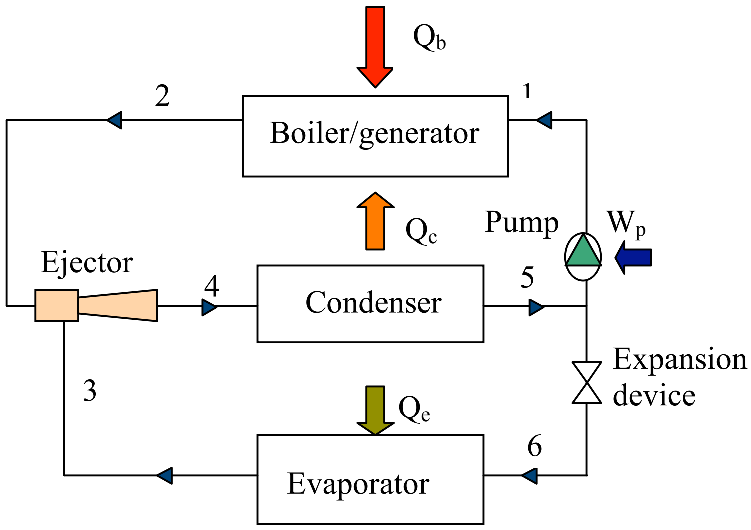
EJECTOR REFRIGERATION SYSTEMS

Description of technology

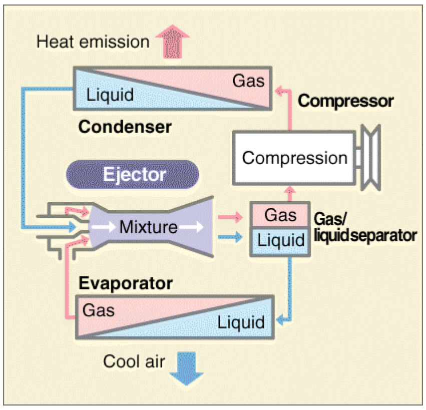
Ejector or jet pump refrigeration is a thermally driven technology that has been used for cooling applications for many years. In their present state of development they have a much lower COP than vapour compression systems but offer advantages of simplicity and no moving parts. Their greatest advantage is their capability to produce refrigeration using waste heat or solar energy as a heat source at temperatures above 80°C.



Referring to the basic ejector refrigeration cycle in Figure 1, the system consists of two loops, the power loop and the refrigeration loop. In the power loop, low-grade heat, Q_b, is used in a boiler or generator to evaporate high pressure liquid refrigerant (process 1-2). The high pressure vapour generated, known as the primary fluid, flows through the ejector where it accelerates through the nozzle. The reduction in pressure that occurs induces vapour from the evaporator, known as the secondary fluid, at point 3. The two fluids mix in the mixing chamber before entering the diffuser section where the flow decelerates and pressure recovery occurs. The mixed fluid then flows to the condenser where it is condensed rejecting heat to the environment, Q_c. A portion of the liquid exiting the condenser at point 5 is then pumped to the boiler for the completion of the power cycle. The remainder of the liquid is expanded through an expansion device and enters the evaporator of the refrigeration loop at point 6 as a mixture of liquid and vapour. The refrigerant evaporates in the evaporator producing a refrigeration effect, Q_e, and the resulting vapour is then drawn into the ejector at point 3. The refrigerant (secondary fluid) mixes with the primary fluid in the ejector and is compressed in the diffuser section before entering the condenser at point 4. The mixed fluid condenses in the condenser and exits at point 5 for the repetition of the refrigeration cycle.

State of Development

The first steam ejector refrigeration system was developed by Maurice Leblanc in 1910 and gained in popularity for air conditioning applications until the development of chlorofluorocarbon refrigerants in the 1930's and their use in the vapour compression cycle which was much more efficient than alternative thermally driven cycles. Research and development continued however and the ejector technology found applications in many engineering fields particularly in the chemical and process industries [1,2,3,4]. Systems have been developed with cooling capacities ranging from a few KW to 60,000 kW but despite extensive development effort the COP of the system, which can be defined as the ratio of the refrigeration effect to the heat input to the boiler, if one neglects the pump work which is relatively small, is still relatively low, less than 0.2. Ejector refrigeration systems are not presently commercially available off the shelf but a number of companies specialise in the design and application of bespoke steam ejector systems that use water as a refrigerant for cooling applications above 0°C.



To improve the efficiency of the simple ejector cycle more complex cycles have been investigated [5] as well as the integration of ejectors with vapour compression and absorption systems. An example of this is the Denso transport refrigeration system [6]. Significant effort has also been devoted to the development of solar driven ejector refrigeration systems [7].

Applications in the food sector

Applications in the food sector will be primarily in areas where waste heat is available to drive the ejector system. Such applications can be found in food processing factories where the ejector refrigeration system can be used for product and process cooling and transport refrigeration. Other possible application is in tri-generation where the ejector refrigeration system can be used in conjunction with combined heat and power systems to provide cooling.

Barriers to uptake of the technology

The main barriers to uptake of ejector refrigeration technology are:

- Lower COP, 0.2~0.3, compared to vapour compression systems and other thermally driven technologies. The COP also drops significantly at operation away from the design point.
- Unavailability of off the shelf systems to facilitate selection for particular applications and lack of 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 applications where there is sufficient waste heat or in tri-generation systems.
- Rising energy costs that could encourage the more effective utilisation of waste heat and better thermal integration of processes in food manufacturing.

Research and development needs

To increase the attractiveness and application of ejector refrigeration systems research and development is required to:

- Increase the efficiency of steady flow ejectors particularly at operation away from the design point.
- Develop alternative ejector types, such as rotodynamic ejectors [8] that offer potential for higher efficiencies.
- Develop ejectors that can operate with other natural refrigerants apart from water, such as CO_2 and hydrocarbons, to extend the range of applications to below $0^{\circ}C$.
- Research into the optimisation of cycles and the integration of ejectors with conventional vapour compression and absorption systems.

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