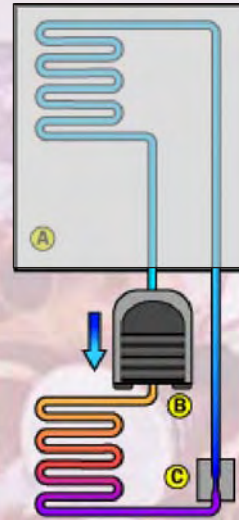


Cryogenics - the technology of cooling

Refrigerators

Refrigerators produce cooling by circulating a refrigerant. In a domestic refrigerator, circulating Freon liquid vapourises and cools the contents. The Freon gas is then compressed, releasing heat in an external heat exchanger. Work is done circulating and compressing the Freon. The net effect is the transfer of heat energy from the cold contents to the hotter room.

- (A) Inside the refrigerator
- (B) Compressor
- (C) Expansion valve



Dilution refrigerators

A **dilution refrigerator** circulates ^3He , in a mixture of the helium isotopes ^3He and ^4He , to reach very low temperatures down to below $2 \times 10^{-3} \text{ K}$ (2 mK).



An Oxford Instruments ^3He - ^4He dilution refrigerator, and a fish-eye view of it in use at Royal Holloway, University of London



Cryogenic liquids

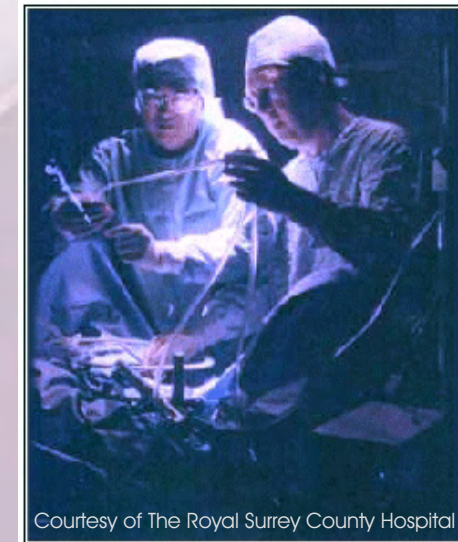
Space Shuttle

The three main engines of the Space Shuttle burn hydrogen and oxygen from vast external fuel tanks. These contain 1,500,000 litres of **liquid hydrogen** and 550,000 litres of **liquid oxygen**, taking up less volume than gas. They have a maximum thrust of $6.9 \times 10^6 \text{ N}$ and fire for 8 minutes, helping to take the shuttle into orbit.

Space Shuttle Atlantis



Cryosurgery is the use of extreme cold to treat cancer. For external tumours, **liquid nitrogen** (at -196°C or 77 K) is applied directly to the skin. For internal tumours, **liquid nitrogen** is circulated through a cryoprobe, which freezes and destroys the cancer cells. This procedure offers the advantage of very quick patient recovery time.



Courtesy of The Royal Surrey County Hospital

First law of thermodynamics

Internal energy increase = work done + heat energy supplied.

Second law of thermodynamics

Work is required to transfer heat energy from cold to hot.