WATER HEAT PIPES

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- Basic principle of operation
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What is a Heat Pipe?

- A heat pipe is an extremely efficient conductor of heat.
- Heat pipe takes advantage of the latent heat of the working fluid to transfer heat at a high rate against a constant pipe temperature.
A simple heat pipe comprises an evacuated tube partly filled with a working fluid.

Using the latent capacity of the fluid, we can transfer large amounts of heat very rapidly from a hot point to a cold point on the tube wall.
Summary of Characteristics

- Heat is transferred by latent means giving a heat transfer rate of around 1000 times that of a solid copper rod.

- Vaporisation and condensation take place at the same temperature allowing high heat transfer at low temperature differences.

- Heat pipes without wicks (Thermosyphons) rely on gravity to return the condensed liquid.
Heat Pipe Features/Benefits

- No moving parts
- High effectiveness
- Low air-pressure drop
- Easy drainage of condensation
- No direct energy requirement
- No cross-contamination
- Long lasting
- Virtually maintenance-free
Heat Pipe Performance Factors

- Concept of thermal resistance
- Overall thermal resistance
- Heat pipe thermal resistance
Heat Pipe Performance Factors

- Airside performance
- Air velocity
- External surface area
- External fin pattern
- External tube diameter and pitch
- Fin and tube materials
Water Based Heat Pipes

- Water used as working fluid
- Internal heat pipe pressure decreases with temperature

- At 20°C Saturation Vapour Pressure for Water = 0.02 Bar
- At 20°C Saturation Vapour Pressure for R134a = 6 Bar
Charging Methods for Water

- Traditional Methods – Purging
  - Only used for individual pipes
  - Water is heated – steam generated forces non-condensable out of pipes
  - Some air remains
  - Non-condensable remain dissolved in water

- Traditional methods – evacuate and charge
  - Evacuation occurs prior to water being added
  - Charge-over from evacuation to charge breaks vacuum
  - Non-condensable dissolved in water ‘out-gas’ overtime

- Enhanced Method
  - Patent applied for technique
  - Evacuation after charging
  - Non-condensable removed during evacuation process
Water as Working Fluid

- **High Latent Heat**
  - Latent heat is the amount of energy absorbed as a given mass of the fluid changes phase from liquid to vapour.
  - Higher latent heat gives better heat transporting capacity of the working fluid.
  - The latent heat of water is approximately 14 times that of R134a, accordingly there is 14 times less mass transfer required to transfer the same heat between the ends of the heat pipe.

- **Reduction in size/cost**
  - Better performance results in reduction in number of rows/FPI required.
  - Reduced air side pressure drop.
Water as Working Fluid

- Greener and more Eco-Friendly
  - Water is harmless to the environment
  - Reduction of carbon footprint in manufacturing heat pipes
  - Water has zero Global Warming Potential (GWP) & Ozone Depletion Potential (ODP)
  - Gain more points in LEED & BREEAM Certification

- High thermal conductivity
  - Better heat transfer for a given temperature differential
  - Reduction in temperature gradient – High efficiency
Higher merit number

- Merit number is a dimensionless formulation of thermal transport properties
- Dimensionless – can be applied to any shape or size of heat pipe
- Gives an indication of relative merit of different fluids at various temperatures
- Higher merit corresponds to low temperature gradient
- At 20ºC merit of water is 10 times higher than refrigerant
- Merit Number 10 times higher means to a good approximation temperature gradient 10 times lower
Test Setup

Test Setup for Loop WHPs
Performance Comparison for WHP

- Test Samples obtained by varying airflow rate through the test rig
- Quantification of performance done in terms of Effectiveness ($\varepsilon$)

$$\varepsilon = \frac{T_1 - T_2}{T_1 - T_3} = \frac{T_4 - T_3}{T_1 - T_3}$$
Sample Test Result for WHP

Details of Test Piece
- Tubes: 12mm X 0.35 Rifled
- Fins: 0.15/Aluminium/Ripple
- Finned length: 600mm
- Number of Rows: 2
- Tubes High: 16

2 Row heat pipe test piece
Sample Comparative Test Result for 2 row test piece using R134a and Water

The comparative results obtained show percentage effectiveness improvements of between 16% and 18%.