Building Thermal Loads and Systems
24CVP305

Semester 1 2024-25 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

<u>Help during the exam</u>

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **THREE** questions.

All questions carry equal marks.

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1. a) The cooling load due to solar gain through glazing (Q_{sg}) can be estimated using the expression:

$$Q_{sg} = A_g\, f_s\, f_c\, q_{sg}$$

Explain the meanings of the terms in this expression. [2 marks]

b) Name, sketch and briefly describe the apparatus used to measure the thermal resistance of building materials. Note the direction of heat flow and comment on why the apparatus is designed as it is to ensure this happens. [6 marks]

c) A small factory is to be heated to a dry resultant temperature of 21 °C, and is depicted in Figure Q1b. The site is subject to normal conditions of exposure, and will be heated using multi-column radiators. Relevant data are given in Table Q1b. An infiltration rate of 1 air change per hour is assumed for this building. The external design temperature is -4 °C. Using the CIBSE steady state simple model: Calculate a suitable design heat loss rate. [12 marks]

Table Q1b: Relevant data for Q1b.

Parameter	***Value***
Internal dimensions	12.0 m X 7.0 m X 4.0 m
Glazing dimensions (each)	2.0 m X 1.5 m
Door A	4.0 m X 3.5 m
Door B	1.0 m X 2.0 m
U-value of floor	0.50 W/m^{2}K
U-value of roof	0.25 W/m^{2}K
U-value of external walls	0.55 W/m^{2}K
U-value of glazing	3.50 W/m^{2}K
U-value of doors	3.00 W/m^{2}K

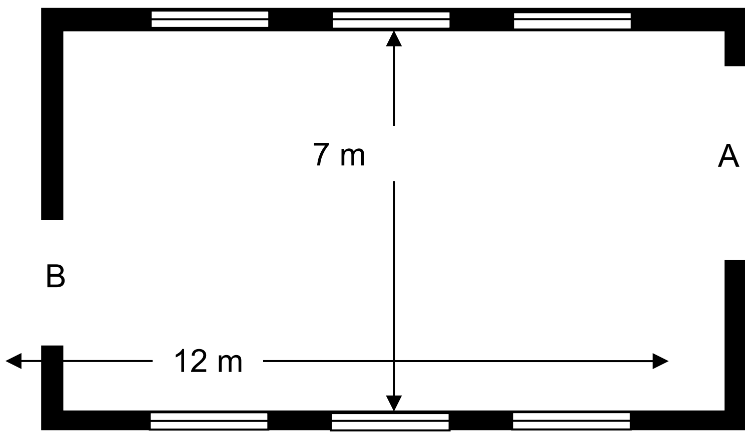

Figure Q1b: Plan of the Factory Building for question 1b.

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2. a) Describe the summer and winter design cycles of a plant with basic re-circulation. [8 marks]

   b) Two streams of air mix. Stream A is from outside, and stream B is re-circulated from an air-conditioned room. The mixed air is cooled and de-humidified using a sprayed coil and then reheated and supplied to the conditioned room. Using the psychrometric chart given in Figure Q2, and the data below, calculate:

      i) The apparatus dew point of the coil. [5 marks]

      ii) The specific cooling load on the coil (kJ/kg of dry mixed air). [2 marks]

      iii) The load (kJ/kg of dry mixed air) on the reheating coil, ignoring any fan heat. [2 marks]

      iv) The mass of air that must be supplied per second, and the sensible load that is being satisfied. [3 marks]

   Data:
   Air stream A: 29 ^{o}C dry bulb, 26 ^{o}C wet bulb. Air stream B: 22 ^{o}C dry bulb and with a relative humidity of 55%. Mix ratio: 9 parts (B) to 1 part (A). Supply condition: 15 ^{o}C dry bulb, 0.0064 kg/kg. Spray coil contact factor 0.85. Room latent load 10 kW, and specific heat of the air per unit mass of dry air 1.02 kJ/kg K.

3. For each of the following heat exchangers, describe: their **application** in buildings, including **the fluids** between which heat is to be transferred; their **construction** which should be **illustrated** with a simple diagram; and the approximate **flow- configuration** (cross-flow or counter-flow):

   a) Heating and cooling coils. [7 marks]

   b) Shell and tube heat exchangers. [6 marks]

   c) Plate heat exchangers. [7 marks]

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4. A low pressure hot water heating system with flow and return temperatures of 80˚C and 70˚C respectfully, is to be designed using medium grade steel. Figure Q4 details the layout and Table Q4a lists the lengths of the pipe sections. Assume 300Pa/m pressure drop for your preliminary sizing and use the data in Table Q4b to answer the following:

   a) State a sensible percentage addition to use in calculations to account for losses on the fittings and bends and identify and state the index leg of the system in Figure Q4. [3 marks]

   b) Neglecting heat losses and taking the specific heat capacity of water to be 4.2 kJ/kgK, determine:

      i) The pipe sizes for the index leg. [6 marks]

      ii) The pressure rise required across the pump. [3 marks]

      iii) The pipe size and excess pressure for branch 'f'. [3 marks]

   c) With the use of a diagram, describe the combined pump/system resistance characteristics for a low temperature hydronic heating system. [5 marks]

Table Q4a: Pipe lengths

Pipe section	a	b	c	d	e	f	g	h	i
Length (flow + return, in m)	40	25	25	25	30	15	15	15	15

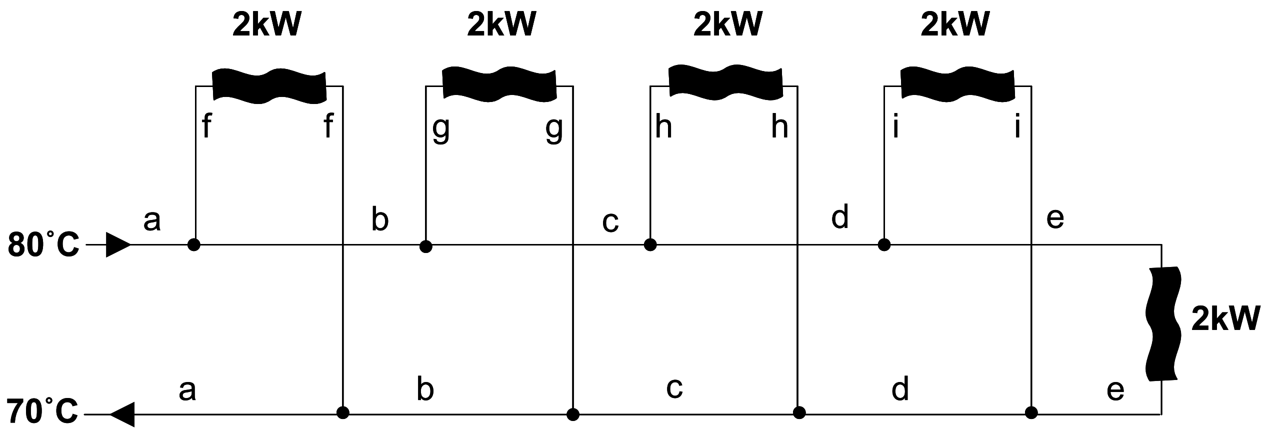

Figure Q4: System layout

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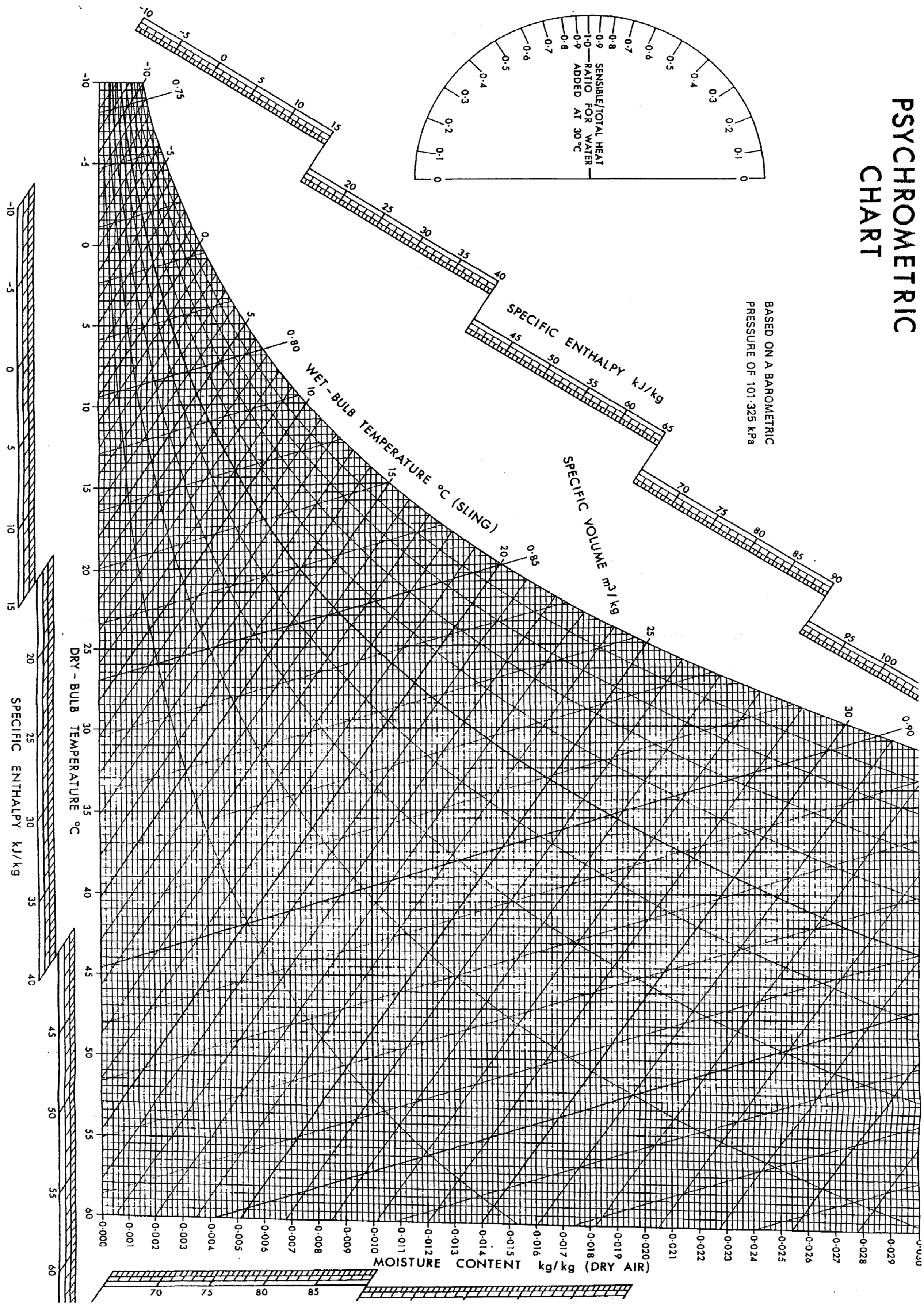

Figure Q2: The Psychrometric Chart.

Table Q4b: Medium grade steel pipe pressure loss data.

Δp_l		10 mm		15 mm		20 mm		25 mm		32 mm		40 mm		50 mm			Δp_l
(Pa/m)	v	M	l_e	M	l_e	M	l_e	M	l_e	M	l_e	M	l_e	M	l_e	v	(Pa/m)
80.0		0.027	0.3	0.055	0.5	0.122	0.7	0.228	1.0	0.480	1.4	0.720	1.8	1.35	2.4		80.0
82.5		0.028	0.3	0.056	0.5	0.124	0.7	0.232	1.0	0.488	1.4	0.732	1.8	1.37	2.4		82.5
85.0		0.028	0.3	0.057	0.5	0.126	0.7	0.236	1.0	0.496	1.4	0.743	1.8	1.39	2.4		85.0
87.5		0.029	0.3	0.058	0.5	0.128	0.7	0.240	1.0	0.503	1.4	0.755	1.8	1.41	2.4		87.5
90.0		0.029	0.3	0.059	0.5	0.130	0.7	0.243	1.0	0.511	1.4	0.766	1.8	1.43	2.4		90.0
92.5		0.029	0.3	0.060	0.5	0.132	0.7	0.247	1.0	0.518	1.5	0.778	1.8	1.45	2.4		92.5
95.0		0.030	0.3	0.061	0.5	0.134	0.7	0.251	1.0	0.526	1.5	0.789	1.8	1.48	2.4		95.0
97.5		0.030	0.3	0.062	0.5	0.136	0.7	0.254	1.0	0.533	1.5	0.800	1.8	1.50	2.4		97.5
100.0		0.031	0.3	0.062	0.5	0.138	0.7	0.258	1.0	0.540	1.5	0.810	1.8	1.52	2.4		100.0
120.0	0.30	0.034	0.3	0.069	0.5	0.152	0.7	0.284	1.0	0.595	1.5	0.893	1.8	1.67	2.4		120.0
140.0		0.037	0.3	0.075	0.5	0.165	0.8	0.308	1.0	0.646	1.5	0.968	1.8	1.81	2.5		140.0
160.0		0.040	0.4	0.081	0.5	0.178	0.8	0.331	1.0	0.693	1.5	1.04	1.8	1.94	2.5		160.0
180.0		0.042	0.4	0.086	0.5	0.189	0.8	0.353	1.0	0.738	1.5	1.11	1.8	2.06	2.5	1.0	180.0
200.0		0.045	0.4	0.091	0.5	0.200	0.8	0.373	1.1	0.780	1.5	1.17	1.9	2.18	2.5		200.0
220.0		0.047	0.4	0.096	0.5	0.211	0.8	0.392	1.1	0.820	1.5	1.28	1.9	2.29	2.5		220.0
240.0		0.050	0.4	0.100	0.5	0.221	0.8	0.411	1.1	0.858	1.5	1.29	1.9	2.40	2.5		240.0
260.0		0.052	0.4	0.105	0.5	0.230	0.8	0.428	1.1	0.895	1.5	1.34	1.9	2.50	2.5		260.0
280.0		0.054	0.4	0.109	0.5	0.239	0.8	0.445	1.1	0.931	1.5	1.39	1.9	2.60	2.6		280.0
300.0		0.056	0.4	0.113	0.5	0.248	0.8	0.462	1.1	0.965	1.5	1.44	1.9	2.69	2.6		300.0
320.0	0.50	0.058	0.4	0.117	0.5	0.257	0.8	0.478	1.1	0.998	1.6	1.49	1.9	2.78	2.6		320.0
340.0		0.060	0.4	0.121	0.5	0.265	0.8	0.493	1.1	1.03	1.6	1.54	1.9	2.87	2.6		340.0
360.0		0.062	0.4	0.125	0.5	0.273	0.8	0.508	1.1	1.06	1.6	1.59	1.9	2.96	2.6		360.0
380.0		0.064	0.4	0.128	0.5	0.281	0.8	0.523	1.1	1.09	1.6	1.63	1.9	3.04	2.6		380.0
400.0		0.065	0.4	0.132	0.5	0.289	0.8	0.537	1.1	1.12	1.6	1.68	1.9	3.12	2.6		400.0
420.0		0.067	0.4	0.135	0.5	0.297	0.8	0.551	1.1	1.15	1.6	1.72	1.9	3.20	2.6	1.5	420.0
440.0		0.069	0.4	0.139	0.5	0.304	0.8	0.564	1.1	1.18	1.6	1.76	1.9	3.28	2.6		440.0
460.0		0.070	0.4	0.142	0.5	0.311	0.8	0.578	1.1	1.21	1.6	1.80	1.9	3.36	2.6		460.0
480.0		0.072	0.4	0.145	0.5	0.318	0.8	0.591	1.1	1.23	1.6	1.84	1.9	3.43	2.6		480.0
500.0		0.074	0.4	0.148	0.5	0.325	0.8	0.603	1.1	1.25	1.6	1.88	1.9	3.51	2.6		500.0
520.0		0.075	0.4	0.151	0.5	0.332	0.8	0.616	1.1	1.29	1.6	1.92	1.9	3.58	2.6		520.0
540.0		0.077	0.4	0.154	0.6	0.338	0.8	0.628	1.1	1.31	1.6	1.96	1.9	3.65	2.6		540.0
560.0		0.078	0.4	0.157	0.6	0.345	0.8	0.640	1.1	1.34	1.6	2.00	1.9	3.72	2.6		560.0
580.0		0.080	0.4	0.160	0.6	0.351	0.8	0.652	1.1	1.36	1.6	2.03	1.9	3.78	2.6		580.0
600.0		0.081	0.4	0.163	0.6	0.355	0.8	0.664	1.1	1.38	1.6	2.07	1.9	3.85	2.6		600.0
620.0		0.082	0.4	0.166	0.6	0.364	0.8	0.675	1.1	1.41	1.6	2.10	1.9	3.92	2.6		620.0
640.0		0.084	0.4	0.169	0.6	0.370	0.8	0.686	1.1	1.43	1.6	2.14	1.9	3.98	2.6		640.0
660.0		0.085	0.4	0.172	0.6	0.376	0.8	0.697	1.1	1.45	1.6	2.17	1.9	4.04	2.6		660.0
680.0		0.087	0.4	0.174	0.6	0.382	0.8	0.708	1.1	1.48	1.6	2.21	1.9	4.11	2.6		680.0
700.0		0.088	0.4	0.177	0.6	0.388	0.8	0.719	1.1	1.50	1.6	2.24	1.9	4.17	2.6		700.0
720.0		0.089	0.4	0.180	0.6	0.393	0.8	0.730	1.1	1.52	1.6	2.27	1.9	4.23	2.6		720.0
740.0		0.091	0.4	0.182	0.6	0.399	0.8	0.740	1.1	1.54	1.6	2.31	2.0	4.29	2.6	2.0	740.0
760.0		0.092	0.4	0.185	0.6	0.405	0.8	0.750	1.1	1.56	1.6	2.34	2.0	4.35	2.6		760.0
780.0		0.093	0.4	0.187	0.6	0.410	0.8	0.761	1.1	1.59	1.6	2.37	2.0	4.41	2.6		780.0
800.0		0.094	0.4	0.190	0.6	0.416	0.8	0.771	1.1	1.61	1.6	2.40	2.0	4.46	2.6		800.0
820.0		0.096	0.4	0.192	0.6	0.421	0.8	0.780	1.1	1.63	1.6	2.43	2.0	4.52	2.6		820.0
840.0		0.097	0.4	0.195	0.6	0.426	0.8	0.790	1.1	1.65	1.6	2.46	2.0	4.58	2.6		840.0
860.0		0.098	0.4	0.197	0.6	0.431	0.8	0.800	1.1	1.67	1.6	2.49	2.0	4.63	2.6		860.0
880.0		0.099	0.4	0.200	0.6	0.437	0.8	0.810	1.1	1.69	1.6	2.52	2.0	4.69	2.6		880.0
900.0		0.100	0.4	0.202	0.6	0.442	0.8	0.819	1.1	1.71	1.6	2.55	2.0	4.74	2.6		900.0
920.0		0.102	0.4	0.204	0.6	0.447	0.8	0.828	1.1	1.73	1.6	2.58	2.0	4.80	2.6		920.0
940.0		0.103	0.4	0.207	0.6	0.452	0.8	0.838	1.1	1.75	1.6	2.61	2.0	4.85	2.6		940.0
960.0		0.104	0.4	0.209	0.6	0.457	0.8	0.847	1.1	1.76	1.6	2.64	2.0	4.90	2.6		960.0
980.0		0.105	0.4	0.211	0.6	0.462	0.8	0.856	1.1	1.78	1.6	2.66	2.0	4.95	2.6		980.0
1 000.0		0.106	0.4	0.213	0.6	0.467	0.8	0.865	1.1	1.80	1.6	2.69	2.0	5.00	2.6		1 000.0
1 100.0		0.112	0.4	0.224	0.6	0.490	0.8	0.909	1.1	1.89	1.6	2.83	2.0	5.26	2.7		1 100.0
1 200.0	1.0	0.117	0.4	0.235	0.6	0.513	0.8	0.950	1.1	1.98	1.6	2.96	2.0	5.49	2.7		1 200.0
1 300.0		0.122	0.4	0.245	0.6	0.535	0.8	0.990	1.1	2.06	1.6	3.08	2.0	5.72	2.7		1 300.0
1 400.0		0.127	0.4	0.254	0.6	0.555	0.8	1.03	1.1	2.14	1.6	3.20	2.0	5.94	2.7		1 400.0
1 500.0		0.131	0.4	0.263	0.6	0.576	0.8	1.07	1.1	2.22	1.6	3.31	2.0	6.16	2.7		1 500.0
1 600.0		0.136	0.4	0.272	0.6	0.595	0.9	1.10	1.1	2.29	1.6	3.42	2.0	6.36	2.7	3.0	1 600.0
1 700.0		0.140	0.4	0.281	0.6	0.614	0.9	1.14	1.2	2.37	1.6	3.53	2.0	6.56	2.7		1 700.0
1 800.0		0.144	0.4	0.290	0.6	0.632	0.9	1.17	1.2	2.44	1.6	3.64	2.0	6.76	2.7		1 800.0
1 900.0		0.148	0.4	0.298	0.6	0.650	0.9	1.20	1.2	2.50	1.6	3.74	2.0	6.94	2.7		1 900.0