

## COOLING AND HEATING

Heating of the hydraulic fluid in operation is caused by inefficiencies. Inefficiencies result in losses of input power (PL) which are converted to heat. The size of heat exchanger required to cool away operational heat load is equal to the total power losses of the hydraulic system and can be expressed as:

$$PL_{\text{total}} = PL_{\text{pump}} + PL_{\text{valves}} + PL_{\text{plumbing}} + PL_{\text{actuators}}$$

In practice the total power loss of a system cannot be accurately calculated due to the number of unknown variables. As a rule of thumb for heat exchanger sizing, a  $PL_{\text{total}}$  of 25% of input power is adequate for most systems. For example, a system with a continuous input power of 100 hp would require a heat exchanger capable of dissipating a heat load of 25 hp.

### Cooling

Air/oil heat exchangers are rated according to the amount of heat dissipated for each degree of difference between the maximum allowable oil temperature and the ambient air temperature at a given flow of oil through the cooler and assuming manufacturers specified fan diameter, pitch and speed remain constant. In the above example if the temperature difference between the oil and air was 70°F (21°C) and the oil flow through the cooler was 8gpm (30L/min) a suitable cooler would be rated at 0.357 hp/°F at a flow of 8gpm ( $0.357 \times 70 = 25$  hp). If ambient conditions changed such that the temperature difference between oil and air dropped to 50°F, all other variables held constant, the same cooler would no longer be adequate ( $0.357 \times 50 = 17.85$  hp).

In the case of water/oil heat exchangers, in addition to the temperature difference between oil and water, the ratio of oil flow to water flow influences cooling performance. Manufacturers typically rate water/oil heat exchangers based on, for example, a temperature difference of 104°F (40°C) and an oil to water flow ratio of 2:1, and publish correction factors for parameters falling outside of these values.

The heat load of an existing hydraulic system can be determined by measuring tank temperature at start up and again after the system has been in operation for a measured amount of time, using the formula:

$$P = \frac{V \times \Delta T}{32.4 \times \Delta t}$$

Where

$$\begin{aligned} P &= \text{power (heat load) in kW} \\ V &= \text{tank volume in litres} \\ \Delta T &= \text{temperature change } (T_2 - T_1) \text{ in } ^\circ\text{C} \\ \Delta t &= \text{time change } (t_2 - t_1) \text{ minutes} \end{aligned}$$

And assuming an oil density of 0.89 kg/litre and specific heat of 2.08 kJ/kg°C

$$\begin{aligned} \text{Conversions: } \quad \text{kW} \div 0.7457 &= \text{hp} \\ \text{US gallons} \times 3.78531 &= \text{litres} \\ (^\circ\text{F} - 32) \div 1.8 &= ^\circ\text{C} \end{aligned}$$

The hydraulic tank dissipates heat through conduction and radiation. To calculate the heat dissipated from a steel reservoir:

$$P = \Delta T \times A \times 0.001$$

Where

$$\begin{aligned} P &= \text{power in hp} \\ \Delta T &= \text{temperature difference between oil and ambient air in } ^\circ\text{F} \\ A &= \text{area of tank in ft}^2 \text{ (excluding base unless elevated at least 6")} \end{aligned}$$

In metric units:

$$P = \Delta T \times A \times 0.016$$

Where

P = power in kW  
 $\Delta T$  = temperature difference between oil and ambient air in °C  
A = area of tank in m<sup>2</sup> (excluding base unless elevated at least 150mm)

In practice, the heat load dissipated by the reservoir or tank is relatively small.

### Heating

In cold weather conditions, when it is necessary to fit a heating element to the tank to maintain hydraulic oil temperature during idle periods, the power of the heating element required can be calculated using the formula:

$$P = \Delta T \times A \times 0.001 \times 0.7457$$

Where

P = power in kW  
 $\Delta T$  = temperature difference between oil and ambient air in °F  
A = area of tank in ft<sup>2</sup>.

In metric units:

$$P = \Delta T \times A \times 0.016$$

Where

P = power in kW  
 $\Delta T$  = temperature difference between oil and ambient air in °C  
A = area of tank in m<sup>2</sup>.

To calculate the power required to heat a hydraulic reservoir from a low ambient to an acceptable operating temperature prior to start up:

$$P = \frac{V \times \Delta T}{32.4 \times \Delta t}$$

Where

P = power in kW  
V = tank volume in litres  
 $\Delta T$  = required temperature change ( $T_2 - T_1$ ) in °C  
 $\Delta t$  = required time change ( $t_2 - t_1$ ) minutes

And assuming an oil density of 0.89 kg/litre and specific heat of 2.08 kJ/kg°C

Conversions: US gallons  $\times$  3.78531 = litres  
(°F - 32)  $\div$  1.8 = °C

### **Installation**

- A relief valve should always be fitted across the inlet and outlet port of the heat exchanger to prevent pressurisation and possible failure should the heat exchanger become blocked.
- Air blast heat exchangers should be situated so that they are at least half the fan diameter clear of any obstructions on both sides of the core.

### **Heat and power equivalents**

1 HP = 2545 BTU/hr = 745.7 watts = 0.7457 kW