6. Calculate the within-run imprecision (coefficient of variation, CV) from the distribution of the individual weighings (w_i) about their mean ($\bar{w}$), corrected for error due to evaporation:

$$CV = \frac{100 \times s}{(\bar{w} + e)}$$

$$\text{where } s = \frac{(w_i - \bar{w})^2}{n - 1}$$

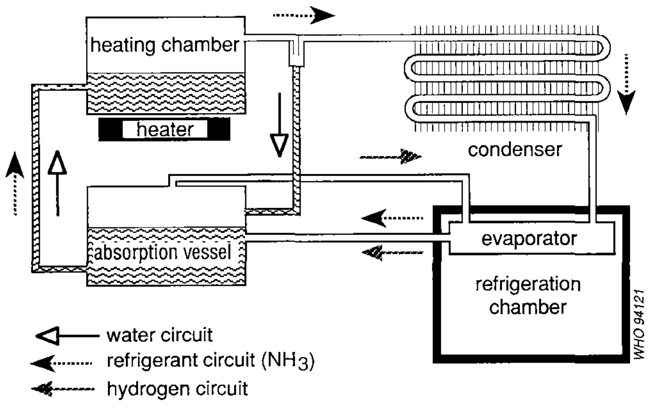
Refrigerators

Refrigeration is the result of the absorption of energy (heat) during the evaporation of a liquid. A refrigerant liquid is circulated through a closed system of pipes, in which on one side (refrigeration chamber) it is vaporized and on the other side (outside the refrigeration chamber) it is condensed. Common refrigerant liquids are ammonia (boiling point −33 °C), and low relative molecular mass chlorofluorocarbons (boiling point near −30 °C). The vaporization of the refrigerant liquid is achieved by either absorption or compression.

Absorption

The absorption system is used mainly in small refrigerators, because it requires more energy input than the compressor system. The closed system of an absorption refrigerator consists of an evaporator, an absorption vessel, a heating chamber and a condenser (Fig. 2.27). The liquid contains ammonia as refrigerant and water as absorbant. The third component in the system is hydrogen, which accelerates the evaporation of ammonia and maintains a constant pressure in the circuit.

Fig. 2.27. Working principle of an absorption refrigerator.



The circuit works at constant pressure and has no moving parts. The operation of the circuit is based on the following principles:

- Water can absorb large quantities of ammonia at ordinary temperatures. The absorption of ammonia in water occurs so fast that a "compression" effect results.
- At modestly elevated temperatures, ammonia separates from water into the gaseous phase.
- Hydrogen does not dissolve in water.

- The laws of partial pressure state that, in a space occupied by a mixture of gases that do not react chemically together, each gas exerts the pressure that it would produce if it occupied the space alone, and the total pressure is the sum of these pressures.

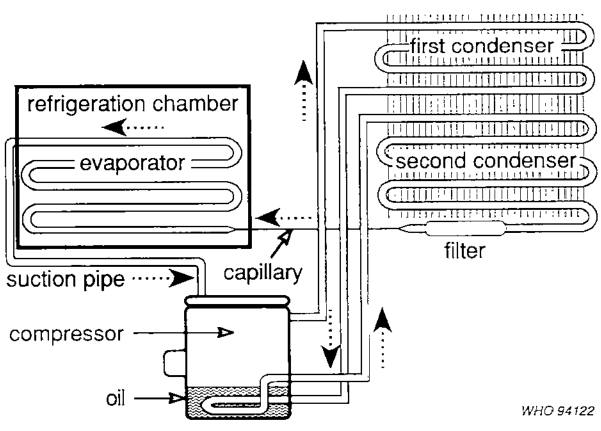
When a mixture of ammonia and water is heated by a flame or an electrical device in the heating chamber, ammonia and a relatively small amount of water will evaporate. The ammonia and water vapour enter a percolator, where the water is condensed. This water, containing a low concentration of ammonia, passes into the absorption vessel. The gaseous ammonia moves to the condenser. Air circulating over the fins of the condenser cools the gaseous ammonia, and it condenses. The liquid ammonia then flows by gravitational forces into the evaporator where it evaporates under low pressure at ambient temperature. This process extracts heat from the storage compartment. The evaporation is accelerated by hydrogen gas passing across the surface of the ammonia. The ammonia–hydrogen mixture travels to the absorption chamber, where the ammonia is absorbed by the water. This process occurs so fast that it keeps the partial pressure of ammonia in the system low and contributes to accelerating evaporation in the evaporator. The hydrogen passes through the water without being absorbed and back to the evaporator.

With the absorption of ammonia the liquid in the absorption chamber increases in density and flows into the heating chamber, from where the refrigeration cycle is repeated.

Compression

Compression systems are used for cold rooms and for some small refrigerators and require mains electricity. They consist of an evaporator, an expansion valve or capillary pipe, a condenser, and a compressor (Fig. 2.28).

Fig. 2.28. Working principle of a compression refrigerator.



A compressor sucks the coolant liquid from the tubes of the evaporator, which are located inside the cooling compartment of the refrigerator. The residual coolant liquid in the evaporator evaporates and in doing so takes up latent heat from the cooling compartment. The vapour is compressed into pipes outside the refrigerator, where it condenses, liberating heat, which is dissipated to the surrounding air by the condenser fins. The condensed coolant liquid is forced through the capillary pipe and expands into the evaporator, from where the refrigeration cycle is repeated. In some refrigerators, the condensed coolant is circulated back to the compressor to take up heat from the compressor oil, which again causes evaporation of the refrigerant. In a second condenser, the coolant is condensed again prior to passing through the capillary tube for expansion and evaporation, while the liberated heat of condensation is dissipated to the environment.

Installation

Electrical compressor-operated refrigerators and freezers should be used only where there is a stable and reliable electricity supply. Fluctuations in the voltage, and frequent power interruptions, are likely to result in damage to the compressor. Absorption refrigerators and freezers are preferred in situations where electricity supply is unreliable.

Equipment should be installed on a flat, horizontal surface, preferably slightly elevated (on pallet or feet) to avoid accumulation of water and moisture under the cabinet. This will prevent the formation of rust and allow easy access for cleaning.

Good practice

- Keep the surrounding area clean.
- Leave at least 20 cm between the cabinet and the wall and other equipment, and avoid exposure to heat and sunshine.
- Keep the refrigerator upright and level. If the cabinet needs to be moved, it should be transported in an upright position.
- Wash the door gasket with soap solution, and rub with glycerol, when the cabinet is defrosted.
- Do not re-open the door immediately after closing.
- Never use sharp instruments to remove ice. Defrosting may be quickened by placing a container of warm water in the refrigerator or freezer after electrical isolation.
- Remove all water from the inside of the refrigerator or freezer after defrosting.
- Do not leave the refrigerator or freezer open unnecessarily.
- Open and close the door gently.

Flammable chemicals must only be stored in cabinets designed for that purpose. Kerosene-operated refrigerators and freezers should be refilled with uncontaminated kerosene. The burner, chimney, and wick must be cleaned regularly. The baffle must be inserted into the chimney.

Maintenance

The following general advice may be helpful for maintenance:

- The refrigerator must be placed so that sufficient air can flow past the condenser (at the back of the refrigerator) for exchange of heat.
- The refrigerator door must seal perfectly to prevent warm outside air from entering the cool chamber.
- The refrigerator must have good insulating walls.
- For photovoltaic (solar-powered) refrigerators, the collector must be positioned so as to receive maximum solar radiation; it must be cleaned periodically to ensure the production of enough electricity.

Daily checks

- Check temperature daily.
- Check the gas bottles or kerosene tank, in the case of gas or kerosene refrigerators, so that more can be ordered in good time.

Monthly checks

- Clear the cool chamber, and defrost the evaporator once a month.
- Swab inside the cabinet with 70% ethanol while it is defrosting.
- Clean the outside of the refrigerator.
- Clean any dust from the condenser.
- Clean the door gasket.
- Clean the burner, and check for gas leakage.
- In photovoltaic refrigerators, check the level of electrolyte solution in the batteries, and fill up with pure distilled water, if necessary.

Door gaskets

On domestic-type refrigerators, the gasket-holding mechanism is the inner shell of the door. This fastens to the outer casing with a ring of screws under the gasket. When this is disassembled in order to change the gasket, the rigidity of the door structure is lost. In order to ensure a good seal upon reassembly, the complete door must first be removed and placed on several boards to keep it as flat as possible. Then, remove the screws and the old gasket, install the new gasket and replace the screws before moving the door. Reinstall the door, with the hinge screws snug but not tight. Shut the door with a piece of paper in the seal, and test for tightness by pulling on the paper. Do this all around the gasket. The hinges may be adjusted outwards by closing the door with a folded cloth in the seal or by bumping with a soft rubber mallet. Adjust until the paper indicates that the door is evenly tight all around, then tighten the screws in the hinges.

Compressor-type refrigerators and freezers

- Clean the condenser (in the compressor compartment) every 6 months with a brush or vacuum cleaner.
- Oil the door fittings, locks, and other moving parts.
- Replacement of the compressor, which would require recharging with refrigerant, should be carried out only by a qualified refrigeration engineer.

Absorption-type refrigerators and freezers

- Check the thermostat.
- Check the heating element.
- If the heating element is working but the refrigerator does not become cool, remove the burner with the tank, or disconnect the refrigerator from the mains. Place upside down for 12 hours, then upright for another 12 hours and re-start normal operation (if the refrigerator or freezer had been transported incorrectly or tilted this action will ensure that the ammonia refrigerant flows back into the correct pipes). If this procedure does not work, send for a qualified refrigeration engineer.

Changing the heating element

1. Disconnect the refrigerator from the mains.
2. Remove the heating element from the chimney.
3. Disconnect from the thermostat.
4. Connect the new element at the ceramic connector or thermostat, using the same terminals.

5. Insert the element into the chimney aperture, making sure it is not placed beside the aperture.

Note: For security reasons, the refrigerant liquid circuit is sealed by the refrigerator manufacturer. It should never be opened, because of the hazardous nature of the liquid.

Spares

Bulb
Heating elements
Thermostats
Wicks
Burner glasses

Tools

Vacuum cleaner or brush
Thermometer

Water purification systems

Pure water is essential for many processes in laboratories and other hospital service departments. The necessary level of purity will depend upon the application for which the water is required. Water purification is expensive; indeed, in the preparation of laboratory chemical reagents, the water may be the most expensive component. Before purchasing and installing a water purification unit, it is, therefore, necessary to define the level of purity required, to avoid excessive and unnecessary expense in producing water that is too pure. Similarly, it is wasteful to use very pure water needed for one task, in another application where such pure water is not required.

The cost of producing water to the required standard of purity will depend upon the purity of the starting material, i.e., the tapwater. This may vary enormously as regards both organic and inorganic content.

There are two main techniques of water purification: demineralization and distillation.

Demineralization

Demineralization systems are particularly suitable for the removal of inorganic ions from water by the use of ion-absorbing resins. They can be easily operated and require no energy input, but they do not remove organic impurities, do not produce sterile water, and may be subject to bacterial contamination, particularly in a warm environment.

Demineralizers contain an insoluble cation exchange resin and an anion exchange resin. These resins may be kept in separate columns (Fig. 2.29) or in a mixed-bed column.

To obtain demineralized water, tapwater is passed through the resin columns, which exchange the solute electrolytes against H^+ and OH^- ions. The conductivity of the deionized water can be measured with a conductivity meter fitted to the outlet of the system.