E3.6 TRANSIENT HEAT CONDUCTION LOG SHEET & DISCUSSION

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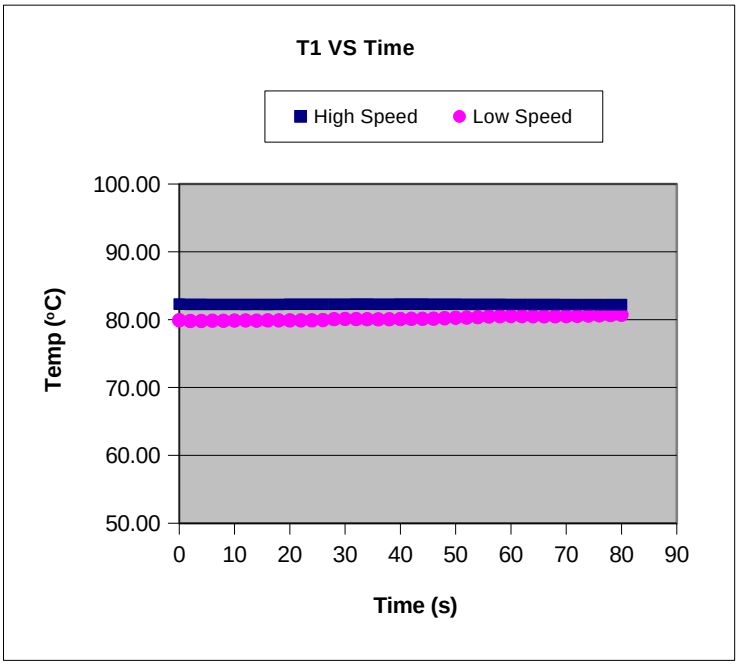
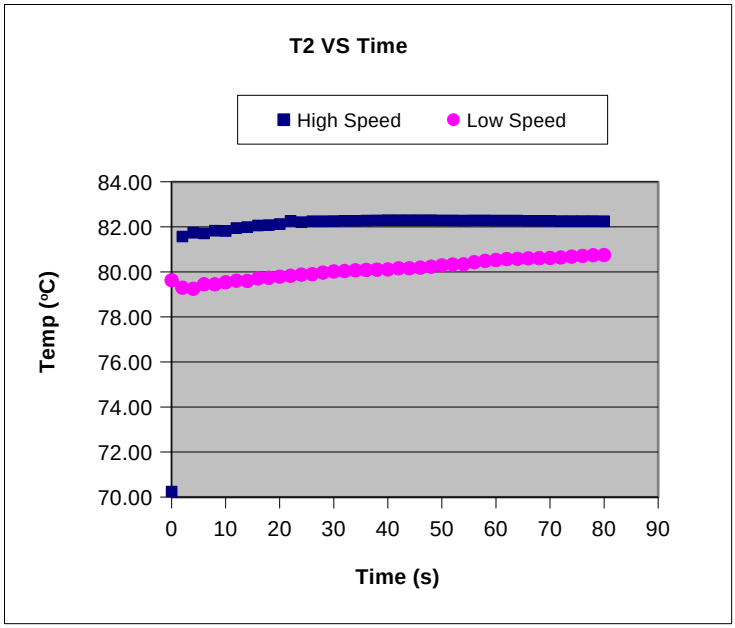
7.1 Temperatures versus Time at different pump rates

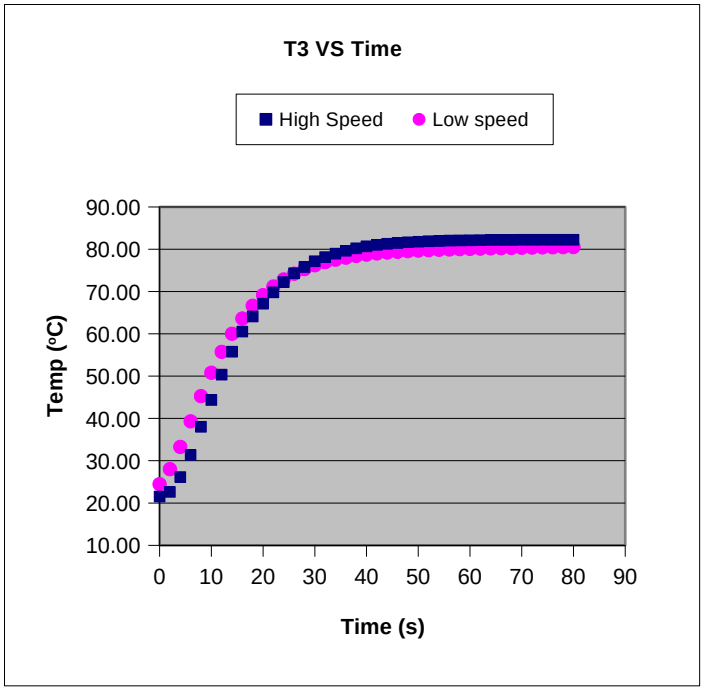
1) **T1 versus Time at different pump rates**



2) **T2 versus Time at different pump rates**



3) T3 versus Time at different pump rates



7.15 Calculation of non-dimensional temperature (Theta), Fo, 1/Bi and h

For High-Speed Pump:

Theta = (Tc – Tinf)/ (Ti – Tinf)

Theta @ t =12s is (Tc – Tinf)/ (Ti – Tinf) where Tc = T3 and Tinf = T1

At t = 12 seconds:

T1 = 82.24, T2 = 81.95, T3 = 50.34 (T3 @ initial t = 0 is 21.52)

Therefore, **Theta** @ t =12s is (50.34 – 82.24)/ (21.52 – 82.24) = **0.525**

Fo = **(alpha * t)/ R^2** where

Alpha (Thermal Diffusivity) = 0.45 x 10^-5

R, radius of cylinder = 0.01

At t = 12 seconds:

Fo = (0.45 x 10^-5 * 12)/ (0.01^2) = **0.54**

1/Bi is determined from Heisler's Chart using Theta and Fo values calculated

Therefore, corresponding **1/Bi** value at t =12s is **1.00**

k/hR = **1/Bi**

where k (Thermal Conductivity) = 16.3

R, radius of cylinder = 0.01

Bi @ t=12s = 1.00

h at t = 12s

h = 16.3/(1*0.01) = **1630**

<u>For Low-Speed Pump:</u>

Theta = **(Tc – Tinf)/ (Ti – Tinf)**

Theta @ t =12s is (Tc – Tinf)/ (Ti – Tinf) where Tc = T3 and Tinf = T1

At t = 12 seconds:

T1 = 79.89, T2 = 79.61, T3 = 55.73 (T3 @ initial t = 0 is 24.46)

Therefore, **Theta** @ t =12s is (55.73 – 79.89)/ (22.46 – 79.89) = **0.436**

Fo = **(alpha * t)/ R^2** where

Alpha (Thermal Diffusivity) = 0.45 x 10^-5

R, radius of cylinder = 0.01

At t = 12 seconds:

Fo = (0.45 x 10^-5 * 12)/ (0.01^2) = **0.54**

1/Bi is determined from Heisler's Chart using Theta and Fo values calculated

Therefore, corresponding **1/Bi** value at t =12s is **0.78**

k/hR = **1/Bi**

where k (Thermal Conductivity) = 16.3

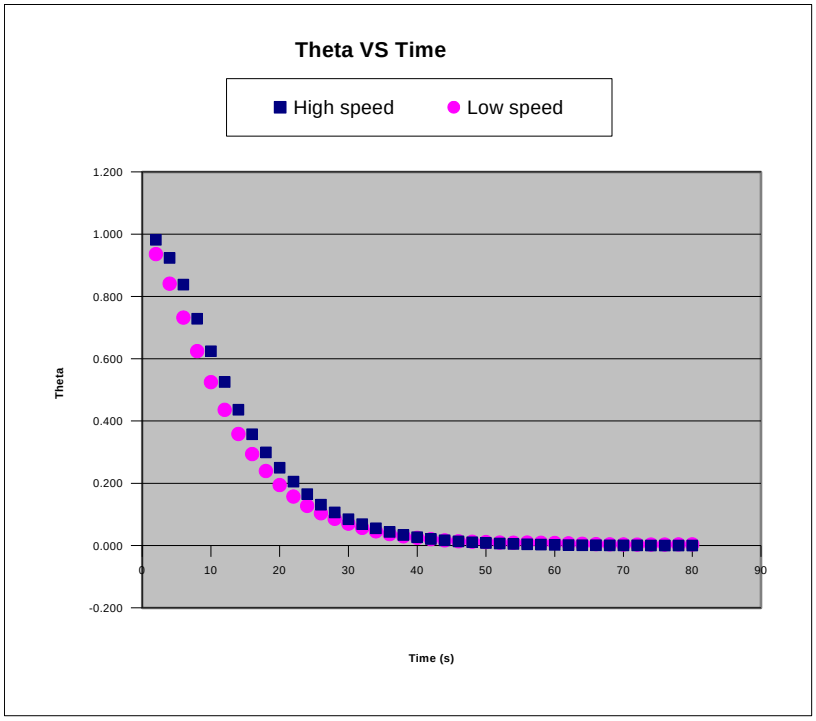
R, radius of cylinder = 0.01

Bi @ t=12s = 0.78

h at t = 12s

h = 16.3/(0.78*0.01) = **2089.74**

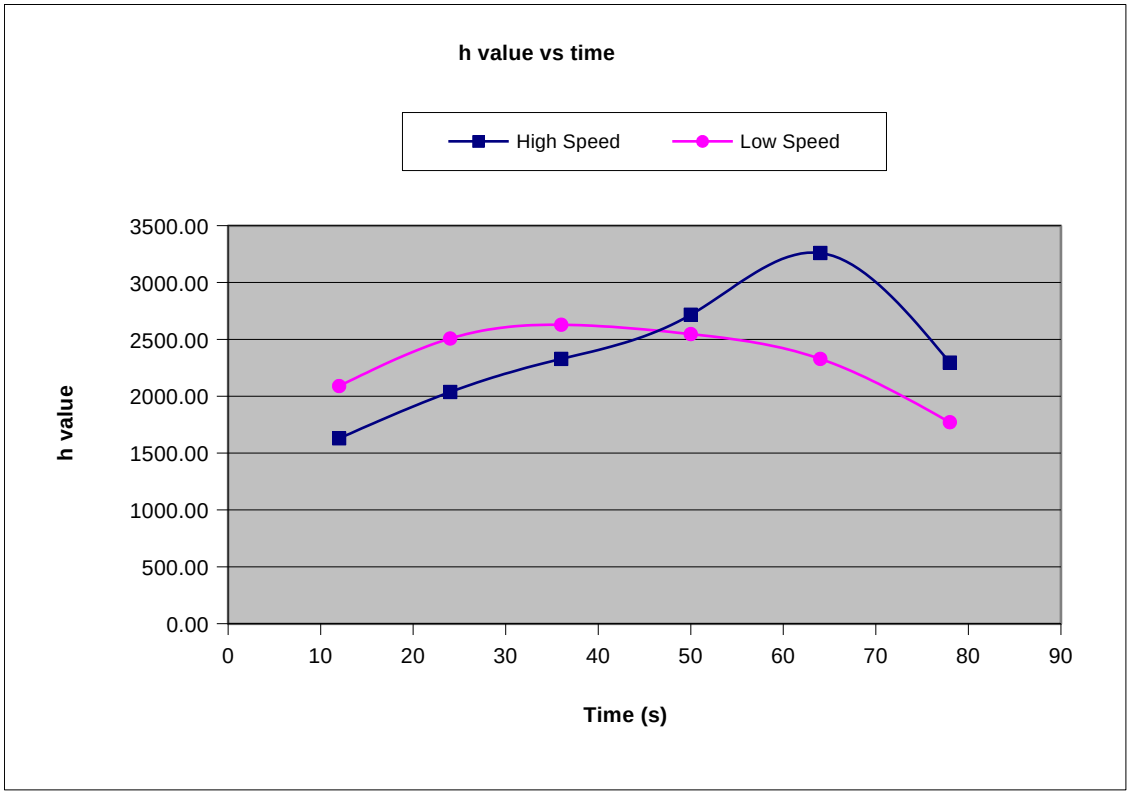
7.2 Non-dimensional temperature different, Theta versus Time at different pump rates



7.3 Effect of pump rates on the heat convection coefficient (h)

From the h values calculated from the data collect for both high and low speed pumps, we can generally deduce that the speed of the pumps has caused a difference in h values during the first 40 seconds of heat transfer and the last 40 seconds of the heat transfer. Looking at the trend, the h values for the low-speed pump is higher than the h values for the high-speed pump for the first 40 seconds of heat transfer. Whereas, after the first 40 seconds, the high-speed pump seems to have a higher h value than the low-speed pump. This shows that when the temperature gradient/difference is high between the rod and the surrounding, the convection rate is higher at lower pump speeds but when the temperature of the rod is approaching the surrounding temperature the convection rate is higher at higher pump speeds.

7.4 Heat convection coefficient (h) versus Time



Pump Speed	Stainless Steel

High			radius = 10 mm				
Time (s)	T1	T2	T3	theta	Fo	1/Bi	h
0	82.30	70.24	21.52				#DIV/0!
2	82.26	81.57	22.61	0.982	**0.09**		#DIV/0!
4	82.26	81.74	26.14	0.924	**0.18**		#DIV/0!
6	82.25	81.71	31.35	0.838	**0.27**		#DIV/0!
8	82.25	81.83	38.01	0.728	**0.36**		#DIV/0!
10	82.25	81.82	44.35	0.624	**0.45**		#DIV/0!
12	82.24	81.95	50.34	0.525	**0.54**	1.00	1630.00
14	82.25	81.99	55.76	0.436	**0.63**		#DIV/0!
16	82.24	82.06	60.54	0.357	**0.72**		#DIV/0!
18	82.25	82.08	64.09	0.299	**0.81**		#DIV/0!
20	82.27	82.13	67.10	0.250	**0.9**		#DIV/0!
22	82.27	82.27	69.80	0.205	**0.99**		#DIV/0!
24	82.27	82.21	72.24	0.165	**1.08**	0.80	2037.50
26	82.28	82.25	74.31	0.131	**1.17**		#DIV/0!
28	82.28	82.25	75.81	0.106	**1.26**		#DIV/0!
30	82.28	82.26	77.16	0.084	**1.35**		#DIV/0!
32	82.29	82.27	78.13	0.068	**1.44**		#DIV/0!
34	82.29	82.27	78.94	0.055	**1.53**		#DIV/0!
36	82.28	82.28	79.62	0.044	**1.62**	0.70	2328.57
38	82.28	82.29	80.22	0.034	**1.71**		#DIV/0!
40	82.29	82.30	80.68	0.026	**1.8**		#DIV/0!
42	82.29	82.30	81.01	0.021	**1.89**		#DIV/0!
44	82.29	82.30	81.27	0.017	**1.98**		#DIV/0!
46	82.28	82.30	81.47	0.013	**2.07**		#DIV/0!
48	82.28	82.30	81.64	0.011	**2.16**		#DIV/0!
50	82.27	82.29	81.77	0.008	**2.25**	0.60	2716.7
52	82.26	82.29	81.87	0.006	**2.34**		#DIV/0!
54	82.26	82.28	81.95	0.005	**2.43**		#DIV/0!
56	82.26	82.29	82.03	0.004	**2.52**		#DIV/0!
58	82.26	82.29	82.08	0.003	**2.61**		#DIV/0!
60	82.25	82.28	82.11	0.002	**2.7**		#DIV/0!
62	82.25	82.28	82.15	0.002	**2.79**		#DIV/0!
64	82.24	82.28	82.17	0.001	**2.88**	0.50	3260.0
66	82.24	82.27	82.18	0.001	**2.97**		#DIV/0!
68	82.24	82.27	82.20	0.001	**3.06**		#DIV/0!
70	82.23	82.27	82.21	0.000	**3.15**		#DIV/0!
72	82.23	82.26	82.21	0.000	**3.24**		#DIV/0!
74	82.23	82.26	82.22	0.000	**3.33**		#DIV/0!
76	82.22	82.26	82.22	0.000	**3.42**		#DIV/0!
78	82.22	82.26	82.23	-0.0002	**3.51**	0.71	2295.8
80	82.22	82.25	82.22	0.000	**3.6**		#DIV/0!

Pump Speed Low			Stainless Steel radius = 10 mm				
Time (s)	T1	T2	T3	theta	Fo	1/Bi	h

0	79.92	79.63	24.46	**No need to calculate at time=zero**			#DIV/0!
2	79.81	79.30	28.00	0.936	**0.09**		#DIV/0!
4	79.81	79.25	33.26	0.841	**0.18**		#DIV/0!
6	79.85	79.45	39.30	0.732	**0.27**		#DIV/0!
8	79.84	79.45	45.26	0.624	**0.36**		#DIV/0!
10	79.87	79.54	50.79	0.525	**0.45**		#DIV/0!
12	79.89	79.61	55.73	0.436	**0.54**	0.78	2089.74
14	79.86	79.60	60.01	0.358	**0.63**		#DIV/0!
16	79.90	79.71	63.61	0.294	**0.72**		#DIV/0!
18	79.90	79.74	66.63	0.239	**0.81**		#DIV/0!
20	79.90	79.79	69.13	0.194	**0.9**		#DIV/0!
22	79.90	79.83	71.18	0.157	**0.99**		#DIV/0!
24	79.91	79.88	72.85	0.127	**1.08**	0.65	2507.69
26	79.95	79.90	74.20	0.104	**1.17**		#DIV/0!
28	80.08	79.97	75.30	0.086	**1.26**		#DIV/0!
30	80.11	80.02	76.20	0.070	**1.35**		#DIV/0!
32	80.09	80.04	76.93	0.057	**1.44**		#DIV/0!
34	80.07	80.07	77.53	0.046	**1.53**		#DIV/0!
36	80.05	80.09	78.01	0.037	**1.62**	0.62	2629.03
38	80.06	80.10	78.41	0.030	**1.71**		#DIV/0!
40	80.10	80.11	78.72	0.025	**1.8**		#DIV/0!
42	80.13	80.16	79.00	0.020	**1.89**		#DIV/0!
44	80.13	80.16	79.21	0.017	**1.98**		#DIV/0!
46	80.15	80.19	79.39	0.014	**2.07**		#DIV/0!
48	80.22	80.23	79.54	0.012	**2.16**		#DIV/0!
50	80.29	80.29	79.67	0.011	**2.25**	0.64	2546.88
52	80.31	80.33	79.78	0.009	**2.34**		#DIV/0!
54	80.37	80.34	79.87	0.009	**2.43**		#DIV/0!
56	80.47	80.43	79.94	0.009	**2.52**		#DIV/0!
58	80.51	80.49	80.02	0.009	**2.61**		#DIV/0!
60	80.54	80.53	80.08	0.008	**2.7**		#DIV/0!
62	80.53	80.57	80.14	0.007	**2.79**		#DIV/0!
64	80.51	80.58	80.20	0.006	**2.88**	0.70	2328.57
66	80.50	80.60	80.25	0.004	**2.97**		#DIV/0!
68	80.51	80.61	80.30	0.004	**3.06**		#DIV/0!
70	80.53	80.62	80.34	0.003	**3.15**		#DIV/0!
72	80.56	80.64	80.39	0.003	**3.24**		#DIV/0!
74	80.61	80.68	80.43	0.003	**3.33**		#DIV/0!
76	80.63	80.71	80.45	0.003	**3.42**		#DIV/0!
78	80.68	80.74	80.48	0.004	**3.51**	0.92	1771.74
80	80.72	80.75	80.51	0.004	**3.6**		#DIV/0!