Air cycle refrigeration

Air cycle refrigeration systems use air as their refrigerant, compressing it and expanding it to create heating and cooling capacity.

Air cycle is not a new technology. Air cycle or 'cold air machines' were available from companies such as J & E Hall (see picture) in the early 1900s. These were used on board ships and by food producers and retailers to provide cooling for their food stores.

However, the development of vapour compression cycles, based initially on ethyl ether, ammonia or sulphur dioxide, but superseded by chlorofluorocarbons (CFCs) led to the gradual replacement of the majority of air cycle systems, except in the field of aircraft air conditioning.

Environmental concerns about CFCs, ozone depletion, global warming and the resulting increasingly stringent legislation have renewed interest in alternatives to the current standard of vapour-compression refrigeration technologies.

The use of air cycle is one of these, offering a benign substitute for CFC refrigerants as well as reduced energy consumption and capital costs for targeted applications.

Why use air cycle?

Air cycle systems have specific advantages that apply to all potential applications:

- The working fluid (air) is free, environmentally benign, safe and non-toxic
- Air cycle equipment is extremely reliable, reducing maintenance costs and system down-time
- The performance of an air cycle unit does not deteriorate as much as that of a vapour-compression unit when operating away from its design point
- When operating in a refrigeration cycle, an air cycle unit can also produce heat at a useful temperature. If this is used together with the cooling, highly efficient, low energy processes are possible

- Air cycle units can produce a much higher temperature difference between the hot and cold sides compared to vapour-compression units. This means that:
    - Very cold air can be produced for near-cryogenic processes
    - Heat can be produced at a useful temperature, which, if used together with the cooling, can result in highly efficient, low energy processes

How does air cycle work?

Air cycle refrigeration works on the reverse Brayton or Joule cycle. Air is compressed and then heat removed, this air is then expanded to a lower temperature than before it was compressed. Work must be taken out of the air during the expansion, otherwise the entropy would increase. Work is taken out of the air by an expansion turbine, which removes energy as the blades are driven round by the expanding air. This work can be usefully employed to run other devices, such as generators or fans. Often, though, it is used to power a directly connected (bootstrap) compressor, which elevates the compressed (hot) side pressure further without added external energy input, essentially recycling the energy removed from the expanding air to compress the high pressure air further. The increase in pressure on the hot side further elevates the temperature and makes the air cycle system produce more useable heat (at a higher temperature). The cold air after the turbine can be used as a refrigerant either directly in an open system, or indirectly by means of a heat exchanger in a closed system. The efficiency of such systems is limited to a great extent by the efficiencies of compression and expansion, as well as those of the heat exchangers employed.

Originally, slow speed reciprocating compressors and expanders were used. The poor efficiency and reliability of such machinery were major factors in the replacement of such systems with vapour compression equipment. However, the development of rotary compressors and expanders (such as in car turbochargers) greatly improved the isentropic efficiency and reliability of the air cycle. Advances in turbine technology, together with the development of air bearings and ceramic components offer further efficiency improvements.

Combining these advances with newly available, compact heat exchangers, which have greatly improved heat transfer characteristics, makes competition with many existing vapour compression quite feasible.

How frperc can help

frperc are a leading organisation in the development of air cycle refrigeration systems. We have built successful prototype domestic refrigerators, retail chiller and freezer cabinets and installed the world's first air cycle buildings air conditioning system

To discuss any aspects of air cycle refrigeration, please contact us on +44 (0)1472 582400 or email us on frperc@grimsby.ac.uk