THE USE OF MINIATURE VAPOUR CYCLE SYSTEMS FOR AIRCREW COOLING

Background

The pilot of a modern high performance jet aircraft wears many layers of flight equipment. In addition to the normal flying clothing, these include full coverage anti-G suit, immersion suit, NBC suit etc. Even in a conditioned cockpit, the thermal insulation effect of these many layers causes a rise in body core temperature with resultant thermal stress.

Thermal stress causes fatigue (increased heart rate, oxygen uptake), dehydration, impaired concentration and ultimately reduces human performance and endurance. A similar problem exists for aircrew of unconditioned aircraft (particularly rotorcraft) deployed in hot climate regions of the world.

An effective method of reducing aircrew thermal stress is the wearing of a liquid cooled vest (LCV) - a garment containing tubing through which a cooled liquid is circulated.

There are a number of systems available for supplying cooling liquid to the LCV including: -

- Aircraft installed systems integrated with the Environmental Control System – an example being the Eurofighter Typhoon.
- Ice pack systems.
- Dry ice systems.
- Miniature vapour cycle systems.

This paper concentrates on the use of miniature vapour cycle systems.

Vapour Cycle Systems – Principles of Operation

A vapour cycle system uses a process of compression and expansion of a refrigerant to transfer heat from one location (evaporator heat exchanger) to another (condenser heat exchanger). The basic principle of the vapour compression cycle is illustrated in figure 1.

Refrigerant gas enters the compressor, where it is compressed and exits as a hot gas. It then passes through the condenser, where heat is transferred from the hot compressed gas to a cooling medium (usually air). As the heat is transferred, the refrigerant condenses and exits as a liquid.

The liquid refrigerant is then expanded (vaporised) at the evaporator, taking heat away from the evaporator medium (either air or liquid). The expansion valve controls the rate at which the refrigerant enters the evaporator.

The refrigerant now in a gaseous state passes into the compressor and the cycle recommences.

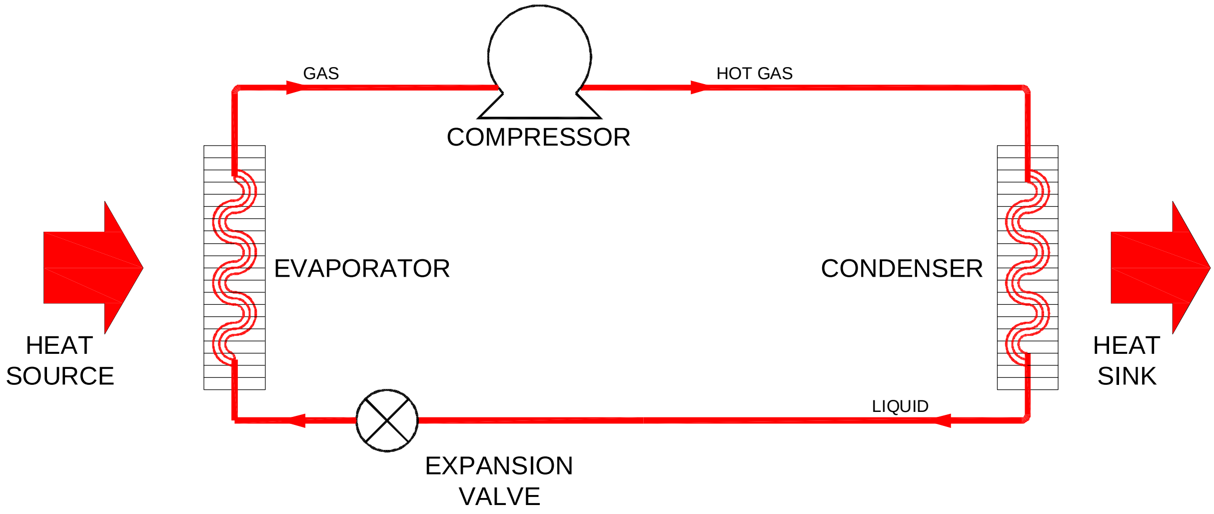

Figure 1

The Secondary Liquid Circuit

Figure 2 illustrates the addition of a secondary liquid circuit, which is used to circulate the liquid in a closed loop through the LCV and the evaporator heat exchanger. A pump maintains the secondary liquid flow.

Body heat from the aircrew is transferred to the liquid at the LCV and circulated to the evaporator heat exchanger, where it is cooled by the vapour cycle system and ultimately dumped to atmosphere at the condenser heat exchanger.

Types of liquid for the secondary circuit include: -

- Ethylene glycol/water
- Tyfoxit F
- Envirokool

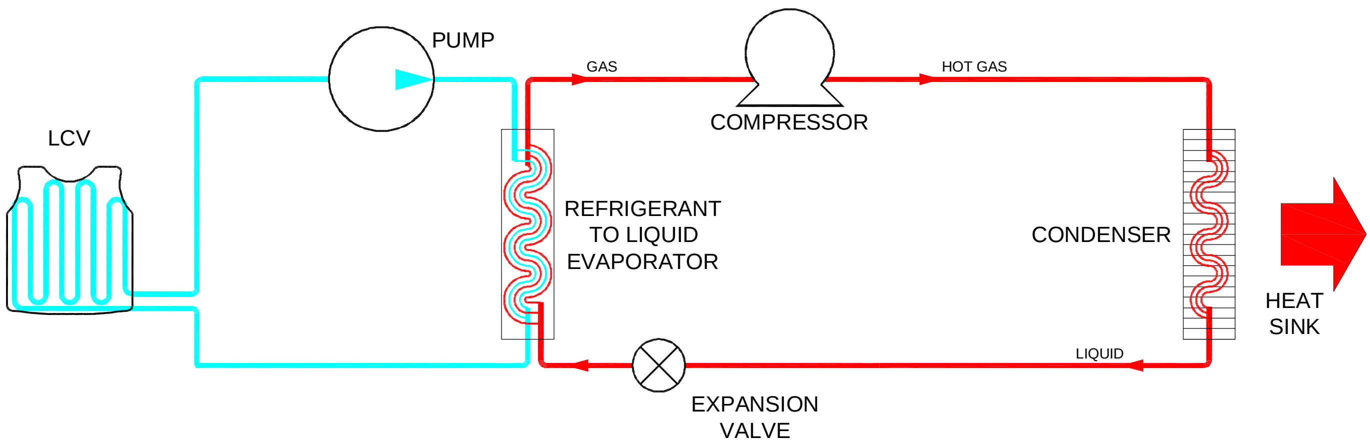

Figure 2

Power Supply and Battery Technology

For operating cost reasons, rechargeable (secondary) batteries are the preferred source of power for vapour cycle based aircrew cooling units.

Currently, the cell technology of choice is Lithium-Ion for the following reasons:

- High energy density.
- Long life (in excess of 500 charge/discharge cycles).
- Light weight.

Improvements in cell technology and the continuing development of fuel cells will further shrink the size and weight of the power source.

Optimal Flow Rate and Temperature Control

Physiological testing has demonstrated that a constant secondary liquid flow rate of 1 litre/minute, coupled with a supply temperature of around 18°C is optimal for effective aircrew cooling. Some adjustment of the supply temperature to cater for individual aircrew preference is considered desirable.

In order to be able to maintain a constant liquid supply temperature throughout a wide range of ambient operating temperatures (10° to 50°C), it is necessary to control the cooling output of the vapour cycle system. This can readily achieved by adjusting the rotational speed of the compressor and pulse width modulation of the expansion valve.

Trials have demonstrated effective liquid temperature control by means of these methods.

Eurofighter Typhoon Aircrew Ground Conditioning Unit

An example of a miniature vapour cycle system used for aircrew cooling is the Eurofighter Typhoon Aircrew Ground Conditioning Unit (AGCU).

The AGCU is used by the aircrew during the ground phase of operations, when in the crew room; during transit between the crew room and aircraft; for periods outside the aircraft between sorties and for periods in the cockpit prior to APU start.

TDP Cooling Unit Demonstrator

A further example is the demonstrator cooling unit produced for the UK MoD Aircrew NBC Protection Technology Demonstration Programme.

The TDP Cooling Unit was designed to explore the potential of reducing overall size and weight, whilst maintaining a level of performance consistent with effective aircrew cooling. A volume reduction in excess of 60% was achieved and mass was reduced by 40%.

Third Generation Cooling Unit

Design studies are continuing on a potential third generation cooling unit, which indicate that further size and weight reductions may be possible. Figure 3 provides a visual representation of the progression of reducing volumes.

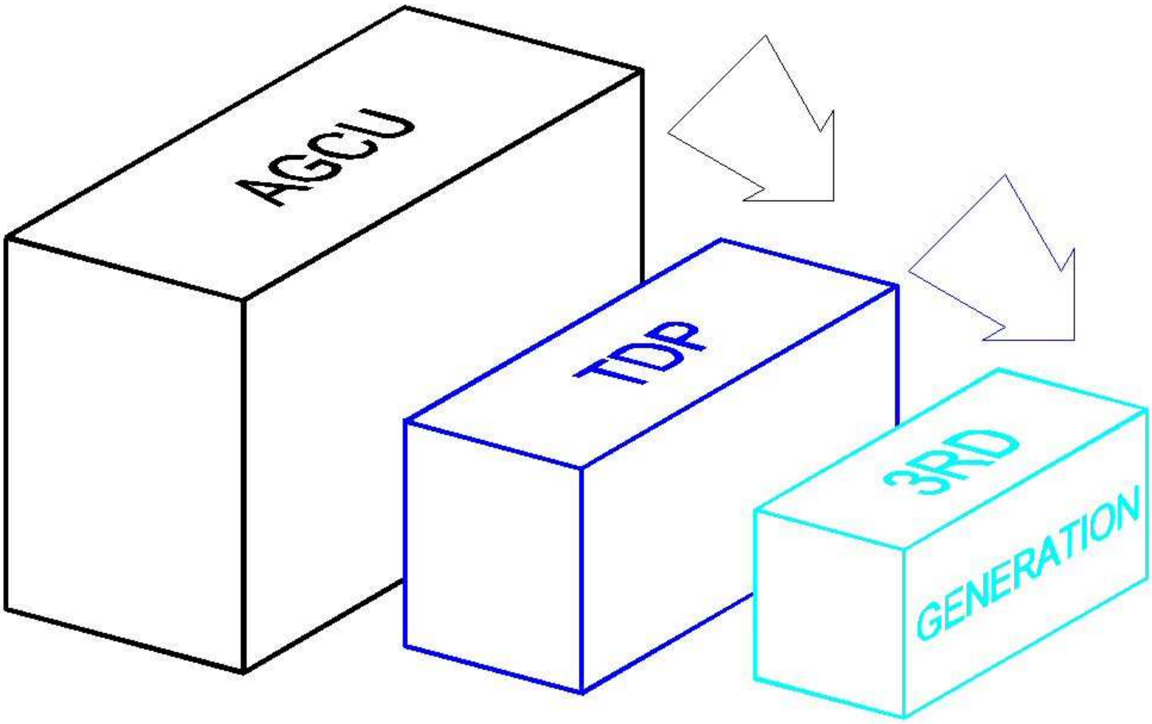

Figure 3

Conclusions

- A miniature vapour cycle system, used in conjunction with a liquid cooled vest, is an effective method of providing aircrew cooling.
  - demonstrated by extensive physiological testing and human subject trials.

- A miniature vapour cycle system is sufficiently small and light to be comfortably portable.

- A miniature vapour cycle system imposes a minimal logistics burden.
  - limited to battery charging only.