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HVAC Made Easy - Environmental Issues and Refrigerants

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Course Content

PART I – OZONE LAYER DEPLETION AND GLOBAL WARMING

Ozone layer depletion and global warming have become a single major environmental issue on the international scale. The choice of refrigerant is interwoven with major environmental concerns of climate change and global warming. Refrigerant selection assumes a key importance in mitigating the effects of environmental issues and selection of HVAC system. This course briefly explores the environmental issues and emphasize how these impact the air-conditioning industry, HVAC engineers and the end users.

Ozone

Ozone is a natural and vital gas in the upper atmosphere about 15-40 kilometers above the earth. This stratospheric ozone layer shields the earth surface from the harmful effects of the sun's radiation by filtering out ultra violet UV-B rays. Any damage to the ozone layer shall result in higher UV radiation reaching earth's surface that shall adversely affect the human health and the environment.

Ultraviolet rays (UVA and UVB) are associated with sunburns, skin cancer, weakening of the immune system and other physical ailments such as cataracts. Increased exposure poses a threat to human health, wildlife, vegetation and crop production. Documented evidence shows that increased UVB radiation affects the human immune system and the ecology of the earth.

What causes Ozone depletion?

The scientific consensus suggests that ozone depletion is caused by ozone depleting substances (ODS). These substances are essentially man made chemicals that contain chlorine or bromine atom with inherent chemical stability and have long lifetime in the atmosphere, in the range of 40 to 150 years. These chemicals and other trace gases drift up into the stratosphere and become involved in chlorine-releasing reactions. The chlorine atoms then react with the ozone molecules in the presence of sunlight and destroy the ozone molecules. Just one chlorofluorocarbon molecule can destroy tens of thousands of ozone molecules.

Common ODS and their applications

A few common ozone-depleting chemicals are listed below with their applications: -

- Chlorofluorocarbons

  Substances like chlorofluorocarbons are extremely stable, synthetic chemical compounds that contain chlorine, fluorine and carbon. They were developed in the 1930s as a substitute for ammonia refrigerants.

  CFCs are used in various applications because they are nontoxic, nonflammable and relatively inexpensive to produce. They are primarily used as a refrigerant for domestic refrigerators and for producing foam cushioning, insulation, solvents and sterilizers. However, when CFCs are released into the air, these gases travel slowly upward and break down the ozone layer. CFCs also find applications in aerosols, hair mousses, household cleaning products and packaging.

- Hydro Chlorofluorocarbons

Hydro chlorofluorocarbons (HCFCs) are chemical compounds related to CFCs. This makes HCFCs less stable and about 95 percent less damaging to the ozone layer. They are mainly used as refrigerant in domestic air conditioning systems and in manufacturing plastic, insulation and packaging.

Because HCFCs do contribute to ozone depletion, they are being phased out of production and use between the years 2010-2020. Therefore, HCFCs should only be used as a short-term alternative replacing CFCs.

- Halons

  These are used as fire extinguishing agents.

- 1,1,1-trichloroethane (methyl chloroform)

  1,1,1-trichloroethane finds applications as a:

  - Solvent for cleaning electronic circuit boards and metal work such as watches and clockworks
  - Thinner such as that for correction fluid
  - Cleaning agent in the textile industry (dry cleaning).

- Carbon tetrachloride

  Carbon tetrachloride is used as a cleaning agent in textile and electronics industries.

- Methyl bromide

  Methyl bromide as a soil fumigant in farming sector

Alternatives and Substitutes

- There has been considerable progress in finding non-ozone-depleting substitutes for ODS in the last few years. Substitutes for air-conditioning and refrigeration applications are now available, such as that CFC-12 can be replaced by HFC-134a. Air-conditioning and refrigeration plants have been modified and re-designed for non-CFC refrigerants
- Halons have been replaced with Inergen and FM200 chemical as a fire-extinguishing agent generally used in electronic processing facilities or clean room applications.
- Plastic film bubble wraps are now widely used for packaging material
- Petroleum solvents could be selected in place of CFC-113 or 1,1,1-trichloroethane in cleaning applications.
- Aqueous cleaning, or even no-clean technology, is alternative processes that can be used by the electronics industry.
- Many household and personal aerosol products such as paint sprays and insecticides now use hydrocarbons (e.g. propane and butane) as propellants instead of CFCs.
- Di-methyl ether may also be used as propellants replacing CFCs.

Climate Change and Global Warming

The terms, global warming and climate change are often used interchangeably. Gases such as carbon dioxide, methane, nitrous oxide, and refrigerants create a greenhouse effect by trapping heat in the lower atmosphere. This makes the Earth warmer because the sun's rays are allowed into the lower atmosphere but the heat from these rays isn't able to escape.

Climate change & global warming is a second major environmental challenge to face the HVAC industry.

What causes this phenomenon?

The earth is warmed by the solar radiation from the sun. The earth and the gasses in the atmosphere absorb about 2/3 of the incoming radiation. The remaining 1/3 is reflected back by cloud cover, airborne particles and the Earth's surface mostly as infrared radiation. Certain gases in the atmosphere can trap that energy and stop it from escaping. This raises the earth's mean temperature. The process is often referred to as the greenhouse effect and the gases that can trap the energy are referred to as greenhouse gasses.

While some trapping of heat is desired, too much can cause the earth to become too warm. Scenarios such as polar ice caps melting with wide spread flooding are an extension of this problem. Climate change happens naturally over many thousand of years. Modern science has been collecting data only for a very short time period making it very difficult to ascertain any trends.

While greenhouse process in an accepted scientific model, there are many mechanisms connected with the process are that are not as clear and are seriously debated. For instance, a rising of the earths mean temperature should produce more evaporation of ocean water and hence more cloud cover. The cloud cover could reduce the incoming solar radiation offset the greenhouse effect. There is enough concern that the ASHARE position paper on climate change suggests global average surface temperatures could rise by 1.8 to 6.3 deg F by 2100 with a corresponding rise in sea levels of 6 to 37 inches by the end of next century.

Common Greenhouse Gasses

The major source is Carbon dioxide (CO_2). The other substances that are greenhouse gasses are methane, nitrous oxide, CFCs, HCFC, HFCs, PFCs and sulphur hexaflouride (SF6).

How Refrigerants affect climate change?

Refrigerants affect climate change in 2 ways.

- The first way is when released directly into the atmosphere. Most of the refrigerants in use today have some level of global warming potential. Some are very high. However the actual release of refrigerant released is very small especially when compared with CO_2
- The 2nd way the refrigerants affect climate change is indirect and deals with system efficiency. Refrigeration and air-conditioning is the major energy intensive operation. Much of the electric power used to operate refrigeration system comes from burning of fossil fuels that emit CO_2. The more efficient the refrigeration system, the less CO_2 released. It is estimated that in North America, 1/3 of the energy consumed is used in buildings. Energy efficient buildings will have a direct and major affect on CO_2 emissions. Conservation of energy, less dependence on fossil energy and shifting renewable energy where possible is key to the reduction in greenhouse gasses.

International Efforts

Montreal Protocol

In an attempt to halt the destruction of ozone layer many countries pledged to phase out the production and eventually the use of many chemicals associated with this problem.

In September 1987, an international treaty aimed at saving the Earth's ozone layer, known as the Montreal Protocol on Substances that Deplete the Ozone Layer, was signed in Montreal, Canada. The Protocol requires to reduce and eliminate the ODS in accordance with agreed schedules.

The Montreal Protocol has been amended five times so far. Its control provisions were strengthened through five adjustments that are summarized below:

- Montreal Protocol: Requires 50% reduction in CFC production by 2000. Other compounds were also controlled.
- London Amendment: Requires 100% phase out of CFC production by 2000
- Copenhagen Amendment: Advances CFC phase out to 1996. Set HCFC consumption cap in 1996 with ratcheted phase out plan as follows:
    - 65% of cap in 2004
    - 35% of cap in 2010
    - 10% of cap in 2015
    - And 0.5% of cap in 2020

  The cap was set based on an ODP-weighed average with 1989 as a base year.

- Vienna Amendment: The CFC portion of the HCFC cap was reduced from 3.1% to 2.8%
- Montreal Protocol Amendments: HCFC consumption from 2020 to 2030 only be used for service on existing equipment.
- Beijing Amendments: HCFC production caps introduce to deal with export issues to developing countries.

Production of CFCs has been stopped completely in 31 Dec 1995 in the USA. The only source of CFCs (in particular R-11 and R-12) is reclamation from existing equipment.

Kyoto Protocol

Kyoto Protocol was signed in 1997 convention on global warming and climate change. The adoption of the Kyoto protocol strengthens the framework with new policies and measures including quantified limitation and reduction objectives to greenhouse gas emissions not covered by the Montreal Protocol.

PART II - REFRIGERANTS

The refrigerants are now synonym with major environmental concerns. The selection of right refrigerant is a key factor in the decision making process during evaluating any new refrigeration proposal. Current and anticipated future restrictions limit or prohibit the use of certain refrigerants. As a minimum, when comparing systems and when all other technical issues are equal, refrigerant selection will tip the scales one way or the other. Replacements and commercial availability have to be born in mind during life cycle operation of the HVAC plant. For designs where the refurbishment or demolition of mechanical refrigeration equipment in involved, the designer will provide detailed step by step guidance and diagrams of this work that complies with the recommendations of ASHARE Guideline 3.

Most Common Commercial Refrigerants

The table below highlights certain facts about most commonly available refrigerants and the refrigerants of the future.

REFRIGERANT	FACTS
R-22 (Monochloro difluoro methane)	Classified as an A1 category (lower toxicity- no flame propagation) refrigerant by ASHRAE. R22 is one of the most efficient and popular refrigerants in the world that is a non-CFC but a HCFC. CFC's have already been phased out; the HCFC's don't have an immediate phasing out plan but shall be stopped for use in new machines by 2010 and are permitted for use until year 2020.
R-134a (Tetrafluoro ethane)	Classified as an A1 category (lower toxicity- no flame propagation) refrigerant by ASHRAE. It is an HFC, which doesn't have impact on the ozone depletion like CFCs and HCFC's. R-134a shall be the main large capacity refrigerant in the HVAC industry for the foreseeable future and has no phase out plan. All the second generation centrifugal, screw and scroll chillers have been designed around R-134a.
R-123 (Dichloro trifluoro ethane)	ASHRAE standard 34 classifies R-123 as a B1 category refrigerant (higher toxicity-no flame propagation). It is the HCFC replacement for CFC-11 and as such is being phased out. In USA, R-123 is already capped and will be reduced to 0.5% production in 2020 for service only until 2030. R-123 is used almost exclusively in negative pressure centrifugal chillers that operate under vacuum. These don't offer any replacement at present. HFC-245a is potential non-ozone depleting

REFRIGERANT	FACTS
	applicable refrigerant substitute for HCFC-123. It was primarily developed as a foam-blowing agent.
R-717 (Ammonia)	R-717 has an excellent performance for low temperature chiller applications. The health and flammability issues surrounding ammonia have been limiting factor in its use. Generally used of cold storage applications. Provided that the safety issues are addressed, R-717 can be used in open drive screw chillers. It is not suited for hermetic motor applications because of material compatibility consideration. R-717 is not suited for centrifugal chillers because of its low molecular weight.
R-410A	R-410A is a near azeotropic HFC blend (50/50 wt. % HFC-32 and HFC-125) that is intended for HCFC-22 replacement. Because it is near azeotropic it is suitable for use in flooded evaporator configuration that is typically of large chillers.
R-407C	R-407C is another HFC blend that is intended for HCFC-22 replacement, but it is zeotropic and is not suited for use in a flooded evaporator. R-407C has been used in reciprocating chillers with direct expansion evaporators.
R-744 (Carbon dioxide)	R-744 is a non-toxic, non-flammable refrigerant. Not very successful in commercial refrigeration due to its low critical point and very high operating pressures of around 900 psig. Application include a dry ice product for refrigeration, as an antiseptic in bacteriology, frozen food industry etc.
R-290 and R-600a (Propane and Isobutane)	Propane and Isobutane have low toxicity, good performance but are highly inflammable. Not recommended for commercial HVAC applications.

Other facts

In light of above facts R-134a scores as the first choice in present scenario. R-22 could be utilized for smaller plants. Typically a refrigeration plant is designed for life cycle of 10-15 years and R-22 shall be available for use until year 2020.

The absorption chiller machines technology using water as their refrigerant could be effectively utilized as an alternate technology. This option must be evaluated particularly where there is a scope of waste heat utilization.

New chiller designs must include features to reduce refrigerant losses. Before CFC were an issue, a loss rate of 15% per year was considered acceptable. But now the CFC and HCFC refrigerants are both an environmental and an economic concern. The new developments minimize shaft seals; install isolation valves around filter assemblies and use brazed instead of flared fittings. In addition high efficiency purge units can limit the refrigerant losses to less than 0.5% per year, including the losses that occur during system maintenance.

Use environment- preferred products that shall be available for the life cycle of the plant for instance a non-CFC type refrigerant should be used.

The commercially available reciprocating, screw and centrifugal chiller machines can operate on non-CFC refrigerant options. But the new generation scroll and screw machines have been specifically developed for use with R-134a refrigerant.

To date, the reciprocating compressors available have been converted to R-134a use from original R-22 designs. No authentic data is available on the capacity de-rating/enhanced performance of reciprocating machine with R-134a refrigerant. This should be investigated, should a reciprocating chiller machine be considered.