

Environmental Awareness Training Manual for Ozone Depleting Substances (ODS) and Other Halocarbons



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This Environmental Awareness Training Manual for Ozone Depleting Substances (ODS) and Other Halocarbons is intended to be an instructional resource for persons requiring certification in accordance with Manitoba's Ozone Depleting Substances Management Program as mandated under the *Manitoba Ozone Depleting Substances and Other Halocarbons Regulation 103/94*.

This training manual is designed to be a resource and compliance reference tool. It highlights provincial regulatory requirements and is intended as a resource for service technicians and other individuals working with ODS and other halocarbons. This training manual was peer reviewed and authorized for use for training and certification purposes in Manitoba, and reflects relevant information on stratospheric ozone depletion and climate change issues. For additional information, readers are encouraged to explore supplemental resources highlighted throughout the manual.

Disclaimer

This training manual is not a substitute for the *Manitoba Ozone Depleting Substances and Other Halocarbons Regulation* (MR 103/94). While care has been taken to ensure accuracy, all examples, illustrations and representations are for purposes of illustration or instruction only. MOPIA is not responsible for errors or omissions contained herein and no endorsement of products, companies or techniques are implied, but rather are used to display or highlight for illustration and training purposes only.

To ensure compliance with Manitoba's Ozone Depleting Substance Program, refer to Manitoba's legislation *Manitoba Ozone Depleting Substances Act* (C.C.S.M. c. 080) and MR 103/94. These publications are available electronically from the Manitoba Laws and Regulations website www.gov.mb.ca/chc/statpub/, or by contacting Manitoba Conservation or the Manitoba Ozone Protection Industry Association (MOPIA).

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Preface

Environmental awareness training and certification is required under the *Manitoba Ozone Depleting Substances and Other Halocarbons Regulation* (MR 103/94). The focus of this environmental awareness training manual and course instruction is on the reduction and elimination of emissions of regulated refrigerants into the atmosphere.

The training manual has been designed as a technical resource for persons, technicians and service personnel who have practical work experience or are involved in the purchase of products or the handling or servicing of equipment containing or intended to contain ozone depleting substances (ODS) or halocarbon alternatives, and require certification to comply with Manitoba's legislation. Persons from various industry sectors requiring training and certification include, but are not limited to, mobile air conditioning (domestic and agricultural), mobile refrigeration (trucking and transport), and residential, commercial or industrial air conditioning or refrigeration stationary systems.

Environmental awareness training is intended to provide participants with information on the safe use, handling, and reduction of emissions of ODS and other halocarbons into the environment, Codes of Practice, regulatory requirements and other relevant environmental and regulatory issues. To ensure continued environmental protection, the benefits of servicing equipment through recovery of all refrigerants for the purpose of reuse, recycling, reclamation or destruction should be recognized.

Persons who are trained and certified under MR 103/94 are encouraged to maintain their awareness of current technology, codes, regulations and other relevant legislation on an on-going basis. This training manual provides a variety of resources for further reference.

This training manual should be used as one element of supplementing knowledge within one's broader occupation or trade. Environmental awareness training and certification

does not recognize, license or imply persons as “trade qualified”. Apprenticeship and trades training is separate from this training. In addition, Transportation of Dangerous Goods (TDG) and Workplace Hazardous Materials Information System (WHMIS) information is not addressed in any detail within this manual. However, when working with ODS and other halocarbons, it is important to recognize and practice workplace, health and safety-related procedures.

Your role in protecting the environment is important. As you further your career in the air conditioning or refrigeration sector, take time to recognize that your actions may affect many others.

Focus on Learning

The various chapters of this training manual has been specifically designed with a number of supplementary features which provide the reader with additional study aids. You are also encouraged to visit the appendix, at the end of this manual, to see any one of the many website links. Features of the training manual include:

- “Did you know” sections: these contain a number of interesting facts that have been highlighted to provide additional information or reinforce core materials
- Special interest boxes
- Special chapter notes with supplemental website resource links.

Preview

Stratospheric Ozone Layer Protection

Canada, along with the rest of the international community, determined that the severity of this ozone issue required collective action to protect it from complete destruction. Since 1989 the federal, provincial and territorial governments have been coordinating efforts to develop and implement a clear, consistent and harmonized program under Canada's *National Action Plan* (NAP) which outlines how ozone depleting substances (ODS) will be controlled, reduced and eliminated in Canada. The NAP has been updated twice in 1998 and 2001, and is approved by the Canadian Council of Ministers of the Environment (CCME).

A wide range of national, provincial, local and industry-led initiatives under the NAP have been coordinated, developed and implemented throughout Canada. Comprehensive regulatory frameworks have been established with ODS use phase-out dates and controls on production and imports. In addition, extended producer responsibility initiatives have been established for some sectors for the safe collection and disposal of surplus ODSs.

The purpose of Manitoba's Ozone Depleting Substances Program is to protect the stratospheric ozone layer through the reduction and eventual elimination of emissions of ODS into the atmosphere. With the addition of new regulated replacement products, the focus of Manitoba's program has expanded to include climate change initiatives. This approach will help to ensure that replacement product emissions from substances such as hydrofluorocarbons (HFCs), which are not ODS but greenhouse gases (GHG), are prevented from being released into the environment. Manitoba's program has a number

of objectives including legislation, regulation, environmental training and certification, and industry and public outreach information.

In Manitoba, the Manitoba Ozone Protection Industry Association (MOPIA) has been appointed under MR 103/94. MOPIA was established in 1994 and is a not-for-profit industry stakeholder association. The Association collaborates with Manitoba Conservation as a service provider to industry and the public to protect the stratospheric ozone layer by providing atmospheric protection information and technical service resources. MOPIA provides environmental awareness training and manages reporting, certification and permitting requirements for trained service technicians, secondary distributors and business owners/operators.

Did you know...

- *Nearly 90% of the earth's ozone is located in the stratosphere, varying from 15 to 50 kilometres above the earth's surface.*
- *The stratospheric ozone layer is a fragile and life-sustaining layer screening out the sun's harmful ultraviolet radiation, which is a direct cause of skin cancer, eye cataracts and weakened immune systems. It also affects the world's ecosystems by reducing crop yields and disrupting aquatic life.*
- *Scientists have shown that chlorofluorocarbons (CFCs) and other ODS are responsible for ozone layer destruction.*
- *Common uses for ODS and other halocarbons include propellants, refrigerant gases, sterilants, solvents and fire-extinguishing agents.*
- *Ozone depletion is among one of the most significant environmental challenges of the past century and will remain a high priority over the next 50 years.*
- *CFCs and other ODS along with their replacements have been identified as significant GHGs contributing to global warming and climate change.*
- *Over a decade ago, Canada accounted for 2.5% of the world's total production and use of ODS. Manitoba accounted for a small proportion of the total Canadian use of ODS at less than 2%.*

- *Ozone depletion is a global environmental problem requiring international cooperation and action to protect the ozone layer and implement comprehensive programming to decrease the use and eliminate emissions of ODS.*
- *In an unprecedented demonstration of global cooperation, the major industrial nations agreed to eliminate the production and importation of CFCs and other ODS under a multilateral international agreement, the Montreal Protocol.*
- *Canada was one of the first countries to ratify the Montreal Protocol in 1987.*
- *The intent of this international agreement is to gradually phase out and eliminate the use of ODS worldwide.*
- *In 1989, a Private Member's Bill, "Bill 18—The Ozone Layer Protection Act," was introduced into the Manitoba Legislature to address the issue of stratospheric ozone depletion.*
- *As of January 2008, 191 nations have committed to achieve the targets set out under the Montreal Protocol.*
- *Implementing the Montreal Protocol has realized a second environmental benefit – slowing down the rate of global warming. Some of the most powerful or potent GHGs are CFCs. Each kilogram of CFC-12 has the same effect on global warming as releasing approximately 11,000 kilograms of carbon dioxide from the burning of fossil fuels over a 100-year period (Source: Martin Mittelstaedt, Globe & Mail, March 6, 2007, p. A8).*

Acknowledgements

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Chapter 1

Environmental Significance of Ozone Depletion

CHAPTER OBJECTIVES

After studying this chapter, the training participant should be able to:

- Describe the ozone layer and its function
- Understand the effects of ozone depletion and the UV index

The Stratospheric Ozone Layer

Ozone is created by natural processes in the earth's atmosphere. The majority of the earth's ozone layer (90%) is primarily responsible for blocking out nearly 99% of the sun's high intensity ultraviolet (UV) radiation. The ozone layer resides in the stratosphere at an altitude of 10-50 km above the earth's surface, with the highest ozone concentration being within the 15-30 km zone (Figure 1).

Ozone concentration is normally ten parts ozone per one million parts air, with the thickness of the ozone layer varying on a worldwide basis. Ozone concentrations are typically thinnest at the equator and gradually grow thicker towards the poles, but will fluctuate depending upon the season.

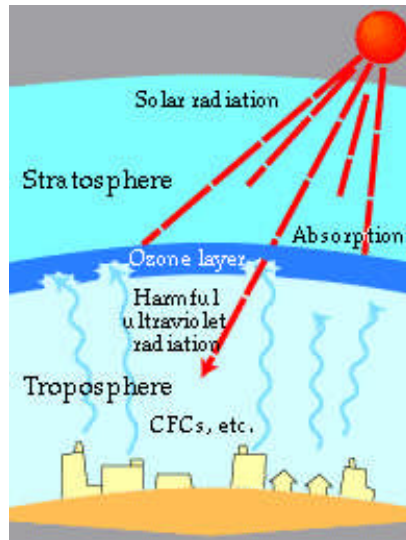


Figure 1. The ozone layer

During winter, the ozone layer begins to increase in depth because of prevailing stratospheric wind patterns known as the Brewer-Dobson Circulation. This phenomenon sees the creation of ozone near the equator, which is transported to the polar regions by stratospheric circulation and is deposited into the lower stratosphere. This effect creates higher concentrations of ozone at the polar regions due to the accumulation of ozone at the lower latitudes.

The highest concentrations of ozone at the North Pole occur during the northern spring (March and April) with the opposite occurring at the South Pole where the lowest concentrations of ozone are recorded during the southern spring (September and October). In North America, ozone concentrations peak during the spring and slowly begin to fall over the course of the summer. Ozone concentrations reach their lowest point in the fall and begin to rise during the winter months.

Ozone Research – The Dobson Unit

A Dobson Unit is the most common unit used in ozone research to identify the “thickness” of the ozone layer and is named after scientist GMB Dobson (Figure 2a). The

thickness of the ozone layer is expressed in Dobson Units (DUs), as it converts what the “physical” thickness of the ozone layer would be if it was compressed to one atmosphere pressure at 0°C.

One DU is defined to be 0.01 mm thickness at standard temperature and pressure or 0.01 mm thickness at 0°C and one atmospheric pressure (Figure 2b). A “healthy” ozone layer ranges between 300-500 DUs, in which the thickness would be the equivalent to a few millimetres or that of a standard coin (Figure 2c).



Figure 2a. GMB Dobson

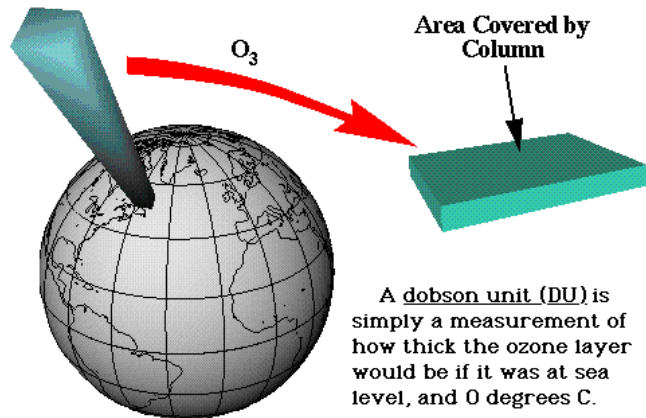


Figure 2b. Dobson Units explained

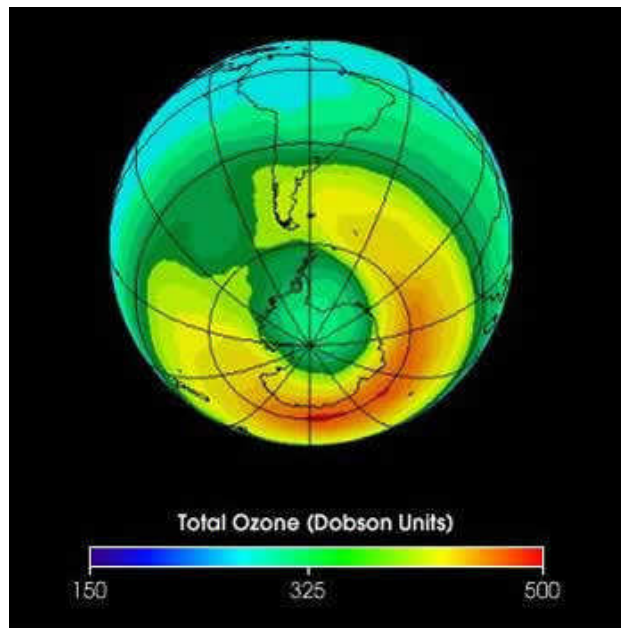


Figure 2c. Dobson Units

The Dobson Ozone Spectrometer (Figures 2d and 2e) helps to measure the strength of the sun's UV rays on four different wavelengths - two in the UV-A range and two in the UV-C range. By gauging the amount of UV-A reaching the earth, it gives scientists the ability to estimate and compare the actual amount of UV-C that is also reaching the earth. Normally, all UV-C rays are blocked out by ozone before reaching the earth's surface. Therefore it can be assumed that if there were no ozone layer, the relative amount of UV-A and UV-C would be almost identical. By knowing the amount of UV-A and UV-C reaching the earth, scientists can determine precisely how much ozone is contained within the stratosphere.



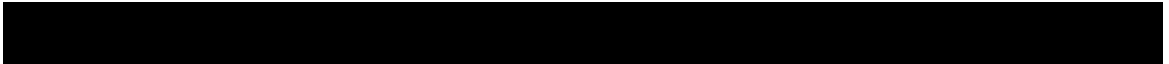
Figure 2d. Dobson's Original Ozone Spectrometer



Figure 2e. Modern-day spectrometer

Discovery of Ozone and the Ozone Layer

Ozone as a substance was first discovered in 1840 by the German scientist Christian Friedrich Schönbein (Figure 3) who appropriately associated “ozien” (the Greek word for smell) with ozone because of an unusual smell emitted during lightning storms. The odor, which has nothing to do with ozone itself, comes from the liberation of electrons through rapid chemical changes.



At very small concentrations (0.015 ppm) ozone has no detectable smell. However, when concentrations increase (1 ppm) it has a sulphur dioxide or rotten egg-like odor. Typically ozone is colourless in its gaseous state, but when cooled to -112°C it transforms into a dark blue liquid and at -193°C a dark blue solid. Ozone within the stratosphere was not discovered until 1913 by two French physicists, Charles Falry and Henri Buisson.

Resource Links:

National Aeronautics and Space Administration (NASA): <http://jwocky.gsfc.nasa.gov/>

- *Provides images of the current global status or thickness of the ozone layer, measured in Dobson Units*

Environment Canada: <http://exp-studies.tor.ec.gc.ca/e/ozone/real.htm>

- *Map of Canada's total ozone layer concentration*

Environment Canada: <http://exp-studies.tor.ec.gc.ca/e/ozone/forecasts.htm>
Canada's daily ozone and UV index forecast



Figure 3. Christian Friedrich Schönbein

Origin and Creation of the Ozone Layer

Stratospheric ozone is created when UV radiation strikes an oxygen molecule with two oxygen atoms (O_2) and separates them into individual atoms. These individual oxygen atoms then unite with unbroken O_2 to create ozone (O_3). This two-step process is illustrated in Figure 4a. Ozone molecules are highly unstable but are long-lived in the stratosphere. When UV radiation hits the ozone molecule it splits it into an oxygen molecule and a single oxygen atom, which continues the oxygen/ozone cycle. Therefore, ozone is naturally created and destroyed on a constant basis and until recently, ozone levels remained fairly stable. This intricate system was not fully understood until the 1930s with the work of British scientist Sidney Chapman (Figure 4b).

Science portrays the ozone layer developing as a result of the presence of oxygen in the earth's atmosphere. Primitive oceanic life forms, such as blue-green algae, began using the power of the sun to separate molecules of water and carbon dioxide, rearranging them into new compounds including oxygen, which was released into the atmosphere. This is commonly known as photosynthesis. Before the development of the ozone layer, all life on earth was limited to the oceans. However, ozone allowed life to flourish and emerge on land.

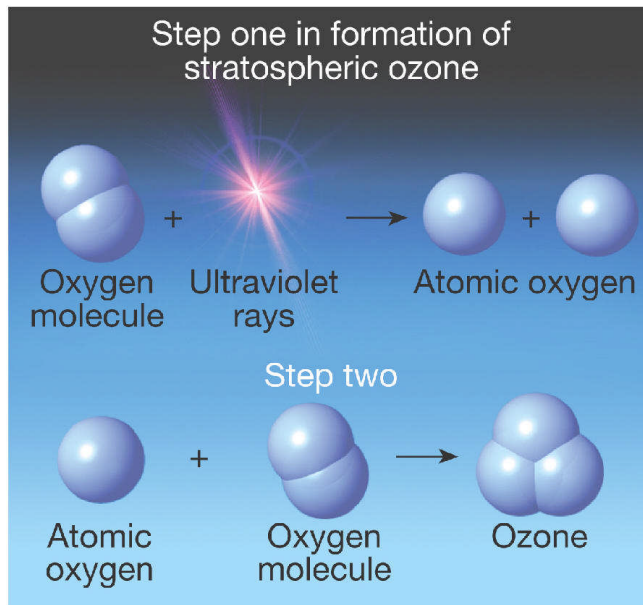


Figure 4a. Ozone creation process



Figure 4b. Sidney Chapman

Ozone Depletion: Theories

The theory of ozone depletion was first suggested in the mid-1960s when research began to focus on the effects of water vapour and chlorine from rocket exhaust and supersonic transport aircraft. In 1970 Dutch chemist Paul Crutzen (Figure 5a) began investigating how chemical compounds, such as nitrogen oxide (NO), stimulated the destruction of ozone molecules. Through his research he found that non-reactive nitrous oxide (N₂O), which is produced naturally in soils by bacteria, ascends into the stratosphere where it is separated by solar radiation into two reactive compounds – NO and nitrogen dioxide (NO₂). These newly-formed compounds, which remain fairly active in the stratosphere for some time, were seen to react catalytically with ozone by separating it into molecular oxygen (O₂) and atomic oxygen (O). Despite having the entire scientific community doubting his methods, Crutzen's work directly paved the way for chemists Mario Molina and F. Sherwood Rowland (Figures 5b and 5c).

During the 1970s, research into the effects of chlorine in the atmosphere was well underway and by 1974 a theory linking ozone destruction to human-made sources of chlorine (chlorofluorocarbons or CFCs) was published by Rowland and Molina in the scientific journal *Nature*. They suggested that when CFCs are purged from air conditioners, refrigerators and aerosol cans, these substances make their way up to the stratosphere where UV rays separate the chlorine from the rest of the molecule. The chlorine atom is free to bond with any oxygen molecule, thus effectively disturbing the natural ozone cycle.

Their theory was met with harsh criticism, especially from industrial and automotive sectors, as CFCs were seen as a necessity for society and there was still a great deal of uncertainty behind the science of ozone depletion at the time. However, nearly ten years later, their theory was proven by British scientist Joe Farman (Figure 5d) whose team discovered a severely depleted layer of ozone, the "Ozone hole" over the Antarctic South Pole.



Figure 5a. Dr. Paul Crutzen



Figure 5b. Dr. Mario Molina



Figure 5c. Dr. Sherwood Rowland

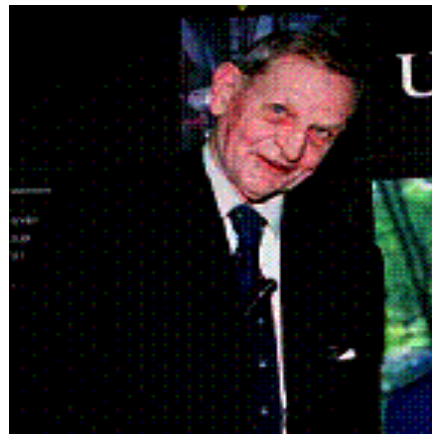


Figure 5d. Joe Farman

Ozone Destruction Process

Ozone is susceptible to destruction from a number of elements including chlorine (Cl), bromine (Br), hydroxyl radicals (OH) and nitric oxide radicals (NO).

The ozone destruction process (as outlined in Figures 6a and b) involves a catalytic reaction cycle where a chain of chemical reactions occur that include the destruction of countless ozone molecules and the survival and continuation of the original chlorine atom that started the cycle. As a result, a single atom of chlorine can destroy hundreds of thousands of ozone molecules in its lifetime before it is neutralized.

Ozone is destroyed when UV rays strike a CFC molecule in the stratosphere, breaking the carbon-chlorine bond and thus freeing the chlorine atom. This atomic chlorine reacts with an ozone molecule by breaking it apart, creating oxygen (O_2) and chlorine monoxide (ClO). When atomic oxygen bonds with the chlorine monoxide, the oxygen-chlorine bond is broken and the chlorine atom is now free to continue the process of destroying ozone molecules. ODS, such as CFCs, are very stable compounds and have a long atmospheric lifetime (CFC-11: 55 years and CFC12: 140 years).

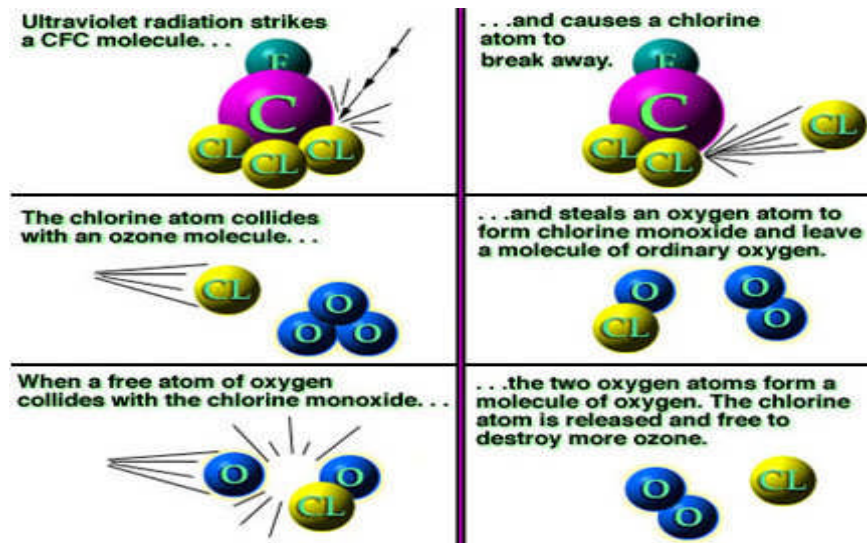


Figure 6a. Ozone depletion process example #1

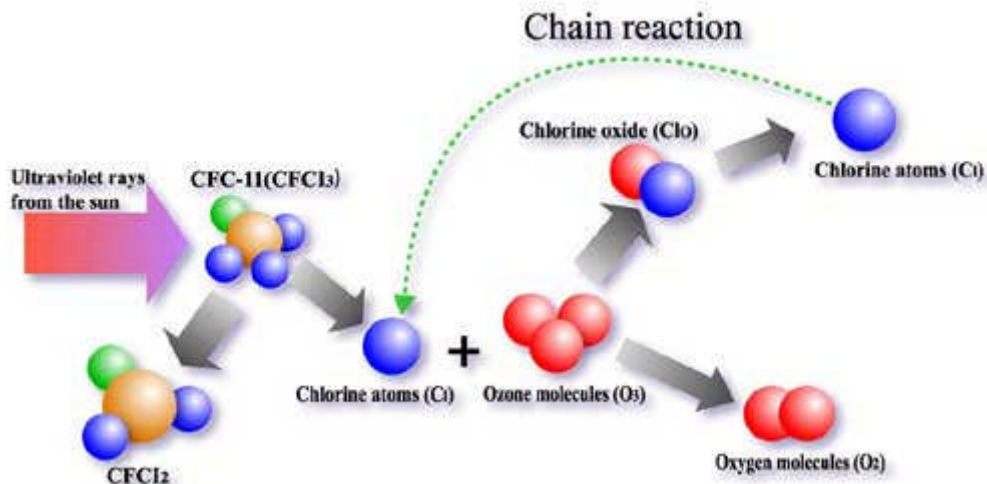


Figure 6b. Ozone depletion process example #2

The Antarctic Ozone Hole

The Antarctic ozone hole (Figure 7a), situated within the Antarctic stratosphere, is an area where recent ozone levels have dwindled to nearly 33% of their pre-1975 values. The hole, which occurs during the Antarctic spring (September-December), is caused by continental polar winds that encircle Antarctica and create a polar vortex. This vortex is responsible for destroying up to 50% of the lower stratospheric ozone. Although ozone depletion occurs through a chain reaction process, the occurrence of polar stratospheric clouds will greatly enhance the rate at which ozone can be destroyed. Extreme periods of cold during the Antarctic winter facilitate the formation of these clouds, and in particular nitric acid or ice particles (generally referred to as aerosols), which provide the perfect setting for chemical reactions to destroy ozone.

Sunlight is also a large factor in Antarctic ozone depletion. When the sun appears in the spring, its 24-hour occurrence provides enough energy to drive photochemical reactions (Figure 7b). The polar vortex and stratospheric clouds begin to dissipate near the end of spring (mid-December) due to warmer temperatures. The infiltration of warm ozone-rich air transported from equatorial regions helps to stop the trend of ozone depletion and allows the hole to “heal” itself.

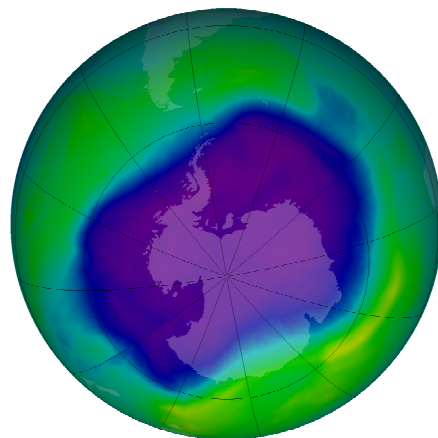


Figure 7a. Antarctic ozone-hole as seen on Sept. 24, 2006 – the ozone hole is characterized by the dark purple region above representing between 200-225 DU.

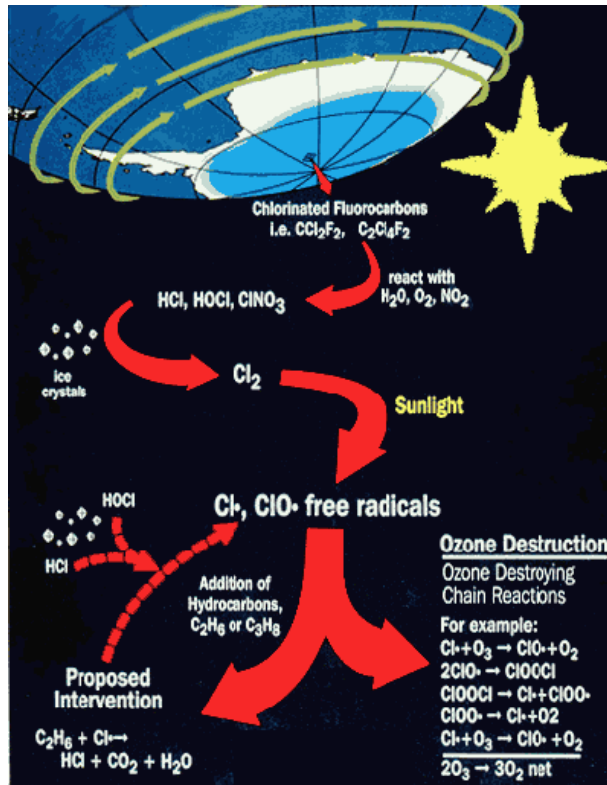


Figure 7b. Stratospheric ozone depletion at the South Pole

Ozone Hole Facts

- From September 21-30, 2006 the ozone hole in the Antarctic polar region broke records for both area and depth.
- The average area of the ozone hole totaled 10.6 million square miles.
- September 24, 2006 also set a record for the largest one-day diameter with an area of 11.4 million square miles (see Figure 7a).
- In October 2006 Dobson Units plunged to 93 from 300 only three months before.
 - Any ozone contained within an 8-13 mile region of this depleted zone was effectively destroyed.
 - Within this critical area, ozone was only measured to read a thickness of 1.2 DUs, which plummeted from an average of 125 DUs only several months prior.
- In September 2006 meteorological instruments recorded Antarctic temperatures to be 9°F colder than yearly averages, which directly caused the hole to expand by 1.2-1.5 million square miles.
- The concentration of ODS in the troposphere (lower atmosphere) was estimated to have peaked in 1995. It was also estimated that concentrations of ODS would have reached peak

levels in the Antarctic stratosphere in 2001. This is a direct result of the efforts of the international community and the Montreal Protocol.

- Since ODS levels have peaked, scientists predict that the overall size of the ozone hole will begin to slowly decrease in area by approximately 0.1-0.2% over the next decade.*
- A study jointly produced by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) entitled Assessment of Ozone Depletion (2006) concluded that ozone recovery will be highlighted by annual variability – with full recovery not expected until approximately 2065.*
- The World Meteorological Organization reported in October 2002 that the Antarctic ozone hole had split into two smaller holes (Figure 7c). One occupied an area just west of the southern tip of South America and the other near the southeast tip of Africa. Prior to the split, the ozone hole for 2002 was the smallest one of the past decade (1992-2002), resulting from warmer-than-average temperatures around the edge of the polar vortex.*
- Each hole was relatively small in size. However, they each contained a core with over 50% of its ozone depleted. The African hole retained both its shape and strength, while the South American hole grew considerably weak. The combined areas of the ozone hole only covered a small portion of Antarctica.*
- The split ozone hole was attributed as a response to unusual meteorological conditions in the Antarctic stratosphere.*

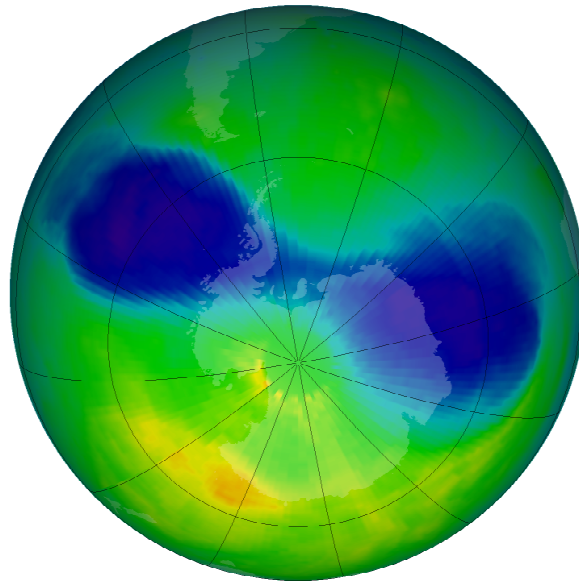


Figure 7c. Split Antarctic ozone hole, 2002

Effects of Ozone Depletion: Ultraviolet Radiation

UV radiation can be classified into three component wavelengths as a means of better understanding the potential negative impacts it has on human and environmental health. These UV wavelengths include:

- UV-A (long wave: 380-315nm)
- UV-B (medium wave: 315-280nm)
- UV-C (short wave: < 280 nm).

1. Human Effects

Although only one of these wavelengths is of greatest concern to humanity - UV-B, the primary cause of skin cancer - the reality is they all have the potential to damage living tissue that significantly leads to the aging of skin. The detrimental effects resulting from UV-A are negligible at best, but can contribute to skin wrinkling, DNA damage and in extreme circumstances skin cancer. UV-A rays typically penetrate human skin the deepest but, are not a known cause of sunburn. UV-C rays, which are extremely harmful to humans, are completely screened out by the ozone layer at around 35 kilometres in altitude. However, little attention is given to this form of radiation.

UV-B rays primarily cause sunburn, with excessive exposure leading to genetic damage and skin cancer. Scientists and medical professionals agree that UV-B radiation is the direct cause of three main types of skin cancer: basal cell carcinoma, squamous cell carcinoma and malignant melanoma. A large number of the reported cases of skin cancer in Canada are basal and squamous cell carcinomas (Figure 8a), which do not cause death because they do not metastasize (spread) and are easily treated through routine surgery. Melanoma, on the other hand, is the most serious but least common form of skin cancer. Symptoms of melanoma (Figure 8b) are generally associated with the appearance of a mole that is linked to intense exposure to the sun. These moles are usually characterized by discolourizations within the mole (black, brown, red, blue or white), asymmetrical borders, or any enlargements in size. Unlike basal and squamous cell carcinomas, melanoma is very likely to spread to other parts of the body and is virtually incurable once it has metastasized. Early detection is key in this case as the timely removal of moles in their early stages prevents the cancer from spreading. UV-B overexposure has also been linked to eye damage, including the lens, cornea and conjunctiva problems and, to the creation of eye cataracts (a clouding of the eye lens that leads to blindness).

Squamous cell carcinoma



Basal cell carcinoma



Figure 8a. Basal and Squamous cell carcinomas



Figure 8b. Malignant melanoma to the face

Skin Cancer Facts

- *Water, sand, concrete and snow all have the potential to reflect and even intensify the ultraviolet solar radiation, which causes skin cancer.*
 - *Fresh snow 80% reflectivity*
 - *Beach sand 15% reflectivity*
- *Skin cancers will usually develop in areas that are most exposed to the sun, which include the head, face, neck, hands and arms.*
- *The most common method of removing melanoma skin cancer is through surgery, which removes the cancer plus a small patch of surrounding skin – all under local anesthetic.*
- *A variety of non-surgical procedures can be used for basal and squamous cell carcinomas. Cryotherapy (liquid nitrogen to freeze and peel the cancer), scraping (curettage), burning (cautery) or radiation treatment can be utilized.*
- *The risk of skin cancer today is greater than it was 20 years ago.*
- *Skin cancer is the second most common type of cancer amongst women.*
- *People should reduce their sun exposure during the hours of 11a.m. and 4p.m. when the sun's rays are at their maximum strength.*
- *People should apply 2 mg of sunscreen to each square centimetre of exposed skin (the approximate equivalent of a teaspoon for each limb – with more generous portions for the torso region).*
- *The sunlight Canadians are exposed to is potent enough to cause skin cancer and premature aging.*
- *The number of newly-reported cases of skin cancer is expected to increase by 30% over the previous decade.*
- *It is expected that one in every seven Canadians will develop one of the three forms of skin cancer in their lifetime.*
- *The number of Canadians diagnosed this year with skin cancer could fill the equivalent of four hockey arenas.*
- *Over 50% of Canadians do not use any type of skin protection when they are exposed to the sun's rays and those who do use it do so incorrectly.*
- *Since 2001 there has been an increase in the reported number of skin cancers from 70,000 to 76,000 per year. This is compared to 58,500 new cases reported in 1994.*
- *Each year 374,000 Australians are diagnosed with one of the non-melanoma forms of skin*

cancer, with nearly 360 people dying as a result.

- *Conversely, 8,800 Australians are diagnosed each year with melanoma, with nearly 1,000 dying as a result.*
- *Out of all new cancers diagnosed in Australia each year, nearly 81% are skin cancers.*
- *Every year doctors in Australia will remove approximately 720,000 lesions from Australians because they are suspected skin cancers.*
- *There is a time lag of approximately 10-30 years before the clinical development (i.e., appearance) of skin cancer. Therefore early detection is of the utmost importance.*
- *There is no such thing as a “safe tan” as a tan indicates damage from the sun’s UV rays. The brown colour produced by a tan is the release of a pigment called melanin, which is an indication of skin damage, as it tries to block the sun’s damaging rays.*
- *Sunburn will usually occur in conditions between 18-27°C, because of the assumption that UV are not strong on a cool day. Unfortunately this is not the case.*
- *Nearly 90% of UV rays can penetrate cloud cover.*
- *Overall, the total amount of UV radiation received by the earth will increase for each 1000-metre increase in altitude.*
- *Even under a half-metre of water, UV rays intensity is still a potent 40% of its land capabilities.*
- *Sufficient levels of vitamin D can be accumulated by simply sitting near or by a window or spending short periods of time outdoors (often only two minutes is necessary).*
- *Tanning beds and solariums are not a healthy alternative to outdoor sunbathing as the amount of UV radiation emitted by tanning beds can be two to five times greater than natural sunlight. A person under the age of 30, who uses a tanning bed more than ten times per year is eight times as likely to develop life-threatening melanoma.*
- *People who have pale skin and light-coloured eyes are most susceptible to burning and development of skin cancer. People of darker complexion, who may tan easily and never burn, can still develop skin cancer if they do not take any preventative measures to protect their skin from UV rays.*

2. *Environmental Effects*

UV-B rays can negatively impact terrestrial ecosystems by reducing crop yields, altering species composition and competition, reducing the capacity for photosynthesis, increasing the risk of disease and stunting growth. Similarly, aquatic studies have shown that phytoplankton, which form the basis of most aquatic food chains, are highly sensitive to increased levels of UV-B radiation as it reduces their mobility and ability to photosynthesize. In addition to the natural environment, the built environment is also susceptible to damage from UV light specifically polymer plastics. For instance, polyvinyl chloride (PVC), typically found in window frames, can undergo a variety of chemical changes including discolouration (yellowing) and loss of structural integrity, which leads to cracking.

Environmental Consequences of Ozone Loss

- *Phytoplankton, which are tiny microscopic algae, form the basis of the marine food chain. Plankton is eaten by krill, which in turn feed Antarctic seals, penguins and whales.*
- *A 16% increase in ozone destruction over the Antarctic would negatively impact phytoplankton communities and could result in the loss of over seven million tons of fish per year.*
- *It has been scientifically proven that UV-B radiation negatively affects Antarctic microorganisms and it is predicted photosynthesis rates amongst phytoplankton will be reduced by nearly 8.5% under the worst conditions.*
- *UV radiation has detrimental effects towards the larvae of both starfish and sea urchins.*
- *UV radiation has the potential to alter oceanic chemistry.*
- *Pure water does not protect against UV radiation. A ray of UV-B radiation would have to travel nearly half a kilometre before it is completely neutralized.*
- *Natural waters may provide some defense against UV radiation in the form of dissolved organic matter, which can shield aquatic organisms from UV-B radiation.*
- *Standing water ecosystems are most susceptible to UV radiation damage as penetration can occur up to several tens of metres in depth. However, turbid or moving water may limit UV penetration up to 10-20 cm.*
- *Some crops and tree species have shown to be UV-B sensitive and therefore will experience some reductions in yield. Some crops and trees are now being genetically modified to be UV-*

B resistant.

- *UV-B radiation has negligible effects on hair-covered animals (cats, dogs, goats, sheep, cattle, etc.). However, they are susceptible to skin cancer where their flesh is exposed and non-pigmented (mouth, nostrils, underbelly, etc.).*
- *For most plants, only a small portion of UV-B radiation that strikes a leaf will actually be absorbed in its tissue. As UV levels increase, the plant will produce more of the UV-absorbing pigment.*
- *Some organisms have the ability to adapt defense mechanisms towards increased UV levels, such as pigment blockers in plants or additional layers of protective tissues.*
- *It is believed that UV-B negatively affects plant life by altering photosynthesis, damaging DNA, changing morphological characteristics and reducing overall productivity.*

The UV Index

In 1992, Environment Canada scientists developed a system to predict and assess the overall intensity of the sun's UV rays based on day-to-day fluctuations in the ozone layer. The index, as seen in Table 1, reads as follows:

Table 1

Range	Value	Action Required
0-2	Low	Minimal Protection
3-5	Moderate	Cover-up
6-7	High	Protection Required
8-10	Very High	Full Protection
11+	Extreme	Avoid Sun Exposure

For more information on Canada's UV Index, please visit:

- www.msc-smc.ec.gc.ca/education/uvindex/index_e.html

or other global measurement systems at:

- http://en.wikipedia.org/wiki/UV_Index
- www.epa.gov/sunwise/uvindex.html

Chapter 1 Review Questions

Complete these questions to reinforce your newly acquired knowledge of ozone depletion. They will assist you to reinforce your memory in view of the upcoming exam.

1. True or false: ozone is created by natural processes in the earth's atmosphere.
2. Ozone is responsible for blocking out what percentage of the sun's harmful ultraviolet radiation?
 - a. 20%
 - b. 75%
 - c. 90%
 - d. None of the above
3. The ozone layer resides 10-50 kilometres above the earth's surface. Which zone has the highest concentration of ozone?
 - a. 5-10 km
 - b. 15-30 km
 - c. 40-50 km
 - d. 50 km and above
4. Which one of the following statements regarding ozone concentrations is true?
 - a. Thinnest at the equator and thickest at the poles
 - b. Thicker at the equator and thinnest at the poles
 - c. Ozone concentrations are uniform across the globe
 - d. None of these statements are true
5. True or false: the Dobson Unit is the least common unit used in ozone research to identify the thickness of the ozone layer.
6. When ozone (the substance) was first discovered in 1840, the Greek word "ozien" was quickly associated with it because it had an unusual...
 - a. Taste
 - b. Appearance
 - c. Sound
 - d. Smell
7. True or false: ozone is naturally being created and destroyed on a constant basis.
8. Rowland and Molina's 1974 ozone depletion theory stated...
 - a. Chlorine (CFCs) disturbed the natural ozone cycle
 - b. Paul Crutzen's earlier ozone research was too inconclusive
 - c. UV rays could separate the chlorine atom from the rest of the CFC molecule
 - d. Both A and C

9. Ozone is destroyed when a single chlorine atom bonds with...
 - a. An ozone molecule
 - b. Another CFC molecule
 - c. Carbon dioxide
 - d. None of the above

10. True or false: one CFC molecule can destroy hundreds of thousands of ozone molecules in its lifetime.

11. CFCs are very stable compounds in the stratosphere. What is the average atmospheric lifespan for one molecule of CFC-12?
 - a. 50 years
 - b. 75 years
 - c. 5 months
 - d. 140 years

12. Which one of the following wavelengths of UV radiation is of greatest concern to humanity?
 - a. UV-A
 - b. UV-B
 - c. UV-C
 - d. None of the above

13. Which one of the following wavelengths of UV radiation is completely blocked out by the ozone layer?
 - a. UV-A
 - b. UV-B
 - c. UV-C
 - d. Ozone completely blocks out all wavelengths of UV radiation

14. True or false: UV radiation helps phytoplankton to photosynthesize.

15. When the UV Index is 11 or higher (extreme), which of the following steps should a person take to protect themselves against overexposure?
 - a. Avoid sun exposure at all costs
 - b. Stay indoors during peak exposure times
 - c. Cover all limbs and apply sunscreen if outdoor activity is necessary
 - d. All of the above

Chapter 2

Understanding Aspects of ODS's and Other Halocarbons

CHAPTER OBJECTIVES

After studying this chapter, the training participant should be able to:

- Understand aspects and environmental consequences of refrigerant usage
- Understand the various initiatives taken to control the use of ODS's and other Halocarbons

Ozone Depleting Substances

Ozone depleting substances (ODS) can be defined as a group of human-made compounds that have been scientifically proven to deplete the ozone layer and contribute to climate change. There are many substances that can be classified as ODS and some of the major compounds include chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform (1,1,1 trichloroethane), carbon tetrachloride (CCl₄), methyl bromide (CH₃Br) and hydrochlorofluorocarbons (HCFCs).

Ozone Depletion Potential (ODP)

Each ozone depleting substance differs in its capacity to destroy ozone molecules, which has prompted scientists to adopt a system where each ODS can be relatively compared to one other. The ODP of an ODS is characterized by the amount of calculated ozone column change as a result of emitting one unit of that gas into the atmosphere relative to the depletion that is caused by a reference gas (CFC-11: ODP 1.0). This allows for different ODS to be compared to each other using a common unit. For example, Halon

2402 (ODP 6.0) is six times more harmful to the ozone layer than CFC-11. Table 2 illustrates the ODP of some selected ODS's, other halocarbons and hydrocarbons.

Table 2

ODS/Halocarbon Type	Ozone Depletion Potential
CFC-11	1.0
CFC-12	1.0
CFC-113	0.8
CFC-114	1.0
CFC-115	0.6
Halon 1301	10.0
Halon 1211	3.0
Halon 2402	6.0
HCFC-22	0.055
HCFC-123	0.02
HFC-134a	0.00
Propane (R-290)	0.00
Certain Common Blended Refrigerants	
R-502 blend of HCFC-22 and CFC-115	0.33
R-500 blend of HFC-152a and CFC-12	0.75

Refrigerant Types (ODS and Other Halocarbons)

1. Chlorofluorocarbons – Banned Substances (Phased Out)

CFCs were some of the most commonly used ODS worldwide, as they were considered to be nontoxic and nonflammable. They are also greenhouse gases and contribute to climate change. CFCs contain atoms of carbon, chlorine and fluorine (Figure 9) and were used as aerosol propellants, insulators (foam blowing), refrigerants, solvents and sterilants.

All refrigerants, including CFCs, have their own unique labeling system to identify the individual number of carbon, hydrogen, chlorine and fluorine atoms each type of molecule has (more information on labeling is provided later on).

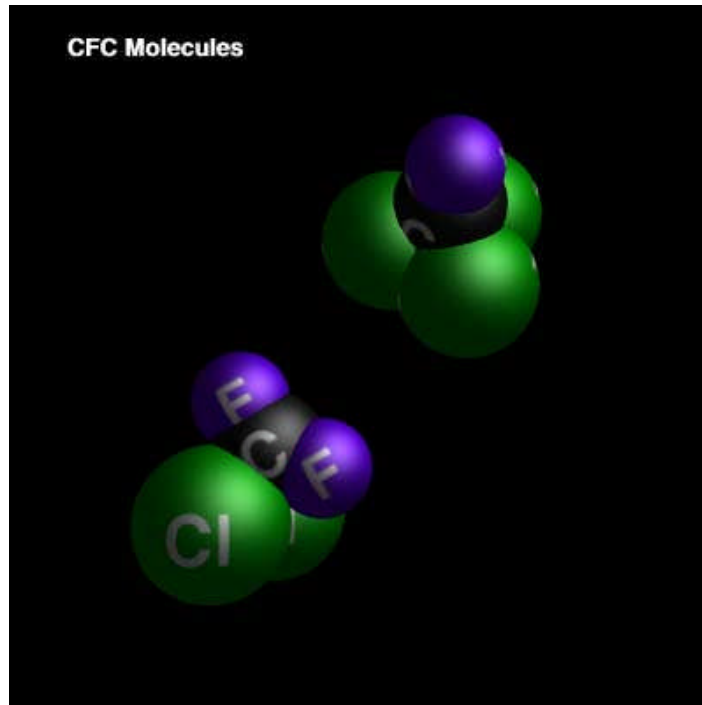


Figure 9. CFC molecule

CFCs first evolved in the 1930s as a safer alternative to the highly toxic gases of ammonia (NH_3), methyl chloride (CH_3Cl) and sulfur dioxide (SO_2) being used as refrigerants since fatal explosions resulted from these substances.

Three large American companies - General Motors, General Electric and Dupont began searching for a less toxic and highly stable replacement. In 1928, Thomas Midgley Jr. (Figure 10a) developed CFCs as a safer alternative and demonstrated this by inhaling a large lungful of his new creation. General Motors and Dupont quickly marketed the product under the trade name "Freon" (Figure 10b) and by 1935, approximately eight million refrigerators in the United States were using CFCs. By 1960 their use had expanded to propellants in hair sprays and medical inhalers, as well as, an alternative for automobile air conditioning systems (Figures 10 c and 10d).



Figure 10a. Tom Midgley Jr.



Figure 10b. Virgin CFC-12



Figure 10c. Vintage fridge



Figure 10d. CFC Spray can

CFC Usage

Dupont Canada, formerly the largest CFC producer in Canada, ceased production of CFCs in 1993 – three full years before the mandatory phase-out under the *Montreal Protocol* (as described in Chapter 4). Under Canadian federal law (the *Ozone Depleting Substances Regulations*), after January 1, 1999 no person is permitted to manufacture or import into Canada a product that contains a CFC, unless a special exemption is granted. Despite strict regulations in Canada, the *Montreal Protocol* allowed for developing countries to produce CFCs for a period of ten years after January 1, 1999 to meet the basic domestic needs of that country. This has led to a black market for illegally obtained CFCs (particularly CFC-12), which are smuggled from developing countries using a

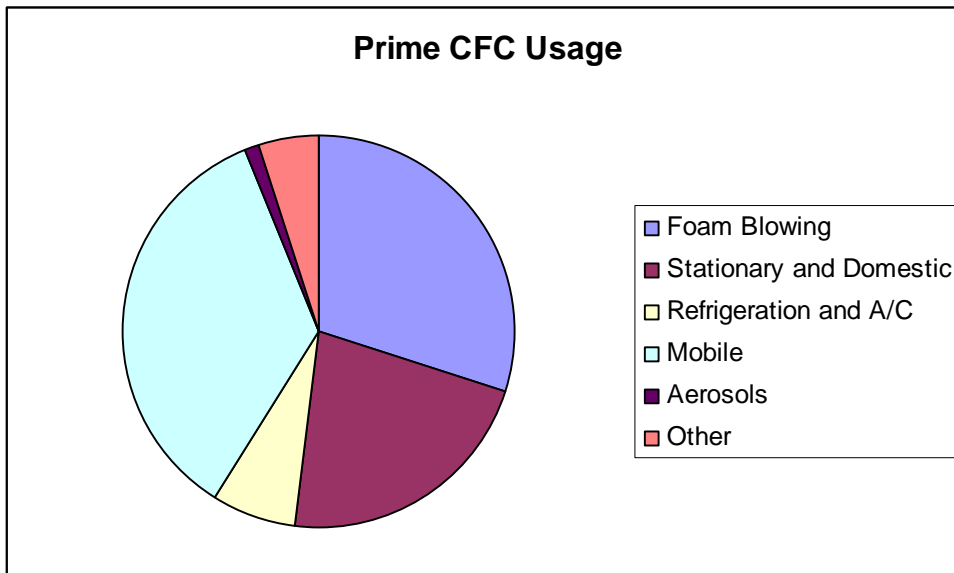
number of creative methods, including mislabeling or hiding amongst legal chemicals. In 2004 one Canadian company was charged \$25,000 for illegally importing 3,090 CFC-containing bar fridges into Canada in 1999 (1.8 ounces of CFC-12 per fridge – a total of 158 kg CFC-12 imported).

Table 3 and Graph 1 illustrates industry usage of CFCs during periods of wide spread use (i.e. 1970-1990s).

Table 3

Foam Blowing	30%
Stationary and domestic	22%
Refrigeration and A/C	7%
Mobile air conditioning	35%
Aerosols	1%
Other	5%

Graph 1



2. Hydrochlorofluorocarbons – Restricted Usage

HCFCs were designated as one of the key replacements for CFCs under the *Montreal Protocol*. Although not as harmful to the ozone layer as CFCs, HCFCs have a significant global warming potential (GWP) that contributes to climate change. HCFCs are used extensively in the refrigeration, air conditioning and foam blowing sectors, and most commonly include HCFC-22 as a refrigerant and HCFC-141b as an insulator in foams. In Canada, as prescribed by the *Montreal Protocol*, the production and consumption of all HCFCs will be phased out by January 1, 2020, with the exception of HCFC-123 which will be phased out by January 1, 2030. Table 4 highlights the phase-out schedule of HCFCs. The latest adjustments were made at the 19th Meeting of the Parties to the *Montreal Protocol* in 2007.

Montreal Protocol		Canada		United States	
Date	Action	Date	Action	Date	Action
January 1, 1996	Establish baseline for domestic HCFC consumption <ul style="list-style-type: none"> • 2.8% of 1989 CFC levels • 100% of 1989 HCFC levels 	January 1, 1996	Baseline for consumption established	January 1, 1996	Baseline for consumption established
January 1, 2004	Consumption reduced 35%	January 1, 2004	Reduce consumption by 35%	January 1, 2004	Production and import of HCFC-141b banned
January 1, 2010	Consumption reduced 75%	January 1, 2010	Reduce consumption by 75% - no new HCFC-22 equipment manufactured or imported	January 1, 2010	No production and import of HCFC-142b and HCFC-22 (in new equipment) - but may be produced or imported for existing equipment
January 1, 2015	Consumption reduced 90%	January 1, 2015	Reduce consumption by 90%	January 1, 2015	No production or importing of any HCFCs - except as refrigerant in existing equipment
January 1, 2020	Consumption reduced 95.5%	January 1, 2020	Reduce consumption by 95.5% - HCFC-123 imported or manufactured until 2030 for use and service in chillers	January 1, 2020	No production and import of HCFC-142b and HCFC-22
January 1, 2030	No consumption of HCFCs allowed	January 1, 2030	HCFCs no longer permitted to be imported or manufactured	January 1, 2030	No production or import of any HCFCs

At future meetings of the Parties to the *Montreal Protocol*, one can anticipate further attempts to accelerate the phase-out timetable for HCFCs, which may be a necessary action needed to meet ozone protection, climate change and energy efficiency objectives. An accelerated phase out of HCFCs would likely advance the replenishment of the Antarctic ozone hole by 2055 and offset nearly 22 gigatons of CO₂ equivalence between 2010-2050.

3. Hydrofluorocarbons – ODS Replacements

Hydrofluorocarbons (HFCs) were originally developed as long-term replacement products for CFCs and HCFCs. HFCs are substances that contain hydrogen, fluorine and carbon. Since these substances do not contain any chlorine and their ODP is zero. However, they are a potent greenhouse gases (GHGs). At present, the most widely used HFC refrigerant on the market is HFC-134a (see Figure 11) because it has thermodynamic properties similar to that of CFC-12, in addition to serving as the building block for many refrigerant blends. It first appeared in the early 1990s as a replacement for CFC-12 and is an inert gas that is primarily used as a refrigerant in domestic refrigeration and mobile air conditioning systems. HFCs have such common utility that every industry sector can relate to them.

HFC-134a has expanded its role to other applications including sterilization, propellant and insulator for foam blowing. Research over the past 15 years has shown that the accumulation of HFCs in the atmosphere has been significant. HFC-134a is one of the seven basket of gases under the Kyoto Protocol. HFCs in general are powerful greenhouse gases with GWPs ranging from 140 (HFC-152a) to 11,700 (HFC-23) compared to CO₂ over a 100-year period. The overall performance of HFCs has also been taken into question and has prompted some European countries to move towards other environmentally friendly alternatives. Early indication is that HFC-based appliances may be significant energy users and have poor performance records in higher temperature situations compared to systems using hydrocarbons. Technology innovations in engineering are likely to advance performance in future for the various alternative applications.



Figure 11. Canister containing HFC-134a

- ***US EPA's: Significant New Alternatives Policy (SNAP)***

SNAP was developed by the United States Environmental Protection Agency (EPA) to evaluate and regulate Class 1 (ODP > 0.2) and Class 2 (ODP < 0.2) substitutes for ODS under the *Clean Air Act*. The purpose of the program is to smoothly transition from ODS to alternatives that offer lower risks to human and environmental health. In the refrigeration and air conditioning sector, HFC-134a has been identified as an acceptable substitute for various CFC and HCFC new and retrofit applications including chillers, industrial refrigeration and air conditioning, cold storage, automobile and mobile transportation, and white goods. In addition, HFCs are being used within other sectors, such as domestic appliances, foam blowing, cleaning solvents, aerosol propellants, and fire and explosion protection.

4. Hydrocarbons and Carbon Dioxide – The Future

These are natural, non-toxic, non-ozone depleting and low GWP replacements for CFCs, HCFCs and HFCs. They are chemical compounds composed of hydrogen and carbon atoms and have a very short atmospheric lifespan of only weeks to months where they eventually break down into their component parts of carbon dioxide and water. Some examples of hydrocarbons used as refrigerants or foam blowing agents include pentane, butane, ethane and propane. These gases have been in use since the late 1800s and have

begun to re-emerge in new equipment manufacturing processes as concern over the environment has grown significantly. Hydrocarbons have been used in a wide variety of applications that include fuels, lubricants, plastics, chemicals and propellants.

- ***Carbon Dioxide***

Due to advances in technology, particularly the manufacture of thin and strong aluminum tubing, carbon dioxide refrigerants have the potential as replacements for halocarbon-based refrigerants. Despite being a global warming gas, releases of carbon dioxide would be insignificant compared to the same amount of HFCs. Small lightweight systems, such as portable air conditioners, are the most effective for carbon dioxide because the high operating pressures let the refrigerant pass through small-diameter tubing, allowing for the design of compact systems. In addition, the most significant property of carbon dioxide as a refrigerant is the low critical temperature of 31.1°C.

Using carbon dioxide as a refrigerant is effectively a carbon neutral process, as the carbon dioxide that is released into the atmosphere was obtained from the atmosphere. It is not like using hydrocarbons which release carbon dioxide that has been trapped within the earth.

Other ODS and Halocarbons

1. Halons

Halons are classified as bromated organic compounds, where one or more of the hydrogen atoms have been replaced with a bromine atom. They are also known as bromofluorocarbons. There are three main types of halons, including Halon-1211, Halon-1301 and Halon-2402 with an atmospheric lifespan between 20-77 years. Halons are typically used in fire suppression equipment (Figure 13) to extinguish electrical and electronic-related fires (mainframe computers, aircraft circuitry, etc.). Of all known ODS, halons have the greatest potential to destroy the ozone layer, with some being as much as ten times more damaging to the ozone layer than CFC-11 or 12.



Figure 13. Halon fire extinguisher

Many computer room air conditioning service and maintenance procedures can potentially trigger a false alarm condition due to the use of extremely sensitive smoke and rate of temperature rise detectors. Maintenance personnel must coordinate their service work with the computer room facility manager to prevent any possibility of an accidental halon release. Computer-based facilities have very specific isolation protocols that must be initiated before starting any type of maintenance work.

It is important to note that due to the longlife span of ODS, almost all the ODS, including halons ever released into the atmosphere, are still in the stratosphere destroying ozone and will continue to be there for many years to come.

2. Carbon Tetrachloride

In its early uses, carbon tetrachloride was applied as a dry-cleaning solvent, aerosol propellant, refrigerant and in certain types of fire extinguishers. From 1940 onwards, carbon tetrachloride was found to have severe health effects, as exposure to high doses of the substance significantly affected the central nervous system, leading to comas and possible death. Its use was eventually limited to pesticide applications. An outright ban on its use was instituted in the United States and restricted in Canada. Carbon tetrachloride was also used in the production of CFC-11 and CFC-12.

3. Methyl Chloroform

This chlorinated solvent was commonly used for cleaning circuit boards in the electronics industry and as an aerosol propellant. The *Montreal Protocol* has since banned its use, beginning in 1996.

4. Methyl Bromide

Sources of methyl bromide can be found in both natural and human activities. In a natural setting, it can be found in the ocean where it is produced by algae and kelp, and on land by certain types of plants. It is also used extensively in the agricultural industry by combining methanol with hydrobromic acid (Figures 14a and 14b). Methyl bromide is primarily used as a soil sterilant or fumigant to neutralize small pests and fungi. The use of methyl bromide has been severely limited by the *Montreal Protocol* because of its high ODP (60 times more powerful than chlorine). Only recently has it been granted critical use exemption under the *Montreal Protocol*. Health effects related to methyl bromide include nausea, headaches, convulsions, and in higher concentrations, death.

5. Sterilants

Sterilants containing ozone depleting substances were used primarily in hospitals to control and eliminate infectious organisms. They were taken out of use in Manitoba in the late 1990's. Alternative bacterial control compounds have been integrated and include 100% ethylene oxide, a product not damaging to the ozone layer.



Figure 14a. Agricultural application of methyl bromide



Figure 14b. Canisters of methyl bromide

Chapter 2 Review Questions

1. True or false: ODS have been scientifically proven to deplete the ozone layer and contribute to climate change.
2. The ozone depleting potential index was designed to...
 - a. Allow different ODS to be compared to each other using a common unit
 - b. Assist with the phase-out of CFCs
 - c. Help certified technicians choose the correct refrigerant for a system
 - d. Measure the amount of UV radiation reaching the earth's surface
3. CFC molecules contain which of the following atoms?
 - a. Chlorine
 - b. Fluorine
 - c. Carbon
 - d. All of the above
4. During the prime-use period of CFCs, which industry sector accounted for the greatest consumption of these substances?
 - a. Aerosols
 - b. Refrigeration and A/C
 - c. Foam Blowing
 - d. Mobile A/C
5. True or false: although HCFCs are somewhat safer for the ozone layer, they still contribute to climate change.
6. True or false: HFCs contain a chlorine atom.
7. HFC-134a is commonly used today because it...
 - a. Shares similar thermodynamic properties with CFC-12
 - b. Acts as a building block for refrigerant blends
 - c. Is cheap to manufacture
 - d. Both A and B
8. What was the main reason behind developing the US EPA's SNAP program?
 - a. To help transition to ODS alternatives with less risk to human and environmental health
 - b. To introduce and test new ODS for the US market
 - c. The program would make it more difficult to smuggle CFCs into the US
 - d. To help the US reach its Kyoto targets and reduce CO₂ emissions
9. The benefits of hydrocarbons include which of the following?
 - a. Low ODP and minimal global warming potential
 - b. Poses a short atmospheric lifespan
 - c. Are beginning to replace CFCs, HCFCs and HFCs

- d. All of the above
10. What advancements in refrigeration technology make it possible to consider using carbon dioxide as a refrigerant?
- a. More powerful compressors
 - b. Thinner, stronger aluminum
 - c. Space-age designs
 - d. Less emphasis on steel components

Chapter 3

Regulatory Context for ODS and Other Halocarbons

CHAPTER OBJECTIVES

After studying this chapter, the training participant should be able to:

- Understand aspects and the environmental consequences of refrigerant usage.
- Understand the various initiatives taken to control the use of ODS and other halocarbons.

Scientific research on ozone depletion dates back to the mid 1960s and policymakers first took action on the issue beginning with the Vienna Convention in 1985. This was the first true international attempt at averting an environmental disaster before the situation became uncontrollable. As a result, the Convention made it a requirement that participating parties must take the most appropriate measures for protecting the stratospheric ozone layer. This multinational attempt was facilitated in part by Mostafa Tolba, Executive Director of the United Nations Environment Programme (UNEP), who sought a true international policy solution for ozone protection. On June 4, 1986 Canada became the first country to ratify the *Vienna Convention*, and as a direct result Canada was recognized as one of the global leaders in the development of the *Montreal Protocol*. Montreal was subsequently selected in recognition of Canada's commitment to the *Vienna Convention* and its dedication to developing a Protocol to control ozone depletion.

Montreal Protocol on Substances that Deplete the Ozone Layer

The *Montreal Protocol on Substances that Deplete the Ozone Layer* establishes a timetable for the reduction in global consumption of ozone depleting substances (i.e.

CFC's, HCFC's) and three halons (see table page 37). The original Protocol, which was initially signed by 24 nations on September 16, 1987, instructs developed nations that CFC consumption (which is defined as production + imports – exports) must be stabilized and/or frozen at 1986 levels one full year following the implementation of the Protocol starting January 1, 1989 (CFCs) and January 1, 1992 (halons). Originally the Protocol called for consumption of CFCs to be reduced by 20% as of 1993-94 and by 50% in 1998-99. All timetables instituted under the Protocol were for developed nations, with developing countries given a grace period for compliance. The Protocol itself has been designed so phase-out timetables can be adjusted or accelerated based on new scientific or technological discoveries. As of 2009, UNEP has identified 195 nations signing and ratifying the *Montreal Protocol*. However, not all nations have accepted the amendments to the Protocol. Only five nations in the world have not ratified the terms of the Protocol.

Economic Benefits Worth the Cost of the *Montreal Protocol*

- *Often times, practitioners of pollution prevention come under heavy scrutiny for not accounting for the economic implications of pollution prevention. This was the case in the mid-1980s, when scientific evidence linking ozone depletion to CFCs was uncertain and economists asked, “Can the global community afford to discontinue the use of ODS?” Despite heavy resistance to this scientific progress, the facts were accepted at face value, the Protocol was signed, and the use of ODS was reduced.*
- *Ten years later in 1997, for the tenth anniversary of the Protocol, Environment Canada launched an independent economic review to assess the overall costs and benefits for the reduction and phase-out of ODS.*
- *Despite being only ten years into the Protocol, the findings were unanimous:*
 - *There were significant net benefits towards human health, fisheries, agricultural production and building material protection*
 - *The technology boom created by the Protocol has had significant environmental and economical benefits*
 - *Every nation in the global community was receiving benefits.*
- *Specific benefits of the Protocol, as seen by the prevention of further ozone destruction, are as follows:*

- *By 2060, 19.1 million cases of non-melanoma skin cancer will have been avoided*
- *Nearly 1.5 million prevented cases of melanoma*
- *Approximately 333,500 prevented skin cancer deaths*
- *About 129 million avoided cases of eye cataracts*
- *\$238 billion in benefits to the world fisheries due to the reduced risk of UV-B damage to marine ecosystems*
- *The benefits to agricultural production will be \$191 billion*
- *For the building industry, the study estimated that benefits towards the use of polyvinyl chloride building materials (PVC) would be in excess of \$30 billion.*
- *Cost savings as a result of technological spinoffs were also examined:*
 - *Aerosol spray manufacturers, by switching away from CFC-based propellants, directly cut industry costs for propellant materials by as much as 80%.*
- *The study estimated that the overall cost to society for the Protocol was or will be \$230 billion over a control period of 1987-2060. In actuality, these costs are lower than what was originally projected, due to technological breakthroughs where alternatives are actually cheaper than the ODS they replaced. The benefits to the Protocol are nearly double this amount, as the benefits far exceed its costs.*

Federal-Provincial Responsibilities: Canada's Ozone Layer Protection Program

After signing the *Montreal Protocol*, Canada initiated the development of policies, highlighting its commitment to the newly-signed international agreement. A federal coordinated program was initiated involving both federal and provincial levels of government, called the Federal-Provincial Working Group on Controls Harmonization (FPWG). Each level of government – federal, provincial and territorial – are responsible for implementing specific regulations in regards to controlling ODS.

*Federal responsibilities focus on issues considered to be of national interest and include ensuring the terms of the Montreal Protocol are implemented within Canada. Two regulations have been developed under the **Canadian Environmental Protection Act (CEPA)**, which include placing stringent controls on the consumption of ODS within Canada. The **Ozone Depleting Substances Regulations, 1998** ensures Canada is in full compliance with the terms stipulated under the Montreal Protocol regarding ODS consumption and reporting. Also, the **Federal Halocarbons Regulations, 2003** regulates all halocarbon-containing equipment and systems on federal works and undertakings. Changes to these regulations can easily be made to reflect any new amendments to phase-out schedules under the Montreal Protocol. CEPA also contains several *Environmental Codes of Practice*,[♦] which provide best practices for pollution prevention and reduction of atmospheric emissions of ODS. In the absence of regulations, the Codes of Practice will be upheld in a court of law.*

Provincial governments enact legislation and regulatory requirements, which stipulate first and foremost the mandatory recovery, recycling, or disposal and destruction of ODS. They also address labeling procedures for all ODS-containing equipment, environmental awareness training for the refrigeration and air conditioning sector, and highlight best-practice repair techniques for any and all ODS-containing equipment. In addition, they are also responsible for regulating ODS leaks and discharges into the atmosphere.

This coordinated approach to stratospheric ozone protection could not have been possible without the Federal/Provincial Working Group on Controls Harmonization (FPWG), which includes representatives from all provinces, territories and the federal government. Since differences do occur between provincial regulations (in terms of methods and priorities), the task of the working group is to maintain a harmonized approach to regulatory activities. In 1992, the Canadian Council of Ministers of the Environment (CCME) approved the first National Action Plan (NAP) for Recovery, Recycling, and Reclamation of Chlorofluorocarbons (CFCs) prepared by the FPWG. The 1992 NAP focused on the recovery, recycling, and reclamation of CFCs and HCFCs within the refrigeration and air conditioning sectors.

Industry Leadership

In 1994, The Manitoba Ozone Protection Industry Association (MOPIA) was formed to assist industry and administer components of the emerging regulatory compliance regime in Manitoba. MOPIA is a collective body representing the various ODS industry sectors throughout the province of Manitoba.

MOPIA has been designated to assist with certain components of MR 103/94. In addition, MOPIA participates in outreach activities to provide a greater understanding (information and assistance) of ODS's and alternatives to stakeholders and the public.

MOPIA administers the provincial certified technician database, works and partners with the various stakeholders and governments, the Enforcement Division of Manitoba Conservation and any other parties with a direct interest in making this initiative succeed.

Several other related industry associations exist and function within Manitoba such as RSES (rses.org), HRAI (hrai.ca), RACCA, BOMO and others. While not entirely focused on ODS management, they function in part to offer their stakeholders support in ODS and product awareness, training or related functions.

♦ *The Environmental Code of Practice for the Elimination of Fluorocarbon Emissions from Refrigeration and Air Conditioning Systems & the Environmental Code of Practice on Halons.*

Chapter 3 Review Questions

1. Which convention paved the way for the development and adoption of an ozone protection protocol?
 - a. Ramsar Convention
 - b. Vienna Convention
 - c. Bern Convention
 - d. Basel Convention

2. The *Montreal Protocol on Substances that Deplete the Ozone Layer* was originally established to do what?
 - a. Phase out the use of CFCs and halons
 - b. Promote the further use of CFCs and halons
 - c. Find new uses for CFCs
 - d. Promote the use of ammonia and sulfur dioxide as safer alternatives to CFCs

3. True or false: developing nations were given a grace period to comply with the terms of the Montreal Protocol.

4. At present (2009), how many nations are Parties to the *Montreal Protocol*?
 - a. 195
 - b. 2
 - c. 107
 - d. 75

5. In Canada, which levels of government are responsible for implementing Canada's Ozone Layer Protection Program?
 - a. Federal
 - b. Provincial
 - c. Territorial
 - d. All of the above

6. The purpose of MOPIA is to...
 - a. Administer certain components of MR 103/94 (i.e., maintain a certified technician database)
 - b. Work towards the protection of the stratospheric ozone layer and climate
 - c. Forge innovative partnerships between the organization and industry, government and the public
 - d. All of the above

Chapter 4

Climate Change, Global Warming and the Greenhouse Effect

CHAPTER OBJECTIVES

After studying this chapter, the training participant should be able to:

- Understand aspects and environmental consequences of refrigerant use
- Understand the various initiatives taken to control the use of ODS and other halocarbons.

Global Warming and Climate Change

Global warming refers to the actual increase in the average atmospheric and oceanic temperatures in the recent decades. During the 20th century, the earth's surface temperature increased approximately 0.6°C +/- 0.2°C. Most scientific authorities attribute this increase to human activities such as releasing carbon dioxide from the combustion of fossil fuels, clearing of land for agriculture, and the use of halocarbons. Since 1979 land temperatures have increased 0.25 °C per decade compared to 0.10 °C for aquatic ecosystems. Research from NASA revealed that 2005 has been the warmest year on record since the late 1800s which exceeded the previous record set in 1998 by several hundredths of a degree Celsius. Figure 15 provides an illustrated synopsis of global warming.

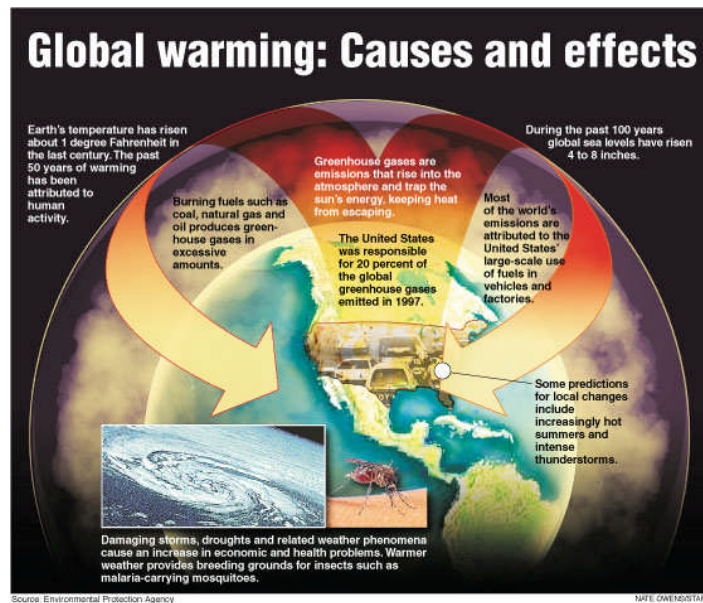


Figure 15. Global Warming

Quick Facts on Global Warming

- *Ice thaws in the Northern Hemisphere are occurring nearly nine days earlier than they did 150 years ago and freezing in the fall happens ten days later.*
- *Since record keeping was instituted in the mid-1800s, the 1990s was the warmest decade on record.*
- *The hottest years on record have been 2005, 1998, 2002, 2003, 2004, 2001, and 1997.*
- *It has been determined that in Alaska, Northwestern Canada and Western Russia temperatures have risen 3-4°C over the past 50 years, which is double the global norm.*
- *By the end of the 21st Century, the UN Intergovernmental Panel on Climate Change (IPCC) predicts that global temperatures will rise an additional 1.6-5.5°C.*
- *Arctic ice acts as a global air conditioner, but since 1978 the overall area of Arctic sea ice has diminished by 9% per decade, in addition to thinning.*
- *It is predicted the Arctic summer ice will disappear by the end of the 21st century.*
- *Between 1960 and 1998, the thickness of global sea ice has decreased by 40%.*
- *If Greenland's glacial ice was to melt, it holds enough trapped water to raise global ocean levels by seven metres.*
- *When established in 1910, Glacier National Park in Montana was home to over 150 glaciers; only 30 reside now.*
- *The snowcap at the peak of Mount Kilimanjaro (5,895 m) has been reduced by 80% since*

1912 and is expected to disappear by 2020.

- Globally, nearly 100 million people live within a distance of one kilometre from coastal areas, and sea levels are expected to rise 10-89 cm over the next century.*
- As a result of increased carbon dioxide emissions, it is predicted that nearly a million of the earth's species (both plants and animals) could be headed towards extinction.*
- Polar bears are directly affected by global warming, as the bear's main food sources - ringed seals - are becoming increasingly less accessible. This is because they live off the ice of Hudson Bay, which is now disappearing at rapid rates each year.*
- This decreases both the polar bears' time and ability to hunt as they return to land in less than acceptable conditions. The overall weight for males and females are down and females are having fewer cubs; however, population decline has not yet occurred.*
- The ice season for Hudson Bay has been reduced by approximately three weeks over the past 20 years, which is directly attributed to global warming.*
- It is estimated that more than 700 million vehicles inhabit the world's roadways.*

Causes of Global Warming: Greenhouse Gases and the Greenhouse Effect

Climate systems are affected through both internal (natural) and external (human) processes. One of the main causes behind global warming is greenhouse gases (GHGs), which are both an internal and external component of the atmosphere contributing to the greenhouse effect. The greenhouse effect (Figures 16a and 16b) is a naturally occurring phenomenon whereby greenhouse gases (water vapour and carbon dioxide) prevent some of the outgoing energy that is radiated from the earth's surface from escaping into space. GHGs retain heat energy much like the glass walls of a greenhouse. Without this natural process the earth would be significantly colder than it currently is and life as we know it would not be possible. Problems such as global warming begin to arise when atmospheric concentrations of GHGs begin to increase.

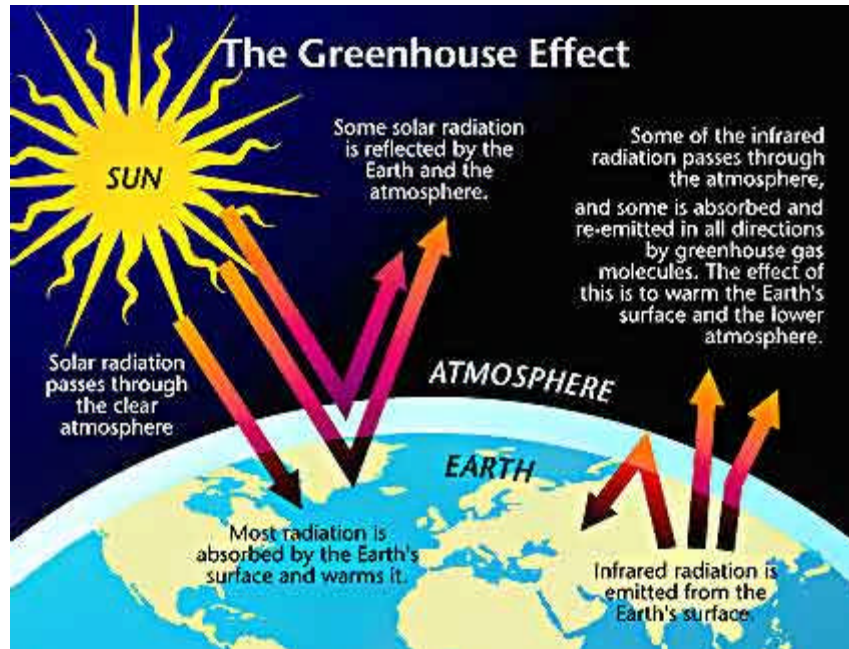


Figure 16a. Greenhouse effect example #1

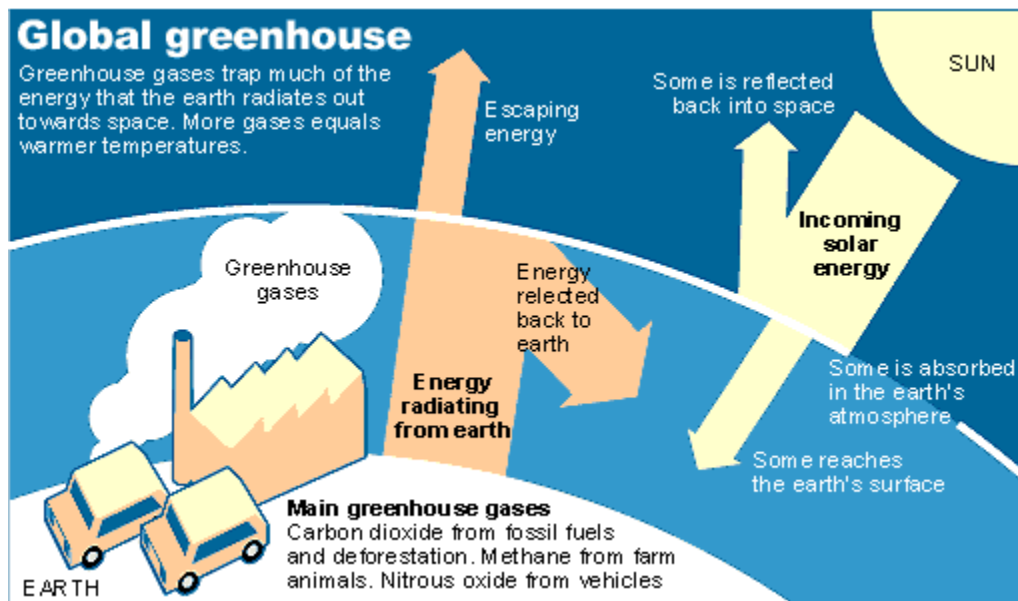


Figure 16b. Greenhouse effect example #2

Greenhouse gases are only transparent to specific wavelengths of radiation. When the sun's radiation hits the earth, some of it is absorbed and then released at longer wavelengths which the GHGs block from going into space, which causes the planet to warm. Water vapour is the most abundant GHG and is responsible for 30-70% of the greenhouse effect, with carbon dioxide contributing 10-30%, methane 5-10% and ozone

3-7%. Many scientists would agree that human-induced global warming is a product of the Industrial Revolution. Since then carbon dioxide emissions have increased 30%, methane 59% and nitrous oxide 15%, which has significantly increased the heat-trapping capabilities of the greenhouse effect.

Carbon dioxide is primarily released into the atmosphere through the combustion of fossil fuels (oil, coal and natural gas), solid wastes and wood products. Methane is emitted as a result of production and transportation of coal, natural gas and oil. It also occurs from decomposing organic wastes from landfills, the raising of livestock and rice paddy farming. CFCs and other halocarbons are also powerful human made GHGs that are effective heat absorbers (Figures 17a and 17b).

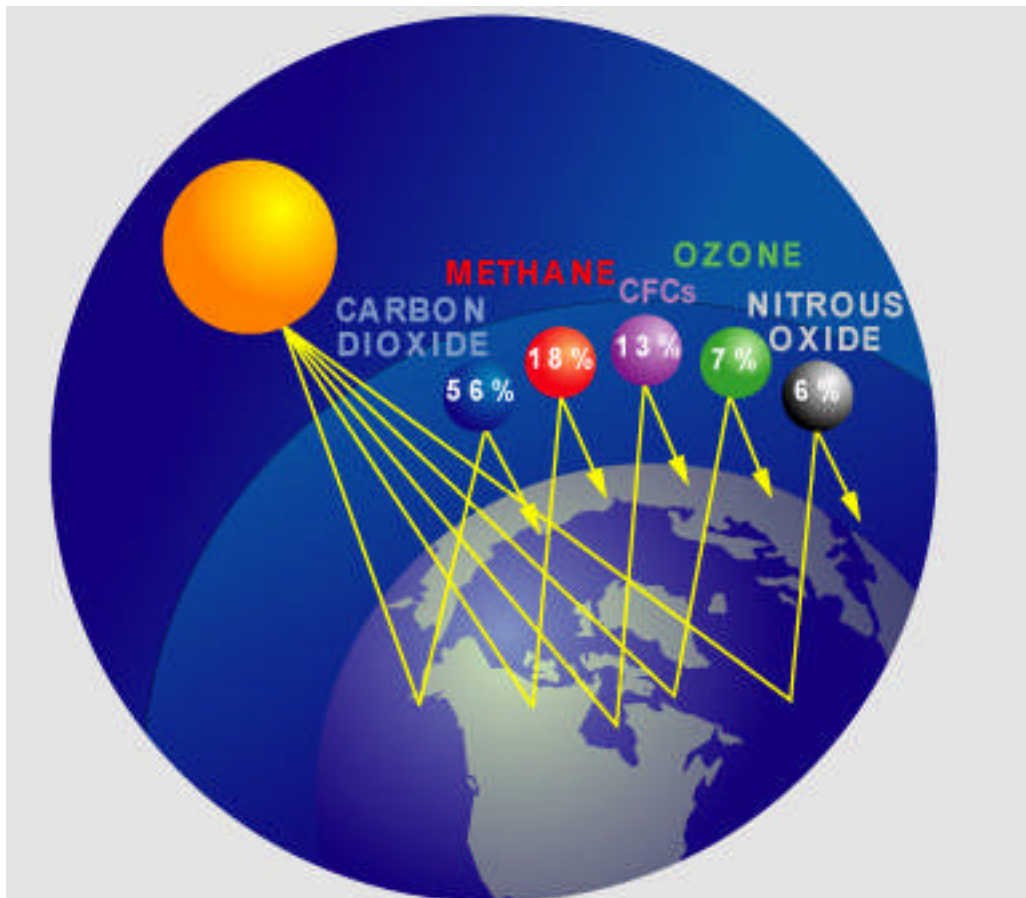


Figure 17a. Greenhouse gas example #1

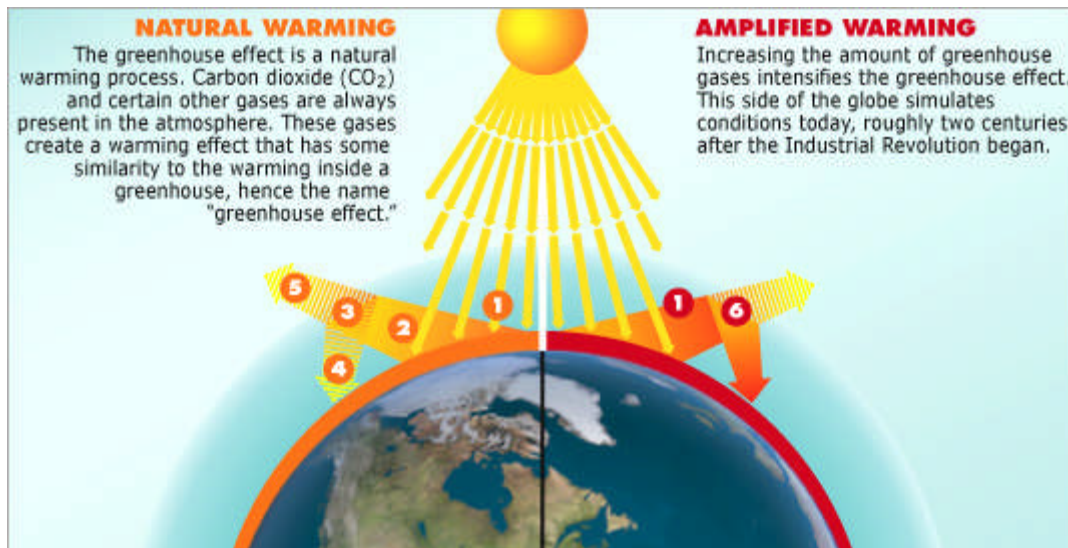


Figure 17b. Greenhouse gas example #2

The Effects of Global Warming

A wide variety of anticipated human and environmental effects are expected to arise in the near future as a result of global warming. An increase in temperature may lead to higher evaporation rates and more precipitation, heavier rainfalls and greater erosion. In northern climates, melting permafrost will accommodate a shift northwards of the treeline, but it may also place northern boreal areas at higher risk for an increase in fire damage. Sea levels will also rise as a result of melting polar icecaps, which will place many of the world's large coastal cities at risk of flood danger. South Atlantic hurricanes will occur with more frequency and intensity (i.e., Florida 2004, Hurricane Katrina 2005). Higher air temperatures will most likely increase the total amount of ozone found in the lower atmosphere. Lower level ozone is seen as more of a hindrance than a help as it now acts as a pollutant. Ground level ozone typically affects the lungs and lung tissue, and people who suffer from asthma and other respiratory illnesses are at greatest risk. The US EPA suggests that a warming of only 4°F would increase ground level ozone levels by 5%. Increased temperatures may also facilitate the spread of tropical diseases, such as those transmitted by mosquitoes (malaria, yellow fever, etc.), because northern areas would become much more suitable for living and breeding of these insects.

Climate Change

Climate change is the designation given to shifts in either global or regional climate over time. Changes in climate are measured over various amounts of time and range from decades to millions of years. These changes may be caused by both natural processes and external forces (human activities).

For more on climate change, please visit Environment Canada's Green Lane:

- www.ec.gc.ca/climate/overview-e.html

Kyoto Protocol

Much like the *Montreal Protocol on Substances that Deplete the Ozone Layer*, the *Kyoto Protocol* is the international commitment to climate change and global warming. The Protocol strengthens the global pledge to the United Nations Framework Convention on Climate Change (UNFCCC). The Protocol was developed and then adopted at the Third Conference of the Parties to the UNFCCC in December 1997, which stipulates developed countries must legally meet emissions reduction targets for 2000 and beyond. The objective of the Protocol is to reverse the ever-increasing trend of GHG emissions into the atmosphere by developed countries, which began during the Industrial Revolution.

A commitment was made by developed countries to jointly reduce the emissions of six key GHGs by at least 5% through meeting group targets, which include:

- *Switzerland, Eastern Europe and European Union: -8%*
- *United States: -7%*
- *Canada, Hungary, Japan and Poland: -6%*
- *Russia, New Zealand and Ukraine: stabilize emissions*
- *Norway: +1%*
- *Australia: +8%*
- *Iceland: +10%*

For the full text of the Kyoto Protocol please visit:

- <http://unfccc.int/resource/docs/convkp/kpeng.pdf>

The Basket of Gases and the Global Warming Potential Index

The six main gases under the Kyoto Protocol include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulfur hexafluoride (SF₆), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Similar to the ODP index, each greenhouse gas is converted into an equivalent unit to which all gases can be compared to - in this case, carbon dioxide. A Global Warming Potential (GWP) Index was developed to assess the potential negative environmental impact that individual gases have by measuring their heat trapping capabilities. The ability of a GHG to contribute to overall climate change will depend on a host of factors, including the amount of gas released, the gases' relative atmospheric lifespan, and its ability to absorb outgoing infrared radiation. The atmospheric lifetimes of carbon dioxide and halocarbons will vary greatly, with some lasting longer than others. For example, in a 100-year timespan since the simultaneous release of a single emission of carbon dioxide and HFC, 0% of the HFC will be present in the atmosphere whereas 41% of the carbon dioxide will remain (19% after 500 years). Thus, the GWP of a gas is determined by assessing its ability to absorb infrared energy combined with the amount of the gas present in the atmosphere and its atmospheric lifespan before it is neutralized.

Table 5

Gas	Atmospheric Lifetime (years)	100-year GWP (direct)
CO ₂		1
CFC-11	55	4,600
CFC-12	140	10,600
HCFC-22	13	1,700
HCFC-141b	11.4	700
HFC-134a	15.6	1,300
Propane	Months	<3
Isobutane	Weeks	<3
Cyclopentane	Weeks	<3

Sources:

<http://archive.greenpeace.org/ozone/greenfreeze/>
www.epa.gov/climatechange/emissions/downloads/ghg_gwp.pdf



Canada and the Kyoto Protocol

Canada was one of the first jurisdictions to sign the Kyoto Protocol on April 29, 1998, with ratification following four years later on December 17, 2002. By embracing the Protocol, the federal government pledged to reduce Canada's GHG emissions by 6% below 1990 levels by the reporting period of 2008-2012. A three-tier strategy was proposed to accomplish emission reductions by developing a system of incentives, regulations and tax measures. However, this approach to reducing industrial GHG emissions has failed to produce results as our overall emissions output has increased by 24% - a far cry from the 6% reduction pledged under Kyoto.

Canada and Climate Change

- Canadian households account for nearly 20% of Canada's overall emissions.*
- Only 18% of Canadians polled were actually concerned regarding the negative impacts of climate change.*
- Nearly 11 million homes (13.7% of the housing stock) were constructed between 1990 and 1995. If plastic air barriers were used as wall coverings during construction, it would have prevented the generation of nearly 2-8 million tons of greenhouse gas emissions.*
- In a span of less than 100 years, Canada has progressed from horse and buggy to 14 million cars on the road.*
- Canadians rank as the world's highest consumers of energy per-capita.*
- It has been forecast that if current trends continued, greenhouse gases emitted from the transportation sector would be 32% above the 1990 levels by 2010.*

Penalties for Non-compliance or Withdrawal from Kyoto

Currently no penalties exist for a country that has ratified the Kyoto Protocol but fails to meet its reduction targets. Also, any country that has ratified the Protocol and wishes to withdraw may do so simply by giving one year's notice.

Chapter 4 Review Questions

1. Global warming refers to...
 - a. The actual rise in average atmospheric and oceanic temperatures
 - b. Humanmade efforts to artificially warm naturally cold areas
 - c. The rise in temperature due to increased volcanic activity
 - d. There is no global warming, it is still a myth
2. Which of the following activities, if any, have been attributed to the rise in global temperatures?
 - a. Burning of fossil fuels
 - b. Clearing of land for agriculture
 - c. Use of halocarbons
 - d. All of the above
3. True or false: climate systems are affected by both natural and external (human) processes.
4. Which of the following statements is true regarding the greenhouse effect?
 - a. The greenhouse effect helps to regulate ocean currents
 - b. The greenhouse effect is a natural phenomena that traps some outgoing radiation from escaping into space
 - c. The earth can survive with or without the greenhouse effect
 - d. The greenhouse effect is still a theoretical principal
5. True or false: the addition of excess greenhouse gases into the atmosphere does not contribute to global warming.
6. Which of the following is considered to be the most abundant greenhouse gas found in the atmosphere today?
 - a. Carbon dioxide
 - b. CFCs
 - c. Ozone
 - d. Water vapour
7. Under the *Kyoto Protocol*, which nations must meet GHG emissions reduction targets?
 - a. United States only
 - b. Developing nations
 - c. European Union
 - d. Developed nations
8. True or false: hydrofluorocarbons (HFCs) are included as one of the six main gases under the *Kyoto Protocol*.

Chapter 5

Refrigerants – Composition And Types

CHAPTER OBJECTIVES

After studying Chapter 5, the training participant will be able to:

- Describe the history of refrigerants
- Define the chemical composition of selected refrigerants
- Explain precautions when handling refrigerants.

INTRODUCTION

The Canadian government, as part of its international commitment to the *Montreal Protocol*, has eliminated the importation, exportation, and production of certain types of designated refrigerants and other ODS. In Manitoba, designated refrigerants are divided into three classes: Class 1 (CFCs), Class 2 (HCFCs) and Class 3 (HFCs). Manitoba, along with most other provinces and territories within Canada have mandated that designated refrigerants be recovered, reclaimed, reused, recycled or destroyed. It is also recommended that all refrigerants, designated and non-designated (hydrocarbons), be treated as though they were designated. The practices and procedures in this text are designed for use with all refrigerants.

HISTORY OF REFRIGERANTS

Refrigerants were developed to meet the needs of the mechanical refrigeration industry. One of the first refrigerants ever used was water. Water is a very effective refrigerant as it will absorb 980 BTU/lb. of heat. By reducing water's boiling point in a vacuum, it can provide cooling temperatures at 4.5°C. The major disadvantage of water as a refrigerant and the reason why it is no longer in use is because of the amount of vacuum required to lower its boiling point (29" Hg). To maintain this low vacuum, systems required a high degree of maintenance.

As the mechanical refrigeration industry grew and the need for efficient refrigerants increased, ammonia and carbon dioxide were primarily used. However, due to their unstable nature, in addition to several fatal accidents involving these substances, their use was discontinued. The development of the automatic refrigerator created a need for newer, stable refrigerants such as sulphur dioxide and methyl chloride. Sulphur dioxide and methyl chloride were stable, non-explosive refrigerants, but are no longer used today because of their toxicity. Later on, CFCs and more recently HCFCs and HFCs became the most common types of refrigerants in use today.

Of all the early refrigerants developed, only ammonia remains as the choice refrigerant in the manufacturing of ice used in arenas and ice-making plants. In order to understand the differences in refrigerants, and more importantly, what makes them different, we must study the chemical composition of the refrigerants themselves.

COMPOSITION OF REFRIGERANTS

Refrigerants are chemical compounds in a liquid or gaseous state that absorb heat by evaporating at low temperatures, and pressures and reject heat by condensing at high temperatures and pressures. In air conditioning and refrigeration systems, refrigerants are used to absorb heat from a space where it is not wanted (i.e. indoor environment) and

expel it to a neutral environment (i.e. usually outdoors). Any substance that experiences a change in state from a liquid to a gas (or vice versa) can be used as a refrigerant in a vapour/compression- type system.

MAKE-UP OF REFRIGERANTS

Matter is anything that has weight and occupies space. Substances and materials are forms of matter. Materials are types of matter that are manufactured or built. Substances are types of matter that consist of component parts. In this text, we shall use the term substances to describe matter, as we are dealing with the type of matter called refrigerants and the components that make up refrigerants.

All matter (substances) consists of extremely small particles called molecules. A molecule is the smallest particle a substance can be divided into and still retain the properties of that substance. A molecule in turn is comprised of two or more atoms. The atoms cannot be broken down during chemical processes.

Atoms can be divided into smaller particles called neutrons, protons and electrons. The atom is the smallest particle known and it is here that the story of matter begins. All matter consists of atoms or a combination of atoms. Carbon is a substance because it is matter and an element because all the atoms of carbon are of the same type.

Sodium chloride (table salt) is a substance and a compound. It is a substance because it is matter and a compound because atoms of different types have combined to form the substance sodium chloride.

IDENTIFYING REFRIGERANTS

There are various methods available to identify refrigerants. In this chapter, refrigerants will be identified by their nomenclature, classification and type. Later, Chapter 7:

Handling Refrigerants will discuss how to properly identify refrigerants located in equipment and containers.

NOMENCLATURE

Since the early 1970s, when it was first discovered that refrigerants were the root cause of ozone destruction, the chemical make-up of refrigerants has been gaining increased importance. As a result, the nomenclature, or numbering and lettering system used to identify refrigerants, has changed. This change has resulted in the letter “R” in front of the numerical designation of halocarbon refrigerants being replaced with the more descriptive letters CFC for chlorofluorocarbon, HCFC for hydrochlorofluorocarbons and HFC for hydrofluorocarbons. The numerical designation identifies the classification of the refrigerant.

SUMMARY OF NOMENCLATURE

Per ASHRAE Standard 34-1992

Number Designation and Safety Classification of Refrigerants

-000 series	Methane-based compounds
-100 series	Ethane-based compounds
-200 series	Propane-based compounds
-300 series	Cyclic organic compounds
-400 series	Zeotropes
-500 series	Azeotropes
-600 series	Organic compounds
-700 series	Inorganic compound
-800 series	Unsaturated organic compounds

A general rule is to add “90” to the CFC’s identification number, with the first digit representing carbon, second hydrogen and third fluorine. Chlorine is calculated by $Cl=2(C+1)-H-F$. For example:

CFC-11: $90 + 11 = 101$

$Cl = 2(1+1)-0-1$

CFC-11: 3 chlorine

$Cl = 2(2)-1$

1 fluorine

$Cl = 4 - 1$

1 carbon

$Cl = 3$

TYPES OF REFRIGERANTS

There are three types of refrigerants: single compound refrigerants, blended refrigerants and mixed refrigerants. Refer to Manitoba Regulation 103/94 for a complete list of prescribed substances under the following: class 1, class 2 and class 3.

SINGLE COMPOUND REFRIGERANTS

Single compound refrigerants contain only one chemical compound. They include methane-based compound refrigerants (000-series), ethane-based compound refrigerants (100-series), and propane-based compound refrigerants (200-series). Methane-based compound refrigerants make up almost all refrigerants used today. The following section is a discussion related to their make-up, composition and use.

Hydrocarbon

The hydrocarbon family of refrigerants consists of, but is not limited to, methane, ethane and propane. These refrigerants are called hydrocarbons because they are made up of two elements: hydrogen and carbon. Hydrocarbons as refrigerants have good heat transfer qualities, although they have flammable and explosive properties. Methane, which is also a natural gas, is used widely as a heating fuel.

Halogenated Hydrocarbon

A halogenated hydrocarbon (halocarbon) usually contains one or more of the following three halogens: fluorine, chlorine or bromine (hydrogen may or may not be present). To create refrigerants, a process called halogenation is used. Halogenation means that one or more of the hydrogen atoms have been removed and replaced with the same number of chlorine, fluorine or bromine halogen atoms. The fluorocarbon family of refrigerants is an example of halogenated hydrocarbons. Examples of these include perfluorocarbons (PFCs).

Fully halogenated

When all the hydrogen atoms are removed from a hydrocarbon and replaced with halogen atoms, the refrigerant is said to be fully halogenated. All CFCs, including CFC-11 and CFC-12, are considered fully halogenated refrigerants.

Partially halogenated

This occurs when at least one of the hydrogen atoms is not replaced with a halogen compound and is then considered partially halogenated. All HCFC refrigerants are considered partially halogenated, of which HCFC-22 and HCFC-123 are examples.

Fluorocarbons

Fluorocarbons are synthetic refrigerants that are a subclassification of halocarbons. These are produced by replacing one or more hydrogen atoms with fluorine. Fluorocarbon refrigerants are further subdivided into chlorofluorocarbons (CFCs), hydrogenated chlorofluorocarbons (HCFCs) and hydrogenated fluorocarbons (HFCs).

Chlorofluorocarbons

CFCs are fully halogenated refrigerants that are made up of chlorine (Cl), fluorine (F) and carbon (C). This group consists of refrigerants such as CFC-11, CFC-12, CFC-500

and CFC-502, and are also known as R-11, R-12, R-500 and R-502. Since CFCs have no hydrogen, they are very stable refrigerants.

Hydrochlorofluorocarbons

HCFCs are partially halogenated refrigerants made up of hydrogen (H), chlorine (Cl), fluorine (F) and carbon (C). HCFC-22 (R-22) and HCFC-123 (R-123) are members of this group. As HCFCs contain hydrogen, they are less stable than CFCs, have a much shorter atmospheric lifespan and tend to break apart before they reach the stratosphere. HCFC refrigerants also contain less chlorine than CFCs. Although HCFCs have only 2-5% of the ozone depletion potential, they are still considered an ODS and will be phased out. See phase-out schedule on page 37.

Hydrofluorocarbons

HFCs are also a partially halogenated refrigerant made up of hydrogen (H), fluorine (F) and carbon (C). HFC-134a (R-134a) is a member of this group. HFCs do not contain any chlorine, but are significant global warmers.

REPLACEMENT REFRIGERANTS

Following the phase-out of CFC refrigerants under the *Montreal Protocol*, the most common replacements were HCFCs and later HFCs. Although the detrimental effects of these substances towards the ozone layer are significantly reduced or eliminated, some do pose a significant threat to global warming. Today HFC-134a is by far one of the most popular replacement refrigerants on the market. However, its global warming potential is 1,300 times more powerful than carbon dioxide over a 100-year period. Therefore, these replacement products are regulated as a class 3 substance under MR 103/94 and must be managed the same way as CFC refrigerants to ensure environmental protection.

REFRIGERANT BLENDS

Refrigerant blends have evolved as research has progressed to find a suitable replacement for CFC-12. A refrigerant blend is a mixture of refrigerants that has been developed to imitate the pressure/temperature relationship similar to that of the original refrigerant. There are three different types of refrigerant blends:

- Azeotropic
- Zeotropic
- Near-azeotropic

The common factor in blended refrigerants is temperature glide. Temperature glide is defined as the temperature difference (measured in °F) between the starting and ending temperatures of a refrigerant phase change within a system, exclusive of any sub-cooling or superheating. A simple explanation of temperature glide is it provides a good indication of how far away the refrigerant is from an azeotropic. The greater the temperature glide, the greater the possibility the refrigerant will fractionate.

Fractionation

When refrigerants fractionate, they separate and change into different compositions. Blends are made from several different refrigerants with different volatilities and when a leak occurs, a greater amount of the more volatile refrigerant leaks out, changing the blend and changing its performance. Many refrigeration specialists would not recommend the use of blends because numerous service problems occur with their usage.

Refrigerants with high temperature glides must have their entire refrigerant charge removed and replaced as a liquid.

Usage of Blends

Blends can either be HCFC or HFC-based, and in some cases a hydrocarbon may be used as one of the components within the blend. When using a blend, it is important that the ASHRAE refrigerant number is identified. Any refrigerant with a 400 designation will almost always be a blend, such as R-401a, and are typically marketed as substitutes for CFC-12. Some manufacturers will incorporate trademarks into their blends, giving the user the impression they are direct “drop-in replacements” for CFC-12.

In reality, no such product exists as a direct “drop-in replacements” for CFC-12 and refrigerant systems will always need retrofitting. Most blends and their lubricants are not compatible with existing CFC-12 systems. Recharging a blend is also quite different than recharging a single stream refrigerant, such as R-12.

Azeotropic Refrigerant

Azeotropic refrigerants are blended refrigerants with a temperature glide of zero. They chemically combine together in such a way that they behave the same as a single compound refrigerant. In the event that a refrigerant leaks, azeotropic refrigerants will leak evenly. Examples of azeotropic refrigerants are R-500 and R-502.

Zeotropic Refrigerant

Zeotropic refrigerants behave as an azeotrope during “normal” operating conditions. They have a temperature glide greater than 10. Zeotropic refrigerants have a tendency to fractionate resulting in different leakage rates of the blended refrigerant. These refrigerants must be removed and replaced in their liquid state. Zeotropic refrigerants are in the 400 series classification (e.g. R-401a).

Near-azeotropic Refrigerant

Near-azeotropic refrigerants also behave as an azeotropic refrigerant during normal operating conditions, with a temperature glide between 0 and 10. However, they still

retain some of their separate characteristics. Near-azeotropic refrigerants have a greater tendency to fractionate or experience a change in composition than azeotropic refrigerants. This results in different leakage rates of near-azeotropic refrigerants, and most near-azeotropic will contain an HCFC in their blend.

MIXED REFRIGERANTS

Mixed refrigerants contain a non-prescribed blend of refrigerants. These usually occur unintentionally when two or more refrigerants are combined or a refrigerant is contaminated.

DISTRIBUTION OF REFRIGERANTS

With the exception of ammonia, all refrigerants used today are halocarbons or blends containing halocarbons.

GENERAL PRECAUTIONS WHEN HANDLING REFRIGERANTS

Under most installation and service situations, refrigerants are safe when reasonable care and caution are exercised. The following is a list of precautions the refrigerant handler should follow when handling or working with refrigerants.

1. Know the refrigerants you are working with. Knowledge of their physical and chemical properties is essential to predicting their behaviour. Examine and understand the material safety data sheet (MSDS) sheets of the substance which describe some of the properties.
2. Never place refrigerants in a system that has not been pressure-tested.
3. Wear proper protective clothing and gloves.

4. Keep the working area well ventilated.
5. Always use approved piping or tubing and, whenever possible, braze joints.
6. Perform a leak test and repair all refrigerant leaks immediately.
7. Avoid refrigerant contact with flames or other hot surfaces as some refrigerants can become toxic and may decompose.
8. Never discharge refrigerants into the atmosphere. It is illegal to do so and is detrimental to both human and environmental health.
9. Never breathe in refrigerant vapours. Treat all refrigerants as if they are toxic.

All refrigerants should be handled safely and with caution.

Chapter 5 Review Questions

1. Which of the following was one of the first refrigerants ever used?
 - a. Ammonia
 - b. Sulfur dioxide
 - c. Water
 - d. CFCs
2. True or false: refrigerants are chemical compounds in a liquid or gaseous state that absorb heat by evaporating at low temperatures and pressures, and reject heat by condensing at high temperatures and pressures.
3. Nomenclature of refrigerants refers to which one of the following?
 - a. Industry trade-names given to refrigerants
 - b. Numbering and lettering system used to identify refrigerants
 - c. A group of slang terms used to generally identify refrigerants
 - d. Nomenclature has nothing to do with refrigerants
4. Which of the following statements best describes the halogenation process?
 - a. The use of halogens (chlorine, fluorine or bromine) for use in lamps
 - b. In a refrigerant, replacing one of more hydrogen atoms with the same number of halogen atoms (chlorine, fluorine or bromine)
 - c. In a refrigerant, it means removing one of more halogen atoms (chlorine, fluorine or bromine) and replacing it with the same number of hydrogen atoms
 - d. None of the above statements best describe the halogenation process
5. Which of the following statements regarding refrigerant blends is false?
 - a. They imitate the temperature/pressure relationship similar to original refrigerants
 - b. There are three different types of blends including azeotropic, zeotropic and near-azeotropic
 - c. A common factor with blended refrigerants is temperature glide
 - d. Blended refrigerants have evolved as research has progressed into finding safer alternatives to flammable hydrocarbons
6. Which of the following best describes fractionation?
 - a. When blends fractionate they separate and change into different compositions
 - b. Fractionation during leaks results in loss of the more volatile refrigerant in the blend – thus changing the blend and its performance.
 - c. Only A
 - d. Both A and B
7. True or false: temperature glide is the temperature difference between the starting and ending temperatures of a refrigerant phase change within a system, exclusive of any sub-cooling or superheating.

8. Which one of the following statements is true?
 - a. Azeotropic refrigerants are blended refrigerants with a temperature glide of 0
 - b. During normal operating conditions, zeotropic refrigerants do not behave like azeotropic refrigerants and have a temperature glide of less than 10
 - c. Near-azeotropic refrigerants have a temperature glide of greater than 10
 - d. None of the above statements are true

9. True or false: mixed refrigerants occur as a result of contamination.

10. Which one of the following is a general rule to follow when handling refrigerants?
 - a. Minimize open air ventilation to prevent contamination
 - b. Never pressure test a system, as it might reverse factory settings
 - c. Never breathe in refrigerant vapours and treat all refrigerants as toxic
 - d. Apply a flame to a refrigerant to test whether or not it is flammable

Chapter 6

Legislation and Regulatory Compliance Issues

CHAPTER OBJECTIVES

After studying this chapter, the training participant will be able to:

- Describe the purpose of the *National Action Plan* (NAP) and Environment Canada's Code of Practice
- Understand your compliance responsibilities of the *Manitoba Ozone Depleting Substances and Other Halocarbons Act and Regulation* 103/94.

INTRODUCTION

In Chapters 1 and 2, refrigerants, their chemical make-up, and the part that refrigerants play in depleting the ozone layer and contributing to climate change have been discussed. Furthermore, the role that governments and industry have played and continue to play in the protection of the ozone layer was revealed. In this chapter, Environment Canada's *Code of Practice for the Elimination of Fluorocarbon Emissions from Refrigeration and Air Conditioning Systems* and the *Manitoba Ozone Depleting Substances Act and Regulation* are described.

NATIONAL ACTION PLAN (NAP)

The NAP was originally prepared in 1992 to guide industry and government in the recovery, recycling, and reclamation of CFCs. It allowed for the development of a multi-jurisdictional framework for harmonizing federal, provincial and territorial governments.

This helped to facilitate the implementation and harmonization of Canada's Ozone Layer Protection Program. The NAP was updated in 1998 and in 2001 and identified new tasks such as transitioning from CFCs and halons to alternative substances, ensuring the proper disposal of (ODS) substances and identifying phase-out approaches for specific industry sectors.

To date, a number of critical objectives within the NAP have been achieved, including:

- Cease production and importation of CFCs and ban their future use
- Timelines established for the phase-out of HCFCs
- Recovery and recycling of CFCs, HCFCs, HFCs and prohibiting their intentional release
- Mandatory environmental awareness "certification" training in all jurisdictions.

ENVIRONMENT CANADA'S CODE OF PRACTICE

Originally, the Code of Practice was developed in 1991 by Environment Canada as required within Section 8 of the *Canadian Environmental Protection Act (CEPA)*. The Code itself acts as a template for primarily reducing the release and emission of CFCs and other halocarbons from refrigeration and air conditioning applications. It is applicable to six main trade sectors:

- Industrial/Commercial
- Residential
- Residential Domestic Appliances
- Mobile Air Conditioning
- Mobile Refrigeration
- Heavy-duty Mobile Air Conditioning

Although not referenced directly as part of the MR 103/94 in Manitoba, the Code of Practice has been adopted in part by several other provincial and territorial governments. The Code of Practice provides a standardized method of practice for technicians working in the various trade sectors and industries mentioned above.

The Code of Practice was revised and updated in 1996 to reflect a number of new developments including new technologies, alternative refrigerants, Canada's commitment to pollution prevention, and the advancement of the goals and objectives of the NAP. In addition, the Code was expanded to adapt best practice procedures for eliminating emissions of both HCFCs and HFCs, and cautions about environmental and safety issues related to the use of hydrocarbons and alternate substances.

Within the Code of Practice, a number of key issues are addressed and include but are not limited to the following:

- Recommended procedures to minimize refrigerant leaks
- Suggested pressure testing procedures for use prior to charging the system
- Suggested charging methods
- Requirements to recover, reuse, recycle and reclaim refrigerants
- Suggested measures to dispose of equipment that has contained a prescribed substance.

The Code of Practice was developed in active consultation with stakeholders from a number of sectors including contractors, labourers, manufacturers, trade associations, regulators, federal and provincial representatives, and environmental non-governmental organizations.

In order to accommodate new technologies and regulatory advancements, further updates to this Code may occur. It has become a useful tool to help harmonize and bridge the gap between differing provincial requirements regarding refrigerant emissions into the atmosphere.

MANITOBA OZONE DEPLETING SUBSTANCES ACT

The *Manitoba Ozone Depleting Substances Act* was proclaimed into force by the Manitoba Legislature in 1992. The Act recognizes that the escape of ODS is harmful to the health of the public and the environment in Manitoba. **The purpose of the *Manitoba Ozone Depleting Substances Act* is to reduce and eventually eliminate the release of ozone depleting substances and halocarbon replacements/alternatives into the atmosphere.** A schedule of fines for violators of the Act is listed below.

Individuals

- Upon the first offence for an individual, a fine not exceeding \$50,000 or imprisonment not exceeding six months or both.
- Upon the second offence for an individual, a fine not exceeding \$100,000 or imprisonment not exceeding one year, or both.
- For each day the offence occurs, from the day the person was charged, a fine not exceeding \$1,000 a day may be levied.

Corporations

- Upon the first offence for a corporation, a fine not exceeding \$500,000.
- Upon the second offence for a corporation, a fine not exceeding \$1,000,000.
- For each day the offence occurs, from the day the corporation was charged, a fine not exceeding \$10,000 a day may be levied.

MANITOBA OZONE DEPLETING SUBSTANCES AND OTHER HALOCARBONS REGULATION 103/94

In Manitoba, persons working with ODSs, halocarbons and regulated parts connected to the closed refrigerant loop are required to follow the procedures set out in the Manitoba Regulation 103/94. Persons working in other jurisdictions should become familiar with requirements for the particular area. Across Canada, provincial, territorial and the federal government have enacted specific legislation for ODS for their jurisdiction.

The following is a summary of some of the key components of the Manitoba Regulation.

- Annual renewal of each technician's certification
- Record keeping and labeling by persons servicing air conditioning and refrigerating equipment
- The mandatory recovery and recycling of designated CFCs, HCFCs, HFCs and halons
- A restriction on the sale and recharging of halon based fire extinguishing systems
- Restrictions on the use of ODS for cleaning purposes (sterilization).
- Permit requirements for equipment (i.e. chillers, halon systems)
- Decommissioning requirements for equipment.

All persons that purchase, use and handle regulated refrigerants or work on closed loop systems must be certified under this regulation. Certified persons will be issued a wallet certificate that must be renewed annually. MOPIA maintains the certification database and issues annual renewals.

The Regulation includes some of the following areas or topics:

- Definitions and applications
- Releases prohibited

- Installation service and repair of equipment
- Use, disposal and storage of ozone depleting substances
- Sales of ozone depleting substances and halocarbons
- Trained service technicians and secondary distributors
- Other general provisions

It is the responsibility of all persons to comply with the Regulation. A copy of the complete text of the Regulation is included in this manual and must be consulted for the purpose of interpretation and application of the law.

The following synopsis has been prepared to assist you in understanding Manitoba's regulatory requirements. It focus is with persons who handle refrigerants.

Section 5: Releases Prohibited

A refrigerant is released when it is intentionally or unintentionally allowed to escape from a closed loop system, sealed component or container into the environment by means of a leak in a system or during the performance of work associated with the installation, servicing or repair of a system.

No person shall release or permit the release of a regulated substance into the environment. The term, "permit" is interpreted as "having knowledge of".

There are exceptions to the, "Release Prohibited" clause such as:

- Halons used for fire extinguishing
- Health care applications, such as in bronchial dilator, inhalable steroids or veterinary sprays
- Safety devices such as relief valves
- Refrigerant released from a designated purge system used on a sub-atmospheric refrigeration system

- Refrigerant released from a charge hose less than 36” in length.

Section 6: Service and Repair by Trained Service Technicians

Only trained service technicians can work on refrigeration and air conditioning equipment or any other type of equipment containing a refrigerant that is regulated. Certification under the Regulation pertains to environmental certification only. Manitoba has apprenticeship programs which further dictate specific trade licenses that may be required within the various trades sectors.

Section 7: Recovery of a Class 1, 2 or 3 Substance

Trained service technicians, who carry out work on air conditioning and refrigeration equipment that has the potential to release refrigerants into the environment, must have with them recognized refrigerant recovery equipment and approved refrigerant containers capable of recovering the entire refrigerant charge. The trained service technician, upon recovering the refrigerant, must reuse, recycle, reclaim or arrange for the destruction of the refrigerant. Air Conditioning Institute (ARI) standard 740-98 must be followed. See: **www.ari.org**

In Canada, *Refrigerant Management Canada* (RMC) operates a national refrigerant management program where it collects surplus refrigerant from certain industry trade sectors for end-of-life management. See: **www.hrai.org/rmc**

Section 8: Repair and Service Records

Trained service technicians must maintain a record of all refrigerants that are charged or recharged into the system, or recovered and stored or sent for destruction. A sample record data sheet can be found in the appendices of this manual. A copy of your record data sheet must be submitted to MOPIA by February 1 of each year, summarizing all work performed during the previous year.

You may contact MOPIA for a copy of the record data form or seek our guidance on recording your refrigerant usage.

Class 1 (CFC) Substance Prohibition

No person is allowed to charge or recharge air conditioning or refrigeration equipment (except white goods) with a Class 1 substance except for chillers until January 1, 2015.

Section 11: Flushing and Testing

Regulated refrigerants cannot be added to refrigeration and air conditioning equipment to flush the equipment of contaminants or test for leaks.

Section 12: Leak Test Requirements

Refrigerant Leaks

A leak occurs in a refrigerant system when refrigerant is allowed to enter or escape a closed loop refrigerant system, sealed component or container through a hole, crack or any other opening that places refrigerant from the closed loop system in contact with the external atmosphere.

Types of Leaks

Leaks in refrigerant systems fall into two main types: inward leaks and outward leaks. Refrigerant leaks, regardless of their type, require the use of a recovery method during repair. Both refrigerant leaks and/or the service required to repair the leak will lead to a release of refrigerant into the environment.

Inward Leaks

Inward leaks occur on refrigerant systems that operate at less than atmospheric pressure. These sub-atmospheric systems draw air and moisture into the system, causing the refrigerant to form an acidic solution. This eventually leads to oil breakdown, corrosion of internal components and sludge formation. Sub-atmospheric chillers operate in a

vacuum resulting in air being drawn into the system. This air must be removed using a purge unit. When air is vented from the purge unit, some refrigerant is vented to the atmosphere along with the air. For this reason, a high-efficiency purge unit designed to minimize the amount of refrigerant released is required (i.e. 0.01kg or air).

Outward Leaks

Outward leaks occur when refrigerant that is pressurized is allowed to escape from a closed loop refrigerant system, sealed refrigerant component or closed refrigerant container. Outward leaks result in refrigerant being released into the atmosphere which causes environmental damage.

Recharging and Topping Up

It is illegal and a contravention of the regulation to recharge or top up refrigerating and air conditioning equipment that has an existing charge, unless the equipment has successfully passed approved leak testing procedures. All leaks must be repaired before the equipment can be re-charged with a refrigerant.

Leak Test Procedure

Manitoba's approved Leak Test Procedure and Leak Detection Methods are highlighted in Chapter 8.

Dismantling Equipment

All equipment must be repaired immediately to make it leak free. When a refrigerant leak exists and the equipment cannot be repaired immediately, the refrigerant must be recovered and the equipment dismantled in a manner that will prevent operation of the equipment. Damage to the equipment will result if the equipment operates without refrigerant.

Section 14: Addition of Contaminants Prohibited

When recovering a refrigerant, it is illegal to add, mix or dissolve a foreign material, substance or waste that will make the refrigerant unacceptable for reclamation.

Mixed Refrigerants

Mixed refrigerants contain a blend of refrigerants not manufactured by a primary source or producer. They usually occur as a result of an unintentional (accidental) mixing of refrigerants during field work. Refrigerant containers must contain only one type of refrigerant.

Mixed refrigerants are unacceptable for reclamation for the following reasons:

- They have a potentially adverse effect on the operation of refrigerant systems
- They can lower the efficiency of the system and increase the cost of service
- They can affect the compatibility of materials used in the refrigerant system
- They may void the manufacturer's warranty and reduce the life expectancy of the equipment
- They can increase service costs due to the high cost of destroying refrigerants.

Contaminated Refrigerants

Contaminated refrigerants are also a form of mixed refrigerant. They are considered to be contaminated when they contain foreign materials or substances. Some example of contaminants and contamination sources are:

- Carbon that results from the breaking down of refrigerant oils
- Strong acidic concentrations in refrigerants resulting from moisture entering the refrigerant system
- Steel or copper filings not removed from the refrigerant system at the time of installation or service
- The oil film coating found inside new copper piping was not removed from the refrigerant system at the time of installation or service.

Section 15: Restriction on Operation of a Compressor Purge System

As sub-atmospheric (less than atmospheric) centrifugal chiller compressor systems are subject to inward leakage, they must use high-efficiency purge systems that meet the Air Conditioning and Refrigeration Institute's (ARI) Standard 580-2001.

Section 15.3: Time-based Restrictions for Chillers

Any person operating a chiller that requires a major overhaul must convert the system to operate without the use of a Class 1 substance or decommission the unit. A chiller may only be recharged with a Class 1 substance (once) if the inability of the unit to function poses immediate threats to human life or health and if the owner/operator immediately notifies Manitoba Conservation regarding the recharging of the unit. Within one year of the charging or recharging, the chiller must either be converted to a non-Class 1 substance or decommissioned.

Section 15.4(1): Class 1 Permits for Chillers

Anyone planning to operate a CFC-based chiller must apply for a Class 1 chiller permit and pay a fee of \$50. As part of the permit, the person shall provide a decommissioning report as to when and how the unit will be decommissioned. Permits expire either on December 31, 2014, the day after a major overhaul, or one year after the unit is charged or recharged. A CFC refill ban is effective January 1, 2015. Section 8(5) – Owners of operators are required to file a report if a class 1 or 2 chiller has been decommissioned replaced or converted so that it does not use CFCs or HCFCs (class 1 and 2).

Section 16: Disposal of Equipment, etc.

When any piece of equipment which contains a refrigerant (i.e., refrigerator, air conditioner, etc.) reaches the end of its useful life, in order to become disposed of, it must have all of its refrigerant charge removed so it can no longer be used for its original intended purpose. A label should be affixed to the equipment prior to the equipment

being disposed. This label states the refrigerant has been responsibly removed from the equipment along with the technician's certification number.

All refrigerant is considered to be removed from a closed loop refrigerant system or refrigerant container when the recovery unit has achieved its maximum vacuum.




Removal of Oil

It is important to note that all lubricant must be removed from the refrigerant system before disposal. To remove refrigerants from small hermetic compressors that do not have oil drains, it is necessary to remove the compressor from the system to drain the lubricant. The best location to remove the oil from the system is at the suction line of the compressor. When using this procedure, a service technician can remove about 95% of the oil lubricant.

When draining oil from larger systems, the oil should be drained from several locations on the system:

- *The compressor crankcase*
- *Low spots around the evaporator*
- *Oil separations or suction accumulators.*

See www.usedoilrecycling.com/en/mb
www.millergroup.ca/waste/hazardous/index.html



Section 17: Return of Class 1, 2 or 3 Substances to Sellers

Any person entitled to purchase a Class 1, 2 or 3 substance may return that substance in an appropriate container to any person who sells that same substance. The seller shall accept for return any Class 1, 2 or 3 substance for storage until it can be delivered to a manufacturer, recycler, reclaimer or for destruction (the seller must ensure one of these actions occurs).

Refrigerant Management Canada (RMC) is responsible for coordinating activities and arrangements related to the collection and destruction of refrigerants from certain industry sectors. Select refrigerant wholesalers have been set up as collection points and will accept refrigerants into the RMC program. Check with your wholesaler or distributor to see if they are partners in this national initiative.

Section 19: Sale of Class 1, 2 or 3 Substances in Containers or Equipment

Regulated refrigerants and new or used equipment or components may be purchased, sold, or transferred in Manitoba by a trained service technician or secondary distributor. White goods, which are defined as being a domestic refrigerator or freezer, window air conditioner, etc., are exempt. Persons who sell or transfer white goods are not required to be certified or have a secondary distributor's permit because these systems are closed loop at the time of purchase. Persons selling or transferring refrigerants must keep a record and provide a copy of this record of sale and transfer to MOPIA before the first day of February each year. An acceptable sample recording form is shown in the appendix.

The record/form must be kept on file for a minimum of three years and made available to an environment officer on request.

Section 18.1: Sale in Inappropriate Containers Prohibited

No person shall offer for sale or purchase a Class 1, 2 or 3 substance unless the product or substance is contained in an appropriate container (designed and manufactured to be refillable).

Section 20: Certification of Technicians

A person, who has successfully completed the *Environmental Awareness Training on Ozone Depleting Substances and Other Halocarbons for Manitoba* course in the proper repair, installation, recovery and recycling procedures for sealed systems, including the recovery of Class 1, 2 and 3 substances, is entitled to be certified as a trained service technician. Certification is valid when renewed annually and paying a fee of \$25.

Section 22: Permits for Secondary Distributors

A secondary distributor is a person, company or firm in Manitoba that is not a manufacturer of a Class 1, 2 or 3 substance or a trained service technician, and who:

- imports a Class 1, 2 or 3 substance into the province; or
- purchases in the province a Class 1, 2 or 3 substance or equipment, other than a white good, that contains a refrigerant or halocarbon.

To become a secondary distributor, the person, company or firm may apply for a permit by filing an application and paying a \$50 fee, renewable annually by January 1.

Section 24: Reporting a Release of a Class 1, 2 or 3 Substance

The release of any refrigerant, except for the special circumstances previously discussed in this chapter, is prohibited in Manitoba. When 10 kg (22 lbs) or more of a refrigerant are released, the owner, operator or person working on the equipment must report the release immediately to an environment officer. The environment officer must be provided with all information regarding the release or leakage of the refrigerant. The above procedure applies to all releases 10 kg or over regardless of whether the release was accidental or intentional. A Leak Report Form complete with reporting instructions can be found in Appendix IV.

Section 25: Labeling of Equipment

Equipment that contains a refrigerant must have a label permanently attached to it and can include a manufacturer's name plate. The name plate identifies, among other things, the type of refrigerant and amount of charge the equipment contains. The name plate is usually attached to the equipment at the time of manufacturing.

New installations may require an additional charge of refrigerant or in some installations the recovery of refrigerant due to the varying lengths of refrigerant line sets. When refrigerant is recovered or charged into a system at start-up, or the refrigerant capacity is changed from what is stated on the manufacturer's nameplate, the equipment label must also be changed. When equipment is recharged with a different refrigerant, the equipment label must be changed. The new label shall be located adjacent to the name plate and must have the following information:

- The type and amount of refrigerant recharged into the equipment
- The date the new refrigerant was recharged into the equipment
- The name of the company or person who recharged the equipment

Labels are also required when equipment which contained a regulated refrigerant is discarded and/or decommissioned under Section 16.

Section 26: Responsibilities of Employers and Contractors

Employers and contractors in the business of installing and servicing equipment that contains a refrigerant, must employ trained service technicians who are certified to handle and use refrigerants. When employers or contractors hire another contractor to install or service equipment containing a refrigerant, the hiring employer or contractor must ensure that the hired contractor is a trained service technician or that he/she employs trained service technicians certified to use and handle refrigerants.

Chapter 6 Review Questions

1. True or false: the National Action Plan was developed to help harmonize all levels of government and facilitate the implementation of Canada's Ozone Layer Protection Program.
2. Environment Canada's Code of Practice was developed to...
 - a. Act as a template for reducing the release and emission of CFCs from refrigeration and air conditioning equipment
 - b. Provide a standardized method of practice for technicians working in various refrigeration and a/c trade sectors
 - c. Address a number of key issues including suggested charging methods and requirements to recover, reuse, recycle, and reclaim refrigerants
 - d. All of the above
3. What best describes the purpose of the *Manitoba Ozone Depleting Substances Act*?
 - a. Promotes the sale and use of ODS in Manitoba
 - b. Looks to reduce and eventually eliminate the release of ODS into the atmosphere
 - c. Permits the release of ODS into the atmosphere
 - d. Allows for the sale of ODS-based equipment in Manitoba
4. True or false: industry members (stakeholders) do not need to consult MR 103/94 to ensure that proper procedures are being followed and standards are being complied with in regards to the law.
5. Under MR 103/94, who are the only persons allowed to work on refrigeration and air conditioning equipment?
 - a. Trained and certified service technicians
 - b. MOPIA employees
 - c. Refrigeration and A/C instructors only
 - d. University professors
6. What must certified technicians always have with them at the jobsite when servicing equipment?
 - a. A licensed vehicle
 - b. A cellular phone
 - c. Specialized refrigerant recovery equipment and recovery tanks
 - d. There is no particular equipment that a certified technician requires on the job site
7. When maintaining records, which one of the following should a certified technician remember to record?
 - a. Time of day repair work occurred
 - b. Outside temperature at time of repair work

- c. Type and amount of refrigerant charged, recharged or recovered from a system
 - d. Date of manufacture of the equipment being serviced
8. True or false: when disposing of equipment, delivery to a local landfill without removing the refrigerant charge fulfils all requirements of MR 103/94.
9. When disposing of an unwanted refrigerant, what should the certified technician do?
- a. Release the refrigerant charge into the atmosphere, as it is the most cost effective method of disposal
 - b. Return the recovered refrigerant in an approved container free of charge to the wholesaler or distributor that originally sold the refrigerant
 - c. Contact the nearest hazardous waste facility
 - d. Deliver the recovery container to a local landfill
10. A person who has successfully completed the *Environmental Awareness Training on Ozone Depleting Substances and Other Halocarbons for Manitoba*, is thus considered...
- a. A certified trained service technician
 - b. A recipient of a university degree
 - c. A LEED certified contractor or consultant
 - d. A person holding an MBA
11. What quantity of refrigerant must be released before a person must notify Manitoba Conservation?
- a. 50 kg
 - b. 10 kg (22 lbs)
 - c. 35 lbs
 - d. 1 tonne
12. Which of the following would require a certified technician to label a piece of equipment?
- a. Any equipment containing a refrigerant
 - b. New equipment installations
 - c. Decommissioned or discarded equipment
 - d. All of the above examples would require a label

Chapter 7

HANDLING

REFRIGERANTS

OBJECTIVES

After studying this chapter, the training participant will be able to:

- Identify refrigerants inside equipment containers
- Identify the various types of refrigerant containers and their safe handling practices
- Describe refrigerant removal and restoration procedures.

IDENTIFICATION OF REFRIGERANTS

Refrigerants are carefully selected and matched for each application and use. Heat pumps, air conditioning and other types of refrigerant equipment are designed to operate with refrigerants manufactured to provide safe and efficient equipment operation. In some trades or occupations, such as residential air conditioning where one type of refrigerant (HCFC-22) is used almost exclusively, this topic may not seem important. In other areas where different types of refrigerants are used, safety hazards can occur when refrigerants are mixed or the wrong refrigerant is used in the equipment.

The first step in the safe and proper handling of refrigerants is to identify the refrigerant. Refrigerants are compressed gases and must be maintained within a closed loop system, sealed component, or container to prevent them from being mixed with other refrigerants or released into the environment.

When the type of refrigerant used in a unit is not known, the following procedure should be used:

- Check the nameplate
- Check the temperature/pressure
- Check the colour coding
- Check the labels.

Check the Name Plate

The name plate on refrigerant equipment will include the refrigerant type and quantity contained in the system. On refrigerant systems where historical data or working knowledge does not exist, caution must be exercised to ensure that refrigerants have not been mixed during previous servicing.

Check Temperature and Pressure

When the manufacturer's installation and specifications manual or name plate are not available, the procedure listed below should be followed:

- Ensure that the equipment is off and at ambient temperature
- Obtain and record the pressure reading of the refrigerant
- Obtain and record the saturation temperature of the refrigerant
- Compare your readings to a refrigerant chart which is readily available from refrigerant manufacturers.

Check Colour-Coding

Refrigerants contained in their factory cylinders can be identified by a colour-coding system. The following is a listing of the most frequently-used refrigerants and their colour codes.

- CFC-11 Orange
- CFC-12 White
- HCFC-22 Green
- CFC-113 Purple
- CFC-114 Dark Blue
- R-500 Orchid
- R-717 Silver
- HFC-134 Light (sky) Blue

Reclaim Cylinders

Colour coding of reclaim cylinders is the same as for virgin refrigerants, with one addition: they are painted yellow on the shoulder with the yellow paint extending 12” down on the side.

Check the Labels

Workplace Hazardous Materials Information System (WHMIS) regulations must be attached to refrigerant containers (see: http://www.hc-sc.gc.ca/ewh-semt/occup-travail/whmis-simdut/index_e.html). The labels, in addition to identifying the refrigeration type, also provide other valuable information. Refrigerant labels are of two types:

Supplier labels

Supplier labels are provided by the refrigerant manufacturer and available from wholesalers. Refrigerant manufacturers usually affix the supplier label to refrigerant containers prior to shipping.

If the supplier label on a refrigerant container is damaged or not legible, it must be replaced immediately.

Workplace labels

Workplace labels are required when a refrigerant is decanted from a supplier's labeled refrigerant container into another approved container. Workplace labels are also required on refrigerant containers that contain recycled or reclaimed refrigerant that will not be reused on the same workday by the person who decanted the refrigerant. Decanted refrigerant stored in a container and reused by the worker in the same day it was decanted does not require a workplace label. Workplace labels must name the product, provide safe handling instructions and have a statement on the label that indicates a Material Safety Data Sheet (MSDS) is available.

REFRIGERANT CONTAINERS

There are three main types of refrigerant containers: drums, cylinders and absorption bottles.

1. Drums

Refrigerant drums are stamped with the following information:

- Department of Transport (DOT) specification number
- Gauge of steel
- Volume of the drum

- Refrigerant manufacturer's symbol

Drum Safety

Some safety considerations when handling drums are:

- Do not use pressure to empty a drum
- Before moving a drum and after each use, be sure its plugs are securely tightened.

2. Cylinders

A cylinder is a vessel designed to contain, transport, dispense, recover and reclaim refrigerants safely. Refrigerant cylinders are manufactured and designed to DOT standards that withstand the normal pressures exerted by the refrigerant liquid/vapour mixtures. Cylinders or any type of pressurized container designed to hold less than 10 kg of refrigerant are not industry standard.

Refrigerant cylinders are available in various types, which include:

- Non-recyclable (disposable)
- Refillable and recyclable
- Reclaimable
- Absorption

Non-Recyclable (Disposable): no longer permitted by law

Non-recyclable cylinders are manufactured from light gauge steel and housed in a shallow carton for added protection. They are not designed to withstand continuous usage, thus giving them the name "one-trip cylinder". Non-recyclable cylinders cannot withstand the effects of moisture and will corrode quickly. Empty non-recyclable cylinders must have a sticker stating that all refrigerant has been recovered prior to returning or disposal. It is illegal to refill a disposable cylinder.

Non-refillable cylinders are dispensing cylinders only. They are equipped with a one-way valve that does not allow refilling. The cylinder is equipped with a ¼” SAE flared outlet. This is a Compressed Gas Association (CGA) 165 connection specified for refrigerant gases and is used voluntarily worldwide. The valve connected to the top of the cylinder is a needle valve consisting of a body and valve stem, and is leak-free when refrigerant is being dispensed. The cylinder valve outlet must be covered with the cap supplied when not in use to keep out foreign materials. The cylinder is equipped with an over-pressure safety device called a rupture disk.

Under section 18.1 of MR 103/94, the use of non-refillable/non-recyclable containers is prohibited (i.e., classified as an inappropriate container). In non-recyclable cylinders, the refrigerant heel (the small remaining quantity of refrigerant remaining in the cylinder after use) was not being recovered and the protective carton added to solid waste problems.

Fully Refillable and Recyclable: acceptable for the sale and purchase of Class 1, 2 or 3 substances

Fully refillable and recyclable cylinders are manufactured from a quality heavy gauge steel. These cylinders are designed to withstand continuous usage over many years. To ensure integrity they must be approved by the Department of Transport (DOT). These cylinders have now returned to use in the industry after a long absence due to environmental concerns. Refillable and recyclable cylinders are much heavier and resist corrosion. Empty refillable and recyclable cylinders must have the refrigerant heel recovered prior to exchanging it at the supplier. Fully refillable and recyclable cylinders must be refilled by the refrigerant manufacturer or by obtaining written permission from the refrigerant manufacturer. The refillable and recyclable cylinder has a permanent packaging that is friendlier to the environment as there is no waste. The cylinder shall have on it safety and product warning information in accordance with the Transportation

of Dangerous Goods and Occupational Health and Safety Regulations. Refillable and recyclable cylinders must be tested every five years.

MSDS must accompany the cylinder providing necessary product safety information. The cylinders are equipped with a ¼” SAE flared outlet valve. This is a Compressed Gas Association (CGA) 165 connection specified for refrigerant gases and is used voluntarily worldwide. The valve is connected to the top of the cylinder. The valve design consists of a body, two valve stems, and a liquid tube which extends into the bottom of the tank and is designed to be leak-free when the refrigerant is being dispensed. The cylinder valve outlet must be covered with the cap supplied when the cylinder is not in use to keep out foreign materials. A fusible plug is a safety relief device that prevents over-pressurizing of the cylinder.

Reclaimable

Reclaimable cylinders are manufactured from high quality heavy gauge corrosion resistant steel. They are designed to withstand continuous usage over many years. Reclaimable cylinders have emerged as a result of current environmental regulations regarding the safe recovery and containment of virgin and contaminated refrigerants. Reclaimable cylinders are returned to the supplier who will send them to a reclamation centre for reprocessing. The cylinder must have safety and product warning information placed on it in accordance with the Transportation of Dangerous Goods and Occupational Health and Safety Regulations. Reclaimable cylinders fall into the refillable category and therefore must be tested every five years. Reclaimable cylinders are the only cylinders that can be refilled without written permission from the refrigerant manufacturers because these cylinders are approved for such use.

MSDS must accompany the cylinder providing necessary product safety information. These cylinders can be used for dispensing, recycling and reclaiming as they are equipped with a two-way valve that allows for the dispensing of recycled or reclaimed refrigerant. Reclaimable cylinders are equipped with a standard (ACME) thread. The valve is connected to the top of the cylinder. The valve design consists of a body, two

valve stems, and a liquid tube which extends to the bottom of the tank and is designed to be leak-free when refrigerant is being dispensed, recycled or reclaimed. The cylinder valve outlet must be kept covered with the cap supplied when not in use to keep out foreign materials. A fusible plug safety relief device is used to prevent over-pressurizing of the cylinder.

3. *Absorption Cylinders*

Absorption cylinder technology is based on the use of a synthetic filler material and the principle of absorption. The absorption cylinder traps refrigerant vapours as they pass through the synthetic filler material in the cylinder. The synthetic filler acts as a molecular sieve absorbing refrigerant vapours. All non-condensable vapours are allowed to escape.

The absorption cylinder has two advantages:

- It virtually eliminates the emission of refrigerants during installation, servicing, and decommissioning of refrigeration and air conditioning equipment
- The cylinders are non-pressurized vessels, which simplifies transportation and reduces regulatory requirements.

REFRIGERANT CYLINDER SAFETY

Relief Valves

All cylinders must be equipped with an over-pressure safety relief device such as a rupture disk or fusible plug. The spring-loaded relief valve is another type of over-pressure safety relief device that is common to the commercial refrigerant sector. Relief valves are designed to relieve vapour pressure only. These valves must never come into contact with liquid refrigerant as the refrigerant expands faster than the relief valve's ability to bleed off the refrigerant vapour.

The rupture disk is a flangible disk typically welded into the cylinder shoulder. Should the cylinder pressure exceed 340 psi., a coin will burst and the cylinder's contents will vent, preventing an explosion.

The fusible plug has a soft material with a low melting point. It is threaded into the bottom of the cylinder. When temperatures exceed 130°F or 340 psi. pressure, it will rupture.

The spring-loaded relief valve is a loaded spring and seat valve set to open when the pressure exceeds 340 psi. The pressure forces the spring to open lifting the valve from its seat and venting the contents through the relief port.

Filling Reusable Cylinders

Little attention has been paid to the dangers that technicians face when recovering refrigerant into reusable cylinders. A good safety record exists in this area primarily because refrigerant has been packaged at the factory in disposable "discharge only" cylinders. Disposable cylinders are filled in a controlled environment at the factory, according to prescribed industry standards set by the cylinder manufacturers.

With the return of reusable cylinders for the storing and removal of refrigerants between equipment and storage or reclaiming sites, the potential for problems and accidents will increase. From a small number of reusable cylinders used in North America in the 1990s, the number has grown to more than several million.

Like all fluids contained in a pressurized cylinder, the liquid refrigerant will expand and the gaseous refrigerant will increase in pressure as the temperature increases. All pressurized vessels are potentially explosive. Anyone witnessing the results of a ruptured cylinder knows the devastating force it unleashes. Returning to reusable cylinders presents technicians with the very important safety issue of preventing the overfilling of refrigerant cylinders when recovering refrigerant and the resulting personal injury, property damage and financial liability. For more information, see Storage Guidelines within the Code of Practice.

Overfilling Cylinders

There are three primary causes of a ruptured cylinder:

1. Overfilling
2. Misuse of relief valves
3. The false sense of security gained from the five-year mandatory certification of cylinders.

Under certain conditions, liquid refrigerants will expand to a point where the cylinder can no longer contain the pressure. Underwriters' Laboratories of Canada (ULC) has scientifically determined the maximum volume of refrigerant that can be safely stored in a cold cylinder and later transferred to locations is 80%.

This expansion condition can exist when a cylinder is filled to a level above 90% of the capacity of the cylinder in the cool of the morning. When temperatures are hot, refrigerant can expand to completely fill the cylinder, causing the cylinder to rupture.

Overfilling can also occur when recovering refrigerants that contain oil. Oils are less dense than refrigerant and therefore weigh less. Care should be taken to ensure that the cylinder is filled to 70% of its capacity by weight.

Caution must be exercised to never overfill the cylinder with virgin refrigerant to more than 80% of its weight by volume. When recovering refrigerant of an unknown quality, such as contaminated refrigerant from a compressor burn-out, a good rule to follow is to fill the cylinder to no more than 70% of its total volume by weight.

Misapplication of Relief Valves on Cylinders

Technicians often mistakenly believe that cylinders equipped with pressure relief valves are safe from reaching dangerous pressure levels. The reality is that relief valves are designed to relieve vapour pressure only, not liquid pressure. When a cylinder is overfilled with liquid refrigerant, the relief valve does not provide the protection it was designed for. Liquid refrigerant under pressure when exposed to a pressure relief valve, will expand faster than the relief valve's designed capacity to bleed off the refrigerant gas, resulting in an over-pressured cylinder and possible rupturing of the cylinder. Whether the cylinder ruptures or not, the relief valve will vent refrigerant into the atmosphere, which is illegal and harmful to the environment.

False Sense of Security

Many technicians gain a false sense of security from the knowledge that cylinders are tested, inspected and certified every five years. There is concern that the corrosive effects of acid in recovered liquid refrigerant could seriously reduce the ability of cylinders to withstand design pressures. The performance of reusable cylinders should never be taken for granted. Care and caution must be exercised at all times when using reusable cylinders to reduce unnecessary stress on the cylinder.

Preventive Measures

The best method of prevention is simply to never overfill reusable cylinders. To assist the technician when recovering refrigerant into reusable cylinders, two types of shutoff devices have been developed and approved.

- External independent protection
- In-cylinder integral protection.

External Independent Protection

External independent protection systems are weight and scale-type systems. There are two types of scales: one is calibrated to visually indicate to the technician that the cylinder is 80% full, and another shuts down the system when the cylinder is 80% full by weight. External independent protection systems have one major disadvantage. The scales used are generally calibrated to the weight of virgin refrigerant. When refrigerant is recovered, it is usually from an operating system which contains oil. The weight of oil is usually between 15% to 20% less than the weight of virgin refrigerant. The result is the scale calibrated to weigh virgin refrigerant may read 80% full when in fact the cylinder could be 100% full by a blend of refrigerant and oil.

In-Cylinder Integral Protection

The in-cylinder integral protection system has an 80% shutoff device (overfill protection device) that physically measures the volume of liquid refrigerant in a cylinder to 80%, whether it is a virgin refrigerant or blended with refrigerant oil.

Since these systems are highly reliable, shutoff devices have been incorporated by a majority of refrigerant recovery equipment manufacturers. It must also be noted that this equipment is designed to operate only with reusable cylinders equipped with integral overfill sensors. The integrated sensor most commonly used is the float-type liquid level switch. In addition to providing positive volumetric overfill protection, this device has

the advantage of being integral to the reusable recovery cylinder. Cylinders equipped with this device are recognizable by a quick disconnect electrical terminal located near the valve.

Operation of Integral Overfill Switch

Integral overfill switches on recovery units generally operate as follows:

- The overfill level switch, which is mounted within the empty cylinder, is connected to the recovery equipment with a quick disconnect cord set.
- The overfill level switch, which is a normally closed switch, completes an electrical circuit to the recovery/recycle equipment, allowing it to operate.
- When the refrigerant level in the cylinder reaches 80%, the float (which is an integral part of the overfill level switch and has been rising with the level of the recovered liquid refrigerant) opens the overfill level switch, automatically de-energizing the recovery/recycling unit until the 80% full cylinder is replaced. .

Cylinder Handling Tips

Whenever possible, use only cylinders equipped with overfill protection.

When exchanging a cylinder with an overfill protection device, insist on receiving another exchange cylinder equipped with the same protection device.

Non-refillable cylinders are equipped with a one-way valve. They must never be used to recover refrigerant or used as a storage cylinder for pressurized air. Non-refillable cylinders are constructed of light gauge steel and are not approved for reclaiming refrigerants or storing air under pressure.

Empty cylinders must have the heel recovered for safety and environmental reasons. A cylinder containing a small amount of refrigerant is as dangerous as a full cylinder. Empty cylinders must be evacuated prior to refilling.

Proper identification of cylinders is essential. Those containing a mixture of refrigerant gases or foreign material cannot have the refrigerant reclaimed. A cylinder that has lost its identification markings must be immediately tagged with an approved WHMIS label.

Cylinder valves must be leak-free when in the closed position. If a refrigerant valve is suspected of leaking, leak test the valve using a soap solution.

Refrigerant Cylinder Safety

- Use appropriate cylinders (refillable).
- Never drop refrigerant cylinders.
- Never apply live steam or a direct flame to a cylinder.
- Do not attempt to repair cylinder valves.
- Never refill old-style disposable cylinders.
- Always open cylinder valve slowly.
- Always close cylinder valve after each use and replace protective cap on valve outlet.
- Never by-pass the overfill safety protection provided on recovery or recycling equipment.
- Keep protective hood on cylinder when not in use.
- Never strike refrigerant cylinders with a hard object.
- Never lift the cylinder by the valve hood or valve.
- Never remove valve from cylinder.
- Handle cylinders carefully, taking extreme care to avoid dents, cuts and scratches.
- Protect cylinders from corrosive atmosphere, such as moisture, salt or chemicals.

- Never use a rusted or deteriorating cylinder. Return to wholesaler for disposal.
- Always recover refrigerant immediately from an overfilled or leaking cylinder.
- Do not remove or alter cylinder markings.
- Do not tamper with safety devices on cylinders.
- Do not fill refrigerant cylinders containing a virgin refrigerant more than 80% of its capacity by weight.
- Caution should be exercised when recovering contaminated refrigerant into a cylinder as it weighs less by volume than virgin refrigerant.
- A good rule to follow is to fill a cylinder that does not have overfill protection to 70% of its capacity when the refrigerant contains a lubricant or a refrigerant of an unknown quality.
- Always keep refrigerant cylinder secured in an upright position.

STORING REFRIGERANT CYLINDERS

Store refrigerant cylinders and drums in a dry, ventilated warehouse or other enclosed area away from heat, flame, corrosive chemicals or fumes, and explosives. Keep containers out of direct sunlight, particularly in warm weather. Since refrigerants expand when heated, they require head space in the top of the cylinder to allow for expansion. Cylinders may be full of liquid at temperatures above 130°F. Never allow a cylinder to get warmer than 125°F (51.7°C). Once the cylinder is full, any further rise in the temperature can result in an abrupt rise in liquid pressure to extremely high levels – enough to cause the cylinder to burst, resulting in serious personal injury.

Storage Area for Cylinders and Drums

Cylinders and drums should always be stored above dirt or damp floors to prevent rusting. Use a platform or parallel rails to separate them from the damp floor. All containers must be secured in place by means of a rack, chain or rope. This prevents them from tipping, rolling or accidentally striking each other or any other object. Since the cylinders and drums are colour-coded, it is easy to identify each refrigerant. Store each refrigerant in a separate area. The storage area should be removed of corrosive chemicals or fumes to avoid damage to threaded areas of the valve and cylinder.

REMOVAL AND RESTORATION OF REFRIGERANTS

The removal and/or restoration of refrigerant from a refrigerant system is accomplished by one of four methods: recover, reuse, recycle or reclaim. Regardless of the method used, it is imperative that refrigerants be removed in accordance with MR 103/94.

“Recover” means to capture in a closed container an ODS or other halocarbon that is removed from air conditioning or refrigeration equipment.

“Reuse” means to return a recovered ODS or other halocarbon to air conditioning or refrigeration equipment after the completion of repairs or service to the equipment.

“Recycle” means to reuse an ODS or other halocarbon that has been recovered from air conditioning or refrigeration equipment in other equipment and has been restored to a higher level of purity.

“Reclaim” means to restore a recovered refrigerant, ODS or other halocarbon substance to its original level of purity and product specification.

PROCEDURE FOR RECLAIMING REFRIGERANT FROM AN AIR CONDITIONER INTO A RECLAIM CYLINDER

When reclaiming refrigerant from large air conditioners, a significant amount of time can be saved by recovering, recycling or reclaiming the refrigerant in its liquid state.

- Weigh and record the weight of the refrigerant reclaim cylinder on a note pad or paper.
- Remove any visible dirt or other foreign particles from the manifold gauge hose ends and the valve. It is recommended that the hose ends of the manifold gauges be equipped with check valves or quick couplers. These valves reduce refrigerant emissions into the environment and provide protection against refrigerant burns.
- Connect the reclaim cylinder to the recover/reclaim hose located on the manifold.
- Connect the low side manifold hose to the low side valve on the reclaim unit, and the high side hose to the high side valve on the reclaim unit.
- Purge the recovery/reclaim manifold hose connection by having the hose connection loosely connected at the reclaim unit and reclaim cylinder. Crack the high and low pressure valves at the manifold for about two seconds, then close both valves. Tighten the hose connections at the reclaim unit and reclaim cylinder. This is becoming an obsolete practice as check valves and quick disconnect hose ends are becoming the new standard.
- Open the low and high side valves on the manifold and open the reclaim cylinder valve.
- Start reclaim unit and recover refrigerant in either its vapour or liquid state to the reclaim cylinder. Become familiar with your unit and the manufacturer's procedure on how to recover refrigerant.

- During the reclaim procedure, constant monitoring of the weight or volume of the refrigerant being recovered is essential. **Care and caution must be exercised at all times when filling cylinders. Never overfill a cylinder.**
- During the refrigerant recovery process, any components that are very cold or frosty should be warmed by a heat gun. This ensures all the refrigerant is removed and speeds up the process of recovery.
- Monitor the cylinder pressure and continue to recover refrigerant until you have recovered the entire refrigerant charge.
- Ensure that the high and low side manifold valves, reclaim unit and reclaim cylinder valves are closed. Remove the low pressure hose by applying pressure against the hose connection to keep it seated while you unthread the knurled nut.
- Remove the high pressure hose by applying pressure against the hose connection to keep it seated while you unthread the knurled nut.
- With the reclaim unit and reclaim cylinder valves closed, apply pressure against the hose connection to keep it seated while you are unthreading the knurled nut.
- The refrigerant reclaim cylinder can now be labeled and shipped back to the manufacturer or reprocessing facility.
- When non-contaminated refrigerant is removed from the system and is to be recycled back into the system, the recycling unit and reclaim cylinder can remain attached to the system with all valves in their closed position. After repairs have been made, the refrigerant can then be recharged back into the system.
- When all refrigerant is reused/recycled and is the same refrigerant you removed from the system, it is suggested practice to record this transaction in your logbook.
- The air conditioner must be marked with the correct refrigerant charge for future reference. As a trained certified technician under MR 103/94, you must ensure the following has been recorded prior to leaving the job site:
 - i) The amount of refrigerant used
 - ii) The type of repair or service performed

- iii) Date and location
 - iv) Whether an ozone depleting substance was removed, recovered, charged or recharged
 - v) The type of ODS or other halocarbon.
- A copy of the record must be left with the equipment owner or operator of the equipment.

Chapter 7 Review Questions

1. Circle all relevant steps necessary to identify an unknown refrigerant type
 - a. Check the name plate
 - b. Check the temperature/pressure
 - c. Check the colour coding
 - d. Check the labels
2. True or false: non-recyclable cylinders are no longer permitted by law and were only used to dispense refrigerant.
3. Circle the best two answers that apply to why fully refillable and recyclable cylinders have been reintroduced onto the market
 - a. Their design allows for continuous usage over many years
 - b. They are easier to lift than disposable cylinders
 - c. They are more environmentally friendly (i.e. less waste)
 - d. The steel used to manufacturer them is more abundant than steel used for disposable cylinders
4. True or false: all cylinders must be equipped with an over-pressure safety relief device such as a rupture disk or fusible plug.
5. Circle the three primary causes of a ruptured cylinder
 - a. Overfilling
 - b. Storage in a cold environment
 - c. Misuse of relief valves
 - d. False sense of security gained from the five year mandatory certification of cylinders
6. How does the external independent protection system help to prevent cylinder overfill?
 - a. A scale visually indicating to the technician that the cylinder is 80% full
 - b. An attachment to the recovery equipment that indicates the cylinder has reached 80% capacity
 - c. A scale shuts down the system when the cylinder is 80% full by weight.
 - d. Both a and c
7. When handling a cylinder, the key is to always remember to...
 - a. Bend with your knees, not with your back – when lifting
 - b. Use only cylinders equipped with overfill protection
 - c. Do not submerge cylinder in water
 - d. Do not leave cylinder in direct sunlight
8. Which of the following are true in regards to storage/storage area for refrigerant cylinders?
 - a. Store in cylinders in a dry, ventilated warehouse

- b. Keep containers out of direct sunlight
 - c. Store cylinders above dirt or damp floors using a platform
 - d. All of the above are true in regards to storage or refrigerant cylinders
9. True or false: reclamation of a refrigerant refers to restoring the recovered refrigerant to its original level of purity and product specification?

Chapter 8

REFRIGERANT CONTROL

OBJECTIVES

After studying this chapter, the training participant will be able to:

- Describe the general principles for controlling refrigerants
- Describe the steps in Manitoba's approved leak testing procedure.

GENERAL CONTROL PRINCIPLES

General refrigerant control consists of the plans, practices and procedures used to prevent or assist in preventing the release of refrigerants into the environment. The following control principles, when applied, will reduce and in some instances eliminate refrigerant emissions.

Some general control principles include:

- Maintaining refrigerant charges within closed loop systems, pre-recharged components and refrigerant containers.
- Reducing and where possible eliminating the discharging of refrigerants.
- Replacing CFCs with HCFCs, HFCs or other alternative refrigerants to reduce their ODP to one that is more environmentally acceptable.
- Reducing the expansion, contraction and vibration of refrigerant systems.

METHODS OF CONTROL

The following are acceptable methods for controlling refrigerant emissions.

Maintaining the Refrigerant Charge within the System

When the refrigerant charge is maintained within its sealed vessel, whether that vessel be a refrigerant system, container or other component, it cannot be released into the atmosphere. Refrigerant releases occur when systems are charged or refrigerant is transferred. Some measures that may reduce the need to access the system or container are:

- Observe operating condition of refrigerant at the liquid line sight glasses.
- Diagnose the system with temperature readings rather than pressure readings.

Using Alternative Refrigerants

The use of alternative refrigerants will not reduce the total volume of refrigerant released. They will, however, reduce environmental damage by utilizing alternative refrigerants with lower ODPs.

Reducing Expansion, Contraction and Vibration

The expansion, contraction, and vibration of refrigerant lines and refrigerant equipment place stress on joints and fittings. To reduce these stresses and the refrigerant leakage that can result, the following information and preventive measures should be considered.

Expansion and contraction

Expansion and contraction occurs seasonally due to outdoor temperature extremes between summer and winter. Operating temperatures and pressure differentials between the on and off cycles of refrigeration and air conditioning systems, plus the high coefficient of expansion of the copper refrigerant lines, result in additional stress on joints and fittings.

The effects of expansion and contraction can be neutralized by using any one or a combination of the following:

- Pipe supports that secure the location of the refrigerant lines and allow the refrigerant line to move
- Trombone bends
- Flexible piping connections.

Vibration

Air conditioning and refrigerating equipment have many moving mechanical parts such as fans, motors and compressors. As a result, refrigeration equipment experience a significant amount of vibration. To neutralize the effects of vibration, any one or a combination of the following should be used:

- Anti-vibration mounts
- Vibration absorbing clamps
- Flexible piping connections
- Trombone bends.

Leakage Control

Refrigerant leakage control is obtained by the application of good work practices, procedures and methods in a conscientious, concerned manner that results in quality workmanship and reduced refrigerant leakage. To prevent refrigerant leaks from occurring, the following work practices are suggested.

- Perform routine maintenance on equipment. This will locate leaks early and reduce refrigerant emissions that result from servicing of refrigeration equipment.
- Perform routine leak checks.

- Always recover, reuse, recycle and reclaim refrigerant.
- Keep gland seals lubricated.
- Use brazed joints on refrigerant lines wherever and whenever possible.
- Protect the closed loop refrigerant system from metal to metal contact.
- Ensure that gasket materials are compatible with the refrigerant being used.
- Always perform a second check on mechanical fittings and valve seats before leaving the job site.
- Always replace the protective caps on valves.
- On commercial systems, ensure the resettable relief valve is not set too low.
- Always lubricate flared fittings with refrigerant oil for better tightness.
- Use the least number of joints possible.
- When checking for leaks only, use the approved leak test procedure.

Manitoba's Leak Testing Procedure

Venting Prohibited

Venting refrigerant is prohibited (i.e. Class 1, 2, and 3). In addition, it is mandatory to leak test by not adding any regulated refrigerants, including all ozone depleting and other halocarbons (see MR 103/94 for a designated list). It is a common industry standard to use nitrogen and/or soap & water. Other methods are also acceptable (see below).

Separate recovery units are required to contain different refrigerants. Cross-contamination of refrigerant gases may cause air conditioning equipment damage if it is replaced in a unit. Mixing of refrigerants is prohibited.

Approved Leak Testing Methods

Under MR 103/94, no person shall recharge or top up equipment that contains an ODS or other halocarbon unless the person first conducts a leak test and permanently repairs the identified leak. Technicians may choose one or more of the following leak test methods to ensure a unit system will work effectively after any ODS is added following the system's repair. The following is the prescribed leak test procedure and a list of acceptable leak testing methods recognized by Manitoba Conservation. They are subject to change.

Prescribed Leak Test Procedure

1. If the system still contains a regulated refrigerant, proceed to #3.
2. If the system has lost its charge and no longer contains a regulated refrigerant, it must first be pressurized using dry nitrogen to a minimum of 150 psi (1034 kPa) or such a pressure as not to rupture the system – for at least half an hour.
3. Use one of the appropriate method(s) indicated under “Acceptable Leak Testing Methods” to detect the presence and location of the leak(s).
4. If no leak is detected after fully and thoroughly leak checking, you may recharge the system with the appropriate or manufacturer designated refrigerant.
5. If a leak is found, isolate that component(s) if possible. Recover any refrigerant from the component or system.
6. Once any remaining refrigerant has been recovered, repair or replace the component or system.
7. Perform another leak test method to confirm that the leak has been repaired. If any leaks are found, repeat #1-7 until all leaks have been repaired.

8. Evacuate the system in accordance with the manufacturer's recommended evacuation/dehydration levels. When the manufacturer's information is unavailable evacuate to 29.87 in Hg. (500 microns) and hold for a minimum of ten minutes.
9. The system has now been evacuated and dehydrated. The system may now be recharged in accordance with the manufacturers certified installation, specifications and service manuals, and the *Environmental Code of Practice for the Elimination of Fluorocarbon Emissions from Refrigeration and Air Conditioning Systems*.
 - An ODS or other halocarbon must not be added to nitrogen or dry air for use as a trace gas. However, you may use the remaining (remnant) gas that was in the system to immediately check for leaks.

Acceptable Leak Testing Methods

There are many different techniques for leak testing, with varying degrees of accuracy depending on the system being tested. The following guidelines are acceptable procedure for leak testing on various stationary refrigeration and air conditioning systems.

The following techniques have been recognized by Manitoba Conservation. The most appropriate leak test method for the circumstance should be chosen and performed by a MR 103/94 certified individual ("trained service technician"). The completing of a leak test is not a guarantee against leaks in the future, and therefore is not meant to replace any existing preventive maintenance program.

- Electronic leak detection
- Halide flame leak detection
- Soap and bubble test
- Ultrasonic leak detection
- Fluorescent dye leak detection

- Standing vacuum test
- Standing nitrogen pressure test

Note: Any additional leak testing technologies that are developed and find acceptance within the refrigeration and air conditioning industry may become acceptable and added to these guidelines. It is recommended that you periodically check with Manitoba Conservation or MOPIA for the latest list of acceptable leak test procedures.

Chapter 8 Review Questions

1. True or false: expansion and contraction of refrigerant lines and equipment occurs seasonally due to outdoor temperature extremes between summer and winter.
2. To reduce or neutralize vibration in refrigeration and a/c systems, which of the following methods should be used?
 - a. Vibration absorbing clamps
 - b. Trombone bends
 - c. Only a
 - d. Both a and b
3. True or false: under MR 103/94, a person is allowed to top up a system with refrigerant without performing a leak test.
4. Identify the leak test procedure below that is not approved by the Minister of Conservation.
 - a. Ultrasonic leak detection
 - b. Fluorescent dye leak detection
 - c. Clip and vent leak detection
 - d. Soap and bubble test

Appendix

Hydrocarbons as Refrigerant Replacements:

Research demonstrates that hydrocarbons can potentially reduce the overall energy consumption of domestic and commercial appliances by up to 15%. This in turn can help reduce the total equivalent warming impact (TEWI), which looks at the total emissions associated with a refrigeration system for both the refrigerant and energy inputs needed to run that system. When comparing identical systems that run hydrocarbons (HCs) to hydrofluorocarbons (HFCs), the TEWI for hydrocarbons will be significantly lower because of the increased energy savings and lower GWP.

New research into the use of propane and butane as refrigerants began in 1992 as a result of a partnership between leading hydrocarbon researchers and a German manufacturing company, DKK Scharfenstein, facilitated by Greenpeace. As a result of this partnership, *Greenfreeze* technology was created for domestic refrigeration systems as it utilizes hydrocarbons for foam blowing and refrigerants. This new technology soon spread across Germany and prompted tens of thousands of environmentally-conscious Germans to preorder *Greenfreeze* refrigerators. Although most other home appliance manufacturers publicly boasted that the concept of a hydrocarbon-based appliance would ultimately fail, this was short-lived as they soon realized the benefits of environmentally-friendly refrigerators.

Greenfreeze refrigerators utilize a special mixture of either propane (R290) and isobutene (R600a), or pure isobutene as a refrigerant (30-70g). Since hydrocarbons have a special thermodynamic property, only one-third of the refrigerant regularly needed in a CFC or HFC-based appliance is used. For the blown foam insulation, cyclopentane is used, in which its insulating properties have been favourably compared with CFC-11 and even outperforms HCFC-141b in some measures.

In some applications, hydrocarbons such as propane and isobutene have proven to be an effective replacement for CFCs and their alternatives in refrigeration systems, especially in low or no-power situations. Highly efficient gas adsorption refrigerators, which are powered by propane, require no electricity and have no moving parts. Many *Greenfreeze* refrigerators that use isobutene may be up to 38% more energy efficient than their halocarbon alternatives, as noted by Bosch-Siemens in their 1993 annual report where they stated hydrocarbon-based appliances accumulated a 50% energy savings. Both domestic and commercial refrigerators converted to hydrocarbons are at minimum 15% more energy efficient than their halocarbon counterparts.

Although deemed environmentally friendly, hydrocarbon refrigerants have been met with harsh criticism in both the United States and Canada because of flammability issues. In the United States, it is illegal to replace CFC-12 refrigerants in vehicles older than 1994 with hydrocarbons, and hydrocarbons used in systems designed for R-134a will void the air conditioning warranty. This is because leaking air conditioning systems charged with hydrocarbons pose serious risks of fire or explosion under the hood of the car or inside the passenger cabin. This is despite some products, such as hydrocarbons (see Figures 12a and 12b), being marketed as direct replacements. Currently 19 states and the District of Columbia prohibit the use of hydrocarbons as a refrigerant in mobile air conditioning systems. The Chair of the SAE Interior Climate Control Standards Committee states new and existing air conditioning systems were not designed by manufacturers to accommodate such a volatile substance similar to that used in the preparation of food on outdoor grills. The US EPA has yet to find conclusive evidence that hydrocarbons are a safe alternative to their non-flammable halocarbon alternatives, and thus have banned them under the authority of the Clean Air Act. Furthermore, none of the major automobile manufacturers or trade associations have fully endorsed the use of hydrocarbons for use in mobile air conditioning systems.

Special Note: *Manitoba Public Insurance Corporation (MPIC) recognizes the use of HFC-134a only in mobile air conditioning systems. Using a refrigerant other than HFC-134a in insured mobile air conditioning systems may have potential liability issues. Check with MPIC first if you are using a refrigerant other than HFC-134a.*



Figure 12a. RedTek Refrigerant



Figure 12b. RedTek Retrofit Kit

Despite these reservations, Greenpeace has argued that the explosive risk associated with hydrocarbons can be easily prevented through the implementation of safety measures during the product design and production processes. The amount of actual hydrocarbon in a *Greenfreeze* refrigerator is merely equal to two cigarette lighters, making the likelihood of an explosion extremely minimal. It takes between 17-39g/cubic metres to create a mixture potent enough to create an explosion. Therefore, in the event of a refrigerant leak, an explosion would be nearly impossible as ignition sources are inaccessible to the absorption of almost 50% of the hydrocarbon into the lubricating mineral oil. As a result, the German safety and standards organization TUEV, has approved hydrocarbon refrigerators as safe and tested for residential and commercial use, which is also a valid mark throughout the European Union. *Greenfreeze* technology is also being exported around the world and is prevalent in many areas including China, India and Australia, where it played a prominent role in the 2000 Summer Olympic Games in Sydney.

Cyclopentane is beginning to emerge in the North American market as a blowing agent in blown foam insulation thanks to an endorsement from the Underwriters Laboratory in the USA, approving up to 113g of hydrocarbons for safe use. However, conversion to hydrocarbon-based appliances in North America within the near term is unlikely. However, there is sincere interest as experiments have shown that even the largest of refrigerators only requires 70g of hydrocarbon, which is within the 113g limit imposed by the Underwriters Laboratory.

Original equipment manufacturers (OEMs) do not manufacture or design parts to operate using hydrocarbons because each type of refrigerant operates at a different temperature and pressures (i.e. CFCs low pressure, hydrocarbons higher pressure). The introduction of hydrocarbons into an air conditioning system by an untrained or uncertified technician can contaminate both the OEM parts and refrigerant/oils. Some OEMs may void the warranty if hydrocarbons or non-designated refrigerants are used or detected in the system. Furthermore, because of their volatile properties (flammable/explosive nature), most untrained individuals can or will likely add more hydrocarbons to the system than needed, so if there is a leak into the passenger compartment this may create the right fuel/air combustion ratio to cause an explosion.

Although Manitoba has no formal regulation governing the use of hydrocarbons, it is best to contact Manitoba Public Insurance (MPI) and equipment manufacturers for the latest information regarding the use of hydrocarbons as a refrigerant alternative in mobile air conditioning systems (as use may void or impact the warranty or insurance). Any person utilizing hydrocarbon refrigerants must be trained and certified to handle regulated refrigerants as retrofitting of systems may include the recovery of a regulated refrigerant. Certain hydrocarbon companies may offer training specific for the proper use of their product.

Amendments to the Montreal Protocol

1. London Amendment: The London Amendment to the *Montreal Protocol* was proposed at the Second Meeting of the Parties in 1990. CFCs were to be gradually phased out by the year 2000 with a 50% reduction by 1995 and an 85% reduction by 1997. Halons were to be phased out by 2000 with a 50% reduction by 1995. Furthermore, three new groups of substances were targeted: other halogenated substances - gradual phase out by-2000 (Annex B), carbon tetrachloride – phase-out by 2000, 85% reduction by 1995 (Annex B), and methyl chloroform – phase-out by 2005, 30% reduction by 1995 and 70% by 2000 (Annex 3, Group 3). Signatories to

the Protocol were also barred from trading these substances with non-party members. A financial mechanism was also introduced (Article 10 of the Protocol), which provided both financial and technical support for developing nations to help foster compliance for their obligations under the Protocol. Finally, the amendment established reporting guidelines for the production and consumption of HCFCs (Annex C, Subgroup 1). The London Amendment was entered into force on August 10, 1992.

2. Copenhagen Amendment: The Copenhagen Amendment to the *Montreal Protocol* was proposed at the Fourth Meeting of the Parties in 1992. Faster phase-out for CFCs, halons, methyl chloroform and carbon tetrachloride was prescribed for all developed nations by 1996, with developing countries allowed to continue production and consumption for essential uses only (i.e., necessary for a safe and healthy society). New restrictions within this amendment targeted HCFC's, with the phase-out date set for 2030 for consumption only (excluding production) for all developed countries. In addition, new restrictions were enforced for production and consumption of HBFCs (phase-out by 1996 because they are a nonessential substance) and a freeze on methyl bromide for developed nations. The Copenhagen Amendment entered into force on June 14, 1994.

3. Montreal Amendment: The Montreal Amendment to the *Montreal Protocol* was proposed at the Ninth Meeting of the Parties in 1997. This is the only amendment that did not place restrictions on new substances under the Protocol. What it did introduce was the installation of a licensing system that allowed for monitoring the trade of substances identified under the Protocol. The Montreal Amendment entered into force November 10, 1999

4. Beijing Amendment: The Beijing Amendment to the *Montreal Protocol* was proposed at the Eleventh Meeting of the Parties in 1999. A freeze was placed on HCFC production for January 1, 2004 for all developed countries and 2016 for developing countries, with trade restrictions in place for 2004. It further restricted

production and consumption of bromochloromethane, which was a new ODS added to the list of controlled substances for phase-out in 2002. The multilateral fund was also replenished to the tune of US\$440 million. The Beijing Amendment entered into force February 25, 2002.

References

Wikipedia (2006)

- <http://en.wikipedia.org/wiki/Ultraviolet>
- http://en.wikipedia.org/wiki/Ozone_Depletion
- http://en.wikipedia.org/wiki/Ozone_Layer
- http://en.wikipedia.org/wiki/Greenhouse_effect
- http://en.wikipedia.org/wiki/Global_Warming
- http://en.wikipedia.org/wiki/Climate_Change
- http://en.wikipedia.org/wiki/Effects_of_global_warming
- http://en.wikipedia.org/wiki/Carbon_Tetrachloride
- http://en.wikipedia.org/wiki/Methyl_chloroform
- <http://en.wikipedia.org/wiki/Haloalkane>
- http://en.wikipedia.org/wiki/Methyl_Bromide

The Ozone Hole (2006)

- <http://www.theozonehole.com/dobsonunit.htm>
- <http://www.theozonehole.com/ozonecreation.htm>
- <http://www.theozonehole.com/ozonedestruction.htm>

United States Environmental Protection Agency (2006)

- <http://www.epa.gov/ozone/science/process.html>
- <http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html>
- <http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissions.html>
- <http://www.epa.gov/spdpublc/title6/609/saepawarning.html>
- http://www.epa.gov/climatechange/emissions/downloads/ghg_gwp.pdf

Environment Canada (2006)

- <http://www.ec.gc.ca/ozone/docs/uo/UVHealth/EN/uvhealth.cfm>

National Aeronautics and Space Administration (2006)

- <http://www.nas.nasa.gov/About/Education/Ozone/ozonelayer.html>
- <http://toms.gsfc.nasa.gov/dobson.html>

National Oceanic and Atmospheric Administration (2006)

- <http://www.cmdl.noaa.gov/noah/publicitn/elkins/cfcs.html>

United Nations Environment Program (2006)

- http://www.unep.ch/Ozone/Treaties_and_Ratification/montreal_protocol_amendments.asp

International Institute for Sustainable Development (2006)

- <http://www.iisd.ca/journal/ott.html>

Canadian Broadcasting Corporation (2006)

- <http://www.cbc.ca/news/background/kyoto/timeline.html>

European Commission (2006)

- <http://ec.europa.eu/environment/climat/kyoto.htm>

Encyclopedia Britannica (1997)

- http://www.britannica.com/nobel/micro/721_4.html

Greenpeace (2007)

- <http://archive.greenpeace.org/ozone/greenfreeze/>
- http://sites.greenpeace.org.au/archives/coke/pdf/exec_summary_final.pdf

World Wide Web

- <http://www.care-refrigerants.co.uk/hmpg/hmpgdisplaylev2.asp?idofuser=&catid=6&catid2=61&where=lev2>
- <http://www.scorecard.org/chemical-profiles/def/odp.html>
- <http://www.ciesin.columbia.edu/docs/011-459/011-459.html>
- http://climatechange.sea.ca/kyoto_protocol.html
- <http://www.saci.uthscsa.edu/PatientServices/glossary.html>
- <http://www.chemheritage.org/EducationalServices/faces/env/readings/missing.htm>
- <http://www.ciesin.columbia.edu/TG/OZ/o3depl.html>
- <http://www.gcrio.org/UNEP1998/UNEP98p62.html>
- <http://www.heco.net/TheTruth.htm>
- http://www.epatest.com/q_refblends.html
- <http://www.sdearthtimes.com/et0800/et0800s10.html>
- <http://www.airah.org.au/downloads/2004-09-02.pdf>

Print

- Canada's Ozone Layer Protection Program a Summary—Montreal Protocol 1987-1997. (1997). *Environment Canada*. p.8.
- Andersen, Stephan O. & K Madhava Sarma. (2002). Protecting the Ozone Layer: The United Nations History. Earthscan Publications Ltd: London.
- Canadian Council of Ministers of the Environment. (2001). National Action Plan for the Environmental Control of Ozone-Depleting Substances (ODS) and their Halocarbon Alternatives. Prepared by the Federal Provincial Working Group on Ozone-Depleting Substances and Halocarbon Alternatives.
- Canadian Council of Ministers of the Environment. (2001). Canada's Strategy to Accelerate the Phase-Out of CFC and Halon Uses and to Dispose of the Surplus Stocks. Prepared by the Federal Provincial Working Group on Ozone-Depleting Substances and Halocarbon Alternatives

Section Review

World Wide Web

- <http://www.albany.edu/faculty/rgk/atm101/o3histor.htm>

Factoid References

World Wide Web

- <http://www.gcric.org/ozone/ozoneFAQs.html>
- http://www.ec.gc.ca/press/protocol_b_e.htm
- http://news.nationalgeographic.com/news/2004/12/1206_041206_global_warming_2.html
- <http://news.bbc.co.uk/1/hi/sci/tech/521451.stm>
- <http://www.cancer.org.au/content.cfm?randid=960742>
- http://www.nasa.gov/vision/earth/environment/ozone_resource_page.html
- <http://www.theozonhole.com/ozonhole2002.htm>
- http://www.cancer.ca/ccs/internet/standard/0,3182,3172_1046449084_langId-en,00.html
- http://cancercare.mb.ca/Communications/nr04/nr_may25_04.shtml
- <http://www.cancer.org.au/content.cfm?randid=960742>
- <http://www.cancercare.on.ca>
- <http://www.healthunit.org/sunsafety/factfiction.htm>
- <http://www.healthunit.org/sunsafety/indoortan.htm>
- <http://www.theozonhole.com/consequences.htm>
- <http://www.stjohns.ca/cityservices/environment/pdfs/climatechange.pdf>

Figure References

World Wide Web

- http://www.agoracosmopolitan.com/home/images/nature/ozonel_ayer1.jpg
- <http://www-atm.physics.ox.ac.uk/user/barnett/ozoneconference/dobson.jpg>
- <http://jwocky.gsfc.nasa.gov/teacher/O3fulllesson/dunit.gif>
- http://www.classzone.com/books/earth_science/terc/content/investigations/es1708/images/es1708_p3_map_dobson_b.jpg
- <http://ozone.gi.alaska.edu/images/dobson.jpg>
- http://www.ingenious.org.uk/media/4.0_SAC/webimages/1032/7/10327189_3.jpg
- <http://www.atmosphere.mpg.de/media/archive/1327.jpg>
- http://www.geography.hunter.cuny.edu/~tbw/wc.notes/1.atmosphere/ozone_3.jpg
<http://www-istp.gsfc.nasa.gov/istp/outreach/workshop/lopez/5.jpg>
- <http://archiwum.wiz.pl/images/duze/1996/04/96042104.JPG>
- <http://www.atomicmuseum.com/tour/photos/mmolina.jpg>
- <http://www.ethlife.ethz.ch/images/row2-1.jpg>
- <http://www.atm.amtp.cam.ac.uk/shuckburgh/ozone/invader2.jpg>
- http://www.fsl.noaa.gov/visitors/education/samii/SAMII_CFC_Ozone.jpg
- <http://www.ntt.co.jp/kankyoe/2001report/detail/img/281-1.jpg>
- <http://www.medicalecology.org/images/atmosphere/ozone.gif>
- <http://ozonewatch.gsfc.nasa.gov/daily.php?date=2006-09-24>
- <http://ozonewatch.gsfc.nasa.gov/daily.php?date=2002-09-24>
- <http://science.nasa.gov/headlines/images/ozone2000/CFCs.jpeg>
- http://www.unep.org/Ozone/Public_Information/image016.gif
- <http://cache.eb.com/eb/image?id=68842>
- <http://www.snappymgr.com/images/items/1130079/1130079-3.jpg>

- http://www.scienceclarified.com/images/uesc_01_img0014.jpg
- http://fmzl.en.alibaba.com/product/50225227/51213243/Fluoric_Refrigerants/R12_Refrigerant/showimg.html
- http://www.aerospecialties.com/catalog/images/H3R_model_B369.jpg
- <http://www.pested.org/images/Mbromide.gif>
- http://www.ffva.com/publications/harvester/Feb06_images/tractor.jpg
- http://www.k-ish.net/Notes/Column/images/A_C_r134.jpg
- <http://www.globalreach.ca/red-tek/leadpic.jpg>
- <http://www.fgilt.com/images/library/rt313.jpg>
- <http://images.webmd.com/images/hw/media68/medical/hw/nr551630.jpg>
- <http://www.networlddirectory.com/images/wiki/melanoma.jpg>
- http://www.ucsusa.org/assets/images/global_warming/ghouse_effect.jpg
- http://chronicle.augusta.com/images/headlines/080402/Global_Warming.jpg
- <http://www.koshland-science-museum.org/exhibitgcc/images/ill-greenhouse01.jpg>
- <http://www.koshland-science-museum.org/exhibitgcc/images/causes02.jpg>
- http://image.guardian.co.uk/sys-images/Guardian/Pix/maps_and_graphs/2000/11/14/climate_greenhouse2.gif

General Reading and Further Information

Manitoba Ozone Protection Industry Association

- <http://www.mopia.ca>

United States: Environmental Protection Industry Association

- **Ozone:** <http://www.epa.gov/ozone/>
- **Climate Change:** <http://www.epa.gov/climatechange/>

Environment Canada

- **Green Lane:** <http://www.ec.gc.ca/envhome.html>
- **Natural Resources Canada:** http://www.nrcan.gc.ca/inter/index_e.html
- **Stratospheric Ozone:** <http://www.ec.gc.ca/ozone/>
- **Total Ozone Map:** <http://exp-studies.tor.ec.gc.ca/e/ozone/real.htm>
- **Ozone and UV Index Forecast:** <http://exp-studies.tor.ec.gc.ca/e/ozone/forecasts.htm>
- **UV Index:** http://www.msc-smc.ec.gc.ca/education/uvindex/index_e.html

United Nations Environment Program

- **UNEP Home:** <http://www.unep.org/>
- **Ozone Secretariat:** <http://ozone.unep.org/index.asp>
- **UNEP DTIE OzonAction:** <http://www.uneptie.org/ozonAction/>
- **Climate Change:** <http://climatechange.unep.net/>

International Institute for Sustainable Development

- **IISD Home:** <http://www.iisd.org/>

National Aeronautics and Space Administration

- **NASA Home:** <http://www.nasa.gov/>
- **Ozone Hole Watch:** <http://ozonewatch.gsfc.nasa.gov/>
- **Climate Change Directory:** <http://gcmd.nasa.gov/>
- **Total Ozone Mapping Spectrometer:** <http://jwocky.gsfc.nasa.gov/>

National Oceanic and Atmospheric Administration

- **NOAA Home:** <http://www.noaa.gov/>
- **Stratospheric Ozone:** <http://www.ozonelayer.noaa.gov/>
- **Climate Portal:** <http://www.noaa.gov/climate.html>

National Geographic

- **Global Warming:** <http://magma.nationalgeographic.com/ngm/0409/feature1/>
- **Ozone:** <http://www.nationalgeographic.com/eye/ozone/ozone.html>

Intergovernmental Panel on Climate Change

- www.ipcc.ch

The Ozone Hole

- <http://www.theozonehole.com/>

Australian Government: Department of Health and Aging

- **National Skin Cancer Awareness Campaign:** <http://www.skincancer.gov.au/>

The Cancer Council Australia

- **Cancer Council Home:** <http://www.cancer.org.au/>
- **Skin Cancer:** <http://www.cancer.org.au/content.cfm?randid=960742>

Canadian Cancer Society

- <http://www.cancer.ca/>

Health Canada

- **Preventing Skin Cancer:** http://www.hc-sc.gc.ca/iyh-vsv/diseases-maladies/cancer_e.html

Cancer Care Manitoba

- www.cancercare.mb.ca

For full text of the *Vienna Convention* please visit:

- <http://sedac.ciesin.columbia.edu/entri/texts/vienna.ozone.layer.protection.1985.html>

For full text of the *Montreal Protocol* please visit:

- <http://www.globelaw.com/Climate/montreal.htm>

For the full text of the *Kyoto Protocol* please visit:

- <http://unfccc.int/resource/docs/convkp/kpeng.pdf>