

## Heat Pipe Test Report

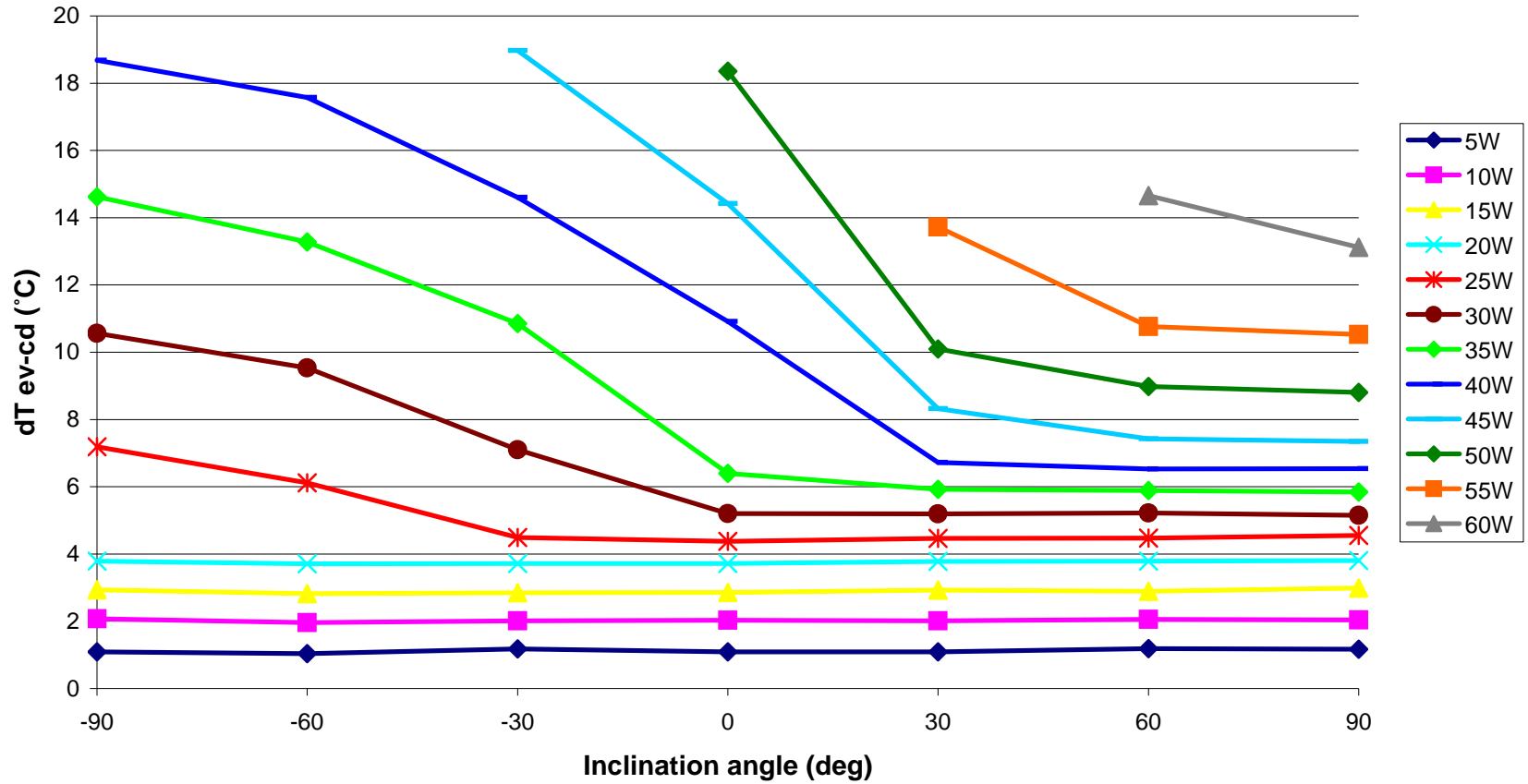
Manufacturer		Enertron		Test conditions		Test date	9/20/2011
Wick structure/ Working fluid		Sintered Powder Metal/ Water		Effective area (m <sup>2</sup> )	1.96E-05	Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block	
Pipe specification		C110 Copper 0.3mm wall thickness		Coolant temp (°C)	35		
Diameter	±0.05 mm	5		Contact length of ev/cd (mm)	50		
Length	±0.10 mm	150		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)	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	5	1.17	0.23	21709	1.97	0.39	12959	36.96	35.79	37.74	37.37	35.56	35.61
	10	2.04	0.20	24965	3.55	0.35	14363	38.73	36.69	40.22	39.42	36.28	36.26
	15	2.99	0.20	25593	5.12	0.34	14918	40.52	37.54	42.63	41.48	36.98	36.89
	20	3.80	0.19	26791	6.78	0.34	15023	42.32	38.52	45.12	43.58	37.61	37.53
	25	4.55	0.18	27965	8.31	0.33	15316	43.90	39.35	47.36	45.59	38.23	38.10
	30	5.15	0.17	29697	9.90	0.33	15441	45.64	40.50	49.87	47.62	38.94	38.76
	35	5.85	0.17	30497	11.46	0.33	15549	47.32	41.48	52.21	49.73	39.59	39.42
	40	6.54	0.16	31169	13.01	0.33	15657	49.02	42.49	54.66	51.69	40.27	40.06
	45	7.35	0.16	31198	14.69	0.33	15601	50.73	43.39	56.97	53.80	40.81	40.58
	50	8.80	0.18	28927	17.32	0.35	14702	53.34	44.54	60.39	56.77	41.32	41.20
	55	10.53	0.19	26609	20.36	0.37	13759	56.39	45.86	64.25	60.36	41.99	41.90
60	13.12	0.22	23295	23.83	0.40	12821	60.30	47.18	68.43	64.37	42.66	42.47	
60	5	1.19	0.24	21453	1.88	0.38	13524	36.93	35.75	37.64	37.28	35.53	35.62
	10	2.05	0.21	24819	3.49	0.35	14593	38.69	36.64	40.18	39.32	36.29	36.24
	15	2.89	0.19	26416	5.11	0.34	14941	40.50	37.60	42.64	41.47	36.94	36.94
	20	3.78	0.19	26918	6.70	0.33	15214	42.28	38.49	45.04	43.53	37.67	37.51
	25	4.48	0.18	28440	8.19	0.33	15542	43.86	39.38	47.24	45.48	38.18	38.15
	30	5.22	0.17	29247	9.90	0.33	15439	45.67	40.44	49.87	47.66	38.98	38.76
	35	5.89	0.17	30269	11.53	0.33	15460	47.43	41.54	52.35	49.75	39.62	39.43
	40	6.53	0.16	31212	13.03	0.33	15641	48.99	42.46	54.59	51.63	40.17	40.00
	45	7.43	0.17	30858	14.86	0.33	15421	50.83	43.40	57.19	53.85	40.76	40.56
	50	8.98	0.18	28351	17.49	0.35	14562	53.51	44.52	60.49	56.95	41.22	41.25
	55	10.77	0.20	26016	20.43	0.37	13709	56.42	45.65	64.22	60.38	42.00	41.74
60	14.66	0.24	20844	23.87	0.40	12804	60.47	45.81	68.27	64.32	42.72	42.13	
30	5	1.09	0.22	23319	1.86	0.37	13728	36.85	35.76	37.65	37.19	35.55	35.58
	10	2.01	0.20	25338	3.47	0.35	14698	38.66	36.65	40.14	39.30	36.26	36.25
	15	2.93	0.20	26118	5.09	0.34	15015	40.50	37.58	42.57	41.45	36.93	36.91
	20	3.78	0.19	26961	6.68	0.33	15253	42.22	38.44	44.98	43.49	37.54	37.58
	25	4.46	0.18	28529	8.19	0.33	15554	43.90	39.44	47.31	45.55	38.29	38.20
	30	5.19	0.17	29422	9.78	0.33	15627	45.59	40.39	49.70	47.53	38.87	38.80
	35	5.92	0.17	30105	11.55	0.33	15428	47.44	41.52	52.36	49.78	39.59	39.44

Inclination Angle (°)	Heat Load (W)	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	40	6.73	0.17	30288	13.21	0.33	15422	49.17	42.45	54.72	51.82	40.14	39.98
	45	8.32	0.18	27543	15.77	0.35	14532	51.73	43.41	58.03	54.84	40.60	40.73
	50	10.09	0.20	25228	18.90	0.38	13471	54.80	44.70	61.90	58.41	41.25	41.25
	55	13.73	0.25	20403	22.32	0.41	12552	59.36	45.63	65.87	62.44	41.97	41.70
0	5	1.09	0.22	23298	1.77	0.35	14419	36.84	35.75	37.64	37.18	35.62	35.67
	10	2.03	0.20	25126	3.46	0.35	14732	38.66	36.63	40.07	39.29	36.22	36.23
	15	2.86	0.19	26721	5.02	0.33	15224	40.48	37.62	42.51	41.39	36.94	36.92
	20	3.72	0.19	27411	6.68	0.33	15260	42.22	38.50	45.02	43.47	37.59	37.55
	25	4.38	0.18	29096	8.22	0.33	15491	43.87	39.49	47.33	45.48	38.23	38.14
	30	5.20	0.17	29360	10.04	0.33	15223	45.77	40.56	50.03	47.75	38.89	38.81
	35	6.40	0.18	27865	11.93	0.34	14937	47.78	41.38	52.67	50.15	39.45	39.50
	40	10.92	0.27	18662	16.09	0.40	12665	52.87	41.95	57.24	55.10	39.99	40.18
	45	14.42	0.32	15897	20.55	0.46	11153	56.99	42.58	62.02	60.08	40.27	40.74
	50	18.36	0.37	13872	25.77	0.52	9883	61.76	43.40	67.78	65.93	40.73	41.45
	-30	5	1.18	0.24	21654	1.80	0.36	14155	36.89	35.72	37.61	37.13	35.55
10		2.01	0.20	25338	3.47	0.35	14669	38.68	36.67	40.11	39.35	36.28	36.24
15		2.85	0.19	26814	5.09	0.34	15000	40.48	37.63	42.54	41.41	36.89	36.88
20		3.71	0.19	27433	6.70	0.34	15196	42.19	38.48	44.95	43.50	37.53	37.51
25		4.49	0.18	28364	8.32	0.33	15311	43.96	39.47	47.45	45.55	38.27	38.10
30		7.10	0.24	21507	11.15	0.37	13705	47.36	40.25	50.96	49.06	38.83	38.90
35		10.85	0.31	16429	15.41	0.44	11568	51.76	40.91	55.54	54.01	39.21	39.52
40		14.60	0.37	13950	20.40	0.51	9988	56.29	41.69	61.05	59.63	39.68	40.21
45		18.97	0.42	12080	26.41	0.59	8677	61.42	42.44	67.42	66.04	39.91	40.73
-60	5	1.04	0.21	24485	1.77	0.35	14411	36.84	35.80	37.61	37.16	35.65	35.59
	10	1.96	0.20	25998	3.50	0.35	14555	38.67	36.72	40.18	39.36	36.28	36.27
	15	2.82	0.19	27071	5.03	0.34	15197	40.42	37.60	42.53	41.40	36.99	36.89
	20	3.71	0.19	27441	6.66	0.33	15287	42.21	38.50	44.94	43.49	37.59	37.52
	25	6.11	0.24	20828	9.33	0.37	13653	45.37	39.26	48.24	46.73	38.11	38.21
	30	9.54	0.32	16022	13.52	0.45	11303	49.64	40.10	52.98	51.63	38.64	38.94
	35	13.28	0.38	13421	18.46	0.53	9657	54.16	40.88	58.46	57.15	39.12	39.58
	40	17.57	0.44	11592	24.30	0.61	8383	59.28	41.71	64.81	63.62	39.56	40.27
-90	5	1.09	0.22	23384	1.83	0.37	13900	36.86	35.77	37.67	37.19	35.57	35.63
	10	2.08	0.21	24544	3.50	0.35	14535	38.74	36.66	40.18	39.38	36.26	36.29
	15	2.93	0.20	26038	5.03	0.34	15185	40.47	37.54	42.51	41.46	36.96	36.95
	20	3.79	0.19	26897	6.79	0.34	15008	42.24	38.45	45.09	43.64	37.54	37.61
	25	7.19	0.29	17706	10.35	0.41	12304	46.47	39.28	49.15	47.90	38.07	38.29
	30	10.57	0.35	14462	14.72	0.49	10382	50.70	40.13	54.12	52.97	38.64	39.03
	35	14.62	0.42	12189	20.19	0.58	8828	55.55	40.93	60.11	58.96	39.02	39.67
	40	18.68	0.47	10906	25.80	0.65	7895	60.49	41.81	66.34	65.12	39.44	40.41

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

Heat pipe tested:  $\phi 5\text{mm} \times 150\text{mm}$  sintered powder metal/ water



## Heat Pipe Test Report

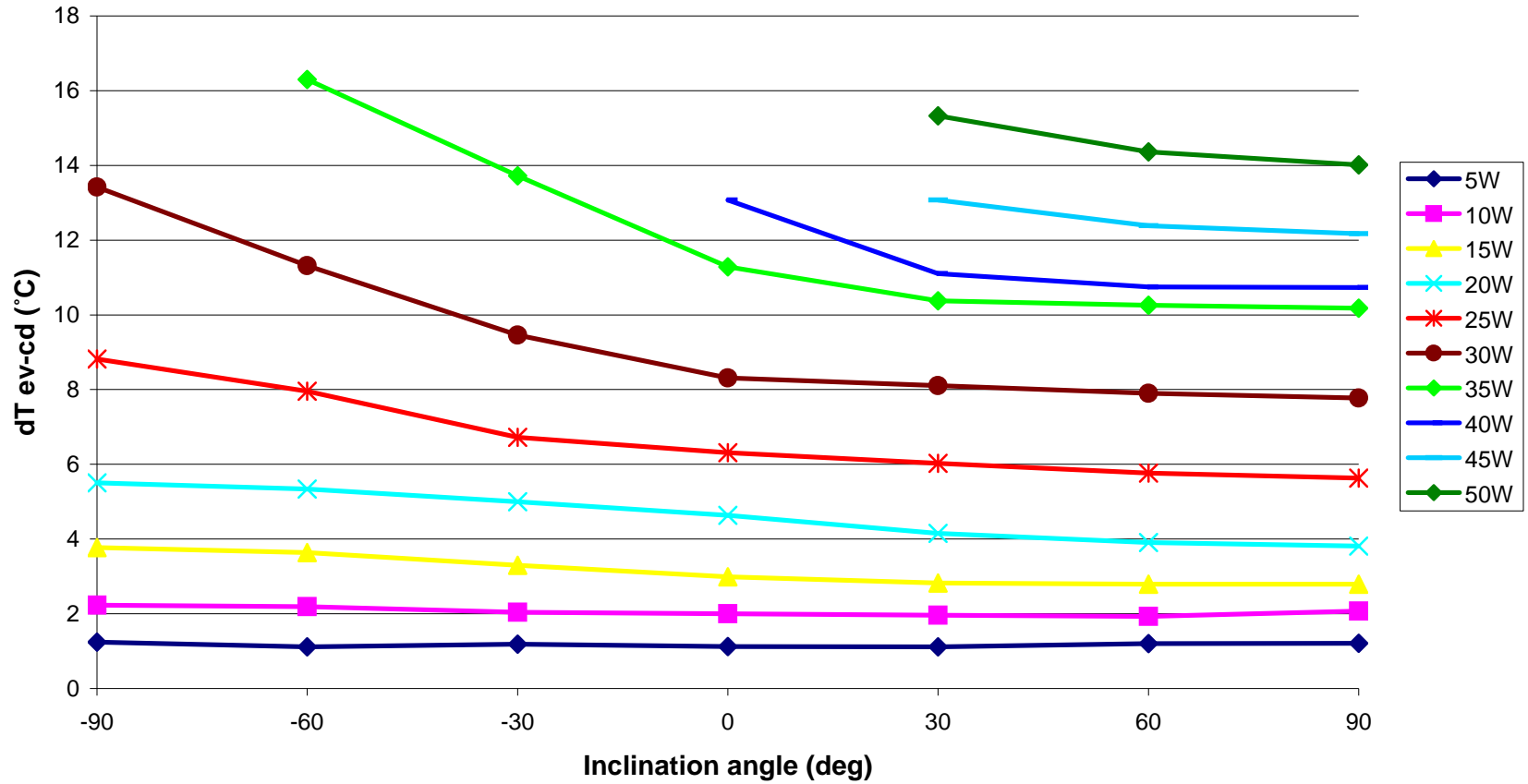
Manufacturer		Enertron		Test conditions		Test date	9/19/2011
Wick structure/ Working fluid		Sintered Powder Metal/ Water		Effective area (m2)	1.96E-05	Note: ev- Evaporator of heat pipe cd- Condenser of heat pipe eb- Evaporator Block cb- Condenser Block	
Pipe specification		C110 Copper 0.3mm wall thickness		Coolant temp (°C)	35		
Diameter	±0.05 mm	5		Contact length of ev/cd (mm)	50		
Length	±0.10 mm	175		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)	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	5	1.21	0.24	26307	2.39	0.48	13318	37.03	35.82	38.10	37.63	35.36	35.59
	10	2.07	0.21	30755	4.01	0.40	15884	38.67	36.60	40.59	39.71	36.08	36.21
	15	2.79	0.19	34251	5.58	0.37	17104	40.20	37.41	42.96	41.81	36.75	36.85
	20	3.82	0.19	33375	7.74	0.39	16450	42.12	38.30	45.94	44.52	37.44	37.54
	25	5.63	0.23	28269	10.05	0.40	15839	44.77	39.14	48.94	47.44	38.11	38.18
	30	7.77	0.26	24570	13.28	0.44	14381	47.83	40.05	52.76	51.29	38.71	38.79
	35	10.18	0.29	21898	16.17	0.46	13782	51.13	40.95	56.39	54.77	39.38	39.44
	40	10.73	0.27	23728	19.11	0.48	13326	52.77	42.03	59.97	58.34	39.99	40.10
	45	12.17	0.27	23542	21.70	0.48	13205	55.07	42.90	63.20	61.39	40.56	40.64
50	14.02	0.28	22707	24.98	0.50	12741	57.98	43.96	67.14	65.26	41.13	41.30	
60	5	1.20	0.24	26482	2.26	0.45	14097	36.99	35.79	38.01	37.54	35.43	35.60
	10	1.93	0.19	33003	3.87	0.39	16442	38.55	36.62	40.44	39.64	36.10	36.23
	15	2.79	0.19	34251	5.53	0.37	17281	40.18	37.40	43.00	41.81	36.77	36.99
	20	3.91	0.20	32597	7.70	0.39	16527	42.13	38.22	45.89	44.43	37.39	37.53
	25	5.77	0.23	27588	10.12	0.40	15730	44.86	39.09	48.96	47.53	38.07	38.18
	30	7.90	0.26	24175	13.36	0.45	14294	47.95	40.05	52.85	51.39	38.72	38.80
	35	10.26	0.29	21719	16.13	0.46	13813	51.20	40.95	56.36	54.77	39.38	39.50
	40	10.75	0.27	23697	19.08	0.48	13348	52.72	41.97	59.95	58.28	39.95	40.12
	45	12.39	0.28	23129	22.01	0.49	13013	55.35	42.97	63.55	61.73	40.57	40.67
50	14.36	0.29	22166	25.63	0.51	12418	58.51	44.15	67.84	65.95	41.18	41.34	
30	5	1.12	0.22	28522	2.19	0.44	14535	36.90	35.79	37.92	37.53	35.43	35.64
	10	1.96	0.20	32481	3.89	0.39	16374	38.56	36.60	40.47	39.67	36.03	36.33
	15	2.83	0.19	33803	5.70	0.38	16765	40.28	37.45	43.12	41.93	36.73	36.93
	20	4.15	0.21	30666	7.85	0.39	16215	42.41	38.26	46.01	44.65	37.33	37.63
	25	6.03	0.24	26416	10.41	0.42	15290	45.17	39.15	49.29	47.85	38.08	38.25
	30	8.10	0.27	23570	13.55	0.45	14092	48.10	40.00	52.96	51.64	38.72	38.78
	35	10.38	0.30	21466	16.34	0.47	13637	51.37	40.99	56.50	54.99	39.36	39.45
	40	11.10	0.28	22937	19.48	0.49	13075	53.00	41.89	60.28	58.68	39.87	40.13
	45	13.07	0.29	21919	22.99	0.51	12459	56.02	42.95	64.44	62.64	40.39	40.70
50	15.33	0.31	20768	27.06	0.54	11762	59.59	44.27	69.16	67.44	41.09	41.39	

Inclination Angle (°)	Heat Load (W)	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
0	5	1.12	0.22	28395	2.21	0.44	14377	36.93	35.81	37.89	37.48	35.35	35.59
	10	2.00	0.20	31879	3.89	0.39	16387	38.62	36.62	40.46	39.72	36.14	36.27
	15	2.99	0.20	31905	5.96	0.40	16012	40.41	37.42	43.29	42.22	36.71	36.88
	20	4.64	0.23	27458	8.21	0.41	15507	42.87	38.23	46.30	45.04	37.37	37.55
	25	6.31	0.25	25227	10.72	0.43	14844	45.46	39.15	49.51	48.20	38.06	38.21
	30	8.31	0.28	22974	13.88	0.46	13762	48.40	40.09	53.35	51.97	38.75	38.82
	35	11.28	0.32	19750	17.42	0.50	12789	52.23	40.94	57.52	56.12	39.33	39.46
	40	13.07	0.33	19480	22.51	0.56	11311	54.88	41.81	63.18	61.79	39.75	40.18
-30	5	1.19	0.24	26839	2.16	0.43	14716	36.98	35.79	37.93	37.50	35.46	35.64
	10	2.04	0.20	31192	4.04	0.40	15766	38.70	36.66	40.60	39.79	36.04	36.27
	15	3.30	0.22	28928	6.12	0.41	15606	40.71	37.41	43.50	42.41	36.78	36.90
	20	5.00	0.25	25455	8.46	0.42	15059	43.29	38.29	46.56	45.38	37.45	37.58
	25	6.73	0.27	23666	11.13	0.45	14300	45.83	39.10	49.89	48.64	38.08	38.20
	30	9.46	0.32	20197	15.39	0.51	12408	49.39	39.94	54.67	53.61	38.66	38.84
	35	13.72	0.39	16238	21.23	0.61	10495	54.40	40.68	61.07	60.02	39.06	39.56
-60	5	1.11	0.22	28625	2.23	0.45	14300	36.96	35.85	37.97	37.50	35.43	35.58
	10	2.19	0.22	29083	4.13	0.41	15403	38.75	36.56	40.68	39.90	36.05	36.27
	15	3.64	0.24	26249	6.30	0.42	15153	41.01	37.37	43.65	42.67	36.76	36.96
	20	5.34	0.27	23852	8.81	0.44	14447	43.59	38.25	46.85	45.78	37.45	37.54
	25	7.96	0.32	19997	12.85	0.51	12388	47.01	39.05	51.45	50.46	38.04	38.17
	30	11.32	0.38	16878	18.18	0.61	10503	51.14	39.82	57.32	56.46	38.49	38.92
	35	16.30	0.47	13668	27.21	0.78	8189	57.04	40.73	66.88	66.09	38.89	39.66
-90	5	1.24	0.25	25712	2.24	0.45	14229	36.99	35.76	38.02	37.52	35.46	35.61
	10	2.23	0.22	28548	4.21	0.42	15122	38.84	36.61	40.80	40.02	36.14	36.27
	15	3.77	0.25	25336	6.40	0.43	14916	41.19	37.42	43.74	42.79	36.77	36.96
	20	5.50	0.28	23146	8.95	0.45	14233	43.77	38.27	46.95	45.98	37.43	37.61
	25	8.82	0.35	18041	14.13	0.57	11266	47.86	39.04	52.62	51.78	37.92	38.22
	30	13.42	0.45	14231	20.61	0.69	9265	53.32	39.90	59.65	58.92	38.39	38.96

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

Heat pipe tested:  $\phi 5\text{mm} \times 175\text{mm}$  sintered powder metal/ water



## Heat Pipe Test Report

Manufacturer		Enertron		Test conditions		Test date	9/17/2011
Wick structure/ Working fluid		Sintered Powder Metal/ Water		Effective area (m2)	1.96E-05	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	5		Contact length of ev/cd (mm)	50		
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)	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	5	2.44	0.49	15687	3.58	0.72	10682	38.25	35.81	39.34	38.92	35.42	35.70
	10	3.89	0.39	19664	5.96	0.60	12809	40.35	36.47	42.52	41.65	35.87	36.38
	15	5.21	0.35	21986	8.10	0.54	14151	42.40	37.19	45.52	44.22	36.49	37.05
	20	6.48	0.32	23568	10.26	0.51	14889	44.45	37.97	48.61	46.93	37.24	37.78
	25	7.38	0.30	25868	12.35	0.49	15464	46.22	38.84	51.53	49.48	37.90	38.42
	30	9.00	0.30	25459	15.09	0.50	15193	48.61	39.61	55.02	52.66	38.51	39.00
	35	11.55	0.33	23146	18.85	0.54	14182	52.07	40.52	59.53	56.93	39.23	39.53
	40	14.41	0.36	21210	22.69	0.57	13465	55.80	41.39	64.03	61.15	39.93	39.86
60	5	2.34	0.47	16331	3.50	0.70	10901	38.11	35.77	39.23	38.83	35.31	35.74
	10	3.85	0.38	19863	5.91	0.59	12926	40.31	36.47	42.43	41.60	35.88	36.34
	15	5.16	0.34	22190	8.09	0.54	14159	42.38	37.21	45.55	44.24	36.56	37.04
	20	6.10	0.30	25051	10.05	0.50	15201	44.02	37.93	48.38	46.73	37.25	37.75
	25	7.40	0.30	25812	12.34	0.49	15474	46.22	38.82	51.51	49.50	37.90	38.43
	30	9.14	0.30	25064	15.17	0.51	15107	48.70	39.56	55.09	52.73	38.52	38.97
	35	11.63	0.33	23000	18.88	0.54	14161	52.18	40.55	59.55	56.95	39.23	39.51
	40	15.36	0.38	19890	23.07	0.58	13246	56.48	41.12	64.36	61.55	40.01	39.76
30	5	2.28	0.46	16768	3.51	0.70	10873	38.08	35.80	39.28	38.77	35.34	35.69
	10	3.80	0.38	20120	5.81	0.58	13158	40.20	36.41	42.34	41.49	35.89	36.33
	15	5.15	0.34	22264	8.09	0.54	14172	42.33	37.18	45.48	44.15	36.47	36.98
	20	6.08	0.30	25130	10.03	0.50	15232	44.07	37.99	48.34	46.69	37.24	37.72
	25	7.43	0.30	25715	12.35	0.49	15464	46.26	38.83	51.52	49.47	37.90	38.39
	30	9.54	0.32	24018	15.61	0.52	14685	49.20	39.66	55.57	53.22	38.58	38.99
	35	14.12	0.40	18936	20.86	0.60	12816	54.68	40.56	61.43	58.91	39.29	39.33
	40	21.19	0.53	14422	27.93	0.70	10942	62.38	41.19	68.90	66.67	39.72	39.99
0	5	2.27	0.45	16857	3.43	0.69	11126	38.06	35.79	39.21	38.74	35.36	35.73
	10	3.75	0.38	20356	5.76	0.58	13268	40.17	36.42	42.31	41.46	35.93	36.33
	15	5.04	0.34	22718	7.98	0.53	14363	42.26	37.21	45.38	44.08	36.48	37.02
	20	6.11	0.31	24994	10.02	0.50	15254	44.13	38.01	48.37	46.72	37.27	37.79
	25	8.16	0.33	23405	13.14	0.53	14535	47.00	38.84	52.35	50.34	37.95	38.45
	30	15.40	0.51	14886	20.52	0.68	11170	54.97	39.57	59.94	58.32	38.14	39.09
	35	22.66	0.65	11802	29.63	0.85	9023	63.16	40.50	69.63	68.06	38.51	39.92

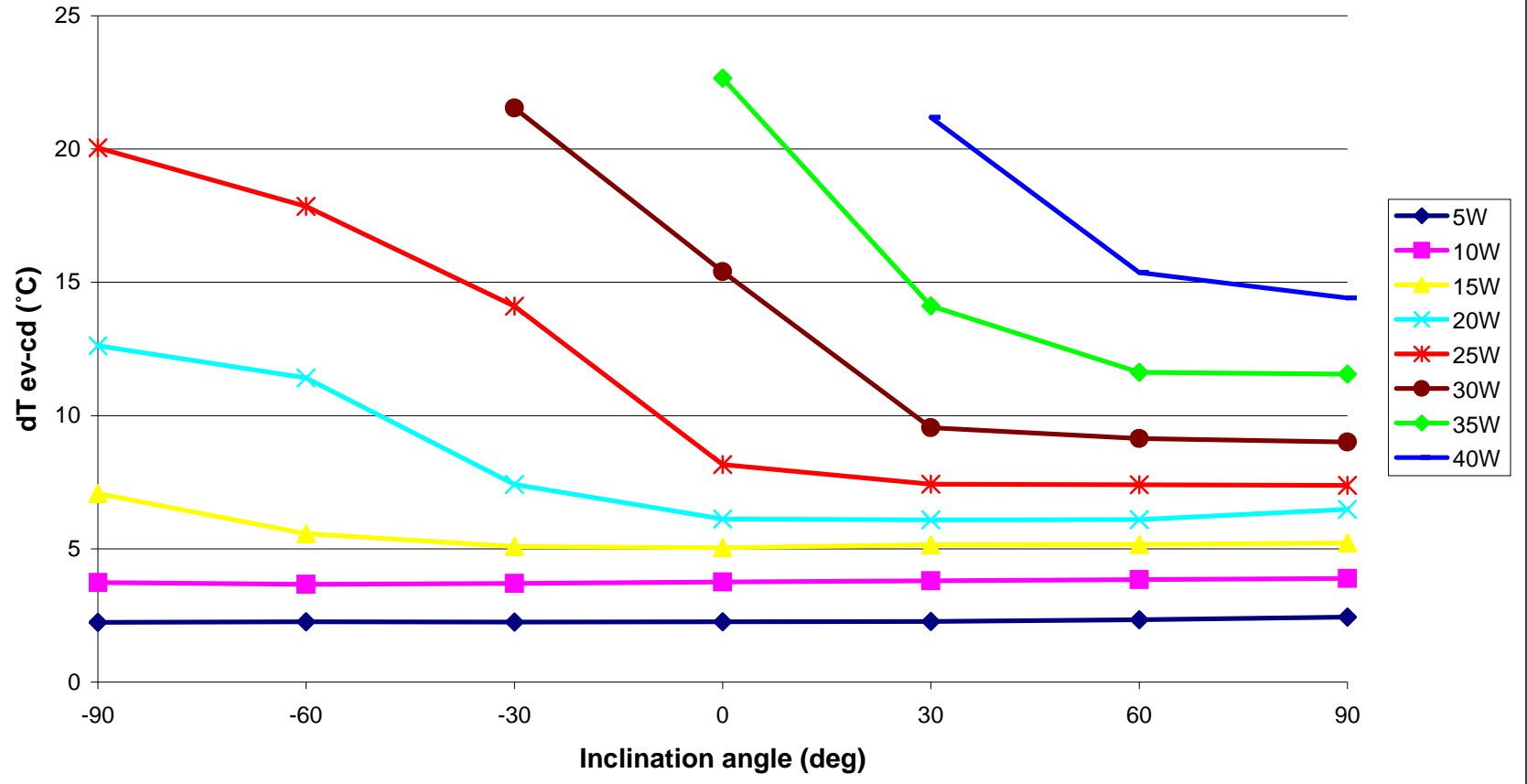


Inclination Angle (°)	Heat Load (W)	dT ev-cd (°C)	Thermal resistance ev-cd (°C/W)	Thermal conductivity ev-cd (W/mK)	dT eb-cb (°C)	Thermal resistance eb-cb (°C/W)	Thermal Conductivity eb-cb (W/mK)	Measured Temperature T (°C)					
								ev	cd	eb1	eb2	cb1	cb2
-30	5	2.26	0.45	16924	3.45	0.69	11081	38.04	35.78	39.22	38.73	35.38	35.68
	10	3.71	0.37	20608	5.77	0.58	13238	40.15	36.44	42.34	41.37	35.89	36.28
	15	5.09	0.34	22509	8.02	0.53	14288	42.30	37.21	45.41	44.12	36.51	36.99
	20	7.41	0.37	20611	11.36	0.57	13454	45.54	38.13	49.64	48.08	37.22	37.78
	25	14.10	0.56	13543	18.63	0.75	10254	52.99	38.89	57.36	56.05	37.58	38.58
	30	21.54	0.72	10641	28.08	0.94	8162	61.39	39.85	67.27	66.09	37.91	39.30
-60	5	2.26	0.45	16894	3.34	0.67	11447	38.02	35.76	39.08	38.66	35.32	35.75
	10	3.67	0.37	20805	5.72	0.57	13367	40.14	36.46	42.29	41.40	35.90	36.37
	15	5.57	0.37	20558	8.56	0.57	13390	42.85	37.27	45.95	44.71	36.52	37.03
	20	11.42	0.57	13381	14.98	0.75	10199	49.55	38.13	53.01	51.95	37.07	37.93
	25	17.85	0.71	10702	23.32	0.93	8190	56.90	39.06	61.90	60.82	37.44	38.64
-90	5	2.24	0.45	17060	3.48	0.70	10970	38.04	35.80	39.25	38.81	35.36	35.74
	10	3.74	0.37	20437	5.76	0.58	13263	40.26	36.52	42.43	41.50	35.97	36.43
	15	7.08	0.47	16188	9.63	0.64	11904	44.38	37.30	46.94	45.94	36.51	37.11
	20	12.63	0.63	12102	16.48	0.82	9269	50.84	38.22	54.55	53.56	37.08	38.06
	25	20.04	0.80	9528	25.81	1.03	7399	59.15	39.11	64.46	63.41	37.44	38.80



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

Heat pipe tested:  $\phi 5\text{mm} \times 200\text{mm}$  sintered powder metal/ water



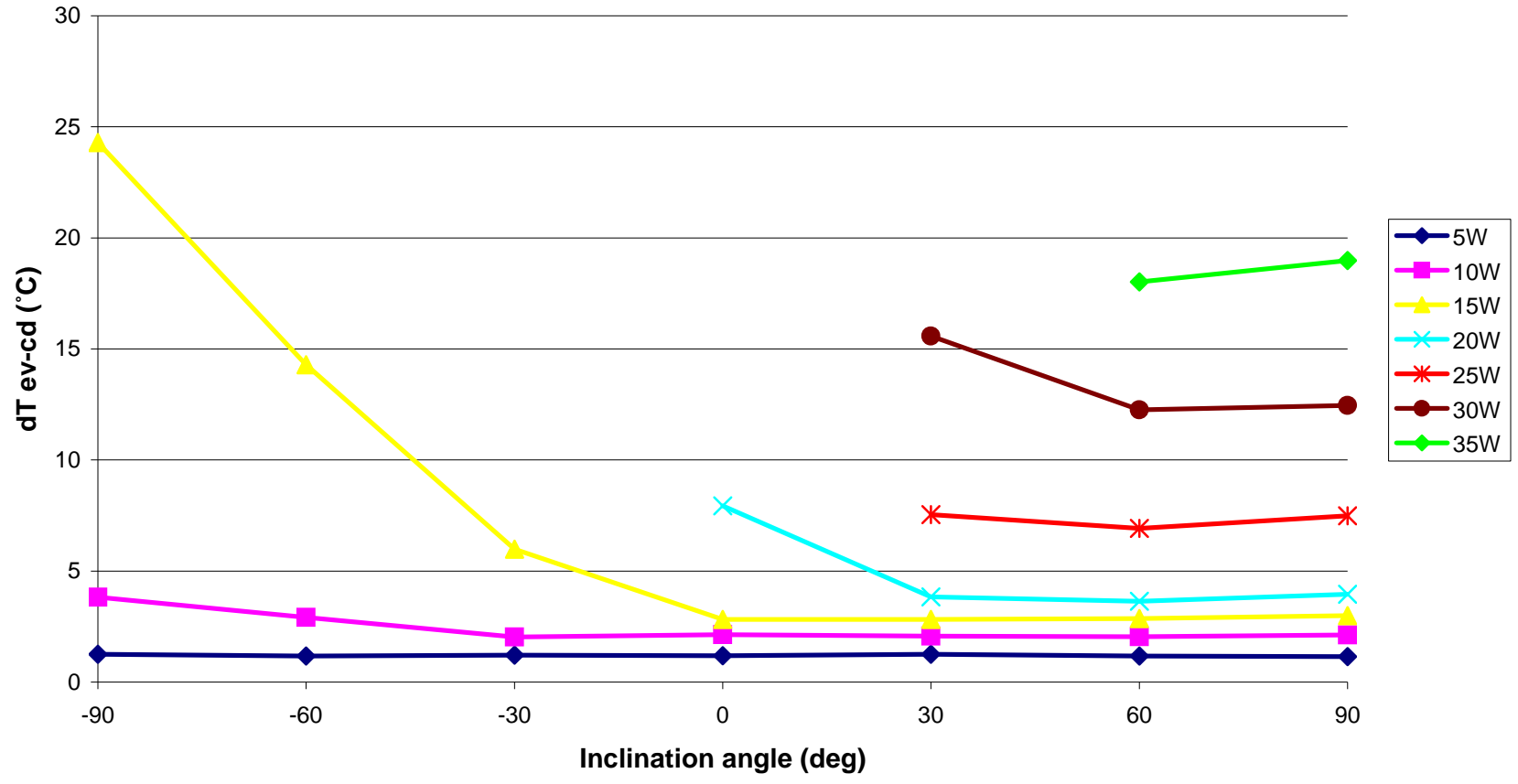
## Heat Pipe Test Report

Manufacturer		Enertron				Test conditions			Test date		9/19/2011				
Wick structure/ Working fluid		Sintered Powder Metal/ Water				Effective area (m2)		1.96E-05		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	5				Contact length of ev/cd (mm)		50							
Length	±0.10 mm	225				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)	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	5	1.15	0.23	38751	1.83	0.37	24418	36.95	35.80	37.69	37.34	35.62	35.76		
	10	2.12	0.21	42001	3.39	0.34	26322	38.71	36.59	39.99	39.35	36.19	36.38		
	15	2.99	0.20	44772	4.84	0.32	27639	40.17	37.19	42.02	41.14	36.64	36.84		
	20	3.96	0.20	45070	6.43	0.32	27709	42.13	38.17	44.59	43.41	37.56	37.58		
	25	7.49	0.30	29741	10.32	0.41	21589	46.63	39.14	49.06	48.01	38.48	37.95		
	30	12.45	0.42	21476	16.31	0.54	16399	52.67	40.22	55.51	54.73	39.32	38.32		
	35	18.98	0.54	16432	23.61	0.67	13213	59.47	40.48	63.14	62.63	39.58	38.98		
60	5	1.17	0.23	38121	1.81	0.36	24607	36.98	35.81	37.70	37.35	35.59	35.83		
	10	2.04	0.20	43690	3.33	0.33	26797	38.66	36.62	39.94	39.33	36.18	36.43		
	15	2.86	0.19	46761	4.68	0.31	28585	40.06	37.20	41.90	40.93	36.63	36.85		
	20	3.64	0.18	48917	6.07	0.30	29386	41.77	38.12	44.21	42.91	37.45	37.53		
	25	6.92	0.28	32180	9.62	0.38	23162	45.80	38.88	48.29	47.13	38.29	37.89		
	30	12.26	0.41	21816	15.90	0.53	16814	52.07	39.81	54.97	54.12	38.88	38.41		
	35	18.02	0.51	17309	22.55	0.64	13835	58.20	40.18	61.98	61.49	39.21	39.17		
30	5	1.25	0.25	35594	1.90	0.38	23442	37.03	35.78	37.72	37.38	35.54	35.76		
	10	2.07	0.21	43036	3.35	0.33	26637	38.65	36.58	39.94	39.29	36.15	36.39		
	15	2.82	0.19	47391	4.65	0.31	28732	39.97	37.14	41.83	40.84	36.56	36.80		
	20	3.84	0.19	46444	6.21	0.31	28700	41.95	38.11	44.30	43.10	37.49	37.50		
	25	7.54	0.30	29547	10.15	0.41	21944	46.44	38.90	48.84	47.74	38.32	37.95		
	30	15.58	0.52	17165	19.42	0.65	13768	54.68	39.10	58.13	57.71	38.50	38.50		
0	5	1.19	0.24	37511	1.94	0.39	23030	37.02	35.83	37.80	37.39	35.54	35.78		
	10	2.13	0.21	41863	3.33	0.33	26781	38.67	36.54	39.90	39.27	36.13	36.38		
	15	2.82	0.19	47374	4.69	0.31	28518	40.01	37.18	41.90	40.89	36.58	36.83		
	20	7.94	0.40	22464	10.76	0.54	16571	46.07	38.13	48.36	48.01	37.13	37.73		
-30	5	1.22	0.24	36617	1.96	0.39	22690	37.09	35.87	37.77	37.42	35.54	35.72		
	10	2.03	0.20	43991	3.37	0.34	26439	38.63	36.61	39.97	39.29	36.11	36.40		
	15	5.98	0.40	22360	8.24	0.55	16234	43.32	37.34	45.10	44.81	36.48	36.96		
-60	5	1.17	0.23	37991	1.97	0.39	22610	37.07	35.90	37.78	37.46	35.53	35.77		
	10	2.92	0.29	30544	4.19	0.42	21261	39.60	36.68	40.70	40.26	36.10	36.48		
	15	14.29	0.95	9354	17.60	1.17	7598	51.64	37.35	54.42	54.13	36.36	36.99		

Inclination Angle (°)	Heat Load (W)	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	5	1.26	0.25	35480	1.95	0.39	22806	37.14	35.88	37.81	37.44	35.56	35.78
	10	3.82	0.38	23313	5.16	0.52	17259	40.44	36.62	41.55	41.29	36.02	36.49
	15	24.30	1.62	5503	27.49	1.83	4864	61.52	37.23	64.24	63.97	36.32	36.92

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

Heat pipe tested:  $\phi 5\text{mm} \times 225\text{mm}$  sintered powder metal/ water

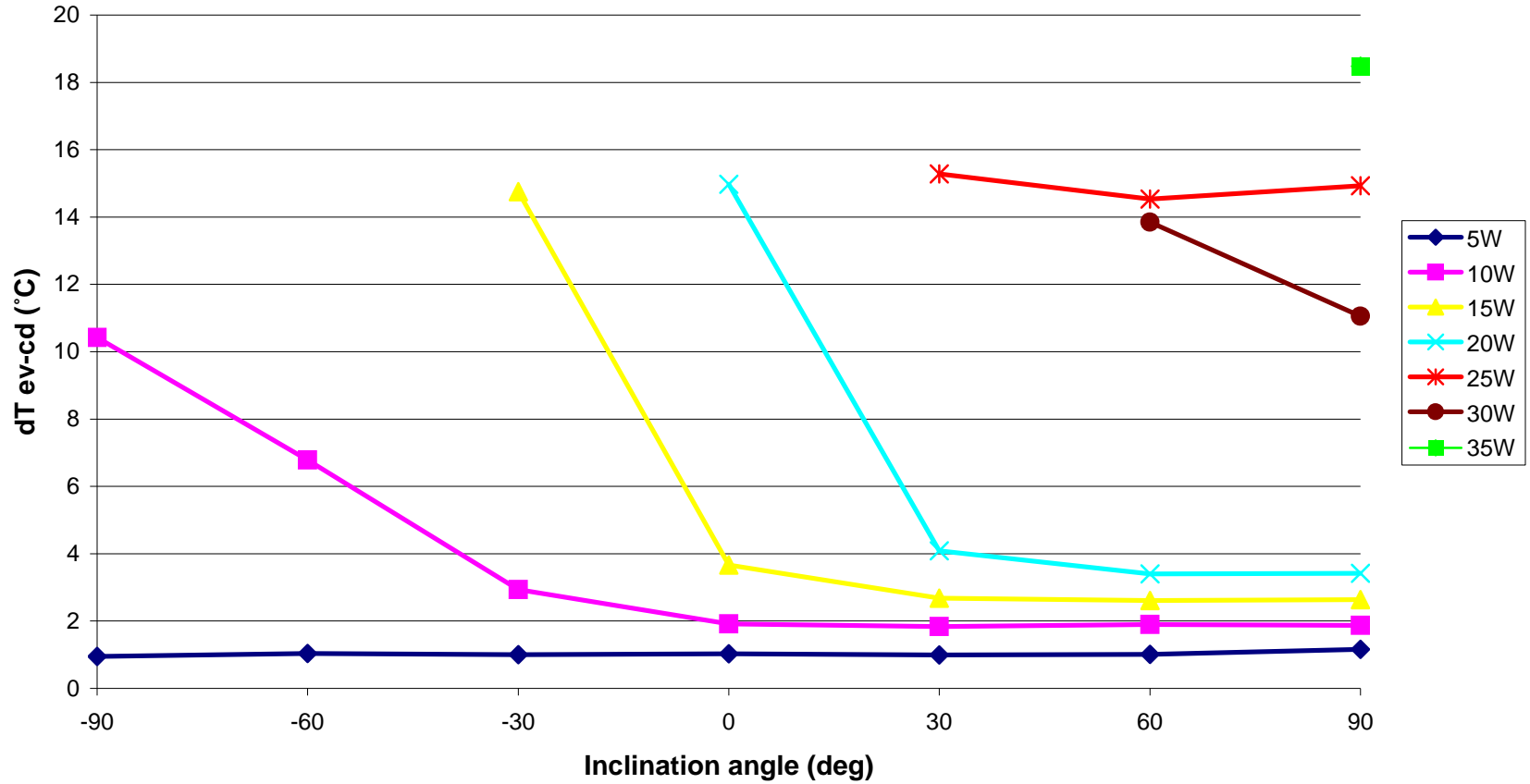


## Heat Pipe Test Report

Manufacturer		Enertron				Test conditions			Test date		9/15/2011		
Wick structure/ Working fluid		Sintered Powder Metal/ Water				Effective area (m2)		1.96E-05	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		5				Contact length of ev/cd (mm)		50					
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)	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	5	1.16	0.23	43981	1.90	0.38	26791	36.97	35.81	37.68	37.27	35.60	35.55
	10	1.88	0.19	54325	3.59	0.36	28405	38.65	36.78	40.17	39.50	36.33	36.17
	15	2.64	0.18	57875	5.27	0.35	29020	40.40	37.76	42.69	41.72	37.02	36.86
	20	3.42	0.17	59637	6.78	0.34	30029	41.77	38.35	44.70	43.42	37.38	37.18
	25	14.93	0.60	17054	20.32	0.81	12533	53.73	38.80	58.34	58.03	37.86	37.87
	30	11.05	0.37	27647	16.19	0.54	18879	51.56	40.50	55.10	54.44	38.94	38.23
	35	18.48	0.53	19288	26.27	0.75	13571	60.74	42.26	65.75	65.15	39.42	38.94
60	5	1.01	0.20	50425	1.85	0.37	27544	36.83	35.82	37.64	37.27	35.61	35.60
	10	1.90	0.19	53667	3.56	0.36	28644	38.59	36.69	40.12	39.42	36.25	36.18
	15	2.61	0.17	58585	5.11	0.34	29894	40.29	37.68	42.53	41.52	37.02	36.80
	20	3.40	0.17	59864	6.81	0.34	29928	41.78	38.37	44.72	43.50	37.36	37.24
	25	14.54	0.58	17517	19.91	0.80	12789	53.31	38.77	57.87	57.56	37.74	37.87
	30	13.85	0.46	22070	19.36	0.65	15788	54.20	40.36	58.23	57.68	38.93	38.28
30	5	1.00	0.20	51134	1.85	0.37	27544	36.78	35.78	37.69	37.23	35.63	35.59
	10	1.83	0.18	55570	3.54	0.35	28782	38.56	36.73	40.06	39.34	36.18	36.14
	15	2.68	0.18	56947	5.15	0.34	29673	40.32	37.64	42.53	41.51	36.91	36.84
	20	4.09	0.20	49845	7.25	0.36	28095	42.45	38.36	45.09	44.02	37.38	37.23
	25	15.28	0.61	16667	20.88	0.84	12195	53.96	38.68	58.78	58.44	37.62	37.84
0	5	1.03	0.21	49494	1.86	0.37	27455	36.84	35.81	37.63	37.21	35.59	35.54
	10	1.92	0.19	53190	3.52	0.35	28970	38.62	36.71	40.14	39.39	36.29	36.21
	15	3.66	0.24	41746	5.80	0.39	26338	41.30	37.64	43.18	42.26	36.98	36.86
	20	14.98	0.75	13602	19.28	0.96	10568	52.88	37.90	56.53	56.20	36.99	37.19
-30	5	1.00	0.20	51032	1.86	0.37	27426	36.80	35.80	37.62	37.23	35.62	35.52
	10	2.94	0.29	34670	4.25	0.42	23978	39.54	36.60	40.68	40.17	36.17	36.19
	15	14.75	0.98	10359	17.42	1.16	8770	51.85	37.10	54.14	53.95	36.50	36.73
-60	5	1.04	0.21	49112	1.86	0.37	27367	36.78	35.74	37.60	37.23	35.59	35.52
	10	6.78	0.68	15019	8.95	0.90	11376	43.34	36.56	45.23	45.06	36.12	36.26
-90	5	0.95	0.19	53554	1.82	0.36	28060	36.78	35.83	37.58	37.23	35.61	35.58
	10	10.42	1.04	9773	12.01	1.20	8481	46.84	36.42	48.26	48.00	36.03	36.21

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

Heat pipe tested:  $\phi$ 5mm x 250mm sintered powder metal/ water



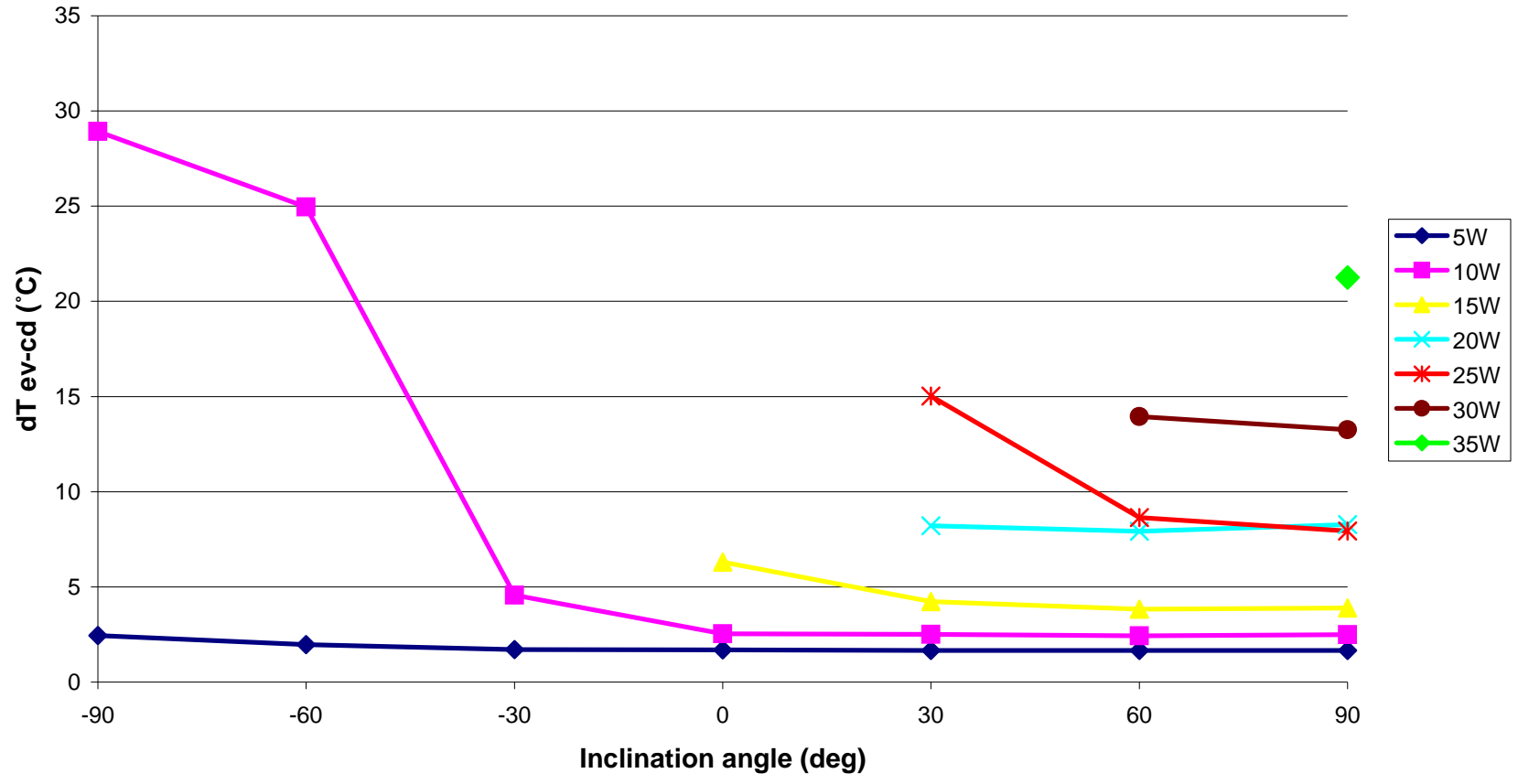
## Heat Pipe Test Report

Manufacturer		Enertron				Test conditions				Test date	9/14/2011				
Wick structure/ Working fluid		Sintered Powder Metal/ Water				Effective area (m2)		1.96E-05		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	5				Contact length of ev/cd (mm)		50							
Length	±0.10 mm	275				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)	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	5	1.67	0.33	34412	2.72	0.54	21088	37.74	36.07	38.35	38.26	35.43	35.75		
	10	2.49	0.25	46002	4.31	0.43	26575	39.32	36.83	40.62	40.42	36.00	36.42		
	15	3.89	0.26	44187	6.11	0.41	28155	41.57	37.68	43.16	42.83	36.69	37.09		
	20	8.27	0.41	27723	11.47	0.57	19985	46.76	38.49	48.57	49.30	37.23	37.70		
	25	7.94	0.32	36076	11.17	0.45	25654	46.90	38.96	48.94	49.07	37.67	38.00		
	30	13.26	0.44	25922	17.97	0.60	19132	53.15	39.88	55.93	56.95	38.52	38.42		
	35	21.26	0.61	18869	29.01	0.83	13824	62.39	41.14	67.20	68.91	39.39	38.70		
60	5	1.66	0.33	34516	2.72	0.54	21057	37.69	36.03	38.26	38.27	35.42	35.67		
	10	2.43	0.24	47118	4.16	0.42	27579	39.24	36.81	40.43	40.31	36.03	36.40		
	15	3.82	0.25	44950	6.02	0.40	28567	41.49	37.67	43.12	42.74	36.72	37.11		
	20	7.93	0.40	28919	10.93	0.55	20978	46.25	38.32	47.99	48.61	37.13	37.61		
	25	8.65	0.35	33127	12.00	0.48	23871	47.66	39.02	49.64	50.05	37.66	38.02		
	30	13.95	0.46	24649	18.73	0.62	18355	53.53	39.59	56.54	57.70	38.41	38.38		
30	5	1.66	0.33	34536	2.73	0.55	20980	37.69	36.03	38.34	38.24	35.37	35.75		
	10	2.51	0.25	45600	4.19	0.42	27329	39.28	36.77	40.50	40.28	36.01	36.39		
	15	4.23	0.28	40607	6.29	0.42	27327	41.88	37.65	43.31	43.05	36.68	37.10		
	20	8.21	0.41	27908	11.31	0.57	20264	46.64	38.43	48.40	49.00	37.20	37.58		
	25	15.02	0.60	19076	19.90	0.80	14396	53.74	38.72	57.08	58.30	37.86	37.72		
0	5	1.70	0.34	33763	2.75	0.55	20850	37.69	35.99	38.30	38.21	35.39	35.63		
	10	2.54	0.25	45044	4.35	0.43	26349	39.37	36.83	40.60	40.45	35.99	36.35		
	15	6.31	0.42	27236	8.76	0.58	19615	43.92	37.60	45.29	45.79	36.58	36.98		
-30	5	1.71	0.34	33467	2.80	0.56	20485	37.73	36.02	38.39	38.23	35.36	35.66		
	10	4.57	0.46	25058	6.33	0.63	18109	41.42	36.84	42.18	42.72	35.91	36.34		
-60	5	1.98	0.40	29011	2.96	0.59	19383	38.00	36.02	38.47	38.49	35.38	35.66		
	10	24.96	2.50	4592	26.81	2.68	4274	61.65	36.69	62.58	62.94	35.73	36.17		
-90	5	2.45	0.49	23424	3.34	0.67	17134	38.46	36.01	38.80	38.98	35.47	35.63		
	10	28.93	2.89	3962	30.61	3.06	3743	65.52	36.60	66.39	66.78	35.80	36.13		



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

Heat pipe tested:  $\phi 5\text{mm} \times 275\text{mm}$  sintered powder metal/ water



## Heat Pipe Test Report

Manufacturer		Enertron				Test conditions				Test date	9/13/2011				
Wick structure/ Working fluid		Sintered Powder Metal/ Water				Effective area (m2)		1.96E-05		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	5				Contact length of ev/cd (mm)		50							
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)	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	5	2.06	0.41	30919	3.46	0.69	18399	37.84	35.79	39.14	38.76	35.31	35.67		
	10	3.47	0.35	36735	5.67	0.57	22464	39.89	36.43	42.11	41.53	35.92	36.38		
	15	5.08	0.34	37566	7.80	0.52	24485	42.41	37.32	45.12	44.22	36.60	37.15		
	20	10.27	0.51	24788	14.18	0.71	17960	48.32	38.04	51.96	51.36	37.21	37.76		
	25	10.28	0.41	30970	14.05	0.56	22656	48.65	38.38	52.29	51.37	37.49	38.07		
	30	20.59	0.69	18551	27.76	0.93	13761	60.07	39.48	66.51	65.75	38.31	38.44		
60	5	2.15	0.43	29652	3.42	0.68	18615	37.91	35.76	39.04	38.81	35.31	35.70		
	10	3.46	0.35	36788	5.66	0.57	22491	39.92	36.46	42.08	41.51	35.88	36.39		
	15	5.20	0.35	36749	7.74	0.52	24678	42.42	37.23	45.02	44.11	36.55	37.10		
	20	9.60	0.48	26526	13.27	0.66	19197	47.52	37.92	50.87	50.34	37.04	37.65		
	25	10.88	0.44	29264	14.88	0.60	21390	49.35	38.47	53.12	52.24	37.53	38.07		
	30	21.57	0.72	17708	29.05	0.97	13147	60.79	39.22	67.82	67.01	38.22	38.51		
30	5	2.12	0.42	30058	3.43	0.69	18577	37.95	35.83	39.08	38.81	35.33	35.70		
	10	3.60	0.36	35348	5.76	0.58	22120	40.11	36.51	42.25	41.61	35.94	36.40		
	15	5.68	0.38	33630	8.05	0.54	23728	42.97	37.30	45.25	44.50	36.56	37.10		
	20	10.50	0.53	24248	14.40	0.72	17688	48.55	38.05	52.04	51.47	37.15	37.56		
	25	21.58	0.86	14753	28.07	1.12	11340	60.03	38.46	66.03	65.33	37.32	37.90		
0	5	2.28	0.46	27971	3.42	0.68	18631	38.01	35.73	39.11	38.80	35.40	35.67		
	10	3.86	0.39	33003	5.82	0.58	21866	40.26	36.40	42.26	41.64	35.88	36.37		
	15	8.52	0.57	22406	11.66	0.78	16374	45.87	37.35	48.69	48.23	36.43	37.17		
-30	5	2.31	0.46	27512	3.47	0.69	18368	38.05	35.74	39.19	38.86	35.39	35.73		
	10	5.06	0.51	25158	6.88	0.69	18514	41.46	36.40	43.19	42.79	35.83	36.39		
-60	5	2.45	0.49	26016	3.50	0.70	18205	38.12	35.67	39.19	38.87	35.38	35.68		
	10	14.93	1.49	8530	17.22	1.72	7394	51.48	36.55	53.49	53.16	35.77	36.44		
-90	5	2.46	0.49	25847	3.53	0.71	18014	38.23	35.76	39.25	38.91	35.36	35.73		
	10	20.58	2.06	6187	22.59	2.26	5638	57.15	36.57	58.82	58.53	35.74	36.44		

