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# ***MODELING AND OPTIMAL SYNTHESIS OF COOLING WATER PUMPING AND DISTRIBUTION SYSTEMS***

**Preliminary Report - Appendix**  
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## RESULTS FOR CASE D1

### Piping Results

Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
1	11,532	2.832	1.11	0.96	1.5	0	-0.15	-0.15	-0.15	-1.5	0.96	1.11	1.00	1.15	-46.6
2	11,532	2.832	4.70	3.68	0	10	1.02	1.02	0.98	10.2	4.70	3.68	4.74	3.72	325.9
3	7,432	2.936	3.68	3.63	10	10	0.05	0.05	0	0.5	3.68	3.63	3.72	3.67	10.8
5	7,232	2.857	3.63	3.58	10	10	0.05	0.05	0	0.5	3.63	3.58	3.67	3.62	10.0
6	6,132	3.041	3.58	3.51	10	10	0.06	0.06	0	0.6	3.58	3.51	3.62	3.56	10.9
7	3,732	2.755	3.52	3.45	10	10	0.07	0.07	0	0.7	3.52	3.45	3.56	3.49	6.9
8	2,732	2.771	3.45	3.37	10	10	0.08	0.08	0	0.8	3.45	3.37	3.49	3.41	6.2
9	1,632	3.007	3.36	3.23	10	10	0.14	0.14	0	1.4	3.36	3.23	3.41	3.27	6.2
10	1,600	2.948	3.23	3.10	10	10	0.13	0.13	0	1.3	3.23	3.10	3.27	3.14	5.8
11	1,200	2.829	3.10	2.96	10	10	0.14	0.14	0	1.4	3.10	2.96	3.14	3.00	4.7
12	400	2.184	2.98	2.84	10	10	0.14	0.14	0	1.4	2.98	2.84	3.00	2.86	1.6
13	4,100	3.027	3.68	3.67	10	10	0.01	0.01	0	0.1	3.68	3.67	3.72	3.72	0.9
14	200	2.981	3.63	3.58	10	10	0.05	0.05	0	0.5	3.63	3.58	3.67	3.62	0.3
16	1,100	2.593	3.59	3.58	10	10	0.01	0.01	0	0.1	3.59	3.58	3.62	3.61	0.4
17	2,400	2.914	3.52	3.51	10	10	0.01	0.01	0	0.1	3.52	3.51	3.56	3.55	0.7
18	1,000	3.123	3.44	3.42	10	10	0.02	0.02	0	0.2	3.44	3.42	3.49	3.47	0.6
19	1,100	2.593	3.38	3.36	10	10	0.01	0.01	0	0.1	3.38	3.36	3.41	3.40	0.4
20	32	2.878	3.23	3.10	10	10	0.13	0.13	0	1.3	3.23	3.10	3.27	3.14	0.1
21	400	2.184	3.12	3.10	10	10	0.01	0.01	0	0.1	3.12	3.10	3.14	3.13	0.2
22	800	2.498	2.97	2.96	10	10	0.01	0.01	0	0.1	2.97	2.96	3.00	2.99	0.3
23	400	2.184	2.84	2.82	10	10	0.01	0.01	0	0.1	2.84	2.82	2.86	2.85	0.2
24	4,100	3.027	1.49	1.48	10	10	0.01	0.01	0	0.1	1.49	1.48	1.53	1.52	0.9



Pipe	Vol. Flow Rate (m3/hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
25	200	2.981	1.60	1.56	10	10	0.05	0.05	0	0.5	1.60	1.56	1.65	1.60	0.3
27	1,100	2.593	2.49	2.48	10	10	0.01	0.01	0	0.1	2.49	2.48	2.53	2.52	0.4
28	2,400	2.914	1.63	1.62	10	10	0.01	0.01	0	0.1	1.63	1.62	1.67	1.66	0.7
29	1,000	3.123	1.77	1.75	10	10	0.02	0.02	0	0.2	1.77	1.75	1.82	1.80	0.6
30	1,100	2.593	2.71	2.69	10	10	0.01	0.01	0	0.1	2.71	2.69	2.74	2.73	0.4
31	32	2.878	2.15	2.01	10	10	0.13	0.13	0	1.3	2.15	2.01	2.19	2.06	0.1
32	400	2.184	1.88	1.87	10	10	0.01	0.01	0	0.1	1.88	1.87	1.91	1.89	0.2
33	800	2.498	2.09	2.07	10	10	0.01	0.01	0	0.1	2.09	2.07	2.12	2.11	0.3
34	400	2.184	2.16	2.15	10	10	0.01	0.01	0	0.1	2.16	2.15	2.19	2.17	0.2
35	4,100	3.027	1.02	1.01	10	10	0.01	0.01	0	0.1	1.02	1.01	1.07	1.06	0.9
36	200	2.981	1.11	1.07	10	10	0.05	0.05	0	0.5	1.11	1.07	1.16	1.11	0.3
38	1,100	2.593	1.14	1.13	10	10	0.01	0.01	0	0.1	1.14	1.13	1.17	1.16	0.4
39	2,400	2.914	1.19	1.18	10	10	0.01	0.01	0	0.1	1.19	1.18	1.23	1.22	0.7
40	1,000	3.123	1.26	1.24	10	10	0.02	0.02	0	0.2	1.26	1.24	1.31	1.29	0.6
41	1,100	2.593	1.35	1.34	10	10	0.01	0.01	0	0.1	1.35	1.34	1.38	1.37	0.4
42	32	2.878	1.60	1.47	10	10	0.13	0.13	0	1.3	1.60	1.47	1.64	1.51	0.1
43	400	2.184	1.63	1.62	10	10	0.01	0.01	0	0.1	1.63	1.62	1.65	1.64	0.2
44	800	2.498	1.76	1.75	10	10	0.01	0.01	0	0.1	1.76	1.75	1.79	1.78	0.3
45	400	2.184	1.91	1.90	10	10	0.01	0.01	0	0.1	1.91	1.90	1.94	1.92	0.2
46	400	2.184	1.90	1.76	10	10	0.14	0.14	0	1.4	1.90	1.76	1.92	1.78	1.6
47	1,200	2.829	1.74	1.60	10	10	0.14	0.14	0	1.4	1.74	1.60	1.78	1.64	4.7
48	1,600	2.948	1.60	1.46	10	10	0.13	0.13	0	1.3	1.60	1.46	1.64	1.51	5.8
49	1,632	3.007	1.46	1.33	10	10	0.14	0.14	0	1.4	1.46	1.33	1.51	1.37	6.2
50	2,732	2.771	1.33	1.25	10	10	0.08	0.08	0	0.8	1.33	1.25	1.37	1.29	6.2
51	3,732	2.755	1.25	1.19	10	10	0.07	0.07	0	0.7	1.25	1.19	1.29	1.22	6.9
52	6,132	3.041	1.18	1.11	10	10	0.06	0.06	0	0.6	1.18	1.11	1.22	1.16	10.9
53	7,232	2.857	1.12	1.07	10	10	0.05	0.05	0	0.5	1.12	1.07	1.16	1.11	10.0
55	7,432	2.936	1.07	1.01	10	10	0.05	0.05	0	0.5	1.07	1.01	1.11	1.06	10.8
56	11,532	3.38	1.00	0.94	10	10	0.06	0.06	0	0.6	1.00	0.94	1.06	1.00	18.4



## Control Valves Results

Control Valve	Valve Type	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (m)	P Static In (bar)	Cv	K	Valve State	Energy Loss (kW)
14	FCV	4,100	1,139	2.18	22.3	3.67	3,209	47.7	Open	248.8
15	FCV	200	56	1.98	20.2	3.58	165	44.5	Open	11.0
17	FCV	1,100	306	1.08	11.0	3.577	1,223	32.2	Open	33.1
18	FCV	2,400	667	1.88	19.2	3.506	2,024	44.3	Open	125.4
19	FCV	1,000	278	1.65	16.9	3.422	900	33.9	Open	45.9
20	FCV	1,100	306	0.66	6.7	3.364	1,569	19.6	Open	20.1
21	FCV	32	9	0.95	9.7	3.099	38	23.0	Open	0.8
22	FCV	400	111	1.22	12.5	3.104	419	51.2	Open	13.6
23	FCV	800	222	0.87	8.9	2.957	992	27.9	Open	19.3
24	FCV	400	111	0.66	6.7	2.822	570	27.6	Open	7.3

## Heat Exchangers Results

Heat Exchanger	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (meters)	Energy Loss (kW)
25	4,100	1,139	0.46	4.7	52.2
26	200	56	0.44	4.5	2.5
28	1,100	306	1.34	13.7	41.1
29	2,400	667	0.42	4.3	28.3
30	1,000	278	0.49	5.0	13.5
31	1,100	306	1.34	13.7	41.1
32	32	9	0.41	4.2	0.4
33	400	111	0.24	2.4	2.7
34	800	222	0.31	3.2	6.9
35	400	111	0.24	2.4	2.7



## RESULTS FOR CASE D2

### Piping Results

Pipe	Vol. Flow Rate (m3/hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
1	11,532	2.832	1.11	0.96	1.5	0	-0.15	-0.15	-0.15	0.0	0.96	1.11	1.00	1.15	-46.6
2	11,532	2.832	3.31	2.29	0	10	1.02	1.02	0.98	0.4	3.31	2.29	3.35	2.33	325.9
3	7,432	2.936	3.24	2.29	10	0	-0.95	-0.95	-0.98	0.3	2.29	3.24	2.33	3.28	-197.1
4	7,432	2.936	4.63	3.62	0	10	1.01	1.01	0.98	0.3	4.63	3.62	4.67	3.66	207.8
5	7,232	2.857	3.62	3.57	10	10	0.05	0.05	0	0.5	3.62	3.57	3.66	3.62	10.0
6	6,132	3.041	3.57	3.50	10	10	0.06	0.06	0	0.7	3.57	3.50	3.62	3.55	10.9
7	3,732	2.755	3.51	3.45	10	10	0.07	0.07	0	0.7	3.51	3.45	3.55	3.48	6.9
8	2,732	2.771	3.45	3.36	10	10	0.08	0.08	0	0.8	3.45	3.36	3.48	3.40	6.2
9	1,632	3.007	3.36	3.22	10	10	0.14	0.14	0	1.4	3.36	3.22	3.40	3.27	6.2
10	1,600	2.948	3.22	3.09	10	10	0.13	0.13	0	1.3	3.22	3.09	3.27	3.14	5.8
11	1,200	2.829	3.10	2.95	10	10	0.14	0.14	0	1.4	3.09	2.95	3.14	2.99	4.7
12	400	2.184	2.97	2.83	10	10	0.14	0.14	0	1.4	2.97	2.83	2.99	2.85	1.6
13	4,100	3.027	2.28	2.28	10	10	0.01	0.01	0	0.1	2.28	2.28	2.33	2.32	0.9
14	200	2.981	3.62	3.57	10	10	0.05	0.05	0	0.5	3.62	3.57	3.66	3.62	0.3
16	1,100	2.593	3.58	3.57	10	10	0.01	0.01	0	0.1	3.58	3.57	3.62	3.60	0.4
17	2,400	2.914	3.51	3.50	10	10	0.01	0.01	0	0.1	3.51	3.50	3.55	3.54	0.7
18	1,000	3.123	3.44	3.42	10	10	0.02	0.02	0	0.2	3.44	3.42	3.48	3.46	0.6
19	1,100	2.593	3.37	3.36	10	10	0.01	0.01	0	0.1	3.37	3.36	3.40	3.39	0.4
20	32	2.878	3.23	3.09	10	10	0.13	0.13	0	1.4	3.22	3.09	3.27	3.13	0.1
21	400	2.184	3.11	3.10	10	10	0.01	0.01	0	0.1	3.11	3.10	3.14	3.12	0.2
22	800	2.498	2.96	2.95	10	10	0.01	0.01	0	0.1	2.96	2.95	2.99	2.98	0.3
23	400	2.184	2.83	2.81	10	10	0.01	0.01	0	0.1	2.83	2.81	2.85	2.84	0.2



Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
24	4,100	3.027	1.49	1.48	10	10	0.01	0.01	0	0.1	1.49	1.48	1.53	1.52	0.9
25	200	2.981	1.60	1.56	10	10	0.05	0.05	0	0.5	1.60	1.56	1.65	1.60	0.3
27	1,100	2.593	2.49	2.48	10	10	0.01	0.01	0	0.1	2.49	2.48	2.53	2.52	0.4
28	2,400	2.914	1.63	1.62	10	10	0.01	0.01	0	0.1	1.63	1.62	1.67	1.66	0.7
29	1,000	3.123	1.77	1.75	10	10	0.02	0.02	0	0.2	1.77	1.75	1.82	1.80	0.6
30	1,100	2.593	2.71	2.69	10	10	0.01	0.01	0	0.1	2.71	2.69	2.74	2.73	0.4
31	32	2.878	2.15	2.01	10	10	0.13	0.13	0	1.4	2.15	2.01	2.19	2.06	0.1
32	400	2.184	1.88	1.87	10	10	0.01	0.01	0	0.1	1.88	1.87	1.91	1.89	0.2
33	800	2.498	2.09	2.07	10	10	0.01	0.01	0	0.1	2.09	2.07	2.12	2.11	0.3
34	400	2.184	2.16	2.15	10	10	0.01	0.01	0	0.1	2.16	2.15	2.19	2.17	0.2
35	4,100	3.027	1.02	1.01	10	10	0.01	0.01	0	0.1	1.02	1.01	1.07	1.06	0.9
36	200	2.981	1.11	1.07	10	10	0.05	0.05	0	0.5	1.11	1.07	1.16	1.11	0.3
38	1,100	2.593	1.14	1.13	10	10	0.01	0.01	0	0.1	1.14	1.13	1.17	1.16	0.4
39	2,400	2.914	1.19	1.18	10	10	0.01	0.01	0	0.1	1.19	1.18	1.23	1.22	0.7
40	1,000	3.123	1.26	1.24	10	10	0.02	0.02	0	0.2	1.26	1.24	1.31	1.29	0.6
41	1,100	2.593	1.35	1.34	10	10	0.01	0.01	0	0.1	1.35	1.34	1.38	1.37	0.4
42	32	2.878	1.60	1.47	10	10	0.13	0.13	0	1.4	1.60	1.47	1.64	1.51	0.1
43	400	2.184	1.63	1.62	10	10	0.01	0.01	0	0.1	1.63	1.62	1.65	1.64	0.2
44	800	2.498	1.76	1.75	10	10	0.01	0.01	0	0.1	1.76	1.75	1.79	1.78	0.3
45	400	2.184	1.91	1.90	10	10	0.01	0.01	0	0.1	1.91	1.90	1.94	1.92	0.2
46	400	2.184	1.90	1.76	10	10	0.14	0.14	0	1.4	1.90	1.76	1.92	1.78	1.6
47	1,200	2.829	1.74	1.60	10	10	0.14	0.14	0	1.4	1.74	1.60	1.78	1.64	4.7
48	1,600	2.948	1.60	1.46	10	10	0.13	0.13	0	1.3	1.60	1.46	1.64	1.51	5.8
49	1,632	3.007	1.46	1.33	10	10	0.14	0.14	0	1.4	1.46	1.33	1.51	1.37	6.2
50	2,732	2.771	1.33	1.25	10	10	0.08	0.08	0	0.8	1.33	1.25	1.37	1.29	6.2
51	3,732	2.755	1.25	1.19	10	10	0.07	0.07	0	0.7	1.25	1.19	1.29	1.22	6.9
52	6,132	3.041	1.18	1.11	10	10	0.06	0.06	0	0.7	1.18	1.11	1.22	1.16	10.9
53	7,232	2.857	1.12	1.07	10	10	0.05	0.05	0	0.5	1.12	1.07	1.16	1.11	10.0
55	7,432	2.936	1.07	1.01	10	10	0.05	0.05	0	0.5	1.07	1.01	1.11	1.06	10.8
56	11,532	3.38	1.00	0.94	10	10	0.06	0.06	0	0.6	1.00	0.94	1.06	1.00	18.4



### Control Valves Results

Control Valve	Valve Type	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (m)	P Static In (bar)	Cv	K	Valve State	Energy Loss (kW)
14	FCV	4,100	1,139	0.79	12.1	2.275	5,354	25.9	Open	89.9
15	FCV	200	56	1.97	20.1	3.573	165	44.3	Open	10.9
17	FCV	1,100	306	1.08	11.0	3.569	1,227	32.0	Open	32.9
18	FCV	2,400	667	1.87	19.1	3.498	2,028	44.1	Open	124.9
19	FCV	1,000	278	1.65	16.8	3.415	902	33.8	Open	45.7
20	FCV	1,100	306	0.65	6.6	3.357	1,578	19.3	Open	19.9
21	FCV	32	9	0.95	9.7	3.092	38	22.9	Open	0.8
22	FCV	400	111	1.21	12.4	3.097	420	50.9	Open	13.5
23	FCV	800	222	0.86	8.8	2.95	996	27.7	Open	19.2
24	FCV	400	111	0.65	6.6	2.815	574	27.3	Open	7.2

### Heat Exchangers Results

Heat Exchanger	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (meters)	Energy Loss (kW)
25	4,100	1,139	0.46	4.7	52.2
26	200	56	0.44	4.5	2.5
28	1,100	306	1.34	13.7	41.1
29	2,400	667	0.42	4.3	28.3
30	1,000	278	0.49	5.0	13.5
31	1,100	306	1.34	13.7	41.1
32	32	9	0.41	4.2	0.4
33	400	111	0.24	2.4	2.7
34	800	222	0.31	3.2	6.9
35	400	111	0.24	2.4	2.7



## RESULTS FOR CASE D3

### Piping Results

Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
1	11,532	2.832	1.11	0.96	1.5	0	-0.15	-0.15	-0.15	0.0	0.96	1.11	1.00	1.15	-46.6
2	11,532	2.832	4.26	3.24	0	10	1.02	1.02	0.98	0.4	4.26	3.24	4.30	3.28	325.9
3	7,232	2.857	3.19	3.14	10	10	0.05	0.05	0.00	0.5	3.19	3.14	3.23	3.18	10.0
4	6,132	3.041	4.48	3.46	0	10	1.01	1.01	0.98	0.3	4.48	3.46	4.52	3.51	172.5
5	6,132	3.041	4.08	3.13	10	0	-0.95	-0.95	-0.98	0.3	3.13	4.08	3.18	4.13	-161.6
6	3,732	2.755	3.47	3.41	10	10	0.07	0.07	0	0.7	3.47	3.41	3.51	3.44	6.9
7	2,732	2.771	3.41	3.32	10	10	0.08	0.08	0	0.8	3.41	3.32	3.44	3.36	6.2
8	1,632	3.007	3.32	3.18	10	10	0.14	0.14	0	1.4	3.32	3.18	3.36	3.23	6.2
9	1,600	2.948	3.18	3.05	10	10	0.13	0.13	0	1.3	3.18	3.05	3.23	3.10	5.8
10	1,200	2.829	3.06	2.91	10	10	0.14	0.14	0	1.4	3.05	2.91	3.10	2.95	4.7
11	400	2.184	2.93	2.79	10	10	0.14	0.14	0	1.4	2.93	2.79	2.95	2.81	1.6
12	4,100	3.027	3.23	3.23	10	10	0.01	0.01	0	0.1	3.23	3.23	3.28	3.27	0.9
13	200	2.981	3.18	3.14	10	10	0.05	0.05	0	0.5	3.18	3.14	3.23	3.18	0.3
14	1,100	2.593	3.14	3.13	10	10	0.01	0.01	0	0.1	3.14	3.13	3.18	3.17	0.4
16	2,400	2.914	3.47	3.46	10	10	0.01	0.01	0	0.1	3.47	3.46	3.51	3.50	0.7
17	1,000	3.123	3.40	3.38	10	10	0.02	0.02	0	0.2	3.40	3.38	3.44	3.42	0.6
18	1,100	2.593	3.33	3.32	10	10	0.01	0.01	0	0.1	3.33	3.32	3.36	3.35	0.4
19	32	2.878	3.19	3.05	10	10	0.13	0.13	0	1.4	3.18	3.05	3.23	3.09	0.1
20	400	2.184	3.07	3.06	10	10	0.01	0.01	0	0.1	3.07	3.06	3.10	3.08	0.2
21	800	2.498	2.92	2.91	10	10	0.01	0.01	0	0.1	2.92	2.91	2.95	2.94	0.3
22	400	2.184	2.79	2.77	10	10	0.01	0.01	0	0.1	2.79	2.77	2.81	2.80	0.2
23	4,100	3.027	1.49	1.48	10	10	0.01	0.01	0	0.1	1.49	1.48	1.53	1.52	0.9





Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
24	200	2.981	1.60	1.56	10	10	0.05	0.05	0	0.5	1.60	1.56	1.65	1.60	0.3
25	1,100	2.593	2.49	2.48	10	10	0.01	0.01	0	0.1	2.49	2.48	2.53	2.52	0.4
27	2,400	2.914	1.63	1.62	10	10	0.01	0.01	0	0.1	1.63	1.62	1.67	1.66	0.7
28	1,000	3.123	1.77	1.75	10	10	0.02	0.02	0	0.2	1.77	1.75	1.82	1.80	0.6
29	1,100	2.593	2.71	2.69	10	10	0.01	0.01	0	0.1	2.71	2.69	2.74	2.73	0.4
30	32	2.878	2.15	2.01	10	10	0.13	0.13	0	1.4	2.15	2.01	2.19	2.06	0.1
31	400	2.184	1.88	1.87	10	10	0.01	0.01	0	0.1	1.88	1.87	1.91	1.89	0.2
32	800	2.498	2.09	2.07	10	10	0.01	0.01	0	0.1	2.09	2.07	2.12	2.11	0.3
33	400	2.184	2.16	2.15	10	10	0.01	0.01	0	0.1	2.16	2.15	2.19	2.17	0.2
34	4,100	3.027	1.02	1.01	10	10	0.01	0.01	0	0.1	1.02	1.01	1.07	1.06	0.9
35	200	2.981	1.11	1.07	10	10	0.05	0.05	0	0.5	1.11	1.07	1.16	1.11	0.3
36	1,100	2.593	1.14	1.13	10	10	0.01	0.01	0	0.1	1.14	1.13	1.17	1.16	0.4
38	2,400	2.914	1.19	1.18	10	10	0.01	0.01	0	0.1	1.19	1.18	1.23	1.22	0.7
39	1,000	3.123	1.26	1.24	10	10	0.02	0.02	0	0.2	1.26	1.24	1.31	1.29	0.6
40	1,100	2.593	1.35	1.34	10	10	0.01	0.01	0	0.1	1.35	1.34	1.38	1.37	0.4
41	32	2.878	1.60	1.47	10	10	0.13	0.13	0	1.4	1.60	1.47	1.64	1.51	0.1
42	400	2.184	1.63	1.62	10	10	0.01	0.01	0	0.1	1.63	1.62	1.65	1.64	0.2
43	800	2.498	1.76	1.75	10	10	0.01	0.01	0	0.1	1.76	1.75	1.79	1.78	0.3
44	400	2.184	1.91	1.90	10	10	0.01	0.01	0	0.1	1.91	1.90	1.94	1.92	0.2
45	400	2.184	1.90	1.76	10	10	0.14	0.14	0	1.4	1.90	1.76	1.92	1.78	1.6
46	1,200	2.829	1.74	1.60	10	10	0.14	0.14	0	1.4	1.74	1.60	1.78	1.64	4.7
47	1,600	2.948	1.60	1.46	10	10	0.13	0.13	0	1.3	1.60	1.46	1.64	1.51	5.8
48	1,632	3.007	1.46	1.33	10	10	0.14	0.14	0	1.4	1.46	1.33	1.51	1.37	6.2
49	2,732	2.771	1.33	1.25	10	10	0.08	0.08	0	0.8	1.33	1.25	1.37	1.29	6.2
50	3,732	2.755	1.25	1.19	10	10	0.07	0.07	0	0.7	1.25	1.19	1.29	1.22	6.9
51	6,132	3.041	1.18	1.11	10	10	0.06	0.06	0	0.7	1.18	1.11	1.22	1.16	10.9
52	7,232	2.857	1.12	1.07	10	10	0.05	0.05	0	0.5	1.12	1.07	1.16	1.11	10.0
53	7,432	2.936	1.07	1.01	10	10	0.05	0.05	0	0.5	1.07	1.01	1.11	1.06	10.8
55	11,532	3.38	1.00	0.94	10	10	0.06	0.06	0	0.6	1.00	0.94	1.06	1.00	18.4
56	7,432	2.936	3.24	3.18	10	10	0.05	0.05	0	0.5	3.24	3.18	3.28	3.23	10.8



## Control Valves Results

Control Valve	Valve Type	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (m)	P Static In (bar)	Cv	K	Valve State	Energy Loss (kW)
14	FCV	4,100	1139	1.7	17.7	3.225	3596	38.0	Open	198.1
15	FCV	200	56	1.5	15.6	3.135	187	34.5	Open	8.5
17	FCV	1,100	306	0.6	6.5	3.132	1594	19.0	Open	19.5
18	FCV	2,400	667	1.8	18.7	3.458	2050	43.2	Open	122.2
19	FCV	1,000	278	1.6	16.4	3.375	913	32.9	Open	44.6
20	FCV	1,100	306	0.6	6.2	3.317	1629	18.2	Open	18.6
21	FCV	32	9	0.9	9.2	3.052	39	21.9	Open	0.8
22	FCV	400	111	1.2	12.0	3.057	427	49.2	Open	13.1
23	FCV	800	222	0.8	8.4	2.910	1020	26.4	Open	18.3
24	FCV	400	111	0.6	6.2	2.775	592	25.6	Open	6.8

## Heat Exchangers Results

Heat Exchanger	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (meters)	Energy Loss (kW)
25	4,100	1,139	0.46	4.7	52.2
26	200	56	0.44	4.5	2.5
28	1,100	306	1.34	13.7	41.1
29	2,400	667	0.42	4.3	28.3
30	1,000	278	0.49	5.0	13.5
31	1,100	306	1.34	13.7	41.1
32	32	9	0.41	4.2	0.4
33	400	111	0.24	2.4	2.7
34	800	222	0.31	3.2	6.9
35	400	111	0.24	2.4	2.7



## RESULTS FOR CASE D4

### First Distribution System

### Piping Results

Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
61	4,100	3.027	1.11	0.97	1.5	0	-0.14	-0.14	-0.15	0.0	0.97	1.11	1.01	1.16	-16.3
63	4,100	3.027	3.25	2.20	0.0	10	1.06	1.06	0.98	0.8	3.25	2.20	3.30	2.24	120.2
65	4,100	3.027	2.20	2.19	10.0	10	0.01	0.01	0.00	0.1	2.20	2.19	2.24	2.23	0.9
67	4,100	3.027	1.52	1.51	10.0	10	0.01	0.01	0.00	0.1	1.52	1.51	1.56	1.56	0.9
69	4,100	3.027	1.05	1.05	10.0	10	0.01	0.01	0.00	0.1	1.05	1.05	1.10	1.09	0.9
71	4,100	3.027	1.05	0.97	10.0	10	0.08	0.08	0.00	0.8	1.05	0.97	1.09	1.01	9.0

### Control Valves Results

Control Valve	Valve Type	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (m)	P Static In (bar)	Cv	K	Valve State	Energy Loss (kW)
66	FCV	4,100	1,134.0	0.670	6.860	2.188	5,782	14.7	Open	76.29

### Heat Exchangers Results

Heat Exchanger	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (meters)	Energy Loss (kW)
68	4,100	1,139	0.46	4.7	52.0



## Second Distribution System

### Piping Results

Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
1	7,432	1.825	1.13	0.98	1.5	0	-0.15	-0.15	-0.15	0.0	0.98	1.13	1.00	1.15	-30.2
2	7,432	2.936	4.78	3.75	0	10	1.03	1.03	0.98	0.5	4.78	3.75	4.82	3.79	213.2
3	7,432	2.936	3.75	3.69	10	10	0.05	0.05	0.00	0.5	3.75	3.69	3.79	3.74	10.8
5	7,232	2.857	3.70	3.65	10	10	0.05	0.05	0.00	0.5	3.70	3.65	3.74	3.69	10.0
6	6,132	3.041	3.64	3.58	10	10	0.06	0.06	0.00	0.7	3.64	3.58	3.69	3.62	10.9
7	3,732	2.755	3.59	3.52	10	10	0.07	0.07	0.00	0.7	3.59	3.52	3.62	3.56	6.9
8	2,732	2.771	3.52	3.44	10	10	0.08	0.08	0.00	0.8	3.52	3.44	3.56	3.48	6.2
9	1,632	3.007	3.43	3.29	10	10	0.14	0.14	0.00	1.4	3.43	3.29	3.48	3.34	6.2
10	1,600	2.948	3.30	3.16	10	10	0.13	0.13	0.00	1.3	3.29	3.16	3.34	3.21	5.8
11	1,200	2.829	3.17	3.03	10	10	0.14	0.14	0.00	1.4	3.17	3.03	3.21	3.07	4.7
12	400	2.184	3.04	2.90	10	10	0.14	0.14	0.00	1.4	3.04	2.90	3.07	2.93	1.6
14	200	2.981	3.69	3.65	10	10	0.05	0.05	0.00	0.5	3.69	3.65	3.74	3.69	0.3
16	1,100	2.593	3.65	3.64	10	10	0.01	0.01	0.00	0.1	3.65	3.64	3.69	3.68	0.4
17	2,400	2.914	3.58	3.57	10	10	0.01	0.01	0.00	0.1	3.58	3.57	3.62	3.61	0.7
18	1,000	3.123	3.51	3.49	10	10	0.02	0.02	0.00	0.2	3.51	3.49	3.56	3.54	0.6
19	1,100	2.593	3.44	3.43	10	10	0.01	0.01	0.00	0.1	3.44	3.43	3.48	3.46	0.4
20	32	2.878	3.30	3.16	10	10	0.13	0.13	0.00	1.4	3.30	3.16	3.34	3.21	0.1
21	400	2.184	3.18	3.17	10	10	0.01	0.01	0.00	0.1	3.18	3.17	3.21	3.19	0.2
22	800	2.498	3.04	3.02	10	10	0.01	0.01	0.00	0.1	3.04	3.02	3.07	3.05	0.3
23	400	2.184	2.90	2.89	10	10	0.01	0.01	0.00	0.1	2.90	2.89	2.93	2.91	0.2
25	200	2.981	1.60	1.55	10	10	0.05	0.05	0.00	0.5	1.60	1.55	1.64	1.60	0.3
27	1,100	2.593	2.49	2.48	10	10	0.01	0.01	0.00	0.1	2.49	2.48	2.52	2.51	0.4



Pipe	Vol. Flow Rate (m <sup>3</sup> /hr)	Velocity (m/s)	P Static Max (bar)	P Static Min (bar)	Elevation Inlet (m)	Elevation Outlet (m)	dP Stag. Total (bar)	dP Static Total (bar)	dP Gravity (bar)	dH (meters)	P Static In (bar)	P Static Out (bar)	P Stag. In (bar)	P Stag. Out (bar)	Energy Loss (kW)
28	2,400	2.914	1.62	1.61	10	10	0.01	0.01	0.00	0.1	1.62	1.61	1.66	1.65	0.7
29	1,000	3.123	1.76	1.74	10	10	0.02	0.02	0.00	0.2	1.76	1.74	1.81	1.79	0.6
30	1,100	2.593	2.70	2.69	10	10	0.01	0.01	0.00	0.1	2.70	2.69	2.74	2.72	0.4
31	32	2.878	2.14	2.01	10	10	0.13	0.13	0.00	1.4	2.14	2.01	2.18	2.05	0.1
32	400	2.184	1.88	1.86	10	10	0.01	0.01	0.00	0.1	1.88	1.86	1.90	1.89	0.2
33	800	2.498	2.08	2.07	10	10	0.01	0.01	0.00	0.1	2.08	2.07	2.11	2.10	0.3
34	400	2.184	2.16	2.14	10	10	0.01	0.01	0.00	0.1	2.16	2.14	2.18	2.17	0.2
36	200	2.981	1.11	1.06	10	10	0.05	0.05	0.00	0.5	1.11	1.06	1.15	1.11	0.3
38	1,100	2.593	1.13	1.12	10	10	0.01	0.01	0.00	0.1	1.13	1.12	1.17	1.15	0.4
39	2,400	2.914	1.19	1.18	10	10	0.01	0.01	0.00	0.1	1.19	1.18	1.23	1.22	0.7
40	1,000	3.123	1.26	1.24	10	10	0.02	0.02	0.00	0.2	1.26	1.24	1.31	1.29	0.6
41	1,100	2.593	1.35	1.33	10	10	0.01	0.01	0.00	0.1	1.34	1.33	1.38	1.37	0.4
42	32	2.878	1.59	1.46	10	10	0.13	0.13	0.00	1.4	1.59	1.46	1.64	1.50	0.1
43	400	2.184	1.62	1.61	10	10	0.01	0.01	0.00	0.1	1.62	1.61	1.65	1.63	0.2
44	800	2.498	1.76	1.74	10	10	0.01	0.01	0.00	0.1	1.76	1.74	1.79	1.78	0.3
45	400	2.184	1.91	1.89	10	10	0.01	0.01	0.00	0.1	1.91	1.89	1.93	1.92	0.2
46	400	2.184	1.89	1.75	10	10	0.14	0.14	0.00	1.4	1.89	1.75	1.92	1.78	1.6
47	1,200	2.829	1.73	1.59	10	10	0.14	0.14	0.00	1.4	1.73	1.59	1.78	1.63	4.7
48	1,600	2.948	1.59	1.46	10	10	0.13	0.13	0.00	1.3	1.59	1.46	1.63	1.50	5.8
49	1,632	3.007	1.46	1.32	10	10	0.14	0.14	0.00	1.4	1.46	1.32	1.50	1.37	6.2
50	2,732	2.771	1.33	1.25	10	10	0.08	0.08	0.00	0.8	1.33	1.25	1.37	1.29	6.2
51	3,732	2.755	1.25	1.18	10	10	0.07	0.07	0.00	0.7	1.25	1.18	1.29	1.22	6.9
52	6,132	3.041	1.17	1.11	10	10	0.06	0.06	0.00	0.7	1.17	1.11	1.22	1.15	10.9
53	7,232	2.857	1.11	1.06	10	10	0.05	0.05	0.00	0.5	1.11	1.06	1.15	1.11	10.0
55	7,432	2.936	1.06	1.01	10	10	0.05	0.05	0.00	0.5	1.06	1.01	1.11	1.05	10.8
56	7,432	2.936	1.01	0.96	10	10	0.05	0.05	0.00	0.5	1.01	0.96	1.05	1.00	10.8



## Control Valves Results

Control Valve	Valve Type	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (m)	P Static In (bar)	Cv	K	Valve State	Energy Loss (kW)
15	FCV	200	55.6	2.047	20.870	3.645	144	58.2	Open	11.37
17	FCV	1,100	305.6	1.153	11.755	3.642	801	75.0	Open	35.22
18	FCV	2,400	666.7	1.951	19.891	3.571	1,794	56.4	Open	130.05
19	FCV	1,000	277.8	1.724	17.575	3.487	771	46.2	Open	47.88
20	FCV	1,100	305.6	0.728	7.422	3.429	879	62.4	Open	22.24
21	FCV	32	8.9	1.024	10.443	3.165	28	41.1	Open	0.91
22	FCV	400	111.1	1.292	13.176	3.169	371	65.4	Open	14.36
23	FCV	200	55.6	2.047	20.870	3.645	144	58.2	Open	11.37
24	FCV	1,100	305.6	1.153	11.755	3.642	801	75.0	Open	35.22

## Heat Exchangers Results

Heat Exchanger	Vol. Flow (m <sup>3</sup> /hr)	Mass Flow (kg/sec)	dP Stag. (bar)	dH (meters)	Energy Loss (kW)
26	200	56	0.44	4.5	2.5
28	1,100	306	1.34	13.7	41.1
29	2,400	667	0.42	4.3	28.3
30	1,000	278	0.49	5.0	13.5
31	1,100	306	1.34	13.7	41.1
32	32	9	0.41	4.2	0.4
33	400	111	0.24	2.4	2.7
34	800	222	0.31	3.2	6.9
35	400	111	0.24	2.4	2.7