

Appendix A

Design Analysis Worksheet

Project Name: _____ Location: _____

Step 1a.	Design temperature	<u>10</u>	°F
Step 1b.	Wind speed	<u>10</u>	mph
Step 2.	Differential temperature	<u>25</u>	°F <i>used for Uponor charts</i>
Step 3.	Surface temperature	<u>38</u>	°F
Step 4.	BTU/h/ft ² load	<u>107</u>	BTU/h/ft ²
Step 5a.	Supply fluid temperature	<u>139</u>	°F
Step 5b.	Tubing on-center (o.c.) distance	<u>12</u>	inches
Step 6.	Area in square feet	<u>3200</u>	ft ²
Step 7.	Total BTU/h	<u>342,400</u>	BTU/h
Step 8a.	Tubing type	<u>PE X</u>	
Step 8b.	Tubing size	<u>3/4</u>	inch
Step 9.	Total amount of tubing	<u>3600</u>	feet
Step 10a.	Active loop length	<u>300</u>	feet
Step 10b.	Number of loops	<u>12</u>	loops
Step 11a.	Leader length	<u>—</u>	feet
Step 11b.	Total loop length	<u>300</u>	feet
Step 12.	Percentage of glycol	<u>50</u>	%
Step 13a.	Flow per foot of tubing	<u>.0099</u>	gpm/ft
Step 13b.	Flow per loop	<u>2.97</u>	gpm/loop
Step 14.	System flow	<u>35.64</u>	gpm
Step 15a.	Head pressure drop per foot	<u>.06869</u>	feet of head
Step 15b.	Head pressure drop/loop	<u>20.307</u>	feet of head*

Refer to **Chapter 6** for instructions on how to complete this worksheet.

*The head pressure drop information is used only for the manifold. For proper pump sizing, add the amount of head pressure drop before and after the manifold location to this value.

Outdoor Temp.	Wind Speed	Surface Temperatures											
		35°F			36°F			37°F			38°F		
25°F	0 mph	19			21			24			26		
		57	60	63	59	62	66	61	65	70	63	67	73
	5 mph	28			31			34			37		
		61	66	71	63	68	75	66	72	79	68	74	82
	10 mph	38			42			46			50		
		66	72	80	69	76	84	72	79	88	74	83	94
20°F	0 mph	30			33			35			38		
		62	67	73	64	69	76	66	71	79	68	75	81
	5 mph	42			45			48			52		
		67	74	83	69	77	85	72	80	89	75	83	93
	10 mph	56			61			64			69		
		74	83	94	77	87	99	79	90	103	83	94	107
15°F	0 mph	41			45			48			51		
		68	75	81	70	78	86	73	81	89	75	83	93
	5 mph	56			59			62			65		
		74	84	94	77	87	97	79	90	100	82	93	104
	10 mph	76			79			84			87		
		84	97	110	87	100	113	90	104	119	92	107	123
10°F	0 mph	55			58			61			64		
		74	83	93	76	86	96	79	89	100	81	92	103
	5 mph	70			73			76			79		
		81	93	106	84	96	108	86	99	112	88	102	116
	10 mph	95			98			103			107		
		93	109	126	96	112	129	99	116	135	102	120	139
5°F	0 mph	69			72			75			77		
		81	92	105	83	95	108	85	98	111	88	101	115
	5 mph	84			88			90			93		
		88	102	117	91	105	121	93	108	124	95	111	127
	10 mph	114			118			121			126		
		102	122	142	105	125	146	108	128	150	111	132	154
0°F	0 mph	83			86			89			92		
		87	101	116	90	104	120	92	107	122	95	110	126
	5 mph	98			102			104			108		
		95	111	129	97	114	133	100	117	135	102	120	139
	10 mph	133			137			141			145		
		112	134	157	114	137	162	117	141	166	120	144	170
-5°F	0 mph	98			101			104			107		
		95	111	128	97	114	132	99	117	135	102	120	139
	5 mph	113			116			119			122		
		102	121	141	104	123	145	107	127	147	109	129	151
	10 mph	152			156			160			165		
		120	146	172	124	150	177	126	153	182	129	156	186
-10°F	0 mph	113			116			119			123		
		102	121	141	104	124	145	107	127	147	110	130	151
	5 mph	127			130			133			136		
		109	130	152	111	133	156	114	136	159	116	139	162
	10 mph	172			175			180			183		
		130	159	190	133	162	194	136	166	198	139	169	202

Shaded areas = Exceeds design limits



151

Flow Per Foot of Active Loop Length

Load In BTU/h/ft ²	Glycol Percentage								
	30% Glycol			40% Glycol			50% Glycol		
	6" o.c.	9" o.c.	12" o.c.	6" o.c.	9" o.c.	12" o.c.	6" o.c.	9" o.c.	12" o.c.
100	0.0042	0.0062	0.0083	0.0043	0.0064	0.0086	0.0046	0.0069	0.0092
102	0.0042	0.0064	0.0085	0.0044	0.0066	0.0087	0.0047	0.0070	0.0094
104	0.0043	0.0065	0.0087	0.0045	0.0067	0.0089	0.0048	0.0072	0.0096
106	0.0044	0.0066	0.0088	0.0045	0.0068	0.0091	0.0049	0.0073	0.0097
108	0.0045	0.0067	0.0090	0.0046	0.0069	0.0092	0.0050	0.0074	0.0099
110	0.0046	0.0069	0.0092	0.0047	0.0071	0.0094	0.0051	0.0076	0.0101
112	0.0047	0.0070	0.0093	0.0048	0.0072	0.0096	0.0051	0.0077	0.0103
114	0.0047	0.0071	0.0095	0.0049	0.0073	0.0098	0.0052	0.0079	0.0105
116	0.0048	0.0072	0.0097	0.0050	0.0075	0.0099	0.0053	0.0080	0.0107
118	0.0049	0.0074	0.0098	0.0051	0.0076	0.0101	0.0054	0.0081	0.0108
120	0.0050	0.0075	0.0100	0.0051	0.0077	0.0103	0.0055	0.0083	0.0110
122	0.0051	0.0076	0.0102	0.0052	0.0078	0.0104	0.0056	0.0084	0.0112
124	0.0052	0.0077	0.0103	0.0053	0.0080	0.0106	0.0057	0.0085	0.0114
126	0.0052	0.0079	0.0105	0.0054	0.0081	0.0108	0.0058	0.0087	0.0116
128	0.0053	0.0080	0.0107	0.0055	0.0082	0.0110	0.0059	0.0088	0.0118
130	0.0054	0.0081	0.0108	0.0056	0.0083	0.0111	0.0060	0.0090	0.0119
132	0.0055	0.0082	0.0110	0.0057	0.0085	0.0113	0.0061	0.0091	0.0121
134	0.0056	0.0084	0.0112	0.0057	0.0086	0.0115	0.0062	0.0092	0.0123
136	0.0057	0.0085	0.0113	0.0058	0.0087	0.0116	0.0062	0.0094	0.0125
138	0.0058	0.0087	0.0116	0.0060	0.0089	0.0119	0.0064	0.0096	0.0128
140	0.0058	0.0087	0.0117	0.0060	0.0090	0.0120	0.0064	0.0096	0.0129
142	0.0059	0.0089	0.0118	0.0061	0.0091	0.0122	0.0065	0.0098	0.0130
144	0.0060	0.0090	0.0120	0.0062	0.0092	0.0123	0.0066	0.0099	0.0132
146	0.0061	0.0091	0.0122	0.0063	0.0094	0.0125	0.0067	0.0101	0.0134
148	0.0062	0.0092	0.0123	0.0063	0.0095	0.0127	0.0068	0.0102	0.0136
150	0.0062	0.0094	0.0125	0.0064	0.0096	0.0128	0.0069	0.0103	0.0138
152	0.0063	0.0095	0.0127	0.0065	0.0098	0.0130	0.0070	0.0105	0.0140
154	0.0064	0.0096	0.0128	0.0066	0.0099	0.0132	0.0071	0.0106	0.0141
156	0.0065	0.0097	0.0130	0.0067	0.0100	0.0134	0.0072	0.0107	0.0143
158	0.0066	0.0099	0.0132	0.0068	0.0101	0.0135	0.0073	0.0109	0.0145
160	0.0067	0.0100	0.0133	0.0069	0.0103	0.0137	0.0073	0.0110	0.0147
162	0.0067	0.0101	0.0135	0.0069	0.0104	0.0139	0.0074	0.0112	0.0149
164	0.0068	0.0102	0.0137	0.0070	0.0105	0.0140	0.0075	0.0113	0.0151
166	0.0069	0.0104	0.0138	0.0071	0.0107	0.0142	0.0076	0.0114	0.0152
168	0.0070	0.0105	0.0140	0.0072	0.0108	0.0144	0.0077	0.0116	0.0154
170	0.0071	0.0106	0.0142	0.0073	0.0109	0.0146	0.0078	0.0117	0.0156
172	0.0072	0.0107	0.0143	0.0074	0.0110	0.0147	0.0079	0.0118	0.0158
174	0.0072	0.0109	0.0145	0.0075	0.0112	0.0149	0.0080	0.0120	0.0160
176	0.0073	0.0110	0.0147	0.0075	0.0113	0.0151	0.0081	0.0121	0.0162
178	0.0074	0.0111	0.0148	0.0076	0.0114	0.0152	0.0082	0.0123	0.0163

Appendix D

Uponor PEX-a Hydronic Friction Loss Tables

3/4" Uponor PEX-a — 50% Propylene Glycol — Feet of Head per Foot of Tubing

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.55	0.00843	0.00793	0.00741	0.00702	0.00661	0.00630	0.00598	0.00547	0.00505	0.00470	0.00441	0.00416	0.00395	0.00377	0.00361	0.00347	0.00334	0.00323	0.00314	0.00305
0.6	0.66	0.01118	0.01054	0.00987	0.00936	0.00883	0.00843	0.00801	0.00734	0.00679	0.00634	0.00595	0.00563	0.00535	0.00510	0.00489	0.00471	0.00454	0.00439	0.00427	0.00415
0.7	0.77	0.01423	0.01344	0.01259	0.01197	0.01130	0.01080	0.01027	0.00943	0.00874	0.00817	0.00768	0.00727	0.00692	0.00661	0.00634	0.00611	0.00590	0.00571	0.00555	0.00540
0.8	0.88	0.01756	0.01660	0.01557	0.01481	0.01401	0.01340	0.01275	0.01173	0.01089	0.01018	0.00959	0.00909	0.00865	0.00827	0.00795	0.00766	0.00740	0.00716	0.00697	0.00678
0.9	0.99	0.02115	0.02001	0.01880	0.01790	0.01694	0.01622	0.01545	0.01423	0.01322	0.01238	0.01168	0.01107	0.01055	0.01009	0.00970	0.00935	0.00904	0.00875	0.00852	0.00830
1.0	1.10	0.02500	0.02368	0.02226	0.02121	0.02009	0.01925	0.01835	0.01693	0.01574	0.01476	0.01393	0.01321	0.01260	0.01206	0.01160	0.01119	0.01082	0.01048	0.01021	0.00994
1.1	1.21	0.02910	0.02758	0.02596	0.02475	0.02346	0.02249	0.02145	0.01981	0.01844	0.01730	0.01634	0.01551	0.01480	0.01418	0.01364	0.01317	0.01273	0.01234	0.01203	0.01172
1.2	1.32	0.03345	0.03172	0.02988	0.02851	0.02704	0.02593	0.02475	0.02288	0.02132	0.02002	0.01891	0.01797	0.01715	0.01644	0.01582	0.01528	0.01478	0.01433	0.01397	0.01361
1.3	1.43	0.03803	0.03609	0.03402	0.03247	0.03082	0.02957	0.02824	0.02613	0.02436	0.02289	0.02165	0.02057	0.01965	0.01884	0.01814	0.01752	0.01696	0.01645	0.01603	0.01563
1.4	1.54	0.04285	0.04069	0.03837	0.03665	0.03481	0.03341	0.03192	0.02955	0.02758	0.02593	0.02453	0.02333	0.02229	0.02138	0.02059	0.01990	0.01926	0.01869	0.01822	0.01776
1.5	1.65	0.04789	0.04550	0.04294	0.04103	0.03898	0.03743	0.03578	0.03315	0.03096	0.02912	0.02756	0.02622	0.02507	0.02405	0.02317	0.02240	0.02169	0.02105	0.02053	0.02002
1.6	1.76	0.05316	0.05053	0.04771	0.04561	0.04335	0.04165	0.03982	0.03692	0.03450	0.03247	0.03075	0.02926	0.02798	0.02686	0.02588	0.02503	0.02424	0.02353	0.02295	0.02239
1.7	1.87	0.05865	0.05577	0.05268	0.05038	0.04791	0.04604	0.04404	0.04086	0.03820	0.03597	0.03408	0.03245	0.03104	0.02980	0.02872	0.02778	0.02691	0.02613	0.02549	0.02487
1.8	1.98	0.06435	0.06122	0.05786	0.05535	0.05266	0.05062	0.04844	0.04496	0.04206	0.03962	0.03755	0.03577	0.03422	0.03287	0.03169	0.03066	0.02971	0.02885	0.02815	0.02746
1.9	2.09	0.07027	0.06688	0.06323	0.06051	0.05759	0.05537	0.05300	0.04923	0.04607	0.04342	0.04117	0.03922	0.03754	0.03606	0.03478	0.03366	0.03262	0.03168	0.03092	0.03017
2.0	2.20	0.07640	0.07274	0.06879	0.06585	0.06270	0.06031	0.05774	0.05366	0.05024	0.04736	0.04492	0.04282	0.04099	0.03939	0.03800	0.03677	0.03565	0.03463	0.03380	0.03299
2.1	2.31	0.08273	0.07879	0.07455	0.07139	0.06799	0.06541	0.06265	0.05825	0.05455	0.05145	0.04882	0.04654	0.04457	0.04284	0.04133	0.04001	0.03879	0.03769	0.03679	0.03592
2.2	2.43	0.08927	0.08504	0.08049	0.07710	0.07346	0.07069	0.06772	0.06299	0.05902	0.05568	0.05285	0.05040	0.04828	0.04641	0.04479	0.04337	0.04205	0.04087	0.03990	0.03895
2.3	2.54	0.09600	0.09149	0.08663	0.08300	0.07910	0.07613	0.07295	0.06789	0.06364	0.06006	0.05702	0.05439	0.05211	0.05011	0.04836	0.04684	0.04542	0.04415	0.04311	0.04209
2.4	2.65	0.10294	0.09813	0.09295	0.08907	0.08491	0.08175	0.07835	0.07294	0.06840	0.06457	0.06132	0.05851	0.05607	0.05393	0.05206	0.05042	0.04891	0.04754	0.04643	0.04534
2.5	2.76	0.11008	0.10496	0.09945	0.09533	0.09090	0.08753	0.08391	0.07815	0.07330	0.06923	0.06576	0.06276	0.06015	0.05786	0.05587	0.05412	0.05250	0.05105	0.04985	0.04869
2.6	2.87	0.11741	0.11198	0.10613	0.10175	0.09705	0.09347	0.08963	0.08350	0.07835	0.07402	0.07032	0.06713	0.06436	0.06192	0.05980	0.05793	0.05621	0.05466	0.05339	0.05214
2.7	2.98	0.12493	0.11919	0.11299	0.10836	0.10337	0.09958	0.09551	0.08901	0.08355	0.07894	0.07502	0.07163	0.06869	0.06610	0.06384	0.06186	0.06003	0.05838	0.05702	0.05570
2.8	3.09	0.13264	0.12658	0.12002	0.11513	0.10986	0.10584	0.10154	0.09466	0.08888	0.08400	0.07985	0.07626	0.07314	0.07039	0.06800	0.06590	0.06395	0.06220	0.06077	0.05936
2.9	3.20	0.14054	0.13415	0.12724	0.12207	0.11651	0.11227	0.10773	0.10046	0.09435	0.08920	0.08481	0.08101	0.07771	0.07480	0.07227	0.07004	0.06799	0.06613	0.06461	0.06313
3.0	3.31	0.14863	0.14190	0.13462	0.12918	0.12333	0.11886	0.11407	0.10641	0.09996	0.09452	0.08989	0.08584	0.08239	0.07933	0.07665	0.07430	0.07213	0.07017	0.06856	0.06699
3.1	3.42	0.15691	0.14983	0.14218	0.13646	0.13030	0.12560	0.12056	0.11250	0.10571	0.09998	0.09510	0.09087	0.08720	0.08397	0.08114	0.07867	0.07637	0.07431	0.07261	0.07096
3.2	3.53	0.16537	0.15794	0.14991	0.14391	0.13744	0.13250	0.12720	0.11873	0.11160	0.10557	0.10044	0.09599	0.09212	0.08872	0.08575	0.08314	0.08073	0.07855	0.07677	0.07502
3.3	3.64	0.17401	0.16623	0.15781	0.15152	0.14473	0.13956	0.13400	0.12511	0.11762	0.11129	0.10590	0.10123	0.09717	0.09359	0.09047	0.08772	0.08519	0.08290	0.08102	0.07919
3.4	3.75	0.18284	0.17469	0.16588	0.15929	0.15219	0.14676	0.14094	0.13163	0.12377	0.11714	0.11149	0.10658	0.10232	0.09857	0.09529	0.09241	0.08975	0.08735	0.08538	0.08345
3.5	3.86	0.19184	0.18333	0.17412	0.16723	0.15980	0.15412	0.14803	0.13828	0.13006	0.12312	0.11720	0.11206	0.10759	0.10366	0.10023	0.09721	0.09441	0.09190	0.08983	0.08781
3.6	3.97	0.20103	0.19214	0.18252	0.17532	0.16756	0.16163	0.15527	0.14508	0.13649	0.12922	0.12303	0.11765	0.11298	0.10886	0.10527	0.10211	0.09918	0.09655	0.09438	0.09227
3.7	4.08	0.21039	0.20112	0.19109	0.18358	0.17548	0.16930	0.16265	0.15202	0.14304	0.13545	0.12898	0.12337	0.11848	0.11418	0.11042	0.10712	0.10406	0.10130	0.09903	0.09682
3.8	4.19	0.21992	0.21027	0.19982	0.19200	0.18356	0.17711	0.17018	0.15909	0.14973	0.14181	0.13506	0.12919	0.12410	0.11960	0.11568	0.11223	0.10903	0.10615	0.10378	0.10147

Continued on next page

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

PRESSURE DROP / HEAD LOSS

Input

Is this a Geothermal Application? ☐

Pipe/Tubing Selection¹

Pipe/Tubing Material:

PEX

Sizing Type (CTS/IPS/Metric):

CTS (ASTM F876/CSA B137.5)

Wall Type (SDR/Schedule):

SDR 9

Nominal Pipe/Tubing Size²:

3/4"

¹ For more information about plastic piping products included in this calculator, please visit the [BCD](#) website.

² "Tubing" refers to products with an actual Outside Diameter (OD) 1/8 inch larger than the nominal size, such as with copper tubing. These products are sometimes referred to as "nominal tubing size" (NTS) or "copper tube size" (CTS). "Pipe" refers to products with an actual OD matching that of iron or steel pipe of the same nominal size. Those products are sometimes referred to as "iron pipe size" (IPS) or "nominal pipe size" (NPS). "Pipe" may also refer to products where the actual OD matches the nominal size (e.g. DN-Metric). Pipe and tubing dimensions used for these calculations are based on dimensional tables found within the listed product standards from ASTM and/or CSA. The Calculator assumes that all pipes have the nominal (i.e., average) outside diameter and an average wall thickness, resulting in an average insider diameter.

Flow Rate:

3 USGPM

Length of Pipe:

300 ft

Fluid Type (Water or % Antifreeze³):

50% Propylene Glycol

Average Fluid Temperature⁴:

120 °F

³For methanol, viscosity and density information is from "Geothermal Heating and Cooling – Design of Ground Source Heat Pump Systems" by Dr. Steve Kavanaugh and Kevin Rafferty (ASHRAE RP-1674) and "Perry's Chemical Engineers' Handbook (7th ed.)" by Perry, R. H., & Green, D. W. Available data is limited to a temperature range of 32°F to 86°F (0°C to 30°C).

For brine mixtures, viscosity and density information is from "ASHRAE Fundamentals 2021 – Chapter 31".

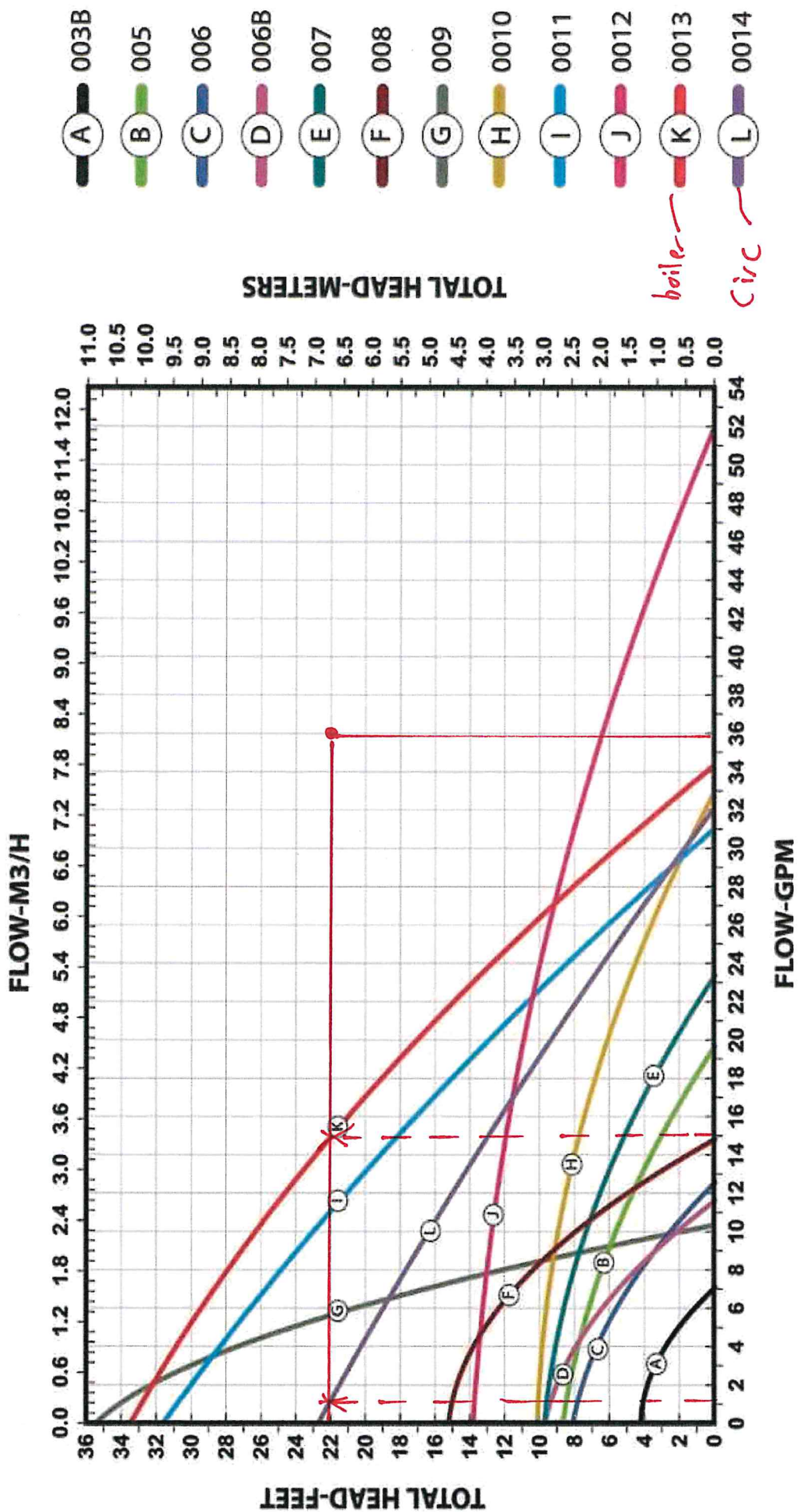
⁴This calculation uses the Darcy Weisbach equation which includes temperature as a variable. As a result some published tables using the Hazen-Williams equation with a standard temperature may show different results.

Fittings (Optional)

	Quantity	Equivalent Length	
Couplings:	0 x	0 ft =	0.0 ft
90° Elbows:	0 x	0 ft =	0.0 ft
Tees (Run):	0 x	0 ft =	0.0 ft
Tees (Branch):	0 x	0 ft =	0.0 ft
Other Fittings, U-bends, Valves:		0 ft =	0.0 ft

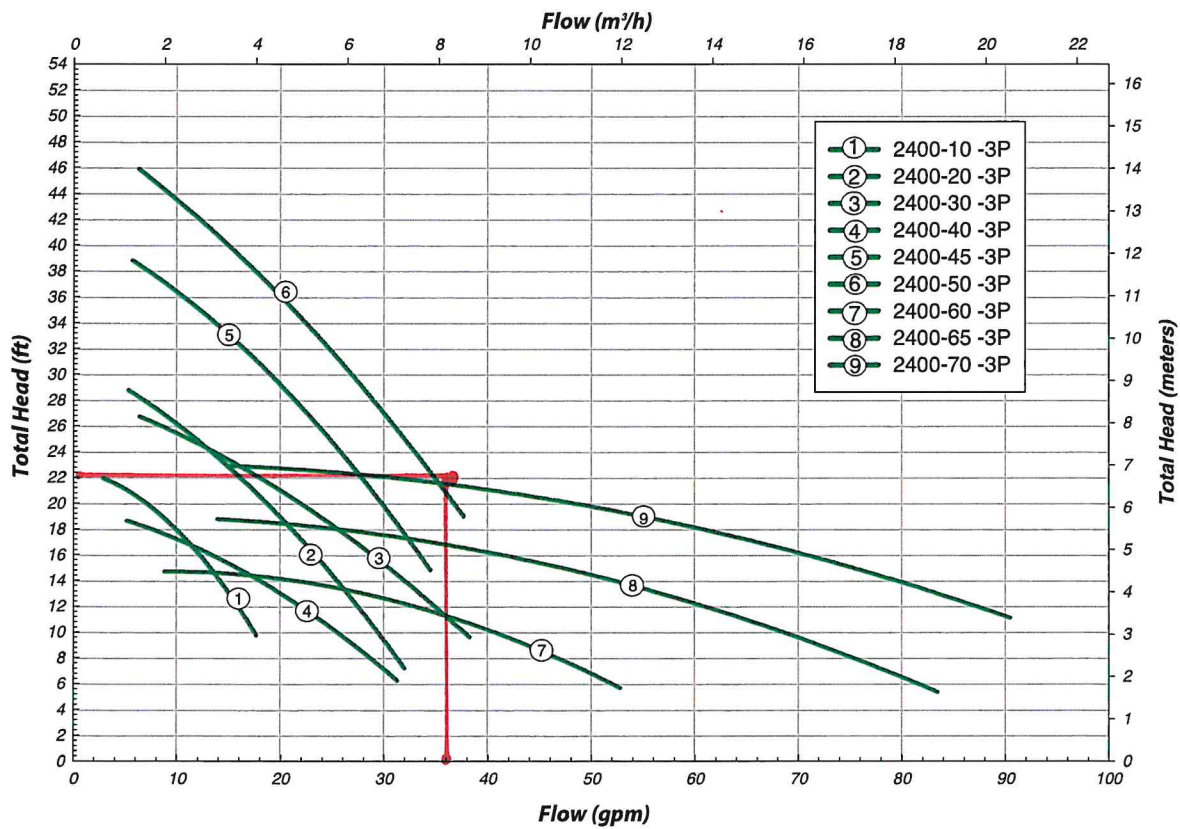
Results

Flow Regime:	Turbulent	
Pressure Drop:	9.71 Psi	66.9 kPa
Head Loss:	22.4 ft water	
Velocity*:	2.72 ft/s	0.83 m/s



Performance Curves 2400 Series High Capacity Circulators

Taco 2400 Series High Capacity Circulators



2400-50-3P
or 2400-70-3P