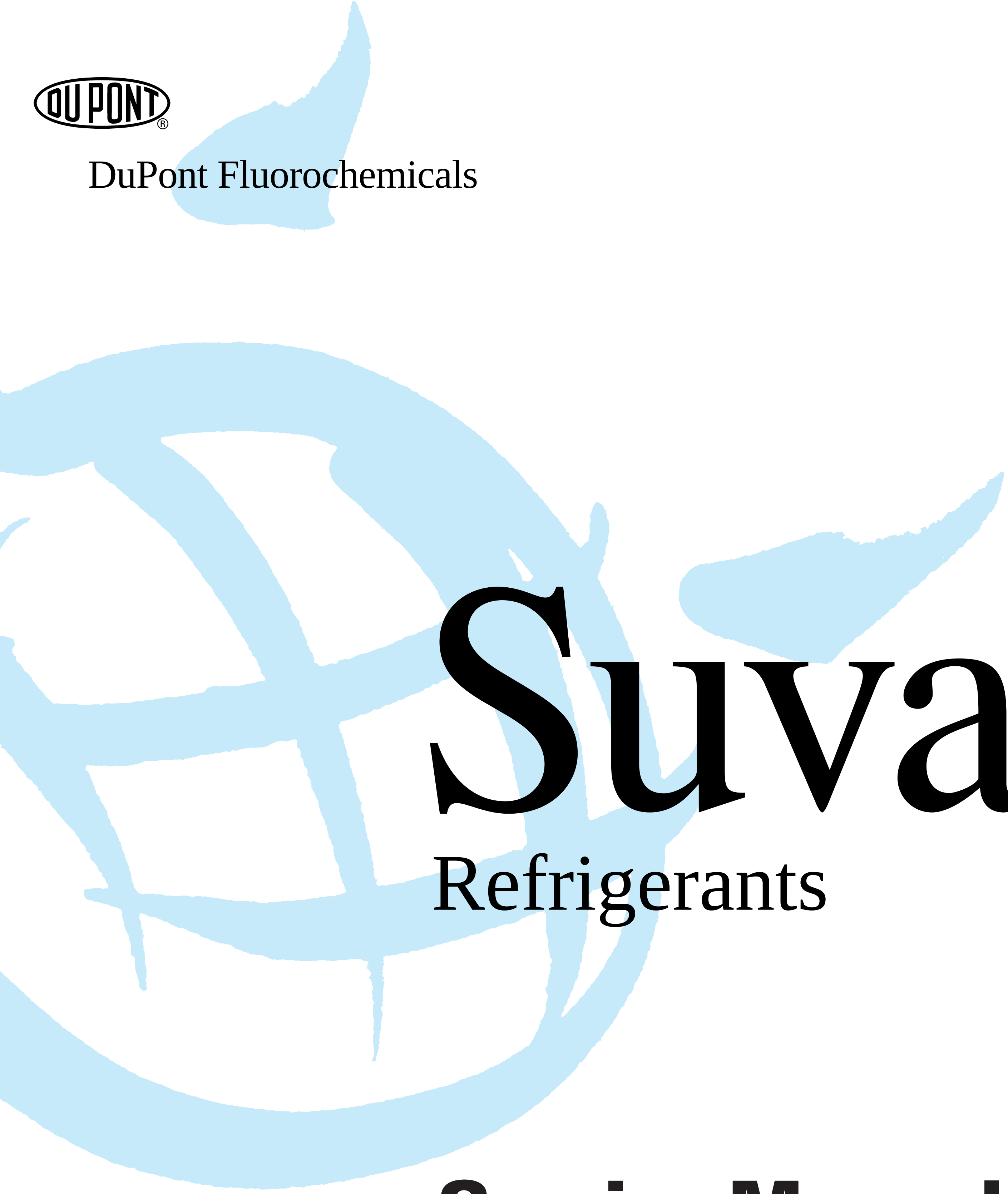
DuPont Fluorochemicals



Suva®

Refrigerants

Service Manual

Foreword

The DuPont Refrigerants Service Manual was first published in 1964 to pass on to service engineers and technicians the knowledge and experience of DuPont scientists and engineers. The Manual was revised and updated three times, most recently in 1983, and published in seven languages.

It is now our pleasure to introduce an entirely new, re-written, European edition. The new title emphasises the changes that the refrigeration industry has experienced and adapted to in the last few years. Despite these changes, many fundamentals remain true.

Refrigeration is essential to many human activities, including the storage, transport and distribution of food, the conservation of pharmaceutical and medical products and temperature control in processing industries. The losses caused if efficient temperature-controlled distribution and storage are not available result in waste that the World ecology cannot afford. Air conditioning is essential to the effective performance of skilled work and the dimensional stability of precision products in all climates during part, if not all, of the year.

Refrigeration and air conditioning systems use refrigerants that are chemicals under pressure. For the safety of the people who work, shop or live close to refrigerated equipment or in air-conditioned spaces, refrigerants should whenever possible be non-flammable, non-explosive and of very low toxicity.

Every effort must be made to avoid leakage from systems, and systems must be reliable. Dismantling and opening up systems for maintenance must be reduced to a minimum. This demands a high level of skill and professionalism from refrigeration technicians.

The purpose of this Manual is to assist those who work directly with both new and existing refrigeration and air conditioning systems to achieve with SUVA refrigerants the highest levels of personal qualification and performance. That is needed more than ever today.

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1.1
The Ozone Layer

1.1.1
Historical background

When CFC-12 was invented in 1928, it was welcomed as the perfect safe refrigerant: chemically and thermally stable, non-flammable, non-explosive, non-corrosive and having very low toxicity. (Toxicologists do not describe any substance as “non-toxic”). In addition, it was a good refrigerant. None of that has changed. So why are Refrigerant-12 and the other CFCs now prohibited from use? The reason is that they are now known to damage, “deplete”, the Ozone Layer.

1.1.2
What is the Ozone Layer?

The *Ozone Layer* is a band of relatively highly concentrated ozone (O_3), up to 10 parts per million (ppm) , in the stratosphere at a height of about 15 to 35 kilometers above the Earth’s surface. This ozone is formed naturally by the action of sunlight on normal oxygen (O_2). Ozone is continually being formed and destroyed by chemical reactions which take place naturally in the stratosphere. There are large natural changes in the concentration of ozone in the layer: for example a change of about 25% between summer and winter over most of Europe.

The importance of the Ozone Layer is that it filters out a certain amount of the ultra-violet radiation that would otherwise reach the surface of the Earth. The part of this radiation with a wavelength of between 280 and 320 nanometers is classed as “UV-B” radiation. There is also “UV-A” , which appears to be harmless, and “UV-C” which is very harmful , but fortunately occurs in only very small amounts. A significant increase in UV-B radiation would have adverse, damaging, effects on human beings, animals and plants. Life evidently grew up on this planet with this filter in place: a reduction or depletion of the Ozone Layer would have serious consequences. These would include damage to crops and water-life, and an increase in cataracts in humans and animals and of certain types of skin cancer in humans.

1.1.3
Ozone depletion

Ozone depletion is the name for what occurs when the rate of ozone destruction increases due to human activities: to the point where the rate of destruction exceeds the natural rate of formation of ozone. Chlorine has been identified as the destructive element that reacts with ozone to convert it to normal oxygen: and because this happens over and over again – a “catalytic chain reaction” – a single atom of chlorine can destroy several thousand molecules of ozone. Bromine is even more damaging than chlorine.

Chlorine released by itself at the Earth’s surface does not affect the Ozone Layer because it reacts with other elements to form various more or less unstable compounds that are diluted and rained out of the lower atmosphere or “troposphere”. Chlorine locked into the very stable CFC molecule does not react until it reaches the stratosphere. There the CFC molecule breaks down, releasing chlorine where it can react with the ozone molecules in the Ozone Layer.

The HCFC molecule is much less stable in the troposphere than a CFC molecule (although it may be very stable in refrigeration use) so that the major part of HCFCs released break down before reaching the Ozone Layer in the stratosphere.

1.1.4
Ozone depletion potential

Ozone depletion potential (ODP) is the calculated amount of ozone depletion caused by the release of a given quantity, say 1 kg, of the compound concerned: compared to the depletion effect of the same mass of CFC-11. The calculation takes into account all the potential effects on stratospheric ozone of the specified compound during the whole time that traces of the compound could remain in the atmosphere: the total potential, or possibility, of that compound to deplete the Ozone Layer.

The ODPs of CFCs are high compared to other substances: CFC-11, having the highest known ODP, is rated as “1.0”. There is no unit of measurement of ODP, only comparative ratings. The ODPs of various compounds, together with their GWP ratings (see 1.3.1 below)are listed in Table 1. HCFCs (for definition of these terms, see 2.1 below) have very much lower ODPs than do CFCs, typically one tenth to one twentieth of the ODPs of CFCs.

HFCs have zero ODP. Since they contain no chlorine or bromine they do not deplete the Ozone Layer.

1.1.5
Current state of the science

The *current state* of the *science* is that there is a virtually unanimous view among scientists who have studied the question and are qualified to form an opinion that the Ozone Layer really is being depleted, and that CFCs are a very significant cause of the depletion. There has not always been such nearly unanimous agreement.

In 1972 a British scientist, Professor James Lovelock, published a report of his attempt to find CFC gases, mainly CFC-12 and CFC-11, in the lower atmosphere ("troposphere"). He was surprised to find only very minor traces, much less than he had expected. Two American scientists, Sherwin *Rowland* and Mario *Molina*, basing themselves on Lovelock's report, published in 1974 a paper that was christened "The Ozone Theory". They also made use of earlier work by Paul *Crutzen*. During the following fifteen years the theory was discussed and questioned, but although the numerical calculations have been changed, the broad lines of the theory are now generally accepted.

Because of their chemical stability, CFCs do not break down and cause pollution in the lower atmosphere or troposphere. They are carried intact up to the level of the Ozone Layer, where under the effect of direct sunlight they do break down. The chlorine radicals that are released by this chemical decomposition then react with ozone molecules in the Ozone Layer, converting them into normal oxygen. The chemical reaction, simplified, is:

CCl_2F_2 CFC-12			=	2 x Cl^+ chlorine radicals	+	CF_2 unstable
Cl^+ chlorine radicals	+	O_3 ozone	=	O_2 oxygen	+	ClO chlorine monoxide
ClO	+	O_3	=	Cl^+	+	2 x O_2

This reaction then repeats itself very many times. It is this "catalytic cycle" that causes depletion of the Ozone Layer.

The "Ozone Theory" remained a theory, without proof, until 1987. In that year the British Antarctic Survey reported a series of observations over twenty years which showed that the Ozone Layer over the South Pole diminished considerably each year in the Southern Hemisphere Spring, the decrease becoming more significant each year during the previous ten years. This is what is called the "Antarctic Ozone Hole". A *NASA* expedition using high-flying aircraft and balloons confirmed the ground-based findings of the Survey, and proved the link with chlorine chemistry.

The Ozone Theory has now (1995) been shown to be essentially correct.

1.1.6
Other theories

Other theories about the Ozone Layer need to be mentioned. They frequently seem convincing, and attract attention because the Layer is not constant. As mentioned in 1.1.2 above, there are important variations between Summer and Winter. Thickness of the Layer also varies according to time of day, and on a longer cycle of about eleven years. The Ozone Layer is not equally thick over the whole Word: it is thickest over the North and South Poles, and thinnest over the Equator. It is consequently very difficult to measure the Layer accurately, and thus to detect the small changes which, fortunately, are all that have occurred to date.

Major volcanic eruptions such as Mt. *Pinatubo* in 1991 do temporarily increase ozone depletion. The effect of such events is relatively short-term, however, and while often significant for one to three years after the eruption, sinks into the background quite rapidly. There are not enough volcanic eruptions to explain the observed decrease in stratospheric ozone.

Supersonic aircraft flying in the stratosphere probably do have an effect on the Ozone Layer, but not a significant effect at the present number of flights.

Methyl bromide is considered to be a significant ozone-depleting compound. There is a natural source of methyl bromide in the oceans. Man-made sources of methyl bromide have been identified as soil fumigation, biomass burning and automobile exhausts from cars running on leaded petrol.

1.1.7
The future of the Ozone Layer

The future of the Ozone Layer, as of late 1995, appears reasonably satisfactory, provided that the actions already taken are continued, according to the terms of the revised Montreal Protocol. The rates of increase in atmospheric concentration of several major ozone-depleting substances, including specifically CFC-11 and CFC-12, have slowed down. Organic chlorine in the troposphere increased by only 1.6% in 1992, compared to 2.9% in 1989. The loading of chlorine and bromine in the troposphere is expected to have reached its peak in 1994 (because of the time taken to assemble and analyse the data this is not yet confirmed), and begin a slow decline from then onwards. The peak loading in the stratosphere is expected about 3-5 years later. Ozone depletion is therefore expected to continue to the end of this decade, with gradual recovery of the Ozone Layer beginning in the 21st Century.

1.2
Global warming

1.2.1
The global warming issue

Global warming issue is a separate issue and is a global problem. It affects the whole climate of the earth with major consequences. Increased warming would have serious social consequences. Climate change would affect crop yields, and possible melting of the polar ice caps could lead to flooding of low-lying coastal areas.

Solar radiation is converted to heat energy by contact with the atmosphere and surface of the Earth. A substantial part of that heat energy is radiated back towards Space, but some is trapped in the atmosphere by various gases. These are called “Greenhouse Gases” because they absorb and thus retain some of the outgoing heat energy, an effect analogous to that of a greenhouse. By raising the temperature of the earth’s surface these gases cause the effect called Global Warming.

The most significant greenhouse gas is carbon dioxide, which is emitted and is present in the atmosphere in very large quantities. Other gases, including CFCs and many of their replacements, are also greenhouse gases. These are present in very much smaller quantities but have more effect per unit mass.

Comparison of the “Global Warming Potential” (GWP) of different gases is rather more complicated than comparison of ODPs. In addition to the properties of the gas itself (infrared energy absorption), it is essential to take into account the average elapsed time before that gas is purged from the atmosphere. There is a very wide range: carbon dioxide remains in the atmosphere for over 500 years, whereas HCFC-123 and HFC-152a have Estimated Atmospheric Lifetimes of less than 2 years.

Although carbon dioxide is the true basis for comparison, it cannot be compared fully with other greenhouse gases because it does not have a finite atmospheric lifetime. Comparison with CFC-11, which has a finite lifetime in the atmosphere of 55 years, is practical. This is designated a Halocarbon GWP or HGWP. GWPs are frequently quoted for specific time periods (“Integration Time Horizons”, or ITH). These are generally 20, 100 and 500 years. GWPs referred to in the literature are usually for an ITH of 100 years unless otherwise stated.

In addition to carbon dioxide and the various fluorocarbons, significant greenhouse gases include methane, and ozone in the troposphere.

1.2.2
TEWI

Total global warming impact (or TEWI) is a systems approach to measuring the environmental impact (as global warming) of a compound as used, in our case as a refrigerant. TEWI takes into account the ‘direct’ effect of the emitted refrigerant (assuming that it is emitted), through its GWP and the ‘indirect’ warming effect of the carbon dioxide emissions due to the energy required to operate the system over its expected lifetime. For a typical modern refrigeration system, indirect global warming typically accounts for over 90% of the TEWI.

2 Background information

2.1
Units

Use of the International System of Units is obligatory in Europe. The system has not been adopted in the USA, and in practice many reference books and specifications are still used that give vital information in either the British/American or old metric systems. Conversion Tables are included as an Appendix to this Manual.

Some remarks may be helpful.

Temperature according to the SI rules should be expressed in Kelvin (K): 0 K = absolute zero. Difference of temperatures is also expressed in Kelvin. Use of degrees Centigrade or Celsius (°C) is permitted, and is followed in this manual.

Pressure in SI units is measured in Pascal (Pa): even for scientific purposes the kiloPascal (kPa) is used but this Manual follows general industry practice in using the bar (b). The bar is close to, but not identical to, the Atmosphere (atm) in the former metric system.

In strict use, 1 bar or 100 kPa is the average atmospheric, or gauge, pressure. Zero bar or 0 kPa is an absolute vacuum and there are no minus numbers. However, most pressure gauges in use are based on zero bar = atmospheric pressure (which is equivalent to 1 bar absolute, 1 standard atmosphere = 101.325 kPa).

American usage makes a clear distinction between psia (pounds per square inch absolute) and psig (pounds per square inch gauge). If you encounter "psi" alone, without the qualifying "a" or "g", it is normally gauge pressure that is meant: this imprecise expression should be reserved for cases where only difference in pressure is referred to.

Viscosity: the SI unit for kinematic viscosity is the Stoke (St). For convenience, the centistoke (cSt) is used for oil viscosity. There is not an exact numerical conversion to Saybolt Universal Second (SUS or SSU) used in the USA because the method of measurement is different.

Liquid measure: the US gallon (3,785 litres) is different from the British, or Imperial, gallon (4,55 litres). Confusion may arise with older equipment: the origin of the equipment concerned will usually clarify is meant.

For smaller liquid measures, in both US and Imperial systems: 1 gallon = 4 quarts = 8 pints.

The *decimal point* may be written differently in Britain or the United States from other European countries. Usage in this manual is shown by these examples:

45 millimetres (mm)	=	0,045 metres (m)
2.100 kilogrammes (kg)	=	2,1 tonnes (t)

Ton of Refrigeration (TR) was historically the cooling effect produced by the melting of one American ton (2000 lb) of ice. It is now standardised at 12000 Btu/h or 200 Btu/min, and still widely used in the USA.

2.2
Basics of refrigeration

2.2.1
Introduction

The "producing" of cold is a heat transfer process which was defined by H.W.Carrier as follows: "Refrigeration is the transfer of heat from where it is undesirable to where it does not create a problem."

The main methods commonly used today are:

Physical methods

a) Change of state from solid to liquid (i.e. ice or use of the latent heat of melting).

b) Change of state through compression and expansion by mechanical refrigeration (use of latent heat of vaporization).

c) Thermoelectric method.

Physico-chemical methods

Method based on absorption and adsorption of certain media.

2.2.2
Fundamentals

By comparison with water, refrigeration is based on the following basic principles.

Fusion

In order to change from solid to liquid at a constant temperature of 0° C, ice absorbs an energy equal to 334,4 kJ/kg (80 kcal/kg). This heat taken from the product to be cooled is called the latent heat of fusion.

Boiling point

This temperature corresponds to the beginning of the change of state from liquid to vapour. This temperature is a function of the pressure above the liquid surface. A given boiling temperature corresponds to each pressure.

Boiling point of water (°C)	Pressure bar (absolute)
151	5
100	1
68	0,3
12,7	0,015
6,7	0,010

Latent heat of vaporization

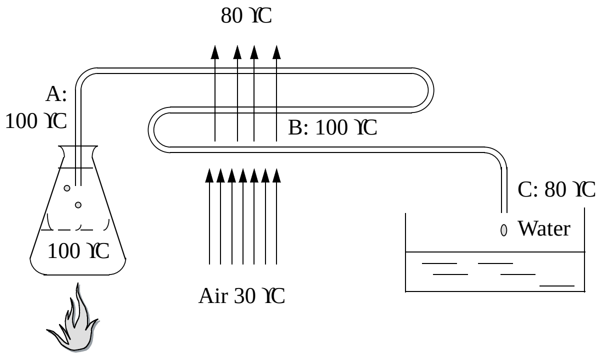
To change from liquid to vapour at 100° C constant temperature at 1,013 bar (760 mmHg) standard atmospheric pressure, water requires an energy input of 2254,69 kJ (539,4 kcal/kg).

Note that standard atmospheric pressure is 1,01325 bar.

Superheat
If after having obtained saturated vapour, further energy is supplied to raise the vapour temperature, the vapour will change from saturated to superheated.

Condensation
Changing from liquid to gas is a reversible phenomenon. If we remove heat from the vapour, it will be changed into water. In the above example, by giving away heat to ambient air, water vapour will change from its gaseous state to liquid between A and B at a constant temperature of 100° C. Between B and C liquid will subcool and change from 100° C to, say, 80° C. (Fig. 1)

Fig. 1



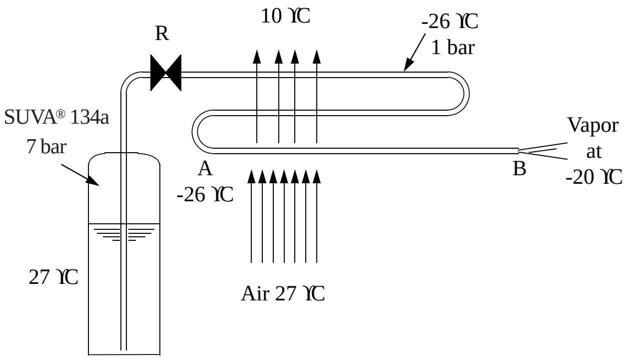
In the case of SUVA®
If we consider the case of SUVA® 134a (1,1,1,2 tetrafluoroethane) we have the following values:

Absolute pressure [bar]	Boiling temperature [°C]	Latent heat of vaporization [kJ/kg]
1	-26,3	217,3
2	-10,1	206,2
3	0,7	198,2
4	8,9	191,8
5	15,7	186,2
6	21,5	181,1

Refrigeration cycle

Evaporation
In order to evaporate, a refrigerant must absorb heat.

Fig. 2



Let us consider the following installation:

a) In the cylinder, SUVA® 134a is liquid at 7 bar.
b) The valve is opened
c) The refrigerant flows into the tube at 1 bar, corresponding to -26.3° C.

Heat is taken from the air at +27° C: the air is cooled to +10° C and the refrigerant changes state from liquid to vapour.

The apparatus in which this change of state occurs is an *evaporator*. (Fig. 2)

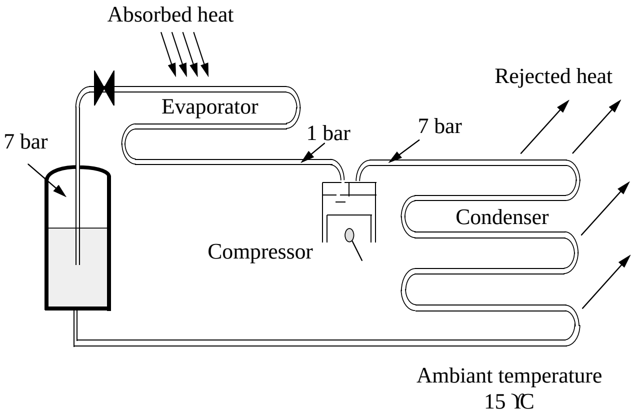
Remark No. 1: If at point A all the refrigerant has been changed into vapour, between A and B the vapour will be superheated: in this example from -26.3° C to -20° C.

Remark No. 2: Each time one kilogramme of SUVA® 134a changes state from liquid to vapour at 1 bar, it requires an energy (heat) input of 217 kJ and is changed into vapour at a density of 5.2 kg/m³.

Compressor condensation

In order to recuperate the refrigerant vapour at the evaporator outlet, we complete the previous set-up as follows (Fig. 3):

Fig. 3



a) Vapour leaving the evaporator enters the compressor, with the inlet valve open.

b) The piston goes down and the total volume of the chamber is filled with vapour.

c) The piston goes up, the inlet valve closes, the pressure in the chamber increases to 7 bar, the exhaust valve opens and the gas at high pressure is let out.

d) The high pressure gas enters the second heat exchanger and gives away heat to the ambient medium. Since the gas is giving heat away, it changes from vapour to liquid.
Vapour is condensed in this heat exchanger called a *condenser*.

e) The liquefied refrigerant is returned to the storage cylinder and the cycle is completed.

Summary

A refrigerant installation is essentially made up of the following components:

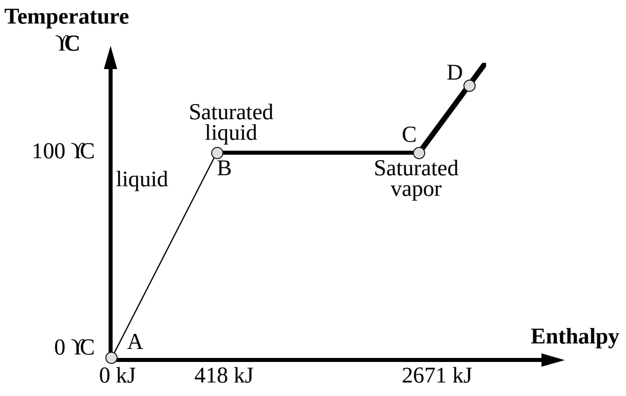
Elements	Roles
Receiver	Reserve of liquid refrigerant allowing to compensate for the variations (leaks or cooling demand) Should be able to contain all the refrigerant in the system.
Accumulator	Vessel on the suction side of the compressor containing a “buffer” volume of superheated vapour. Allows for variations in evaporator load and protects the compressor.
Evaporator	Heat exchanger – absorbs heat from the ambient medium (cools the service medium) and allows evaporation of the refrigerant.
Compressor	A gas pump causing the refrigerant vapour to change from low pressure to high pressure.
Condenser	Heat exchanger – rejects heat from the system. Condensation of the refrigerant occurs in the condenser.
Expansion Device	Allows the refrigerant to go from high to low pressure and regulates the flow into the evaporator.

Diagrams

Water

a) Temperature/Enthalpy

Fig. 4



At atmospheric pressure of 1 bar, one kilogramme of water changes as on Fig. 4.

A-B: The liquid is heated from 0° C to 100° C.

At B the first vapour appears. An energy (heat) input of 418 kJ is required.

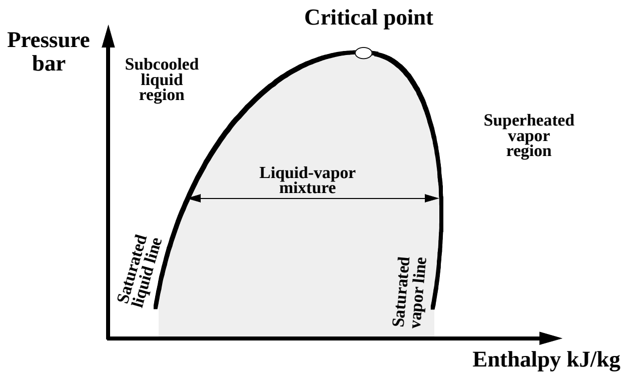
B-C: The fluid is changed from liquid to saturated vapour. At C the last liquid has disappeared. During this change of state, temperature is constant and an energy input of (2671 – 418 kJ) = 2253 kJ is required to ensure this transformation.

C-D: The vapour can be further heated. To increase the temperature of 1 kilogramme vapour by 1° C, an input of 1,88 kJ (0,45 kcal) is required.

b) Pressure/Enthalpy

A diagram as below exists for each type of SUVA® refrigerant (Fig. 5).

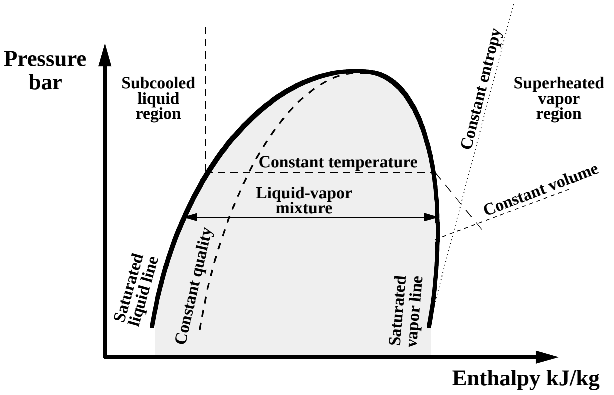
Fig. 5



SUVA® refrigerants

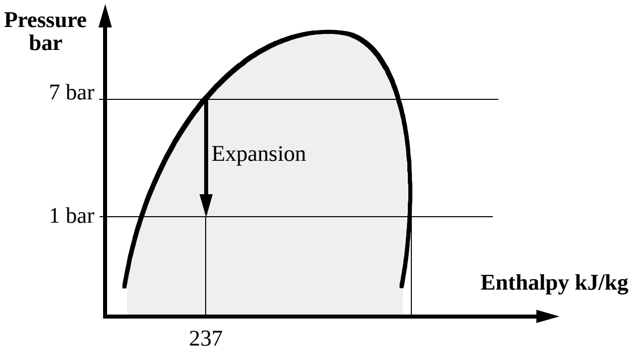
The pressure enthalpy is as follows (Fig. 6):

Fig. 6



a) Expansion

Fig. 7

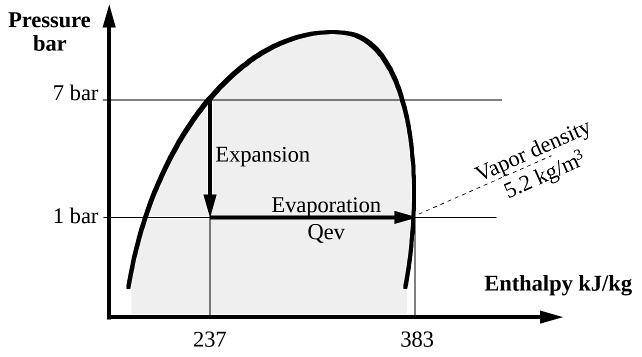


The pressure drops from 7 to 1 bar (Fig. 7), the enthalpy (or internal energy stored in the refrigerant SUVA® 134a) is 237 kJ/kg. We can see that part of the refrigerant has vaporized. This expansion or pressure drop takes place through the *Expansion Device* which is typically a:

- thermostatic expansion valve;
- automatic or electronic expansion valve;
- capillary tube;
- hand-operated valve.

b) Evaporation

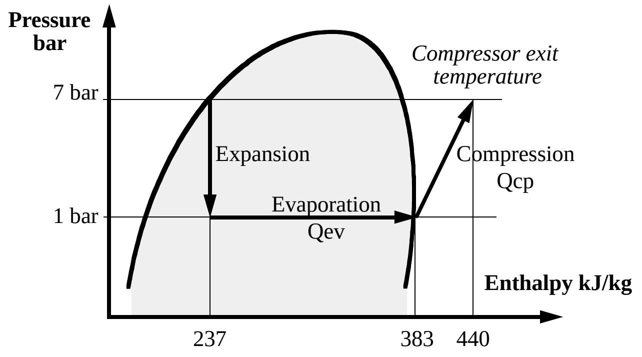
Fig. 8



In order to vaporize, the refrigerant increases its enthalpy from 237 kJ/kg to 383 kJ/kg (Fig. 8); in other words, one kilogramme SUVA® 134a absorbs 146 kJ to complete the change into vapour at 5.2 kg/m³.

c) Compression

Fig. 9

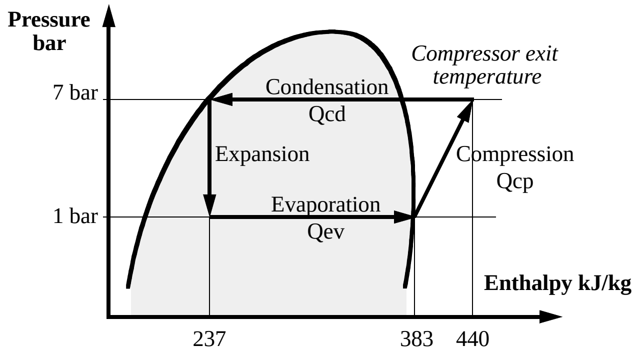


During compression (Fig. 9), the refrigerant takes up energy (heat) corresponding to the work (energy) required by the compressor.

The required work increases with pressure and temperature. The required work is 57 kJ/kg.

d) Condensation

Fig. 10



After the compressor, the refrigerant vapour enters the condenser (Fig. 10).

The first stage allows the vapour to cool down to the temperature corresponding to the saturation curve.

The second stage consists of condensing the refrigerant. In other words, the condenser will evacuate the heat taken up in the evaporator as well as the heat of compression.

Qev + Qcp = Qcd

e) COP

The coefficient of performance is an important ratio in evaluating heat pumps: it also applies to refrigeration.

It can be defined as follows:
COP = (heat obtained)/(heat used) = Qcd/Qcp
In this case: COP = (440-237)/(440-383) = 3.6

2.3
Definition of types of fluorocarbons

CFC: chlorofluorocarbon. Saturated aliphatic molecule containing carbon (C), fluorine (F) and chlorine (Cl) atoms and no others. Best known CFCs are CFC-11 (CCl_3F) and CFC-12 (CCl_2F_2): others include CFC-115 ($CF_3.CC1F_2$). Used as refrigerants, and in the past for other applications such as aerosol propellants, solvents and plastic blowing agents, because of their stability and other unique properties. CFCs are now known to damage the ozone layer.

HCFC: hydro-chlorofluorocarbon. Chemically similar to CFCs with the important difference that HCFCs contain one or more hydrogen (H) atoms. The presence of the hydrogen atom makes the HCFC molecule less stable in the atmosphere than a CFC, consequently less damaging to the ozone layer, but not completely non-damaging. Best known HCFC is HCFC-22 ($CHClF_2$). Others include HCFC-123 ($CF_3.CHCl_2$), HCFC-124 ($CF_3.CHClF$), HCFC-141b ($CCl_2F.CH_3$) and HCFC-142b ($CClF_2.CH_3$).

HFC: hydrofluorocarbon. Saturated aliphatic molecule containing carbon, fluorine and hydrogen. Specifically, a HFC does not contain any chlorine or other halogen, and consequently has no ozone depletion effect, they all have zero ODP. Best known HFC is HFC-134a ($CH_2F.CF_3$): others include HFC-125 ($CHF_2.CF_3$) and HFC-23 (CHF_3). Several HFCs are flammable: HFC-32 (CH_2F_2), HFC-152a ($CH_3.CHF_2$) and HFC-143a ($CH_3.CF_3$). Mixed with other non-flammable refrigerants these may be used in non-flammable blends.

PFC: perfluorocarbon. Molecule contains carbon and fluorine only. Sometimes referred to as “FC”. Examples are PFC-14 (CF_4) and PFC-116 ($CF_3.CF_3$). Perfluorocarbons are generally very long-lived greenhouse gases.

BCFC: bromo-chlorofluorocarbon. Similar to CFCs but with one or more bromine (Br) atoms in the molecule. Sometimes referred to as “halons” because their principal application used to be as fire extinguishing agents: R-13B1 ($CBrF_3$) has been used as a refrigerant. The bromine atom is now known to be more damaging to the ozone layer than the chlorine atom.

Refrigerant fluids are identified by a number based on the original fluorocarbon numbering system developed by Du Pont in the 1930s and adopted world-wide since then. Definitions are issued by ASHRAE, the IIR and national standards authorities such as DIN and BSI. The prefix “R-” (for Refrigerant) frequently replaces the letters used above. For example, R-134a is the same as HFC-134a.

Numbers in the R-500 series, such as R-502, denote azeotropes. The R-400 series refrigerants are non-azeotropes (very occasionally called “zeotropes”), blends or “NARMs” (see below). These numbers are allocated by ASHRAE and do not describe the chemical composition of the refrigerants.

Several non-fluorocarbon fluids are used as refrigerants. They are often called “not-in-kind” (NIK) and are given a “R” designation. These refrigerants often have significant safety implications:

HC: hydrocarbon. Contains only carbon and hydrogen (and is consequently highly flammable and explosive). Examples are HC-290 (propane, C_3H_8) and HC-600 (butane, C_4H_{10}).

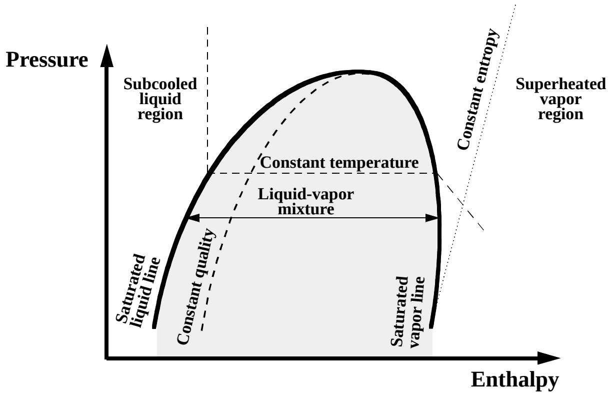
R-700 series denotes inorganic refrigerants, for example R-717 (ammonia, NH_3). Ammonia is flammable, and is very toxic.

2.4
Single component refrigerants and azeotropes

Both single component refrigerants and true azeotropes behave in the same way (Fig. 11). The saturated vapour phase has the same composition as the liquid phase. They boil, and also condense, at one constant temperature for a given pressure, and have a “simple” Pressure/Enthalpy chart.

The original FREON® refrigerants such as R-11, R-12, and R-502 belong to this group, as do some of the new SUVA® refrigerants, for example SUVA® 123 and SUVA® 134a.

Fig. 11

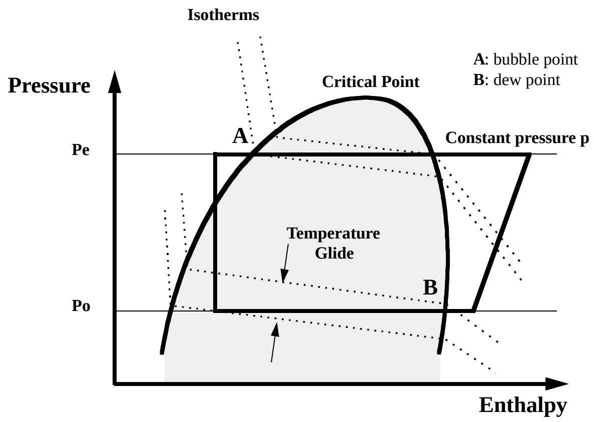


2.5
Non-Azeotropic Refrigerants

The Non-Azeotropic Refrigerants which interest us are blends which behave to a limited extent in a similar way to true azeotropes. For this reason they are generally referred to as non-azeotropic refrigerants, or sometimes as NARMs, which stands for Near Azeotropic Refrigerant Mixtures (or fluids). All the refrigerants of the ASHRAE R-400 series are included in this group. These include SUVA® MP39 (R-401A), SUVA® MP66 (R401B), SUVA® HP80 (R-402A), SUVA® HP81 (R-402B), SUVA® R-404A, SUVA® R-407C and SUVA® R-410A.

For these refrigerants the composition of the saturated vapour is different from that of the saturated liquid (Fig. 12). This means that as evaporation proceeds (as the vapour quality increases in the evaporator), the composition of the boiling liquid changes. This change in composition is associated with a change (an increase) in boiling point temperature at the given pressure. Thus, during the process of evaporation of these refrigerants, at constant pressure, there is an increase in the temperature. This increase in temperature is called the *“Evaporator Temperature Glide”*.

Fig. 12



Conversely, during condensation, as the vapour quality decreases, there is a fall in the equilibrium condensing temperature at constant condensing pressure *(Condenser Temperature Glide)*.

These Temperature Glides are different for each refrigerant: and the Evaporator Glide is often a slightly different value than the Condenser Glide for a given refrigerant. In the case of the SUVA® refrigerants the Evaporator Glides range from around 0.5K for SUVA® HP62 to as much as 6K for SUVA® 9000.

The Saturation Property Tables of these non-azeotropic refrigerants are slightly different in format from those for single component, or azeotropic, refrigerants. The non-azeotropes have two different Saturation Pressure/Temperature curves : one for the Saturated Liquid, also known as the *Bubble Point*, and the other for the Saturated Vapour, also known as the *Dew Point*. This compares to the one curve representing Saturated Liquid *and* Vapour for single refrigerants or true azeotropes. In the property tables for non-azeotropes or blends, the different Pressure/Temperature values for both Saturated Liquid and Saturated Vapour are given.

The Pressure/Enthalpy charts for non-azeotropic refrigerant blends are also slightly different from those for single-component refrigerants. The *isotherms*, or lines of constant temperature, in the two phase region are *not* parallel to the *isobars*, or lines of constant pressure. Fig. 12 the Evaporator and Condenser glides can be seen.
The Pressure/Enthalpy chart for a non-azeotrope is used as explained in the Fig. 12 to define and describe the operation of the refrigeration system.

2.6
The practical implications of using Non-Azeotropic Refrigerants

There are certain important differences between non-azeotropes and single-component refrigerants that must be borne in mind when using SUVA® Blends. These will be described in more detail in the appropriate sections of this manual.

1) Always charge liquid phase. Because the equilibrium vapour composition is different from the composition of the liquid, the refrigerant must be transferred from its container using the liquid line. If the cylinder does not have a dip-tube, it must be turned upside-down. It is not a problem if the liquid flashes into vapour after it has entered the transfer line. This liquid phase charging is not necessary if the entire contents of the cylinder is to be transferred to one refrigeration unit.

2) When adjusting the operation of the refrigeration system it is important to use the correct Saturation Curve :
For Evaporator Superheat (compressor suction) the *Saturated Vapour* (Dew Point) values should be used.
For Condenser Subcooling the Saturated Liquid (Bubble Point) values should be used.

3) The effective Condensing Temperature is the average of the Bubble and Dew Point Temperatures for the given pressure. In calculating the effective Evaporating Temperature, allow for the Flash Gas.

3 DuPont SUVA® Refrigerants

3.1
The range of DuPont SUVA® Refrigerants

SUVA® Refrigerants are tailored to replace CFC refrigerants, either in retrofitting existing equipment or for first fill in new equipment. To ensure optimum performance while maintaining non-flammability, retrofit refrigerants are usually blends. All of the SUVA® range of refrigerants have very low, or zero, Ozone Depletion Potential (ODP). All are non-flammable, even in the event of a leak or a spill. All have very low toxicity.

The DuPont SUVA® range of refrigerants consists of blend; and single components (or pure products). Most of the SUVA® Blends have been allocated R- numbers by ASHRAE, in the R-400 series for non-azeotropes.

DuPont SUVA® Designation BLENDS:	ASHRAE Number	Boiling Point at 1.01325 bar	Composition wt%
SUVA® MP39	R-401A	-33.0° C	HCFC-22: 53% HFC-152a: 13% HCFC-124: 34%
SUVA® MP52	R-401C	-28.4° C	HCFC-22: 33% HFC-152a: 15% HCFC-124: 52%
SUVA® MP66	R-401B	-34.7° C	HCFC-22: 61% HFC-152a: 11% HCFC-124: 28%
SUVA® HP80	R-402A	-49.2° C	HCFC-22: 38% HFC-125: 60% HC-290: 2%
SUVA® HP81	R-402B	-47.4° C	HCFC-22: 60% HFC-125: 38% HCFC-124: 2%
SUVA® 404A	R-404A	-46.5° C	HFC-125: 44% HFC-143a: 52% HCFC-134a: 4%
SUVA® 407C	R-407C	-43.6° C	HFC-125: 25% HFC-134a: 52 % HFC-32: 23%
SUVA® 410A	R-410A	-51.8° C	HFC-32: 50% HFC-125: 50%
SUVA® 95	R-508B	-88.0° C	HFC-23: 46% HFC-116: 54%

Pure Products: HCFCs (Hydro-chlorofluorocarbons)	Boiling Point 1.01325 bar	Chemical Formula
FREON® 22	-40.8° C	$CHClF_2$
SUVA® 123	27.8° C	$CF_3.CHCl_2$
SUVA® 124	-12.1° C	$CHF_2.CClF_2$

Pure Products: HFCs (Hydrofluorocarbons)	Boiling Point 1.01325 bar	Chemical Formula
FREON® 23	-80.0° C	CHF_3
SUVA® 125	-48.1° C	$CHF_2.CF_3$
SUVA® 134a	-26.1° C	$CH_2F.CF_3$

HFCs that are flammable as a single product are not designated SUVA® because of their flammability. These products may be used as components in SUVA® Blends with non-flammable products, which suppress their flammability. SUVA® Blends that contain flammable HFCs are safe to handle, even in the event of a leak or a spill.

Pure Products: HFCs (Flammable Hydrofluorocarbons)	Boiling Point 1.01325 bar	Chemical Formula
HFC-32	-51.7° C	CH_2F_2
HFC-143a	-47.7° C	$CH_3.CF_3$
HFC-152a	-24.1° C	$CH_3.CHF_2$

3.2
Selection of DuPont refrigerants

The choice of a SUVA® refrigerant will depend on the application as well as on the type of CFC to replace. Typical applications, and the recommended SUVA® Refrigerants, are:

		DuPont SUVA® Refrigerants	
Application	CFC/HCFC refrigerants	Retrofit	New Systems
Air Conditioning in buildings and Industrial temperature control	R-11	SUVA® 123	SUVA® 123 or
	R-12	SUVA® 134a SUVA® MP39*	SUVA® 134a
	R-22	SUVA® 407C	SUVA® 407C SUVA® 410A
Split and Window A /C systems	R-22	SUVA® 407C	SUVA® 407C SUVA® 410A
Air and Marine A/C systems	R-114, R-12B1	SUVA® 124	SUVA® 124 SUVA® 236fa
Automobile Air Conditioning	R-12	SUVA® 134a SUVA® MP52	SUVA® 134a
Fresh food storage, above 0° C	R-12	SUVA® MP39	SUVA® 134a
Domestic Refrigerators, Drink Coolers, Commercial and Restaurant non-frozen chilled food storage	R-12	SUVA® MP39	SUVA® 134a
Light commercial refrigeration	R-22	SUVA® 404A	SUVA® 404A SUVA® 404A
Frozen Food storage below -18°C	R-502	SUVA® HP80 SUVA® HP81	SUVA® 404A
Refrigerated Transport	R-12	SUVA® MP66	SUVA® 134a
Low Temperature Transport	R-502	SUVA® HP80	SUVA® 404A
Medium Temperature commercial refrigeration	R-12, R-500	SUVA® MP39 SUVA® MP66	SUVA® 134a
Low to Medium Temperature commercial refrigeration	R-22	SUVA® 404A	SUVA® 404A
Very low temperature	R-13B1 R-13 R-503	SUVA® 410A HFC-23 SUVA® 95	SUVA® 410A HFC-23 SUVA® 95

* In direct expansion systems only

This list is intended as a guide, to cover the situations most likely to be encountered. The equipment owner may request the use of the permanent or "New System" refrigerant in a retrofit, usually to ensure the lowest ODP. Retrofitting directly to a SUVA® HFC Refrigerant can of course be done, but takes longer and costs more than the simple change to a SUVA® Blend.

4 Compatibility of SUVA® Refrigerants with materials

4.1
Thermal decomposition

SUVA® refrigerants will decompose when exposed to high temperatures or to a naked flame. Decomposition may produce toxic and irritating compounds, such as hydrogen chloride or hydrogene fluoride. The decomposition products released will irritate the nose and throat. Therefore it is important to prevent decomposition by following DuPont Material Safety Data Sheet (MSDS) recommendations for handling and use.

4.2
Compatibility with materials

Because the SUVA® refrigerants will be used in many different applications, it is important to review materials of construction for compatibility when designing new equipment, retrofitting existing equipment and preparing storage and handling facilities. Since SUVA® products have been developed as refrigerants, the compatibility data summarised here includes materials commonly used in refrigeration applications.

4.2.1
Compatibility with metals

Most commonly used construction metals, such as steel, cast iron, brass, copper, tin, lead and aluminium, can be used satisfactorily with SUVA® refrigerants under normal conditions of use. At very high temperature (such as experienced during brazing) some of the metals may act as catalysts for the breakdown of the compound.

Magnesium alloys and aluminum containing more than 2% of magnesium are not recommended for the use in systems containing SUVA®, particularly where water may be present.

Most of the halocarbons may react violently with highly reactive materials, such as the alkali and alkaline earth metals, sodium, potassium, barium, etc., in their free metallic form. Materials become more reactive when finely ground or powdered, and in this state magnesium and aluminum may react with compounds containing fluorine especially at higher temperature. Highly reactive materials should not be brought into contact with hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC) until a careful study is made and appropriate safety precautions are taken.

4.2.2
Compatibility with elastomers

Laboratory tests showed that elastomers normally used with R-12 are compatible with the SUVA® MP blends. Tests also showed no compatibility problems with metals, plastics, wire insulation and other components normally used in R-12 systems.

There is considerable variation in the effect of SUVA® refrigerants on elastomers and rubbers used as “O” rings, in shaft seals and other applications. This is because such parts are compounded from the basic polymer together with plasticizers and other products. In laboratory tests, samples of elastomers were immersed in the liquid refrigerant at room temperature until maximum, or equilibrium, swelling occurred. Elastomers which swell excessively are not recommended for use in refrigeration systems with SUVA® refrigerant.

4.2.3
Compatibility with plastics

A brief summary of the effect of the SUVA® refrigerants on various plastic materials is given in the table on the next page, but compatibility should be tested for specific applications. Differences in polymer structure and molecular weight, plasticizer, temperature and other factors may alter the resistance of the plastic to SUVA® refrigerants.

Compatibility of plastics with SUVA® Refrigerants

Rating: 0 – compatible 1 – borderline 2 – incompatible

Refrigerant		R-11	SUVA® 123	R-12	SUVA® 134a	SUVA® MP	R-22	SUVA® 407C	SUVA® 410A	R-502	SUVA® HP80/81	SUVA® 404A	SUVA® 124
Plastic	Trademark												
HDPE	Alathon®	1	1	1	0	1	1	0	0	1	-	0	0
PP		2	1	1	0	1	1	1	1	1	1	0	1
PS	Styron®	2	2	1	1	2	2	1	1	2	2	1	1
Polyvinvyl Chloride													
PVC		1	1	0	0	1	1	0	0	1	1	0	0
CPVC		0		0	0	1	1	0	0	1	1	0	0
Fluorocarbon													
PTFE	Teflon®	1	1	1	1	1	1	1	1	1	1	1	1
ETFE	Tefzel®	1		1	1	2	1	1	1	1	1	1	2
PVDF		0		0	1	1	1	1	1	1	1	0	0
Ionomer	Surlyn®	2		1	0	1	1	0	0	1	1	0	1
Acrylic	Lucite®	0	2	0	2	2	2	2	2	2	2	2	2
ABS	Kralastic®	0	2	0	0	2	2	2	2	2	2	0	2
Cellulosic	Ethocel®	2	2	2	2	2	2	2	2	2	2	2	2
Epoxy		0	0	0	0	0	0	0	0	0	0	0	0
Acetal	Delrin®	0	1	0	0	1	1	1	1	1	0	0	0
PPO	Noryl®	2		0	0	2	2	1	1	2	2	0	0
PC	Tuffak®	0	2	0	0	2	2		1	2	2	0	0
Polyester													
PBT	Valox®	0		0	0	0	0	0	0	0	0	0	
Polyarylate	Arylon®	0		0	0	2	2	1	1	2	2	0	
Nylon	Zytel®	0	0	0	0	0	0	0	0	0	0	0	0
PI	Vespel®			0			0	-		0	0	0	0
PEI	Ultem®	0		0	0	0	1	-	-	1	-	0	0
PPS	Ryton®	1		0	0	1	1	0	1	1	1	0	1
Polysulfone		0		0	0	2	2	1	1	1	2	0	0

5 Lubricants and their behaviour with SUVA® Refrigerants

Lubricants are an essential component of all refrigerant systems. A refrigeration compressor requires lubrication like any mechanical equipment. Oil is necessary to lubricate the bearings, and the pistons in the case of a reciprocating compressor. In addition, particularly in a screw compressor, the oil acts as a seal: it performs this sealing function to a lesser, but important, extent in other types of compressors. Within the compressor, the oil helps to absorb and carry away the heat generated by the working of the compressor.

5.1
Lubricants for use with SUVA® Refrigerants

In almost all cases the mineral oils (MO) previously used with CFC refrigerants should not be used with the new HFC- containing refrigerants. This is because these new refrigerants have very different solvent properties from CFCs.

While the new HCFC containing refrigerants do have a slightly lower miscibility with mineral oils than do the CFC refrigerants extensive field experience has shown that, in practice, in many situations, these new refrigerants do perform reliably when using mineral oils.

Synthetic oils are now available that have been tested extensively with SUVA Refrigerants. The three types that are now most used are:

Alkyl Benzene (AB) oils have been used in the refrigeration industry for over 25 years: selected for high miscibility with HCFC refrigerants (and with CFCs), and for excellent thermal stability. They are currently used in many low temperature applications when CFCs or R-22 is used. AB oils are only used in specific applications with HFCs.

Polyester (POE) lubricants are particularly recommended for most applications with HFCs. The basic product can be “tailored” for optimum performance in specific equipment or applications. POE lubricants are first choice with SUVA® 134a, SUVA® 407C, SUVA® 410A or SUVA® 404A. POE lubricants will absorb moisture from the air and should be handled carefully.

Polyalkylene Glycol (PAG) lubricants are widely used in mobile applications such as automobile air conditioning with SUVA® 134a. (PAGs have a strong affinity for water and are particularly liable to pick up moisture from the atmosphere, therefore care in handling is essential.) POE lubricants also absorb atmospheric moisture, and should be handled so as to minimise exposure to air.

Compressor manufacturers carry out extensive test programmes of oils for use with their equipment, and issue recommendations based on their own tests and experience. Their advice should always be taken into consideration. If the compressor is under warranty when an oil change is made, to use an oil not approved by the compressor OEM might invalidate the warranty. Even if the compressor is no longer under warranty, the advice of the OEM should not be disregarded without good reason.

5.2
Miscibility of lubricants and SUVA® Refrigerants

AB oils and MO are mutually miscible. AB oils with SUVA® MP Blends can tolerate much more residual MO than POE lubricants with HFC refrigerants. Retrofitted systems with AB and SUVA® MP39 have operated satisfactorily containing 50% MO. When the new refrigerant is SUVA® 134a and the new lubricant is POE, experience indicates that up to 5% or exceptionally 10% of MO can be allowed to remain in the system. For evaporating temperatures below -20° C, 5% of MO should be regarded as the maximum.

5.3
Residual mineral oil

When “retrofitting” or converting an existing system from CFC-12 or another CFC refrigerant to a SUVA® Refrigerant, it will be necessary to change the mineral oil to another lubricant type (see above). Most of the old oil will be in the compressor crankcase: it can be drained and sent for disposal at the same time as the CFC refrigerant is removed and sent for reclamation. However the oil in the refrigeration circuit may be a significant quantity, depending on the design of the system, particularly the length of the piping runs.

The effect of too much residual MO will be oil return problems and possibly heat transfer problems also. If the system is equipped with sufficient instrumentation to detect loss of cooling performance, it can be checked: if it is performing poorly, an additional oil change should be carried out. If the consequences of system under-performance would be serious, for example in process temperature control or in holding chilled or frozen food within close limits, an extra oil change should be considered as an insurance.

The major oil companies that specialise in producing and supplying refrigeration oils offer analytical services to inform the refrigeration engineer of the proportion of MO to AB or POE lubricant: and also, separately, of the condition of the MO, which may have deteriorated during use. Oil test kits that can be used in the field to measure the residual mineral oil content in POE lubricant are readily available.

5.4
Lubricant quality

Refrigeration oils have special requirements beyond those of other industrial lubricants. With a few exceptions, the oil is in constant contact with the refrigerant and to a greater or lesser extent circulates with it. The oil must be able to circulate freely throughout the system: it must remain fluid at low temperatures so as not to accumulate in the evaporator. The oil must at the same time be viscous enough to lubricate and to perform its sealing function at relatively high temperatures in the compressor. Stability is essential because the oil remains constantly in the system, where it is in continual contact with system components in different materials, and with the refrigerant itself.

Some oil is likely to leak into the circuit even with an externally lubricated or “oil-free” compressor.

The essential properties of a refrigeration oil are:

- Adequate lubrication
- Stability
- Solubility in refrigerant

(Other properties include low floc point and, for hermetic or semi-hermetic compressors, dielectric strength).

As explained above, natural mineral oils are not used with modern non-CFC refrigerants, with the exception of HCFC-22. All HFC refrigerants, including SUVA® blends, operate with various types of tailor-made “Synthetic” oils.

5.5
Lubricant viscosity

It is necessary to distinguish between the *standard viscosity* of an oil, used to identify it, and the actual viscosity of that same oil in a refrigeration system.

5.5.1
Standard viscosity

Standard viscosity is measured at 40°C and expressed in centiStokes (cSt). Lubricants in use range from 15 to more than 170 cSt. Those most frequently used are either 32 or 68 cSt viscosity. Lower viscosities are used in the smaller hermetic compressors. Higher viscosities such as 100 cSt are found in large compressors, particularly screw and centrifugal types.

Compressor OEMs specify the types of lubricant suitable for use in their compressors, primarily by their viscosity. In most cases the compressor is shipped from the factory charged with lubricant from a particular supplier. The OEM’s technical bulletins normally specify a number of lubricants from other suppliers which are technically acceptable as service replacements. These include retrofit guidelines for changing from CFC to replacement refrigerants. This is based on the testing and experience of that manufacturer.

In the USA, oil viscosity is measured at 100°F (37.8° C) by a different method, and the result is expressed in Saybolt Universal Seconds (SUS or SSU). The two scales do not correspond exactly, but for the viscosities most frequently encountered, an approximate conversion is:

■ 150 SUS	32 cSt
■ 300 SUS	68 cSt
■ 450 SUS	100 cSt

5.5.2
Viscosity in a Refrigeration system

The lubricant in a refrigerant system is exposed to very considerable variations in temperature. For example, with a hermetic compressor system charged with HCFC-22, evaporating at -40° C, the compressor discharge temperature may be as high as 177° C. The oil in circulation with the refrigerant therefore experiences a temperature difference of over 200° C in a period that may be only a few minutes.

In addition to the effect of temperature on the viscosity of the oil, the refrigerant also affects the viscosity. Refrigerant dissolves in the oil, and the oil/refrigerant mixture has a lower viscosity than the oil by itself. The amount of refrigerant dissolved in the oil at a given point in the circuit is a function of:

- The type of refrigerant.
- The lubricant.
- Temperature: more refrigerant will be dissolved in the oil at a lower temperature. As the temperature of the lubricant rises, refrigerant will boil off out of the solution.
- Pressure: an increased pressure will counteract the effect of rising temperature by forcing the refrigerant to remain in the solution.

The viscosity of the refrigerant/lubricant mixture affects how easily the lubricant phase can be returned to the compressor. Even if a refrigerant and lubricant are immiscible, the refrigerant may be partially soluble in the lubricant. Refrigerant solubility in the lubricant helps to reduce the viscosity of the lubricant, making it easier for the lubricant phase to flow through the system

In a refrigeration system, a lubricant which is immiscible with the refrigerant will form a separate phase and can collect (generally referred to as “oil logging”) in the evaporator or at low points in the system.

5.5.3
Lubricant Circulation: Oil return to the compressor

In a well-operating system, all the lubricant that leaves the compressor moves around the circuit with the refrigerant and returns to the compressor, where it again acts as a lubricant. This does not always happen, and lubricant may accumulate in the circuit. The two main effects of this are to starve the compressor of lubricant, which may cause lubrication problems: and the refrigerant circulation may be obstructed, with a consequent loss of efficiency.

One possible reason for poor lubricant return may be using a lubricant with too high viscosity. As noted above, compressor OEMs specify the lubricant viscosity, but may suggest a range of viscosities. If lubricant return is a problem, it may be useful to check that the lowest recommended viscosity is in use.

Since the evaporator is the coldest point in the circuit, it might be assumed that lubricant viscosity will be highest there. This is not always the case. Because of the dilution effect of refrigerant dissolved in the lubricant, highest viscosity is normally found in the suction line, at the point where the superheat (increase in temperature above the evaporating temperature) is about 20 – 25° C.

A heat exchanger between the liquid and suction lines can usefully be fitted at this point.

System geometry and line velocities can help to physically move the oil through the system and back to the compressor, even for immiscible lubricant/refrigerant mixtures. Field experience with R-401A and R-402A has shown that mineral oil can successfully be returned to the compressor in systems, such as refrigerator/freezers, with the compressor located at the base of the unit. Systems with long runs of piping or with low points in the piping which can trap oil need a more miscible lubricant (such as AB) to return oil to the compressor.

The suction line should have sufficient gas velocity. Recommended viscosities are approximately 3.5 m/s (200 m/mn) in horizontal lines: and 7.5 m/s in vertical risers. Velocities should not exceed 15 m/s to reduce noise and to avoid excessive pressure drop. Good piping design in larger systems includes sloping the line towards the compressor, and installing traps at the top and bottom of vertical lines.

5.5.4
Lubricant separator

A lubricant separator is a device, normally fitted in the hot gas line immediately downstream of the compressor, which separates lubricant droplets from the refrigerant stream. The lubricant is then returned directly to the compressor, which eliminates, or at least reduces, lubricant circulation problems. A lubricant separator is essential with a twin-screw compressor, which uses large quantities of lubricant. It is useful in a system that combines a compressor whose manufacturer specifies a high-viscosity lubricant, with a low evaporating temperature. A lubricant separator should always be fitted in a flooded evaporator system, and is recommended for any system with long or complex piping runs, or low gas velocity. Many compressor OEMs include a lubricant separator as a standard option. They can also be purchased as a separate item.

Although a lubricant separator is often the solution to lubricant circulation problems in large or medium-sized systems, these point should be borne in mind:

- A lubricant separator is a pressure vessel, subject to the relevant codes and standards: it may therefore be a significant addition to the cost of the installation.
- It is difficult to clean a lubricant separator after a burn-out.
- Lubricant separators vary in efficiency: some lubricant will usually pass through into the circuit. The gas velocity recommendations of approximately 3.5 m/s in horizontal lines and 7.5 m/s in vertical risers should not be disregarded even if a lubricant separator is fitted.
- In a large system with long piping runs a refrigerant circulation pump is often fitted. Lubricant in the circulating refrigerant will lubricate the pump.

5.6
Charging the lubricant

5.6.1
Lubricant and service refrigerants

As stated above, always consult the compressor OEM, or refer to the OEM’s technical literature for specific lubricant recommendations and retrofit guidelines for the alternative refrigerant, particularly if the system is still under warranty. Failure to follow the manufacturer’s recommendations could void the warranty of the equipment.

5.6.2
Precautions

If lubricant is not handled correctly, air and moisture can enter the system, either directly or in the lubricant.

Keep lubricant containers sealed until the moment of use. As far as possible, purchase lubricant in the correct-sized containers for each job. Never pour lubricant in the open from one container to another.

Charge lubricant into a compressor using the methods outlined below, or equivalent methods recommended by the compressor manufacturer.

When removing used lubricant from a compressor, wear eye protection and rubber, neoprene or similar gloves. Degraded lubricant may contain acidic products.

5.6.3
Charging the lubricant

This is necessary in these cases:

Although most new compressors are supplied already charged with lubricant, there may be exceptions where an initial charge is the responsibility of the installation or service engineer.

A “top-up” charge is normally required to compensate for the part of the initial charge that is in circulation. Check the compressor manufacturer’s instructions for the correct level in the lubricant sight glass: this may vary from one model to another. Read the level when the system has settled down under normal operating conditions. Overfilling with lubricant can damage the compressor.

When changing refrigerant, it is usually necessary to change the lubricant. The volume of the new lubricant to be charged is normally the same as the volume removed. It will be less than the complete initial charge, unless it has been decided to remove the lubricant in circulation as well.

Lubricant may have degraded in service, and need to be replaced for that reason.

5.6.4
Normal lubricant charging procedure

This is the same in all the cases above:

1) Equipment required:

- Vacuum pump.
- Charging line, fitted with a shut-off valve and a screw connection to match the thread of the lubricant filler plug on the compressor.
- Pressure gauge: not absolutely essential, but useful.

1) Pump down the system to reduce loss of refrigerant, then isolate the compressor by closing both service valves. Connect the vacuum pump to one of the service valves. Reduce pressure within the compressor to a slight positive pressure - approx 0.1 bar – then stop pump. Remove compressor lubricant plug, screw in charging line with shut-off valve closed.

2) Carefully open suction service valve. Let sufficient refrigerant vapour enter the compressor to restore the slight positive pressure, then close suction service valve. Open the shut-off valve in the charging line to purge air. Remove cap from lubricant container and insert the end of the charging line to the bottom. Close shut-off valve.

3) Re-start vacuum pump. When pressure in the compressor is slightly below atmospheric, open the shut-off valve carefully. Fill lubricant to correct level, as shown in compressor sight-glass, then close shut-off valve.

4) Stop vacuum pump, restore slight positive pressure by opening the suction service valve as before. Disconnect charging line and replace lubricant filler plug.

This method of charging lubricant makes sure that no air or moisture will enter the system. There will be a small loss of refrigerant, which may need to be replaced.

Be careful not to empty the lubricant container completely, as this will pump air into the compressor. If this does happen, replace the lubricant filler plug and pull a complete vacuum.

Small quantities of lubricant, to “top up” the lubricant charge can be added using a lubricant syringe. Air will not enter the system during the short time that the lubricant filler plug is open because refrigerant dissolved in the lubricant in the compressor crank-case will maintain the necessary slight positive pressure, as it comes out of solution.

If a ***lubricant pump*** is available, it should be used. A well-designed lubricant pump can fill lubricant in measured quantity against the pressure in the compressor crank-case.

5.6.5
Draining lubricant

Draining lubricant is necessary:

- When changing from CFC to SUVA® Refrigerant requires removing the major part of the Mineral Lubricant.
- If the lubricant has degraded and become acid during service.
- After a burn-out: If there is any doubt that the clean-up was not completely successful.

5.6.6
Recommended method

Equipment required:

- Vacuum pump.
- Connecting line.
- Receptacle for lubricant to be removed: an old lubricant container can be used, but a graduated glass flask is recommended.
- A length of copper tubing: shaped, and of suitable diameter, so that when it is inserted through the lubricant filler opening in the compressor, the end reaches bottom of the crank-case sump.
- Plastic sealing material.
- Seal the connecting line , and the vacuum line, into the top of the receptacle, using the plastic sealing material or “mastic”.
- Close both service valves to isolate the compressor.
- Start the vacuum pump. By pulling a vacuum in the receptacle, this draws the lubricant out of the compressor into the receptacle. If, as recommended, this is a graduated glass flask, the engineer can check the quantity and colour of the lubricant withdrawn.

5.6.7
Alternative method

Refrigerant pressure can be used instead of vacuum. The same length of shaped copper tubing is used: however it is sealed into the lubricant filler opening in the compressor. Sufficient refrigerant vapour is let into the compressor through the suction service valve to create a positive pressure in the crank-case. This causes the lubricant to flow out into the receptacle.

This method removes the lubricant less completely than the Recommended Method. It is more suitable for taking a small sample of lubricant for analysis.

5.6.8
Possible entry of air

After removing lubricant by either method, there is a danger that air, with its associated moisture, may have entered the compressor. Counter pressure of refrigerant coming out of solution from the lubricant will certainly limit the entry of air, but may not keep it out altogether.

Before starting to charge fresh lubricant, flush any air out of the compressor by opening the suction service valve. Quickly screw in the lubricant filler plug, then close the valve. Most air, and air-borne moisture, will be driven out through the lubricant filler opening.

If the compressor has been open to atmosphere for any length of time, and particularly if solvent has been used to flush out polymerised lubricant or sludge, pull a complete vacuum on the compressor before charging fresh lubricant. The purpose of this work is to get clean, moisture-free, lubricant into an uncontaminated system.

6 How to deal with contaminants

6.1
Importance of keeping system free of contaminants

Almost all system breakdowns can be traced back to the presence of some undesirable contaminant. Systems today operate at high temperatures, with fast-running compressors and close tolerances. Total system cleanliness must be the aim of every installation engineer. It is equally necessary that the field service engineer, called in to repair or replace a component, does not spoil his good work by introducing contaminants that will cause trouble later.

It must be remembered that a refrigeration or air conditioning system is a closed circuit. Once a contaminant enters the system it will stay there: only action by a service engineer can remove it.

The action of contaminants is usually slow. A system may start up initially and run perfectly: a few months, or even years, later it may be found to be badly damaged, perhaps beyond repair. The good reputation of a service engineer, of an installation or service company, and ultimately of the whole industry, depends on accurate and conscientious work.

6.2
The principal contaminants

The principal contaminants are:

- Air
- Water
- Oxides
- Solid particles

Others, less frequently encountered, are:

- Anti-freeze agents
- Soldering flux
- Solvents, particularly chlorinated solvents
- Unsuitable leak detection dyes
- Nitrogen and other gases are included in the paragraph on air

6.2.1
Air

Air must be removed from the system to make it possible to charge the refrigerant. If a small amount of air remains, the system will be able to operate, but there will be problems.

Air includes atmospheric moisture, which will cause rusting of iron or steel parts, and corrosion of other parts. Air will oxidise the lubricant, causing it to form sludge, and will oxidise other components.

Air and other gases such as nitrogen have an additional bad effect. The general name given to these gases is non-condensible gas (NCG). At normal compressor operating temperatures these gases are not compressed as readily as SUVA® Refrigerant vapour. This causes higher pressure, and consequently higher temperature, in the cylinder head and discharge valve. This is precisely the part of the system that already has the highest temperature. A higher temperature is undesirable. Generally speaking, any chemical reaction proceeds twice as fast for every 10°C rise in temperature. Thus systems with excessive air or other NCG will be significantly less stable than one that has been properly evacuated.

There may be a good design reason for operating a compressor at a high temperature. But from the point of view of stability, the lower the temperature the better.

Nitrogen that has been used to protect parts of the system during welding or brazing must be removed afterwards. Dry nitrogen is pumped into new compressors before they leave the factory to protect the interior of the compressor from corrosion. This is good practice, but the compressor lubricant becomes saturated with nitrogen. Nitrogen is practically inert, and is therefore less dangerous than air, but it is a NCG that resists compression. It must be fully evacuated to avoid over-heating the compressor.

6.2.2
Water

It should be noted that water aggravates the effect of other contaminants. If a system contains air but is perfectly dry (an unlikely situation in practice), rust will not form. All acids, and particularly inorganic acids such as hydrochloric and hydrofluoric acids, are more corrosive in the presence of moisture than in a dry system.

6 2.3
Oxides

The principal oxides that may be encountered in a refrigeration system are:

- Red iron oxide Fe_2O_3
- Black iron oxide Fe_3O_4
- Red copper oxide Cu_2O
- Black copper oxide CuO
- Iron oxides (rust is Fe_2O_3) are most frequently due to the action of air and water. When a compressor is opened and dismantled for repair work, all internal surfaces must be protected at once with lubricant or grease, which is to be removed immediately before reassembly.

- Copper oxides are usually due to incorrect brazing techniques (see Chapter 9, Brazing and Soldering).
- Oxides may react further to produce corrosive metal salts, and if water is present this reaction may continue almost indefinitely.
- Rust will tend to separate from the metal surface as solid particles.

6.2.4
Solid particles

Most solid particles enter the system as a result of careless preparation and assembly. See Paragraph 9.1 below for recommendations on cutting tubing. Pipes and components should not be forced into place, as this can cause small metal particles to break off. Tubing, and components such as sight-glasses and filter-driers, are normally supplied with protective caps. These should be kept in place until immediately before being fitted, to prevent dust from entering.

Fine metallic particles may appear during the “running-in” period of a new compressor. Rust, as noted above, may form in the system. Solid particles can block the expansion device, and cause wear in the compressor.

The main protection against solid particles is the metal mesh screen of the filter-drier. In bad cases, this too can become blocked and will need to be changed. The compressor lubricant pump also normally incorporates a filter screen of, typically, 25 microns (0.025 mm). New compressors are also very often fitted with a **compressor suction filter**. When installing the compressor, make sure that this filter can be removed easily.

Some compressor manufacturers recommend that the suction filter be removed and discarded after an initial running-in-period. It is probably better practice to replace the filter with a new one, or clean and replace the old filter. This way, the compressor has long-term protection against solid particles. If the suction filter is retained, inspection and cleaning or replacement should be part of the regular maintenance schedule. A blocked filter is better than no filter, but it will interfere with the running of the system and may even stop it.

It is good practice to change the lubricant after a new open or semi-hermetic compressor has run for a short period. This is normally covered by the compressor manufacturer's recommendations or instructions, which should be followed.

6.2.5
Other contaminants

Although less frequent, these are possible causes of trouble.

Anti-freeze agents should never be used, because most commercial antifreezes are oxidants, and may also be unstable at compressor temperatures. Should one of these products have been added to a system, this is one of the rare cases (other than a burn-out) where a complete change of the refrigerant and lubricant is justified.

Soldering flux is usually reactive, causing corrosion, and also virtually insoluble in SUVA® refrigerants. Use the techniques outlined in Chapter 9 to prevent flux from entering the system. Once in a system, flux is very difficult to remove. It may be necessary to replace a blocked component such as a filter-drier.

Solvents such as perchlorethylene and trichlorethylene may have been used as degreasing agents in the manufacture of components. Good-quality components from reputable manufacturers do not contain any residual solvent. Thorough evacuation before charging will remove solvents along with other volatile contaminants. Chlorinated solvents are not recommended and can decompose at high temperatures to produce hydrochloric acid.

6.3
Evacuation

6.3.1
Purpose of evacuating a system before charging

The purpose of evacuating a system before charging is:

- To remove air.
- To remove moisture.
- To remove any gas that may be dissolved in the compressor lubricant, if the compressor is charged with lubricant.

6.3.2
Method of evacuation

The method of evacuation chosen, and the time taken, will depend on:

- Size, or internal volume, of the system.
- Amount of liquid water present in the system.
- Capacity of the vacuum pump.
- Length and diameter of the connecting lines.
- Presence, or absence, of lubricant.

6.3.3
Water present as vapour

Water present only as vapour will be removed with the air, therefore is not a problem.

Liquid water must evaporate and become vapour before it can be removed.

The boiling point of water, which is 100° C at normal atmospheric pressure (1.013 bar), becomes lower at lower pressures.

For most effective moisture removal it is therefore necessary to warm the system: this must be done gently, with a heat lamp or a warm-air electric heater. Never use a welding torch as this could damage a part of the system.

Note: Evacuation is not effective at removing moisture dissolved in POE or PAG oils (see 7.6).

6.3.4
Accurate vacuum at low levels

For reading the vacuum accurately at low levels, a thermocouple vacuum gauge is necessary. The ordinary compound vacuum gauge is only accurate down to about 50 Torr. This is not sufficient for effective deep evacuation.

To determine that evacuation is complete: close the valve between the vacuum pump and the system. Wait five minutes for the slight rise in pressure due to flow ceasing. Read the pressure. After 30 minutes, or longer if possible on a large system, read the pressure again. If there has been no rise in pressure, the system is ready for charging.

6.3.5
Evacuation methods

Deep evacuation in one step to 0,05-0,1 Torr is the most reliable method, but it takes longest.

Triple evacuation is often used, because it is quick and does not require a special vacuum gauge. The system is evacuated to 50 Torr, then the vacuum is broken with dry oxygen free nitrogen (OFN) until it is at atmospheric pressure. This operation is repeated. When the system is evacuated for the third time, it is ready for charging, after checking that there has been no rise in pressure. Break vacuum this time with SUVA® refrigerants.

This method has two disadvantages. It will not remove liquid water, and it causes wasteful emissions of fluorocarbon refrigerant.

One-purge evacuation to 1-2 Torr is a compromise between the other two methods.

Evacuate the system to approximately 2 Torr.

6.3.6
Capacity of the vacuum pump

Capacity of the vacuum pump must be sufficient for the internal volume of the system.. Typically, a pump of 90 l/min. is recommended for a system of 7-8 kW.

Of greater importance than pump capacity is the *length* and *diameter* of the connecting lines. For example, evacuation through a 1/4 inch (6.35 mm) line will take *8 times* longer than through a 1/2 inch (12,7 mm) line. Evacuation by a line 2 m long will take twice as long as through a 1 m line. Two lines are recommended to evacuate the high side and low side simultaneously.

6.3.7
Quantity of liquid water

If any significant quantity of liquid water is present: *a cold trap* is valuable as it serves to protect the lubricant in the vacuum pump from moisture. This moisture may reduce the capacity of the pump to achieve the lower pressures recommended.

Such a trap can be easily fabricated from material available in most shops. All welded joints should be vacuum tight.

6.4
Disposal of contaminated refrigerant

In many cases, contaminated refrigerant can be recovered using special equipment built for this purpose.

Refrigerant that is partially decomposed or very heavily contaminated cannot usually be reclaimed. Attempting to do so may result in damage, by corrosion, to the reclaimer unit and to the cylinders used for transporting the refrigerant to the reclaimer.

Heavily contaminated or decomposed refrigerant must never be discharged either indoors, or outside buildings. This is prohibited by law in most countries. Decomposed refrigerant may contain toxic breakdown products and present a safety hazard.

Contaminated refrigerants must be eliminated in special incineration plants.

Consult your SUVA® distributor on how to have this waste collected for destruction.

Old refrigeration lubricant can be disposed of by burning it. Almost all countries have incineration stations where this work can be done.

7 Water and drying

7.1
Why worry about water?

Too much water in a refrigeration system may lead to the following effects:

1) The formation of ice or hydrate in the expansion valve or capillary tube may restrict the flow of refrigerant or, in severe cases, stop it altogether.

2) Rusting, corrosion, lubricant sludging and general deterioration of the system.

3) Water may not contribute directly to refrigerant decomposition: but the presence of water multiplies the damaging effect of the acids formed in the lubricant/refrigerant reaction.

Note: A hydrate is a solid, similar in appearance to ice or frost. It is a complex molecule, made up of water and refrigerant. Hydrates may form at a higher temperature than ice: and may remain solid at a temperature at which ice would melt.

7.2
How much water is safe?

There is no "safe" level, and there is general agreement that the less water present the better. It should in all cases be below the solubility level (see section 7.4.2).

Water can enter a system with the refrigerant, the lubricant or with the piping and components. Since only the SUVA® Refrigerants is under DuPont's control, we set the very high standard of 10 parts per million (ppm) maximum for SUVA® Refrigerants shipped from DuPont Approved Reloaders to their customers in the field. Refrigeration lubricant may contain up to 50 ppm water.

7.3
Solubility

7.3.1
Solubility of water in liquid refrigerants

The solubility of water in HFC refrigerants and blends such as SUVA® 134a, SUVA® HP62 or SUVA® 9000 is typically more than 10 times that in CFC refrigerants. Due to the risk of hydrolysis when water reacts with POE (ester) lubricant to form acid, the requirement of low humidity in a HFC/POE system must be complied with. Nevertheless water is less soluble in some refrigerants than in others. If more water is present, it will exist as a separate liquid water phase or, if the temperature is low enough, as ice or hydrate.

7.3.2
Solubility of refrigerant in water

In all cases, the solubility of fluorinated refrigerants in water is quite low and ordinarily is of little concern in operating systems. However, in some applications there is a possibility of refrigerant coming into contact with water through equipment failure in heat pump or refrigeration condensers, water chillers, drinking fountains, etc. If this happens, the amount of refrigerant that might dissolve in the water may be significant and the contaminated water should not be dischanged without treatment.
Because water may be present in the valve fittings and the charging line, it is good practice to pass the refrigerant through a drier when charging.

7.4
Moisture indicator

7.4.1
Sight glass indicator

The moisture indicator is a sight glass containing an element (cobalt salt) which reacts with the moisture contained in the refrigerant.. Exposed to moisture, this chemical changes its colour, normally from pink to blue.

Moisture indicators for HFCs are different from CFC® indicators. Ensure that your component supplier provides the appropriate indicator type. It will normally react by changing colour at about 30 to 75 ppm moisture. However, tests have shown that these "universal" moisture indicators do not always react until the system has been exposed to too high a moisture level.

Therefore it is advisable to check with the moisture indicator supplier the performance of a specific indicator.

7.4.2
Liquid indicator

A liquid indicator in a refrigeration system must be able to give the refrigeration engineer reliable information on whether the moisture level in the installation is, or is becoming, too high. The acceptable level depends on what effect the moisture content will have on the life of components, especially the compressor. This moisture limit depends on the type of refrigerant, the type of oil, water solubility in them, and special requirements for dryness.

Traditionally the dryness requirement was generally met if the moisture content was maintained at a level where the risk of ice formation was eliminated.. For example, in a CFC-12 system, this would be a water content of 25 ppm maximum at room temperature.

Maximum moisture levels of 50 ppm are normally recommended in SUVA® 134a plant.

Liquid line moisture indicators, situated between the drier and the expansion valve, can give other information. Bubbles in the sight glass will indicate a problem such as:

- Lack of refrigerant.
- Severe pressure drop through the filter, probably due to clogging.
- Lack of pressure in the condenser.
- Insufficient sub-cooling.

When installing a moisture indicator note that:

1) It must not be heated above 135° C. This means that it must be cooled while being soldered to the line or the indicator itself, and the gasketing material of the sight glass, will be damaged.

2) Particularly in a large system, it is a good idea to install the indicator on a by-pass line parallel to the main liquid line. It is enough for the indicator to have only a small refrigerant throughput to reach equilibrium. It will also be less influenced by the presence of impurities.

3) The moisture indicator may be mounted either upstream or downstream of the liquid-line filter-drier. An upstream position makes it possible to place the filter-drier closer to the expansion device, and may give earlier indication of the presence of excess moisture. A downstream position will show at once if the filter is blocked, as bubbles will appear in the sight glass.

7.5
Field drying

All refrigeration and air-conditioning systems should be thoroughly dried in the field before charging with refrigerant. Whenever any part of the system is opened, air and water can enter. It is necessary to remove these contaminants to ensure that subsequent operation of the equipment will be as free of trouble as possible. Even with factory charged and sealed units, it is desirable to evacuate and dry connecting lines and other parts that may have been open to the air, even if only for a short time.

The best method of drying equipment in the field is by using a good vacuum pump to reduce the pressure in the system below the vapour pressure of water, thus causing it to boil or evaporate and the vapours to be withdrawn by the pump. If the deep vacuum is broken by introducing oxygen free nitrogen to above atmospheric pressure and the system is then re-evacuated, the time required for good dehydration can be reduced and the same degree of dryness produced.

If a good vacuum pump is not available and the system does not contain free water an open type compressor can be used for evacuation. When using a compressor, two purges with nitrogen are recommended. Details of these evacuation methods are given under the section on evacuation. Note especially the description of a cold trap to aid in removing water vapour or water from systems.

A hermetic compressor is not recommended because the design usually requires a flow of cold refrigerant vapour to keep the motor cool. When used in evacuation there is little flow of refrigerant, so that the motor temperature may become high enough to cause failure.

If no form of evacuating equipment is available, blowing nitrogen through the system will do some good and would be better than not doing anything.

When preparing systems for use with HFC Refrigerants and POE oils it is essential to use at least two nitrogen flushes and use a good vacuum pump to ensure a deep vacuum.

Regardless of the method of drying, be sure to add a liquid line drier, if it is at all possible. Even though the system has been carefully dried it is quite likely and even possible that some additional water may enter during the charging of the refrigerant and the lubricant. Furthermore, as time goes on, water may be extracted from various components of the system and may even be formed by the reaction between air and some of the materials present. Driers also tend to scavenge decomposition products and to filter out other contaminants in the system.

7.6
Function of the filter-drier

The filter-drier has three main functions:

To adsorb moisture which, despite precautions, may have remained in the circuit or may be introduced with the refrigerant or lubricant. The presence of water makes the system less stable and may cause ice formation in the expansion valve or in the evaporator.

The second function is to neutralise acids that may evolve in the system. These acids may damage the electric motors of hermetic or semi-hermetic compressors, and may cause copper-plating and other problems in all types of compressors.

An additional function is to retain solid particles and prevent them from reaching, and damaging, the compressor. A metal mesh filter is normally incorporated for this purpose.

8 How to keep systems clean and dry

8.1
Cleanliness and SUVA® Refrigerants

Here are some tips on good handling practice to maintain cleanliness.

Buy quality SUVA® Refrigerants in cylinders filled by Du Pont authorised reloaders to be sure that you are getting a clean, dry refrigerant.

Do not try to transfer SUVA® or other refrigerants in the field because:

- It is impossible to keep out all moisture and air.
- The receiving container is seldom physically clean.
- The receiving container is seldom uncontaminated chemically.
- The danger of accidentally over-filling a service cylinder always exists. The lack of proper transfer equipment makes field transferring uneconomical and hazardous.

In an emergency, if transferring refrigerant from one container to another is unavoidable, be sure to charge any transferred refrigerant through a fully activated drier about the same size as would be used on a 1 kW system.

8.2
Maintenance tips for cylinders

Always replace outlet connection caps as soon as the valve is closed and the cylinder disconnected. This prevents dirt from entering the valve and reduces the chance of damage to threads.

- Store SUVA® refrigerant cylinders in a cool, dry place, if possible upright, secured, for example by a chain, to prevent falling.
- Do not force cylinder connections. You can strip threads which, in turn, can cause leaks. Remember, valves cannot be repaired when attached to the cylinder.
- Do not tamper with built-in safety devices on the cylinder valve.
- Do not use cylinders as rollers or supports.

8.3
Benefits of clean, dry tubing and fittings

The way copper tubing is handled is one of the keys to maintaining clean, dry systems. Coils of dehydrated tubing come moisture-free and free of all other contaminants. They are physically clean as well. To maintain cleanliness, do three things:

- Keep out air and moisture, as much as possible.
- Keep dirt and debris out of the tubing interior.
- Avoid oxidizing the copper metal when making soldered or brazed connections.

Follow recommendations outlined in Chapter “Brazing and soldering”.

Tips on handling tubing
Schedule work. Don’t cut into a new copper coil near the end of the day. However, if necessary:

- Use all lengths cut from the coil and reseal the remaining lengths;
- Seal all openings in the system when leaving the job for any length of time.

Hard-drawn copper tubing or pipe
The same comments apply to copper pipe. Use only pipe or hard-drawn tubing that has been cleaned and capped by the manufacturer. Reseal tubing if it is not used immediately. Use great care in handling to keep the tubing as clean and dry as when it is purchased.

Factory handling of condensing units and coils
Manufacturers of air-conditioning and refrigeration equipment insist on rigid cleaning, dehydration and evacuation practices as part of their standard quality control. Quality-control personnel not only examine incoming semi-finished parts and supplies, but they are charged with the responsibility of excluding all contaminants from the finished product.

- Refrigerants and lubricants, for example, are analyzed regularly to make sure that rigid quality specifications are met.
- Hermetic motors are degreased to remove all traces of unstable lubricants and solvents, and are dehydrated to the point where insulating materials can no longer give up moisture.
- All compressor parts, including hermetic shells, are cleaned and considerable precaution is exercised to prevent rusting before final assembly.
- Finished condensers and evaporators are cleaned and dehydrated and either assembled into complete systems or sealed until used at some future date.
- This care in handling should be continued through every step of installation and servicing in the field, if systems are to do the job they were designed to do.

9 Brazing and soldering

Brazing flux and other materials used in the joining of refrigerant lines can be a major source of contamination, so good brazing technique is critical. The method of heat application can either increase or minimize the amount of brazing contaminants in a system.

To ensure leak light systems good practice (and in many countries environmental regulations) require the use of brazed joints. Flare joints should not be used. Where a component has to be removed for maintenance, compression joints should be used.

9.1
Preparation of tubing

If it is necessary to cut the tubing, use a tube cutter rather than a hack saw. If you use a saw, slant the tubing downward if possible to keep the metal dust and small pieces out of the section to be used. Of course, if both sections are to be used, this is difficult. Remove burrs from cut edge with a special tool or a file or knife if you cannot obtain the tool.

Both the outside of the tubing and the inside of the fitting must be bright, shiny and clean. Use a soft wire brush or sand cloth. Emery cloth is not recommended since it may leave marks in the copper. The surface should be smooth so the solder will flow evenly. The cleaning should be done just before soldering to avoid reoxidation of the surface. On the other hand, do not file away more copper than is necessary to make the surface clean and bright.

9.2
Proper fit of joint

The clearance between the tube and the fitting should be 0,04 mm. This fit will permit the tube to enter the fitting easily without binding and will not be too loose.

Clearances that are too tight will restrict the capillary flow of solder in the joint and a poor or incomplete bond will result. Clearances that are too large will not permit the capillary flow of solder and voids will cause poor joints.

A joint with 0,04 mm clearance will give maximum joint strength because the solder will be in shear stress. If the clearance is too large the solder will be in tensile stress. Resistance to tensile stress is lower than resistance to shear stress.

9.3
Vent with inert gas

When heat is applied to copper in the presence of air, copper oxide forms on exterior and interior tubing surfaces. This oxide is easily washed from the tube surface when the system is put into operation and is then free to circulate with the refrigerant and lubricant. Lubricant-borne oxides are inevitably exposed to high temperatures at the compressor discharge valve where the oxides can cause decomposition of the lubricant and refrigerant.

It is easy and well worthwhile to prevent oxide formation. Isolate the section of line being worked on and sweep an inert gas, preferably dry nitrogen, through the tubing being brazed. Nitrogen will displace air and prevent oxidation of steel pipe or copper tubing at soldering or brazing temperatures. The nitrogen should flow just enough to displace the air that is in the tubing. From 30 to 90 litres/minute is usually sufficient.

- The nitrogen is usually quite dry, but using a drier is good insurance.
- It is good business to provide each service truck with a supply of dry nitrogen because of the substantial dividends which can be realized in better performance of non-contaminated systems.

Whenever working with dry nitrogen, certain precautions should be observed. The pressure in a fresh nitrogen cylinder at room temperature is approximately 165 bar which is far above the bursting pressure of refrigerant cylinders and components. For this reason, *always use a pressure-reducing valve or regulating device in the line connecting the nitrogen cylinder to the system.*

9.4
Fluxes

Be sure to use a soldering flux of the correct type. Avoid one that contains ammonia since it may have harmful effects when used with copper. Always stir the flux before using. Some of the ingredients may settle to the bottom on standing, especially in hot weather (for paste types). Use a brush to apply the flux – not your finger. Some of the chemicals in fluxes are very reactive. Gently heat the tubing and joint before applying flux if it is in paste form so that it will spread evenly and smoothly.

Use just the right amount of flux so that a thin film covers the surface of both tubing and fitting. Too little flux gives a poor bond and too much is wasteful and makes for a poor-looking job. Keep the flux well back from the edge of the tubing (at least 5 mm) and from the inner end of the fitting.

Be sure that no flux gets into the tubing. It is one of the worst contaminants in refrigeration equipment. As little as 3 g of flux in a 25 kg charge will be insoluble in FREON® 22 or SUVA® Refrigerants and may cause trouble in the expansion valve or capillary tubing.

A recommended practice is to insert the end of the tubing part way into the fitting and then apply the flux to avoid getting any on the inside. Then push the tubing all the way in and rotate the fitting or tubing a few times if possible to spread the flux evenly over the area. It is also important to support the assembly so there is no strain on the joint during soldering or cooling.

9.5
Applying heat

Heat the joint as evenly as possible by directing the torch at the bottom of the fitting socket and at the tubing alternately. If one part has a greater mass than the other, it will require more heating time.

Avoid letting the flame touch the seam where the solder will be applied because it can burn the flux. From time to time while heating touch with the solder to see if the metal is hot enough to melt it. Be careful not to overheat. High temperatures can decompose the flux and affect the solder. Heat only enough to melt the solder.

In some cases it may not be possible to apply the flux before assembling the joint. If so, put a moderate amount of flux on the tube near the joint and warm slightly. Then heat the fitting evenly till the flux melts and is drawn into the joint.

9.6
Applying solder

9.6.1
Melting solder

When the tubes and fittings are hot enough to melt the solder, touch the tube joint with the solder wire at several places. Capillary action will draw the molten solder into the joint and around the tube. Then a ring of solder appears all around the tube, the job is finished and a good, leak-proof joint has been made. To make a neat appearing joint in soft solder joints, wipe the tube with a cloth while the solder is still hot. Do not cool the joint rapidly while the joint is near the solder melting temperature.

9.6.2
Large-diameter tubing

Large-diameter tubing must be brazed piecemeal. To make a sound joint with large tubing, play the flame alternately from tube to fitting while melting the brazing alloy over a small section of the joint. Each additional bit of alloy must be drawn into the joint and fused with the alloy already in place. If too much flux is applied, you can end up with a poor joint. The flux can occupy space intended for brazing metal in the fitting. In time, the flux will break away and the joint will leak. Double-tip torches are available for use on large diameter tubing so that the tubing can be heated more uniformly. In some cases, two torches can be used.

9.6.3
Low melting, silver bearing, solder

Low melting, silver bearing, solder is easy to use with different metals and is especially recommended for use in the food industry. Silver alloys containing cadmium should not be used on components that may come into contact with food because of the possibility of cadmium poisoning.

9.7
Breaking soldered or brazed joints

9.7.1
Servicing all types of refrigeration systems

In servicing all types of refrigeration systems it may be necessary to break refrigerant lines to repair leaks at a connection or joint, or to replace components such as expansion valves, compressors, condensers or evaporators. *Don't apply heat to a line under refrigerant pressure.* The hazard of line rupture or refrigerant-propelled molten solder will always be present. Don't unsolder a connection in a line under vacuum because air and moisture will enter and contaminate the system. To keep air and moisture from entering the system when breaking a joint, apply a very slight positive pressure on the system before opening it to the air.

Clean the outside of the joint and apply flux. Heat the fitting evenly until the solder melts and the joint can be separated.

Cap all openings to the system immediately. Use flare plugs or flare caps if the system uses flare fittings. For unsoldered connections use an elastomer or mastic as a sealer.

9.7.2
Some local corrosion

Some local corrosion will result from decomposition of the refrigerant, so clean the mating parts thoroughly before rejoining them. Provide good ventilation to remove irritating fumes from the working space because the flame may come in contact with a small amount of refrigerant present in the line and cause it to break down. Resulting vapours are more irritating than dangerous. Never apply a flame to any part of a system containing ammonia vapour.

9.7.3
Epoxy resins compatibility

Epoxy resins are compatible with the SUVA® refrigerants and are used in refrigeration service work. In many cases they can be used in places where soldering or brazing would be difficult. Techniques of application have been worked out and information can be obtained from the supplier or manufacturer.

Specify that it is for a refrigeration system application.

10 Motor burn-outs

10.1
General

The majority of systems that are charged with SUVA® Refrigerants have hermetic or semi-hermetic compressors. This type of compressor has several advantages over the open type, but it does present one problem. If the electric motor that drives the compressor burns out, the decomposition products will be transformed by the refrigerant throughout the system necessitating a thorough clean-out of the entire system. The compressor, obviously has to be replaced.

Both the frequency of burn-outs and the amount of contamination in the system have been reduced by protective devices, such as thermistor-controlled electrical cut-outs, fitted by compressor manufacturers. Nevertheless burn-outs do occur, and the field service engineer must know how to deal with them.

In order to avoid repeat burn-outs, it is essential to:

1. Remove all carbon and other solid deposits. Carbon that is carried by circulation of the refrigerant to the replacement compressor is very likely to cause a repeat burn-out.

2. Remove entirely any contaminant that is accidentally or deliberately introduced during the clean-up operation. The most frequent such contaminants are air, water and solvent.

It is almost always necessary to replace the compressor. It is possible, but not generally advisable, to repair a semi-hermetic compressor without removing it from the system. Repair of a compressor is a job for a specialist. The compressor manufacturer or his appointed distributor will normally undertake this work. There are also independent companies that specialize in the repair and rebuilding of damaged compressors. It does not concern the field service engineer whether the replacement compressor which he installs is new or reconditioned, provided that it carries an effective guarantee from a reputable company.

Recommendations and instructions of the compressor manufacturer should always be followed. The following points are given for general guidance in dealing with small and medium-sized reciprocating compressor burn-outs.

10.2
Safety precautions

Take care not to inhale the vapours from a burn-out. Toxic decomposition products may be present.

Ensure good *ventilation* at all times.

Wear *rubber gloves* and eye protection. The lubricant from a burned out compressor is normally acid. Avoid getting this lubricant on clothing.

10.3
Preliminary inspection

Check the electricity supply and the accessible electrical circuits.

The compressor may fail to start for some other reasons.

If electricity supply is available in all phases and at the correct voltage, use a megohmmeter to check for a short-circuit between windings or from windings to earth. Electrical continuity confirms a burn-out without further investigation. Take care not to burn out the thermistor (if fitted) while testing.

Take a sample of lubricant from the compressor. Dark colour, and an «acidic» reading by an Acid Test Kit is an indication of a burnout, when the compressor will not start.

If the compressor has been installed with isolating valves, in accordance with recent recommendations, these should be closed. Refrigerant from the compressor itself should be vented out of doors, using a suitable line. Opportunity should be taken to catch lubricant droplets from each valve on a clean white paper or cloth, and inspect for cleanliness; or, alternatively, the presence of carbon or other debris.

It is normal to find carbon only on the suction side because the suction port is (in most compressors) directly connected to the motor. If the burn-out occurred when the compressor was stationary, the high-pressure side is usually clean. However, if the compressor continued to run during a «slow» burn-out, both sides will be contaminated with carbon and acidic sludge from the lubricant.

At this stage, enough information should be available to decide how much of the system has been affected by the burn-out. It should not be necessary to cut any of the lines to inspect for the presence of carbon.

10.4
What to do with the refrigerant?

There are two alternatives:

- Recover it, and send it to be reclaimed or disposed of.
- Leave it in the system.

Recovery and reclaim or disposal is the best course of action, provided that a suitable service exists reasonably close to the site. Care must be taken not to overfill the cylinders or other containers used to transport the recovered refrigerant because of the hazard of such a container becoming liquid-full.

In most countries there are dedicated containers that can be obtained from Authorized distributors

To leave the refrigerant in the system is possible only in the case of a large quantity and a burn-out that has not spread far through the system. The system must incorporate isolating valves and a sufficiently large receiver, because of the next steps to be taken.

Discharge out of doors has been current practice in the past. This practice is no longer permitted by law. The refrigerant should therefore not be vented to the open air, but instead should be recovered for further reclamation or for destruction.

Refrigerant from a burned-out system *must never be discharged*.

10.5
Clean-up

10.5.1
No significant quantities of carbon and other debris

If no significant quantities of carbon and other debris have spread through the system, and particularly if the lubricant is not seriously acid (acid number less than 0.05 ppm), no special steps are necessary.

It is sufficient to replace the compressor, and to replace the filter-drier with a new one. The new filter-drier should be one size larger than that previously, or normally, fitted, if available in the same length. Otherwise, change the filter-drier or its core within 24 hours.

10.5.2
System is heavily contaminated

When the system is heavily contaminated, further action is necessary. Two methods are available: the Filter-Drier method is normal, but flushing with refrigerant or oil may be used. The refrigerant or oil must be the same as is to be used in the system after it is returned to service.

In either case, all restrictive devices such as expansion valves, solenoid valves and filter-driers should be removed and either replaced or cleaned.

10.5.3
Clean-up filter-drier

Clean-up filter-drier, sometimes called the System Cleaner Method, is generally recommended by compressor manufacturers. The procedure is simple, in that the system is brought back into operation rapidly using a fresh charge of its normal refrigerant. Replaceable core filter-driers, described as Burn-out or Clean-up type, are installed in both the suction line and (if possible, one size larger than normal) in the liquid line. Careful follow-up is necessary: the field service engineer responsible must allocate the time necessary for this.

It is necessary to check the pressure drop across the filter-driers and change the cores as required: also check the head pressure of the compressor, because non-condensable gases may have been produced. Follow the detailed instructions given by the filter manufacturers.

Note: If the system contained heavy contamination when started up after fitting the new filter-driers, the filters may become blocked very quickly.

10.6
Follow-up

Irrespective of the method of clean-up used, regular visits at intervals of about two weeks should be make to a system that has suffered a burn-out. These visits should always include inspection and acid test of the lubricant.

The lubricant, and the cores of the filter-driers, should be changed as often as necessary until the lubricant is clear and free of acidity: only then can it be said that the job is complete.

11 Charging refrigerant into system

11.1
Importance of proper charging

The main job of a service engineer is to keep highly precise, modern, mechanical cooling-system running as the design engineer intended. It is essential to know the proper way to handle refrigerant and the best methods of charging or adding refrigerant to all types of systems. All systems do not use the same refrigerant. All systems do not use the same amount of charge even though capacities may be entirely comparable.

11.2
Check the name-plate on factory-assembled systems

All manufacturers include a name-plate that clearly lists the refrigerants for which the system was designed. It also frequently states the amount of the refrigerant charge. Always check the name-plate before charging or adding refrigerant to a system. How much charge to use will vary widely from system to system. This makes it doubly important always to check the name-plate.

11.3
Check manufacturers' catalogues

Catalogues and service bulletins are available from equipment suppliers and air-conditioning and refrigeration distributors and wholesalers. Keep them on file and study them before charging a system. Liquid receiver capacities for most condensing units, and for complete systems supplied by manufacturers for field erection, can be found in the bulletins.

11.4
Vapour charging

Do not charge SUVA® blends vapour phase.
This means that the refrigerant should be remove from the cylinder as a liquid (either from the dip tube in a two value cylinder or by inverting the cylinder). The liquid is allowed to evaporate (flash) in the charging lines.
Small systems with a single component refrigerant such as SUVA® 134a are usually charged through the gauge port of the compressor suction service valve. Normal procedure is:

1) Back-seat suction service valve as for normal operation.

2) Loosely connect line from from service manifold to suction service valve gauge port.

3) Connect centre line from manifold to the refrigerant cylinder.
4) Back-seat discharge service valve.

5) Loosely connect remaining line from service manifold to discharge sevice valve gauge port.

6) Slightly open cylider valve to purge vapour up to the compressor discharge service valve.

7) Tighten discharge service valve connection at gauge port.

8) Purge vapour from cylinder up to compressor suction service valve.

9) Tighten suction service valve connection at gauge port. Open both compressor service valves.

10) Place cylinder of SUVA® refrigerant on weighing scale.

11) Pressurise system to full cylinder pressure and make final leak check.

12) Start compressor. Run until head pressure and suction pressur stabilise. (If system has a low-pressure control this may cause the compressor to short-cycle. If this occurs, note the cut-out pressure and admit refrigerant from the cylinder to increase suction pressure by 0.7 to 1.0 bar above the cut-out setting)

Open the cylinder valve completely and control the flow of refrigerant from the manifold.

From time to time, note suction pressure with the cylinder valve closed.

From time to time note discharge pressure to see that it does not rise rise above the level normally expected under operating conditions. For air-cooled systems, the discharge pressure should be approximately the the pressure corresponding to ambient temperature plus 11° C (refrigeration) to 17° C (air conditioning).

13) When correct weight of refrigerant has been introduced, close cylinder valve and disconnect charging line.

14) When satisfied that the system is operating as it should, back-seat both suction and discharge service valves. Bleed pressure from both gauge lines through the manifold charging port.

15) Replace cylinder valve cap and fit flare plugs in open ends of charging and gauge lines. Replace plugs in gauge ports of compressor service valves.

Notes:
1) If possible, refrigerant should always be charged by weight, using a good scale: or by volume, using a charging cylinder with a scale that compensates for changes in refrigerant density due to temperature. There must be appropriate scales for different refrigerants.

2) Sight glass charging: It used to be customary to charge CFC refrigerants until no bubbles appeared in the sight glass. This method is not always applicable to SUVA® refrigerants, particularly when using POE lubricants. For correct charging, see paragraph 11.6.

3) If cylinder pressure drops too low for further charging before the job is finished, place cylinder in a bucket of *warm* (25° – 45° C) water, or use a heat lamp to increase pressure. Do not apply heat with a torch. *Never* heat cylinder above 50° C.

11.5
Liquid charging

Charging the refrigerant in the liquid phase has always been customary for larger systems. It is essential for charging SUVA® blends. If a complete charge is to be added to an evacuated system the liquid is frequently charged through the compressor discharge service valve. The compressor is not operated while charging. The procedure for attaching the manifold and purging the lines is similar to that described for vapour charging.

On most systems, a charging port is located on the liquid line downstream from the receiver.

In this case, refrigerant can be added while the system is not operating. General suggestions will not always apply to specific operations but the following outline may be helpful.

11.5.1
Connect the refrigerant cylinder to the charging port

Connect the refrigerant cylinder to the charging port. Use as short a line as possible to minimize water contamination or use a drier if indicated by conditions. The cylinder should be upside down if it does not have a liquid/vapour valve.

Install a pressure gauge so that the compressor discharge pressure can be observed.

11.5.2
Crack cylinder valve and purge charging line

With the connection to the charging port loose, crack cylinder valve and purge charging line with refrigerant using the VAPOUR hand wheel of a cylinder fitted with a liquid/vapour valve. Tighten connection, open cylinder valve and check for leaks.

11.5.3
Close the valve at the receiver outlet

Close the valve at the receiver outlet or if there is no receiver close the valve in the liquid line upstream from the charging port. This is necessary to prevent the condensing pressure from forcing liquid into the cylinder.

11.5.4
Slowly open the charging port valve and charge liquid

With the compressor running, slowly open the charging port valve and charge liquid using the LIQUID hand wheel at a rate fast enough to keep the compressor from cutting out on low-pressure control if possible. The refrigerant flow can also be controlled by the cylinder valve to avoid ending up with a hose full of liquid refrigerant. The same result can be obtained by closing the cylinder valve first when charging is finished.

11.5.5
Watch the discharge pressure

Watch the discharge pressure. A rapid rise in pressure indicates that the condenser is filling with liquid. If this is the case, the system pump-down capacity has been exceeded. Stop charging from the cylinder and open the liquid line valve. If the system still seems low on charge, an auxiliary receiver may be needed.

When the proper weight of refrigerant has been added, close the cylinder valve and let the low-pressure control stop the compressor.

Close the charging port valve and vent refrigerant vapour from the hose by loosening connection.

Open the liquid line valve or receiver outlet valve and check the operation of the system.

Replace cap on cylinder valve and charging valve. Plug both ends of the charging hose or manifold so it will be clean for the next use.

11.6
System without a sight glass

The following suggestions may be useful if a sight glass is not installed and information on the correct charge is not available:

1) Connect charging line and gauge manifold to compressor.

2) Attach thermometer to evaporator outlet.

3) Run compressor and after about ten minutes read both gauges and the thermometer.

4) Add refrigerant.

5) Close cylinder valve and after a few minutes read the suction and discharge pressure and the thermometer. Both gauges should read a little higher than in 11.7.3. The thermometer may read a bit lower. On water-cooled systems having a good supply of cold water, discharge pressure may not increase.

6) Repeat steps 4 and 5 until no further change is noted in the gauge reading.

7) Read the thermometer and check against the refrigerant saturation temperature as shown by the suction pressure gauge – that is, the corresponding refrigerant temperature at low-side pressure. Difference between saturation temperatures at evaporator pressure and the thermometer reading should be the superheat setting of the expansion valve. This value is usually 5° – 6° C. Allow for a thermometer reading of 1° C higher than the actual vapour temperature.

8) Again add a small amount of refrigerant and observe the thermometer for any change. No change indicates that full liquid flow is being supplied to the expansion valve. System operating conditions must have reached an equilibrium before this final reading is made.

9) Add a reserve of refrigerant based on size of the system.

The above procedure can be applied to capillary tube systems with the exception of step 9.

11.7
Charging a small capillary tube system or a VRV (Variable Refrigerant Volume) air conditioning unit

The best way to charge a small capillary tube system is also the simplest, provided that no refrigerant is discharged to atmosphere:

1) Withdraw all refrigerant remaining in the system. Recover it for reclamation.

2) Then recharge on a weight basis.

3) Use the amount of SUVA® refrigerant specified by the manufacturer on the name-plate, or in his service bulletin.

There are other methods by which you can add refrigerant to make up a complete charge. They involve checking the pressure and temperature conditions at various parts of the system as outlined. This extra work usually takes more time and gives very little in return so that in most cases, on such small systems, it pays to replace the charge completely.

12 Leak detection

With the increasing focus on refrigerant containment, both from cost and environmental considerations, it is becoming ever more important to ensure that refrigeration systems are leak free when installed and that if leaks develop during operation, these are rapidly corrected.

12.1
Designing to reduce leaks

Leaks may occur in refrigeration, air-conditioning, heat pump and heat recovery systems for a variety of reasons. The frequency of leaks may be reduced by good workmanship and care in assembling new installations. The following points deserve attention:

- Good brazing and soldering techniques.
- Brazing in preference to screw connections.
- Compression screwed connections in preference to flared connections. (Note that in several countries flared connections are no longer permitted in refrigeration piping.)
- Good piping layout to avoid stress in the lines; adequate supports particularly of long piping runs.
- Use of vibration eliminators.
- Use of good-quality components designed for the appropriate pressure and temperature conditions.
- Installation of renewable components such as filter-driers in such a way that they can be removed and replaced without unnecessary loss of refrigerant.
- A new system should be pressure-tested before being evacuated and charged.

In addition, while a certain number of isolating valves are desirable to avoid loss of refrigerant during servicing: quality and mounting of valves should not permit them to become themselves the source of leaks. The same considerations apply to pressure relief devices.

Nevertheless, experience has shown that it is virtually impossible to eliminate leaks completely, particularly in systems that have been in service for some years.

It is therefore necessary to be able to detect leaks and identify them precisely so that they can be repaired.

12.2
Symptoms

Refrigerant leakage reduces the charge in the system. Low refrigerant charge may be shown by:

1) Bubbles in the sight glass. These may also be caused by an obstruction in the liquid line, for example a partial blockage of the filter-drier.

2) Evaporator temperature too low. This, also, may be due to an obstruction in the liquid line: or to malfunction or partial blockage of the expansion valve.

Consequences can be serious, for example freezing of food that should not be frozen, or icing-up of an air conditioning system evaporator.

3) Compressor short-cycling, stopping and re-starting more frequently than is normal for the size and type of compressor. More than about 12 times per hour would generally be regarded as excessive. Short-cycling may also be due to malfunction or incorrect setting of the compressor controls.

4) Compressor over-heating: in this case due to insufficient refrigerant flow to cool the compressor. This, as in the case above, may be due to an obstruction elsewhere in the circuit.

5) Compressor running continuously, due to loss of cooling capacity. There is not enough refrigerant in the circuit to achieve the required performance.

6) Low liquid level in the receiver: in a system with a sight glass in the liquid receiver, and provided that the normal level is known, this is the most reliable indication of loss of refrigerant charge.

As will be seen from the examples above, the symptoms of loss of refrigerant charge are not clear. This emphasises the advantages of a positive method of identifying leaks.

It is better not to wait for leaks to appear, but to inspect for them on a regular basis. On large systems, where continuous reliable operation is critical, leak inspection should be made on a regular weekly schedule.

12.3
Methods

Leak detection is an external method for detecting the losses of refrigerant from a refrigeration system. Leak detection is achieved by means of a sensor incorporated in the instrument. This is a technology that is rapidly evolving. Not all the detec-

tors being marketed today are sufficiently sensitive to certain of the alternative refrigerants (particularly HFCs, which do not contain chlorine). Several of the leak detectors require routine recalibration or regular replacement of their sensor capsule. It is very important to select a detector that is adequate for the refrigerants that will be encountered, and that its maintenance requirements be understood and adhered to.
The leak detecting systems available today can be divided into two different groups, based on their function :

- Leak Detection : to warn that there is a leak situation;
- Pinpointing : to identify, precisely, the location of the leak to enable preventive measures to be taken.

All of these systems require a means of detecting the presence of refrigerant vapours in low concentrations in air. There are several technologies utilized for the refrigerant detector sensor. These result in detectors which are either :

- Non selective : these usually function by detecting a change in the thermal conductivity or heat capacity of air caused by the presence of another vapour.
- Halogen Specific: a variety of “electronic” technologies are used. Some are more sensitive to chlorine containing compounds than to HFCs. The most suitable show similar sensitivity to all halogens.
- Compound specific: these detectors are designed to measure concentrations of one specified refrigerant in the presence of other refrigerants. Such detectors are generally only available as fixed units, but portable units are beginning to become available. They generally incorporate an infra-red spectrophotometer which can be tuned to select a specific absorption frequency which is characteristic of the compound desired.

12.3.1
Leak detection

Leak detection is usually carried out by means of a fixed unit (known as a *leak monitor*) which has fixed sampling points at specific locations. These either draw samples of air sequentially through an analysing unit, or the Monitor has remote sensor units placed at selected locations. The unit is programmed to give an alarm signal if a leak occurs.. The alarm signal can be local or remote; it is common practice for supermarket systems to send the alarm signal through a modem link to a service contractor’s premises. Many systems have data storage capability to allow sophisticated analysis of refrigeration system losses over time.

Leak monitors also fulfil an important Occupational Health and Safety role by routinely analysing the air in occupied enclosed spaces (such as machine rooms) and warning when and where acceptable exposure levels are exceeded. Such monitors are compulsory in most countries for Ammonia and for R-123 Machine rooms. It is probable that they will become a statutory requirement in many countries for all refrigerants in systems above a certain, threshold, charge size.

12.3.2
Pinpointing

Pinpointing is undertaken using portable (usually hand-held) leak detectors. These are often known as “electronic” leak detectors. The hand held systems usually fall into one of two types:

- Pumped “sniffer”; or
- Detector head

The pumped sniffer consists of a small hand held unit which contains the pump and detector. A sample of air is drawn in through a flexible tube. These systems tend to be more robust, and often more sensitive, than the «detector head» systems. As against this, response times are usually slower, because the sample has to travel down the sample tube to the detector.

In the detector head units the sensor is actually at the tip of the flexible nozzle. This gives faster response times, however the sensor capsule is exposed to dirt, grease and other contaminants, and as a result often suffers from premature failure or loss of sensitivity. The capsule should be, and usually is, readily replaceable.

The hand held detector usually gives an audible warning of a leak (sometimes coupled with a simple visual display). Many models have an adjustable sensitivity control.

In addition to refrigerant sensor technologies the following techniques are also widely used in pinpointing leaks in refrigeration systems:

- Soap bubbles, (in fact usually liquid detergent) generally used only during system assembly/installation. This is a simple, moderately sensitive, method of finding leaks.
- System additives. A fluorescent dye is the basis of an additive system marketed under several trade names. The dye is soluble in the refrigeration compressor lubricant and leaks out wherever there is a refrigerant leak. The dye becomes visible as a bright yellow-green stain under UV light.

- Battery or mains powered hand held UV lamps are supplied as part of the additive system. The dye is easy to clean away after the leak has been repaired. It is important to confirm that equipment warranties will not be voided by the addition of such dyes to the system.
- Halogen Torch. The flame of the torch changes colour, but only in reaction to chlorine containing substances; it will detect CFCs and HCFCs but will not detect HFCs (SUVA® 134a, SUVA® 404A, SUVA® 407C, etc.). It has several limitations, for example it is difficult to use in windy or drafty places, and it may be a safety hazard. The halogen torch is being made obsolete by the modern electronic hand held leak detectors.

13 Retrofitting existing systems

13.1
Conversion of existing systems from CFC to non-CFC refrigerants

As explained in chapter 1 above, CFC refrigerants are not permitted to be manufactured or sold in Europe and in most other regions of the World. Therefore if an existing system loses its charge of CFC refrigerant, as a result of a leak, an accident or because it was necessary to open up the system for maintenance, that system must be charged with a non-CFC refrigerant when it goes back into service.

The choice that the owner of the system must face is:

- To attempt to find some reclaimed CFC refrigerant to minimise the change. This course of action will become increasingly difficult and expensive.
- To scrap the equipment and replace it by a new unit running on a HFC or other permanent replacement non-CFC refrigerant. Unless the equipment is in poor condition or approaching the end of its useful life, this is an expensive choice.
- To replace the CFC refrigerant with a HFC refrigerant such as SUVA® 134a. This is complicated, time-consuming and expensive for normal commercial and industrial systems (but is generally recommended in the case of Automobile air conditioning systems).
- To replace the old charge with a SUVA® service refrigerant. *It is this comparatively easy and inexpensive course of action that is normally recommended. It requires minimal change to the refrigeration system.*

13.2
How to choose the non-CFC refrigerant

The first step is to find out which refrigerant was previously used. In the absence of correct labelling of the system indicating the refrigerant type, the charged quantity and the lubricant, the service engineer will have to investigate before working on the unit. Therefore it is recommended that the system owner keeps a log book or other record close to the unit. If the system was previously maintained by a colleague in your own company, or by another company in the area, you can find out, and save time, by a phone call before visiting the site. Otherwise the pressure will probably tell you, and only in a very unusual case will it be necessary to call for a chemical analysis. That could happen if through mistakes in the past a mixture of CFC or other refrigerants had been charged.

Assuming that there is no recycled CFC available and that the system owner decides to retrofit the system rather than replacing the unit by a completely new system, there is a choice between two options to be made:

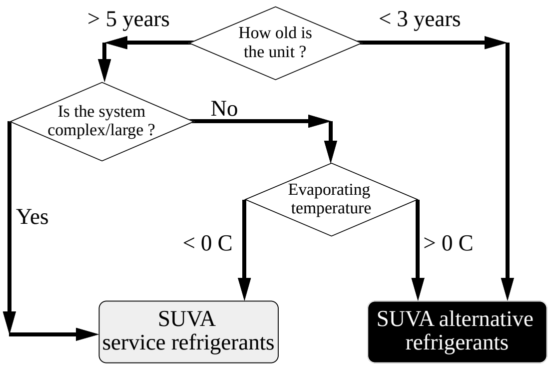
- Either retrofit the existing unit with a service refrigerant or
- Convert the unit to a HFC refrigerant.

The service refrigerants generally offer the most cost effective way of retrofitting equipment that has been operating on CFCs. This is especially true for old equipment (>3-5 years).

A simple decision tree describing the situation is given below:

Fig. 14

DECISION TREE



Note:
FREON® 22 is often considered as a retrofit option. If available, it is a suitable replacement for R-502 in medium to high temperature applications. For CFC-12, or R-502 at low temperature, FREON® 22 is more mechanically complicated and more expensive than the service or alternative retrofit options.

There are some exceptions to the above decision tree:

- Automotive A/C: None of the automotive OEMs recommend anything other than HFC-134a as a retrofit refrigerant.
- Systems with flooded evaporators: generally these refrigeration systems should not use a significantly glided refrigerant. They should use instead SUVA® 134a or SUVA® HP62.
- Systems with centrifugal compressors: Consult the manufacturer or qualified consultant as this type of system normally requires significant modifications.

13.3
Converting refrigeration installations from R-12 to SUVA® MP39 and SUVA® MP66

CFC-12 is the most widely used CFC refrigerant, therefore the majority of conversions will involve replacing CFC-12. SUVA® MP blends have been designed to replace CFC-12 in existing equipments calling only for minor modifications to the system, as they have thermodynamic properties very similar to those of CFC-12. The blends recommended, except for automobile air conditioning, are SUVA® MP39 or SUVA® MP66.

13.3.1
Selection

The choice between SUVA® MP39 and SUVA® MP66 will be based on the application and its typical operating conditions.

SUVA® MP39
SUVA® MP39 is recommended for high (over 0° C) and medium temperature CFC-12 systems. The capacity efficiency of SUVA® MP39 is comparable to that of CFC-12 in systems operating at evaporating temperatures down to -25° C, such as:

- Walk-in coolers
- Food and dairy display cases
- Beverage dispensers
- Beverage vending machines
- Household refrigerators and refrigerator/freezers

SUVA® MP66
SUVA® MP66 has comparable capacity to CFC-12 in systems operating at evaporating temperatures below -25° C, which makes it suitable for use in transport refrigeration equipment and commercial freezers. SUVA® MP66 can also be used to replace R-500.

13.3.2
Compatibility with materials and lubricants

Compatibility with lubricants
See paragraph 5.1 above (p 21)

Replace the MO which is almost invariably the lubricant in a R-12 system.

Generally, the compressor manufacturer specifies the appropriate lubricant for use with SUVA® MP refrigerants in his compressors.

Materials of construction
It is not necessary to replace elastomers, plastics, metals, wire insulation or other components from the existing R-12 system: provided that they are in good condition.

For the choice of desiccant in the filter dryer, see 13.3.3 below.

13.3.3
Components to change

Filter-drier
The filter-drier, or its core, must be changed and replaced by a unit containing a molecular sieve desiccant that is compatible with SUVA® MP refrigerants. Certain filter-driers contain only molecular sieve granules, for example:

- XH-9 by UOP (Division of Union Carbide)
- MS 594 by GRACE Chemicals.

Some types of “Solid Core” filter-drier which contain a mixture of different desiccants, are compatible with SUVA® MP refrigerants. Consult your filter-drier supplier.

Refrigerant
Since SUVA® MP39 and SUVA® MP66 are near azeotropic mixtures, it is essential to charge them exclusively in *Liquid phase*. See Section 11.5 above.

For most installations, the SUVA® MP charge will be 75% to 90% of the previous R-12 charge, by weight.

Other components
Generally, it is not necessary to change the expansion device, pressure gauges or other components of the system.

For moisture-indicating sight glasses, see chapter 7 above.

13.3.4
Equipment required for conversion

General considerations
Use the recovery cylinders provided by your refrigerant supplier.

Indicate clearly the refrigerant you want to recover when ordering the recovery cylinders to ensure that you use appropriate cylinders.

Do not over-fill cylinders. Do not mix refrigerants.

Equipment required

- Personal safety equipment (eye protection, gloves,...)
- Recovery Unit: To withdraw the R-12 as completely as possible from the installation, and to minimise CFC emissions to the atmosphere.
- Scale: To weigh the R-12 withdrawn, and to ensure the correct weight of the SUVA® MP charge.
- Recovery Cylinder: one or more, on loan from your SUVA® Refrigerant supplier.
- Vacuum Pump: of adequate capacity.
- Refrigerant Charging Manifold, incorporating pressure gauges.
- Lubricant Charging Line.
- Leak Detector: To check system for leaks after charging with SUVA® MP. Since both blends contain HCFC-22, a conventional type, preferably an electronic one, may be used.

13.3.5
Conversion procedure

1) Before starting the conversion to SUVA® MP refrigerant, record all the operating parameters of the system, particularly the return gas temperature and subcooled temperature under normal operating conditions, using the *retrofit report*, which you can get from your SUVA® Refrigerant supplier.

2) Switch on the compressor lubricant heater (if fitted), if possible several hours before the conversion, to ensure that the lubricant is completely de-gassed.

3) Using the Recovery Unit, evacuate the R-12 from the system into the Recovery Cylinder(s). Record the weight of the recovered R-12 and return the recovered CFC refrigerant to your SUVA® Refrigerant supplier.

4) Ensure that the compressor cannot accidentally start up, by removing the fuse or switching off the mains supply. Attach a tag or label to the fuse holder or switch. Make sure that the lubricant heater is switched off.

5) If required drain the mineral lubricant from the compressor, from the lubricant separator and other components if fitted, as completely as possible. Record the volume of lubricant removed, then place it in an appropriate recipient to be disposed of in accordance with the regulations in force. (Your SUVA® Refrigerant supplier can advise you).

6) Charge the new lubricant into the compressor, the same volume as removed in the previous step.

7) Replace the filter-drier by one compatible with SUVA® MP39 or SUVA® MP66.

8) Pull vacuum on the entire system. Follow normal procedure to eliminate air and other non-condensible gases from the circuit (3 to 5 mbar).

9) Charge the installation with the SUVA® MP refrigerant *exclusively* in *liquid phase*, to 75% by weight of the previous R-12 charge. The optimum system charge will depend on the operating conditions of the installation and its design. For most installations, the appropriate charge will be between 75% and 90% of the R-12 weight.

10) Re-start the system and allow the system to reach stable operating conditions.

11) Optimise the performance of the system by completing the SUVA® MP charge, still in *liquid phase*, through the compressor suction port until the same operating conditions are reached as recorded with CFC-12 (return gas temperature, subcooled temperature). Make use also of the liquid line sight-glass and of the pressure gauges when completing the refrigerant charge.

Note:
Do not overcharge the system! By controlling liquid subcooling and vapor superheat you make sure that the system is properly charged.

When the system is operating normally with its final charge, expect to find:

- In most cases, the suction pressure will be very close to that when operating with R-12.
- The discharge pressure will normally be between 0,7 and 1,4 bar higher than with R-12.

12) Adjust the high-pressure and low-pressure safety cut-outs, if necessary.

13) Carry out complete leak check.

14) Replace the “R-12” sticker by a “SUVA® MP39” or “SUVA® MP66” sticker as appropriate. On the same or on a separate sticker record the type and viscosity of the new lubricant.

Complete the retrofit report with the new operating parameters of the system.

Note:
Any welding or brazing operation, for example change of the filter drier, must be carried out under an inert (nitrogen) atmosphere, to avoid any risk of carbon or copper oxide formation.

13.4
Converting refrigeration installations from R-502 to SUVA® HP80 and SUVA® HP81

R-502 is an azeotrope consisting of 48.8 wt % HCFC-22 and 51.2 wt % CFC-115. It has until now been widely used for low temperatures, down to about -40° C. Principal applications were in frozen food and ice-cream cabinets: and in refrigerated trucks and containers.

Because CFC-115 is a CFC, and also a long-lived greenhouse gas, R-502 is banned in the same way as CFC-12 and other CFCs.

SUVA® HP80 and SUVA® HP81 Refrigerants have thermodynamic properties similar to those of R-502. They were developed specifically for use in existing R-502 refrigeration installations, to enable them to remain in service.

13.4.1
Selection of the refrigerant

The choice between SUVA® HP80 and SUVA® HP81 will be based on the application and its typical operating conditions:

SUVA® HP80: For low-temperature applications with an evaporating temperature of the order of -40° C, SUVA® HP80 offers a similar discharge temperature to R-502, and improved refrigerating capacity. However the COP is slightly lower than that of R-502.

SUVA® HP81: For installations where energy efficiency is the main consideration, SUVA® HP81 offers the best COP, typically equal to or better than that of R-502: and an increase in refrigerating capacity. In view of its performance, SUVA® HP81 is the ideal candidate for commercial applications having evaporating temperatures no lower than -30° C.

Important note: If SUVA® HP81 is used in a system with an evaporating temperature of the order of -40° C, the compressor discharge temperature may be as much as 15° C higher than with R-502. Such excessive discharge temperatures may adversely affect the lubrication system, and shorten the life of the compressor.

13.4.2
Compatibility

Lubricants
Tests have shown that SUVA® HP80 is slightly less miscible with mineral lubricants (MO) than R502. Extensive field experience has shown that, in practice, in many situations, SUVA® HP80 does perform reliably when using mineral oils.

Tests on actual refrigeration systems with mixtures of alkylbenzene (AB) and MO, e.g. Shell 2212, have given satisfactory results. So have polyolester (POE) lubricants, particularly with SUVA® HP80.

Other laboratory tests have shown that SUVA® HP81 is adequately miscible with mineral oils. Nevertheless, it is recommended to use the same lubricants as proposed above for SUVA® HP80: 50/50 mixtures of AB and MO, or POE. (In many R-502 refrigeration systems AB and AB/MO lubricant mixtures are already used.)

Basically, the same viscosity should be used as with R-502. However, you might consider the use of the next higher viscosity grade if charging POE lubricants.

In all cases you should consult your lubricant supplier and compressor manufacturer.

Materials of construction
It is not necessary to replace elastomers, plastics, metals, wire insulation or other components from the existing R-502 system: provided that they are in good condition

For choice of desiccants in the filter-drier, see 13.4.3 below.

13.4.3
Components to change

Filter-drier
The filter-drier, or its core, must be changed and replaced by a unit containing molecular sieve desiccant compatible with SUVA® HP refrigerants. Filter-driers are available that contain only molecular sieve granules: for example:

- XH-9 by UOP (Division of Union Carbide)
- MS 594 by GRACE Chemicals.

Some types of “Solid Core” filter-drier, for example *sporlan* “Catch ALL”, which contains a mixture of different desiccants, are compatible with SUVA® HP refrigerants. Consult your filter-drier supplier.

Refrigerant
Since SUVA® HP80 and SUVA® HP81 are both semi-azeotropes (near azeotropic mixtures), it is essential to charge them exclusively in *liquid phase*.

For most installations, the SUVA® HP charge will be 90%

to 95% of the previous R-502 charge, by weight.

Other components

Generally, it is not necessary to change the Expansion Device, Pressure Gauges or other components of the system. For lubricant, see paragraph 13.4.2 above.

For moisture-indicating sight glasses, see chapter 7 above.

13.4.4
Equipment required for conversion

General consideration

Use the recovery cylinders provided by your SUVA® Refrigerant supplier.

Indicate clearly the refrigerant you want to recover when ordering the recovering cylinders to ensure that you use appropriate cylinders.

- Do not over-fill cylinders.
- Do not mix refrigerants.

Equipment required

- Personal safety equipment (eye protection, gloves,...)
- Recovery Unit: to withdraw the R-502 as completely as possible from the installation, and to minimise CFC emissions to the atmosphere.
- Scale: to weigh the R-502 withdrawn, and ensure correct weight of the SUVA® HP charge.
- Recovery Cylinder: one or more.
- Vacuum Pump: of adequate capacity, and whose performance has been checked regularly with a vacuum gauge.
- Refrigerant Charging Lines: in the form of a manifold, incorporating pressure gauges.
- Lubricant Charging Line.
- Leak Detector: to check system for leaks after charging with SUVA® HP. Since both blends contain HCFC-22, the conventional type, preferably electronic, may be used.

13.4.5
Conversion procedure

1) Before starting the conversion to SUVA® HP refrigerant, record all the operating parameters of the existing R-502 system, particularly the return gas temperature and the subcooled temperature under normal working conditions. Use the *retrofit report*, available from your SUVA® Refrigerant supplier.

2) Switch on the compressor lubricant heater, if possible several hours before starting to evacuate the system, to ensure that the lubricant is fully de-gassed.

3) Using the Recovery Unit, evacuate the R-502 from the system into the Recovery Cylinder(s) provided. Record the weight of the R-502, and return the recovered refrigerant to your SUVA Refrigerant supplier.

4) Ensure that the compressor cannot accidentally start up, by removing the fuse or locking open the power switch. Affix a tag or label to the fuse holder or switch. Make sure that the lubricant heater is switched off.

5) Where applicable drain the mineral lubricant from the compressor, and from the lubricant separator and other components if fitted, as completely as reasonably possible. Record the volume of lubricant removed, then place it in an appropriate recipient to be disposed of in accordance with the regulations in force.

6) Charge the new lubricant into the compressor, to the same volume as removed in the previous step.

7) Replace the filter-drier by one compatible with SUVA® HP80 or SUVA® HP81.

8) Pull vacuum on the entire system. Follow normal procedure to eliminate air and other non-condensible gases from the circuit (3 to 5 mbar).

9) Charge the installation with SUVA® HP Refrigerant *exclusively* in *liquid phase*, to 90% by weight of the previous R-502 charge. To prevent liquid entering the compressor, install a throttle valve in the charging line. The optimum system charge will depend on the operating conditions of the installation and its internal configuration. For most installations the appropriate charge will be between 90% and 95% of the R-502 weight.

10) Re-start the system and wait until the operating conditions stabilise.

11) Optimise the performance of the system by completing the SUVA® HP charge, still in *liquid phase*, into the compressor suction port. Make also use of the liquid line sight-glass and of the pressure gauges when completing the refrigerant charge.

12) When the system is operating normally with its final charge, expect to find: – With SUVA® HP80: discharge pressure 2 to 3 bar higher than with R-502, but an equivalent discharge temperature. – With SUVA® HP81: discharge pressure 1.5 to 2 bar higher . If the evaporating temperature with

SUVA® HP81 is below -35° C, see Note in paragraph 13.4.1.

13) Adjust the high-pressure and low-pressure safety cutouts.

14) Carry out complete leak check.

15) Replace the “R-502” sticker by a “SUVA® HP80” or “SUVA® HP81” sticker as appropriate. On the same or a separate sticker record the type and viscosity of the lubricant.

16) Make a complete report on the new operating parameters of the system, using the retrofit report.

Note:
Any welding or brazing operation, for example to change the filter-drier, must be carried out in an inert (nitrogen) atmosphere, to avoid any danger of carbon or copper oxide build-up.

14 Safety

14.1
Safe handling of SUVA® HP refrigerants and environmental effects

14.1.1
Introduction

SUVA® refrigerants have been developed to replace FREON® refrigerants that have been used for over 50 years. They were originally introduced to replace non-fluorocarbon refrigerants that were flammable, dangerously toxic, or both. ALL FREON® and SUVA® refrigerants are:

- Practically non-flammable and non-explosive.
- Of very low toxicity.
- Non-corrosive under normal conditions.

These properties apply to SUVA® refrigerants under normal, correct, conditions of use. It is necessary to understand the properties of SUVA® refrigerants: and to observe the precautions listed below.

14.1.2
Properties

Pressure
All SUVA® refrigerants except SUVA® 123 are liquefied gases shipped under pressure. They are supplied in cylinders and other shipping containers which are of adequate strength and which comply with pressure vessel regulations.

Pressure of SUVA® refrigerants at normal temperature (25° C) range from 0.45 bar (Suva 123) to 13.8 bar (SUVA® 125). Refrigeration equipment must be of sufficient pressure resistance for the refrigerant employed. (note: SUVA® 123 is liquid at room temperature).

Very slight odour
SUVA® refrigerants have a slight, ethereal odour. This can only be perceived if they are present in relatively high concentrations in the air being breathed.

Vapour heavier than air
SUVA® refrigerant vapour is up to six times heavier than air.

It will tend to accumulate in low places almost like a liquid. The vapour will displace air, if it is present in very large quantities.

SUVA® refrigerant vapour will decompose if exposed to flames or very hot metal surfaces. Decomposition products are toxic but warning of their presence is given by very pungent irritating acid vapours. It is almost impossible to remain voluntarily in an area containing more than a few ppm of these decomposition products.

14.1.3
Threshold limit value

The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended TLVs for many industrial chemicals. The TLV-TWA is a time-weighted average concentration in air for a normal 8 hour work day and 40 hour work week, to which nearly all workers may be exposed, day after day, without adverse effect. For most of the chemicals examined, including the FREON compounds, some exposure above the TLV-TWA is permitted if compensated for by an equivalent exposure below the TLV-TWA limit during the rest of the day: this is defined as the short-term exposure limit (STEL). In other cases a Ceiling (TLV-C) is defined, the concentration that should not be exceeded even instantaneously. The highest TLV-TWA value assigned to any chemical (except carbon dioxide) is 1.000 ppm by volume.

The TLVs laid down by ACGIH are generally accepted by the responsible authorities in other countries, but there may be specific exceptions.

The following SUVA® compounds have been evaluated and given the 1.000 ppm rating:

SUVA® 134a, 124, 125, MP39, MP66, HP80, HP81, 404A, 407C, 410A, SUVA® 95.

14.1.4
Handling precautions

Avoid excessive concentration of SUVA® refrigerant vapour. Vapours are heavier than air and can accumulate in low places. Workplaces should have adequate ventilation. If it is necessary to discharge significant quantities of SUVA® vapour, this should be done out of doors.

The maximum allowable workplace concentration (TLV), normally 1.000 ppm, should be observed.

Do not inhale concentrated SUVA® vapour, or swallow liquid SUVA® refrigerant, for any reason.

Keep away from flames and hot metal surfaces. SUVA® vapour can decompose at high temperatures to give toxic products. Warning of this is given by irritating, acidic, decomposition products. If these occur, evacuate the area and ventilate thoroughly.

Do not weld and braze when SUVA® refrigerant vapours are present. Do not place gas or electric heaters in places where SUVA® vapours are expected. It is advisable not to smoke in presence of SUVA® refrigerant vapour.

If it is necessary to enter an area containing a high concentration of refrigerant vapour or of decomposition products of

SUVA® refrigerants wear a full-face breathing apparatus with independent air supply. Filter masks are not recommended.

Protect hands and skin from contact with liquid SUVA® Refrigerants, which can cause frostbite. SUVA® 123 does not cause frostbite but removes natural greases from the skin. This makes the skin vulnerable to infection. Wear gloves when handling SUVA® refrigerants.

Protect eyes from splashing with liquid SUVA® refrigerant. Wear eye protection.

Do not over-heat cylinders. They may be warmed to assist in transferring SUVA® refrigerants, but never above 50° C. Lower temperatures are specified in some countries. Use a bucket of warm water: an electrical blanket or a heated cupboard (in each case fitted with a control thermostat): never a welding torch. Localized heating can weaken a cylinder so that it is no longer safe under normal pressure. Overheating may lead to a liquid-full cylinder and the development of hydraulic pressure which may be sufficient to rupture the cylinder.

Do not over-fill cylinders. If a cylinder is full of liquid refrigerant, the pressure increases very rapidly with only slight rise in temperature. Under these conditions the cylinder may burst.

Do not damage cylinders. A cylinder must not be dropped or used as a roller or support. If a cylinder or its valve is, or appears to be, damaged, do not attempt to repair it. This is a job for a specialist. Return it to your SUVA® refrigerant distributor.

Lubricant from a refrigeration system should be handled carefully. It may contain acids, particularly after a burnout. Wear gloves, protective clothing and eye protection.

Flush pipes with dry nitrogen when brazing or welding part of a refrigeration system.

Release pressure of any system or component before welding or brazing. Systems, and components such as compressors and heat exchangers, are frequently pressurized to more than normal working pressure for leak testing. If repaired by welding or brazing while still under pressure, the rise in temperature may increase pressure sufficiently to rupture the component.

Never use oxygen to flush pipes or parts of systems. Oxygen and refrigeration lubricant can form explosive mixtures.

14.1.5
First aid

Frostbite. Warm the affected skin to body temperature as soon as possible.

Eyes. If SUVA® refrigerant is splashed into the eyes, rinse with plenty of water. Always consult a doctor or an optician.

Persons overcome by SUVA® vapour. They should immediately go, or be moved, to fresh air. Lie down, do not take exercise. Use artificial respiration if person is unconscious. Call a doctor.

Do not use chemical products of the adrenaline-ephedrine group. In combination with excessive SUVA® vapour concentration, these can produce cardiac arrhythmia leading to ventricular fibrillation.

Appendix

I)
SI Conversion tables

Definitions

The definition of the most important SI units of the metric system are as follow:

Length	**Meter (m)** 1 m is the length of the path travelled by light in a vacuum during a time interval of 1/299 792 458 of a second.
Mass	**Kilogramme (kg)** 1 kg is the mass of the international prototype in custody of the Bureau International des Poids et Mesures at Sèvres, near Paris.
Time	**Second (s)** 1 s is the duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state $2s_{12}$ of the Caesium 133 atom.
Force	**Newton (N)** 1 Newton is the force which applied to a body having a mass of 1 kilogramme gives it an acceleration of 1 m/s^2.
Temperature	**Kelvin (k)** Kelvin is the interval of the thermodynamic scale on which the temperature of the triple point of water is 273.15 degrees.
Energy	**Joule (J)** 1 Joule is the work done when a force of 1 Newton is applied in its own direction over a distance of 1 meter.
Power	**Watt (W)** 1 Watt is the power produced when work is performed at the rate of 1 Joule per second.

Other conversions

Temperature

K = °C + 273.15	=	(°F + 459.67)/1.8
°R = °F + 459.67	=	(°C + 273.15) x 1.8
°C = (°F - 32)/1.8		
°F = 1.8 °C + 32		

Conversion factors

To conv´ert from:	To:	Multiply by:
Pressure		
1 atm	bar	1.01325
1 Pa (N/m^2)	bar	10^{-5}
1 kg/ m^2	bar	$0.98066.10^{-4}$
1 kg/c m^2	bar	0.98066
1 Torr (mmHg)	bar	$1.333.10^{-3}$
1 mH2O	bar	$0.9805.10^{-1}$
1 lb/sq.in. (psi*)	bar	$6.80474.10^{-2}$
1 in.H2O (4 °C)	bar	$2.491.10^{-3}$
1 ft H2O (4 °C)	bar	$2.989.10^{-2}$
Length		
1 in.	m	$25.4 . 10^{-3}$
1 ft	m	0.30480
1 yd	m	0.9144
1 statute mile	m	1609.344
1 nautical mile	m	1853.18
Surface		
1 sq.in.	m^2	$6.45160.10^{-4}$
1 sq.ft	m^2	$9.29030.10^{-2}$
1 sq.yd	m^2	0.83613
1 Acre	m^2	4047
1 sq. mile	m^2	2589998
Volume		
1 cu.in	m^3	$1.63871.10^{-5}$
1 cu.ft	m^3	$2.83168.10^{-2}$
1 cu.yd	m^3	0.764555
1 US gallon	m^3	$3.78534.10^{-3}$
1 Imperial gallon	m^3	$4.54596.10^{-3}$
1 US bushel	m^3	$3.524.10^{-2}$
1 US fluid oz.	m^3	$2.957.10^{-5}$
Linear speed		
1 m/min	m/s	0.01667
1 km/h	m/s	0.2778
1 cm/s	m/s	10^{-2}
1 mile/h	m/s	0.4470
1 yd/s	m/s	0.9144
1 ft/min	m/s	$0.5080.10^{-2}$
1 ft/s	m/s	0.3048
1 in./s	m/s	0.0254
1 knot	m/s	0.5144
Rotation speed		
1 RPM	Rad/s	0.10472
Mass units		
1 g	kg	10^{-3}
1 t	kg	10^{3}
1 oz.	kg	$2.83495.10^{-2}$
1 lb	kg	0.453592
1 short ton (USA)	kg	907.18487
1 long ton (UK)	kg	1016.0471
1 grain	kg	$6.480.10^{-5}$
Specific volume		
1 cm3/g	m^3/kg	10^{-3}
1 l/g	m^3/kg	1
1 cu.ft/lb	m^3/kg	$62.42795.10^{-3}$
1 cu.in/lb	m^3/kg	$0.361271.10^{-4}$
1 Imp.gal/lb	m^3/kg	0.01002
1 US gal./lb	m^3/kg	0.008345
Density		
1 kg/l	kg/m^3	10^{3}
1 g/cm^3	kg/m^3	10^{3}
1 g/l	kg/m^3	1
1 lb/cu.ft	kg/m^3	16.01847
1 lb/cu.in	kg/m^3	27680
1 lb/Imp.gal	kg/m^3	99.77644
1 lb/US gal	kg/m^3	119.8264
Force		
1 dyne	N	10^{-5}
1 kg	N	9.8066
1 sthene (sn)	N	10^{3}
1 poundal	N	$1.383.10^{-1}$
Energy, work		
1 erg	J	10^{-7}
1 kgm	J	9.8066
1 kJ	J	10^{3}
1 kcal	J	$4.184.10^{3}$
1 chh	J	$2.648.10^{6}$
1 kWh	J	$3.600.10^{6}$
1 Hp h	J	$2.684.10^{6}$
1 BTU (mean)	J	1055.87
Power		
1 erg/s	W	10^{-7}
1 kgm/s	W	9.8066
1 kW	W	10^{3}
1 kcal/h	W	1.163
1 ch	W	$0.735.10^{3}$
1 kcal/s	W	$4.184.10^{3}$
1 Hp	W	745.7
1 BTU/h	W	0.293
1 T Ref.	W	3516.8

II)
Physical properties and ashrae standard 34 classification of SUVA® refrigerants

Physical property	Units	FREON® 22	HFC-23	SUVA® 123	SUVA® 124	SUVA® 125	SUVA® 134a	SUVA® MP39	SUVA® MP52	SUVA® MP66	SUVA® HP80	SUVA® HP81	SUVA® 404A	SUVA® 407C	SUVA® 410A	SUVA® 95
ASHRAE nomenclature		R-22	R-23	R-123	R-124	R-125	R-134a	R-401A	R-401C	R-401B	R-402A	R-402B	R-404A	R-407C	R-410A	R-508B
Molecular weigh	g/mol	86.47	70.02	152.93	136.5	120.0	102.0	94.4	101.0	92.8	101.55	94.71	97.6	86.2	72.58	95.39
Boiling point (1.013 bar)	°C	-40.75	82.03	27.9	-12.1	-48.1	-26.1	-33.0	-28.4	-34.7	-49.2	-47.4	-46.7	-43.6	-51.5.8	-88.3
Freezing point	°C	-160.0	-155.2	-107.0	-199.0	-103.0	-101.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Critical temperature	°C	96.0	25.9	183.7	122.5	66.2.0	101.1	108	113	106	75.5	82.6	72.1	86.7	72.1	14.0
Critical pressure	bar	49.77	48.36	36.68	36.3	36.3.0	40.60	46.04	43.66	46.82	41.35	44.45	37.32	46.0	49.2	39.2
Critical density	kg/m^3	525	525.0	550.0	553.8	571.9	515.3	510.6	512.3	512.7	541.7	530.7	484.5	506.8	488.9	587.6
Liquid density @ 25° C	kg/m^3	1194	670	1463	1364	1189.7	1206	1194	1211	1193	1151	1156	1048	1136	1062	335
Density, saturated vapour @ -15° C	kg/m^3	12.88	71.45	1.146	5.996	25.68	8.288	7.713	6.723	8.247	19.93	16.90	18.196	11.14	18.52	121.8
Specific heat liquid @ 25° C	kJ/(kg.K)	1.25	1.44 @ -30° C	0.965	1.13	1.37	1.44	1.30	1.28	1.30	1.370	1.340	1.530	1.537	1.834	n/a
Specific heat vapour @ 25° C, 1.013 bar	kJ/(kg.K)	0.657	0.736	0.721	0.741	0.809	0.852	0.735	0.745	0.724	0.755	0.725	0.870	0.829	0.826	n/a
Vapour pressure @ 25° C	bar	10.4	47.4	0.91	3.83	13.81	6.66	7.73	6.56	8.19	13.37	12.54	12.55	11.85	16.53	42.5
Heat of vaporisation, at boiling point	kJ/kg	233.5	239.4	174.2	167.9	164.4	217.1	227.4	216.9	229.4	194.0	210.0	202.1	246.1	264.3	167.1
Thermal conductivity liquid @ 25° C	W/(m K)	0.088	0.098	0.0810	0.072	0.0652	0.0824	0.09	0.0868	0.09	$6.9.10^{-2}$	$7.35.10^{-2}$	$6.83.10^{-2}$	$8.24.10^{-2}$	$8.51.10^{-2}$	n/a
Thermal conductivity vapour @ 25° C, 1.013 bar	W/(m K)	0.0105	0.0104	0.0112	0.0130	0.0166	0.0145	0.0119	0.0121	0.0119	$1.266.10^{-2}$	$1.205.10^{-2}$	$1.346.10^{-2}$	$1.199.10^{-2}$	$1.243.10^{-2}$	n/a
Liquid viscosity @ 25° C	mPa.s (cP)	0.198	0.167 @ -30° C	0.456	0.314	0.137	0.202	0.194	0.212	0.190	$1.38.10^{-4}$	$1.45.10^{-4}$	$1.28.10^{-4}$	$1.58.10^{-4}$	$1.25.10^{-4}$	n/a
Vapour viscosity @ 25° C, 1.013 bar	mPa.s (cP)	0.0127	0.0118 @ -30° C	0.0110	0.0131	0.013	0.012	121	120	121	$1.29. 10^{-5}$	$1.28.10^{-5}$	$1.22.10^{-5}$	$1.28.10^{-5}$	$1.31.10^{-5}$	n/a

Physical properties of SUVA® refrigerants (cont'd)

Physical property	Units	FREON® 22	HFC-23	SUVA® 123	SUVA® 124	SUVA® 125	SUVA® 134a	SUVA® MP39	SUVA® MP52	SUVA® MP66	SUVA® HP80	SUVA® HP81	SUVA® 404A	SUVA® 407C	SUVA® 410A	SUVA® 95
Solubility of the refrigerant in water at 25° C	wt %	0.30	0.10	0.39	0.145	0.09	0.15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Solubility of water in the refrigerant at 25° C	wt %	0.13	n/a	0.08	0.07	0.07	0.11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flammability limit in air	Vol %	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Autoignition Temperature	°C	635	765	730	n/a	733	743	681	n/a	685	723	641	728	733	n/a	>750
Ozone depletion potential	CFC-11 = 1	0.05	0	0.02	0.02	0	0	0.03	0.03	0.035	0.02	0.03	0	0	0	0
Halocarbon global warming potential	CFC-11 - 1	0.34	n/a	0.02	0.10	0.84	0.28	0.22	0.17	0.24	0.63	0.52	0.94	0.38	0.45	n/a
Global Warming Potential (GWP) (100 yr ITH. For CO2, GWP = 1)	–	1700	12100	90	480	3200	1300	1080	830	1190	2570	2240	3750	1600	1890	12300
EINECS inventory status and UL recognition	Included	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Inhalation exposure limit	AEL*, ppm (8 and 12 hr., TWA)	1000	1000	30	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
ASHRAE colour coding	PMS code			428	335	465	2975	177	3268	413	461	385	021	471	507	302
	COLOUR			light grey	dark green.	medium brown	light blue	pink-red (coral)		light green grey	light brown-sand	green brown-olive	orange	brown	rose	navy blue

III)

Pressure-enthalpy (mollier) diagrams for:

FREON® 22

SUVA® HCFC-123

SUVA® HCFC-124

SUVA® HFC-125

SUVA® HFC-134a

SUVA® MP 39

SUVA® MP 52

SUVA® MP 66

SUVA® 404A

SUVA® HP 80

SUVA® HP 81

SUVA® 407C

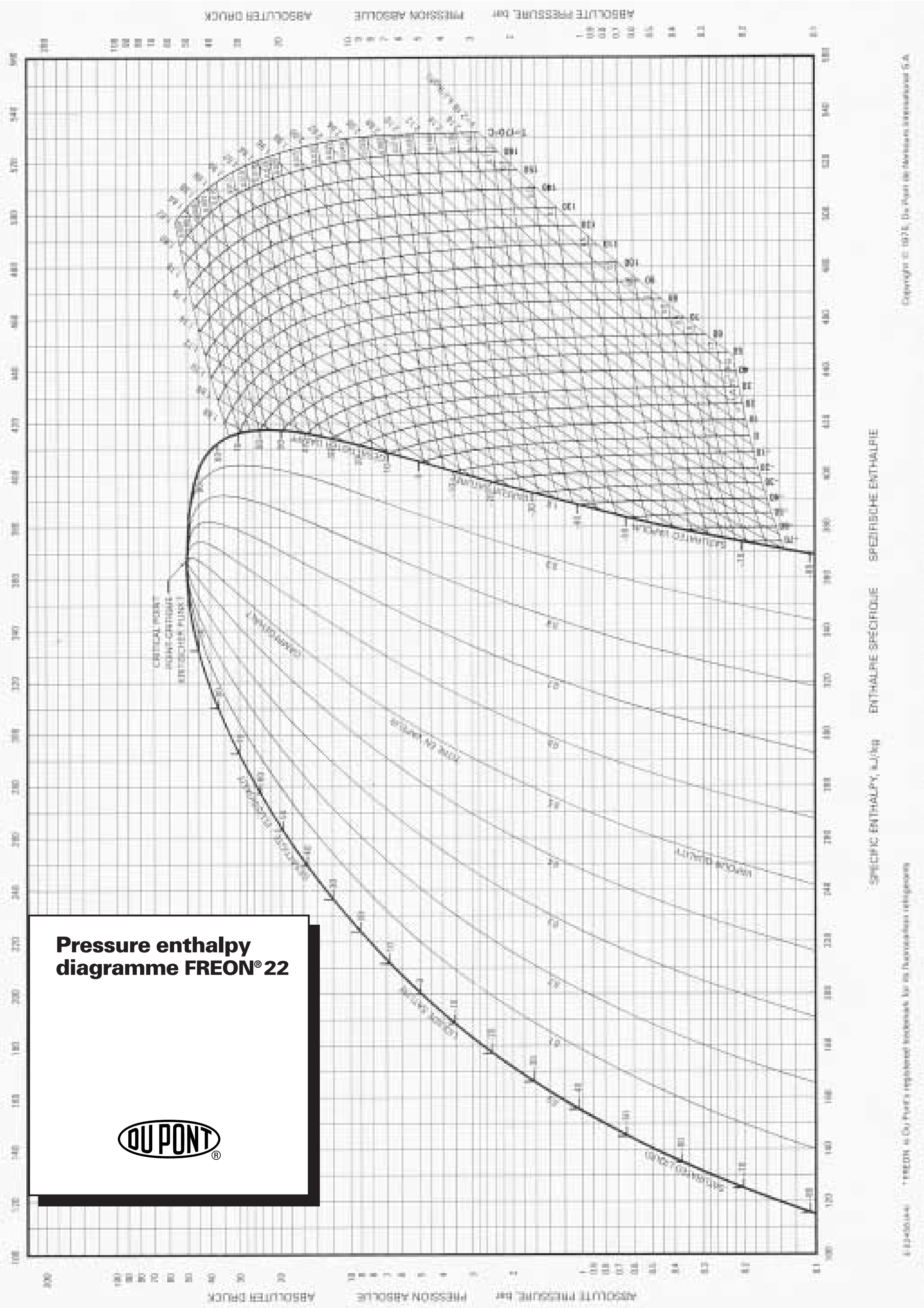
SUVA® 410A

HFC-23

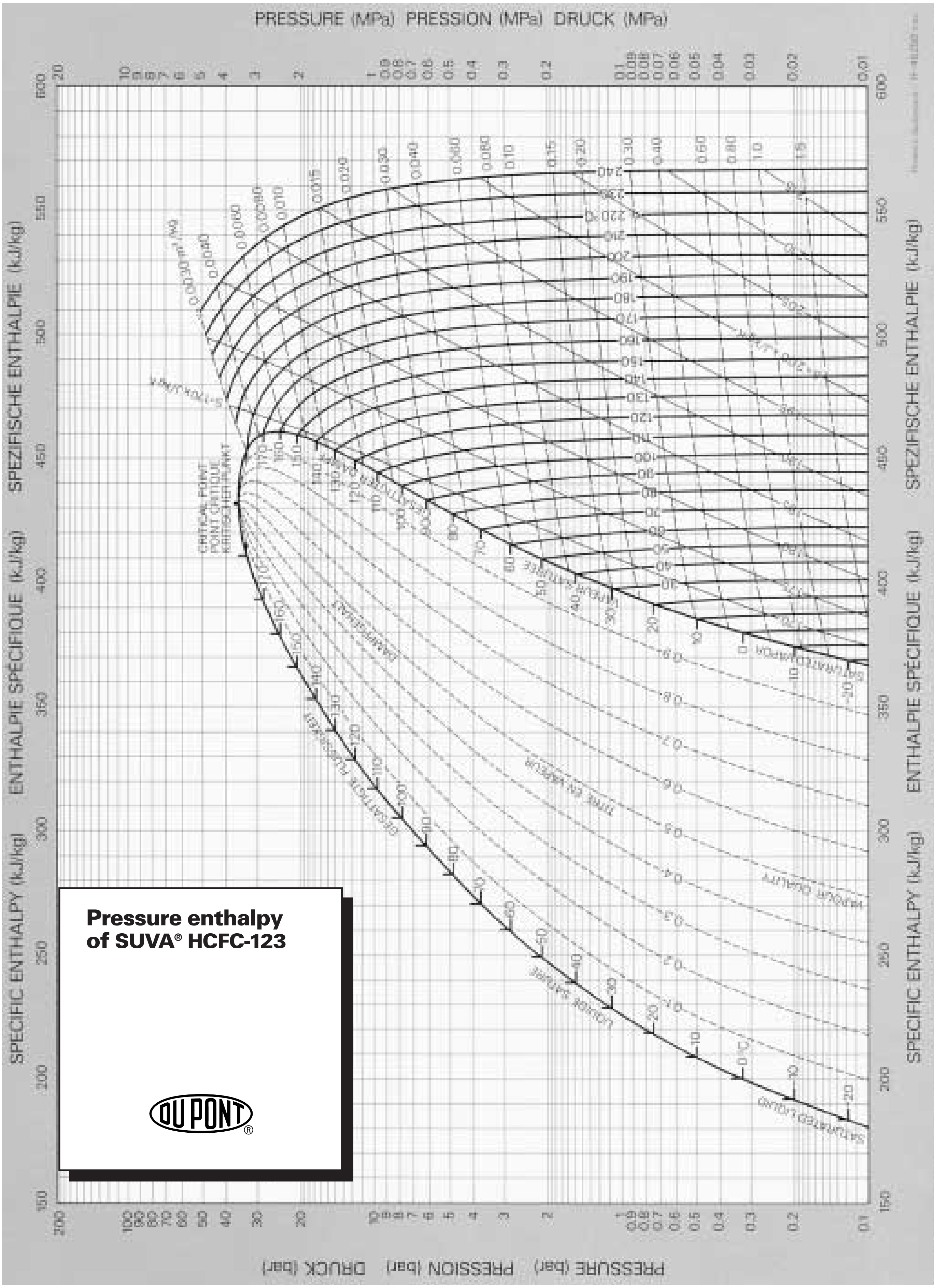
SUVA® 236fa

SUVA® 95

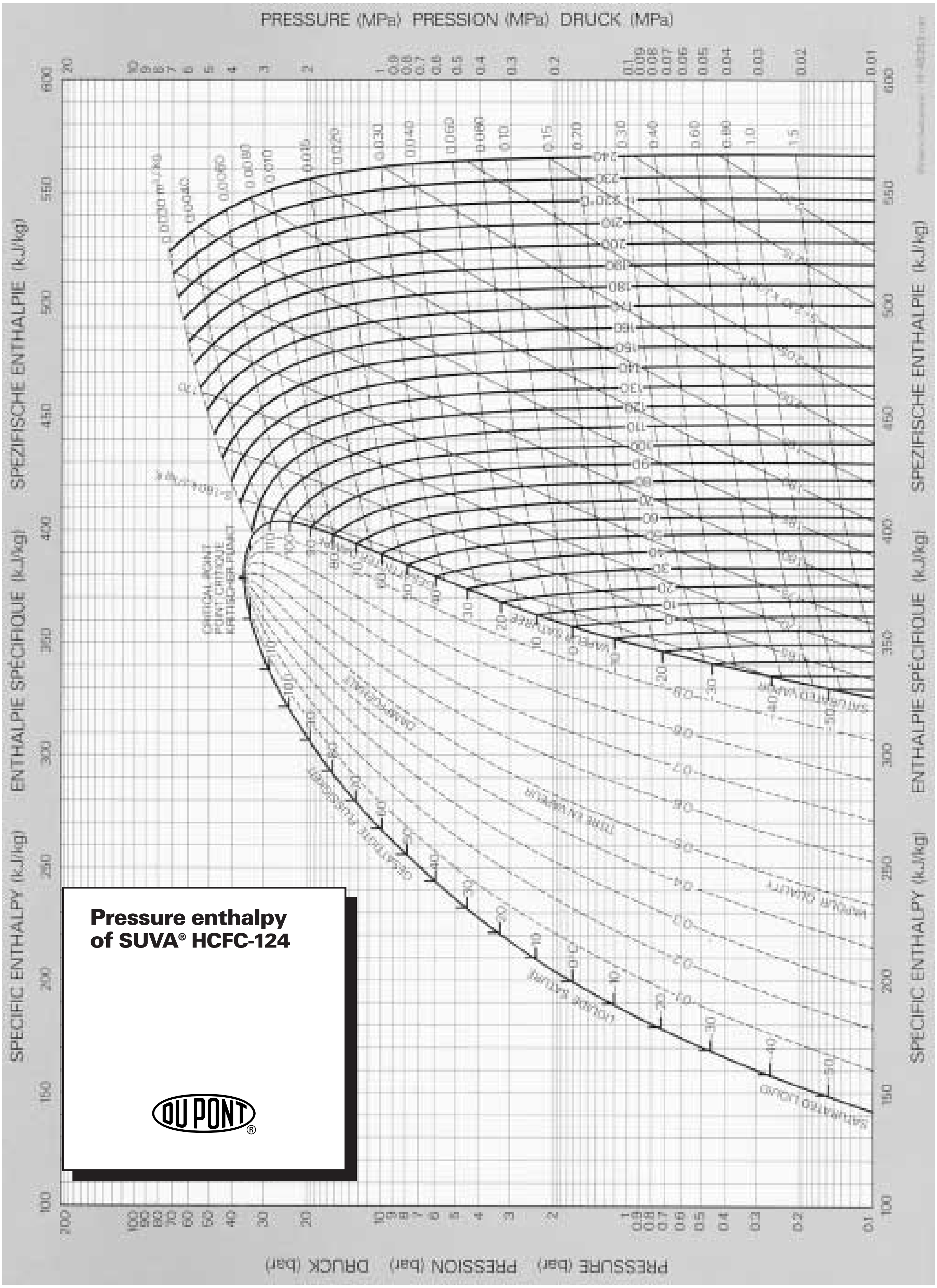
SUVA® 507



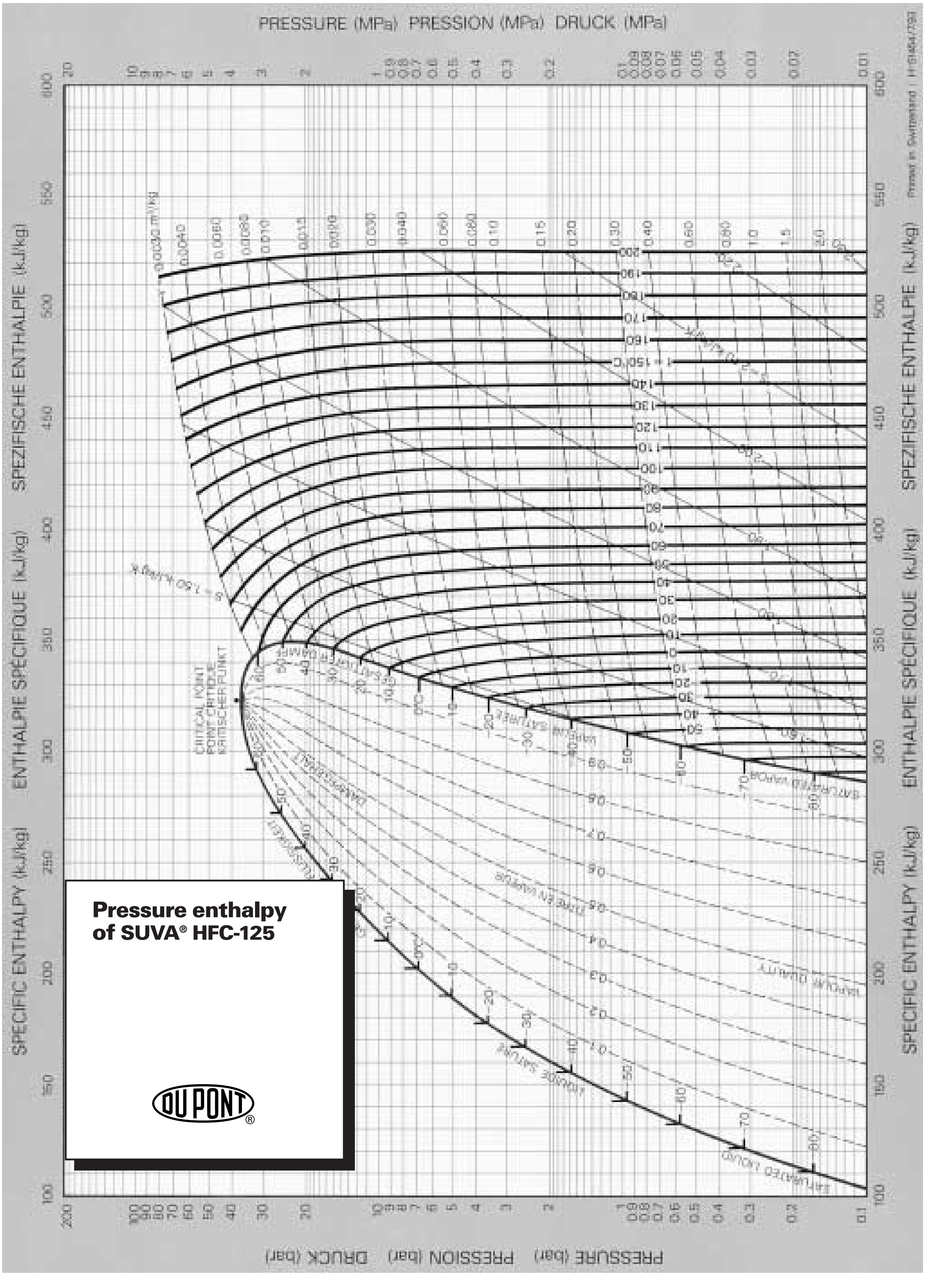
Pressure enthalpy diagramme FREON® 22



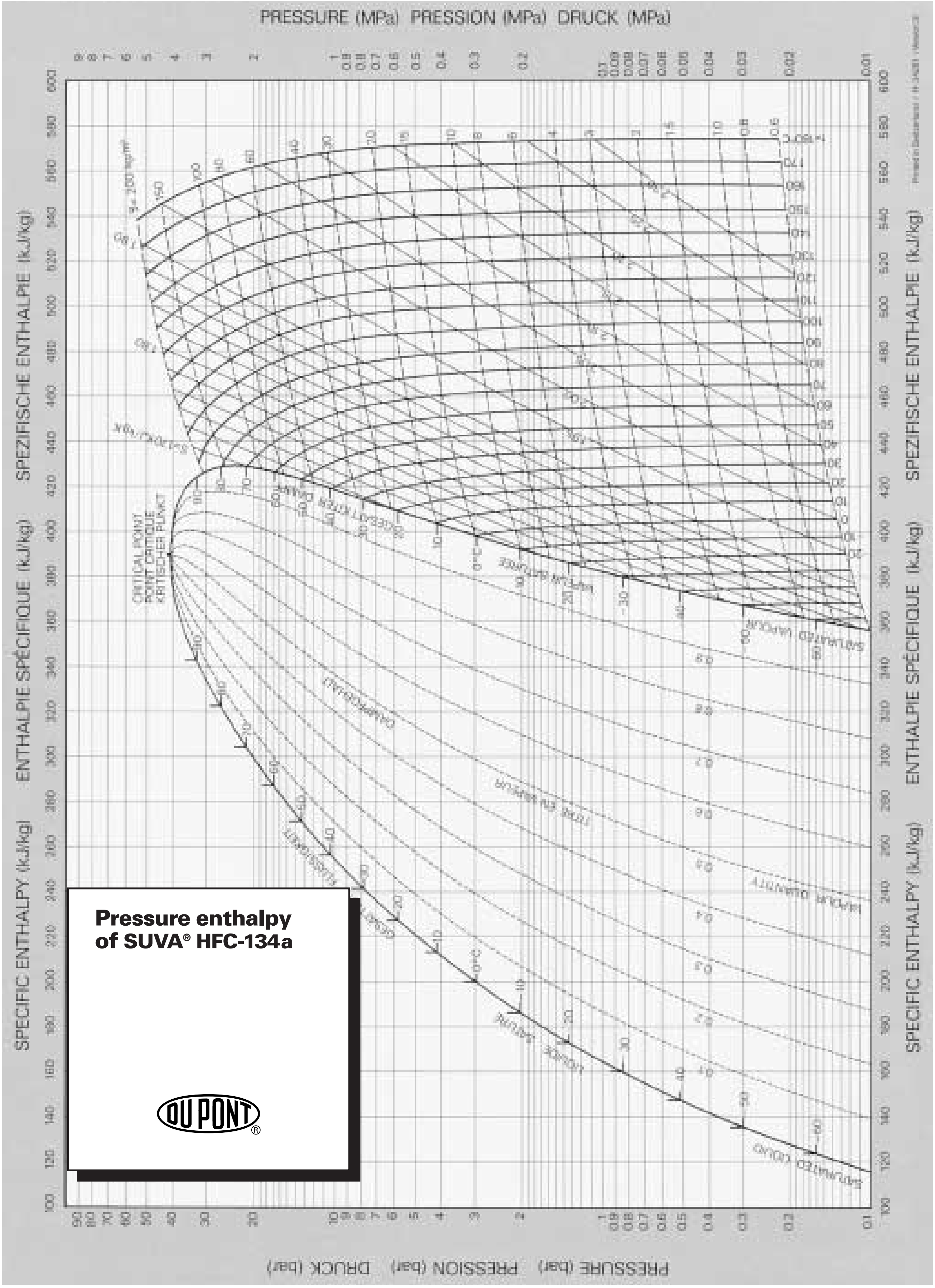
Pressure enthalpy of SUVA® HCFC-123



Pressure enthalpy of SUVA® HCFC-124

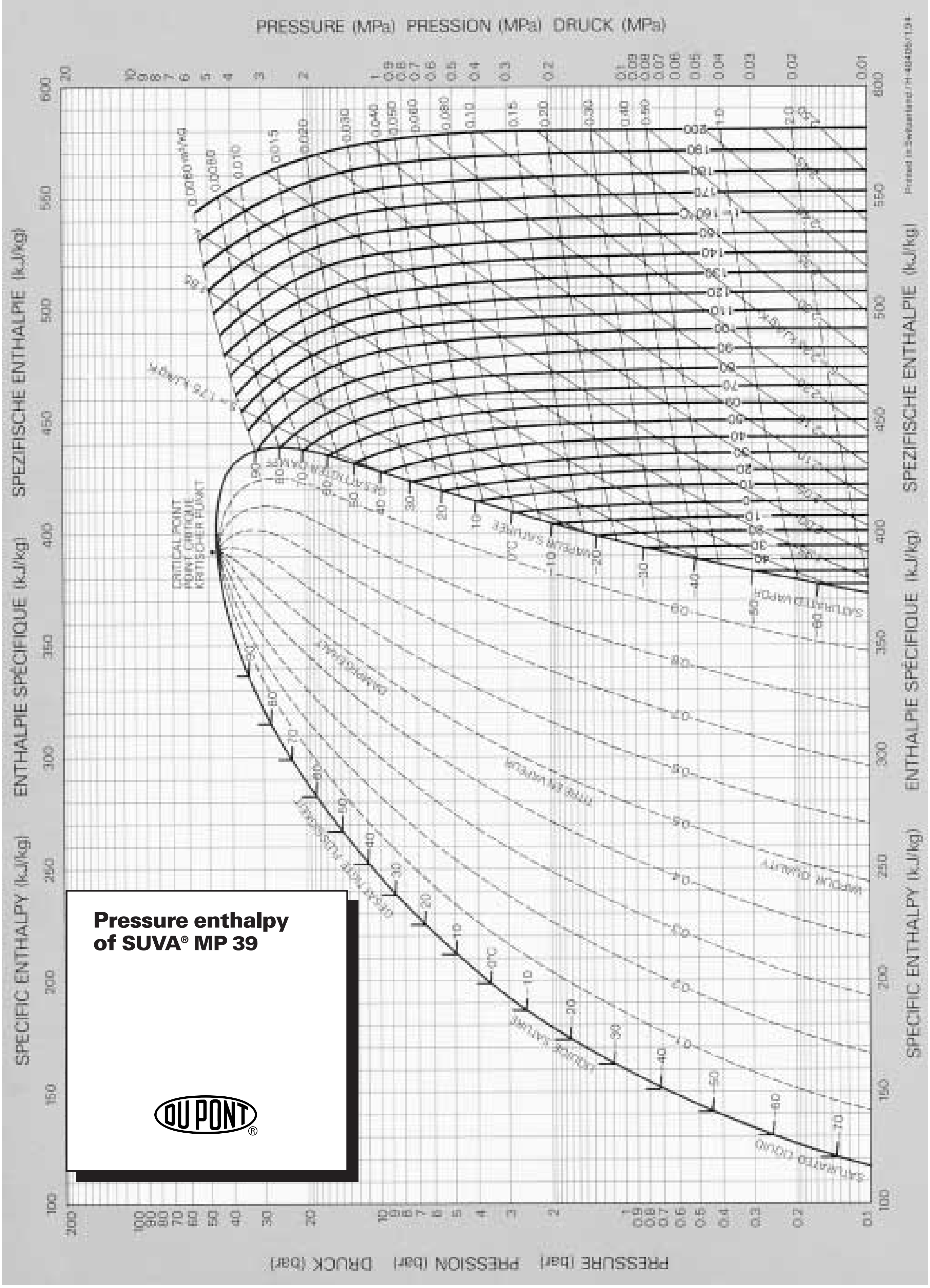


Pressure enthalpy of SUVA® HFC-125



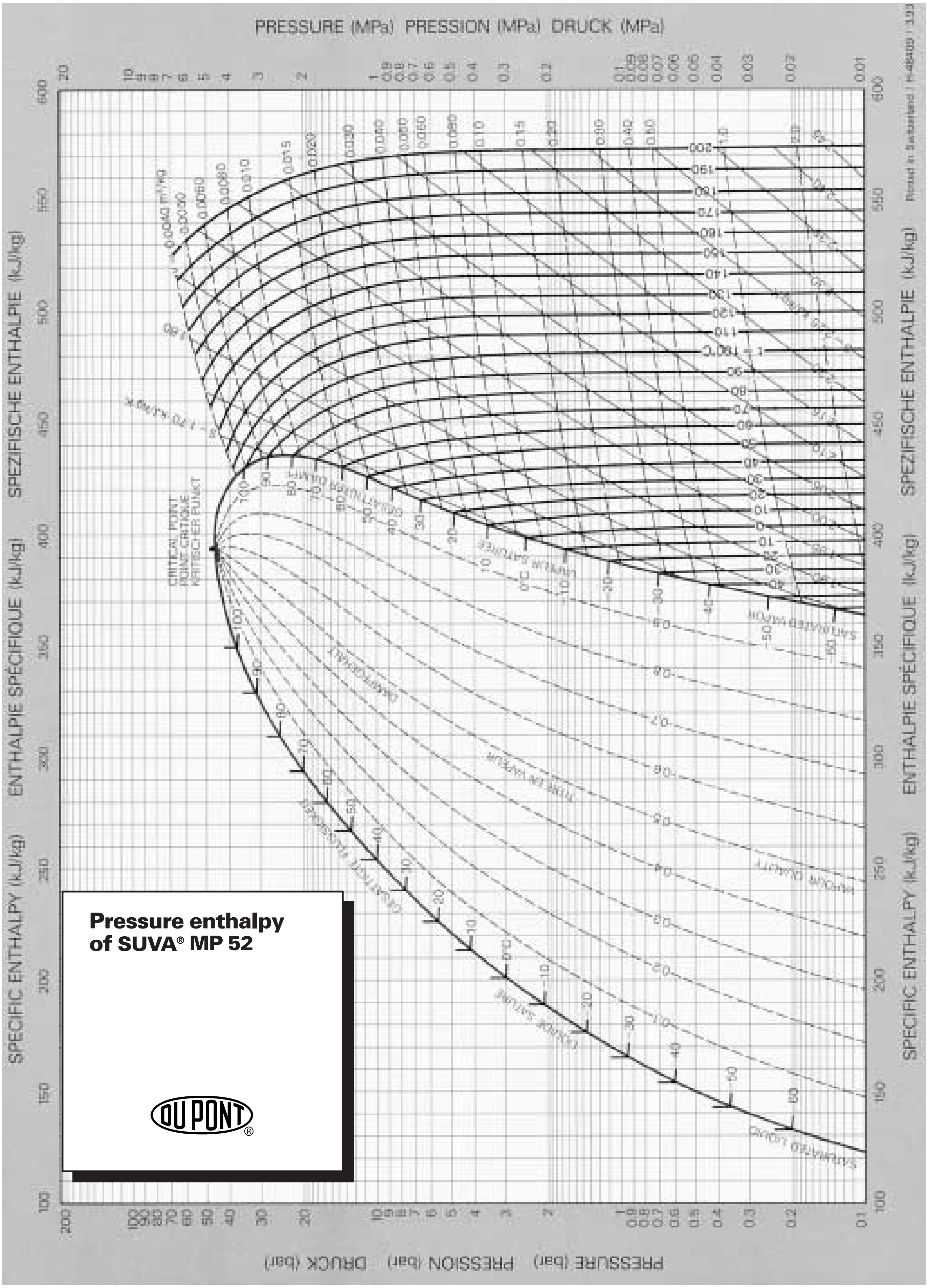
Pressure enthalpy of SUVA® HFC-134a

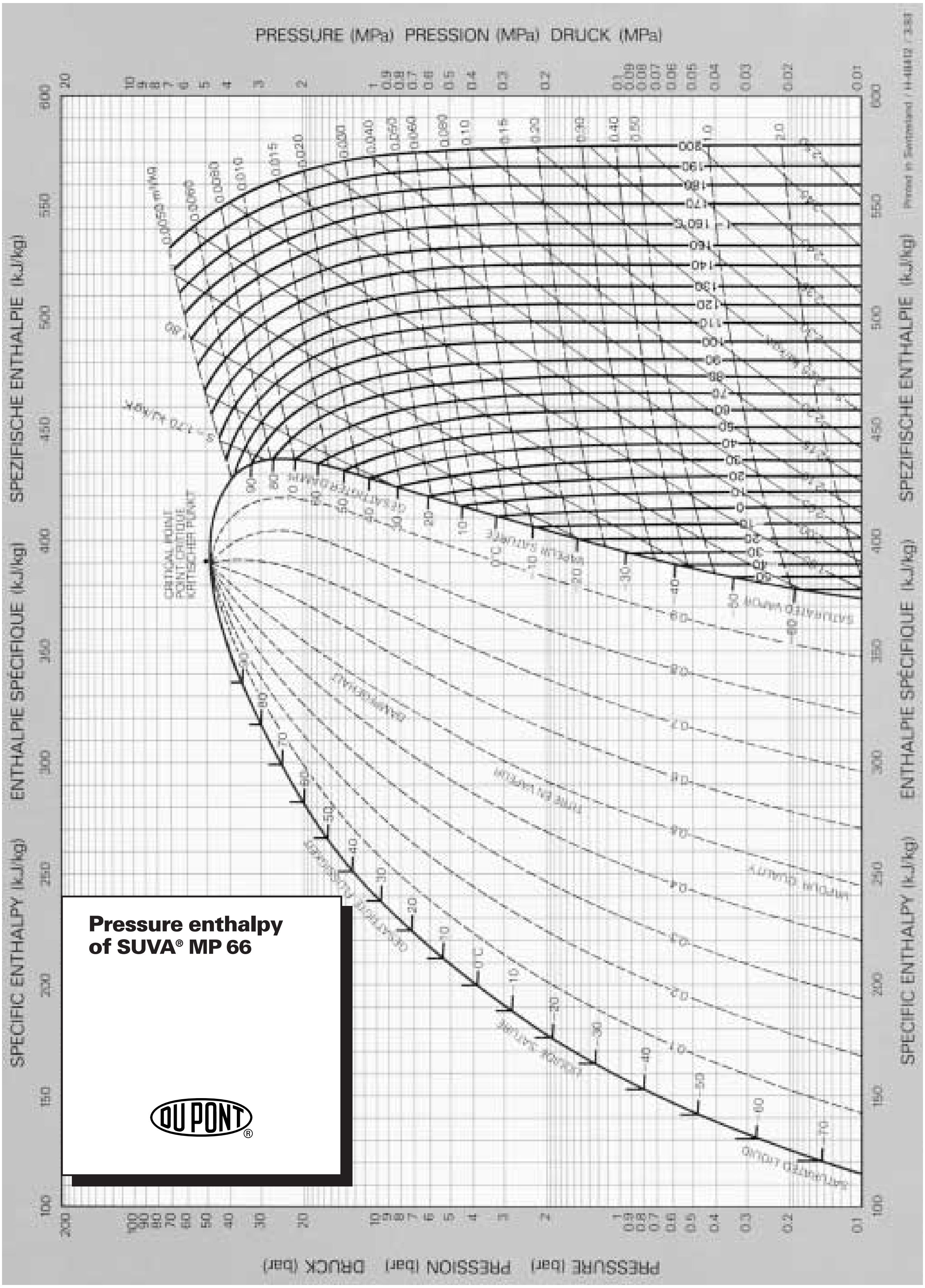
DUPONT®



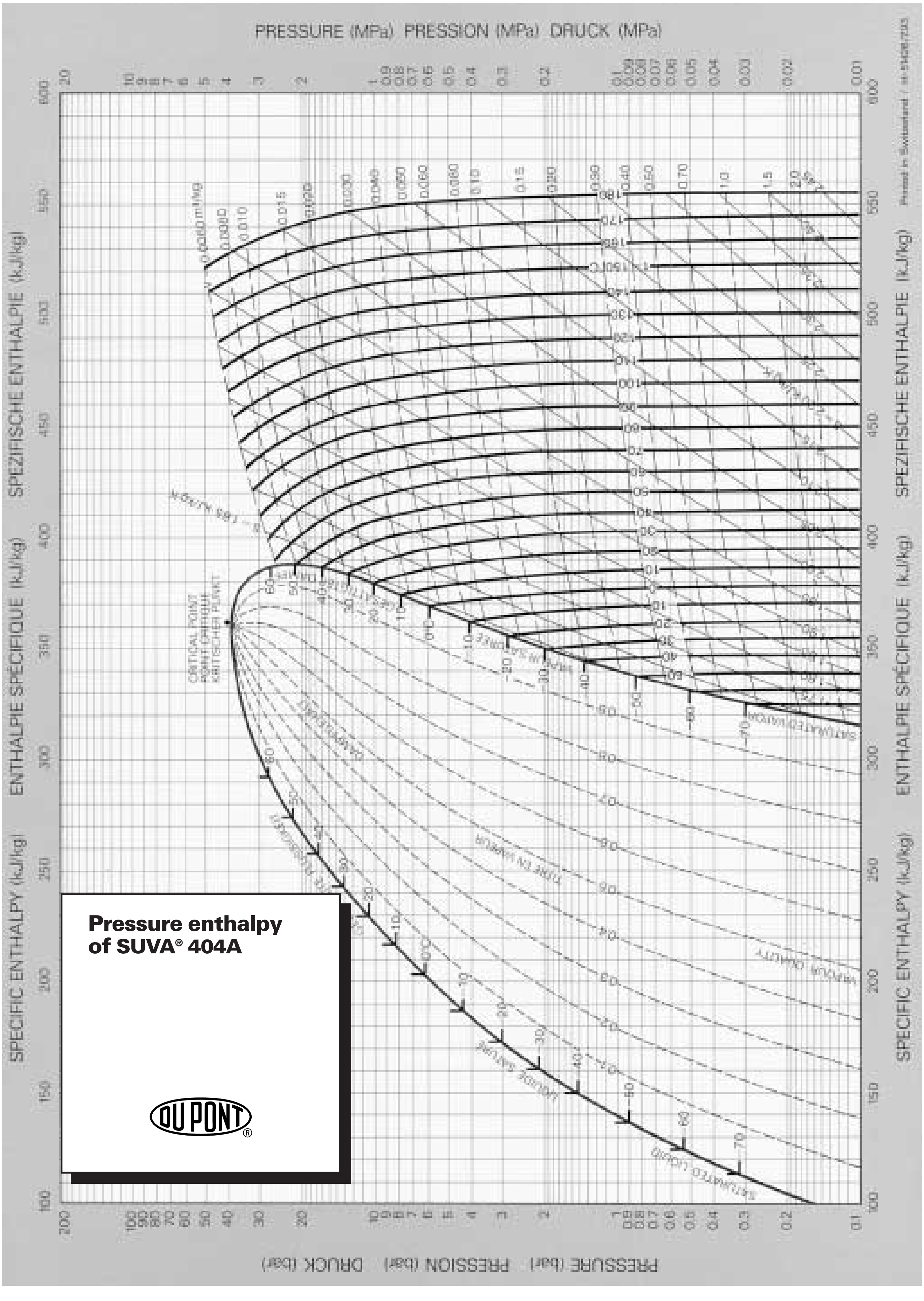
Pressure enthalpy of SUVA® MP 39

Pressure enthalpy of SUVA® MP 52

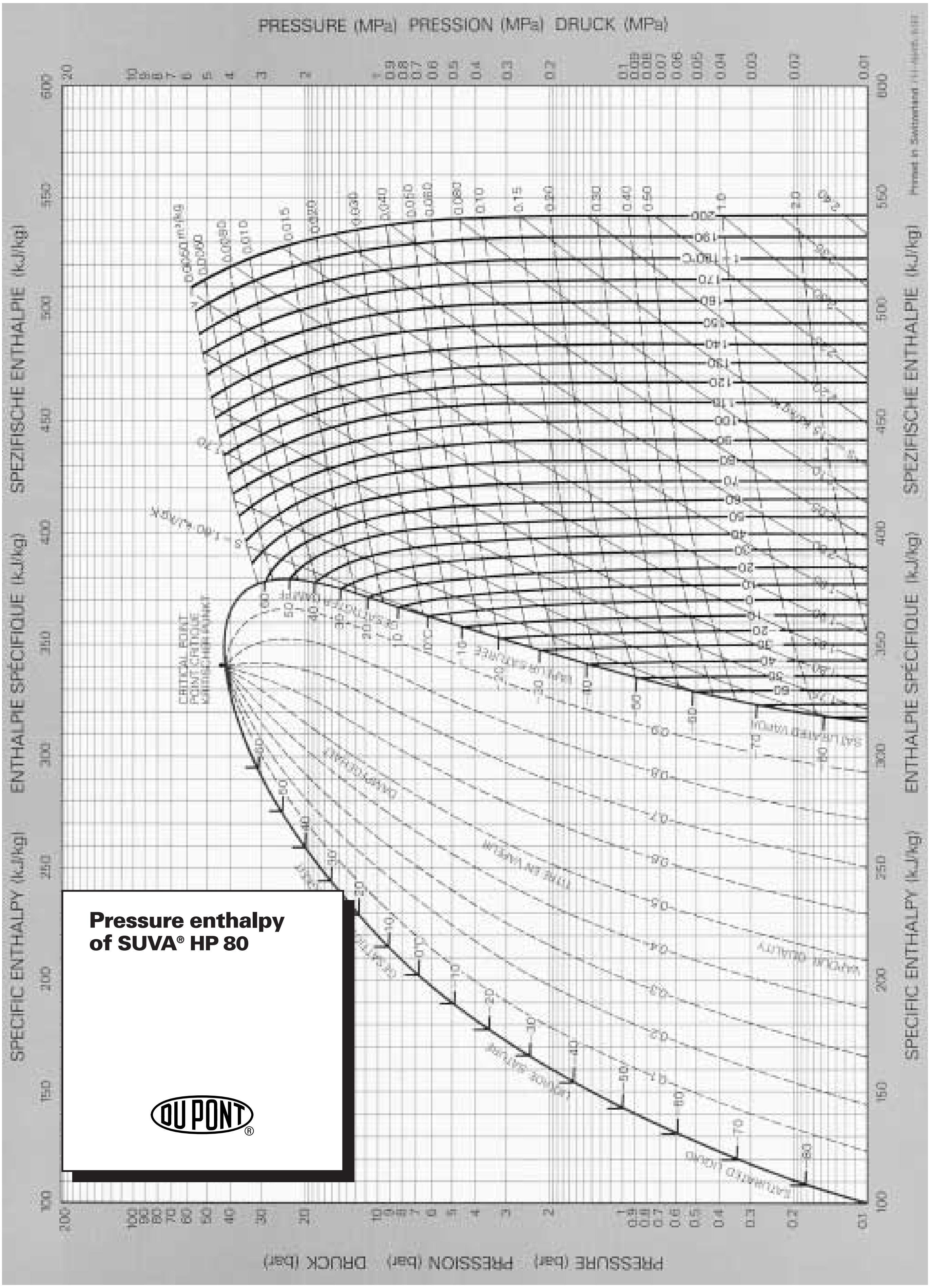




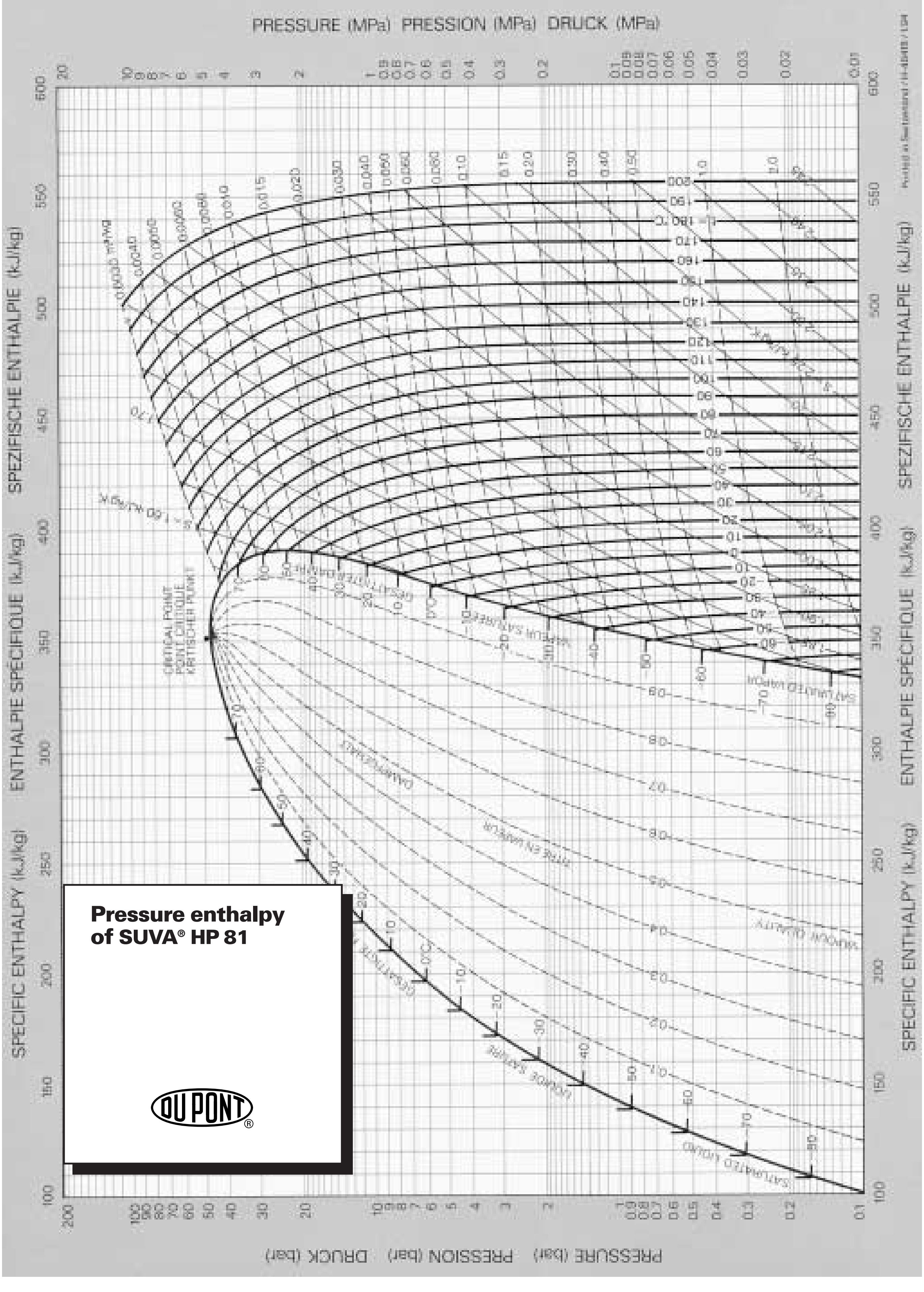
Pressure enthalpy of SUVA® MP 66



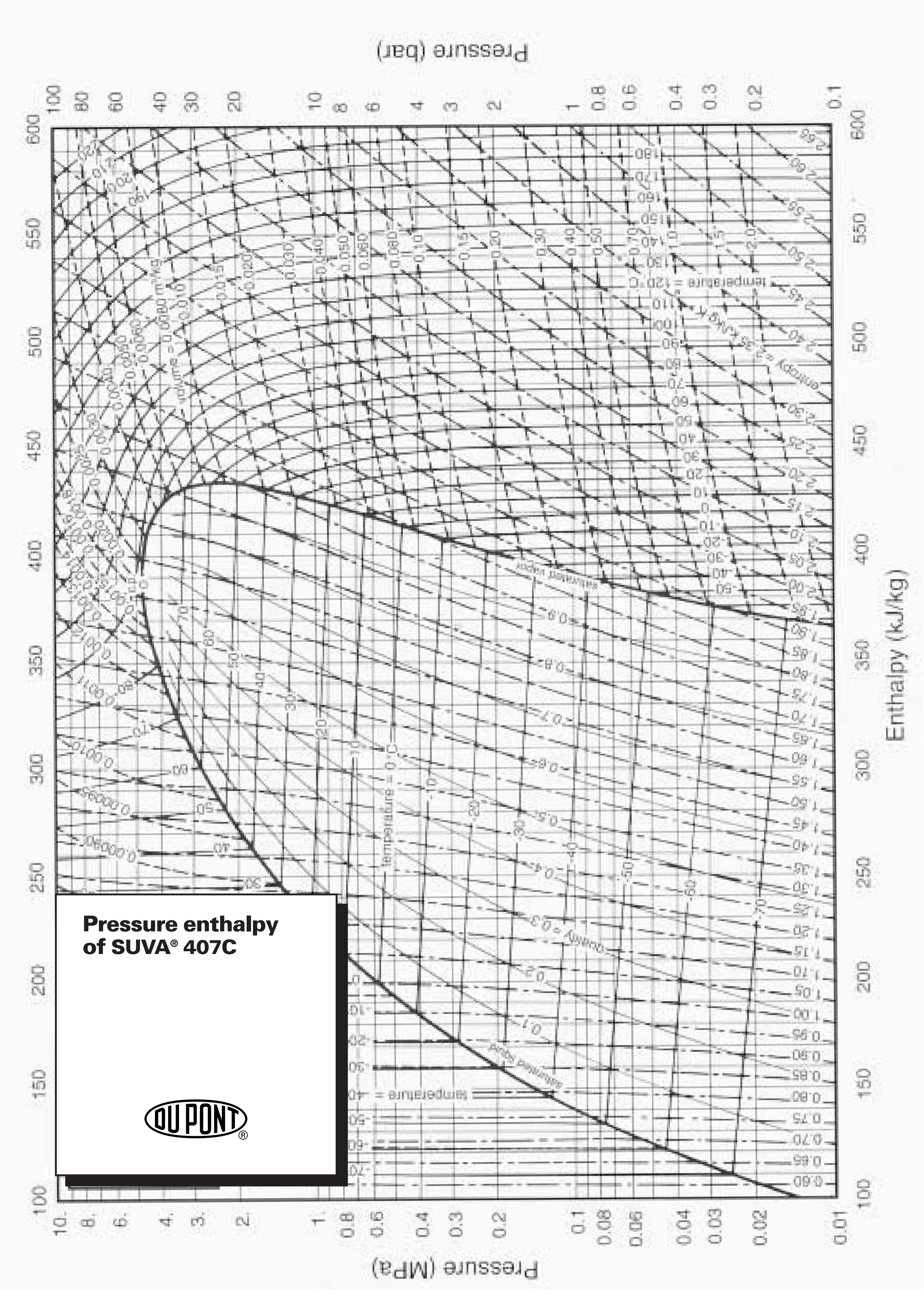
Pressure enthalpy of SUVA® 404A



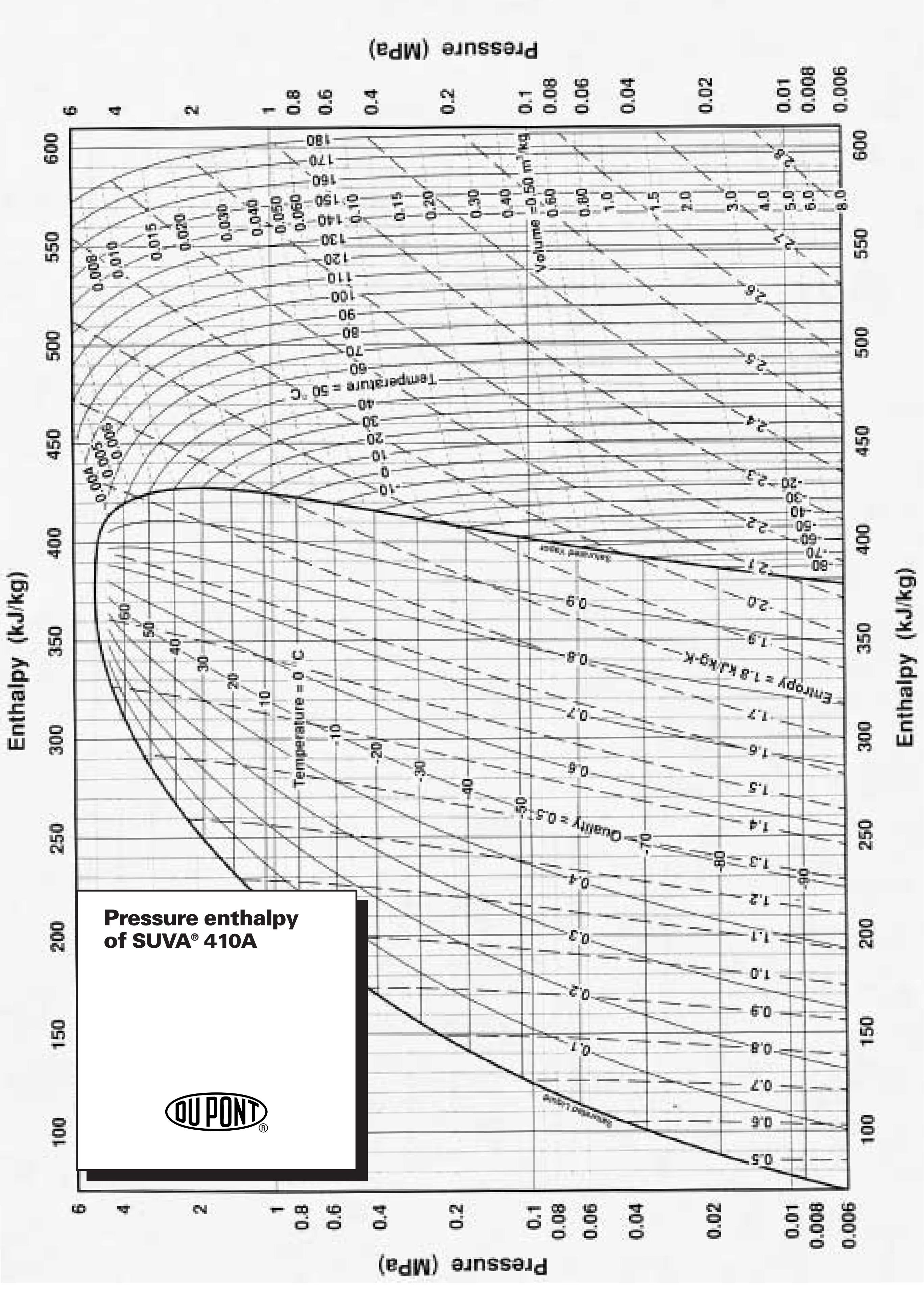
Pressure enthalpy of SUVA® HP 80



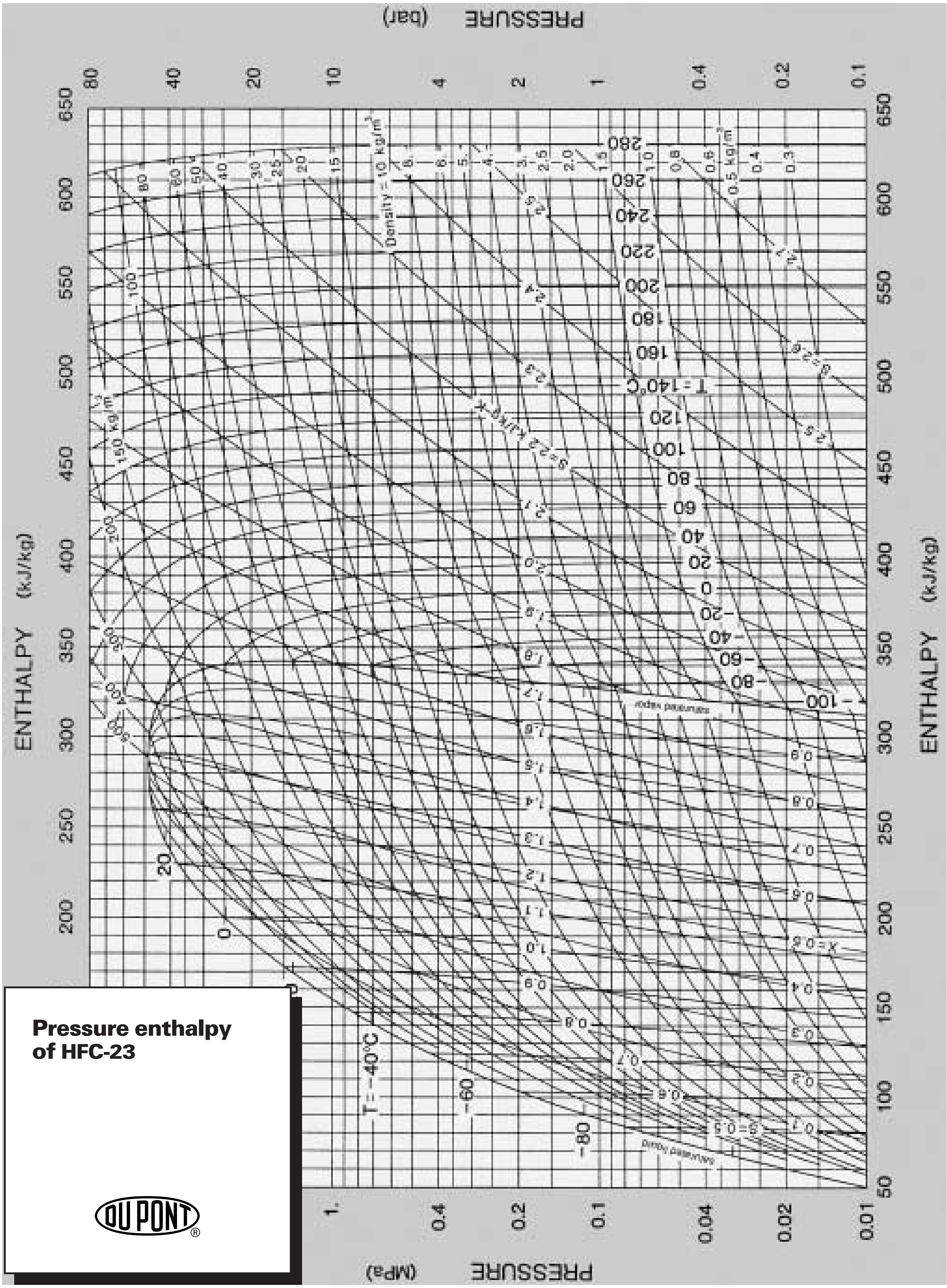
Pressure enthalpy of SUVA® HP 81



Pressure enthalpy of SUVA® 407C

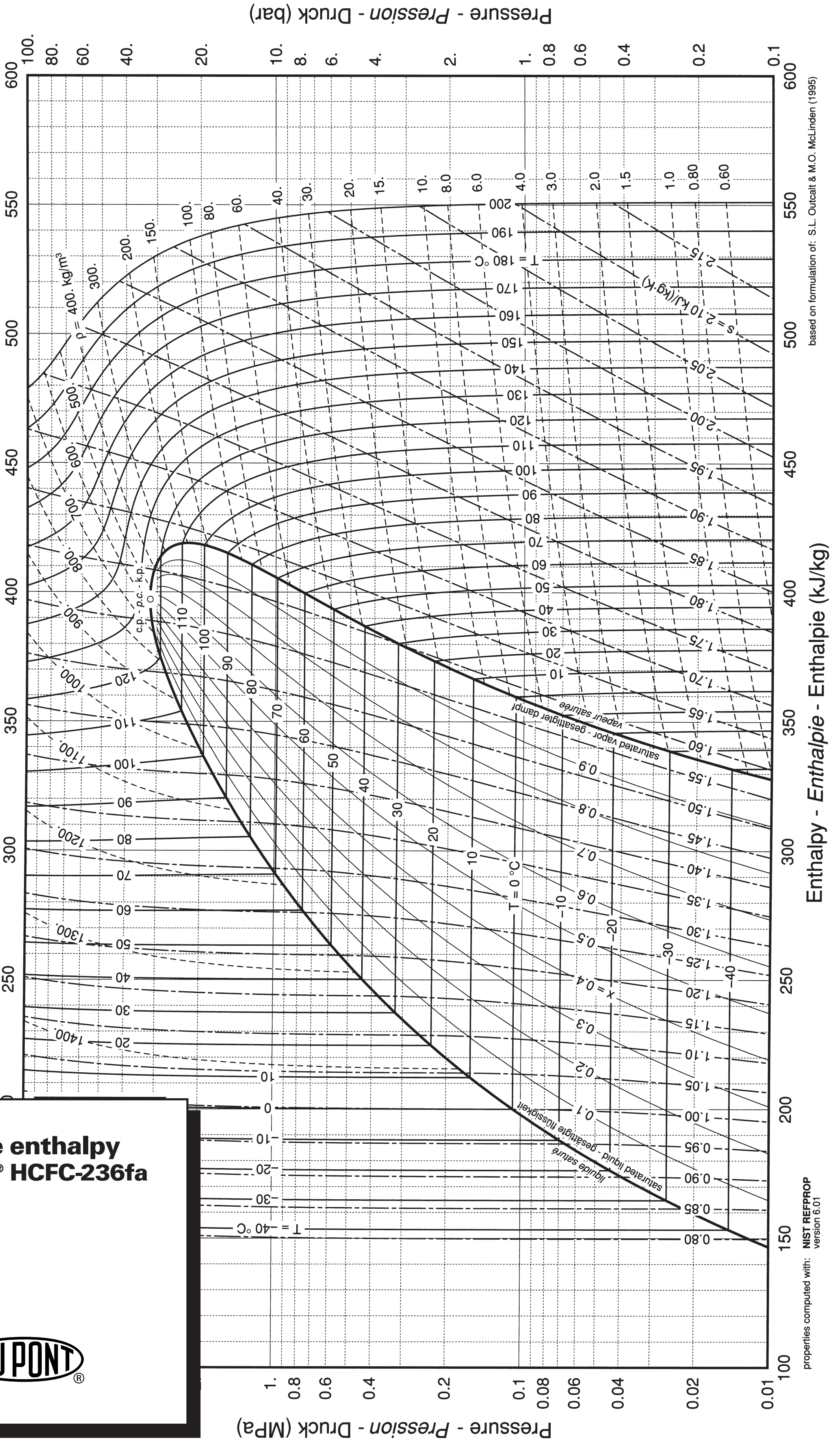


Pressure enthalpy of SUVA® 410A



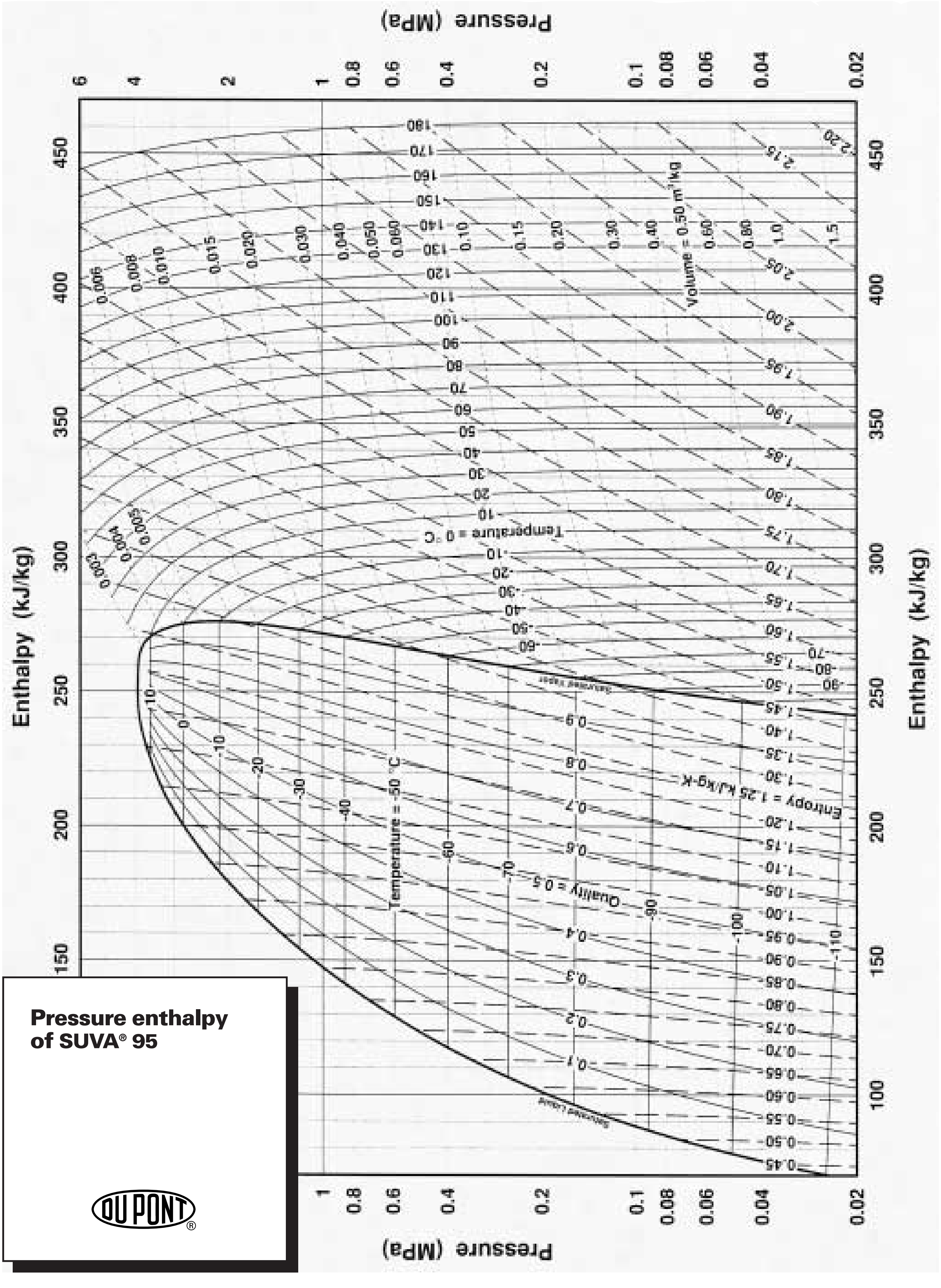
Pressure enthalpy of HFC-23

Pressure enthalpy of SUVA® HCFC-236fa

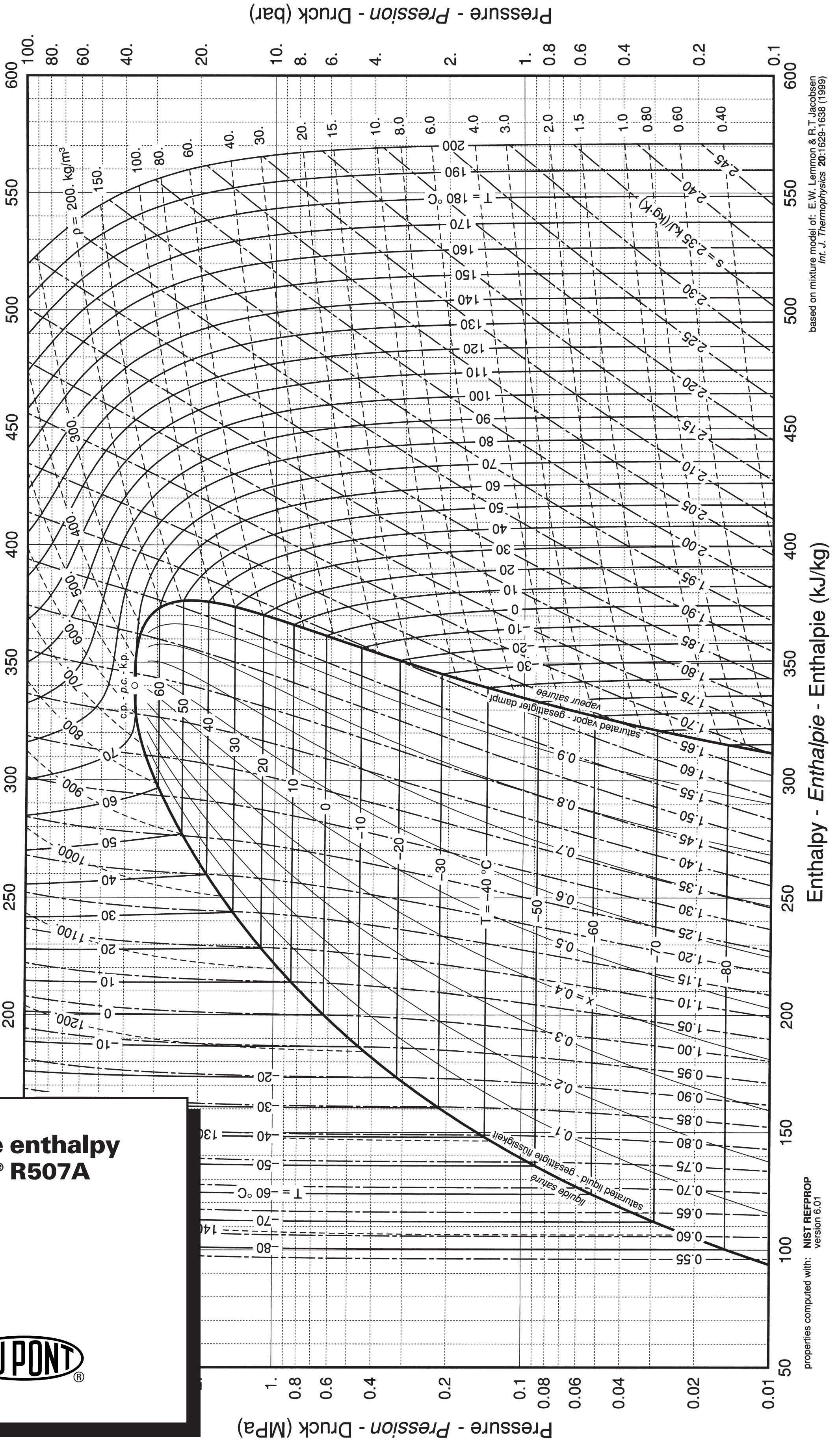


properties computed with: **NIST REFPROP** version 6.01

based on formulation of: S.L. Outcalt & M.O. McLinden (1995)



Pressure enthalpy of SUVA® 95



Pressure enthalpy of SUVA® R507A

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