AIR CYCLE REFRIGERATION

Description of technology

Air cycle systems can produce low temperatures for refrigeration by subjecting the gaseous refrigerant (air) to a sequence of processes comprising compression, followed by constant pressure cooling, and then expansion to the original pressure to achieve a final temperature lower than at the start of compression. Air cycle refrigeration is based on the reversed Joule (or Brayton) cycle illustrated in figure 1.

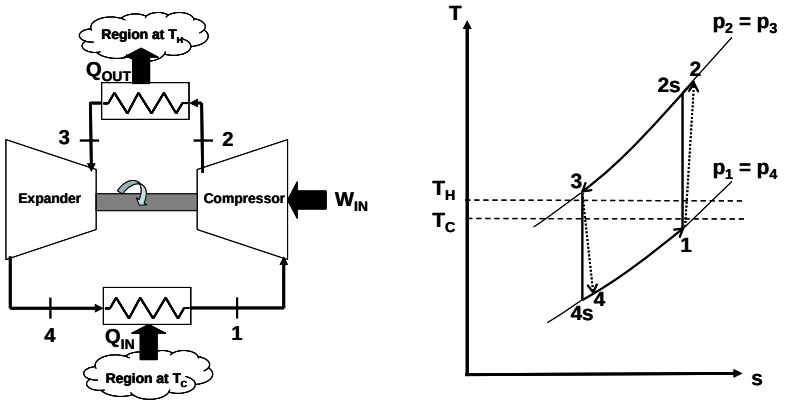

Figure 1 Reversed joule cycle

Air cycles can be classified as closed, open or semi-open/closed. **Closed cycles** are, by definition, sealed systems and consequently there is no direct contact between the working fluid and the product being cooled. Hence, in comparison with open and semi-open/closed cycles an additional heat exchanger (with associated temperature difference) is required for transferring heat from the refrigeration load. **Open cycles** can be open on either the low-pressure side or the high-pressure side of the cycle. Cold air leaving the system passes through the refrigerated space coming in direct contact with the product being cooled. **Semi-Open/Closed cycles** are also open to the refrigerated space, where the cold air comes into direct contact with the product being cooled but the air is then drawn back through the low-pressure side of the regenerator to the compressor.

State of Development

Air cycle is a reasonably well established technology. Plant operating characteristics are understood and issues such as condensation and icing have been addressed and solutions developed. Closed and open air cycle systems have been developed by industrial companies with refrigeration capacities ranging from 11 to 700 kW for closed systems and from 15 to 300 kW for open systems. Information on coefficient of performance for refrigeration is sparse but most values quoted are in the range 0.4 to 0.7. It is also noted that the efficiency of air cycle systems is relatively unaffected under part load conditions.

Applications in the food sector

Air cycle refrigeration can deliver air temperatures down to -100°C, giving it a niche position in the -50°C to -100°C range, beyond the capability of vapour compression plant, and is a cost-effective alternative to the use of cryogenics for low temperature food freezing operations. Air cycles also generate high air temperatures, typically of over 200°C, that can be used in combination with the low temperatures to integrate cooking and refrigeration processes.

In the food sector air cycle technology can be applied to rapid chilling and/or freezing (including air blast, tunnel, spiral, fluidised bed and rotary tumble equipment); for refrigerated transport (trucks, containers, rail freight, ships, air cargo); and for integrated rapid heating and cooling (cook-chill-freeze or hot water/steam raising and refrigeration).

Barriers to uptake of the technology

The main barriers to uptake of air cycle technology are:

- unavailability of packaged equipment off the shelf for application in the food sector

- insufficient experience and performance data from commercial applications to provide confidence in the application of the technology.

Key drivers to encourage uptake

The main drivers to encourage uptake of the technology in the food sector are:

- successful demonstration of the benefits of the technology in specific promising applications, such as: combined refrigeration and cooking/heating and transport refrigeration.
- rising energy costs and requirement for faster food processing to increase throughput and reduce energy consumption.
- more stringent regulations on the use of HFC refrigerants and other natural refrigerant alternatives

Research and development needs

To increase the attractiveness of air cycle systems, research and development is required to:

- increase the efficiency and availability of small turbo-machines.
- improve the effectiveness and reduce costs of compact heat exchangers
- develop component sizing, integration and control strategies for specific applications to increase system efficiency at reasonable cost.