B52HB-16

A practical handbook for implementing CSA B52-13, Mechanical refrigeration code

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Contents

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Preface

This is the second edition of CSA B52 HB, *A practical handbook for implementing CSA B52-13, Mechanical refrigeration code*.

The primary objective of this handbook is to provide both novice and experienced users of CSA B52 with a concise, user-friendly guide to understanding and implementing the requirements of CSA B52. The B52 Code, which originated in 1939, has been regularly updated throughout the years and is now in its eleventh edition. This handbook also briefly describes the evolution of CSA B52, touching on the Code's development process, updates and interpretations, and the relationship between the Code and jurisdictional regulations.

Changes in the CSA B52-13 Standard are reflected in this edition of the handbook.

As society has been advocating the change to natural refrigerants in order to preserve the environment, there are many safety issues which must be addressed. This version of the CSA B52 handbook will provide many of the recommended minimum safety protocols to be adhered to, in order to avoid issues. Many of the changes along with an explanation are as follows:

a) Clause 3 has been updated to add the following definitions:
   i) automated control;
   ii) fade-out vessel;
   iii) gas cooler;
   iv) manual control;
   v) pressure-regulating relief valve;
   vi) primary refrigerant;
   vii) secondary refrigerant;
   viii) subcritical;
   ix) subcritical system;
   x) systems;
   xi) supercritical;
   xii) thermal relief device (or thermal expansion relief device);
   xiii) transcritical system; and
   xiv) triple point;
b) Updates to Clause 4.3.1.2.3: This Clause provides explanations and figures of the various system types with reference to the evaporator containing refrigerant being in contact with the occupied space;
c) Updates to Clauses 5.5.1, 5.6, 5.7.1, and 5.8.1 and the addition of Clause 5.9.2.1c): As R-744 carbon dioxide is becoming a major refrigerant within refrigeration and heat pump systems, the CSA B52 committee has gone to extensive measures to provide the most up-to-date minimum safety requirements as can be found within some of these clauses;
d) The addition of a note to Clause 6.3 and an update to Clause 6.3d);
e) Updates to Clauses 7.2.2.1 and the addition of Clause 7.2.2.4: Further changes attributed to the reintroduction of R-744;
f) Updates to Clause 7.2.3 to include
   i) renumbering of Clauses 7.2.3.1.1, 7.2.3.1.2, and 7.2.3.3 of the 2005 edition; and
   ii) the addition of Clauses 7.2.3.2, 7.2.3.2.1, and 7.2.3.2.2;
g) Updates to Clause 7.2.4: R-744's physical properties demonstrate that it has pressures higher than standard refrigeration components pressure ratings. The expansion rate of R-744 is nearly double that of standard refrigerants. It is for this reason emphasis must be placed on the avoidance of the

trapping of liquid. Many of the changes to the Code will address minimum recommended practices to avoid pressure related concerns;

h) Updates to Table 6;

i) The addition of Clause 7.3.6.5;

j) Updates to Clauses 8.1, 8.2, 8.3, 8.4.1, and 8.4.3 and the addition of Clause 8.4.4: Previous versions of CSA B52 typically did not address in detail preventative maintenance of systems and service practices. It is evident with the advent of higher pressure refrigerants, and in an effort to preserve the environment and reduce energy consumption, preventative maintenance of systems is required to ensure the equipment and its surroundings do not become compromised as a result of poor service and maintenance practices. Poor service and/or maintenance practices can result in a rupture of pressurized components resulting in loss of charge and potential personnel injury and damage to the building environment. Service and maintenance will help avoid system-debilitating causes and concerns such as corrosion, blockages, poor heat transfer, and low operating efficiencies resulting in higher than normal energy consumption and obviously reducing loss of system charge and prolonging equipment lifespan, etc. It is for these reasons that the B52 committee has advocated minimum recommended service and maintenance practices, such as refrigerant charging and withdrawal and evacuation and scheduled routine maintenance as per the equipment manufacturer's and governmental guidelines. Annexes I, J, K and L have been added for information to provide the user with background knowledge which can assist in the implementation of CSA B52;

k) Updates to Annex I: This Annex provides information regarding replacement refrigerants and hydrocarbon refrigerants;

l) The addition of Annex J: This addition to the Code highlights some of the concerns when using R-744. Issues such as the effects of moisture and contact with ammonia, along with handling precautions and emphasis of eliminating potential hazards when using R-744;

m) The addition of Annex K: This addition provides some of the physical properties of R-744. Although carbon dioxide is designated as a Class A1 refrigerant, as with any refrigerant, it will displace oxygen in higher than normal quantities. As with all refrigerants, precautionary care must be taken to avoid asphyxiation; and

n) The addition of Annex L: As new refrigerants are continuously being developed and some of the older refrigerants still found within systems, the B52 committee has decided it would be advantageous to the user to maintain information on some of the more commonly used refrigerants. Also, CSA B52 recommends that the user refer to ASHRAE 34 for the most current information regarding refrigerants.

CSA gratefully acknowledges the work of Gino Defibo in the development of this handbook. Members of the B52 Technical Committee also contributed to its development.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

2) *All enquiries regarding this Special Publication should be addressed to CSA Group, 178 Rexdale Blvd., Toronto, Ontario, Canada M9W 1R3.*

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0 Introduction

General

Since its first publication in 1939, CSA B52, *Mechanical refrigeration code*, has achieved an impressive degree of consensus as the Canadian standard for the safe usage of various types and sizes of mechanical refrigeration systems. The Code provides the public with the minimum requirements for the design, construction, installation, testing, and maintenance of mechanical refrigeration systems.

Over the years, however, a need has been expressed for a supplementary document explaining the meaning of the Code and the relationship between the Code's requirements and federal, provincial, and territorial jurisdictional regulations. This handbook is intended to help users such as design engineers, installing contractors, owners, system operators, system inspectors, and regulators achieve a better understanding of CSA B52 and its application.

The evolution of CSA B52

The first edition

During the late 1930s, a Joint Committee on Refrigeration, appointed by Québec's Department of Labour in co-operation with the Canadian Refrigeration and Air Conditioning Association, and representatives of refrigeration system manufacturers met in Montréal. They prepared the first drafts of the Code for local purposes, in an attempt to set up standards for the application, installation, and use of refrigerating machinery.

These drafts, at the request of Québec's Department of Labour, were submitted to the Canadian Engineering Standards Association (now CSA Group) to be considered as the basis for an interprovincial code for mechanical refrigeration. The Canadian Engineering Standards Association set up a Committee on Mechanical Refrigeration, which included representatives of manufacturers, general users, and regulatory authorities. The following organizations were represented on that committee:

a) Frigidaire, a Division of General Motors, Montréal;
b) Canadian Westinghouse Co. Ltd., Hamilton;
c) Universal Cooler Co. of Canada, Brantford;
d) Kelvinator of Canada Ltd., Montréal;
e) Linde Canadian Refrigeration Co. Ltd., Montréal;
f) Canadian Industries Ltd., Montreal;
g) Canadian General Electric, Toronto;
h) Canadian Refrigeration and Air Conditioning Association;
i) Canadian Institute of Chemistry;
j) Canadian National Railways;
k) Engineering Institute of Canada;
l) National Research Council;
m) Canadian Pacific Railway Co.;
n) Canadian Gas Association;

o) Ontario Department of Labour;
p) Department of National Health;
q) Québec Department of Labour;
r) Fire Marshall of Ontario; and
s) Province of British Columbia.

Twenty-seven of the committee's twenty-eight members were from the provinces of Québec and Ontario. The only representative from the rest of the country was from Vancouver, British Columbia.

Many factors not directly associated with the science or technology of refrigeration had to be considered. It took about two years for the committee to incorporate a number of changes suggested by the mature judgments of the interests represented. In addition, the Air Conditioning Industries Branch of the Toronto Board of Trade and the Refrigeration Industries Committee on Codes, sponsored by the American Society of Refrigerating Engineers (ASRE, precursor of ASHRAE) and governed by rules and regulations of the American Standards Association, provided a wealth of information and practical assistance.

Approval of the Code was obtained in April 1939, and in September 1939 the Main Committee of CESA authorized publication of the Code as a CESA Standard. Published in October 1939, No. B52-1939, *Canadian Engineering Standards Association Mechanical Refrigeration Code,* was adopted by the provinces as the standard interprovincial code for mechanical refrigeration.

Refrigerant classifications
The 1939 edition of the Code listed just eighteen refrigerants in three groups:

a) Group 1:
   i) Carbon dioxide, CO_2;
   ii) Dichlorodifluoromethane (Freon-12), CCl_2F_2;
   iii) Dichloromonofluoromethane (Freon-21), $CHCl_2F$;
   iv) Dichlorotetrafluoroethane (Freon-114), $C_2Cl_2F_4$;
   v) Dichloromethane (Carrene No. 1), CH_2Cl_2;
   vi) Trichloromonofluoromethane (Freon-11); and
   vii) Carrene No. 2, CCl_3F.
b) Group 2:
   i) Ammonia, NH_3;
   ii) Dichloroethylene, $C_2H_2Cl_2$;
   iii) Ethyl chloride, C_2H_5Cl;
   iv) Methyl chloride, CH_3Cl;
   v) Methyl formate, $HCOOCH_3$; and
   vi) Sulphur dioxide, SO_2.
c) Group 3:
   i) Butane, C_4H_{10};
   ii) Ethane, C_2H_6;
   iii) Ethylene, C_2H_4;
   iv) Isobutane, $(CH_3)_3CH$; and
   v) Propane, C_3H_8.

The previous edition of CSA B52, by contrast, lists thirty-eight refrigerants in six groups—striking evidence of the complication of refrigeration technology in the last seven decades.

As a result of the environmental regulations controlling the use of refrigerants, the current edition of CSA B52 lists only twenty refrigerants in six groups with an additional number of infrequently used refrigerants found in Annex L. The number of refrigerants supported within the context of CSA B52 is substantially less than in recent editions as a result of the fact that many refrigerants are no longer environmentally acceptable and new refrigerants are being created regularly on an ongoing basis. Any refrigerants not found within the confines of the CSA B52, should be verified using ASHRAE 34

Updating the Code
Over the years, CSA B52 has been managed effectively to keep up to date with new refrigerants and new technology. In 1951, the second edition of the Code replaced the original edition. In subsequent editions, clauses were reorganized, appendices were added, and new requirements were addressed. The frequency of new editions was not very high until the early 1990s, when the countdown to the full phase-out of CFC refrigerants began, following the adoption of the Montréal Protocol, which was signed in 1987 and entered into force on January 1, 1989. Since then, six new editions have been published (in 1991, 1992, 1995, 1999, 2005 and 2013).

With changes in refrigerant usage, changes in the technology of material and equipment, and changes in approaches to public safety and the protection of the environment, CSA B52 has kept pace, so that stakeholders have always had a Code that addressed the design, construction, installation, and maintenance of mechanical refrigeration systems to minimize the risk of human injury. The routine maintenance of mechanical refrigeration systems is imperative in order to maintain the safe operating conditions of the original design and installation of a refrigeration system. It is for this reason that there have been substantial modifications to Clause 8, from previous versions of CSA B52.

Process of CSA B52 development

Consensus process
CSA Group standards in general reflect a national consensus of producers and users, including manufacturers, consumers, retailers, unions, professional organizations, and governmental agencies. The standards are used widely by industry and commerce and often adopted by municipal, provincial, and federal governments in their regulations, particularly in the fields of health, safety, building, construction, and the environment.

Individuals, companies, and associations across Canada indicate their support for CSA Group's standards development by volunteering their time and skills to CSA committee work and supporting the Association's objectives through sustaining memberships.

All CSA Group standards reflect a reasonable agreement among a number of capable individuals whose collective interest provides, to the greatest practicable extent, a balance between the needs of producers, users, regulators, and others with relevant interests in the subject at hand.

CSA Technical Committee
CSA B52 is prepared by the CSA Technical Committee on Mechanical Refrigeration, under the jurisdiction of the Strategic Steering Committee on Mechanical Industrial Equipment Safety, and is formally approved by the Technical Committee. The Technical Committee membership consists of representatives of three groups of interests: producers, regulators, and general users.

Interpretations
Even though the implementation of interpretations of CSA B52 within any particular jurisdiction rests with that jurisdiction's regulatory authority, requests for interpretation can be submitted to CSA Group staff for formal action. Such requests should, as a minimum

a) define the problem, making reference to a specific clause;
b) provide an explanation of the circumstances surrounding the actual field situation; and

c) be phrased
   i) preferably as a question, to permit a specific “Yes” or “No” answer; or
   ii) alternatively, as a statement, to permit an “agree” or “disagree” answer.

A CSA Group project manager will review the request in consultation with the B52 Technical Committee Chair and decide whether the answer should be prepared with or without the involvement of the full B52 Technical Committee. After the appropriate members have been contacted and a consensus on the answer is achieved, the CSA Group project manager responds to the inquiry.

Relationship of CSA B52 and jurisdictional regulations

Note: *The following is adapted from a paper by Dr. K.T. Lau of the Alberta Boilers Safety Association.*

Codes and standards are usually written by panels of experts with particular knowledge in a specific field. They normally do not have the force of law until adopted officially by a jurisdiction. CSA B52 is such a code: it does not have the force of law until adopted officially by provincial and territorial jurisdictions. Even upon adoption, the regulatory authorities having jurisdiction should be consulted as to the extent of the adoption, as the Code may have been adopted with exemptions or with additional requirements.

In Canada, pressure equipment safety is generally under the jurisdiction of provincial and territorial governments. Each government has legislation that includes a safety codes act and regulations that represent the provincial or territorial laws. Often, safety codes and standards are adopted as part of government regulations, to ensure a reasonable level of public safety. These codes and standards are then enforced by the provincial or territorial law. Strict compliance is required, and the adopted codes and standards are no different from any other government regulation.

If there are differences between the requirements of the main text of the jurisdictional regulations and requirements in adopted codes and standards, the requirements of the safety codes act take precedence, since the act is the enabling statute under which the regulations are empowered. For that reason, there may be cases in which a code is adopted with certain exemptions or with additional requirements.

Adopting codes and standards as part of provincial or territorial regulations is very advantageous. Even a technologically advanced and financially well-to-do jurisdiction would find it difficult, if not impossible, to duplicate the technical expertise available in a panel such as the B52 Technical Committee. In the present economic climate, there is even less incentive and justification for a jurisdiction to attempt to do so.

Another consideration is trade and reciprocity between jurisdictions. It is particularly important in a country like Canada, with multiple jurisdictions controlling pressure equipment, that similar, if not identical, requirements be adopted across the land.

The industry and the public also benefit from the adoption of codes and standards, and from enforcement by provincial or territorial law, as this provides a level playing field for all and allows a wide range of parties to have a say in the development of the regulations. The participation of industry and jurisdictional representatives is critical if codes and standards are to be adopted as part of government regulations.

All codes and standards address certain administrative issues, in addition to purely technical requirements. The administrative requirements have mainly to do with documentation that provides the proof that the technical requirements of the standards have been met. These documents may simply be records of materials used or the process or procedure to document the design, quality control system, qualification of personnel, or certification of inspection or code requirement compliance.

Provincial and territorial jurisdictional authorities
The B52 Technical Committee has industry representatives (producers and users) and representatives from all provincial and territorial jurisdictions. By working together, the latter are able to include the Code in their safety code acts and regulations. The Canadian provincial and territorial jurisdictional authorities are listed below. They should be consulted for information on whether CSA B52 has been fully adopted or adopted with exemptions or additional requirements.

British Columbia Safety Authority (BCSA)
Engineering and Standards Department Design Registration
400-88 6th St., Flr 6
New Westminster, BC V3L 5B3
Phone: 604-660-6286
Fax: 604-660-6215

Alberta Boilers Safety Association (ABSA)
9410 20th Avenue,
Edmonton, Alberta T6N 0A4
Phone: 780-437-9100
Fax: 780-437-7787

Saskatchewan Corrections and Public Safety
Licensing and Inspections Branch
1855 Victoria Ave., Rm 330
Regina, SK S4P 3V7
Phone: 306-787-4509
Fax: 306-787-9273

Manitoba Department of Labour and Immigration
500-401 York Ave.
Winnipeg, MB R3C 0P8
Phone: 204-945-3373
Fax: 204-948-2309

Technical Standards & Safety Authority (TSSA) (Ontario)
Boiler and Pressure Vessel Safety Division
3300 Bloor St. W., 14th Floor, Centre Tower
Toronto, ON M8X 2X4
Phone: 416-734-3300
Fax: 416-231-1060

Régie du bâtiment du Québec
545 boul. Cremazie est, 4e étage
Montréal, QC H2M 2V2
Phone: 514-873-6538
Fax: 514-873-9936

New Brunswick Department of Public Safety Inspection Services
495A Prospect St.
PO Box 6000
Fredericton, NB E3B 5H1
Phone: 506-453-3498
Fax: 506-457-7394

Nova Scotia Environment and Labour Public Safety Division
5151 Terminal Rd., 5th Flr
PO Box 697
Halifax, NS B3J 2T8
Phone: 902-424-5721
Fax: 902-424-3239

Department of Community and Cultural Affairs
(Prince Edward Island) Inspection Services Branch
31 Gordon Dr.
PO Box 2000
Charlottetown, PE C1A 7N8
Phone: 902-368-5567
Fax: 902-368-5526

Service NL, Government of Newfoundland and Labrador
149 Smallwood Drive
PO Box 8700
St. John’s, NL A1B 4J6
Phone: 709-729-2747
Fax: 709-729-2071

Yukon Government
Consumer and Safety Services
2071 2 Ave.
PO Box 2703
Whitehorse, YT Y1A 2C6
Phone: 867-667-5741
Fax: 867-393-6249

Government of the Northwest Territories
Public Works and Services
Laing Bldg, 1st Flr
PO Box 1320
Yellowknife, NT X1A 2L9
Phone: 867-920-3257
Fax: 867-873-0117

Government of Nunavut Department of Public Works and Services
Bag 200
Cambridge Bay, NT X0B 0C0
Phone: 867-983-4151
Fax: 867-983-4152

Basic refrigeration theory and R-744 (carbon dioxide) refrigeration

Refrigeration is a process of drawing heat from substances in order to lower their temperature. Heat is the mechanism that transfers energy across the boundary of systems with differing temperatures, always toward the lower temperature.

Mechanical refrigeration is based on the fact that certain fluids at different pressures and temperatures can absorb heat from or reject heat to their surroundings by changing state from liquid to vapour and from vapour to liquid. These fluids are called refrigerants. In Clause 3.1 of CSA B52, "refrigerant" is defined as follows:

> **Refrigerant** — a fluid that absorbs heat at a low temperature and pressure, with a change of state, and rejects it at a higher temperature and pressure.

Refrigerants are the working fluids in refrigeration, air conditioning, and heat pump systems. They absorb heat from one area, such as a cold-storage locker or an air-conditioned space, and reject it into another, such as outdoor air or water, usually through evaporation and condensation, respectively. Standard vapour compression refrigeration systems utilized refrigerants that operated below the critical point (subcritical) as specified in Clause 3, Item e). With the advent of R-744 (carbon dioxide) as a refrigerant, there are some applications known as "transcritical systems" where the heat absorption process will occur in the subcritical region, but the heat rejection may occur in the supercritical region (above the critical point) as specified in Clause 3, Item g). When operating in the supercritical region, high side refrigerant rejects heat through a gas cooler (desuperheating or sensible change). The design of refrigeration equipment depends on the properties of the selected refrigerant. The selection process involves making a compromise between the desirable thermodynamic properties of the refrigerant and its other properties. A refrigerant must satisfy many requirements, some of which are not directly related to its ability to transfer heat. Chemical stability under the intended conditions of use is the most important characteristic. In some applications, safety codes may require a nonflammable refrigerant of low toxicity.

The most common thermodynamic properties of refrigerants are temperature, pressure, and specific volume or density. Additional thermodynamic properties include entropy, internal energy, and enthalpy. Entropy measures the molecular disorder of a system. The more mixed a system, the greater its entropy. Conversely, an orderly or unmixed configuration is one of low entropy. Enthalpy is a combination of other properties and is defined by the following formula:

$h = U + pV$ (BTU/lb)

where

U = internal energy per unit mass

p = pressure

V = specific volume

The properties of the latest and most frequently used refrigerants have been tabulated and can be extracted from such tables manually or with a suitable computer program. Further information can be found in any textbook on refrigeration theory and in the *ASHRAE Handbook*.

Due to the impact on climate change resulting from the use of flurocarbon refrigerants, the use of refrigerants having lower damaging effects on the environment are becoming more predominant. Natural refrigerants such as ammonia (R-717) and propane (R-290), while having excellent refrigeration properties, have other concerns such as flammability or toxicity, hence the reintroduction of carbon dioxide (R-744), a refrigerant having low global warming potential and low toxicity and flammability levels, yet very high operating pressures. These high operating pressures result in major concerns regarding the design, installation, operation, and maintenance of systems utilizing R-744. Many of these concerns will be addressed within CSA B52.

The ASHRAE safety designations of the three most common natural refrigerants are as follows:
a) R-717 (ammonia) – B2;
b) R-290 (propane) – A3; and
c) R-744 (carbon dioxide) – A1.

Many of the HFC refrigerants currently in use including: R-134a, 404A, 407C, 410A, and 507 all have ASHRAE “A1” safety designations.

Clause 3.1 defines the following terms required to understand the operation of transcritical refrigeration systems as may be found with some carbon dioxide (R-744) systems:

Critical point — a point on the saturation curve where the refrigerant liquid and vapour have identical volume, density, and enthalpy, and where there is no latent heat.

Subcritical — the state of fluids when they are at pressures and temperatures below their critical values.

Subcritical system — a vapour compression refrigeration system where both evaporation and condensation occur in the subcritical region below a refrigerant’s critical point.

Supercritical — the state of fluids when they are at pressures and temperatures above their critical values.

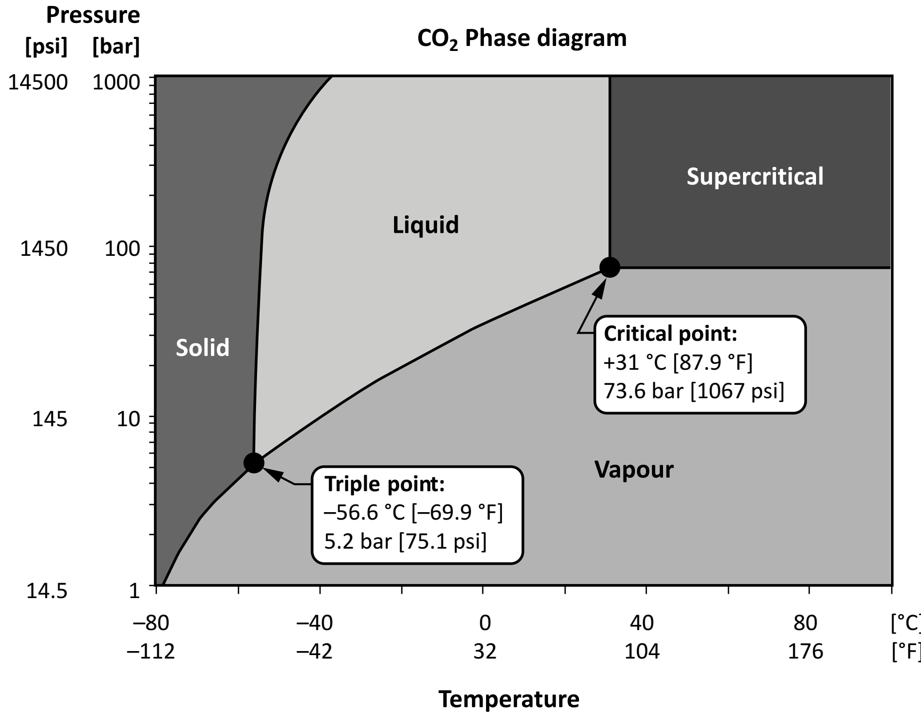
Transcritical system — a vapour compression refrigeration system where evaporation occurs in the subcritical region and heat rejection occurs in the supercritical region using a gas cooler instead of a condenser.

Triple point — the particular temperature and pressure at which three different phases of one substance can coexist in equilibrium.
Note: *Water is an example of a substance that has a well-known triple point*

Standard vapour compression refrigeration systems utilize refrigerants operating below the critical point (subcritical) as specified in Clause 3, Item e). With the growing demand of R-744 (carbon dioxide) as a refrigerant, there are some applications referred to as “transcritical systems”, where the heat absorption process will occur in the subcritical region, while the heat rejection process may occur in the supercritical region (above the critical point) as specified in Clause 3, Item g). During times while operating in the supercritical region, the high side refrigerant rejects heat through a gas cooler (desuperheating or sensible change). During times while operating below the critical point, the gas cooler behaves as a condenser. A transcritical refrigeration system will have the refrigerant behaving as a subcooled liquid, saturated liquid/vapour, superheated vapour, below the critical point and as a dense fog, above the critical point of the refrigerant. Transcritical systems, as found in R-744 applications, would have the evaporators, expansion devices and suction lines operating below the critical point of the refrigerant. The discharge of the compressor high side, the discharge line, the gas cooler (replacing the condenser), and the pressure reducing valve all operate at pressures above the critical point of the refrigerant. When ambient conditions are below approximately 27 °C (80 °F), or the refrigerant saturated condensing temperature is 31.1 °C (87.9 °F), the system operates below the critical point and the gas cooler becomes a condenser.

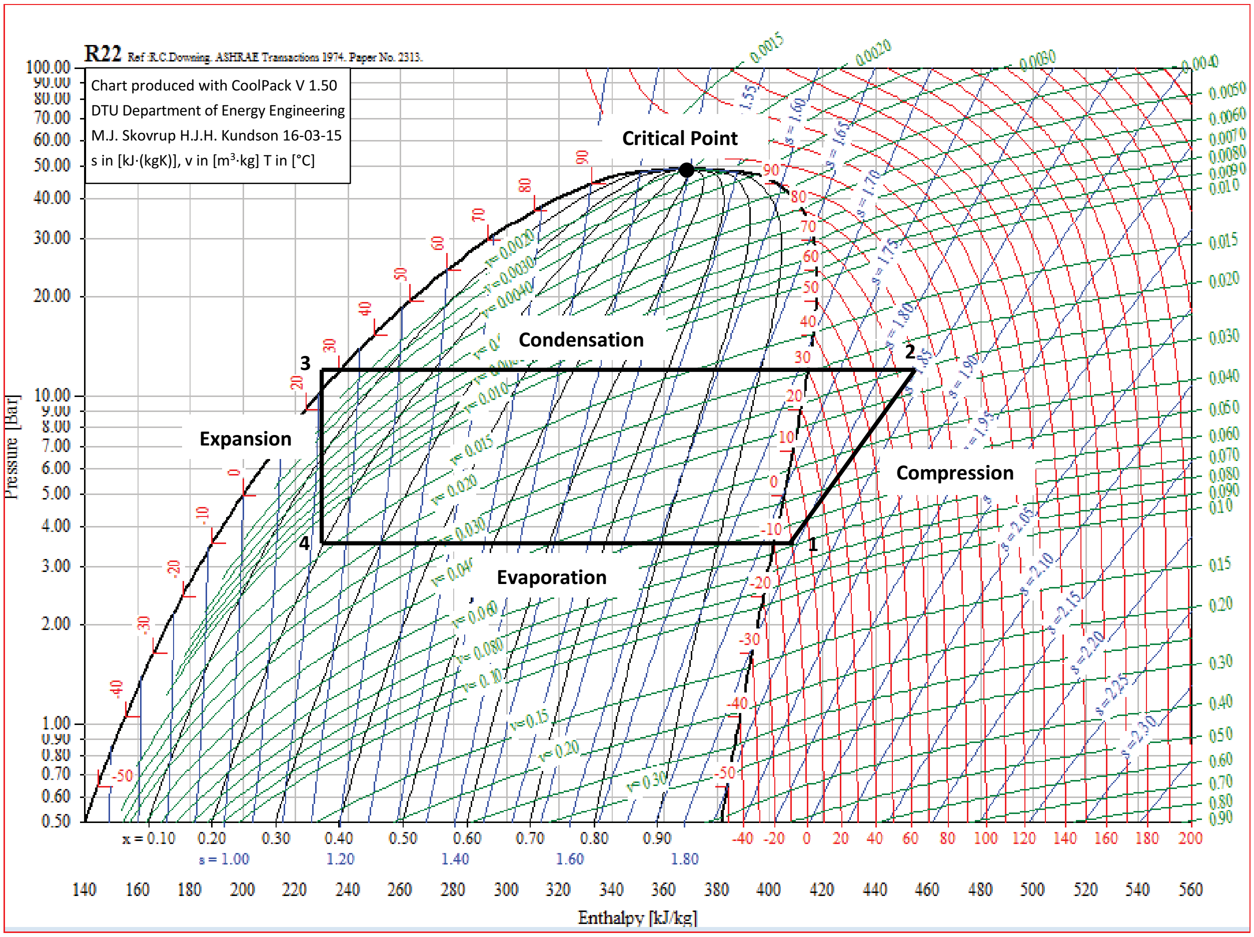
Any conditions above the critical point of the R-744 (i.e., 31.1 °C (87.9 °F)), would be referred to as a "supercritical fluid" and the R-744 is neither a liquid nor a vapour, but in reality, a dense fog-like state.

Figure 1
CO_2 phase diagram



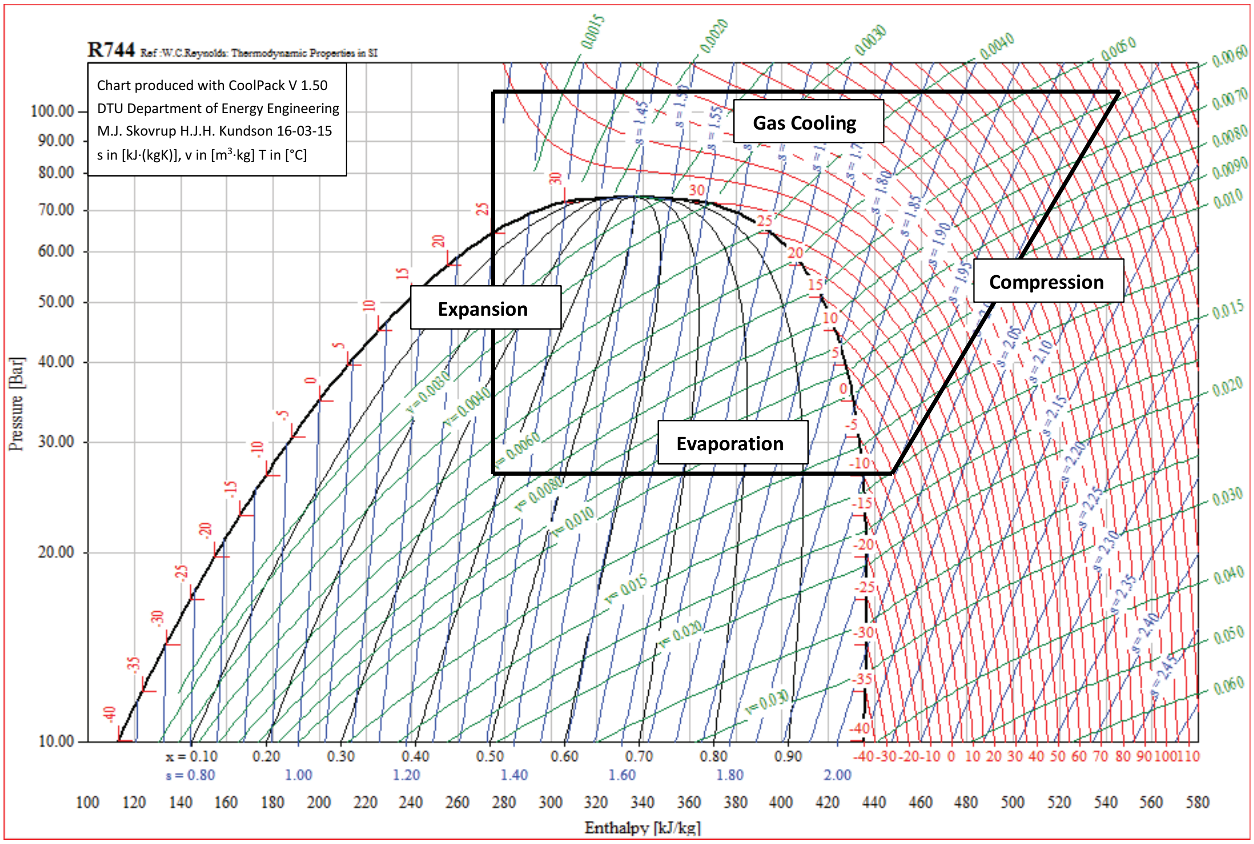
Source: *Copyright Danfoss Industrial Refrigeration A/S, "CO_2 refrigerant for industrial refrigeration", http://danfoss.ipapercms.dk/refrigerationandairconditioning/ra/danfossindustrialrefrigeration/co2refrigerant/?Page=24.*

Figure 2
Pressure enthalpy diagram of a subcritical refrigeration system as typically found in every day applications



Source: *Mollier from CoolPack V1.50, DTU Department of Energy Engineering, M.J. Skovrup H.J.H. Kundson – Properties: R.C. Downing, ASHRAE Transactions 1974 Paper 2313; Cycle addition: Natural Resources Canada, 16-03-15.*

Figure 3
Pressure enthalpy diagram of a transcritical refrigeration system as found in R-744 transcritical applications



Source: *Mollier from CoolPack V1.50, DTU Department of Energy Engineering, M.J. Skovrup H.J.H. Kundson – Properties: W.C. Reynolds: Thermodynamic Properties in SI; Cycle addition: Natural Resources Canada, 16-03-15.*

Standard refrigeration components, as found in typical subcritical applications, are designed for high side pressures not exceeding 4.1 MPa (600 psig). When R-744 is used, pressures of greater than 4.1 MPa (600 psig) are easily reached at temperatures around 7.2 °C (45 °F). Hence, equipment used above these pressures will require acceptable design and installation procedures.

As can be seen by the sample R-744 PT chart (see Table 1), we observe extremely high operating pressures, especially in the normal condensing temperature ranges.

Table 1
R-744 PT chart

Temperature, °C (°F)	Pressure, MPa – abs	Temperature, °C (°F)	Pressure, MPa (psig)
*** –56.6 (–69.8)**	*** 0.52 (60.7)**	–3.9 (25)	3.13 (440.1)
–40 (–40)	1.00 (131.0)	–1.1 (30)	3.38 (475.5)
–37.2 (–35)	1.11 (146.4)	1.7 (35)	3.64 (512.8)
–34.4 (–30)	1.23 (163.0)	4.4 (40)	3.91 (552.3)
–31.7 (–25)	1.35 (180.9)	7.2 (45)	4.20 (593.8)
–28.9 (–20)	1.48 (200.0)	10 (50)	4.50 (637.6)
–26.1 (–15)	1.62 (220.5)	12.8 (55)	4.80 (683.7)
–23.3 (–10)	1.77 (242.4)	15.6 (60)	5.15 (732.2)
–20.6 (–5)	1.93 (265.8)	18.3 (65)	5.50 (783.3)
–17.8 (0)	2.11 (290.7)	21.1 (70)	5.87 (837.0)
–15 (5)	2.28 (317.1)	23.9 (75)	6.26 (893.7)
–12.2 (10)	2.48 (345.3)	26.7 (80)	6.68 (953.6)
–9.4 (15)	2.68 (375.1)	29.4 (85)	7.13 (1,018.3)
–6.7 (20)	2.90 (406.7)	**** 31.1 (87.9)**	**** 7.38 (1,056)**

where
* = Triple point(solid/liquid/vapour)
** = Critical point

The transcritical refrigeration system may be found in a two temperature application, using compound compression or booster compression (two compressors in series) in order to obtain the required pressures, as can be seen in Figure 4. Common transcritical applications may include: supermarkets, commercial refrigeration, ice rinks and heat pumps.

The first stage compression or low pressure and low temperature evaporators can typically operate as low as 1000 kPa (131 psig) at minus 40 °C (–40 °F), while the second stage compression or intermediate pressures and evaporator temperatures are operating at about 3.4 MPa (475 psig) and –1.1 °C (+30 °F). All equipment on the low side and intermediate range would be deemed as subcritical. The suction of the second stage (transcritical) compressor would be at intermediate pressures corresponding to the high temperature evaporator’s operation. The discharge of the transcritical compressor can experience pressures easily above 9.0 MPa (1,300 psig). This supercritical refrigerant would then enter a gas cooler where, rather than desuperheating, condensing, and subcooling as found within a standard condenser, we may witness only desuperheating of the dense fog-like refrigerant vapour. Once the refrigerant has been desuperheated, it will enter a pressure reducing valve and then a flash tank. As the desuperheated refrigerant falls in pressure and temperature, the R-744 increases in volume and begins to condense. The vapour is drawn off of the top of the flash tank and enters the second stage compressor inlet. The remaining liquid in the flash tank, will then travel to the high temperature and low temperature evaporators expansion devices, where the typical refrigeration process will occur.

The R-744 transcritical systems are not intended for every application, ambient and environment, but as with any refrigeration application, they will be selected on the various criteria: cost, environmental foot print, ambient conditions, system design, etc.

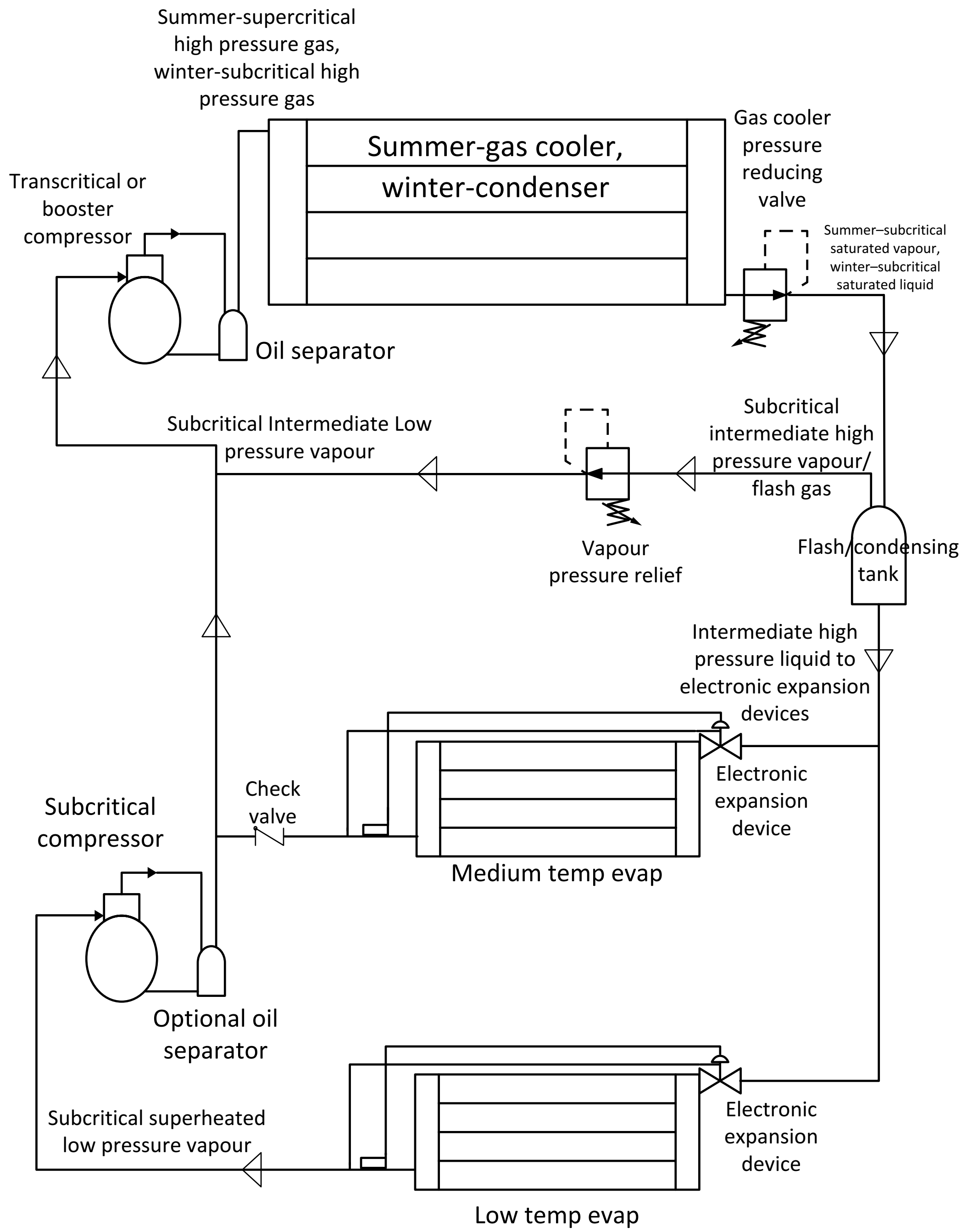
A major concern with carbon dioxide is the triple point, where the R-744 may exist as a solid, liquid, or vapour at –56.6 °C and 520 kPa (absolute) (–69.8 °F and 60.7 psig). This can result in issues while charging and/or pressure relief and these systems must be vapour charged to above the triple point pressure.

Although R-744 refrigerant is carbon dioxide, one must remember that there are various grades of CO_2 and that R-744 is commonly referred to as Coleman grade or Grade 4 CO_2 having very high purity and very low moisture levels. Moisture within a system will create acids.

Refer to Annexes J and K for more information on R-744.

Note: *Solid carbon dioxide (dry ice) expands to 845 times its volume. It will easily displace the oxygen within an enclosed space. Excessive carbon dioxide levels may cause asphyxiation by oxygen deprivation.*

Figure 4
R-744 transcritical refrigeration



1 Scope of CSA B52

The scope of CSA B52 is to provide minimum requirements for the design, construction, installation, inspection and maintenance of all mechanical refrigeration systems, as provided for by provincial and territorial acts, to minimize the risk of human injury. The Code applies to all refrigeration systems installed subsequent to its jurisdictional adoption, whether in new or existing premises, to systems that undergo a substitution of refrigerant, and to parts of a refrigeration system that are replaced in, or added to, refrigeration systems installed prior to its adoption.

The word “adoption” refers to the date a jurisdiction adopts the Code, and so not necessarily to the year in which the Code was published.

2 Reference publications

Since editions of CSA B52 are published approximately every five years, the edition or publication date shown for a reference publication may not represent the most recent version of the publication. The user is advised to consult the latest edition of each publication.

Reference publications include CSA B51, *Boiler, Pressure Vessel, and Pressure Piping Code*, American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standards, American Society of Mechanical Engineers (ASME) standards, American Society for Testing and Materials (ASTM) standards. IOR (Institute of Refrigeration), National Research Council (*National Building Code of Canada),* and CO_2 for Industrial Refrigeration (Danfoss Industrial Refrigeration).

3 Definitions and abbreviations

Clause 3.1 of CSA B52 provides specific definitions for technical terms related to refrigeration systems, as well as terms connected to the Code’s adoption, administration, and relation to jurisdictional requirements. Key terms related to the classification of refrigeration systems are also defined.

Definitions specific to R-744 CO_2 systems are found in the CSA B52 Definitions and abbreviations section. The following are some key terms for CO_2 systems:

a) Fade-out vessel: Essentially an expansion tank used with high-pressure refrigerants such as R-744 (carbon dioxide) subcritical systems during standby conditions, with the purpose of preventing over pressurization within the system and loss of charge (used with subcritical systems).
b) Gas cooler: Replaces the condenser in transcritical applications during periods of higher outdoor temperatures when the high side pressure refrigerant is supercritical. During lower ambient temperatures, the high side pressure drops below the critical point and the gas cooler becomes a condenser. See Figure 3.
c) Pressure-regulating relief valve: Since R-744 (carbon dioxide) has a relatively high temperature triple point; the relief of pressure within the system, to the fade out vessel, must be controlled to prevent solidification of the vapour, via a pressure regulating relief valve.
d) Subcritical: This is where a refrigerant is below the critical point. Its physical characteristics behave as any regular fluid when as a vapour, liquid, or in saturation.
e) Subcritical system: A refrigeration system operating below the critical point with reference to the pressure enthalpy or Mollier diagram. For the Mollier diagram. See Figure 2.
f) Supercritical: This is where the refrigerant is above the critical point. The refrigerant’s gas and liquid densities are equal above the critical point. The refrigerant is no longer a gas nor a liquid; rather it appears as a dense fog. The critical point of R-744 (carbon dioxide) is 31.1 °C at 7.36 MPa (87.9 °F, 1,067 psi).
g) Transcritical system: This is a refrigeration system where the low side operates below the critical point (subcritical) and the high side operates above the critical point (supercritical). See Figure 3.
h) Triple point: This is the pressure and temperature at which a substance can behave as a solid, liquid, or vapour. This becomes a concern when charging, recovering, or relieving system pressures

