445.2	1.9290	0.0833	445.1	1.9258	0.0808	445.0	1.9228	35
40	0.0904	449.7	1.9462	0.0875	449.5	1.9429	0.0848	449.4	1.9398	0.0823	449.3	1.9367	40
45	0.0920	454.0	1.9600	0.0891	453.9	1.9568	0.0864	453.8	1.9536	0.0838	453.7	1.9506	45
50	0.0937	458.4	1.9737	0.0907	458.3	1.9705	0.0879	458.2	1.9673	0.0853	458.1	1.9643	50
55	0.0953	462.9	1.9873	0.0923	462.7	1.9841	0.0895	462.6	1.9810	0.0869	462.5	1.9779	55
60	0.0969	467.3	2.0008	0.0939	467.2	1.9976	0.0910	467.1	1.9945	0.0883	467.0	1.9915	60
65	0.0985	471.9	2.0142	0.0954	471.7	2.0111	0.0925	471.6	2.0080	0.0898	471.5	2.0049	65
70	0.1001	476.4	2.0276	0.0970	476.3	2.0244	0.0941	476.2	2.0213	0.0913	476.1	2.0183	70
75	0.1018	481.0	2.0408	0.0986	480.9	2.0377	0.0956	480.8	2.0346	0.0928	480.7	2.0316	75
80	0.1034	485.6	2.0540	0.1001	485.5	2.0508	0.0971	485.4	2.0478	0.0942	485.3	2.0448	80
85	0.1050	490.2	2.0671	0.1017	490.1	2.0639	0.0986	490.0	2.0609	0.0957	489.9	2.0579	85
90	0.1066	494.9	2.0801	0.1032	494.8	2.0769	0.1001	494.7	2.0739	0.0972	494.6	2.0709	90
95	0.1082	499.6	2.0930	0.1048	499.6	2.0899	0.1016	499.5	2.0868	0.0986	499.4	2.0838	95
100	0.1098	504.4	2.1059	0.1063	504.3	2.1027	0.1031	504.2	2.0997	0.1001	504.1	2.0967	100
105	0.1113	509.2	2.1186	0.1079	509.1	2.1155	0.1046	509.0	2.1125	0.1016	508.9	2.1095	105
110	0.1129	514.0	2.1313	0.1094	514.0	2.1282	0.1061	513.9	2.1252	0.1030	513.8	2.1222	110
115	0.1145	518.9	2.1440	0.1110	518.8	2.1408	0.1076	518.7	2.1378	0.1045	518.7	2.1349	115
120	0.1161	523.8	2.1565	0.1125	523.7	2.1534	0.1091	523.6	2.1504	0.1059	523.6	2.1474	120
125	0.1177	528.8	2.1690	0.1140	528.7	2.1659	0.1106	528.6	2.1629	0.1074	528.5	2.1599	125
130	0.1193	533.7	2.1814	0.1156	533.6	2.1783	0.1121	533.6	2.1753	0.1088	533.5	2.1724	130
135	0.1208	538.7	2.1938	0.1171	538.7	2.1907	0.1136	538.6	2.1876	0.1103	538.5	2.1847	135
140	0.1224	543.8	2.2060	0.1186	543.7	2.2029	0.1151	543.6	2.1999	0.1117	543.6	2.1970	140
145	0.1240	548.9	2.2183	0.1202	548.8	2.2152	0.1166	548.7	2.2122	0.1132	548.6	2.2092	145

VP.	360.0 (-6.30°C)			370.0 (-5.60°C)			380.0 (-4.90°C)			390.0 (-4.20°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0659)	(410.3)	(1.7995)	(0.0642)	(410.7)	(1.7987)	(0.0625)	(411.2)	(1.7979)	(0.0610)	(411.6)	(1.7971)	
-5	0.0663	411.4	1.8036	0.0643	411.2	1.8005	—	—	—	—	—	—	-5
0	0.0678	415.4	1.8186	0.0658	415.3	1.8155	0.0640	415.1	1.8126	0.0622	415.0	1.8096	0
5	0.0694	419.5	1.8334	0.0673	419.4	1.8304	0.0654	419.2	1.8275	0.0636	419.1	1.8246	5
10	0.0709	423.7	1.8482	0.0688	423.5	1.8452	0.0669	423.4	1.8422	0.0650	423.2	1.8393	10
15	0.0724	427.8	1.8627	0.0703	427.7	1.8597	0.0683	427.5	1.8568	0.0665	427.4	1.8540	15
20	0.0739	432.0	1.8772	0.0718	431.9	1.8742	0.0698	431.7	1.8713	0.0679	431.6	1.8685	20
25	0.0754	436.3	1.8915	0.0733	436.1	1.8885	0.0712	436.0	1.8856	0.0693	435.8	1.8828	25
30	0.0769	440.5	1.9057	0.0747	440.4	1.9027	0.0726	440.3	1.8999	0.0707	440.1	1.8971	30
35	0.0784	444.8	1.9198	0.0762	444.7	1.9168	0.0740	444.6	1.9140	0.0720	444.4	1.9112	35
40	0.0799	449.2	1.9337	0.0776	449.0	1.9308	0.0755	448.9	1.9280	0.0734	448.8	1.9252	40
45	0.0814	453.5	1.9476	0.0790	453.4	1.9447	0.0769	453.3	1.9418	0.0748	453.2	1.9391	45
50	0.0828	458.0	1.9613	0.0805	457.8	1.9584	0.0783	457.7	1.9556	0.0762	457.6	1.9528	50
55	0.0843	462.4	1.9750	0.0819	462.3	1.9721	0.0797	462.2	1.9693	0.0775	462.1	1.9665	55
60	0.0857	466.9	1.9885	0.0833	466.8	1.9857	0.0810	466.7	1.9829	0.0789	466.5	1.9801	60
65	0.0872	471.4	2.0020	0.0847	471.3	1.9991	0.0824	471.2	1.9963	0.0802	471.1	1.9936	65
70	0.0886	476.0	2.0154	0.0862	475.9	2.0125	0.0838	475.7	2.0097	0.0816	475.6	2.0070	70
75	0.0901	480.5	2.0287	0.0876	480.4	2.0258	0.0852	480.3	2.0230	0.0829	480.2	2.0203	75
80	0.0915	485.2	2.0418	0.0890	485.1	2.0390	0.0865	485.0	2.0362	0.0842	484.9	2.0335	80
85	0.0930	489.8	2.0550	0.0904	489.7	2.0521	0.0879	489.6	2.0494	0.0856	489.5	2.0467	85
90	0.0944	494.5	2.0680	0.0918	494.4	2.0652	0.0893	494.3	2.0624	0.0869	494.3	2.0597	90
95	0.0958	499.3	2.0809	0.0932	499.2	2.0781	0.0906	499.1	2.0754	0.0882	499.0	2.0727	95
100	0.0973	504.0	2.0938	0.0946	504.0	2.0910	0.0920	503.9	2.0883	0.0896	503.8	2.0856	100
105	0.0987	508.9	2.1066	0.0959	508.8	2.1038	0.0933	508.7	2.1011	0.0909	508.6	2.0984	105
110	0.1001	513.7	2.1193	0.0973	513.6	2.1165	0.0947	513.5	2.1138	0.0922	513.4	2.1111	110
115	0.1015	518.6	2.1320	0.0987	518.5	2.1292	0.0960	518.4	2.1265	0.0935	518.3	2.1238	115
120	0.1029	523.5	2.1446	0.1001	523.4	2.1418	0.0974	523.3	2.1390	0.0948	523.2	2.1364	120
125	0.1043	528.4	2.1571	0.1015	528.4	2.1543	0.0987	528.3	2.1516	0.0961	528.2	2.1489	125
130	0.1058	533.4	2.1695	0.1028	533.3	2.1667	0.1001	533.3	2.1640	0.0974	533.2	2.1614	130
135	0.1072	538.4	2.1819	0.1042	538.4	2.1791	0.1014	538.3	2.1764	0.0988	538.2	2.1737	135
140	0.1086	543.5	2.1942	0.1056	543.4	2.1914	0.1027	543.3	2.1887	0.1001	543.3	2.1860	140
145	0.1100	548.6	2.2064	0.1069	548.5	2.2036	0.1041	548.4	2.2009	0.1014	548.3	2.1983	145

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

TEMP. °C	400.0 (-3.50°C)			430.0 (-1.80°C)			450.0 (-0.10°C)			480.0 (1.40°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0595)	(412.0)	(1.7964)	(0.0561)	(412.9)	(1.7946)	(0.0531)	(413.8)	(1.7930)	(0.0504)	(414.7)	(1.7914)	
0	0.0605	414.8	1.8068	0.0566	414.4	1.7999	0.0531	413.9	1.7933	0.0000	0.0	0.0000	0
5	0.0619	418.9	1.8217	0.0579	418.5	1.8149	0.0544	418.1	1.8084	0.0512	417.7	1.8022	5
10	0.0633	423.1	1.8365	0.0592	422.7	1.8297	0.0557	422.3	1.8233	0.0524	421.9	1.8171	10
15	0.0647	427.2	1.8512	0.0606	426.9	1.8444	0.0569	426.5	1.8380	0.0536	426.1	1.8319	15
20	0.0660	431.5	1.8657	0.0619	431.1	1.8590	0.0582	430.7	1.8526	0.0548	430.4	1.8466	20
25	0.0674	435.7	1.8801	0.0632	435.4	1.8734	0.0594	435.0	1.8671	0.0560	434.6	1.8611	25
30	0.0688	440.0	1.8943	0.0645	439.7	1.8877	0.0606	439.3	1.8814	0.0572	439.0	1.8754	30
35	0.0701	444.3	1.9084	0.0657	444.0	1.9019	0.0619	443.7	1.8956	0.0584	443.3	1.8897	35
40	0.0715	448.7	1.9225	0.0670	448.3	1.9159	0.0631	448.0	1.9097	0.0595	447.7	1.9038	40
45	0.0728	453.1	1.9364	0.0683	452.7	1.9298	0.0643	452.4	1.9237	0.0607	452.1	1.9178	45
50	0.0742	457.5	1.9502	0.0696	457.2	1.9437	0.0655	456.9	1.9375	0.0618	456.6	1.9317	50
55	0.0755	461.9	1.9638	0.0708	461.6	1.9574	0.0667	461.4	1.9513	0.0630	461.1	1.9454	55
60	0.0768	466.4	1.9774	0.0721	466.1	1.9710	0.0679	465.9	1.9649	0.0641	465.6	1.9591	60
65	0.0781	471.0	1.9909	0.0733	470.7	1.9845	0.0691	470.4	1.9785	0.0652	470.1	1.9727	65
70	0.0794	475.5	2.0044	0.0746	475.3	1.9980	0.0702	475.0	1.9919	0.0664	474.7	1.9861	70
75	0.0808	480.1	2.0177	0.0758	479.9	2.0113	0.0714	479.6	2.0053	0.0675	479.3	1.9995	75
80	0.0821	484.8	2.0309	0.0770	484.5	2.0245	0.0726	484.3	2.0185	0.0686	484.0	2.0128	80
85	0.0834	489.4	2.0440	0.0783	489.2	2.0377	0.0738	488.9	2.0317	0.0697	488.7	2.0260	85
90	0.0847	494.2	2.0571	0.0795	493.9	2.0508	0.0749	493.7	2.0448	0.0708	493.4	2.0391	90
95	0.0860	498.9	2.0701	0.0807	498.7	2.0638	0.0761	498.4	2.0578	0.0719	498.2	2.0521	95
100	0.0873	503.7	2.0830	0.0820	503.5	2.0767	0.0773	503.2	2.0707	0.0730	503.0	2.0651	100
105	0.0885	508.5	2.0958	0.0832	508.3	2.0895	0.0784	508.0	2.0836	0.0741	507.8	2.0780	105
110	0.0898	513.3	2.1085	0.0844	513.1	2.1023	0.0796	512.9	2.0964	0.0752	512.7	2.0907	110
115	0.0911	518.2	2.1212	0.0856	518.0	2.1150	0.0807	517.8	2.1091	0.0763	517.6	2.1035	115
120	0.0924	523.2	2.1338	0.0868	522.9	2.1276	0.0819	522.7	2.1217	0.0774	522.5	2.1161	120
125	0.0937	528.1	2.1463	0.0880	527.9	2.1401	0.0830	527.7	2.1342	0.0785	527.5	2.1287	125
130	0.0950	533.1	2.1588	0.0892	532.9	2.1526	0.0842	532.7	2.1467	0.0796	532.5	2.1411	130
135	0.0962	538.1	2.1712	0.0904	537.9	2.1650	0.0853	537.7	2.1591	0.0807	537.5	2.1536	135
140	0.0975	543.2	2.1835	0.0916	543.0	2.1773	0.0864	542.8	2.1715	0.0818	542.6	2.1659	140
145	0.0988	548.3	2.1957	0.0928	548.1	2.1896	0.0876	547.9	2.1837	0.0828	547.7	2.1782	145
150	0.1000	553.4	2.2079	0.0940	553.2	2.2018	0.0887	553.0	2.1959	0.0839	552.9	2.1904	150
155	—	—	—	—	—	—	—	—	—	0.0850	558.0	2.2026	155

TEMP. °C	500.0 (2.90°C)			530.0 (4.40°C)			550.0 (5.70°C)			580.0 (7.10°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0479)	(415.5)	(1.7889)	(0.0457)	(416.3)	(1.7885)	(0.0436)	(417.0)	(1.7872)	(0.0417)	(417.8)	(1.7859)	
5	0.0484	417.3	1.7962	0.0458	416.8	1.7905	—	—	—	—	—	—	5
10	0.0495	421.5	1.8112	0.0469	421.1	1.8055	0.0445	420.7	1.8000	0.0424	420.3	1.7947	10
15	0.0507	425.7	1.8260	0.0480	425.3	1.8204	0.0456	424.9	1.8150	0.0434	424.5	1.8098	15
20	0.0518	430.0	1.8407	0.0491	429.6	1.8352	0.0467	429.2	1.8298	0.0444	428.9	1.8246	20
25	0.0530	434.3	1.8553	0.0502	433.9	1.8497	0.0477	433.6	1.8444	0.0454	433.2	1.8393	25
30	0.0541	438.6	1.8697	0.0513	438.3	1.8642	0.0488	437.9	1.8589	0.0464	437.6	1.8538	30
35	0.0552	443.0	1.8840	0.0524	442.6	1.8785	0.0498	442.3	1.8733	0.0474	442.0	1.8682	35
40	0.0563	447.4	1.8981	0.0534	447.0	1.8927	0.0508	446.7	1.8875	0.0484	446.4	1.8825	40
45	0.0574	451.8	1.9121	0.0545	451.5	1.9067	0.0518	451.2	1.9016	0.0494	450.8	1.8966	45
50	0.0585	456.3	1.9261	0.0556	456.0	1.9207	0.0529	455.7	1.9155	0.0504	455.3	1.9106	50
55	0.0596	460.8	1.9399	0.0566	460.5	1.9345	0.0539	460.2	1.9294	0.0514	459.9	1.9245	55
60	0.0607	465.3	1.9536	0.0577	465.0	1.9483	0.0549	464.7	1.9432	0.0523	464.4	1.9383	60
65	0.0618	469.9	1.9672	0.0587	469.6	1.9619	0.0559	469.3	1.9568	0.0533	469.0	1.9519	65
70	0.0629	474.5	1.9806	0.0597	474.2	1.9754	0.0568	473.9	1.9704	0.0542	473.6	1.9655	70
75	0.0639	479.1	1.9941	0.0607	478.8	1.9888	0.0578	478.6	1.9838	0.0552	478.3	1.9790	75
80	0.0650	483.8	2.0074	0.0618	483.5	2.0021	0.0588	483.2	1.9971	0.0561	483.0	1.9923	80
85	0.0661	488.5	2.0206	0.0628	488.2	2.0154	0.0598	487.9	2.0104	0.0571	487.7	2.0056	85
90	0.0671	493.2	2.0337	0.0638	492.9	2.0285	0.0608	492.7	2.0236	0.0580	492.5	2.0188	90
95	0.0682	498.0	2.0468	0.0648	497.7	2.0416	0.0617	497.5	2.0366	0.0589	497.2	2.0319	95
100	0.0693	502.8	2.0597	0.0658	502.5	2.0546	0.0627	502.3	2.0496	0.0599	502.1	2.0449	100
105	0.0703	507.6	2.0726	0.0668	507.4	2.0675	0.0637	507.1	2.0626	0.0608	506.9	2.0578	105
110	0.0713	512.5	2.0854	0.0678	512.3	2.0803	0.0646	512.0	2.0754	0.0617	511.8	2.0707	110
115	0.0724	517.4	2.0981	0.0688	517.2	2.0930	0.0656	516.9	2.0881	0.0626	516.7	2.0835	115
120	0.0734	522.3	2.1108	0.0698	522.1	2.1057	0.0665	521.9	2.1008	0.0635	521.7	2.0961	120
125	0.0745	527.3	2.1233	0.0708	527.1	2.1183	0.0675	526.9	2.1134	0.0645	526.7	2.1088	125
130	0.0755	532.3	2.1358	0.0718	532.1	2.1308	0.0684	531.9	2.1259	0.0654	531.7	2.1213	130
135	0.0765	537.3	2.1483	0.0728	537.2	2.1432	0.0694	537.0	2.1384	0.0663	536.8	2.1338	135
140	0.0776	542.4	2.1606	0.0738	542.2	2.1556	0.0703	542.0	2.1508	0.0672	541.9	2.1462	140
145	0.0786	547.5	2.1729	0.0748	547.3	2.1679	0.0713	547.2	2.1631	0.0681	547.0	2.1585	145
150	0.0796	552.7	2.1851	0.0757	552.5	2.1801	0.0722	552.3	2.1753	0.0690	552.1	2.1707	150
155	0.0807	557.8	2.1972	0.0767	557.7	2.1923	0.0731	557.5	2.1875	0.0699	557.3	2.1829	155

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

TEMP. °C	600.0 (8.40°C) V	H	S	630.0 (9.60°C) V	H	S	650.0 (10.30°C) V	H	S	680.0 (12.00°C) V	H	S	TEMP. °C
	(0.0400)	(418.4)	(1.7847)	(0.0384)	(419.1)	(1.7835)	(0.0370)	(419.7)	(1.7824)	(0.0356)	(420.3)	(1.7813)	
10	0.0404	419.8	1.7896	0.0385	419.4	1.7846	—	—	—	—	—	—	10
15	0.0414	424.1	1.8047	0.0395	423.7	1.7998	0.0378	423.3	1.7950	0.0362	422.9	1.7904	15
20	0.0424	428.5	1.8195	0.0405	428.1	1.8147	0.0387	427.7	1.8100	0.0371	427.3	1.8054	20
25	0.0433	432.8	1.8343	0.0414	432.4	1.8295	0.0396	432.1	1.8248	0.0380	431.7	1.8203	25
30	0.0443	437.2	1.8489	0.0423	436.8	1.8441	0.0405	436.5	1.8395	0.0389	436.1	1.8350	30
35	0.0453	441.6	1.8633	0.0433	441.3	1.8586	0.0414	440.9	1.8540	0.0397	440.6	1.8496	35
40	0.0462	446.1	1.8776	0.0442	445.7	1.8729	0.0423	445.4	1.8684	0.0406	445.0	1.8640	40
45	0.0472	450.5	1.8918	0.0451	450.2	1.8871	0.0432	449.9	1.8826	0.0415	449.5	1.8783	45
50	0.0481	455.0	1.9058	0.0460	454.7	1.9012	0.0441	454.4	1.8967	0.0423	454.1	1.8924	50
55	0.0491	459.6	1.9197	0.0469	459.3	1.9152	0.0450	459.0	1.9107	0.0432	458.6	1.9064	55
60	0.0500	464.1	1.9335	0.0478	463.8	1.9290	0.0458	463.5	1.9246	0.0440	463.2	1.9203	60
65	0.0509	468.7	1.9472	0.0487	468.4	1.9427	0.0467	468.2	1.9383	0.0448	467.9	1.9341	65
70	0.0518	473.4	1.9608	0.0496	473.1	1.9563	0.0476	472.8	1.9520	0.0457	472.5	1.9478	70
75	0.0527	478.0	1.9743	0.0505	477.7	1.9699	0.0484	477.5	1.9655	0.0465	477.2	1.9613	75
80	0.0536	482.7	1.9877	0.0514	482.5	1.9833	0.0493	482.2	1.9790	0.0473	481.9	1.9748	80
85	0.0546	487.4	2.0010	0.0522	487.2	1.9966	0.0501	486.9	1.9923	0.0481	486.7	1.9882	85
90	0.0555	492.2	2.0142	0.0531	492.0	2.0098	0.0510	491.7	2.0055	0.0490	491.5	2.0014	90
95	0.0564	497.0	2.0273	0.0540	496.8	2.0229	0.0518	496.5	2.0187	0.0498	496.3	2.0146	95
100	0.0572	501.8	2.0404	0.0548	501.6	2.0360	0.0526	501.4	2.0318	0.0506	501.1	2.0277	100
105	0.0581	506.7	2.0533	0.0557	506.5	2.0489	0.0535	506.2	2.0447	0.0514	506.0	2.0407	105
110	0.0590	511.6	2.0662	0.0566	511.4	2.0618	0.0543	511.1	2.0576	0.0522	510.9	2.0536	110
115	0.0599	516.5	2.0790	0.0574	516.3	2.0746	0.0551	516.1	2.0704	0.0530	515.9	2.0664	115
120	0.0608	521.5	2.0917	0.0583	521.3	2.0873	0.0559	521.1	2.0832	0.0538	520.8	2.0791	120
125	0.0617	526.5	2.1043	0.0591	526.3	2.1000	0.0567	526.1	2.0958	0.0546	525.9	2.0918	125
130	0.0625	531.5	2.1168	0.0600	531.3	2.1125	0.0576	531.1	2.1084	0.0553	530.9	2.1044	130
135	0.0634	536.6	2.1293	0.0608	536.4	2.1250	0.0584	536.2	2.1209	0.0561	536.0	2.1169	135
140	0.0643	541.7	2.1417	0.0616	541.5	2.1374	0.0592	541.3	2.1333	0.0569	541.1	2.1294	140
145	0.0652	546.8	2.1541	0.0625	546.6	2.1498	0.0600	546.4	2.1457	0.0577	546.2	2.1417	145
150	0.0660	551.9	2.1663	0.0633	551.8	2.1621	0.0608	551.6	2.1580	0.0585	551.4	2.1540	150
155	0.0669	557.1	2.1785	0.0641	557.0	2.1743	0.0616	556.8	2.1702	0.0592	556.6	2.1662	155
160	0.0678	562.4	2.1906	0.0650	562.2	2.1864	0.0624	562.0	2.1823	0.0600	561.8	2.1784	160
165	—	—	—	—	—	—	0.0632	567.3	2.1944	0.0608	567.1	2.1905	165

TEMP. °C	700.0 (13.20°C) V	H	S	730.0 (14.30°C) V	H	S	750.0 (15.40°C) V	H	S	800.0 (17.50°C) V	H	S	TEMP. °C
	(0.0343)	(420.9)	(1.7602)	(0.0331)	(421.4)	(1.7792)	(0.0320)	(422.0)	(1.7782)	(0.0300)	(423.0)	(1.7763)	
15	0.0347	422.5	1.7858	0.0333	422.1	1.7814	—	—	—	—	—	—	15
20	0.0356	426.9	1.8010	0.0341	426.5	1.7966	0.0328	426.1	1.7924	0.0304	425.2	1.7841	20
25	0.0364	431.3	1.8159	0.0350	430.9	1.8116	0.0337	430.5	1.8074	0.0312	429.7	1.7993	25
30	0.0373	435.7	1.8307	0.0358	435.4	1.8264	0.0345	435.0	1.8223	0.0320	434.2	1.8143	30
35	0.0381	440.2	1.8453	0.0367	439.8	1.8411	0.0353	439.5	1.8370	0.0328	438.8	1.8291	35
40	0.0390	444.7	1.8597	0.0375	444.4	1.8556	0.0361	444.0	1.8515	0.0336	443.3	1.8437	40
45	0.0398	449.2	1.8740	0.0383	448.9	1.8699	0.0369	448.5	1.8659	0.0343	447.9	1.8582	45
50	0.0407	453.8	1.8882	0.0391	453.4	1.8841	0.0377	453.1	1.8802	0.0351	452.5	1.8725	50
55	0.0415	458.3	1.9023	0.0399	458.0	1.8982	0.0385	457.7	1.8943	0.0358	457.1	1.8867	55
60	0.0423	462.9	1.9162	0.0407	462.6	1.9122	0.0392	462.3	1.9083	0.0365	461.7	1.9008	60
65	0.0431	467.6	1.9300	0.0415	467.3	1.9260	0.0400	467.0	1.9221	0.0373	466.4	1.9147	65
70	0.0439	472.2	1.9437	0.0423	472.0	1.9397	0.0408	471.7	1.9359	0.0380	471.1	1.9285	70
75	0.0447	476.9	1.9573	0.0431	476.7	1.9533	0.0415	476.4	1.9495	0.0387	475.8	1.9422	75
80	0.0455	481.7	1.9708	0.0438	481.4	1.9669	0.0423	481.1	1.9631	0.0394	480.6	1.9558	80
85	0.0463	486.4	1.9841	0.0446	486.2	1.9803	0.0430	485.9	1.9765	0.0401	485.4	1.9692	85
90	0.0471	491.2	1.9974	0.0454	491.0	1.9936	0.0438	490.7	1.9898	0.0408	490.2	1.9826	90
95	0.0479	496.0	2.0106	0.0461	495.8	2.0068	0.0445	495.5	2.0030	0.0415	495.1	1.9959	95
100	0.0487	500.9	2.0237	0.0469	500.7	2.0199	0.0452	500.4	2.0162	0.0422	499.9	2.0090	100
105	0.0494	505.8	2.0367	0.0476	505.5	2.0329	0.0460	505.3	2.0292	0.0429	504.9	2.0221	105
110	0.0502	510.7	2.0497	0.0484	510.5	2.0459	0.0467	510.2	2.0422	0.0436	509.8	2.0351	110
115	0.0510	515.6	2.0625	0.0491	515.4	2.0587	0.0474	515.2	2.0550	0.0443	514.8	2.0480	115
120	0.0518	520.6	2.0753	0.0499	520.4	2.0715	0.0481	520.2	2.0678	0.0450	519.8	2.0608	120
125	0.0525	525.6	2.0879	0.0506	525.4	2.0842	0.0489	525.2	2.0805	0.0457	524.8	2.0736	125
130	0.0533	530.7	2.1005	0.0514	530.5	2.0968	0.0496	530.3	2.0932	0.0463	529.9	2.0862	130
135	0.0540	535.8	2.1131	0.0521	535.6	2.1093	0.0503	535.4	2.1057	0.0470	535.0	2.0988	135
140	0.0548	540.9	2.1255	0.0528	540.7	2.1218	0.0510	540.5	2.1182	0.0477	540.1	2.1113	140
145	0.0556	546.0	2.1379	0.0536	545.8	2.1342	0.0517	545.7	2.1306	0.0484	545.3	2.1237	145
150	0.0563	551.2	2.1502	0.0543	551.0	2.1465	0.0524	550.8	2.1429	0.0490	550.5	2.1360	150
155	0.0571	556.4	2.1624	0.0550	556.2	2.1587	0.0531	556.1	2.1552	0.0497	555.7	2.1483	155
160	0.0578	561.7	2.1746	0.0557	561.5	2.1709	0.0538	561.3	2.1673	0.0503	561.0	2.1605	160
165	0.0586	566.9	2.1867	0.0565	566.8	2.1830	0.0545	566.6	2.1795	0.0510	566.2	2.1727	165
170	—	—	—	—	—	—	0.0552	571.9	2.1915	0.0517	571.5	2.1847	170

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

P.	1500.0 (39.60°C)			1600.0 (42.00°C)			1700.0 (44.40°C)			1800.0 (46.60°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0155)	(431.6)	(1.7556)	(0.0144)	(432.3)	(1.7530)	(0.0134)	(432.9)	(1.7504)	(0.0126)	(433.3)	(1.7478)	
40	0.0155	432.0	1.7570	—	—	—	—	—	—	—	—	—	40
45	0.0161	437.2	1.7732	0.0147	435.4	1.7628	0.0135	433.5	1.7525	—	—	—	45
50	0.0166	442.3	1.7891	0.0152	440.6	1.7790	0.0140	438.9	1.7691	0.0129	437.0	1.7593	50
55	0.0171	447.3	1.8047	0.0157	445.8	1.7949	0.0145	444.1	1.7853	0.0134	442.4	1.7759	55
60	0.0176	452.4	1.8200	0.0162	450.9	1.8104	0.0150	449.4	1.8012	0.0139	447.8	1.7920	60
65	0.0180	457.4	1.8350	0.0167	456.0	1.8257	0.0154	454.6	1.8167	0.0143	453.1	1.8078	65
70	0.0185	462.5	1.8498	0.0171	461.1	1.8407	0.0159	459.8	1.8319	0.0147	458.3	1.8233	70
75	0.0190	467.5	1.8644	0.0175	466.3	1.8555	0.0163	464.9	1.8469	0.0152	463.6	1.8385	75
80	0.0194	472.6	1.8789	0.0180	471.4	1.8701	0.0167	470.1	1.8616	0.0156	468.8	1.8534	80
85	0.0199	477.7	1.8931	0.0184	476.5	1.8845	0.0171	475.3	1.8761	0.0160	474.0	1.8681	85
90	0.0203	482.7	1.9072	0.0188	481.6	1.8987	0.0175	480.4	1.8905	0.0164	479.3	1.8826	90
95	0.0207	487.8	1.9211	0.0192	486.7	1.9127	0.0179	485.6	1.9047	0.0168	484.5	1.8969	95
100	0.0212	492.9	1.9349	0.0197	491.9	1.9266	0.0183	490.8	1.9187	0.0171	489.7	1.9110	100
105	0.0216	498.1	1.9486	0.0201	497.1	1.9404	0.0187	496.0	1.9325	0.0175	495.0	1.9250	105
110	0.0220	503.2	1.9621	0.0205	502.2	1.9540	0.0191	501.2	1.9462	0.0179	500.2	1.9388	110
115	0.0224	508.4	1.9755	0.0208	507.4	1.9675	0.0195	506.5	1.9598	0.0182	505.6	1.9525	115
120	0.0228	513.6	1.9888	0.0212	512.7	1.9808	0.0198	511.7	1.9733	0.0186	510.8	1.9660	120
125	0.0232	518.8	2.0019	0.0216	517.9	1.9941	0.0202	517.0	1.9866	0.0189	516.1	1.9794	125
130	0.0236	524.0	2.0150	0.0220	523.2	2.0072	0.0206	522.3	1.9998	0.0193	521.4	1.9927	130
135	0.0240	529.3	2.0280	0.0224	528.4	2.0202	0.0209	527.6	2.0129	0.0196	526.8	2.0058	135
140	0.0244	534.6	2.0408	0.0228	533.8	2.0332	0.0213	532.9	2.0259	0.0200	532.1	2.0189	140
145	0.0248	539.9	2.0536	0.0231	539.1	2.0460	0.0216	538.3	2.0387	0.0203	537.5	2.0318	145
150	0.0252	545.2	2.0663	0.0235	544.4	2.0587	0.0220	543.7	2.0515	0.0207	542.9	2.0447	150
155	0.0256	550.6	2.0789	0.0239	549.8	2.0714	0.0224	549.1	2.0642	0.0210	548.3	2.0574	155
160	0.0260	556.0	2.0914	0.0242	555.2	2.0839	0.0227	554.5	2.0769	0.0213	553.8	2.0700	160
165	0.0264	561.4	2.1038	0.0246	560.7	2.0964	0.0230	559.9	2.0893	0.0217	559.2	2.0826	165
170	0.0267	566.8	2.1161	0.0250	566.1	2.1088	0.0234	565.4	2.1017	0.0220	564.7	2.0951	170
175	0.0271	572.3	2.1284	0.0253	571.6	2.1211	0.0237	570.9	2.1141	0.0223	570.2	2.1074	175
180	0.0275	577.8	2.1406	0.0257	577.1	2.1333	0.0241	576.4	2.1263	0.0226	575.8	2.1197	180
185	0.0279	583.3	2.1527	0.0260	582.6	2.1454	0.0244	582.0	2.1385	0.0230	581.3	2.1319	185
190	0.0282	588.8	2.1647	0.0264	588.2	2.1575	0.0247	587.6	2.1506	0.0233	586.9	2.1441	190
195	—	—	—	0.0267	593.8	2.1694	0.0251	593.1	2.1626	0.0236	592.5	2.1561	195
200	—	—	—	—	—	—	—	—	—	0.0239	598.2	2.1681	200

MP. C	1900.0 (48.80°C)			2000.0 (50.80°C)			2200.0 (54.70°C)			2400.0 (58.40°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0118)	(433.7)	(1.7452)	(0.0111)	(434.0)	(1.7426)	(0.0099)	(434.4)	(1.7373)	(0.0089)	(434.5)	(1.7318)	
50	0.0119	435.1	1.7495	—	—	—	—	—	—	—	—	—	50
55	0.0124	440.7	1.7665	0.0115	438.8	1.7572	0.0099	434.7	1.7383	—	—	—	55
60	0.0129	446.1	1.7831	0.0120	444.4	1.7742	0.0104	440.7	1.7563	—	—	—	60
65	0.0133	451.5	1.7992	0.0124	449.9	1.7906	0.0108	446.5	1.7736	0.0090	436.6	1.7381	65
70	0.0137	456.9	1.8149	0.0128	455.4	1.8066	0.0113	452.2	1.7904	0.0095	442.8	1.7566	70
75	0.0142	462.2	1.8303	0.0132	460.8	1.8223	0.0117	457.8	1.8066	0.0099	448.8	1.7742	75
80	0.0146	467.5	1.8454	0.0136	466.2	1.8376	0.0120	463.4	1.8224	0.0103	454.6	1.7912	80
85	0.0149	472.8	1.8603	0.0140	471.5	1.8527	0.0124	468.9	1.8379	0.0107	460.4	1.8076	85
90	0.0153	478.1	1.8749	0.0144	476.9	1.8675	0.0128	474.3	1.8531	0.0110	466.1	1.8236	90
95	0.0157	483.4	1.8894	0.0147	482.2	1.8821	0.0131	479.8	1.8680	0.0114	471.7	1.8392	95
100	0.0161	488.6	1.9036	0.0151	487.5	1.8965	0.0134	485.2	1.8827	0.0117	477.3	1.8545	100
105	0.0164	493.9	1.9177	0.0155	492.9	1.9106	0.0138	490.7	1.8971	0.0121	482.9	1.8695	105
110	0.0168	499.2	1.9316	0.0158	498.2	1.9247	0.0141	496.1	1.9114	0.0124	488.4	1.8843	110
115	0.0171	504.5	1.9454	0.0161	503.5	1.9385	0.0144	501.5	1.9255	0.0127	493.9	1.8988	115
120	0.0175	509.8	1.9590	0.0165	508.9	1.9522	0.0147	506.9	1.9394	0.0130	499.4	1.9131	120
125	0.0178	515.2	1.9725	0.0168	514.3	1.9658	0.0150	512.4	1.9531	0.0133	504.9	1.9272	125
130	0.0182	520.5	1.9858	0.0171	519.6	1.9792	0.0154	517.8	1.9667	0.0136	510.5	1.9411	130
135	0.0185	525.9	1.9990	0.0175	525.0	1.9925	0.0157	523.3	1.9801	0.0139	516.0	1.9549	135
140	0.0188	531.3	2.0122	0.0178	530.4	2.0057	0.0160	528.7	1.9935	0.0142	521.5	1.9685	140
145	0.0191	536.7	2.0252	0.0181	535.9	2.0188	0.0162	534.2	2.0067	0.0144	527.0	1.9820	145
150	0.0195	542.1	2.0381	0.0184	541.3	2.0317	0.0165	539.7	2.0197	0.0147	532.6	1.9953	150
155	0.0198	547.6	2.0509	0.0187	546.8	2.0446	0.0168	545.2	2.0327	0.0150	538.1	2.0085	155
160	0.0201	553.0	2.0635	0.0190	552.3	2.0573	0.0171	550.8	2.0455	0.0153	543.7	2.0216	160
165	0.0204	558.5	2.0761	0.0193	557.8	2.0700	0.0174	556.3	2.0583	0.0155	549.3	2.0345	165
170	0.0207	564.0	2.0887	0.0196	563.3	2.0825	0.0177	561.9	2.0709	0.0158	554.9	2.0474	170
175	0.0211	569.6	2.1011	0.0199	568.9	2.0950	0.0180	567.5	2.0835	0.0161	560.5	2.0601	175
180	0.0214	575.1	2.1134	0.0202	574.4	2.1074	0.0182	573.1	2.0959	0.0163	566.1	2.0728	180
185	0.0217	580.7	2.1257	0.0205	580.0	2.1196	0.0185	578.7	2.1083	0.0166	571.8	2.0853	185
190	0.0220	586.3	2.1378	0.0208	585.7	2.1318	0.0188	584.4	2.1206	0.0168	577.4	2.0977	190
195	0.0223	591.9	2.1499	0.0211	591.3	2.1440	0.0190	590.1	2.1328	0.0171	583.1	2.1101	195
200	0.0226	597.6	2.1619	0.0214	597.0	2.1560	0.0193	595.8	2.1449	0.0173	588.8	2.1223	200
205	—	—	—	0.0217	602.7	2.1680	0.0196	601.5	2.1569	0.0176	594.6	2.1345	205
210	—	—	—	—	—	—	—	—	—	0.0178	600.3	2.1466	210
										0.0181	606.1	2.1586	

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

TEMP. °C	600.0 (8.40°C) V	H	S	630.0 (9.60°C) V	H	S	650.0 (10.80°C) V	H	S	680.0 (12.00°C) V	H	S	TEMP. °C
	(0.0400)	(418.4)	(1.7847)	(0.0384)	(419.1)	(1.7835)	(0.0370)	(419.7)	(1.7824)	(0.0356)	(420.3)	(1.7813)	
10	0.0404	419.8	1.7896	0.0385	419.4	1.7846	—	—	—	—	—	—	10
15	0.0414	424.1	1.8047	0.0395	423.7	1.7998	0.0378	423.3	1.7950	0.0362	422.9	1.7904	15
20	0.0424	428.5	1.8196	0.0405	428.1	1.8147	0.0387	427.7	1.8100	0.0371	427.3	1.8054	20
25	0.0433	432.8	1.8343	0.0414	432.4	1.8295	0.0396	432.1	1.8248	0.0380	431.7	1.8203	25
30	0.0443	437.2	1.8489	0.0423	436.8	1.8441	0.0405	436.5	1.8395	0.0389	436.1	1.8350	30
35	0.0453	441.6	1.8633	0.0433	441.3	1.8586	0.0414	440.9	1.8540	0.0397	440.6	1.8496	35
40	0.0462	446.1	1.8776	0.0442	445.7	1.8729	0.0423	445.4	1.8684	0.0406	445.0	1.8640	40
45	0.0472	450.5	1.8918	0.0451	450.2	1.8871	0.0432	449.9	1.8826	0.0415	449.5	1.8783	45
50	0.0481	455.0	1.9058	0.0460	454.7	1.9012	0.0441	454.4	1.8967	0.0423	454.1	1.8924	50
55	0.0491	459.6	1.9197	0.0469	459.3	1.9152	0.0450	459.0	1.9107	0.0432	458.6	1.9064	55
60	0.0500	464.1	1.9335	0.0478	463.8	1.9290	0.0458	463.5	1.9246	0.0440	463.2	1.9203	60
65	0.0509	468.7	1.9472	0.0487	468.4	1.9427	0.0467	468.2	1.9383	0.0448	467.9	1.9341	65
70	0.0518	473.4	1.9608	0.0496	473.1	1.9563	0.0476	472.8	1.9520	0.0457	472.5	1.9478	70
75	0.0527	478.0	1.9743	0.0505	477.7	1.9699	0.0484	477.5	1.9655	0.0465	477.2	1.9613	75
80	0.0536	482.7	1.9877	0.0514	482.5	1.9833	0.0493	482.2	1.9790	0.0473	481.9	1.9748	80
85	0.0546	487.4	2.0010	0.0522	487.2	1.9966	0.0501	486.9	1.9923	0.0481	486.7	1.9882	85
90	0.0555	492.2	2.0142	0.0531	492.0	2.0098	0.0510	491.7	2.0055	0.0490	491.5	2.0014	90
95	0.0564	497.0	2.0273	0.0540	496.8	2.0229	0.0518	496.5	2.0187	0.0498	496.3	2.0146	95
100	0.0572	501.8	2.0404	0.0548	501.6	2.0360	0.0526	501.4	2.0318	0.0506	501.1	2.0277	100
105	0.0581	506.7	2.0533	0.0557	506.5	2.0489	0.0535	506.2	2.0447	0.0514	506.0	2.0407	105
110	0.0590	511.6	2.0662	0.0566	511.4	2.0618	0.0543	511.1	2.0576	0.0522	510.9	2.0536	110
115	0.0599	516.5	2.0790	0.0574	516.3	2.0746	0.0551	516.1	2.0704	0.0530	515.9	2.0664	115
120	0.0608	521.5	2.0917	0.0583	521.3	2.0873	0.0559	521.1	2.0832	0.0538	520.8	2.0791	120
125	0.0617	526.5	2.1043	0.0591	526.3	2.1000	0.0567	526.1	2.0958	0.0546	525.9	2.0918	125
130	0.0625	531.5	2.1168	0.0600	531.3	2.1125	0.0576	531.1	2.1084	0.0553	530.9	2.1044	130
135	0.0634	536.6	2.1293	0.0608	536.4	2.1250	0.0584	536.2	2.1209	0.0561	536.0	2.1169	135
140	0.0643	541.7	2.1417	0.0616	541.5	2.1374	0.0592	541.3	2.1333	0.0569	541.1	2.1294	140
145	0.0652	546.8	2.1541	0.0625	546.6	2.1498	0.0600	546.4	2.1457	0.0577	546.2	2.1417	145
150	0.0660	551.9	2.1663	0.0633	551.8	2.1621	0.0608	551.6	2.1580	0.0585	551.4	2.1540	150
155	0.0669	557.1	2.1785	0.0641	557.0	2.1743	0.0616	556.8	2.1702	0.0592	556.6	2.1662	155
160	0.0678	562.4	2.1906	0.0650	562.2	2.1864	0.0624	562.0	2.1823	0.0600	561.8	2.1784	160
165	—	—	—	—	—	—	0.0632	567.3	2.1944	0.0608	567.1	2.1905	165

TEMP. °C	700.0 (13.20°C) V	H	S	730.0 (14.30°C) V	H	S	750.0 (15.40°C) V	H	S	800.0 (17.50°C) V	H	S	TEMP. °C
	(0.0343)	(420.9)	(1.7802)	(0.0331)	(421.4)	(1.7792)	(0.0320)	(422.0)	(1.7782)	(0.0300)	(423.0)	(1.7763)	
15	0.0347	422.5	1.7858	0.0333	422.1	1.7814	—	—	—	—	—	—	15
20	0.0356	426.9	1.8010	0.0341	426.5	1.7966	0.0328	426.1	1.7924	0.0304	425.2	1.7841	20
25	0.0364	431.3	1.8159	0.0350	430.9	1.8116	0.0337	430.5	1.8074	0.0312	429.7	1.7993	25
30	0.0373	435.7	1.8307	0.0358	435.4	1.8264	0.0345	435.0	1.8223	0.0320	434.2	1.8143	30
35	0.0381	440.2	1.8453	0.0367	439.8	1.8411	0.0353	439.5	1.8370	0.0328	438.8	1.8291	35
40	0.0390	444.7	1.8597	0.0375	444.4	1.8556	0.0361	444.0	1.8515	0.0336	443.3	1.8437	40
45	0.0398	449.2	1.8740	0.0383	448.9	1.8699	0.0369	448.5	1.8659	0.0343	447.9	1.8582	45
50	0.0407	453.8	1.8882	0.0391	453.4	1.8841	0.0377	453.1	1.8802	0.0351	452.5	1.8725	50
55	0.0415	458.3	1.9023	0.0399	458.0	1.8982	0.0385	457.7	1.8943	0.0358	457.1	1.8867	55
60	0.0423	462.9	1.9162	0.0407	462.6	1.9122	0.0392	462.3	1.9083	0.0365	461.7	1.9008	60
65	0.0431	467.6	1.9300	0.0415	467.3	1.9260	0.0400	467.0	1.9221	0.0373	466.4	1.9147	65
70	0.0439	472.2	1.9437	0.0423	472.0	1.9397	0.0408	471.7	1.9359	0.0380	471.1	1.9285	70
75	0.0447	476.9	1.9573	0.0431	476.7	1.9533	0.0415	476.4	1.9495	0.0387	475.8	1.9422	75
80	0.0455	481.7	1.9708	0.0438	481.4	1.9669	0.0423	481.1	1.9631	0.0394	480.6	1.9558	80
85	0.0463	486.4	1.9841	0.0446	486.2	1.9803	0.0430	485.9	1.9765	0.0401	485.4	1.9692	85
90	0.0471	491.2	1.9974	0.0454	491.0	1.9936	0.0438	490.7	1.9898	0.0408	490.2	1.9826	90
95	0.0479	496.0	2.0106	0.0461	495.8	2.0068	0.0445	495.5	2.0030	0.0415	495.1	1.9959	95
100	0.0487	500.9	2.0237	0.0469	500.7	2.0199	0.0452	500.4	2.0162	0.0422	499.9	2.0090	100
105	0.0494	505.8	2.0367	0.0476	505.5	2.0329	0.0460	505.3	2.0292	0.0429	504.9	2.0221	105
110	0.0502	510.7	2.0497	0.0484	510.5	2.0459	0.0467	510.2	2.0422	0.0436	509.8	2.0351	110
115	0.0510	515.6	2.0625	0.0491	515.4	2.0587	0.0474	515.2	2.0550	0.0443	514.8	2.0480	115
120	0.0518	520.6	2.0753	0.0499	520.4	2.0715	0.0481	520.2	2.0678	0.0450	519.8	2.0608	120
125	0.0525	525.6	2.0879	0.0506	525.4	2.0842	0.0489	525.2	2.0805	0.0457	524.8	2.0736	125
130	0.0533	530.7	2.1005	0.0514	530.5	2.0968	0.0496	530.3	2.0932	0.0463	529.9	2.0862	130
135	0.0540	535.8	2.1131	0.0521	535.6	2.1093	0.0503	535.4	2.1057	0.0470	535.0	2.0988	135
140	0.0548	540.9	2.1255	0.0528	540.7	2.1218	0.0510	540.5	2.1182	0.0477	540.1	2.1113	140
145	0.0556	546.0	2.1379	0.0536	545.8	2.1342	0.0517	545.7	2.1306	0.0484	545.3	2.1237	145
150	0.0563	551.2	2.1502	0.0543	551.0	2.1465	0.0524	550.8	2.1429	0.0490	550.5	2.1360	150
155	0.0571	556.4	2.1624	0.0550	556.2	2.1587	0.0531	556.1	2.1552	0.0497	555.7	2.1483	155
160	0.0578	561.7	2.1746	0.0557	561.5	2.1709	0.0538	561.3	2.1673	0.0503	561.0	2.1605	160
165	0.0586	566.9	2.1867	0.0565	566.8	2.1830	0.0545	566.6	2.1795	0.0510	566.2	2.1727	165
170	—	—	—	—	—	—	0.0552	571.9	2.1915	0.0517	571.6	2.1847	170

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

TEMP. °C	400.0 (-3.50°C)			430.0 (-1.80°C)			450.0 (-0.10°C)			480.0 (1.40°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0595)	(412.0)	(1.7964)	(0.0561)	(412.9)	(1.7946)	(0.0531)	(413.8)	(1.7930)	(0.0504)	(414.7)	(1.7914)	
0	0.0605	414.8	1.8068	0.0566	414.4	1.7999	0.0531	413.9	1.7933	0.0000	0.0	0.0000	0
5	0.0619	418.9	1.8217	0.0579	418.5	1.8149	0.0544	418.1	1.8084	0.0512	417.7	1.8022	5
10	0.0633	423.1	1.8365	0.0592	422.7	1.8297	0.0557	422.3	1.8233	0.0524	421.9	1.8171	10
15	0.0647	427.2	1.8512	0.0606	426.9	1.8444	0.0569	426.5	1.8380	0.0536	426.1	1.8319	15
20	0.0660	431.5	1.8657	0.0619	431.1	1.8590	0.0582	430.7	1.8526	0.0548	430.4	1.8466	20
25	0.0674	435.7	1.8801	0.0632	435.4	1.8734	0.0594	435.0	1.8671	0.0560	434.6	1.8611	25
30	0.0688	440.0	1.8943	0.0645	439.7	1.8877	0.0606	439.3	1.8814	0.0572	439.0	1.8754	30
35	0.0701	444.3	1.9084	0.0657	444.0	1.9019	0.0619	443.7	1.8956	0.0584	443.3	1.8897	35
40	0.0715	448.7	1.9225	0.0670	448.3	1.9159	0.0631	448.0	1.9097	0.0595	447.7	1.9038	40
45	0.0728	453.1	1.9364	0.0683	452.7	1.9298	0.0643	452.4	1.9237	0.0607	452.1	1.9178	45
50	0.0742	457.5	1.9502	0.0696	457.2	1.9437	0.0655	456.9	1.9375	0.0618	456.6	1.9317	50
55	0.0755	461.9	1.9638	0.0708	461.6	1.9574	0.0667	461.4	1.9513	0.0630	461.1	1.9454	55
60	0.0768	466.4	1.9774	0.0721	466.1	1.9710	0.0679	465.9	1.9649	0.0641	465.6	1.9591	60
65	0.0781	471.0	1.9909	0.0733	470.7	1.9845	0.0691	470.4	1.9785	0.0652	470.1	1.9727	65
70	0.0794	475.5	2.0044	0.0746	475.3	1.9980	0.0702	475.0	1.9919	0.0664	474.7	1.9861	70
75	0.0808	480.1	2.0177	0.0758	479.9	2.0113	0.0714	479.6	2.0053	0.0675	479.3	1.9995	75
80	0.0821	484.8	2.0309	0.0770	484.5	2.0245	0.0726	484.3	2.0185	0.0686	484.0	2.0128	80
85	0.0834	489.4	2.0440	0.0783	489.2	2.0377	0.0738	488.9	2.0317	0.0697	488.7	2.0260	85
90	0.0847	494.2	2.0571	0.0795	493.9	2.0508	0.0749	493.7	2.0448	0.0708	493.4	2.0391	90
95	0.0860	498.9	2.0701	0.0807	498.7	2.0638	0.0761	498.4	2.0578	0.0719	498.2	2.0521	95
100	0.0873	503.7	2.0830	0.0820	503.5	2.0767	0.0773	503.2	2.0707	0.0730	503.0	2.0651	100
105	0.0885	508.5	2.0958	0.0832	508.3	2.0895	0.0784	508.0	2.0836	0.0741	507.8	2.0780	105
110	0.0898	513.3	2.1085	0.0844	513.1	2.1023	0.0796	512.9	2.0964	0.0752	512.7	2.0907	110
115	0.0911	518.2	2.1212	0.0856	518.0	2.1150	0.0807	517.8	2.1091	0.0763	517.6	2.1035	115
120	0.0924	523.2	2.1338	0.0868	522.9	2.1276	0.0819	522.7	2.1217	0.0774	522.5	2.1161	120
125	0.0937	528.1	2.1463	0.0880	527.9	2.1401	0.0830	527.7	2.1342	0.0785	527.5	2.1287	125
130	0.0950	533.1	2.1588	0.0892	532.9	2.1526	0.0842	532.7	2.1467	0.0796	532.5	2.1411	130
135	0.0962	538.1	2.1712	0.0904	537.9	2.1650	0.0853	537.7	2.1591	0.0807	537.5	2.1536	135
140	0.0975	543.2	2.1835	0.0916	543.0	2.1773	0.0864	542.8	2.1715	0.0818	542.6	2.1659	140
145	0.0988	548.3	2.1957	0.0928	548.1	2.1896	0.0876	547.9	2.1837	0.0828	547.7	2.1782	145
150	0.1000	553.4	2.2079	0.0940	553.2	2.2018	0.0887	553.0	2.1959	0.0839	552.9	2.1904	150
155	—	—	—	—	—	—	—	—	—	0.0850	558.0	2.2026	155

TEMP. °C	500.0 (2.90°C)			530.0 (4.40°C)			550.0 (5.70°C)			580.0 (7.10°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0479)	(415.5)	(1.7899)	(0.0457)	(416.3)	(1.7885)	(0.0436)	(417.0)	(1.7872)	(0.0417)	(417.8)	(1.7859)	
5	0.0484	417.3	1.7962	0.0458	416.8	1.7905	—	—	—	—	—	—	5
10	0.0495	421.5	1.8112	0.0469	421.1	1.8055	0.0445	420.7	1.8000	0.0424	420.3	1.7947	10
15	0.0507	425.7	1.8260	0.0480	425.3	1.8204	0.0456	424.9	1.8150	0.0434	424.5	1.8098	15
20	0.0518	430.0	1.8407	0.0491	429.6	1.8352	0.0467	429.2	1.8298	0.0444	428.9	1.8246	20
25	0.0530	434.3	1.8553	0.0502	433.9	1.8497	0.0477	433.6	1.8444	0.0454	433.2	1.8393	25
30	0.0541	438.6	1.8697	0.0513	438.3	1.8642	0.0488	437.9	1.8589	0.0464	437.6	1.8538	30
35	0.0552	443.0	1.8840	0.0524	442.6	1.8785	0.0498	442.3	1.8733	0.0474	442.0	1.8682	35
40	0.0563	447.4	1.8981	0.0534	447.0	1.8927	0.0508	446.7	1.8875	0.0484	446.4	1.8825	40
45	0.0574	451.8	1.9121	0.0545	451.5	1.9067	0.0518	451.2	1.9016	0.0494	450.8	1.8966	45
50	0.0585	456.3	1.9261	0.0556	456.0	1.9207	0.0529	455.7	1.9155	0.0504	455.3	1.9106	50
55	0.0596	460.8	1.9399	0.0566	460.5	1.9345	0.0539	460.2	1.9294	0.0514	459.9	1.9245	55
60	0.0607	465.3	1.9536	0.0577	465.0	1.9483	0.0549	464.7	1.9432	0.0523	464.4	1.9383	60
65	0.0618	469.9	1.9672	0.0587	469.6	1.9619	0.0559	469.3	1.9568	0.0533	469.0	1.9519	65
70	0.0629	474.5	1.9806	0.0597	474.2	1.9754	0.0568	473.9	1.9704	0.0542	473.6	1.9655	70
75	0.0639	479.1	1.9941	0.0607	478.8	1.9888	0.0578	478.6	1.9838	0.0552	478.3	1.9790	75
80	0.0650	483.8	2.0074	0.0618	483.5	2.0021	0.0588	483.2	1.9971	0.0561	483.0	1.9923	80
85	0.0661	488.5	2.0206	0.0628	488.2	2.0154	0.0598	487.9	2.0104	0.0571	487.7	2.0056	85
90	0.0671	493.2	2.0337	0.0638	492.9	2.0285	0.0608	492.7	2.0236	0.0580	492.5	2.0188	90
95	0.0682	498.0	2.0468	0.0648	497.7	2.0416	0.0617	497.5	2.0366	0.0589	497.2	2.0319	95
100	0.0693	502.8	2.0597	0.0658	502.5	2.0546	0.0627	502.3	2.0496	0.0599	502.1	2.0449	100
105	0.0703	507.6	2.0726	0.0668	507.4	2.0675	0.0637	507.1	2.0626	0.0608	506.9	2.0578	105
110	0.0713	512.5	2.0854	0.0678	512.3	2.0803	0.0646	512.0	2.0754	0.0617	511.8	2.0707	110
115	0.0724	517.4	2.0981	0.0688	517.2	2.0930	0.0656	516.9	2.0881	0.0626	516.7	2.0835	115
120	0.0734	522.3	2.1108	0.0698	522.1	2.1057	0.0665	521.9	2.1008	0.0635	521.7	2.0961	120
125	0.0745	527.3	2.1233	0.0708	527.1	2.1183	0.0675	526.9	2.1134	0.0645	526.7	2.1088	125
130	0.0755	532.3	2.1358	0.0718	532.1	2.1308	0.0684	531.9	2.1259	0.0654	531.7	2.1213	130
135	0.0765	537.3	2.1483	0.0728	537.2	2.1432	0.0694	537.0	2.1384	0.0663	536.8	2.1338	135
140	0.0776	542.4	2.1606	0.0738	542.2	2.1556	0.0703	542.0	2.1508	0.0672	541.9	2.1462	140
145	0.0786	547.5	2.1729	0.0748	547.3	2.1679	0.0713	547.2	2.1631	0.0681	547.0	2.1585	145
150	0.0796	552.7	2.1851	0.0757	552.5	2.1801	0.0722	552.3	2.1753	0.0690	552.1	2.1707	150
155	0.0807	557.8	2.1973	0.0767	557.7	2.1923	0.0731	557.5	2.1875	0.0699	557.3	2.1829	155
160	—	—	—	—	—	—	0.0741	562.7	2.1996	0.0708	562.5	2.1950	160

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

P.	320.0 (-9.50°C)			330.0 (-8.70°C)			340.0 (-7.90°C)			350.0 (-7.10°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0738)	(408.5)	(1.8031)	(0.0716)	(408.9)	(1.8021)	(0.0696)	(409.4)	(1.8012)	(0.0677)	(409.9)	(1.8004)	
-5	0.0753	412.1	1.8166	0.0728	411.9	1.8132	0.0705	411.7	1.8099	0.0683	411.6	1.8067	-5
0	0.0770	416.1	1.8316	0.0745	415.9	1.8282	0.0722	415.8	1.8249	0.0699	415.6	1.8217	0
5	0.0787	420.2	1.8463	0.0762	420.0	1.8430	0.0738	419.9	1.8397	0.0715	419.7	1.8365	5
10	0.0804	424.3	1.8610	0.0778	424.1	1.8576	0.0754	424.0	1.8544	0.0731	423.8	1.8512	10
15	0.0821	428.4	1.8755	0.0794	428.3	1.8722	0.0770	428.1	1.8689	0.0746	428.0	1.8658	15
20	0.0838	432.6	1.8898	0.0811	432.5	1.8865	0.0786	432.3	1.8833	0.0762	432.2	1.8802	20
25	0.0854	436.8	1.9041	0.0827	436.7	1.9008	0.0801	436.5	1.8976	0.0777	436.4	1.8945	25
30	0.0871	441.1	1.9182	0.0843	440.9	1.9150	0.0817	440.8	1.9118	0.0792	440.7	1.9087	30
35	0.0887	445.4	1.9323	0.0859	445.2	1.9290	0.0833	445.1	1.9258	0.0808	445.0	1.9228	35
40	0.0904	449.7	1.9462	0.0875	449.5	1.9429	0.0848	449.4	1.9398	0.0823	449.3	1.9367	40
45	0.0920	454.0	1.9600	0.0891	453.9	1.9568	0.0864	453.8	1.9536	0.0838	453.7	1.9506	45
50	0.0937	458.4	1.9737	0.0907	458.3	1.9705	0.0879	458.2	1.9673	0.0853	458.1	1.9643	50
55	0.0953	462.9	1.9873	0.0923	462.7	1.9841	0.0895	462.6	1.9810	0.0868	462.5	1.9779	55
60	0.0969	467.3	2.0008	0.0939	467.2	1.9976	0.0910	467.1	1.9945	0.0883	467.0	1.9915	60
65	0.0985	471.8	2.0142	0.0954	471.7	2.0111	0.0925	471.6	2.0080	0.0898	471.5	2.0049	65
70	0.1001	476.4	2.0276	0.0970	476.3	2.0244	0.0941	476.2	2.0213	0.0913	476.1	2.0183	70
75	0.1018	481.0	2.0408	0.0986	480.9	2.0377	0.0956	480.8	2.0346	0.0928	480.7	2.0316	75
80	0.1034	485.6	2.0540	0.1001	485.5	2.0508	0.0971	485.4	2.0478	0.0942	485.3	2.0448	80
85	0.1050	490.2	2.0671	0.1017	490.1	2.0639	0.0986	490.0	2.0609	0.0957	489.9	2.0579	85
90	0.1066	494.9	2.0801	0.1032	494.8	2.0769	0.1001	494.7	2.0739	0.0972	494.6	2.0709	90
95	0.1082	499.6	2.0930	0.1048	499.6	2.0899	0.1016	499.5	2.0868	0.0986	499.4	2.0838	95
.00	0.1098	504.4	2.1059	0.1063	504.3	2.1027	0.1031	504.2	2.0997	0.1001	504.1	2.0967	100
105	0.1113	509.2	2.1186	0.1079	509.1	2.1155	0.1046	509.0	2.1125	0.1016	508.9	2.1095	105
110	0.1129	514.0	2.1313	0.1094	514.0	2.1282	0.1061	513.9	2.1252	0.1030	513.8	2.1222	110
115	0.1145	518.9	2.1440	0.1110	518.8	2.1408	0.1076	518.7	2.1378	0.1045	518.7	2.1349	115
120	0.1161	523.8	2.1565	0.1125	523.7	2.1534	0.1091	523.6	2.1504	0.1059	523.6	2.1474	120
125	0.1177	528.8	2.1690	0.1140	528.7	2.1659	0.1106	528.6	2.1629	0.1074	528.5	2.1599	125
130	0.1193	533.7	2.1814	0.1156	533.6	2.1783	0.1121	533.6	2.1753	0.1088	533.5	2.1724	130
135	0.1208	538.7	2.1938	0.1171	538.7	2.1907	0.1136	538.6	2.1876	0.1103	538.5	2.1847	135
140	0.1224	543.8	2.2060	0.1186	543.7	2.2029	0.1151	543.6	2.1999	0.1117	543.6	2.1970	140
145	0.1240	548.9	2.2183	0.1202	548.8	2.2152	0.1166	548.7	2.2122	0.1132	548.6	2.2092	145

MP.	360.0 (-6.30°C)			370.0 (-5.60°C)			380.0 (-4.90°C)			390.0 (-4.20°C)			TEMP. °C
	V	H	S	V	H	S	V	H	S	V	H	S	
	(0.0659)	(410.3)	(1.7995)	(0.0642)	(410.7)	(1.7987)	(0.0625)	(411.2)	(1.7979)	(0.0610)	(411.6)	(1.7971)	
-5	0.0663	411.4	1.8036	0.0643	411.2	1.8005	—	—	—	—	—	—	-5
0	0.0678	415.4	1.8186	0.0658	415.3	1.8155	0.0640	415.1	1.8126	0.0622	415.0	1.8096	0
5	0.0694	419.5	1.8334	0.0673	419.4	1.8304	0.0654	419.2	1.8275	0.0636	419.1	1.8246	5
10	0.0709	423.7	1.8482	0.0688	423.5	1.8452	0.0669	423.4	1.8422	0.0650	423.2	1.8393	10
15	0.0724	427.8	1.8627	0.0703	427.7	1.8597	0.0683	427.5	1.8568	0.0665	427.4	1.8540	15
20	0.0739	432.0	1.8772	0.0718	431.9	1.8742	0.0698	431.7	1.8713	0.0679	431.6	1.8685	20
25	0.0754	436.3	1.8915	0.0733	436.1	1.8885	0.0712	436.0	1.8856	0.0693	435.8	1.8828	25
30	0.0769	440.5	1.9057	0.0747	440.4	1.9027	0.0726	440.3	1.8999	0.0707	440.1	1.8971	30
35	0.0784	444.8	1.9198	0.0762	444.7	1.9168	0.0740	444.6	1.9140	0.0720	444.4	1.9112	35
40	0.0799	449.2	1.9337	0.0776	449.0	1.9308	0.0755	448.9	1.9280	0.0734	448.8	1.9252	40
45	0.0814	453.5	1.9476	0.0790	453.4	1.9447	0.0769	453.3	1.9418	0.0748	453.2	1.9391	45
50	0.0828	458.0	1.9613	0.0805	457.8	1.9584	0.0783	457.7	1.9556	0.0762	457.6	1.9528	50
55	0.0843	462.4	1.9750	0.0819	462.3	1.9721	0.0797	462.2	1.9693	0.0775	462.1	1.9665	55
60	0.0857	466.9	1.9885	0.0833	466.8	1.9857	0.0810	466.7	1.9829	0.0789	466.5	1.9801	60
65	0.0872	471.4	2.0020	0.0847	471.3	1.9991	0.0824	471.2	1.9963	0.0802	471.1	1.9936	65
70	0.0886	476.0	2.0154	0.0862	475.9	2.0125	0.0838	475.7	2.0097	0.0816	475.6	2.0070	70
75	0.0901	480.5	2.0287	0.0876	480.4	2.0258	0.0852	480.3	2.0230	0.0829	480.2	2.0203	75
80	0.0915	485.2	2.0418	0.0890	485.1	2.0390	0.0865	485.0	2.0362	0.0842	484.9	2.0335	80
85	0.0930	489.8	2.0550	0.0904	489.7	2.0521	0.0879	489.6	2.0494	0.0856	489.5	2.0467	85
90	0.0944	494.5	2.0680	0.0918	494.4	2.0652	0.0893	494.3	2.0624	0.0869	494.3	2.0597	90
95	0.0958	499.3	2.0809	0.0932	499.2	2.0781	0.0906	499.1	2.0754	0.0882	499.0	2.0727	95
100	0.0973	504.0	2.0938	0.0946	504.0	2.0910	0.0920	503.9	2.0883	0.0896	503.8	2.0856	100
105	0.0987	508.9	2.1066	0.0959	508.8	2.1038	0.0933	508.7	2.1011	0.0909	508.6	2.0984	105
110	0.1001	513.7	2.1193	0.0973	513.6	2.1165	0.0947	513.5	2.1138	0.0922	513.4	2.1111	110
115	0.1015	518.6	2.1320	0.0987	518.5	2.1292	0.0960	518.4	2.1265	0.0935	518.3	2.1239	115
120	0.1029	523.5	2.1446	0.1001	523.4	2.1418	0.0974	523.3	2.1390	0.0948	523.2	2.1364	120
125	0.1043	528.4	2.1571	0.1015	528.4	2.1543	0.0987	528.3	2.1516	0.0961	528.2	2.1489	125
130	0.1058	533.4	2.1695	0.1028	533.3	2.1667	0.1001	533.3	2.1640	0.0974	533.2	2.1614	130
135	0.1072	538.4	2.1819	0.1042	538.4	2.1791	0.1014	538.3	2.1764	0.0988	538.2	2.1737	135
140	0.1086	543.5	2.1942	0.1056	543.4	2.1914	0.1027	543.3	2.1887	0.1001	543.3	2.1860	140
145	0.1100	548.6	2.2064	0.1069	548.5	2.2036	0.1041	548.4	2.2009	0.1014	548.3	2.1983	145
150	—	—	—	—	—	—	0.1054	553.5	2.2131	0.1027	553.5	2.2105	150

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

TEMP. °C	240.0 (-16.90°C) V	H	S	250.0 (-15.90°C) V	H	S	260.0 (-14.90°C) V	H	S	270.0 (-13.90°C) V	H	S	TEMP. °C
	(0.0970)	(404.0)	(1.8121)	(0.0934)	(404.7)	(1.8108)	(0.0899)	(405.3)	(1.8095)	(0.0868)	(405.8)	(1.8083)	
-15	0.0979	405.5	1.8177	0.0937	405.3	1.8133	—	—	—	—	—	—	-15
-10	0.1001	409.4	1.8328	0.0959	409.3	1.8284	0.0920	409.1	1.8242	0.0883	408.9	1.8201	-10
-5	0.1023	413.4	1.8476	0.0980	413.2	1.8433	0.0940	413.1	1.8391	0.0903	412.9	1.8351	-5
0	0.1045	417.4	1.8624	0.1001	417.2	1.8581	0.0961	417.1	1.8539	0.0923	416.9	1.8499	0
5	0.1067	421.4	1.8770	0.1022	421.2	1.8727	0.0981	421.1	1.8686	0.0943	420.9	1.8646	5
10	0.1089	425.5	1.8915	0.1043	425.3	1.8872	0.1001	425.2	1.8831	0.0962	425.0	1.8791	10
15	0.1111	429.6	1.9059	0.1064	429.4	1.9016	0.1022	429.3	1.8975	0.0982	429.1	1.8935	15
20	0.1133	433.7	1.9201	0.1085	433.6	1.9159	0.1042	433.4	1.9118	0.1002	433.3	1.9078	20
25	0.1154	437.9	1.9343	0.1106	437.8	1.9300	0.1062	437.6	1.9260	0.1021	437.5	1.9220	25
30	0.1176	442.1	1.9483	0.1127	442.0	1.9441	0.1082	441.9	1.9400	0.1040	441.7	1.9361	30
35	0.1197	446.4	1.9622	0.1148	446.2	1.9580	0.1102	446.1	1.9540	0.1060	446.0	1.9500	35
40	0.1219	450.7	1.9761	0.1168	450.5	1.9719	0.1122	450.4	1.9678	0.1079	450.3	1.9639	40
45	0.1240	455.0	1.9898	0.1189	454.9	1.9856	0.1142	454.8	1.9815	0.1098	454.6	1.9777	45
50	0.1261	459.4	2.0034	0.1209	459.2	1.9992	0.1161	459.1	1.9952	0.1117	459.0	1.9913	50
55	0.1283	463.8	2.0169	0.1230	463.7	2.0128	0.1181	463.5	2.0088	0.1136	463.4	2.0049	55
60	0.1304	468.2	2.0304	0.1250	468.1	2.0262	0.1201	468.0	2.0222	0.1155	467.9	2.0183	60
65	0.1325	472.7	2.0437	0.1271	472.6	2.0396	0.1221	472.5	2.0356	0.1174	472.4	2.0317	65
70	0.1346	477.2	2.0570	0.1291	477.1	2.0529	0.1240	477.0	2.0489	0.1193	476.9	2.0450	70
75	0.1367	481.8	2.0702	0.1311	481.7	2.0661	0.1260	481.6	2.0621	0.1212	481.5	2.0582	75
80	0.1389	486.4	2.0833	0.1332	486.3	2.0792	0.1279	486.2	2.0752	0.1231	486.1	2.0714	80
85	0.1410	491.0	2.0963	0.1352	490.9	2.0922	0.1299	490.8	2.0882	0.1250	490.7	2.0844	85
90	0.1431	495.7	2.1093	0.1372	495.6	2.1052	0.1318	495.5	2.1012	0.1268	495.4	2.0974	90
95	0.1452	500.4	2.1222	0.1392	500.3	2.1180	0.1338	500.2	2.1141	0.1287	500.1	2.1103	95
100	0.1473	505.1	2.1350	0.1413	505.0	2.1309	0.1357	505.0	2.1269	0.1306	504.9	2.1231	100
105	0.1493	509.9	2.1477	0.1433	509.8	2.1436	0.1377	509.7	2.1396	0.1325	509.6	2.1358	105
110	0.1514	514.7	2.1603	0.1453	514.6	2.1562	0.1396	514.6	2.1523	0.1343	514.5	2.1485	110
115	0.1535	519.6	2.1729	0.1473	519.5	2.1688	0.1415	519.4	2.1649	0.1362	519.3	2.1611	115
120	0.1556	524.5	2.1854	0.1493	524.4	2.1814	0.1434	524.3	2.1774	0.1380	524.2	2.1736	120
125	0.1577	529.4	2.1979	0.1513	529.3	2.1938	0.1454	529.2	2.1899	0.1399	529.2	2.1861	125
130	0.1598	534.4	2.2103	0.1533	534.3	2.2062	0.1473	534.2	2.2023	0.1418	534.1	2.1985	130
135	0.1618	539.4	2.2226	0.1553	539.3	2.2185	0.1492	539.2	2.2146	0.1436	539.1	2.2108	135
140	—	—	—	—	—	—	0.1511	544.2	2.2269	0.1455	544.2	2.2231	140

TEMP. °C	280.0 (-13.00°C) V	H	S	290.0 (-12.10°C) V	H	S	300.0 (-11.20°C) V	H	S	310.0 (-10.30°C) V	H	S	TEMP. °C
	(0.0838)	(406.4)	(1.8072)	(0.0810)	(406.9)	(1.8061)	(0.0785)	(407.5)	(1.8051)	(0.0760)	(408.0)	(1.8041)	
-10	0.0850	408.7	1.8162	0.0818	408.6	1.8124	0.0789	408.4	1.8087	0.0762	408.2	1.8051	-10
-5	0.0869	412.7	1.8312	0.0837	412.6	1.8274	0.0807	412.4	1.8237	0.0779	412.2	1.8201	-5
0	0.0888	416.7	1.8460	0.0856	416.6	1.8422	0.0825	416.4	1.8386	0.0797	416.3	1.8350	0
5	0.0907	420.8	1.8607	0.0874	420.6	1.8569	0.0843	420.5	1.8533	0.0814	420.3	1.8498	5
10	0.0926	424.9	1.8753	0.0893	424.7	1.8715	0.0861	424.6	1.8679	0.0832	424.4	1.8644	10
15	0.0945	429.0	1.8897	0.0911	428.9	1.8860	0.0879	428.7	1.8824	0.0849	428.6	1.8789	15
20	0.0964	433.2	1.9040	0.0929	433.0	1.9003	0.0897	432.9	1.8967	0.0866	432.7	1.8932	20
25	0.0983	437.4	1.9182	0.0947	437.2	1.9145	0.0914	437.1	1.9109	0.0883	437.0	1.9075	25
30	0.1002	441.6	1.9323	0.0965	441.5	1.9286	0.0932	441.3	1.9250	0.0900	441.2	1.9216	30
35	0.1020	445.9	1.9463	0.0984	445.7	1.9426	0.0949	445.6	1.9390	0.0917	445.5	1.9356	35
40	0.1039	450.2	1.9601	0.1002	450.0	1.9565	0.0967	449.9	1.9529	0.0934	449.8	1.9495	40
45	0.1057	454.5	1.9739	0.1020	454.4	1.9702	0.0984	454.3	1.9667	0.0951	454.2	1.9633	45
50	0.1076	458.9	1.9876	0.1037	458.8	1.9839	0.1002	458.7	1.9804	0.0968	458.5	1.9770	50
55	0.1094	463.3	2.0011	0.1055	463.2	1.9975	0.1019	463.1	1.9940	0.0985	463.0	1.9906	55
60	0.1113	467.8	2.0146	0.1073	467.7	2.0110	0.1036	467.6	2.0075	0.1001	467.4	2.0041	60
65	0.1131	472.3	2.0280	0.1091	472.2	2.0244	0.1053	472.1	2.0209	0.1018	471.9	2.0175	65
70	0.1149	476.8	2.0413	0.1108	476.7	2.0377	0.1070	476.6	2.0342	0.1035	476.5	2.0309	70
75	0.1168	481.4	2.0545	0.1126	481.3	2.0509	0.1088	481.2	2.0475	0.1051	481.1	2.0441	75
80	0.1186	486.0	2.0677	0.1144	485.9	2.0641	0.1105	485.8	2.0606	0.1068	485.7	2.0573	80
85	0.1204	490.6	2.0807	0.1161	490.5	2.0771	0.1122	490.4	2.0737	0.1084	490.3	2.0703	85
90	0.1222	495.3	2.0937	0.1179	495.2	2.0901	0.1139	495.1	2.0867	0.1101	495.0	2.0833	90
95	0.1240	500.0	2.1066	0.1196	499.9	2.1030	0.1156	499.8	2.0996	0.1117	499.7	2.0962	95
100	0.1258	504.8	2.1194	0.1214	504.7	2.1159	0.1173	504.6	2.1124	0.1134	504.5	2.1091	100
105	0.1276	509.6	2.1322	0.1231	509.5	2.1286	0.1189	509.4	2.1252	0.1150	509.3	2.1219	105
110	0.1294	514.4	2.1448	0.1249	514.3	2.1413	0.1206	514.2	2.1379	0.1167	514.1	2.1345	110
115	0.1312	519.2	2.1574	0.1266	519.2	2.1539	0.1223	519.1	2.1505	0.1183	519.0	2.1472	115
120	0.1330	524.1	2.1700	0.1284	524.1	2.1664	0.1240	524.0	2.1630	0.1199	523.9	2.1597	120
125	0.1348	529.1	2.1824	0.1301	529.0	2.1789	0.1257	528.9	2.1755	0.1216	528.8	2.1722	125
130	0.1366	534.0	2.1948	0.1318	534.0	2.1913	0.1274	533.9	2.1879	0.1232	533.8	2.1846	130
135	0.1384	539.0	2.2072	0.1336	539.0	2.2037	0.1290	538.9	2.2003	0.1248	538.8	2.1970	135
140	0.1402	544.1	2.2194	0.1353	544.0	2.2159	0.1307	543.9	2.2125	0.1264	543.9	2.2092	140

Table (D.2) Continued

ABSOLUTE PRESSURE, kPa

MP. °C	160.0 (-26.50°C) V (0.1424)	H (398.1)	S (1.8255)	170.0 (-25.10°C) V (0.1345)	H (399.0)	S (1.8234)	180.0 (-23.80°C) V (0.1274)	H (399.8)	S (1.8215)	190.0 (-22.50°C) V (0.1211)	H (400.6)	S (1.8197)	TEMP. °C
25	0.1434	399.2	1.8301	0.1346	399.0	1.8238	—	—	—	—	—	—	-25
20	0.1466	403.0	1.8453	0.1376	402.9	1.8390	0.1296	402.7	1.8330	0.1225	402.5	1.8274	-20
-15	0.1498	406.9	1.8603	0.1407	406.7	1.8540	0.1325	406.5	1.8481	0.1252	406.4	1.8424	-15
-10	0.1531	410.7	1.8752	0.1437	410.6	1.8689	0.1354	410.4	1.8630	0.1280	410.2	1.8574	-10
-5	0.1563	414.7	1.8899	0.1468	414.5	1.8837	0.1383	414.3	1.8778	0.1307	414.2	1.8722	-5
0	0.1595	418.6	1.9045	0.1498	418.5	1.8983	0.1412	418.3	1.8924	0.1335	418.1	1.8868	0
5	0.1627	422.6	1.9190	0.1528	422.4	1.9128	0.1440	422.3	1.9069	0.1362	422.2	1.9013	5
10	0.1659	426.6	1.9333	0.1558	426.5	1.9272	0.1469	426.3	1.9213	0.1389	426.2	1.9158	10
15	0.1690	430.7	1.9476	0.1588	430.6	1.9414	0.1497	430.4	1.9356	0.1416	430.3	1.9301	15
20	0.1722	434.8	1.9617	0.1618	434.7	1.9556	0.1526	434.5	1.9498	0.1443	434.4	1.9442	20
25	0.1754	439.0	1.9758	0.1648	438.8	1.9696	0.1554	438.7	1.9638	0.1470	438.6	1.9583	25
30	0.1785	443.1	1.9897	0.1678	443.0	1.9836	0.1582	442.9	1.9778	0.1497	442.8	1.9723	30
35	0.1817	447.4	2.0035	0.1707	447.2	1.9974	0.1610	447.1	1.9916	0.1523	447.0	1.9861	35
40	0.1848	451.6	2.0173	0.1737	451.5	2.0111	0.1638	451.4	2.0054	0.1550	451.3	1.9999	40
45	0.1880	455.9	2.0309	0.1767	455.8	2.0248	0.1666	455.7	2.0190	0.1577	455.6	2.0136	45
50	0.1911	460.3	2.0444	0.1796	460.2	2.0384	0.1694	460.1	2.0326	0.1603	459.9	2.0271	50
55	0.1942	464.7	2.0579	0.1826	464.6	2.0518	0.1722	464.4	2.0461	0.1630	464.3	2.0406	55
60	0.1974	469.1	2.0713	0.1855	469.0	2.0652	0.1750	468.9	2.0595	0.1656	468.8	2.0540	60
65	0.2005	473.6	2.0846	0.1885	473.4	2.0785	0.1778	473.3	2.0728	0.1683	473.2	2.0674	65
70	0.2036	478.1	2.0978	0.1914	477.9	2.0917	0.1806	477.8	2.0860	0.1709	477.7	2.0806	70
75	0.2067	482.6	2.1109	0.1944	482.5	2.1049	0.1834	482.4	2.0991	0.1736	482.3	2.0937	75
80	0.2098	487.2	2.1240	0.1973	487.1	2.1179	0.1862	487.0	2.1122	0.1762	486.9	2.1068	80
85	0.2129	491.8	2.1369	0.2002	491.7	2.1309	0.1889	491.6	2.1252	0.1788	491.5	2.1198	85
90	0.2160	496.4	2.1498	0.2032	496.3	2.1438	0.1917	496.2	2.1381	0.1815	496.2	2.1327	90
95	0.2191	501.1	2.1627	0.2061	501.0	2.1566	0.1945	500.9	2.1509	0.1841	500.8	2.1456	95
100	0.2222	505.8	2.1754	0.2090	505.8	2.1694	0.1972	505.7	2.1637	0.1867	505.6	2.1583	100
105	0.2253	510.6	2.1881	0.2119	510.5	2.1821	0.2000	510.4	2.1764	0.1893	510.3	2.1710	105
110	0.2284	515.4	2.2007	0.2148	515.3	2.1947	0.2028	515.2	2.1890	0.1920	515.2	2.1837	110
115	0.2315	520.2	2.2132	0.2178	520.2	2.2072	0.2055	520.1	2.2016	0.1946	520.0	2.1962	115
120	0.2346	525.1	2.2257	0.2207	525.0	2.2197	0.2083	525.0	2.2141	0.1972	524.9	2.2087	120
125	0.2377	530.0	2.2381	0.2236	530.0	2.2321	0.2110	529.9	2.2265	0.1998	529.8	2.2211	125
130	—	—	—	—	—	—	0.2138	534.8	2.2388	0.2024	534.7	2.2335	130

MP. °C	200.0 (-21.30°C) V (0.1154)	H (401.3)	S (1.8180)	210.0 (-20.10°C) V (0.1101)	H (402.0)	S (1.8164)	220.0 (-19.00°C) V (0.1054)	H (402.7)	S (1.8149)	230.0 (-17.90°C) V (0.1010)	H (403.4)	S (1.8134)	TEMP. °C
-20	0.1160	402.3	1.8220	0.1102	402.2	1.8168	—	—	—	—	—	—	-20
-15	0.1187	406.2	1.8371	0.1127	406.0	1.8319	0.1073	405.8	1.8270	0.1024	405.7	1.8223	-15
-10	0.1213	410.1	1.8520	0.1152	409.9	1.8469	0.1097	409.8	1.8420	0.1047	409.6	1.8373	-10
-5	0.1239	414.0	1.8668	0.1177	413.9	1.8617	0.1121	413.7	1.8568	0.1070	413.5	1.8522	-5
0	0.1265	418.0	1.8815	0.1202	417.8	1.8764	0.1145	417.7	1.8716	0.1093	417.5	1.8669	0
5	0.1291	422.0	1.8960	0.1227	421.9	1.8910	0.1169	421.7	1.8861	0.1116	421.6	1.8815	5
10	0.1317	426.1	1.9105	0.1252	425.9	1.9054	0.1193	425.8	1.9006	0.1139	425.6	1.8960	10
15	0.1343	430.1	1.9248	0.1276	430.0	1.9198	0.1216	429.9	1.9149	0.1161	429.7	1.9103	15
20	0.1368	434.3	1.9390	0.1301	434.1	1.9340	0.1240	434.0	1.9292	0.1184	433.9	1.9246	20
25	0.1394	438.4	1.9531	0.1326	438.3	1.9481	0.1263	438.2	1.9433	0.1206	438.0	1.9387	25
30	0.1420	442.6	1.9670	0.1350	442.5	1.9620	0.1287	442.4	1.9573	0.1229	442.2	1.9527	30
35	0.1445	446.9	1.9809	0.1374	446.7	1.9759	0.1310	446.6	1.9712	0.1251	446.5	1.9666	35
40	0.1471	451.2	1.9947	0.1399	451.0	1.9897	0.1333	450.9	1.9850	0.1273	450.8	1.9804	40
45	0.1496	455.5	2.0084	0.1423	455.4	2.0034	0.1356	455.2	1.9987	0.1296	455.1	1.9941	45
50	0.1521	459.8	2.0220	0.1447	459.7	2.0170	0.1380	459.6	2.0123	0.1318	459.5	2.0078	50
55	0.1547	464.2	2.0355	0.1471	464.1	2.0305	0.1403	464.0	2.0258	0.1340	463.9	2.0213	55
60	0.1572	468.7	2.0489	0.1495	468.5	2.0439	0.1426	468.4	2.0392	0.1362	468.3	2.0347	60
65	0.1597	473.1	2.0622	0.1519	473.0	2.0573	0.1449	472.9	2.0526	0.1384	472.8	2.0481	65
70	0.1622	477.6	2.0754	0.1543	477.5	2.0705	0.1472	477.4	2.0658	0.1406	477.3	2.0613	70
75	0.1647	482.2	2.0886	0.1567	482.1	2.0837	0.1495	482.0	2.0790	0.1428	481.9	2.0745	75
80	0.1672	486.8	2.1017	0.1591	486.7	2.0968	0.1518	486.6	2.0921	0.1450	486.5	2.0876	80
85	0.1697	491.4	2.1147	0.1615	491.3	2.1098	0.1540	491.2	2.1051	0.1472	491.1	2.1006	85
90	0.1723	496.1	2.1276	0.1639	496.0	2.1227	0.1563	495.9	2.1180	0.1494	495.8	2.1136	90
95	0.1748	500.8	2.1404	0.1663	500.7	2.1356	0.1586	500.6	2.1309	0.1516	500.5	2.1264	95
100	0.1772	505.5	2.1532	0.1687	505.4	2.1483	0.1609	505.3	2.1437	0.1538	505.2	2.1392	100
105	0.1797	510.3	2.1659	0.1711	510.2	2.1611	0.1632	510.1	2.1564	0.1560	510.0	2.1520	105
110	0.1822	515.1	2.1786	0.1734	515.0	2.1737	0.1654	514.9	2.1690	0.1581	514.8	2.1646	110
115	0.1847	519.9	2.1911	0.1758	519.8	2.1863	0.1677	519.7	2.1816	0.1603	519.7	2.1772	115
120	0.1872	524.8	2.2036	0.1782	524.7	2.1988	0.1700	524.6	2.1941	0.1625	524.6	2.1897	120
125	0.1897	529.7	2.2160	0.1805	529.6	2.2112	0.1722	529.6	2.2066	0.1646	529.5	2.2021	125
130	0.1922	534.7	2.2284	0.1829	534.6	2.2236	0.1745	534.5	2.2189	0.1668	534.4	2.2145	130
135	—	—	—	—	—	—	0.1768	539.5	2.2312	0.1690	539.4	2.2268	135

APPENDIX D

Table (D.1) Saturation Properties for R-407C

TEMP. °C	PRESSURE kPa		VOLUME m3/kg		DENSITY kg/m3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP. °C
	LIQUID pf	VAPOR pg	LIQUID vf	VAPOR vg	LIQUID 1/vf	VAPOR 1/vg	LIQUID hf	LATENT hfg	VAPOR hg	LIQUID sf	VAPOR sg	
-40	119.7	85.0	0.0007	0.2577	1378.9	3.880	146.6	242.9	389.5	0.7903	1.8487	-40
-39	125.3	89.3	0.0007	0.2460	1375.4	4.065	147.9	242.3	390.2	0.7957	1.8468	-39
-38	131.1	93.8	0.0007	0.2349	1371.9	4.257	149.1	241.7	390.8	0.8011	1.8449	-38
-37	137.1	98.5	0.0007	0.2244	1368.3	4.456	150.4	241.0	391.4	0.8064	1.8430	-37
-36	143.3	103.4	0.0007	0.2145	1364.8	4.662	151.7	240.4	392.1	0.8118	1.8412	-36
-35	149.8	108.5	0.0007	0.2051	1361.3	4.876	153.2	239.5	392.7	0.8184	1.8394	-35
-34	156.4	113.8	0.0007	0.1962	1357.7	5.098	154.5	238.8	393.4	0.8237	1.8377	-34
-33	163.3	119.2	0.0007	0.1877	1354.2	5.327	155.8	238.2	394.0	0.8290	1.8360	-33
-32	170.5	124.9	0.0007	0.1797	1350.6	5.564	157.1	237.6	394.6	0.8343	1.8343	-32
-31	177.8	130.8	0.0007	0.1721	1347.1	5.810	158.3	236.9	395.3	0.8396	1.8326	-31
-30	185.5	136.9	0.0007	0.1649	1343.5	6.064	159.6	236.3	395.9	0.8449	1.8310	-30
-29	193.3	143.2	0.0007	0.1580	1339.9	6.327	160.9	235.6	396.5	0.8501	1.8294	-29
-28	201.5	149.8	0.0007	0.1515	1336.3	6.599	162.2	234.9	397.2	0.8554	1.8278	-28
-27	209.9	156.5	0.0008	0.1453	1332.7	6.880	163.3	234.5	397.8	0.8596	1.8263	-27
-26	218.6	163.6	0.0008	0.1394	1329.2	7.171	164.4	234.0	398.4	0.8643	1.8248	-26
-25	227.6	170.9	0.0008	0.1338	1325.6	7.472	165.7	233.3	399.0	0.8696	1.8233	-25
-24	236.8	178.4	0.0008	0.1285	1322.0	7.782	167.1	232.6	399.7	0.8748	1.8218	-24
-23	246.3	186.2	0.0008	0.1234	1318.3	8.102	168.4	231.9	400.3	0.8801	1.8204	-23
-22	256.2	194.2	0.0008	0.1186	1314.7	8.433	169.7	231.2	400.9	0.8854	1.8189	-22
-21	266.3	202.6	0.0008	0.1140	1311.1	8.775	171.0	230.5	401.5	0.8907	1.8176	-21
-20	276.8	211.2	0.0008	0.1096	1307.5	9.127	172.4	229.7	402.1	0.8959	1.8162	-20
-19	287.5	220.1	0.0008	0.1054	1303.8	9.491	173.7	229.0	402.7	0.9012	1.8148	-19
-18	298.6	229.2	0.0008	0.1014	1300.2	9.866	175.1	228.3	403.4	0.9064	1.8135	-18
-17	310.0	238.7	0.0008	0.0975	1296.5	10.253	176.4	227.5	404.0	0.9117	1.8122	-17
-16	321.8	248.5	0.0008	0.0939	1292.9	10.651	177.8	226.8	404.6	0.9169	1.8109	-16
-15	333.8	258.6	0.0008	0.0904	1289.2	11.062	179.1	226.0	405.2	0.9221	1.8097	-15
-14	346.3	269.0	0.0008	0.0871	1285.5	11.486	180.5	225.3	405.8	0.9274	1.8084	-14
-13	359.0	279.7	0.0008	0.0839	1281.9	11.923	181.9	224.5	406.4	0.9326	1.8072	-13
-12	372.2	290.8	0.0008	0.0808	1278.2	12.372	183.2	223.7	407.0	0.9378	1.8060	-12
-11	385.7	302.2	0.0008	0.0779	1274.5	12.835	184.5	223.1	407.6	0.9425	1.8048	-11
-10	399.6	313.9	0.0008	0.0751	1270.8	13.313	185.9	222.3	408.2	0.9478	1.8037	-10
-9	413.8	326.0	0.0008	0.0724	1267.1	13.804	187.3	221.5	408.8	0.9530	1.8025	-9
-8	428.5	338.5	0.0008	0.0699	1263.3	14.311	188.7	220.7	409.3	0.9582	1.8014	-8
-7	443.5	351.3	0.0008	0.0674	1259.6	14.831	190.1	219.9	409.9	0.9635	1.8003	-7
-6	458.9	364.5	0.0008	0.0651	1255.9	15.368	191.5	219.0	410.5	0.9687	1.7992	-6
-5	474.8	378.1	0.0008	0.0628	1252.1	15.919	192.9	218.2	411.1	0.9739	1.7981	-5
-4	491.0	392.1	0.0008	0.0607	1248.4	16.487	194.3	217.4	411.7	0.9791	1.7970	-4
-3	507.7	406.5	0.0008	0.0586	1244.6	17.071	195.7	216.5	412.2	0.9843	1.7959	-3
-2	524.8	421.2	0.0008	0.0566	1240.8	17.671	197.1	215.7	412.8	0.9896	1.7949	-2
-1	542.3	436.4	0.0008	0.0547	1237.0	18.289	198.6	214.8	413.4	0.9948	1.7938	-1
0	560.3	452.0	0.0008	0.0528	1233.2	18.924	200.0	213.9	413.9	1.0000	1.7928	0
1	578.7	468.0	0.0008	0.0511	1229.4	19.577	201.4	213.0	414.5	1.0052	1.7918	1
2	597.6	484.5	0.0008	0.0494	1225.6	20.249	202.9	212.1	415.0	1.0104	1.7908	2
3	616.9	501.4	0.0008	0.0478	1221.8	20.939	204.3	211.2	415.6	1.0156	1.7898	3
4	636.7	518.7	0.0008	0.0462	1217.9	21.649	205.8	210.3	416.1	1.0209	1.7888	4
5	657.0	536.6	0.0008	0.0447	1214.1	22.378	207.3	209.4	416.6	1.0261	1.7879	5
6	677.8	554.8	0.0008	0.0432	1210.2	23.127	208.7	208.4	417.2	1.0313	1.7869	6
7	699.0	573.6	0.0008	0.0418	1206.3	23.898	210.2	207.5	417.7	1.0365	1.7859	7
8	720.8	592.8	0.0008	0.0405	1202.4	24.689	211.7	206.5	418.2	1.0418	1.7850	8
9	743.0	612.5	0.0008	0.0392	1198.5	25.502	213.2	205.6	418.8	1.0470	1.7841	9
10	765.8	632.8	0.0008	0.0380	1194.6	26.338	214.7	204.6	419.3	1.0522	1.7831	10
11	789.1	653.5	0.0008	0.0368	1190.7	27.196	216.2	203.6	419.8	1.0574	1.7822	11
12	812.9	674.7	0.0008	0.0356	1186.8	28.078	217.7	202.6	420.3	1.0627	1.7813	12
13	837.3	696.5	0.0008	0.0345	1182.8	28.984	219.2	201.6	420.8	1.0679	1.7804	13
14	862.2	718.8	0.0008	0.0334	1178.8	29.914	220.8	200.5	421.3	1.0732	1.7794	14
15	887.6	741.7	0.0009	0.0324	1174.8	30.870	222.3	199.5	421.8	1.0784	1.7785	15
16	913.6	765.1	0.0009	0.0314	1170.8	31.852	223.8	198.4	422.3	1.0837	1.7776	16
17	940.2	789.1	0.0009	0.0304	1166.8	32.860	225.4	197.4	422.7	1.0889	1.7767	17
18	967.3	813.6	0.0009	0.0295	1162.8	33.896	226.9	196.3	423.2	1.0942	1.7758	18
19	995.1	838.7	0.0009	0.0286	1158.7	34.960	228.5	195.2	423.7	1.0995	1.7749	19

APPENDIX D

Table (D.1) Saturation Properties for R-407C

TEMP.	PRESSURE kPa		VOLUME m3/kg		DENSITY kg/m3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP.
°C	LIQUID pf	VAPOR pg	LIQUID vf	VAPOR vg	LIQUID 1/vf	VAPOR 1/vg	LIQUID hf	LATENT hfg	VAPOR hg	LIQUID sf	VAPOR sg	°C
-40	119.7	85.0	0.0007	0.2577	1378.9	3.880	146.6	242.9	389.5	0.7903	1.8497	-40
-39	125.3	89.3	0.0007	0.2460	1375.4	4.065	147.9	242.3	390.2	0.7957	1.8468	-39
-38	131.1	93.8	0.0007	0.2349	1371.9	4.257	149.1	241.7	390.8	0.8011	1.8439	-38
-37	137.1	98.5	0.0007	0.2244	1368.3	4.456	150.4	241.0	391.4	0.8064	1.8430	-37
-36	143.3	103.4	0.0007	0.2145	1364.8	4.662	151.7	240.4	392.1	0.8118	1.8412	-36
-35	149.8	108.5	0.0007	0.2051	1361.3	4.876	153.2	239.5	392.7	0.8184	1.8394	-35
-34	156.4	113.8	0.0007	0.1962	1357.7	5.098	154.5	238.8	393.4	0.8237	1.8377	-34
-33	163.3	119.2	0.0007	0.1877	1354.2	5.327	155.8	238.2	394.0	0.8290	1.8360	-33
-32	170.5	124.9	0.0007	0.1797	1350.6	5.564	157.1	237.6	394.6	0.8343	1.8343	-32
-31	177.8	130.8	0.0007	0.1721	1347.1	5.810	158.3	236.9	395.3	0.8396	1.8326	-31
-30	185.5	136.9	0.0007	0.1649	1343.5	6.064	159.6	236.3	395.9	0.8448	1.8310	-30
-29	193.3	143.2	0.0007	0.1580	1339.9	6.327	160.9	235.6	396.5	0.8501	1.8294	-29
-28	201.5	149.8	0.0007	0.1515	1336.3	6.599	162.2	234.9	397.2	0.8554	1.8278	-28
-27	209.9	156.5	0.0008	0.1453	1332.7	6.880	163.3	234.5	397.8	0.8596	1.8263	-27
-26	218.6	163.6	0.0008	0.1394	1329.2	7.171	164.4	234.0	398.4	0.8643	1.8248	-26
-25	227.6	170.9	0.0008	0.1338	1325.6	7.472	165.7	233.3	399.0	0.8696	1.8233	-25
-24	236.8	178.4	0.0008	0.1285	1322.0	7.782	167.1	232.6	399.7	0.8748	1.8218	-24
-23	246.3	186.2	0.0008	0.1234	1318.3	8.102	168.4	231.9	400.3	0.8801	1.8204	-23
-22	256.2	194.2	0.0008	0.1186	1314.7	8.433	169.7	231.2	400.9	0.8854	1.8189	-22
-21	266.3	202.6	0.0009	0.1140	1311.1	8.775	171.0	230.5	401.5	0.8907	1.8176	-21
-20	276.8	211.2	0.0008	0.1096	1307.5	9.127	172.4	229.7	402.1	0.8959	1.8162	-20
-19	287.5	220.1	0.0008	0.1054	1303.8	9.491	173.7	229.0	402.7	0.9012	1.8149	-19
-18	298.6	229.2	0.0008	0.1014	1300.2	9.866	175.1	228.3	403.4	0.9064	1.8135	-18
-17	310.0	238.7	0.0008	0.0975	1296.5	10.253	176.4	227.5	404.0	0.9117	1.8122	-17
-16	321.8	248.5	0.0009	0.0939	1292.9	10.651	177.8	226.8	404.6	0.9169	1.8109	-16
-15	333.8	258.6	0.0008	0.0904	1289.2	11.062	179.1	226.0	405.2	0.9221	1.8097	-15
-14	346.3	269.0	0.0008	0.0871	1285.5	11.486	180.5	225.3	405.8	0.9274	1.8084	-14
-13	359.0	279.7	0.0008	0.0839	1281.9	11.923	181.9	224.5	406.4	0.9326	1.8072	-13
-12	372.2	290.8	0.0008	0.0808	1278.2	12.372	183.2	223.7	407.0	0.9378	1.8060	-12
-11	385.7	302.2	0.0008	0.0779	1274.5	12.835	184.5	223.1	407.6	0.9425	1.8048	-11
-10	399.6	313.9	0.0008	0.0751	1270.8	13.313	185.9	222.3	408.2	0.9478	1.8037	-10
-9	413.8	326.0	0.0008	0.0724	1267.1	13.804	187.3	221.5	408.8	0.9530	1.8025	-9
-8	428.5	338.5	0.0008	0.0699	1263.3	14.311	188.7	220.7	409.3	0.9582	1.8014	-8
-7	443.5	351.3	0.0008	0.0674	1259.6	14.831	190.1	219.9	409.9	0.9635	1.8003	-7
-6	458.9	364.5	0.0008	0.0651	1255.9	15.368	191.5	219.0	410.5	0.9687	1.7992	-6
-5	474.8	378.1	0.0008	0.0628	1252.1	15.919	192.9	218.2	411.1	0.9739	1.7981	-5
-4	491.0	392.1	0.0008	0.0607	1248.4	16.487	194.3	217.4	411.7	0.9791	1.7970	-4
-3	507.7	406.5	0.0008	0.0586	1244.6	17.071	195.7	216.5	412.2	0.9843	1.7959	-3
-2	524.8	421.2	0.0008	0.0566	1240.8	17.671	197.1	215.7	412.8	0.9896	1.7949	-2
-1	542.3	436.4	0.0008	0.0547	1237.0	18.289	198.6	214.8	413.4	0.9948	1.7938	-1
0	560.3	452.0	0.0008	0.0528	1233.2	18.924	200.0	213.9	413.9	1.0000	1.7928	0
1	578.7	468.0	0.0008	0.0511	1229.4	19.577	201.4	213.0	414.5	1.0052	1.7918	1
2	597.6	484.5	0.0008	0.0494	1225.6	20.249	202.9	212.1	415.0	1.0104	1.7908	2
3	616.9	501.4	0.0008	0.0478	1221.8	20.939	204.3	211.2	415.6	1.0156	1.7898	3
4	636.7	518.7	0.0008	0.0462	1217.9	21.649	205.8	210.3	416.1	1.0209	1.7888	4
5	657.0	536.6	0.0008	0.0447	1214.1	22.378	207.3	209.4	416.6	1.0261	1.7879	5
6	677.8	554.8	0.0008	0.0432	1210.2	23.127	208.7	208.4	417.2	1.0313	1.7869	6
7	699.0	573.6	0.0008	0.0418	1206.3	23.898	210.2	207.5	417.7	1.0365	1.7859	7
8	720.8	592.8	0.0008	0.0405	1202.4	24.689	211.7	206.5	418.2	1.0418	1.7850	8
9	743.0	612.5	0.0008	0.0392	1198.5	25.502	213.2	205.6	418.8	1.0470	1.7841	9
10	765.8	632.8	0.0008	0.0380	1194.6	26.338	214.7	204.6	419.3	1.0522	1.7831	10
11	789.1	653.5	0.0008	0.0368	1190.7	27.196	216.2	203.6	419.8	1.0574	1.7822	11
12	812.9	674.7	0.0008	0.0356	1186.8	28.079	217.7	202.6	420.3	1.0627	1.7813	12
13	837.3	696.5	0.0008	0.0345	1182.8	28.984	219.2	201.6	420.8	1.0679	1.7804	13
14	862.2	718.8	0.0008	0.0334	1178.8	29.914	220.8	200.5	421.3	1.0732	1.7794	14
15	887.6	741.7	0.0009	0.0324	1174.8	30.870	222.3	199.5	421.8	1.0784	1.7785	15
16	913.6	765.1	0.0009	0.0314	1170.8	31.852	223.8	198.4	422.3	1.0837	1.7776	16
17	940.2	789.1	0.0009	0.0304	1166.8	32.860	225.4	197.4	422.7	1.0889	1.7767	17

APPENDIX D

Table (D.1) Saturation Properties for R-407C

TEMP. °C	PRESSURE kPa		VOLUME m3/kg		DENSITY kg/m3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP. °C
	LIQUID pf	VAPOR pg	LIQUID vf	VAPOR vg	LIQUID 1/vf	VAPOR 1/vg	LIQUID hf	LATENT h/g	VAPOR hg	LIQUID sf	VAPOR sg	
-40	119.7	85.0	0.0007	0.2577	1378.9	3.880	146.6	242.9	389.5	0.7903	1.8497	-40
-39	125.3	89.3	0.0007	0.2460	1375.4	4.065	147.9	242.3	390.2	0.7957	1.8468	-39
-38	131.1	93.8	0.0007	0.2349	1371.9	4.257	149.1	241.7	390.8	0.8011	1.8449	-38
-37	137.1	98.5	0.0007	0.2244	1368.3	4.456	150.4	241.0	391.4	0.8064	1.8430	-37
-36	143.3	103.4	0.0007	0.2145	1364.8	4.662	151.7	240.4	392.1	0.8118	1.8412	-36
-35	149.8	108.5	0.0007	0.2051	1361.3	4.876	153.2	239.5	392.7	0.8184	1.8394	-35
-34	156.4	113.8	0.0007	0.1962	1357.7	5.098	154.5	238.8	393.4	0.8237	1.8377	-34
-33	163.3	119.2	0.0007	0.1877	1354.2	5.327	155.8	238.2	394.0	0.8290	1.8360	-33
-32	170.5	124.9	0.0007	0.1797	1350.6	5.564	157.1	237.6	394.6	0.8343	1.8343	-32
-31	177.8	130.8	0.0007	0.1721	1347.1	5.810	158.3	236.9	395.3	0.8396	1.8326	-31
-30	185.5	136.9	0.0007	0.1649	1343.5	6.064	159.6	236.3	395.9	0.8448	1.8310	-30
-29	193.3	143.2	0.0007	0.1580	1339.9	6.327	160.9	235.6	396.5	0.8501	1.8294	-29
-28	201.5	149.8	0.0007	0.1515	1336.3	6.599	162.2	234.9	397.2	0.8554	1.8278	-28
-27	209.9	156.5	0.0008	0.1453	1332.7	6.880	163.3	234.5	397.8	0.8596	1.8263	-27
-26	218.6	163.6	0.0008	0.1394	1329.2	7.171	164.4	234.0	398.4	0.8643	1.8248	-26
-25	227.6	170.9	0.0008	0.1338	1325.6	7.472	165.7	233.3	399.0	0.8696	1.8233	-25
-24	236.8	178.4	0.0008	0.1285	1322.0	7.782	167.1	232.6	399.7	0.8748	1.8218	-24
-23	246.3	186.2	0.0008	0.1234	1318.3	8.102	168.4	231.9	400.3	0.8801	1.8204	-23
-22	256.2	194.2	0.0008	0.1186	1314.7	8.433	169.7	231.2	400.9	0.8854	1.8189	-22
-21	266.3	202.6	0.0008	0.1140	1311.1	8.775	171.0	230.5	401.5	0.8907	1.8176	-21
-20	276.8	211.2	0.0008	0.1096	1307.5	9.127	172.4	229.7	402.1	0.8959	1.8162	-20
-19	287.5	220.1	0.0008	0.1054	1303.8	9.491	173.7	229.0	402.7	0.9012	1.8148	-19
-18	298.6	229.2	0.0008	0.1014	1300.2	9.866	175.1	228.3	403.4	0.9064	1.8135	-18
-17	310.0	238.7	0.0008	0.0975	1296.5	10.253	176.4	227.5	404.0	0.9117	1.8122	-17
-16	321.8	248.5	0.0008	0.0939	1292.9	10.651	177.8	226.8	404.6	0.9169	1.8109	-16
-15	333.8	258.6	0.0009	0.0904	1289.2	11.062	179.1	226.0	405.2	0.9221	1.8097	-15
-14	346.3	269.0	0.0008	0.0871	1285.5	11.486	180.5	225.3	405.8	0.9274	1.8084	-14
-13	359.0	279.7	0.0008	0.0839	1281.9	11.923	181.9	224.5	406.4	0.9326	1.8072	-13
-12	372.2	290.8	0.0008	0.0808	1278.2	12.372	183.2	223.7	407.0	0.9378	1.8060	-12
-11	385.7	302.2	0.0008	0.0779	1274.5	12.835	184.5	223.1	407.6	0.9425	1.8048	-11
-10	399.6	313.9	0.0008	0.0751	1270.8	13.313	185.9	222.3	408.2	0.9478	1.8037	-10
-9	413.8	326.0	0.0008	0.0724	1267.1	13.804	187.3	221.5	408.8	0.9530	1.8025	-9
-8	428.5	338.5	0.0008	0.0699	1263.3	14.311	188.7	220.7	409.3	0.9582	1.8014	-8
-7	443.5	351.3	0.0008	0.0674	1259.6	14.831	190.1	219.9	409.9	0.9635	1.8003	-7
-6	458.9	364.5	0.0008	0.0651	1255.9	15.368	191.5	219.0	410.5	0.9687	1.7992	-6
-5	474.8	378.1	0.0008	0.0628	1252.1	15.919	192.9	218.2	411.1	0.9739	1.7981	-5
-4	491.0	392.1	0.0008	0.0607	1248.4	16.487	194.3	217.4	411.7	0.9791	1.7970	-4
-3	507.7	406.5	0.0008	0.0586	1244.6	17.071	195.7	216.5	412.2	0.9843	1.7959	-3
-2	524.8	421.2	0.0008	0.0566	1240.8	17.671	197.1	215.7	412.8	0.9896	1.7949	-2
-1	542.3	436.4	0.0008	0.0547	1237.0	18.289	198.6	214.8	413.4	0.9948	1.7938	-1
0	560.3	452.0	0.0008	0.0528	1233.2	18.924	200.0	213.9	413.9	1.0000	1.7928	0
1	578.7	468.0	0.0008	0.0511	1229.4	19.577	201.4	213.0	414.5	1.0052	1.7918	1
2	597.6	484.5	0.0008	0.0494	1225.6	20.249	202.9	212.1	415.0	1.0104	1.7908	2
3	616.9	501.4	0.0008	0.0478	1221.8	20.939	204.3	211.2	415.6	1.0156	1.7898	3
4	636.7	518.7	0.0008	0.0462	1217.9	21.649	205.8	210.3	416.1	1.0209	1.7888	4
5	657.0	536.6	0.0008	0.0447	1214.1	22.378	207.3	209.4	416.6	1.0261	1.7879	5
6	677.8	554.8	0.0008	0.0432	1210.2	23.127	208.7	208.4	417.2	1.0313	1.7869	6
7	699.0	573.6	0.0008	0.0418	1206.3	23.898	210.2	207.5	417.7	1.0365	1.7859	7
8	720.8	592.8	0.0009	0.0405	1202.4	24.689	211.7	206.5	418.2	1.0418	1.7850	8
9	743.0	612.5	0.0008	0.0392	1198.5	25.502	213.2	205.6	418.8	1.0470	1.7841	9
10	765.8	632.8	0.0008	0.0380	1194.6	26.338	214.7	204.6	419.3	1.0522	1.7831	10
11	789.1	653.5	0.0008	0.0368	1190.7	27.196	216.2	203.6	419.8	1.0574	1.7822	11
12	812.9	674.7	0.0009	0.0356	1186.8	28.078	217.7	202.6	420.3	1.0627	1.7813	12
13	837.3	696.5	0.0008	0.0345	1182.8	28.984	219.2	201.6	420.8	1.0679	1.7804	13
14	862.2	718.8	0.0008	0.0334	1178.8	29.914	220.8	200.5	421.3	1.0732	1.7794	14
15	887.6	741.7	0.0009	0.0324	1174.8	30.870	222.3	199.5	421.8	1.0784	1.7785	15
16	913.6	765.1	0.0009	0.0314	1170.8	31.852	223.8	198.4	422.3	1.0837	1.7776	16
17	940.2	789.1	0.0009	0.0304	1166.8	32.860	225.4	197.4	422.7	1.0889	1.7767	17
18	967.3	813.6	0.0009	0.0295	1162.8	33.896	226.9	196.3	423.2	1.0942	1.7758	18
19	995.1	838.7	0.0009	0.0286	1158.7	34.960	228.5	195.2	423.7	1.0995	1.7749	19

APPENDIX D

Table (D.1) Saturation Properties for R-407C

TEMP. °C	PRESSURE kPa		VOLUME m3/kg		DENSITY kg/m3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP. °C
	LIQUID pf	VAPOR pg	LIQUID vf	VAPOR vg	LIQUID 1/vf	VAPOR 1/vg	LIQUID hf	LATENT hfg	VAPOR hg	LIQUID sf	VAPOR sg	
-40	119.7	85.0	0.0007	0.2527	1378.9	3.880	146.6	242.9	389.5	0.7903	1.8487	-40
-39	125.3	89.3	0.0007	0.2450	1375.4	4.065	147.9	242.3	390.2	0.7957	1.8468	-39
-38	131.1	93.8	0.0007	0.2349	1371.9	4.257	149.1	241.7	390.8	0.8011	1.8449	-38
-37	137.1	98.5	0.0007	0.2244	1368.3	4.456	150.4	241.0	391.4	0.8064	1.8430	-37
-36	143.3	103.4	0.0007	0.2145	1364.8	4.662	151.7	240.4	392.1	0.8118	1.8412	-36
-35	149.8	108.5	0.0007	0.2051	1361.3	4.876	153.2	239.5	392.7	0.8184	1.8394	-35
-34	156.4	113.8	0.0007	0.1962	1357.7	5.098	154.5	238.8	393.4	0.8237	1.8377	-34
-33	163.3	119.2	0.0007	0.1877	1354.2	5.327	155.8	238.2	394.0	0.8290	1.8360	-33
-32	170.5	124.9	0.0007	0.1797	1350.6	5.564	157.1	237.6	394.6	0.8343	1.8343	-32
-31	177.8	130.8	0.0007	0.1721	1347.1	5.810	158.3	236.9	395.3	0.8396	1.8326	-31
-30	185.5	136.9	0.0007	0.1649	1343.5	6.064	159.6	236.3	395.9	0.8448	1.8310	-30
-29	193.3	143.2	0.0007	0.1580	1339.9	6.327	160.9	235.6	396.5	0.8501	1.8294	-29
-28	201.5	149.8	0.0007	0.1515	1336.3	6.599	162.2	234.9	397.2	0.8554	1.8278	-28
-27	209.9	156.5	0.0008	0.1453	1332.7	6.880	163.3	234.5	397.8	0.8596	1.8263	-27
-26	218.6	163.6	0.0008	0.1394	1329.2	7.171	164.4	234.0	398.4	0.8643	1.8248	-26
-25	227.6	170.9	0.0008	0.1338	1325.6	7.472	165.7	233.3	399.0	0.8696	1.8233	-25
-24	236.8	178.4	0.0008	0.1285	1322.0	7.782	167.1	232.6	399.7	0.8748	1.8218	-24
-23	246.3	186.2	0.0008	0.1234	1318.3	8.102	168.4	231.9	400.3	0.8801	1.8204	-23
-22	256.2	194.2	0.0008	0.1185	1314.7	8.433	169.7	231.2	400.9	0.8854	1.8189	-22
-21	266.3	202.6	0.0008	0.1140	1311.1	8.775	171.0	230.5	401.5	0.8907	1.8176	-21
-20	276.8	211.2	0.0008	0.1096	1307.5	9.127	172.4	229.7	402.1	0.8959	1.8162	-20
-19	287.5	220.1	0.0008	0.1054	1303.8	9.491	173.7	229.0	402.7	0.9012	1.8148	-19
-18	298.6	229.2	0.0008	0.1014	1300.2	9.866	175.1	228.3	403.4	0.9064	1.8135	-18
-17	310.0	238.7	0.0008	0.0975	1296.5	10.253	176.4	227.5	404.0	0.9117	1.8122	-17
-16	321.8	248.5	0.0008	0.0939	1292.9	10.651	177.8	226.8	404.6	0.9169	1.8109	-16
-15	333.8	258.6	0.0008	0.0904	1289.2	11.062	179.1	226.0	405.2	0.9221	1.8097	-15
-14	346.3	269.0	0.0008	0.0871	1285.5	11.486	180.5	225.3	405.8	0.9274	1.8084	-14
-13	359.0	279.7	0.0008	0.0839	1281.9	11.923	181.9	224.5	406.4	0.9326	1.8072	-13
-12	372.2	290.8	0.0008	0.0808	1278.2	12.372	183.2	223.7	407.0	0.9378	1.8060	-12
-11	385.7	302.2	0.0008	0.0779	1274.5	12.835	184.5	223.1	407.6	0.9425	1.8048	-11
-10	399.6	313.9	0.0008	0.0751	1270.8	13.313	185.9	222.3	408.2	0.9478	1.8037	-10
-9	413.8	326.0	0.0008	0.0724	1267.1	13.804	187.3	221.5	408.8	0.9530	1.8025	-9
-8	428.5	338.5	0.0008	0.0699	1263.3	14.311	188.7	220.7	409.3	0.9582	1.8014	-8
-7	443.5	351.3	0.0008	0.0674	1259.6	14.831	190.1	219.9	409.9	0.9635	1.8003	-7
-6	458.9	364.5	0.0008	0.0651	1255.9	15.368	191.5	219.0	410.5	0.9687	1.7992	-6
-5	474.8	378.1	0.0008	0.0628	1252.1	15.919	192.9	218.2	411.1	0.9739	1.7981	-5
-4	491.0	392.1	0.0008	0.0607	1248.4	16.487	194.3	217.4	411.7	0.9791	1.7970	-4
-3	507.7	406.5	0.0008	0.0586	1244.6	17.071	195.7	216.5	412.2	0.9843	1.7959	-3
-2	524.8	421.2	0.0008	0.0566	1240.8	17.671	197.1	215.7	412.8	0.9896	1.7949	-2
-1	542.3	436.4	0.0008	0.0547	1237.0	18.289	198.6	214.8	413.4	0.9948	1.7938	-1
0	560.3	452.0	0.0008	0.0528	1233.2	18.924	200.0	213.9	413.9	1.0000	1.7928	0
1	578.7	468.0	0.0009	0.0511	1229.4	19.577	201.4	213.0	414.5	1.0052	1.7918	1
2	597.6	484.5	0.0008	0.0494	1225.6	20.249	202.9	212.1	415.0	1.0104	1.7908	2
3	616.9	501.4	0.0008	0.0478	1221.8	20.939	204.3	211.2	415.6	1.0156	1.7898	3
4	636.7	518.7	0.0009	0.0462	1217.9	21.649	205.8	210.3	416.1	1.0209	1.7888	4
5	657.0	536.6	0.0008	0.0447	1214.1	22.378	207.3	209.4	416.6	1.0261	1.7879	5
6	677.8	554.8	0.0008	0.0432	1210.2	23.127	208.7	208.4	417.2	1.0313	1.7869	6
7	699.0	573.6	0.0008	0.0418	1206.3	23.898	210.2	207.5	417.7	1.0365	1.7859	7
8	720.8	592.8	0.0008	0.0405	1202.4	24.689	211.7	206.5	418.2	1.0418	1.7850	8
9	743.0	612.5	0.0008	0.0392	1198.5	25.502	213.2	205.6	418.8	1.0470	1.7841	9
10	765.8	632.8	0.0009	0.0380	1194.6	26.338	214.7	204.6	419.3	1.0522	1.7831	10
11	789.1	653.5	0.0008	0.0368	1190.7	27.196	216.2	203.6	419.8	1.0574	1.7822	11
12	812.9	674.7	0.0008	0.0356	1186.8	28.078	217.7	202.6	420.3	1.0627	1.7813	12
13	837.3	696.5	0.0008	0.0345	1182.8	28.984	219.2	201.6	420.8	1.0679	1.7804	13
14	862.2	718.8	0.0008	0.0334	1178.8	29.914	220.8	200.5	421.3	1.0732	1.7794	14
15	887.6	741.7	0.0009	0.0324	1174.8	30.870	222.3	199.5	421.8	1.0784	1.7785	15
16	913.6	765.1	0.0009	0.0314	1170.8	31.852	223.8	198.4	422.3	1.0837	1.7776	16
17	940.2	789.1	0.0009	0.0304	1166.8	32.860	225.4	197.4	422.7	1.0889	1.7767	17
18	967.3	813.6	0.0009	0.0295	1162.8	33.896	226.9	196.3	423.2	1.0942	1.7758	18
19	995.1	838.7	0.0009	0.0286	1158.7	34.960	228.5	195.2	423.7	1.0995	1.7749	19

ملخص

استخدام غاز التبريد R-407C [52% R-134a, 25% R-125 and 23% R-32] كبديل لغاز التبريد R-134a في مجمدة عرض مصنعه محليا

إعداد

أحمد محمد أبو جري

إشراف

الأستاذ الدكتور محمود حماد

الهدف من هذا البحث هو فحص ودراسة أداء مجمدة عرض مصنعه محليا تعمل بغاز التبريد R-407C بدلا من غاز التبريدR-134a بدون إجراء تعديلات في تصميم المجمدة المستخدمة. إن غاز R-407C إضـــافة لمواصـــفاته المقاربة من مواصفات غاز التبريدR-134a حيث إن كليهما غير ضار بالبيئة، فقد أبدى نجاحا واضحا عند استخدامه في أجهزة التكييف.

تم إجراء التجارب على ثلاث شحنات مختلفة لغاز التبريدR-407C ، وهي ٢٠٠،١٥٠، و ٢٥٠غرام، وذلك لمعرفة أي كمية تعطي الأداء الأفضل ومقارنتها بأداء غاز التبريدR-134a .

أظهـــرت النـــتائج أن أفضل شحنة للمجمدة المستخدمة هي ٢١٠غرام. العمل بهذه الشحنة أعطى معاملات أداء (COP)تصل إلى ٣،٠(عند درجة حرارة مبخر -١٥°م،درجة حرارة مكثف ٣٩ °م،ودرجـــة حرارة جو ٢٢،٥°م)وهي أقل بنسبة ٣٢،١٣% من تلك التي تحصل عند استخدام R-134a عند نفس الظروف.

بشـــكل عام، فإن البحث أثبت أن غاز التبريد R-407C هو بديل غير ناجح لغازR-134a لدى استخدامه في المجمدات.