Calculation of an oil/air cooler

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In all hydraulic systems any kind of restriction heats the oil. The oil temperature becomes higher and higher until the added thermal energy has the same value as the radiation energy and the energy which is caused by convection which both are absorbed by the surrounding atmosphere. After a certain operation time the temperature becomes stationary. If this temperature is too high, the oil must be cooled.

Hot oil costs money!

The oil changing period gets shorter. Gaskets and wearing components must be changed and the hydraulic system efficiency is reduced. In order to choose the required cooler type we must know the required cooling performance.

Approximate calculation

The required cooling performance P_K can generally be calculated as in the following term:

$$P_M = \frac{p \times Q_{oil}}{600 \times \eta} \qquad P_K = P_M\,(1 - \eta)$$

Hydraulic circuits with constant pumps have a general efficiency from approximately 70-75%, η = 0,7 bis 0,75 /
circuits with variable pumps: η = 0,75 bis 0,80.

η = general efficiency
P_K = required cooling performance [kW]
P_M = required motor power [kW]
p = oil pressure [bar]
Q_P = oil flow [l/min]

How to find out the required cooling performance with the rise in temperature:

For existing hydraulic circuits the heat input to the oil can be accurately determined if the rise in temperature is known over a certain period of time. This then gives the amount of heat to be exchanged by the cooler in order to maintain the system at an optimum operating temperature.

$$P_K = \frac{m \times c \times (t_2 - t_1)}{1000\ T}$$

P_K = required cooling performance [kW]
m = const. mass of the reservoir [kg]
c = specific heat capacity [Wh/kg°C]
(c~0,53 for hydraulic oil, c~1,16 for water)
t_1 = oil temperature at the begin [°C]
t_2 = oil temperature at the end [°C]
T = heat up time [h]

Temperature behaviour:

1. oil temperature difference Δt_{oil} by one pass
2. air temperature increase Δt_L

$$1.\ \Delta t_{oil} = \frac{36 \times P_K}{Q_{oil}}\ [^\circ C] \qquad 2.\ \Delta t_L = \frac{P_K}{Q_L}\ [^\circ C]$$

Selection of the cooler:

After calculation the required cooling performance (P_K), the specific cooling performance (P_{spec}) must be determined.

$$P_{spec} = \frac{P_K}{t_{oil} - t_L}\ [kW/^\circ C]$$

P_{spec} = specific cooling performance (kW/°C)
T_{oil} = oil temperature inlet (°C)
T_L = air temperature inlet (°C)

Enter the value of P_{spec} (kW/°C) on the vertical line on the cooling performance diagram and determine the junction with the horizontal line for oil flow (l/min) of the required cooler type. In most of the cases it is enough if this line is lying close to a curve in the diagram because the cooling capacity is calculated with enough safeties.

Calculation of the oil pressure drop:
If the right cooler is found, we recommend to check the oil pressure drop and to avoid too high oil pressure loss after through the cooler.

The values indicated in the diagram are valid for hydraulic oil with a viscosity of 30cSt (appr. ISO VG 32). Multiply the pressure drop by the correction factor f according to the used hydraulic oil viscosity.

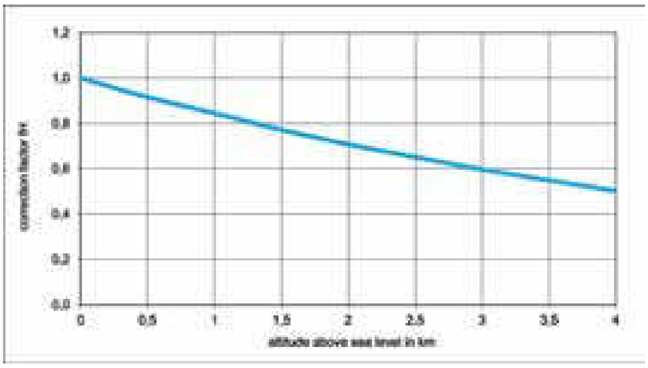
$\Delta p = \Delta p30cst \times f_p$

Δp = oil pressure drop [bar]
Δp_{30cst} = oil pressure drop at 30cst oil viscosity [bar]
fp = correction factor for the oil viscosity [ ]

We also recommend you to check the oil pressure drop also for extreme situation (e.g. cold start). If necessary bypass valves should be installed to avoid overpressure.

Correction factor f_H

for cooling performance depending on the altitude (approximate value).



Correction factor f_p

for oil pressure drop (approximate value)