Fundamentals of Refrigeration and Air Conditioning

المرحلة الثانية

محاضرة رقم (8)

موائع التبريد

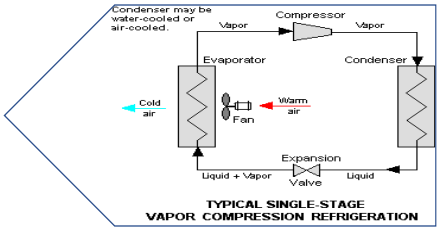
Refrigerants

Email (Hassan.Ghanim.Hassan@uomus.edu.iq)

Fundamentals of Refrigeration and Air Conditioning

Hassan Rijabo

Lecture 8
Refrigerants



TYPICAL SINGLE-STAGE VAPOR COMPRESSION REFRIGERATION

AL MUSTAKBAL UNIVERSITY
College of Engineering and Technology
Department of Mechanical Power Engineering

Hassan.Ghanim.Hassan@uomus.edu.ly
hvac.eng.edu
Ref_AC

Lecture 8 : Refrigerants

History Of Refrigeration

- Refrigeration relates to the cooling of air or liquids, thus providing lower temperature to preserve food, cool beverages, make ice and for many other .
- Most evidence indicate that the Chinese were the first to store natural ice and snow to cool drinks and other delicacies.
- Ancient people of India and Egypt cooled liquids in porous earthen jars.
- In 1834, Jacob Perkins, an American, developed a closed refrigeration system using liquid expansion and then compression to produce cooling. He used Ether as refrigerant, in a hand- operated compressor, a water-cooled condenser and an evaporator in liquid cooler.

Refrigeration Principle

- Modern refrigeration and air-conditioning equipment is dominated by vapour compression refrigeration technology built upon the thermodynamic principles of the reverse Carnot cycle.
- Refrigerant Changes phases during cooling and used again and again.

What is a Refrigerant

- Refrigerants are used as working substances in a Refrigeration systems.
- Fluids suitable for refrigeration purposes can be classified into primary and secondary refrigerants.
- Primary refrigerants are those fluids, which are used directly as working fluids, for example in vapour compression and vapour absorption refrigeration systems.
- These fluids provide refrigeration by undergoing a phase change process in the evaporator.
- Secondary refrigerants are those liquids, which are used for transporting thermal energy from one location to other. Secondary refrigerants are also known under the name brines or antifreezes

Email (Hassan.Ghanim.Hassan@uomus.edu.iq)

What is Chlorofluorocarbons

- Today's refrigerants are predominantly from a group of compounds called halocarbons (halogenated hydrocarbons) or specifically fluorocarbons.
- Chlorofluorocarbons were first developed by General Motor's researchers in the 1920's and commercialized by DuPont as "Freon's".

Halocarbon Refrigerants

- Halocarbon Refrigerant are all synthetically produced and were developed as the Freon family of refrigerants.

Examples :

- CFC's : R11, R12, R113, R114, R115

Freon Group Refrigerants Application and ODP Values

Refrigerant	Areas of Application	ODP
CFC 11(R11)	Air-conditioning Systems ranging from 200 to 2000 tons in capacity. It is used where low freezing point and non-corrosive properties are important.	1.0
CFC 12 (R 12)	It is used for most of the applications. Air-conditioning plants, refrigerators, freezers, ice-cream cabinets, water coolers, window air-conditioners, automobile air conditioners.	1.0
CFC 13 (R 13)	For low temp refrigeration up to - 90 °C in cascade system	1.0
CFC113(R113)	Small to medium air-conditioning system and industrial cooling	1.07
CFC114(R114)	In household refrigerators and in large industrial cooling	0.8
Blend of R22 and R115 (R502)	Frozen food ice-cream display cases and warehouses and food freezing plants. An excellent general low temp refrigerant	0.34

What is Ozone Layer

- Ozone is an isotope of oxygen with three atoms instead of normal two. It is naturally occurring gas which is created by high energy radiation from the Sun.
- The greatest concentration of ozone are found from 12 km to 50 km above the earth forming a layer in the stratosphere which is called the ozone layer.
- This layer, which forms a semi-permeable blanket, protects the earth by reducing the intensity of harmful ultra-violet (UV) radiation from the sun.

Ozone Layer Depletion

- In the early70's,scientists Sherwood Roland and Mario Molina at the University of California at Irvine were the first to discover the loss of ozone in stratosphere while investigating the ozone layer from high flying aircraft and spacecraft.
- They postulated the theory that exceptionally stable chlorine containing fluorocarbons could, overtime, migrate to the upper reaches of the atmosphere and be broken by the intense radiation and release chlorine atoms responsible for catalytic ozone depletion.

OZONE LAYER DEPLETION

- **NORMAL REACTION**
- $O_2 = O + O$
- $O_2 + O = O_3$
- But CFC refrigerants leaked during the manufacturing and normal operation or at the time of servicing or repair, mix with surrounding air and rise to troposphere and then into stratosphere due to normal wind or storm. The Ultraviolet rays act on CFC releasing Cl atom, which retards the normal reaction:
- **RETARDED REACTION**
- $O_3 = O_2 + O$
- $CCL_2F_2 = CCLF_2 + CL$
- $O_3 + CL = CLO + O_2$
- $O + CLO = CL + O_2$

Harmful consequences of ozone depletion

- ***For Humans*** Increase in
- skin cancer سرطان الجلد
- snow blindness العمى الثلجي
- Cataracts اعتام عدسة العين

Less immunity to

- infectious diseases
- malaria
- herpes
- ***For plants***
- smaller size
- lower yield
- increased toxicity
- altered form

- ***For marine life*** Reduced
- Plankton العوالق
- juvenile fish الاسماك الصغيرة
- larval crabs and shrimps يرقات الروبيان

MONTREAL PROTOCOL

- **SIGNED IN 1987 UNDER THE UNITED NATIONS ENVIRONMENT PROGRAMME 'UNEP', AFTER MUCH DISCUSSIONS**
- **MORE THAN 170 COUNTRIES HAVE RATIFIED**
- **ONE OF MOST SUCCESSFUL EXAMPLE OF INTERNATIONAL COOPERATION IN UN HISTORY**

Montreal protocol- Control Schedule

ozone depleting substance	developed countries	developing countries
CFCs	phased out end of 1995	total phase out by 2010
halons	phased out end of 1993	total phase out by 2010
HCFCs	total phase out by 2020	total phase out by 2040

Refrigerant selection criteria

- Selection of refrigerant for a particular application is based on the following requirements:
  - i. Thermodynamic and thermo-physical properties
  - ii. Environmental and safety properties
  - iii. Economics

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Thermodynamic and thermo-physical properties

- The requirements are:
- a) Suction pressure: At a given evaporator temperature, the saturation pressure should be above atmospheric for prevention of air or moisture ingress into the system and ease of leak detection. Higher suction pressure is better as it leads to smaller compressor displacement
- b) Discharge pressure: At a given condenser temperature, the discharge pressure should be as small as possible to allow light-weight construction of compressor, condenser etc.
- c) Pressure ratio: Should be as small as possible for high volumetric efficiency and low power consumption
- d) Latent heat of vaporization: Should be as large as possible so that the required mass flow rate per unit cooling capacity will be small

Thermodynamic and thermo-physical properties

- In addition to the above properties; the following properties are also important:
- e) Isentropic index of compression: Should be as small as possible so that the temperature rise during compression will be small
- f) Liquid specific heat: Should be small so that degree of sub cooling will be large leading to smaller amount of flash gas at evaporator inlet
- g) Vapour specific heat: Should be large so that the degree of superheating will be small
- h) Thermal conductivity: Thermal conductivity in both liquid as well as vapour phase should be high for higher heat transfer coefficients
- i) Viscosity: Viscosity should be small in both liquid and vapour phases for smaller frictional pressure drops
- The thermodynamic properties are interrelated and mainly depend on normal boiling point, critical temperature, molecular weight and structure.

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Environmental and safety properties

- At present the environment friendliness of the refrigerant is a major factor in deciding the usefulness of a particular refrigerant. The important environmental and safety properties are:

- a) Ozone Depletion Potential (ODP): According to the Montreal protocol, the ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances. Refrigerants having non-zero ODP have either already been phased-out (e.g. R 11, R 12) or will be phased-out in near-future(e.g. R22). Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e., CFCs and HCFCs) or bromine cannot be used under the new regulations

Environmental Effects of Refrigerants

Global warming :

Refrigerants directly contributing to global warming when released to the atmosphere

Indirect contribution based on the energy consumption of among others the compressors (CO_2 produced by power stations)

Environmental and safety properties

- b) Global Warming Potential (GWP): Refrigerants should have as low a GWP value as possible to minimize the problem of global warming. Refrigerants with zero ODP but a high value of GWP (e.g. R134a) are likely to be regulated in future.

- c) Total Equivalent Warming Index (TEWI): The factor TEWI considers both direct (due to release into atmosphere) and indirect (through energy consumption) contributions of refrigerants to global warming. Naturally, refrigerants with as a low a value of TEWI are preferable from global warming point of view.

Environmental and safety properties

- d) Toxicity: Ideally, refrigerants used in a refrigeration system should be non-toxic. Toxicity is a relative term, which becomes meaningful only when the degree of concentration and time of exposure required to produce harmful effects are specified. Some fluids are toxic even in small concentrations. Some fluids are mildly toxic, i.e., they are dangerous only when the concentration is large and duration of exposure is long. In general the degree of hazard depends on:

  - - Amount of refrigerant used vs total space
  - - Type of occupancy
  - - Presence of open flames
  - - Odor of refrigerant, and
  - - Maintenance condition

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Environmental and safety properties

- e) Flammability: The refrigerants should preferably be non-flammable and non-explosive. For flammable refrigerants special precautions should be taken to avoid accidents.
- f) Chemical stability: The refrigerants should be chemically stable as long as they are inside the refrigeration system.
- g) Compatibility: with common materials of construction (both metals and non-metals)
- h) Miscibility with lubricating oils: Oil separators have to be used if the refrigerant is not miscible with lubricating oil (e.g. ammonia). Refrigerants that are completely miscible with oils are easier to handle(R12).

Environmental and safety properties

- Ease of leak detection: In the event of leakage of refrigerant from the system, it should be easy to detect the leaks.

Economic properties:

- The refrigerant used should preferably be inexpensive and easily available.

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