Understanding Heat Pipe performance

1. REQUIRED HEAT EXTRACTION RATE

If;

C	=	Heat content (to be removed)	J
t	=	Design cycle time	s
Q	=	Heat extraction rate,	W

then the heat energy removal rate necessary to achieve the design cycle time is given by;

HEAT EXTRACTION RATE; $$Q = \frac{C}{t} \quad \text{W}$$

2. CYCLE AVERAGE COOL PIPE TEMPERATURE

The heat transport capability of a Cool Pipe is temperature dependent. It is therefore first necessary to establish its temperature of operation before determining how rapidly the Cool Pipe will remove heat energy from the polymer. For the purpose of these Technical Notes, the calculation of the Cool Pipe temperature is based on the required heat extraction rate given by 2. above., the temperature gradient through the core pin, the temperature gradient through the core pin/Cool Pipe interface and the polymer injection/ejection temperatures.

Heat extraction rate;

Let;

Q = Heat extraction rate W (given by 2. above).

Core pin temperature gradient;

If;

δT_c	=	Core pin temperature gradient,	^oC
d_c	=	Core pin outer diameter,	mm
d_{cp}	=	Cool Pipe diameter,	mm
l_h	=	Core pin length in contact with the molten polymer,	mm
λ	=	Thermal conductivity of the core material (see appendix 2),	$W\ m^{-1}\ {}^oC^{-1}$

then the core pin temperature gradient is given by;

$$\delta T_c = Q\left[\frac{\log_e\left(\frac{d_c}{d_{cp}+0.2}\right)}{2\pi l_h \lambda}\right]10^3 \quad {}^oC$$

Core pin/Cool Pipe interface temperature gradient;

If;

δT_i	=	Core pin/Cool Pipe interface temperature gradient,	^oC
d_{cp}	=	Cool Pipe diameter,	mm
l_h	=	Core pin length in contact with the molten polymer,	mm

then the interface temperature gradient is given by;

$$\delta T_i \quad = \quad Q\left[\frac{\log_e\left(\frac{d_{cp}+0.2}{d_{cp}}\right)}{1.8\pi l_h}\right]10^3 \quad {}^oC$$

Injection/ejection temperatures;

Let;

T_1 = Polymer injection temperature, ^oC
T_2 = Component ejection temperature, ^oC

Cool Pipe average temperature;

If;

T_{AV} = Cool Pipe average temperature,

Then;

AVERAGE COOL PIPE TEMPERATURE; $T_{AV} = \left(\frac{T_1 + T_2}{2}\right) - \left(\delta T_c + \delta T_i\right) \quad {}^oC$

3. COOL PIPE HEAT TRANSPORT CAPABILITY

Table 1 below gives the heat transport capabilities of different diameter Cool Pipes at different temperatures. From the table, select the appropriate Cool Pipe diameter and the nearest temperature **below** the cycle average Cool Pipe temperature and read off the cooling capacity.

	Cooling Capacity, Watts				
Dia.mm.	25°C	50°C	100°C	150°C	200°C
2.0	9	11	14	15	14
2.5	13	16	20	22	20
3.0	18	23	28	31	28
4.0	36	42	48	53	48
5.0	57	66	76	82	76
6.0	69	80	92	99	92
8.0	96	111	128	138	128
10.0	122	142	163	177	163
12.0	150	175	202	218	202
15.0	205	240	275	300	275
20.0	275	320	370	395	370

COOL PIPE HEAT TRANSPORT CAPABILITY; Q_{cp} W

4. REQUIRED/ACTUAL HEAT TRANSPORT COMPARISON

If Q_{cp} from 4 above is greater than or equal to Q from 2. above, then the chosen diameter Cool Pipe, d_{cp} is acceptable and step 6. below should be checked.

If Q_{cp} from 4 above is less than Q from 2. above, then either;

a) The chosen Cool Pipe diameter, d_{cp}, must be increased until $Q_{cp} = Q$, or,

b) The design cycle time, t, must be increased until $Q = Q_{cp}$.

5. COOL PIPE COOLED LENGTH

The rate of transfer of heat energy from the Cool Pipe surface into the cooling water is dependent upon a number of factors. These include the velocity of the cooling water over the Cool Pipe surface and the tool geometry around the cooled section of the Cool Pipe. Precise calculation of the necessary length of the Cool Pipe to be cooled is, therefore, complex. Acceptably accurate results may, however, be obtained as follows;

Let;

Q	=	Heat extraction rate,	W
T_{AV}	=	Cool Pipe average temperature,	^{o}C
T_{W}	=	Cooling water temperature,	^{o}C
d_{cp}	=	Cool Pipe diameter,	mm
l_{c}	=	Minimum necessary cooled Cool Pipe length,	mm

then the minimum necessary cooled Cool Pipe length is given by;

MINIMUM COOLED COOL PIPE LENGTH; $$l_c = \frac{42.44Q}{d_{cp}\left(T_{AV} - T_{W}\right)} \quad \text{mm}$$