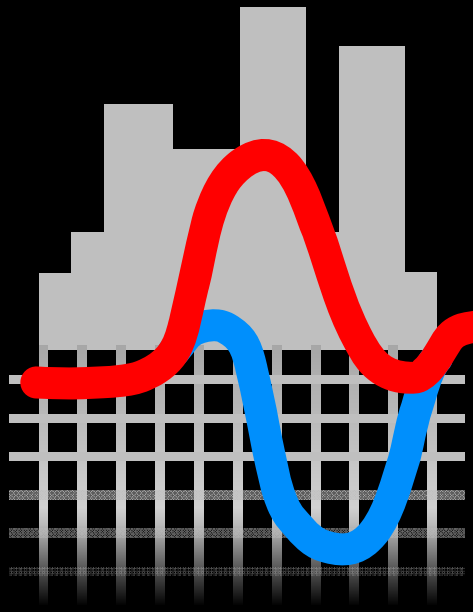


Facility Dynamics
ENGINEERING

Controlling Analog Processes

The Impact of Lags on a Condenser Water System Control Process (Supplemental)

Presented By:

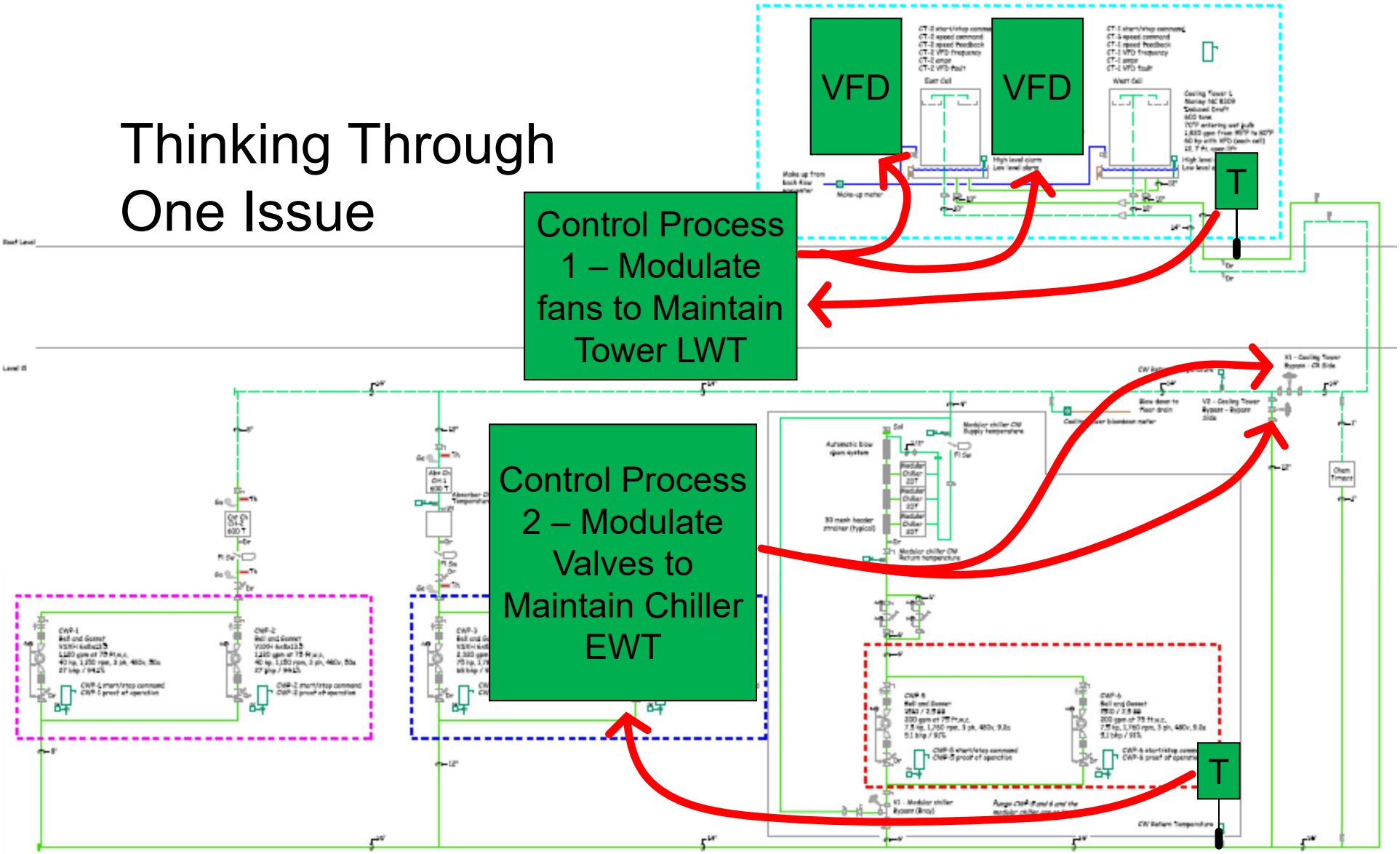
David Sellers; Facility Dynamics Engineering

Senior Engineer

NAVFAC, San Diego

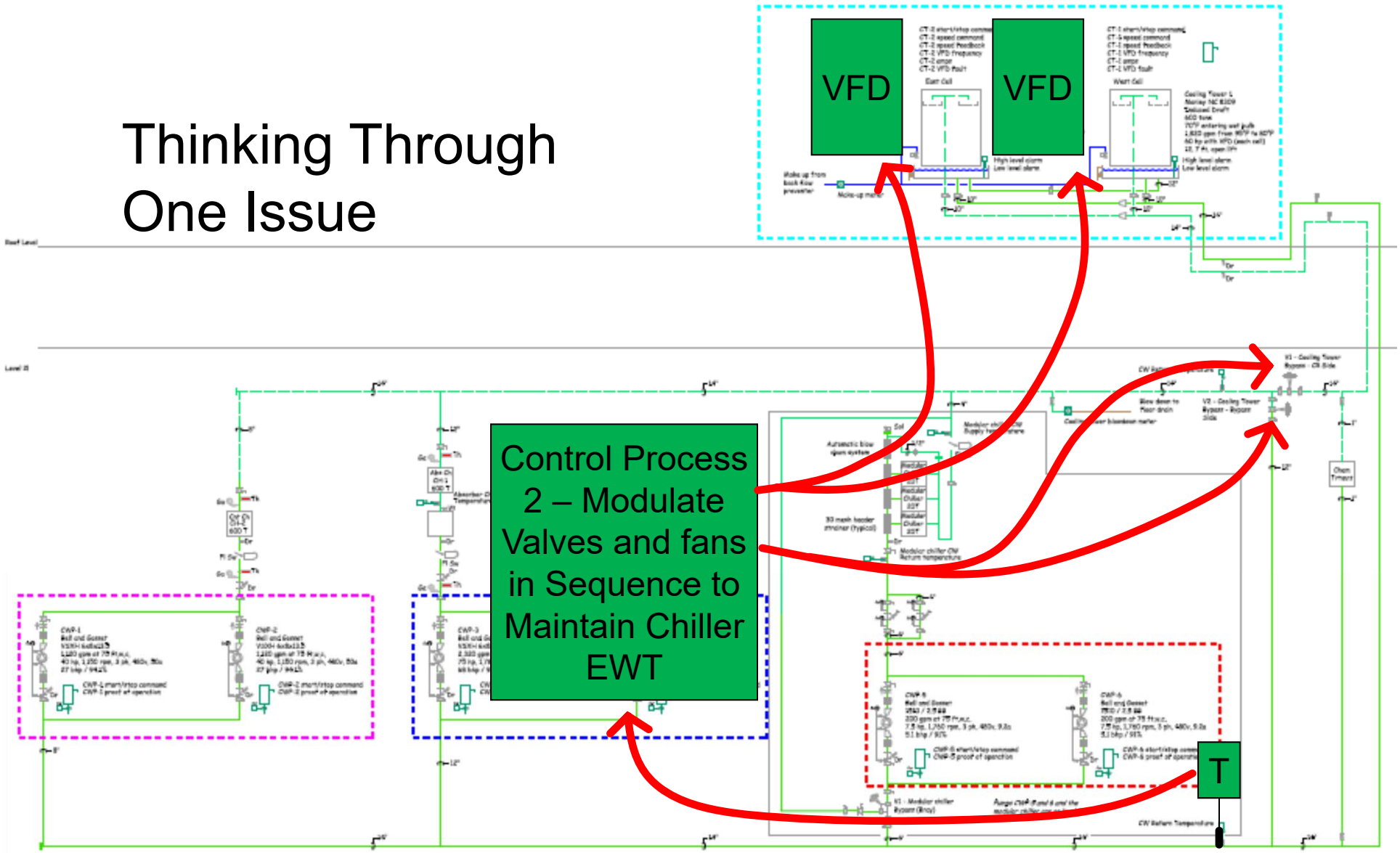
Sutardja Dia Hall

Thinking Through One Issue



Given the information that follows what are the pros and cons of controlling the tower fans and bypass valve based on two independent loops …

Thinking Through One Issue



… or one loop?

Thinking Through a Control Process

- Minimum flow rate is 200 gpm (Modular chiller only; when below 50°F OAT in Berkeley CA)
- Maximum flow rate is 3,640 gpm (transitioning from absorber to centrifugal or vice versa)
- Typical flow rate is 1,320 – 2,520 gpm (centrifugal or absorber plus modular chiller)

Black Iron Pipe Data

Source - ASHRAE 2012 Systems and Equipment Handbook, Chapter 46, Pipe, Tubes, and Fittings, Table 2

Nominal Size, inches	Pipe OD, inches	Schedule Number or Weight[a]	Wall Thickness, inches	Inside Diameter, inches	Surface Area, square feet		Cross Section, square inches		Weight, pounds/foot		Working Pressure, ASTM A53 B to 400°F[c]		
					Outside, sq.ft.	Inside, sq.ft.	Metal Area	Flow Area	Pipe	Water	Mfg. Process	Joint Type[b]	Rating, psig
1/4	0.54	40 ST	0.088	0.364	0.141	0.095	0.125	0.104	0.424	0.045	CW	T	188
		80 XS	0.119	0.302	0.141	0.079	0.157	0.072	0.535	0.031	CW	T	871
3/8	0.675	40 ST	0.091	0.493	0.177	0.129	0.167	0.191	0.567	0.083	CW	T	203
		80 XS	0.423	0.177	0.111	0.217	0.141	0.738	0.061	CW	T	820	
1/2	0.84	40 ST	0.109	0.622	0.22	0.163	0.25	0.304	0.85	0.131	CW	T	214
		80 XS	0.546	0.22	0.143	0.32	0.234	1.087	0.101	CW	T	753	
3/4	1.05	40 ST	0.113	0.824	0.275	0.216	0.333	0.533	1.13	0.231	CW	T	217
		80 XS	0.742	0.275	0.194	0.433	0.432	1.47	0.187	CW	T	681	
1	1.315	40 ST	0.133	1.049	0.344	0.275	0.494	0.864	1.68	0.374	CW	T	226
		80 XS	0.957	0.344	0.251	0.639	0.719	2.17	0.311	CW	T	642	
1-1/4	1.66	40 ST	0.14	1.38	0.435	0.361	0.669	1.5	2.27	0.647	CW	T	229
		80 XS	1.278	0.435	0.335	0.881	1.28	2.99	0.555	CW	T	594	
1-1/2	1.9	40 ST	0.145	1.61	0.497	0.421	0.799	2.04	2.72	0.881	CW	T	231
		80 XS	1.5	0.497	0.393	1.068	1.77	3.63	0.765	CW	T	576	
2	2.375	40 ST	0.154	2.067	0.622	0.541	1.07	3.36	3.65	1.45	CW	T	230
		80 XS	1.939	0.622	0.508	1.48	2.95	5.02	1.28	CW	T	551	
2-1/2	2.875	40 ST	0.203	2.469	0.753	0.646	1.7	4.79	5.79	2.07	CW	W	533
		80 XS	2.323	0.753	0.608	2.25	4.24	7.66	1.83	CW	W	835	
3	3.5	40 ST	0.216	3.068	0.916	0.803	2.23	7.39	7.57	3.2	CW	W	482
		80 XS	2.9	0.916	0.759	3.02	6.6	10.25	2.86	CW	W	767	
4	4.5	40 ST	0.237	4.026	1.178	1.054	3.17	12.73	10.78	5.51	CW	W	430
		80 XS	3.826	1.178	1.002	4.41	11.5	14.97	4.98	CW	W	695	
6	6.625	40 ST	0.28	6.065	1.734	1.588	5.58	28.89	18.96	12.5	ERW	W	696
		80 XS	5.761	1.734	1.508	8.4	26.07	28.55	11.28	ERW	W	1209	
8	8.625	30	0.277	8.071	2.258	2.113	7.26	51.16	24.68	22.14	ERW	W	526
		40 ST	0.322	7.981	2.258	2.089	8.4	50.03	28.53	21.65	ERW	W	643
		80 XS	0.5	7.625	2.258	1.996	12.76	45.66	43.35	19.76	ERW	W	1106
10	10.75	30	0.307	10.136	2.814	2.654	10.07	80.69	34.21	34.92	ERW	W	485
		40 ST	0.365	10.02	2.814	2.623	11.91	78.85	40.45	34.12	ERW	W	606
		XS	0.5	9.75	2.814	2.552	16.1	74.66	54.69	32.31	ERW	W	887
		80	0.593	9.564	2.814	2.504	18.92	71.84	64.28	31.09	ERW	W	1081
12	12.75	30	0.33	12.09	3.338	3.165	12.88	114.8	43.74	49.68	ERW	W	449
		ST	0.375	12	3.338	3.141	14.58	113.1	49.52	48.94	ERW	W	528
		40	0.406	11.938	3.338	3.125	15.74	111.9	53.48	48.44	ERW	W	583
		XS	0.5	11.75	3.338	3.076	19.24	108.4	65.37	46.92	ERW	W	748
		80	0.687	11.376	3.338	2.978	26.03	101.6	88.44	43.98	ERW	W	1076
14	14	30 ST	0.375	13.25	3.665	3.469	16.05	137.9	54.53	59.67	ERW	W	481
		40	0.437	13.126	3.665	3.436	18.62	135.3	63.25	58.56	ERW	W	580
		XS	0.5	13	3.665	3.403	21.21	132.7	72.04	57.44	ERW	W	681
		80	0.75	12.5	3.665	3.272	31.22	122.7	106.05	53.11	ERW	W	1081
16	16	30 ST	0.375	15.25	4.189	3.992	18.41	182.6	62.53	79.04	ERW	W	421
		40 XS	0.5	15	4.189	3.927	24.35	176.7	82.71	76.47	ERW	W	596
18	18	ST	0.375	17.25	4.712	4.516	20.76	233.7	70.54	101.13	ERW	W	374
		30	0.437	17.126	4.712	4.483	24.11	230.3	81.91	99.68	ERW	W	451
		XS	0.5	17	4.712	4.45	27.49	227	93.38	98.22	ERW	W	530
		40	0.562	16.876	4.712	4.418	30.79	223.7	104.59	96.8	ERW	W	607
20	20	20 ST	0.375	19.25	5.236	5.039	23.12	291	78.54	125.94	ERW	W	337
		30 XS	0.5	19	5.236	4.974	30.63	283.5	104.05	122.69	ERW	W	477
		40	0.593	18.814	5.236	4.925	36.15	278	122.82	120.3	ERW	W	581

a. Numbers are schedule numbers per ASME Standard B36.10M; ST = Standard Weight; XS = Extra Strong.

b. T = Thread; W = Weld

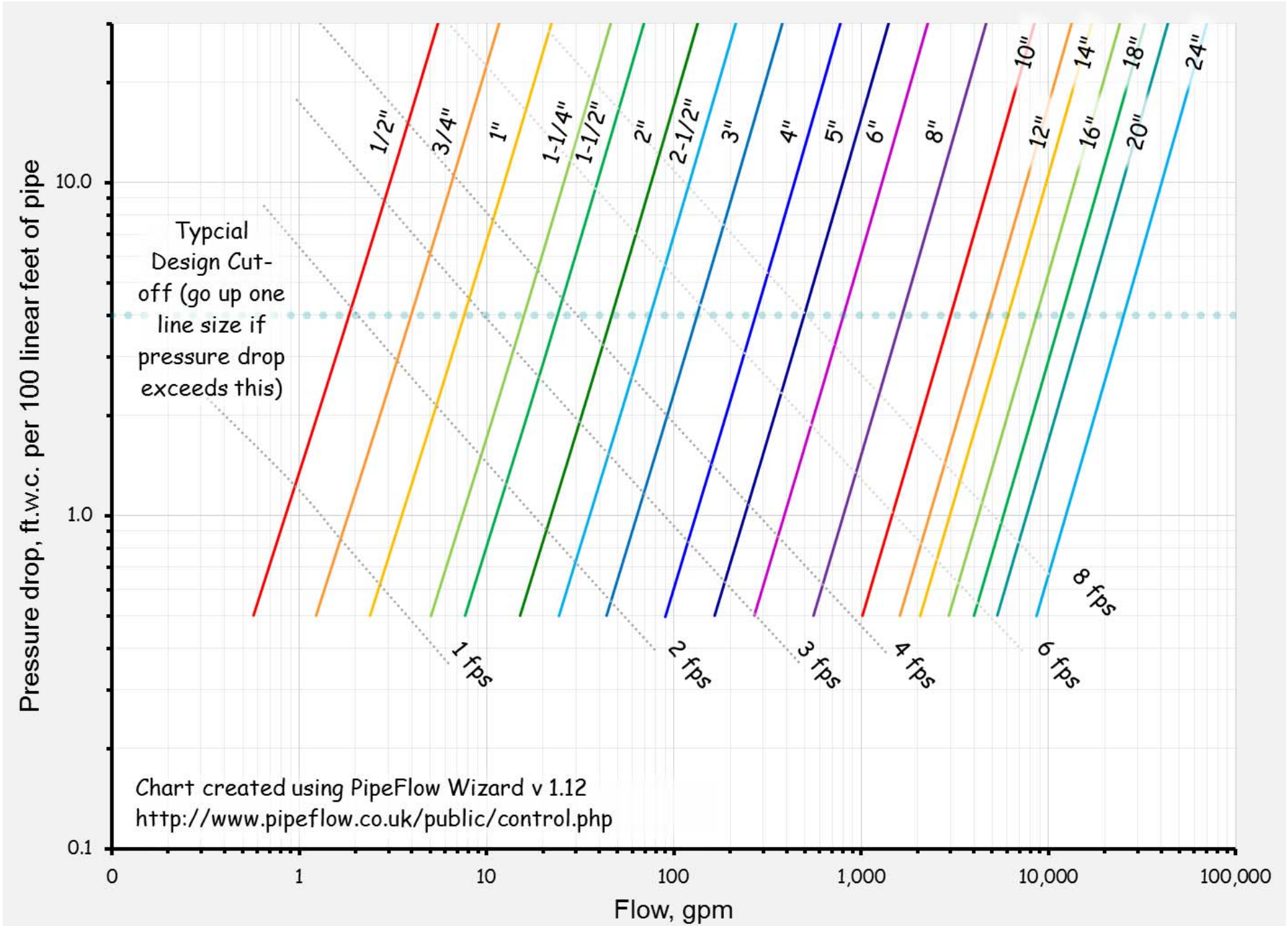
c. Working pressures were calculated per ASME B31.9 using furnace butt-weld (continuous weld, CW) pipe through 4 in. and electric resistance weld (ERW) thereafter. The allowance A has been taken as:

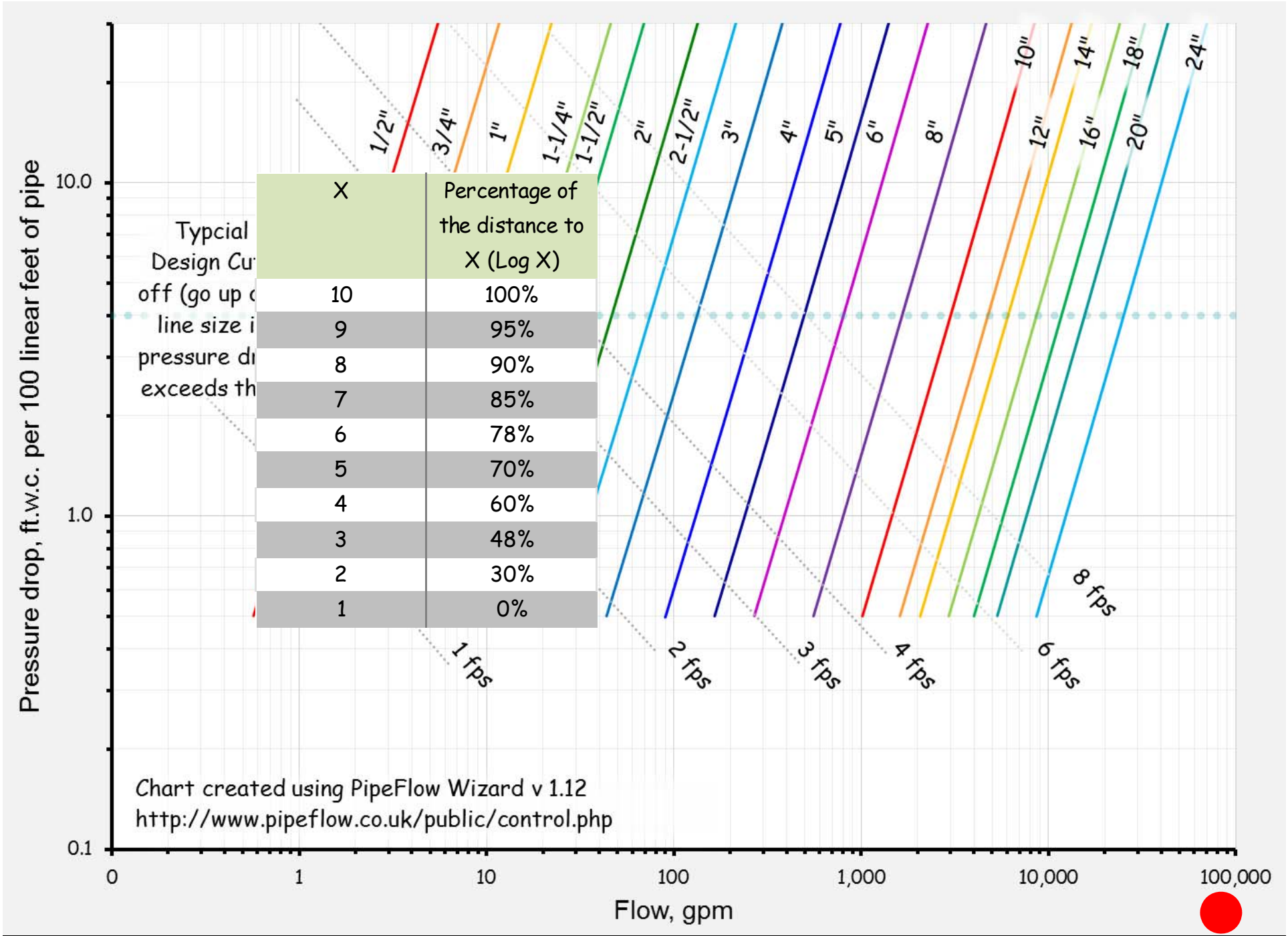
(1) 12.5% of t for mill tolerance on pipe wall thickness, plus

(2) An arbitrary corrosion allowance of 0.025 in. for pipe sizes through NPS 2 and

(3) A thread cutting allowance for sizes through NPS 2.

Because the pipe wall thickness of threaded standard pipe is so small after deducting allowance A, the mechanical strength of the pipe is impaired. It is good practice to limit standard weight threaded pipe pressure to 90 psig for steam and 125 psig for water.


Pressure drop, ft.w.c. per 100 linear feet of pipe
10.0
1.0
0.1
Typcial Design Cut-off (go up one line size if pressure drop exceeds this)
1/2"
3/4"
1"
1-1/4"
1-1/2"
2"
2-1/2"
3"
4"
5"
6"
8"
10"
12"
14"
16"
18"
20"
24"
1 fps
2 fps
3 fps
4 fps
6 fps
8 fps
Chart created using PipeFlow Wizard v 1.12
http://www.pipeflow.co.uk/public/control.php
0
1
10
100
1,000
10,000
100,000
Flow, gpm



X	Percentage of the distance to X (Log X)
10	100%
9	95%
8	90%
7	85%
6	78%
5	70%
4	60%
3	48%
2	30%
1	0%