

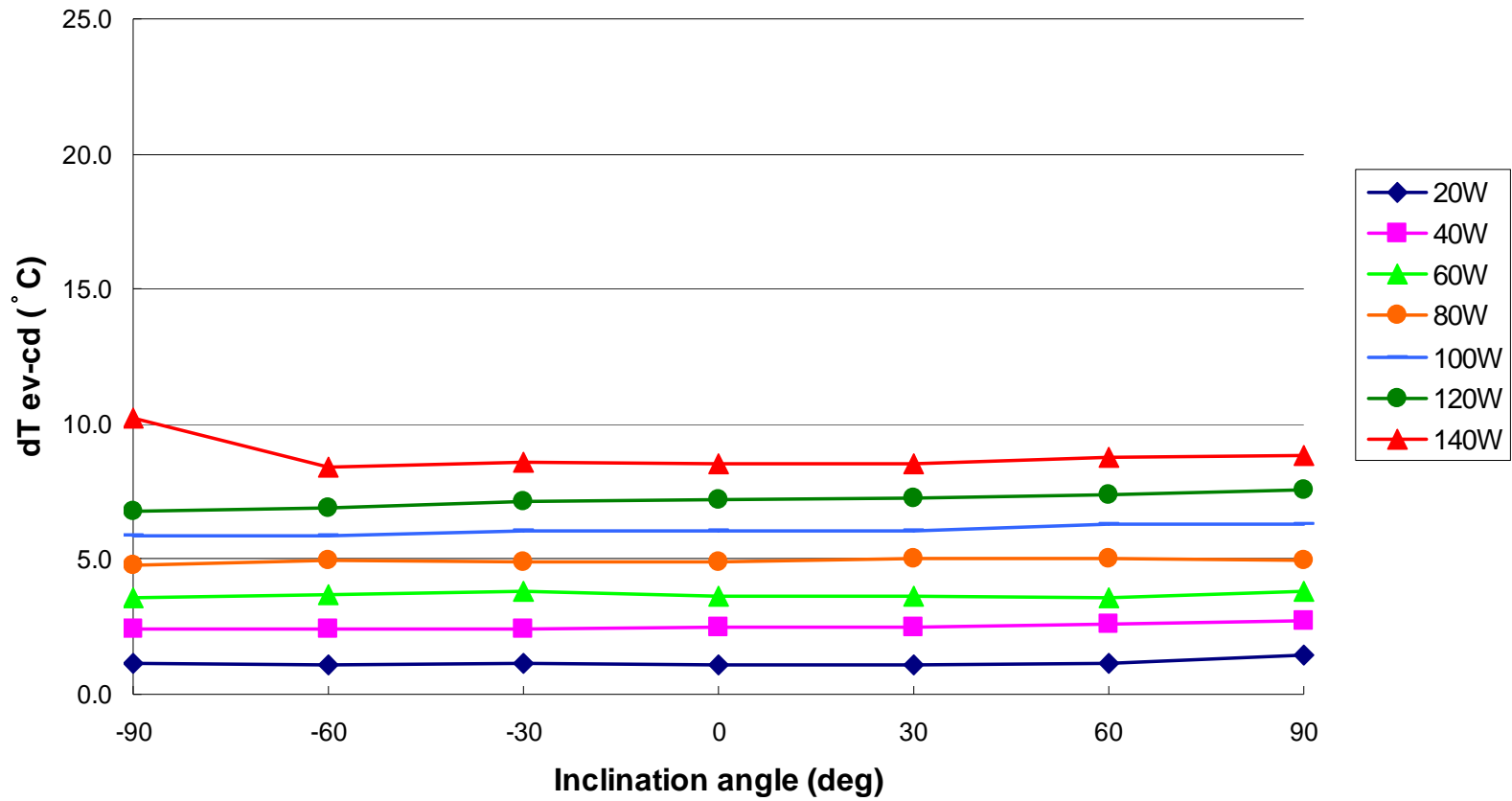
## Heat Pipe Test Report

Manufacturer		Enertron					Test conditions				Test date	3/24/2014				
Wick structure/ Working fluid		Sintered Powder Metal/ Water					Effective area (m <sup>2</sup> )		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block					
Pipe specification		C110 Copper 0.3mm wall thickness					Coolant temp (°C)		35							
Diameter		±0.05 mm		12			Contact length of ev/cd (mm)		55							
Length		±0.10 mm		200			At 90° the evaporator is directly below the condenser; 0° is horizontal.									
Flatten thickness		±0.05 mm		n/a												
Bend angle		±1 deg		n/a												
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)							
									ev	cd	eb1	eb2	cb1	38		
90	20	17.68	1.45	0.07	17684	1.65	0.08	15540	38.85	37.40	39.00	39.00	37.50	37.20		
	40	35.37	2.75	0.07	18648	3.05	0.08	16814	42.35	39.60	42.70	42.60	39.60	39.60		
	60	53.05	3.23	0.05	23853	4.40	0.07	17483	45.13	41.90	45.90	46.20	42.00	41.30		
	80	70.74	4.95	0.06	20721	5.70	0.07	17994	49.08	44.13	49.60	49.20	44.10	43.30		
	100	88.42	6.35	0.06	20190	15.55	0.16	8245	52.63	46.28	53.20	52.80	37.70	37.20		
	120	106.10	7.55	0.06	20377	8.70	0.07	17684	55.75	48.20	56.60	56.00	48.10	47.10		
	140	123.79	8.83	0.06	20339	10.20	0.07	17597	59.48	50.65	60.10	60.00	50.50	49.20		
60	20	17.68	1.18	0.06	21823	1.35	0.07	18994	38.83	37.65	38.90	38.70	37.70	37.20		
	40	35.37	2.58	0.06	19916	2.95	0.07	17384	42.40	39.83	42.60	42.30	39.80	39.20		
	60	53.05	3.85	0.06	19980	4.35	0.07	17684	45.78	41.93	46.10	45.80	42.00	41.20		
	80	70.74	5.03	0.06	20411	5.90	0.07	17384	49.08	44.05	49.60	49.30	44.00	43.10		
	100	88.42	6.28	0.06	20432	7.05	0.07	18186	52.43	46.15	52.90	52.70	46.20	45.30		
	120	106.10	7.38	0.06	20861	8.50	0.07	18100	55.68	48.30	56.40	55.90	48.40	46.90		
	140	123.79	8.78	0.06	20455	10.00	0.07	17949	59.40	50.63	59.80	59.80	50.40	49.20		
30	20	17.68	1.10	0.06	23311	1.35	0.07	18994	38.73	37.63	38.80	38.80	37.70	37.20		
	40	35.37	2.50	0.06	20513	2.90	0.07	17684	42.35	39.85	42.50	42.40	39.70	39.40		
	60	53.05	3.65	0.06	21075	4.30	0.07	17890	45.58	41.93	46.10	45.70	41.90	41.30		
	80	70.74	5.00	0.06	20513	5.70	0.07	17994	49.03	44.03	49.30	49.20	44.10	43.00		
	100	88.42	6.08	0.06	21104	7.15	0.07	17931	52.40	46.33	52.90	52.80	46.30	45.10		
	120	106.10	7.28	0.06	21148	8.60	0.07	17890	55.55	48.28	56.00	56.00	48.00	46.80		
	140	123.79	8.55	0.06	20993	9.95	0.07	18039	59.15	50.60	59.70	59.80	50.70	48.90		
0	20	17.68	1.08	0.05	23853	1.30	0.06	19724	38.75	37.68	38.80	38.80	37.70	37.30		
	40	35.37	2.48	0.06	20721	2.90	0.07	17684	42.23	39.75	42.50	42.20	39.70	39.20		
	60	53.05	3.65	0.06	21075	4.40	0.07	17483	45.60	41.95	45.90	45.80	42.10	40.80		
	80	70.74	4.90	0.06	20932	5.70	0.07	17994	49.00	44.10	49.40	49.20	44.20	43.00		
	100	88.42	6.03	0.06	21279	6.90	0.07	18581	52.53	46.50	52.90	52.80	46.60	45.30		
	120	106.10	7.23	0.06	21294	9.35	0.08	16455	55.78	48.55	56.20	56.20	46.60	47.10		
	140	123.79	8.55	0.06	20993	9.85	0.07	18222	59.80	51.25	60.20	60.40	51.50	49.40		

Heat Pipe Test Report (cont.)															
Manufacturer			Enertron			Test conditions				Test date		3/24/2014			
Wick structure/ Working fluid			Sintered Powder Metal/ Water			Effective area (m <sup>2</sup> )		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block					
Pipe specification			C110 Copper 0.3mm wall thickness			Coolant temp (°C)		35							
Diameter ±0.05 mm			12			Contact length of ev/cd (mm)		55							
Length ±0.10 mm			200			At 90° the evaporator is directly below the condenser; 0° is horizontal.									
Flatten thickness ±0.05 mm			n/a												
Bend angle ±1 deg			n/a												
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)						
									ev	cd	eb1	eb2	cb1	cb2	
-30	20	17.68	1.18	0.06	21823	1.40	0.07	18315	38.65	37.48	38.70	38.70	37.60	37.00	
	40	35.37	2.45	0.06	20932	2.95	0.07	17384	42.28	39.83	42.30	42.40	39.90	38.90	
	60	53.05	3.83	0.06	20111	4.40	0.07	17483	45.80	41.98	46.00	46.00	42.10	41.10	
	80	70.74	4.88	0.06	21039	5.70	0.07	17994	49.18	44.30	49.50	49.50	44.40	43.20	
	100	88.42	6.08	0.06	21104	7.05	0.07	18186	52.68	46.60	53.00	53.00	46.70	45.20	
	120	106.10	7.15	0.06	21517	8.45	0.07	18207	55.85	48.70	56.40	56.50	49.00	47.00	
	140	123.79	8.60	0.06	20871	10.10	0.07	17771	59.90	51.30	60.30	60.60	51.70	49.00	
-60	20	17.68	1.10	0.06	23311	1.45	0.07	17684	38.78	37.68	38.80	38.80	37.60	37.10	
	40	35.37	2.43	0.06	21148	2.75	0.07	18648	42.30	39.88	42.30	42.30	40.00	39.10	
	60	53.05	3.70	0.06	20791	4.35	0.07	17684	45.83	42.13	46.00	46.10	42.30	41.10	
	80	70.74	4.88	0.06	21039	5.80	0.07	17684	49.18	44.30	49.40	49.70	44.50	43.00	
	100	88.42	5.90	0.06	21730	7.05	0.07	18186	52.53	46.63	52.80	53.10	46.90	44.90	
	120	106.10	6.90	0.06	22297	8.10	0.07	18994	55.68	48.78	55.90	56.30	49.00	47.00	
	140	123.79	7.93	0.06	22649	9.70	0.07	18504	59.13	51.20	59.40	60.30	51.80	48.50	
-90	20	17.68	1.13	0.06	22793	1.20	0.06	21368	38.88	37.75	38.90	38.70	38.10	37.10	
	40	35.37	2.45	0.06	20932	2.85	0.07	17994	42.40	39.95	42.40	42.60	40.10	39.20	
	60	53.05	3.60	0.06	21368	4.05	0.07	18994	45.83	42.23	45.80	46.10	42.40	41.40	
	80	70.74	4.43	0.06	23179	5.45	0.07	18820	49.00	44.58	49.30	49.50	44.90	43.00	
	100	88.42	6.03	0.06	21279	7.20	0.07	17807	52.60	46.58	53.00	53.00	47.00	44.60	
	120	106.10	6.70	0.06	22963	8.10	0.07	18994	55.50	48.80	55.60	56.50	49.30	46.60	
	140	123.79	10.23	0.07	17554	11.55	0.08	15540	61.30	51.08	62.50	61.30	52.40	48.30	

**Heat pipe performance (dT vs Inclination angles at various heat loads)**

Heat pipe tested: 12mm x 200mm sintered powder metal wick / water

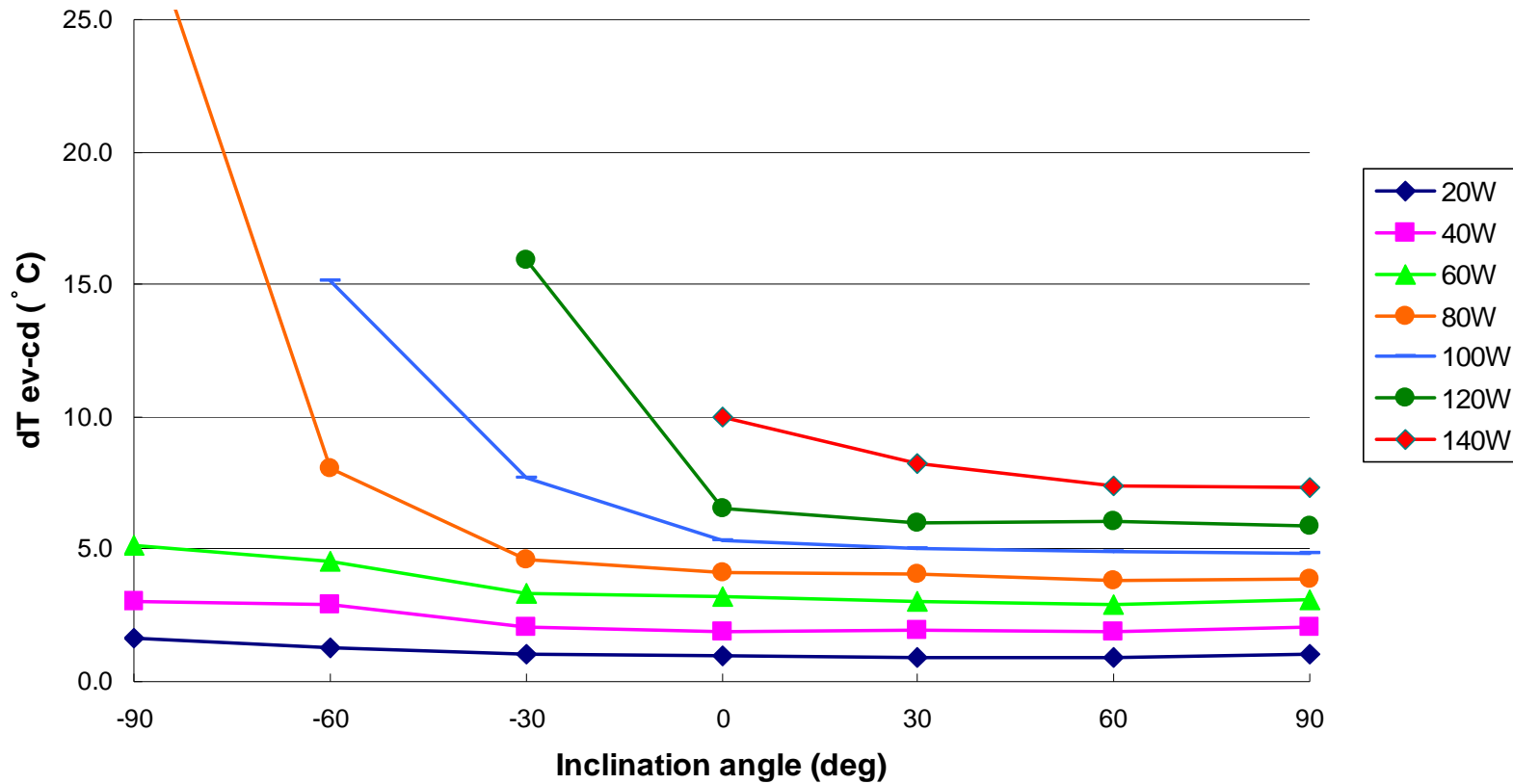


Heat Pipe Test Report																
Manufacturer			Enertron				Test conditions				Test date		3/24/2014			
Wick structure/ Working fluid			Sintered Powder Metal/ Water				Effective area (m <sup>2</sup> )		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block					
Pipe specification			C110 Copper 0.3mm wall thickness				Coolant temp (°C)		35							
Diameter ±0.05 mm			12				Contact length of ev/cd (mm)		55							
Length ±0.10 mm			250				At 90° the evaporator is directly below the condenser; 0° is horizontal.									
Flatten thickness ±0.05 mm			n/a													
Bend angle ±1 deg			n/a													
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)							
									ev	cd	eb1	eb2	cb1	38		
90	20	17.68	1.00	0.05	34484	1.10	0.05	31349	38.33	37.33	38.40	38.20	37.30	37.10		
	40	35.37	2.05	0.05	33643	2.10	0.05	32841	41.65	39.60	41.80	41.40	39.70	39.30		
	60	53.05	3.08	0.05	33643	3.30	0.06	31349	45.00	41.93	45.30	44.80	42.00	41.50		
	80	70.74	3.90	0.05	35368	4.25	0.05	32455	47.93	44.03	48.30	48.00	44.30	43.50		
	100	88.42	4.85	0.05	35550	5.45	0.05	31636	51.15	46.30	51.50	51.30	46.50	45.40		
	120	106.10	5.88	0.05	35217	6.60	0.06	31349	54.35	48.48	54.70	54.60	48.60	47.50		
	140	123.79	7.35	0.05	32841	7.90	0.06	30555	57.55	50.20	57.50	57.80	50.30	49.20		
60	20	17.68	0.88	0.04	39410	1.00	0.05	34484	38.40	37.53	38.40	38.50	37.50	37.40		
	40	35.37	1.90	0.05	36298	2.20	0.06	31349	41.60	39.70	41.70	41.70	39.70	39.30		
	60	53.05	2.93	0.05	35368	3.20	0.05	32328	44.85	41.93	45.00	44.80	42.00	41.40		
	80	70.74	3.88	0.05	35596	4.50	0.06	30652	48.00	44.13	48.30	48.20	44.20	43.30		
	100	88.42	4.95	0.05	34832	5.55	0.06	31066	51.20	46.25	51.50	51.30	46.30	45.40		
	120	106.10	6.05	0.05	34199	6.85	0.06	30205	54.28	48.23	54.60	54.60	48.20	47.30		
	140	123.79	7.40	0.05	32620	8.20	0.06	29437	57.50	50.10	57.80	57.80	50.10	49.10		
30	20	17.68	0.90	0.04	38315	1.05	0.05	32841	38.35	37.45	38.40	38.40	37.40	37.30		
	40	35.37	1.95	0.05	35368	2.15	0.05	32078	41.38	39.43	41.40	41.40	39.30	39.20		
	60	53.05	3.05	0.05	33918	3.50	0.06	29557	44.68	41.63	44.90	44.90	41.70	41.10		
	80	70.74	4.03	0.05	34269	4.55	0.06	30315	47.78	43.75	48.00	48.00	43.80	43.10		
	100	88.42	5.10	0.05	33807	5.75	0.06	29986	51.00	45.90	51.20	51.40	46.00	45.10		
	120	106.10	6.00	0.05	34484	6.75	0.06	30652	53.80	47.80	54.00	54.20	47.90	46.80		
	140	123.79	8.25	0.06	29259	9.15	0.07	26381	58.48	50.23	58.90	58.90	50.20	49.30		
0	20	17.68	0.95	0.05	36298	1.10	0.05	31349	38.40	37.45	38.40	38.60	37.60	37.20		
	40	35.37	1.90	0.05	36298	2.10	0.05	32841	41.38	39.48	41.40	41.40	39.50	39.10		
	60	53.05	3.22	0.05	32078	3.70	0.06	27960	44.68	41.45	44.70	45.10	41.50	40.90		
	80	70.74	4.13	0.05	33439	4.75	0.06	29039	47.75	43.63	48.00	48.00	43.70	42.80		
	100	88.42	5.33	0.05	32379	6.05	0.06	28499	50.95	45.63	51.20	51.30	45.70	44.70		
	120	106.10	6.53	0.05	31709	7.20	0.06	28736	54.08	47.55	54.20	54.50	47.80	46.50		
	140	123.79	9.98	0.07	24199	10.35	0.07	23322	59.78	49.80	60.00	60.00	49.80	49.50		

Heat Pipe Test Report (cont)															
Manufacturer			Enertron			Test conditions				Test date		3/24/2014			
Wick structure/ Working fluid			Sintered Powder Metal/ Water			Effective area (m <sup>2</sup> )		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block					
Pipe specification			C110 Copper 0.3mm wall thickness			Coolant temp (°C)		35							
Diameter		±0.05 mm	12		Contact length of ev/cd (mm)		55								
Length		±0.10 mm	250		At 90° the evaporator is directly below the condenser; 0° is horizontal.										
Flatten thickness		±0.05 mm	n/a												
Bend angle		±1 deg	n/a												
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)						
									ev	cd	eb1	eb2	cb1	38	
-30	20	17.68	1.05	0.05	32841	1.20	0.06	28736	38.45	37.40	38.50	38.50	37.40	37.20	
	40	35.37	2.08	0.05	33237	2.35	0.06	29348	41.45	39.38	41.50	41.70	39.50	39.00	
	60	53.05	3.35	0.06	30881	3.75	0.06	27587	44.88	41.53	45.00	45.10	41.70	40.90	
	80	70.74	4.60	0.06	29986	5.10	0.06	27046	48.18	43.58	48.50	48.40	43.80	42.90	
	100	88.42	7.68	0.08	22465	8.00	0.08	21552	53.25	45.58	54.60	51.80	45.90	44.50	
	120	106.10	15.90	0.13	13013	16.20	0.14	12772	62.90	47.00	68.60	57.30	48.30	45.20	
-60	20	17.68	1.25	0.06	27587	1.35	0.07	25543	38.78	37.53	38.80	38.80	37.60	37.30	
	40	35.37	2.88	0.07	23989	3.00	0.07	22989	42.30	39.43	42.50	42.30	39.70	39.10	
	60	53.05	4.55	0.08	22736	4.80	0.08	21552	46.18	41.63	47.00	45.50	41.90	41.00	
	80	70.74	8.03	0.10	17188	8.60	0.11	16039	51.58	43.55	53.80	50.10	44.30	42.40	
	100	88.42	15.15	0.15	11381	15.50	0.16	11124	60.05	44.90	65.60	54.90	46.20	43.30	
-90	20	17.68	1.65	0.08	20899	1.65	0.08	20899	39.10	37.45	39.40	38.60	37.60	37.10	
	40	35.37	3.05	0.08	22612	3.50	0.09	19705	42.38	39.33	42.60	42.80	39.70	38.70	
	60	53.05	5.13	0.09	20186	5.70	0.10	18149	46.80	41.68	47.70	46.70	42.20	40.80	
	80	70.74	30.00	0.38	4598	30.55	0.38	4515	74.68	44.68	81.80	67.90	46.00	42.60	

**Heat pipe performance (dT vs Inclination angles at various heat loads)**

Heat pipe tested: 12mm x 250mm sintered powder metal wick / water



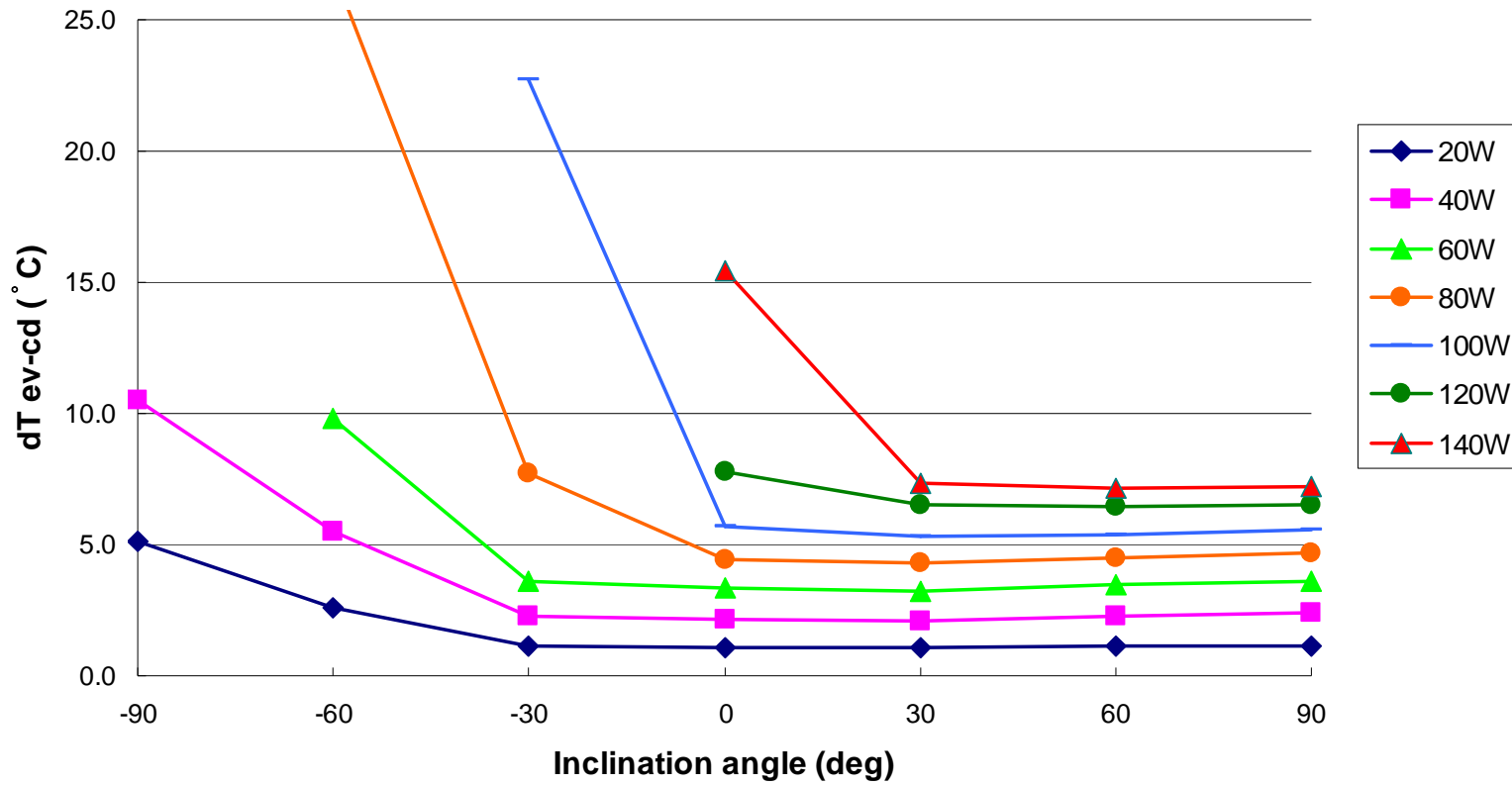
Heat Pipe Test Report															
Manufacturer			Enertron			Test conditions				Test date		3/24/2014			
Wick structure/ Working fluid			Sintered Powder Metal/ Water			Effective area (m <sup>2</sup> )		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block					
Pipe specification			C110 Copper 0.3mm wall thickness			Coolant temp (°C)		35							
Diameter ±0.05 mm			12			Contact length of ev/cd (mm)		55							
Length ±0.10 mm			300			At 90° the evaporator is directly below the condenser; 0° is horizontal.									
Flatten thickness ±0.05 mm			n/a												
Bend angle ±1 deg			n/a												
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)						
									ev	cd	eb1	eb2	cb1	cb2	
90	20	17.68	1.17	0.06	37030	1.25	0.06	34660	38.52	37.35	38.30	38.40	37.10	37.10	
	40	35.37	2.38	0.06	36485	2.25	0.06	38512	41.73	39.35	41.40	41.50	39.30	39.10	
	60	53.05	3.60	0.06	36105	4.40	0.07	29540	45.20	41.60	45.70	45.80	41.50	41.20	
	80	70.74	4.70	0.06	36873	5.35	0.07	32393	48.38	43.68	49.00	48.50	43.60	43.20	
	100	88.42	5.55	0.06	39032	6.15	0.06	35224	51.28	45.73	51.70	51.60	45.70	45.30	
	120	106.10	6.50	0.05	39993	7.00	0.06	37136	54.30	47.80	54.70	54.40	47.80	47.30	
	140	123.79	7.23	0.05	41976	8.70	0.06	34860	57.33	50.10	57.80	58.10	49.40	49.10	
60	20	17.68	1.25	0.06	34660	1.70	0.09	25486	38.40	37.15	38.70	38.70	37.20	36.80	
	40	35.37	2.30	0.06	37674	2.70	0.07	32093	41.50	39.20	41.90	41.70	39.30	38.90	
	60	53.05	3.55	0.06	36613	3.90	0.07	33327	45.03	41.48	45.20	45.10	41.40	41.10	
	80	70.74	4.50	0.06	38512	4.80	0.06	36105	48.00	43.50	48.10	48.10	43.40	43.20	
	100	88.42	5.40	0.05	40116	5.85	0.06	37030	51.03	45.63	51.10	51.30	45.60	45.10	
	120	106.10	6.43	0.05	40460	6.80	0.06	38228	53.98	47.55	53.80	54.40	47.60	47.00	
	140	123.79	7.18	0.05	42269	8.50	0.06	35680	57.35	50.18	57.70	57.90	49.40	49.20	
30	20	17.68	1.08	0.05	40303	1.35	0.07	32093	38.35	37.28	38.50	38.60	37.30	37.10	
	40	35.37	2.10	0.05	41262	2.45	0.06	35368	41.45	39.35	41.60	41.80	39.40	39.10	
	60	53.05	3.20	0.05	40618	3.55	0.06	36613	44.85	41.65	44.80	45.20	41.60	41.30	
	80	70.74	4.33	0.05	40070	4.60	0.06	37674	48.03	43.70	48.00	48.40	43.80	43.40	
	100	88.42	5.30	0.05	40873	5.75	0.06	37674	51.10	45.80	51.10	51.60	45.80	45.40	
	120	106.10	6.53	0.05	39840	6.90	0.06	37674	54.35	47.83	54.10	54.80	47.80	47.30	
	140	123.79	7.43	0.05	40846	8.60	0.06	35265	57.60	50.18	57.80	58.10	49.40	49.30	
0	20	17.68	1.10	0.06	39387	1.45	0.07	29880	38.45	37.35	38.60	38.80	37.30	37.20	
	40	35.37	2.18	0.05	39840	2.50	0.06	34660	41.65	39.48	41.70	42.00	39.50	39.20	
	60	53.05	3.33	0.06	39091	3.75	0.06	34660	45.08	41.75	45.10	45.50	41.80	41.30	
	80	70.74	4.45	0.06	38944	4.75	0.06	36485	48.33	43.88	48.30	48.60	43.90	43.50	
	100	88.42	5.68	0.06	38172	6.00	0.06	36105	51.75	46.08	51.60	52.20	46.20	45.60	
	120	106.10	7.78	0.06	33434	8.05	0.07	32292	55.90	48.13	55.70	56.50	48.60	47.50	
	140	123.79	15.45	0.11	19630	16.15	0.12	18779	64.40	48.95	66.30	62.80	47.60	49.20	

Heat Pipe Test Report (cont)														
Manufacturer		Enertron			Test conditions					Test date		3/24/2014		
Wick structure/ Working fluid		Sintered Powder Metal/ Water			Effective area (m <sup>2</sup> )			1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block				
Pipe specification		C110 Copper 0.3mm wall thickness			Coolant temp (°C)			35						
Diameter		±0.05 mm	12		Contact length of ev/cd (mm)			55						
Length		±0.10 mm	300		At 90° the evaporator is directly below the condenser; 0° is horizontal.									
Flatten thickness		±0.05 mm	n/a											
Bend angle		±1 deg	n/a											
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)					
									ev	cd	eb1	eb2	cb1	cb2
-30	20	17.68	1.13	0.06	38512	1.50	0.08	28884	38.60	37.48	38.90	39.00	37.60	37.30
	40	35.37	2.25	0.06	38512	2.65	0.07	32698	41.75	39.50	41.90	42.20	39.60	39.20
	60	53.05	3.60	0.06	36105	4.00	0.07	32494	45.33	41.73	45.40	45.80	41.90	41.30
	80	70.74	7.73	0.10	22434	7.90	0.10	21937	51.33	43.60	52.80	50.00	44.20	42.80
	100	88.42	22.73	0.23	9533	23.05	0.23	9398	67.53	44.80	73.20	62.70	46.70	43.10
-60	20	17.68	2.58	0.13	16825	3.00	0.15	14442	39.65	37.08	40.60	39.40	37.30	36.70
	40	35.37	5.50	0.14	15755	6.05	0.15	14322	44.63	39.13	46.90	43.40	39.70	38.50
	60	53.05	9.80	0.16	13263	10.25	0.17	12681	50.98	41.18	54.80	47.90	42.20	40.00
	80	70.74	26.60	0.33	6515	27.15	0.34	6383	69.00	42.40	73.50	65.60	43.90	40.90
-90	20	17.68	5.13	0.26	8454	5.95	0.30	7282	42.10	36.98	44.10	41.60	37.40	36.40
	40	35.37	10.48	0.26	8272	10.95	0.27	7913	49.58	39.10	52.70	47.30	39.90	38.20



### Heat pipe performance (dT vs Inclination angles at various heat loads)

Heat pipe tested: 12mm x 300mm sintered powder metal wick / water

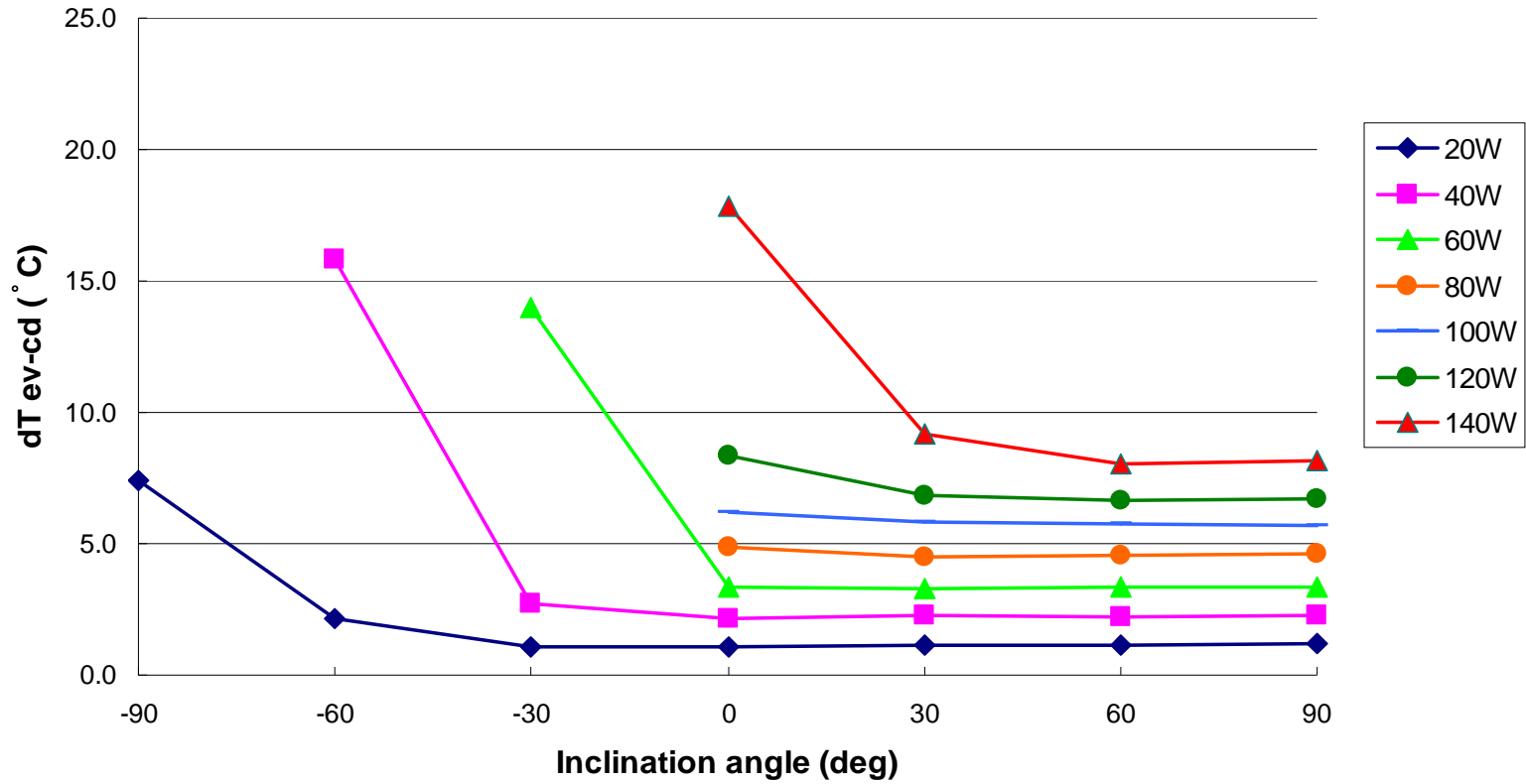


## Heat Pipe Test Report

Manufacturer		Enertron					Test conditions				Test date	3/20/2014							
Wick structure/ Working fluid		Sintered Powder Metal/ Water					Effective area (m2)		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block								
Pipe specification		C110 Copper 0.3mm wall thickness					Coolant temp (°C)		35										
Diameter		±0.05 mm		12			Contact length of ev/cd (mm)		55										
Length		±0.10 mm		350			At 90° the evaporator is directly below the condenser; 0° is horizontal.												
Flatten thickness		±0.05 mm		n/a															
Bend angle		±1 deg		n/a															
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)										
									ev	cd	eb1	eb2	cb1	cb2					
90	20	17.68	1.18	0.06	44398	1.25	0.06	41734	38.33	37.15	38.40	38.10	37.10	36.90					
	40	35.37	2.30	0.06	45363	2.40	0.06	43473	41.60	39.30	41.80	41.20	39.20	39.00					
	60	53.05	3.37	0.06	46440	3.70	0.06	42298	44.77	41.40	45.30	44.50	41.30	41.10					
	80	70.74	4.63	0.06	45118	4.80	0.06	43473	48.40	43.78	49.10	47.30	43.60	43.20					
	100	88.42	5.72	0.06	45601	6.05	0.06	43114	51.52	45.80	52.40	50.60	45.70	45.20					
	120	106.10	6.68	0.06	46892	17.00	0.14	18412	54.30	47.63	55.30	52.80	37.10	37.00					
	140	123.79	8.15	0.06	44806	9.15	0.07	39910	58.40	50.25	58.10	58.90	49.20	49.50					
60	20	17.68	1.15	0.06	45363	1.25	0.06	41734	38.28	37.13	38.50	38.10	37.10	37.00					
	40	35.37	2.22	0.06	46892	2.60	0.07	40129	41.43	39.20	41.70	41.50	39.20	38.80					
	60	53.05	3.33	0.06	47068	4.05	0.07	38643	44.55	41.23	45.00	44.80	41.10	40.60					
	80	70.74	4.58	0.06	45611	5.45	0.07	38288	48.00	43.43	48.60	48.40	43.30	42.80					
	100	88.42	5.75	0.06	45363	6.95	0.07	37531	51.53	45.78	52.30	52.00	45.50	44.90					
	120	106.10	6.63	0.06	47246	7.90	0.07	39621	54.13	47.50	54.90	54.60	47.20	46.50					
	140	123.79	8.03	0.06	45504	9.05	0.06	40351	58.45	50.43	58.20	58.90	49.50	49.50					
30	20	17.68	1.15	0.06	45363	1.30	0.06	40129	38.30	37.15	38.40	38.20	37.10	36.90					
	40	35.37	2.25	0.06	46371	2.65	0.07	39372	41.38	39.13	41.60	41.50	39.00	38.80					
	60	53.05	3.33	0.06	47068	3.90	0.06	40129	44.50	41.18	44.90	44.70	41.10	40.70					
	80	70.74	4.50	0.06	46371	5.35	0.07	39004	47.88	43.38	48.40	48.10	43.20	42.60					
	100	88.42	5.80	0.06	44972	6.90	0.07	37803	51.35	45.55	52.00	51.70	45.30	44.60					
	120	106.10	6.85	0.06	45694	9.45	0.08	33122	54.33	47.48	55.90	54.60	47.00	44.60					
	140	123.79	9.18	0.07	39801	10.25	0.07	35627	59.75	50.58	59.20	60.20	49.60	49.30					
0	20	17.68	1.08	0.05	48528	1.25	0.06	41734	38.30	37.23	38.40	38.30	37.20	37.00					
	40	35.37	2.18	0.05	47970	7.00	0.18	14905	41.28	39.10	41.40	41.40	30.00	38.80					
	60	53.05	3.35	0.06	46717	3.90	0.07	40129	44.50	41.15	44.70	44.70	41.00	40.60					
	80	70.74	4.95	0.06	42156	5.75	0.07	36290	49.10	44.15	49.40	49.40	43.70	43.60					
	100	88.42	6.05	0.06	43114	6.95	0.07	37531	53.53	47.48	54.30	54.20	47.00	47.60					
	120	106.10	8.35	0.07	37486	9.00	0.08	34778	55.83	47.48	56.00	55.60	47.00	46.60					
	140	123.79	17.82	0.13	20492	18.40	0.13	19846	67.80	49.98	70.40	64.80	50.20	48.20					
-30	20	17.68	2.25	0.11	23186	2.40	0.12	21736	41.75	39.50	41.90	41.70	39.60	39.20					
	40	35.37	2.75	0.07	37940	2.95	0.07	35368	42.23	39.48	42.50	42.10	39.50	39.20					
	60	53.05	14.00	0.23	11179	15.70	0.26	9968	55.23	41.23	60.10	53.20	41.70	40.20					
-60	20	17.68	2.15	0.11	24264	2.85	0.14	18304	39.43	37.28	40.00	39.00	36.40	36.90					
	40	35.37	15.08	0.38	6921	16.05	0.40	6501	54.20	39.13	57.20	52.80	39.60	38.30					
-90	20	17.68	7.38	0.37	7074	7.75	0.39	6731	44.53	37.15	45.80	43.80	37.40	36.70					

**Heat pipe performance (dT vs Inclination angles at various heat loads)**

Heat pipe tested: 12mm x 350mm sintered powder metal wick / water



## Heat Pipe Test Report

Manufacturer		Enertron					Test conditions				Test date	3/18/2014				
Wick structure/ Working fluid		Sintered Powder Metal/ Water					Effective area (m <sup>2</sup> )		1.13E-04		Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block					
Pipe specification		C110 Copper 0.3mm wall thickness					Coolant temp (°C)		35							
Diameter		±0.05 mm		12			Contact length of ev/cd (mm)		55							
Length		±0.10 mm		400			At 90° the evaporator is directly below the condenser; 0° is horizontal.									
Flatten thickness		±0.05 mm		n/a												
Bend angle		±1 deg		n/a												
Inclination Angle (°)	Heat Load (W)	Heat Flux (W/cm <sup>2</sup> )	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)							
									ev	cd	eb1	eb2	cb1	cb2		
90	20	17.68	1.60	0.08	38131	1.98	0.10	30891	38.95	37.35	39.05	38.85	37.45	36.50		
	40	35.37	3.15	0.08	38736	3.45	0.09	35368	42.30	39.15	42.50	42.65	39.35	38.90		
	60	53.05	4.40	0.07	41597	5.20	0.09	35198	45.75	41.35	46.25	46.40	41.45	40.80		
	80	70.74	5.90	0.07	41362	6.93	0.09	35240	49.35	43.45	49.95	50.05	43.30	42.85		
	100	88.42	6.80	0.07	44860	8.23	0.08	37088	52.70	45.90	53.85	53.45	45.85	45.00		
	120	106.10	7.70	0.06	47540	9.13	0.08	40116	55.85	48.15	57.00	56.70	48.15	47.30		
	140	123.79	8.25	0.06	51766	8.70	0.06	49088	60.00	51.75	58.10	60.50	50.80	50.40		
60	20	17.68	1.50	0.08	40673	1.77	0.09	34371	38.55	37.05	38.60	38.75	37.10	36.70		
	40	35.37	2.90	0.07	42075	3.60	0.09	33894	42.00	39.10	42.40	42.45	39.05	38.60		
	60	53.05	4.30	0.07	42565	5.15	0.09	35539	45.55	41.25	45.95	46.10	41.25	40.50		
	80	70.74	5.40	0.07	45192	6.75	0.08	36154	49.05	43.65	49.70	49.85	43.45	42.60		
	100	88.42	6.40	0.06	47664	7.90	0.08	38614	52.45	46.05	53.05	53.35	45.80	44.80		
	120	106.10	7.15	0.06	51197	9.03	0.08	40560	54.85	47.70	56.00	55.80	47.35	46.40		
	140	123.79	8.68	0.06	49229	8.75	0.06	48808	59.28	50.60	57.30	60.00	50.00	49.80		
30	20	17.68	1.55	0.08	39361	1.83	0.09	33430	38.75	37.20	38.80	38.85	37.20	36.80		
	40	35.37	2.80	0.07	43578	3.40	0.09	35888	42.00	39.20	42.40	42.40	39.20	38.80		
	60	53.05	4.20	0.07	43578	5.10	0.09	35888	45.50	41.30	46.00	46.00	41.30	40.50		
	80	70.74	5.25	0.07	46483	6.60	0.08	36975	48.80	43.55	49.60	49.60	43.40	42.60		
	100	88.42	6.25	0.06	48808	7.80	0.08	39109	52.15	45.90	52.50	53.10	45.40	44.60		
	120	106.10	7.00	0.06	52294	9.30	0.08	39361	54.80	47.80	55.90	55.90	47.00	46.20		
	140	123.79	10.65	0.08	40100	10.85	0.08	39361	61.10	50.45	59.10	62.00	49.50	49.90		
0	20	17.68	1.65	0.08	36975	1.95	0.10	31287	38.55	36.90	38.60	38.80	37.10	36.40		
	40	35.37	2.80	0.07	43578	3.68	0.09	33202	41.85	39.05	43.00	42.15	39.20	38.60		
	60	53.05	4.05	0.07	45192	4.85	0.08	37738	45.15	41.10	45.60	45.60	41.20	40.30		
	80	70.74	6.35	0.08	38431	8.35	0.10	29226	50.60	44.25	51.30	51.40	43.40	42.60		
	100	88.42	15.65	0.16	19492	18.60	0.19	16400	62.45	46.80	66.85	59.50	45.00	44.15		
-30	20	17.68	4.05	0.20	15064	4.60	0.23	13263	41.55	37.50	42.65	40.80	37.50	36.75		
	40	35.37	19.45	0.49	6273	10.35	0.26	11789	48.55	29.10	51.40	47.20	39.75	38.15		
-60	20	17.68	17.35	0.87	3516	17.48	0.87	3491	54.15	36.80	54.85	53.25	37.05	36.10		
-90	20	17.68	20.90	1.05	2919	21.05	1.05	2898	57.65	36.75	58.50	56.75	37.05	36.10		

**Heat pipe performance (dT vs Inclination angles at various heat loads)**

Heat pipe tested: 12mm x 400mm sintered powder metal wick / water

