STEAM SPECIALTY SALES LTD.
DESIGN SPECIALISTS FOR STEAM, AIR AND WATER SYSTEMS

ENGINEERING GUIDE

CONTENTS

16 Cosentino Drive. Scarborough, Ontario M1P 3A2 Tel: (416) 291-1111 Fax: (416) 754-3481
WWW.STEAMSPECIALTY.COM E-mail: infotoronto@steamspecialty.com

PROPERTIES OF SATURATED STEAM

h = Total heat of steam, Btu per pound v = Specific volume, cubic feet per pound

Pressure psi (gage)	Temperature F° (sat.)		Saturated Liquid	Saturated Vapor	TOTAL TEMPERATURE, °F												
					220	240	260	280	300	320	340	360	380	400	420	440	460
0	212	h	180.1	1150.4	1154.4	1164.2	1173.8	1183.3	1192.8	1202.3	1211.7	1221.1	1230.5	1239.9	1249.3	1258.8	1268.2
		v	0.0167	26.80	27.15	28.00	28.85	29.70	30.53	31.37	32.20	33.03	33.85	34.68	35.50	36.32	37.14
5	228	h	196.2	1156.3		1162.3	1172.2	1182.0	1191.6	1201.2	1210.8	1220.3	1229.7	1239.2	1248.7	1258.2	1267.6
		v	0.0168	20.089		20.48	21.11	21.74	22.36	22.98	23.60	24.21	24.82	25.43	26.04	26.65	27.25
10	240	h	208.4	1160.6			1170.7	1180.6	1190.5	1200.2	1209.8	1219.4	1229.0	1238.5	1248.1	1257.6	1267.1
		v	0.0169	16.303			16.819	17.330	17.836	18.337	18.834	19.329	19.821	20.31	20.80	21.29	21.77
15	250	h	218.8	1164.1			1169.1	1179.3	1189.3	1199.1	1208.9	1218.6	1228.3	1237.9	1247.5	1257.0	1266.6
		v	0.0170	13.746			13.957	14.390	14.816	15.238	15.657	16.072	16.485	16.897	17.306	17.714	18.121
20	259	h	227.9	1167.1			1167.5	1177.9	1188.1	1198.1	1208.0	1217.8	1227.5	1237.2	1246.8	1256A	1266.1
		v	0.0171	11.898			11.911	12.288	12.659	13.025	13.387	13.746	14.103	14.457	14.810	15.162	15.512
25	267	h	236.0	1169.7				1176.5	1186.8	1197.0	1207.0	1216.9	1226.7	1236.5	12462	1255.9	1265.5
		v	0.0171	10.498				10.711	11.040	11.364	11.684	12.001	12.315	12.628	12.938	13.247	13.555
30	274	h	243.4	1172.0				1175.0	1185.6	1195.9	1206.0	1216.0	1225.9	1235.8	1245.6	1255.3	1265.0
		v	0.0172	9.401				9.484	9.781	10.072	10.359	10.643	10.925	11.204	11.482	11.758	120033
40	287	h	256.3	1175.9					1183.0	1193.6	1204.0	1214.3	1224.4	1234.3	1244.3	1254.1	1263.9
		v	0.0173	7.787					7.947	8.192	8.432	8.668	8.902	9.134	9.364	9.592	9.819
50	298	h	267.5	1179.1					1180.3	1191.3	1202.0	1212.5	1222.7	1232.9	1242.9	1252.9	1262.8
		v	0.0174	6.655					6.676	6.889	7.096	7.300	7.501	7.700	7.896	8.091	8.285
60	308	h	277.4	1181.9						1188.9	1199.9	1210.6	1221.1	1231.4	1241.6	1251.7	1261.7
		v	0.0175	5.816						5.9321	6.116	6.296	6.473	6.648	6.820	6.991	7.161
70	316	h	286.4	1184.2						1186.4	1197.7	1208.7	1219.4	1229.9	1240.2	1250.4	1260.6
		v	0.0176	5.168						5.200	5.366	5.528	5.687	5.843	5.997	6.150	6.301
80	324	h	294.6	1186.2							1195.5	1206.7	1217.7	1228.3	1238.8	1249.2	1259.4
		v	0.0177	4.652							4.773	4.921	5.065	5.207	5.347	5.485	5.621
90	331	h	302.1	1188.1							1193.2	1204.7	1215.9	1226.7	1237.4	1247.9	1258.2
		v	0.0178	4.232							4.292	4.429	4.562	4.693	4.821	4.947	5.071
100	338	h	309.1	1189.7							1190.8	1202.7	1214.1	1225.2	1236.0	1246.6	1257.1
		v	0.0178	3.882							3.895	4.022	4.146	4.267	4.385	4.502	4.617
125	353	h	324.8	1193.0								1197.3	1209.4	1211.1	1232.3	1243.3	1254.1
		v	0.0180	3.220								3.258	3.365	3.468	3.569	3.667	3.764
150	366	h	338.5	1195.6									1204.5	1216.7	1228.4	1239.8	1251.0
		v	0.0182	2.752									2.818	2.910	2.998	3.085	3.169
175	378	h	350.8	1197.6									1199.3	1212.2	1224.5	1236.3	1247.8
		v	0.0183	2.404									2.414	2.498	2.577	2.655	2.730
200	388	h	361.9	1199.3										1207.4	1220.3	1232.6	1244.5
		v	0.0185	2.134										2.180	2.253	2.324	2.393
225	397	h	372.1	1200.6										1202.5	1216.0	1228.8	1241.1
		v	0.0186	1.9183										1.9276	1.9964	2.062	2.126
250	406	h	381.6	1201.7											1211.5	1224.9	1237.6
		v	0.0187	1.7422											1.7870	1.8488	1.9081
275	414	h	390.5	1202.6											1206.8	1220.8	1234.0
		v	0.0188	1.5954											1.6130	1.6717	1.7277
300	422	h	398.8	1203.2												1216.5	1230.3
		v	0.0190	1.4711												1.5222	1.5755
350	436	h	414.1	1204.1												1207.5	1222.4
		v	0.0192	1.2720												1.2831	1.3326
400	448	h	428.1	1204.6													1214.0
		v	0.0194	1.1194													1.1468
450	460	h	440.9	1204.6													
		v	0.0196	0.9985													
500	470	h	452.9	1204.2													
		v	0.0198	0.9004													
550	480	h	464.1	1203.7													
		v	0.0200	0.8191													
600	489	h	474.7	1203.0													
		v	0.0202	0.7503													

*Adapted with permission from “Thermodynamic Properties of Steam”, Keenan and Keyes, published by John Wiley & Sons, Inc.

PROPERTIES OF SATURATED STEAM CONT'D.

h = Total heat of steam, Btu per pound v = Specific volume, cubic feet per pound

TOTAL TEMPERATURE, °F																Temp-erature °F (sat.)	Pres-sure psi (gage)
480	500	520	540	560	580	600	620	640	660	680	700	720	740	750			
1277.6	1287.1	1296.6	1306.2	1315.7	1325.3	1334.8	1344.5	1354.2	1363.8	1373.5	1383.2	1393.0	1402.8	1407.7	h	212	0
37.96	38.78	39.60	40.41	41.23	42.04	42.86	43.68	44.49	45.31	46.12	46.94	47.75	48.56	48.97	v		
1277.1	1286.6	1296.2	1305.7	1315.3	1324.8	1334.4	1344.1	1353.8	1363.5	1373.2	1382.9	1392.7	1402.6	1407.5	h	228	5
27.86	28.46	29.06	29.67	30.27	30.87	31.47	32.07	32.67	33.27	33.87	34.47	35.07	35.67	35.96	v		
1276.6	1286.2	1295.8	1305.3	1314.9	1324.5	1334.1	1343.8	1353.5	1363.2	1372.9	1382.6	1392.5	1402.3	1407.2	h	240	10
22.26	22.74	23.22	23.71	24.19	24.68	25.16	25.64	26.12	26.60	27.08	27.56	28.04	28.52	28.76	v		
1276.2	1285.7	1295.3	1304.9	1314.5	1324.2	1333.8	1343.5	1353.2	1362.9	1372.6	1382.4	1392.3	1402.1	1407.0	h	250	15
18.528	18.933	19.337	19.741	20.144	20.547	20.95	21.35	21.75	22.15	22.56	22.96	23.36	23.76	23.96	v		
1275.7	1285.3	1294.9	1304.5	1314.1	1323.8	1333.5	1343.2	1352.9	1362.6	1372.3	1382.1	1391.9	1401.8	1406.7	h	259	20
15.862	16.210	16.558	16.905	17.251	17.597	17.943	18.288	18.633	18.977	19.322	19.666	20.01	20.35	20.52	v		
1275.2	1284.8	1294.5	1304.1	1313.8	1323.4	1333.1	1342.8	1352.5	1362.3	1372.1	1381.9	1391.7	1401.6	1406.5	h	267	25
13.862	14.168	14.473	14.778	15.082	15.385	15.688	15.990	16.293	16.595	16.896	17.198	17.499	17.8001	7.951	v		
1274.7	1284.4	1294.0	1303.7	1313.4	1323.1	1332.8	1342.5	1352.2	1362.0	1371.8	1381.6	1391.5	1401.4	1406.3	h	274	30
12.307	12.580	12.852	13.123	13.394	13.665	13.935	14.204	14.473	14.742	15.011	15.279	15.547	15.815	15.949	v		
1273.7	1283.4	1293.2	1302.9	1312.6	1322.4	1332.1	1341.9	1351.7	1361.5	1371.3	1381.1	1391.0	1400.9	1405.8	h	287	40
10.044	10.269	10.493	10.717	10.940	11.162	11.384	11.605	11.826	12.047	12.268	12.488	12.708	12.927	13.037	v		
1272.7	1282.5	1292.3	1302.1	1311.9	1321.7	1331.5	1341.3	1351.1	1360.9	1370.8	1380.6	1390.5	1400.4	1405.4	h	298	50
8.478	8.670	8.861	9.051	9.240	9.429	9.618	9.806	9.993	10.181	10.368	10.555	10.741	10.928	11.021	v		
1271.6	1281.5	1291.4	1301.3	1311.1	1321.0	1330.8	1340.6	1350.5	1360.3	1370.2	1380.1	1390.0	1399.9	1404.9	h	308	60
7.329	7.496	7.663	7.829	7.994	8.159	8.323	8.486	8.649	8.812	8.975	9.138	9.300	9.462	9.543	v		
1270.6	1280.6	1290.5	1300.5	1310.4	1320.2	1330.1	1340.0	1349.9	1359.8	1369.7	1379.6	1389.6	1399.5	1404.5	h	316	70
6.450	6.599	6.747	6.894	7.041	7.187	7.332	7.477	7.622	7.766	7.910	8.054	8.198	8.341	8.413	v		
1269.5	1279.6	1289.6	1299.6	1309.6	1319.5	1329.4	1339.4	1349.3	1359.3	1369.2	1379.1	1389.1	1399.0	1404.0	h	324	80
5.756	5.891	6.024	6.156	6.288	6.419	6.550	6.680	6.810	6.940	7.069	7.199	7.327	7.456	7.520	v		
1268.5	1278.6	1288.7	1298.8	1308.8	1318.8	1328.7	1338.7	1348.7	1358.6	1368.6	1378.5	1388.5	1398.5	1403.5	h	331	90
5.195	5.317	5.439	5.559	5.679	5.799	5.918	6.036	6.154	6.272	6.389	6.506	6.623	6.740	6.798	v		
1267.4	1277.7	1287.8	1297.9	1308.0	1318.0	1328.1	1338.1	1348.0	1358.0	1368.0	1378.0	1388.1	1398.1	1403.1	h	338	100
4.730	4.843	4.955	5.066	5.176	5.285	5.394	5.503	5.611	5.719	5.827	5.934	6.041	6.148	6.201	v		
1264.7	1275.2	1285.5	1295.8	1306.0	1316.2	1326.4	1336.5	1346.6	1356.6	1366.7	1376.8	1386.9	1397.0	1402.0	h	353	125
3.860	3.954	4.047	4.140	4.232	4.323	4.413	4.503	4.593	4.683	4.772	4.861	4.949	5.038	5.082	v		
1261.9	1272.6	1283.2	1293.6	1304.0	1314.3	1324.6	1334.8	1345.0	1355.2	1365.3	1375.4	1385.6	1395.8	1400.8	h	366	150
3.252	3.334	3.414	3.494	3.573	3.652	3.730	3.807	3.884	3.960	4.037	4.113	4.188	4.264	4.301	v		
1259.0	1270.0	1280.8	1291.4	1302.0	1312.4	1322.8	1333.2	1343.5	1353.7	1363.9	1374.2	1384.4	1394.6	1399.7	h	378	175
2.804	2.877	2.948	3.019	3.089	3.157	3.226	3.294	3.361	3.429	3.495	3.562	3.628	3.694	3.727	v		
1256.0	1267.3	1278.3	1289.2	1299.9	1310.5	1321.0	1331.4	1341.8	1352.2	1362.5	1372.8	1383.1	1393.3	1398.5	h	388	200
2.460	2.525	2.590	2.653	2.716	2.777	2.839	2.900	2.960	3.019	3.079	3.139	3.198	3.256	3.286	v		
1253.0	1264.5	1275.8	1286.9	1297.8	1308.5	1319.2	1329.8	1340.3	1350.7	1361.1	1371.5	1381.9	1392.2	1397.3	h	397	225
2.187	2.247	2.306	2.364	2.421	2.477	2.533	2.587	2.642	2.696	2.750	2.804	2.857	2.910	2.936	v		
1249.9	1261.7	1273.2	1284.5	1295.6	1306.5	1317.3	1328.0	1338.7	1349.2	1359.7	1370.2	1380.6	1391.0	1396.2	h	406	250
1.9654	2.021	2,076	2.129	2.181	2.233	2.284	2.334	2.384	2.434	2.483	2.532	2.580	2.629	2.653	v		
1246.6	1258.8	1270.6	1282.1	1293.4	1304.5	1315.5	1326.3	1337.0	1347.7	1358.3	1368.8	1379.3	1389.8	1395.0	h	414	275
1.7816	1.8338	1.8846	1.9342	1.9829	2.031	2.078	2.125	2.171	2.217	2.262	2.307	2.352	2.396	2.418	v		
1243.3	1255.8	1267.9	1279.7	1291.2	1302.5	1313.6	1324.5	1335.4	1346.1	1356.8	1367.4	1378.0	1388.6	1393.8	h	422	300
1.6266	1.6759	1.7237	1.7703	1.8159	1.8607	1.9048	1.9483	1.9912	2.034	2.076	2.118	2.159	2.200	2.220	v		
1236.4	1249.6	1262.4	1274.7	1286.6	1298.2	1309.7	1320.9	1332.0	1343.0	1353.9	1364.7	1375.4	1386.1	1391.4	h	436	350
1.3795	1.4243	1.4675	1.5094	1.5501	1.5900	1.6291	1.6676	1.7056	1.7430	1.7801	1.8168	1.8531	1.8892	1.9071	v		
1229.0	1243.2	1256.6	1269.4	1281.8	1293.9	1305.7	1317.2	1328.6	1339.8	1350.9	1361.9	1372.8	1383.6	1389.0	h	448	400
1.1908	1.2325	1.2724	1.3108	1.3480	1.3842	1.4196	1.4544	1.4885	1.5222	1.5554	1.5883	1.6207	1.6529	1.6689	v		
1221.2	1236.3	1250.5	1264.0	1276.9	1289.4	1301.6	1313.5	1325.1	1336.5	1347.8	1359.0	1370.1	1381.1	1386.5	h	460	450
1.0416	1.0811	1.1186	1.1544	1.1889	1.2224	1.2550	1.2868	1.3180	1.3488	1.3789	1.4088	1.4382	1.4675	1.4819	v		
1212.8	1229.0	1244.0	1258.3	1271.8	1284.8	1297.3	1309.6	1321.5	1333.2	1344.7	1356.1	1367.3	1378.4	1384.0	h	470	500
0.9204	0.9584	0.9941	1.0280	1.0604	1.0917	1.1221	1.1516	1.1805	1.2088	1.2367	1.2641	1.2913	1.3180	1.3313	v		
	1221.4	1237.4	1252.4	1266.5	1280.0	1293.0	1305.6	1317.8	1329.8	1341.6	1353.2	1364.6	1375.8	1381.4	h	480	550
	0.8565	0.8909	0.9234	0.9542	0.9838	1.0124	1.0401	1.0671	1.0935	1.1195	1.1449	1.1700	1.1947	1.2070	v		
	1213.2	1230.3	1246.1	1261.0	1275.1	1288.5	1301.5	1314.1	1326.3	1338.3	1350.2	1361.8	1373.2	1378.9	h	489	600
	0.7703	0.8040	0.8353	0.8649	0.8931	0.9203	0.9465	0.9720	0.9968	1.0211	1.0450	1.0684	1.0916	1.1030	v		

Pressure to Vacuum

Gage Indicated		Absolute Pressure		
PSIG	Inches of Hg	PSIA	Inches of Hg	Torricelli
-14.70000	29.92000	0.0	0.0	0.0
-14.69998	29.91996	0.00002	0.00004	0.001
-14.69996	29.91992	0.00004	0.00008	0.002
-14.69994	29.91988	0.00006	0.00012	0.003
-14.69992	29.91984	0.00008	0.00016	0.004
-14.69990	29.91980	0.00010	0.00020	0.005
-14.69981	29.91961	0.00019	0.00039	0.010
-14.69961	29.91921	0.00039	0.00079	0.020
-14.69942	29.91882	0.00058	0.00118	0.030
-14.69923	29.91843	0.00077	0.00157	0.040
-14.69903	29.91803	0.00097	0.00197	0.050
-14.69806	29.91606	0.00194	0.00394	0.100
-14.69613	29.91212	0.00387	0.00788	0.200
-14.69449	29.90818	0.00551	0.01182	0.300
-14.69226	29.90424	0.00774	0.01576	0.400
-14.69032	29.90030	0.00968	0.01970	0.500
-14.68066	29.88063	0.01934	0.03937	1.000
-14.66698	29.84126	0.03302	0.07874	2.000
-14.64197	29.80189	0.05803	0.11811	3.000
-14.62262	29.76252	0.07738	0.15748	4.000
-14.60329	29.72315	0.09671	0.19685	5.000
-14.50658	29.52630	0.19342	0.39370	10.000
-14.40980	29.32940	0.29020	0.59060	15.000
-14.31320	29.13260	0.38680	0.78740	20.000
-14.21840	28.93570	0.48160	0.98430	25.000
-14.20870	28.920	0.49130	1.000	25.400
-14.11970	28.740	0.58030	1.181	30.000
-13.75700	28.000	0.94330	1.920	48.770
-12.28300	25.000	2.41700	4.920	124.970
-10.31800	21.000	4.38200	8.920	226.570
-8.84400	18.000	5.85600	11.920	302.770
-7.37000	15.000	7.320	14.920	378.970
-5.89600	12.000	8.804	17.920	455.770
-4.91300	10.000	9.787	19.920	505.970
-3.93000	8.000	10.770	21.920	556.770
-2.94800	6.000	11.752	23.920	607.570
-1.96500	4.000	12.735	25.920	658.370
-0.98300	2.000	13.732	27.920	709.170
-0.49100	1.000	14.209	28.920	733.570
-0.24600	0.500	14.454	29.420	747.270
ATMOSPHERIC				
0.0	0.0	14.700	29.920	760.000
+ 0.30		15.000	30.540	775.720
+ 1.00		15.700	31.970	811.910
+ 2.00		16.700	34.000	863.630
+ 10.00		24.700	50.290	277.35

Properties of Water

Water Temp.	Saturation Pressure	Weight	Weight Density	Specific Volume
Deg. F	PSIA	lbs/Gallon	lbs/Cu.Ft.	Cu.Ft./lb
32	0.0886	8.344	62.414	0.016022
40	0.1216	8.345	62.426	0.016019
50	0.1780	8.343	62.410	0.016023
60	0.2561	8.338	62.371	0.016033
70	0.3629	8.329	62.305	0.016050
80	0.5068	8.318	62.220	0.016072
90	0.6981	8.304	62.116	0.016099
100	0.9492	8.288	61.996	0.016130
110	1.2750	8.270	61.862	0.016165
120	1.6927	8.250	61.713	0.016204
130	2.2230	8.228	61.550	0.016247
140	2.8892	8.205	61.376	0.016293
150	3.7184	8.180	61.188	0.016343
160	4.7414	8.154	60.994	0.016395
170	5.9926	8.126	60.787	0.016451
180	7.5110	8.097	60.569	0.016510
190	9.340	8.067	60.343	0.016572
200	11.526	8.035	60.107	0.016637
210	14.123	8.002	59.862	0.016705
212	14.696	7.996	59.812	0.016719
220	17.186	7.969	59.613	0.016775
240	24.968	7.898	59.081	0.016926
260	35.427	7.823	58.517	0.017089
280	49.200	7.743	57.924	0.017264
300	67.005	7.661	57.307	0.01745
350	134.604	7.431	55.586	0.01799
400	247.259	7.172	53.648	0.01864
450	422.55	6.880	51.467	0.01943
500	680.86	6.543	48.948	0.02043
550	1045.43	6.143	45.956	0.02176
600	1543.2	5.655	42.301	0.02364
650	2208.4	4.999	37.397	0.02674
700	3094.3	3.651	27.307	0.03662

NOTE:
Weight of water per gallon is based on 7.48052 gallons per cubic foot.

Specific gravity of water @ 60°F = 1.00

Condensation Warm-up Loads

Steam Pressure PSIG	HEADER SIZE														0°F* Correct Factor
	2"	2½"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	24"	
1	6.4	10.2	13.3	19.0	25.7	33.3	50	71	94	111	145	184	216	301	1.50
5	7.2	11.4	14.9	21.2	28.7	37.2	56	80	105	124	163	206	241	336	1.45
10	7.8	12.4	16.2	23.0	31.2	40.5	61	86	114	135	177	224	262	365	1.41
20	8.8	14.0	18.3	26.0	35.2	45.7	69	98	129	153	200	253	296	413	1.37
40	10.3	16.4	21.4	30.5	41.3	53.6	81	114	151	179	234	296	347	484	1.32
60	11.5	18.2	23.9	34.0	46.0	59.7	90	127	169	200	261	330	387	539	1.29
80	12.5	19.8	25.9	36.9	50.0	64.8	98	138	183	217	283	358	420	585	1.27
100	13.3	21.1	27.7	39.4	53.4	69.3	104	148	195	231	302	383	449	625	1.26
125	14.3	22.6	29.6	42.2	57.2	74.2	112	158	209	248	324	410	481	670	1.25
150	15.1	24.0	31.4	44.7	60.6	78.6	118	168	222	263	343	434	509	709	1.24
175	15.9	25.2	33.0	47.0	63.7	82.7	124	176	233	276	361	457	536	746	1.23
200	16.6	26.4	34.5	49.1	66.6	86.4	130	184	244	289	377	477	560	779	1.22
250	17.9	28.5	37.3	53.0	71.9	93.3	140	199	263	312	407	515	604	842	1.21
300	26.3	40.2	53.8	78.6	109.0	150.0	228	338	464	557	716	896	1096	1555	1.20
400	29.3	44.8	59.9	87.7	121.5	167.0	254	376	517	620	798	998	1221	1733	1.19
500	32.1	48.9	65.5	95.7	132.8	182.5	277	411	566	678	872	1091	1335	1894	1.18
600	34.6	52.9	70.7	103.4	143.4	197.1	299	444	611	732	942	1179	1441	2045	1.17

Condensation loads are in pounds per hour per 100 feet of insulated steam main with ambient temperature of 70°F and an insulation efficiency of 80%.

Loads are based on Schedule 40 pipe for pressures up to and including 250 PSIG and on schedule 80 pipe for pressures above 250 PSIG.

Condensation Loads

Steam Pressure PSIG	HEADER SIZE														0°F* Correct Factor
	2"	2½"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	24"	
1	4.6	5.5	6.6	8.3	10.1	11.8	15.1	18.6	21.8	23.8	26.9	30.1	33.2	39.4	1.40
5	5.1	6.1	7.3	9.3	11.3	13.3	16.9	20.8	24.4	26.6	30.1	33.7	37.2	44.1	1.37
10	5.7	6.8	8.2	10.3	12.6	14.8	18.9	23.2	27.2	29.7	33.7	37.6	41.5	49.3	1.34
20	6.7	8.0	9.7	12.2	14.8	17.4	22.3	27.4	32.1	35.1	39.7	44.4	49.0	58.2	1.29
40	8.4	10.0	12.0	15.1	18.4	21.7	27.7	34.1	40.0	43.6	49.5	55.3	61.0	72.5	1.24
60	9.7	11.6	13.9	17.6	21.4	25.2	32.2	39.6	46.5	50.7	57.5	64.3	71.0	84.3	1.22
80	10.9	13.0	15.6	19.7	24.0	28.2	36.2	44.4	52.2	57.0	64.6	72.2	79.7	94.7	1.20
100	11.9	14.3	17.1	21.6	26.4	31.0	39.7	48.9	57.4	62.6	71.0	79.4	87.7	104.2	1.18
125	13.2	15.7	18.9	23.8	29.1	34.2	43.8	53.9	63.3	69.1	78.4	87.6	96.8	115.0	1.17
150	14.3	17.1	20.5	25.9	31.6	37.2	47.6	58.6	68.8	75.2	85.3	95.3	105.3	125.2	1.16
175	15.3	18.3	22.0	27.8	33.9	40.0	51.2	63.0	74.0	80.9	91.7	102.6	113.3	134.7	1.15
200	16.3	19.5	23.4	29.7	36.2	42.6	54.6	67.2	78.9	86.2	97.8	109.4	120.8	143.7	1.14
250	18.2	21.8	26.2	33.1	40.4	47.6	61.1	75.2	88.3	96.5	109.5	122.4	135.3	160.8	1.13
300	20.0	23.9	28.8	36.4	44.4	52.4	67.1	82.7	97.1	106.1	120.5	134.7	148.9	177.1	1.12
400	23.4	27.9	33.6	42.5	51.9	61.2	78.6	96.8	113.8	124.3	141.1	157.8	174.5	207.6	1.11
500	26.5	31.7	38.2	48.4	59.1	69.7	89.4	110.2	129.5	141.6	160.8	179.8	198.8	236.6	1.10
600	29.6	35.4	42.6	54.0	66.0	77.8	100.0	123.2	144.9	158.4	179.8	201.2	223.5	264.8	1.09

Condensation loads are in pounds per hour per 100 feet of insulated steam main with ambient temperature of 70°F and an insulation efficiency of 80%.

Chart loads represent losses due to radiation and convection for saturated steam.

CONVERSION TABLES

LIQUID WEIGHTS and MEASURES

To Convert	To	Multiply By
Gallons	Liters	3.7853
Gallons	Cu. Inches	231
Gallons	Cu. Feet	0.1337
Gallons	Cu. Meters	0.00379
Gallons	Lbs. of Water	8.339
Liters	Gallons	0.26418
Liters	Cu. Inches	61.025
Liters	Cu. Feet	0.0353
Liters	Cu. Meters	0.001
Liters	Lbs. of Water	2.202
Cu. Inches	Gallons	0.00433
Cu. Inches	Liters	0.01639
Cu. Inches	Cu. Feet	0.00058
Cu. Inches	Cu. Meters	0.000016
Cu. Inches	Lbs. of Water	0.0362
Cu. Feet	Gallons	7.48052
Cu. Feet	Liters	28.316
Cu. Feet	Cu. Inches	1728
Cu. Feet	Cu. Meters	0.0283
Cu. .Feet	Lbs. of Water	62.371
Cu. Meters	Gallons	264.17
Cu. Meters	Liters	999.972
Cu. Meters	Cu. Inches	61023.74
Cu. Meters	Cu. Feet	35.3145
Cu. Meters.	Lbs. of Water	2202.61
Lbs. of Water	Gallons	0.11992
Lbs. of Water	Liters	0.45419
Lbs. of Water	Cu. Inches	27.643
Lbs. of Water	Cu. Feet	0.01603
Lbs. of Water	Cu. Meters	0.000454

LINEAL MEASURES

Inches	mm	25.4
Inches	cm	2.54
Inches	Meters	0.0254
Feet	cm	30.48
Feet	Meters	0.3048
mm	Inches	0.03937
mm	Feet	0.00328
cm	Inches	0.3937
cm	Feet	0.03281
Meters	Feet	3.28

AREA

Sq. Inches	Sq. Feet	0.006944
Sq. Inches	Sq. cm	6.4516
Sq. Feet	Sq. Inches	144
Sq. Feet	Sq. cm	929.03
Sq. Feet	Sq. Meters	0.0929
Sq. cm	Sq. Inches	0.155
Sq. cm	Sq. Feet	0.00108
Sq. cm	Sq. Meters	0.0001
Sq. Meter	Sq. Inches	1550
Sq. Meter	Sq. Feet	10.76

CONVERSIONS of PRESSURE AND HEAD

To Convert	To	Multiply By
Lbs .per Sq .In.	Lbs. per Sq. Ft.	144
Lbs. per Sq. In.	Atmospheres	0.06805
Lbs. per Sq. In.	Ins. of Water	27.728
Lbs. per Sq. In.	Ft. of Water	2.3106
Lbs. per Sq. In.	Ins. of Mercury	2.03602
Lbs. per Sq. In.	mm of Mercury	51.715
Lbs. per Sq. In.	Bar	0.06895
Lbs. per Sq. In.	kg per Sq. cm	0.070307
Lbs. per Sq. In.	kg per Sq. M	703.070
Lbs. per Sq. Ft.	Lbs. per Sq. In.	0.0069445
Lbs. per Sq. Ft.	Atmospheres	0.000473
Lbs. per Sq. Ft.	Ins. of Water	0.1926
Lbs. per Sq. Ft.	Ft. of Water	0.01605
Lbs. per Sq. Ft.	Ins. of Mercury	0.014139
Lbs. per Sq. Ft.	mm of Mercury	0.35913
Lbs. per Sq. Ft.	Bar	0.000479
Lbs. per Sq. Ft.	kg per Sq. cm	0.000488
Lbs. per Sq. Ft.	kg per Sq. M	4.88241
Atmospheres	Lbs. per Sq. In.	14.696
Atmospheres	Lbs. per Sq. Ft.	2116.22
Atmospheres	Ins. of Water	407.484
Atmospheres	Ft. of Water	33.957
Atmospheres	Ins. of Mercury	29.921
Atmospheres	mm of Mercury	760
Atmospheres	Bar	1.01325
Atmospheres	kg per Sq. cm	1.0332
Atmospheres	kg per Sq. M	10332.27
Ins. of Water	Lbs. per Sq. In.	0.03609
Ins. of Water	Lbs. per Sq. Ft.	5.1972
Ins. of Water	Atmospheres	0.002454
Ins.of Water	Ft. of Water	0.08333
Ins. of Water	Ins. of Mercury	0.07343
Ins. of Water	mm of Mercury	1.8651
Ins. of Water	Bar	0.00249
Ins. of Water	kg per Sq. cm	0.00253
Ins. of Water	kg per Sq. M	25.375
Ft. of Water	Lbs. per Sq. In.	0.432781
Ft. of Water	Lbs. per Sq. Ft.	63.3205
Ft. of Water	Atmospheres	0.029449
Ft. of Water	Ins. of Water	12
Ft. of Water	Ins. of Mercury	0.88115
Ft. of Water	mm of Mercury	22.3813
Ft. of Water	Bar	0.029839
Ft. of Water	kg per Sq. cm	0.03043
Ft. of Water	kg per Sq. M	304.275
Ins. of Mercury	Lbs. per Sq. In.	0.491154
Ins. of Mercury	Lbs. per Sq. Ft.	70.7262
Ins. of Mercury	Atmospheres	0.033421
Ins. of Mercury	Ins. of Water	13.6185
Ins. of Mercury	Ft. of Water	1.1349
Ins. of Mercury	mm of Mercury	25.40005
Ins. of Mercury	Bar	0.033864
Ins. of Mercury	kg per Sq. cm	0.03453
Ins. of Mercury	kg per Sq. M	345.316
mm of Mercury	Lbs. per Sq. In.	0.019337
mm of Mercury	Lbs. per Sq. Ft.	2.7845
mm of Mercury	Atmospheres	0.001316
mm of Mercury	Ins. of Water	0.53616
mm of Mercury	Ft. of Water	0.04468
mm of Mercury	Ins. of Mercury	0.03937
mm of Mercury	Bar	0.00133
mm of Mercury	kg per Sq. cm	0.00136
mm of Mercury	kg per Sq. M	13.59509
kg per Sq. cm	Lbs. per Sq. In.	14.2233
kg per Sq. cm	Lbs. per Sq. Ft.	2048.155
kg per Sq. cm	Atmospheres	0.96784
kg per Sq. cm	Ins. of Water	394.38
kg per Sq. cm	Ft. of Water	32.865
kg per Sq. cm	Ins. of Mercury	28.959
kg per Sq. cm	mm of Mercury	735.559
kg per Sq. cm	Bar	0.98067
kg per Sq. cm	kg per Sq. M	10000

Note: All weights and measures of water are based on temperature of 60°F.

Note: Temperature of Water and Mercury is 68°F and 32°F respectively.

TEMPERATURE

To convert Fahrenheit to Celsius: $\frac{°F - 32}{1.8}$

To convert Celsius to Fahrenheit: (1.8 x °C) + 32

VELOCITY

1 Ft per Sec. = 0.3048 M Per Sec.

1 M per Sec. = 3.2808 Ft. per Sec.

Pipe Data tables

Pipe Size (in.)	Outside Diameter (in.)	Weight Class	Carbon Steel Sched.	Stainless Steel Sched.	Wall Thickness (in.)	Inside Diameter (in.)	Circum. (Ext.) (in.)	Circum (Int.) (in.)	Flow Area (sq. in.)	Weight of Pipe (lbs/Ft.)	Weight of Water (lbs/Ft.)	Gallons of Water per Ft.	Section Modulus	Pipe Size (in.)
		—	—	10S	.049	.307		.96	.074	.19	.032	.004	.00437	
1/8	.405	STD	40	40S	.068	.269	1.27	.85	.057	.24	.025	.003	.00523	1/8
		XS	80	80S	.095	.215		.68	.036	.31	.016	.002	.00602	
		—	—	10S	.065	.410		1.29	.132	.33	.057	.007	.01032	
1/4	.540	STD	40	40S	.088	.364	1.70	1.14	.104	.42	.045	.005	.01227	1/4
		XS	80	80S	.119	.302		.95	.072	.54	.031	.004	.01395	
		—	—	10S	.065	.545		1.71	.233	.42	.101	.012	.01736	
3/8	.675	STD	40	40S	.091	.493	2.12	1.55	.191	.57	.083	.010	.0216	3/8
		XS	80	80S	.126	.423		1.33	.141	.74	.061	.007	.0255	
		—	—	5S	.065	.710		2.23	.396	.54	.172	.021	.0285	
		—	—	10S	.083	.674		2.12	.357	.67	.155	.019	.0341	
		STD	40	40S	.109	.622		1.95	.304	.85	.132	.016	.0407	
1/2	.840	XS	80	80S	.147	.546	2.64	1.72	.234	1.09	.102	.012	.0478	1/2
		—	160	—	.187	.466		1.46	.171	1.31	.074	.009	.0527	
		XXS	—	—	.294	.252		.79	.050	1.71	.022	.003	.0577	
		—	—	5S	.065	.920		2.89	.665	.69	.288	.035	.0467	
		—	—	10S	.083	.884		2.78	.614	.86	.266	.032	.0566	
		STD	40	40S	.113	.824	3.30	2.59	.533	1.13	.231	.028	.0706	
3/4	1.050	XS	80	80S	.154	.742		2.33	.433	1.47	.188	.022	.0853	3/4
		—	160	—	.219	.612		1.92	.296	1.94	.128	.015	.1004	
		XXS	—	—	.308	.434		1.36	.148	2.44	.064	.008	.1103	
		—	—	5S	.065	1.185		3.72	1.103	.87	.478	.057	.0760	
		—	—	10S	.109	1.097		3.45	.945	1.40	.409	.049	.1151	
		STD	40	40S	.133	1.049	4.13	3.30	.864	1.68	.375	.045	.1328	
1	1.315	XS	80	80S	.179	.957		3.01	.719	2.17	.312	.037	.1606	1
		—	160	—	.250	.815		2.56	.522	2.84	.230	.027	.1903	
		XXS	—	—	.358	.599		1.88	.282	3.66	.122	.015	.2136	
		—	—	5S	.065	1.530		4.81	1.839	1.11	.797	.096	.1250	
		—	—	10S	.109	1.442		4.53	1.633	1.81	.708	.085	.1934	
		STD	40	40S	.140	1.380		4.34	1.495	2.27	.649	.078	.2346	
1 1/4	1.660	XS	80	80S	.191	1.278	5.22	4.02	1.283	3.00	.555	.067	.2913	1 1/4
		—	160	—	.250	1.160		3.64	1.057	3.76	.458	.055	.3421	
		XXS	—	—	.382	.896		2.81	.630	5.21	.273	.033	.4110	
		—	—	5S	.065	1.770		5.56	2.461	1.28	1.066	.128	.1662	
		—	—	10S	.109	1.682		5.28	2.222	2.09	.963	.115	.2598	
		STD	40	40S	.145	1.610	5.97	5.06	2.036	2.72	.882	.106	.3262	
1 1/2	1.900	XS	80	80S	.200	1.500		4.71	1.767	3.63	.765	.092	.4118	1 1/2
		—	160	—	.281	1.338		4.20	1.406	4.86	.608	.073	.5078	
		XXS	—	—	.400	1.100		3.46	.950	6.41	.420	.049	.5977	
		—	—	5S	.065	2.245		7.05	3.958	1.61	1.72	.206	.2652	
		—	—	10S	.109	2.157		6.78	3.654	2.64	1.58	.190	.4204	
		STD	40	40S	.154	2.067		6.49	3.355	3.65	1.45	.174	.5606	
2	2.375	XS	80	80S	.218	1.939	7.46	6.09	2.953	5.02	1.28	.153	.7309	2
		—	160	—	.344	1.687		5.30	2.241	7.46	.97	.116	.9790	
		XXS	—	—	.436	1.503		4.72	1.774	9.03	.77	.092	1.1040	
		—	—	5S	.083	2.709		8.51	5.764	2.48	2.50	.299	.4939	
		—	—	10S	.120	2.635		8.28	5.453	3.53	2.36	.283	.6868	
		STD	40	40S	.203	2.469		7.76	4.788	5.79	2.07	.249	1.064	
2 1/2	2.875	XS	80	80S	.276	2.323	9.03	7.30	4.238	7.66	1.87	.220	1.339	2 1/2
		—	160	—	.375	2.125		6.68	3.546	10.01	1.54	.184	1.638	
		XXS	—	—	.552	1.771		5.56	2.464	13.69	1.07	.128	1.997	

PIPE DATA TABLES CONT'D.

Pipe Size (in.)	Outside Diameter (in.)	Weight Class	Carbon Steel Sched.	Stainless Steel Sched.	Wall Thickness (in.)	Inside Diameter (in.)	Circum. (Ext.) (in.)	Circum (Int.) (in.)	Flow Area (sq. in.)	Weight of Pipe (lbs/Ft.)	Weight of Water (lbs/Ft.)	Gallons of Water per Ft.	Section Modulus	Pipe Size (in.)
		—	—	5S	.083	3.334		10.47	8.730	3.03	3.78	.454	.744	
		—	—	10S	.120	3.260		10.24	8.347	4.33	3.62	.434	1.041	
		STD	40	40S	.216	3.068		9.64	7.393	7.58	3.20	.384	1.724	
3	3.500	XS	80	80S	.300	2.900	11.00	9.11	6.605	10.25	2.86	.343	2.225	3
		—	160	—	.438	2.624		8.24	5.408	14.32	2.35	.281	2.876	
		XXS	—	—	.600	2.300		7.23	4.155	18.58	1.80	.216	3.424	
		—	—	5S	.083	4.334		13.62	14.75	3.92	6.39	.766	1.249	
		—	—	10S	.120	4.260		13.38	14.25	5.61	6.18	.740	1.761	
		STD	40	40S	.237	4.026		12.65	12.73	10.79	5.50	.661	3.214	
4	4.500	XS	80	80S	.337	3.826	14.14	12.02	11.50	14.98	4.98	.597	4.271	4
		—	120	—	.438	3.624		11.39	10.31	19.00	4.47	.536	5.178	
		—	160	—	.531	3.438		10.80	9.28	22.51	4.02	.482	5.898	
		XXS	—	—	.674	3.152		9.90	7.80	27.54	3.38	.405	6.791	
		—	—	5S	.109	5.345		16.79	22.44	6.36	9.72	1.17	2.498	
		—	—	10S	.134	5.295		16.63	22.02	7.77	9.54	1.14	3.029	
		STD	40	40S	.258	5.047		15.86	20.01	14.62	8.67	1.04	5.451	
5	5.563	XS	80	80S	.375	4.813	17.48	15.12	18.19	20.78	7.88	.945	7.431	5
		—	120	—	.500	4.563		14.34	16.35	27.04	7.09	.849	9.250	
		—	160	—	.625	4.313		13.55	14.61	32.96	6.33	.759	10.796	
		XXS	—	—	.750	4.063		12.76	12.97	38.55	5.61	.674	12.090	
		—	—	5S	.109	6.407		20.13	32.24	7.60	13.97	1.68	3.576	
		—	—	10S	.134	6.357		19.97	31.74	9.29	13.75	1.65	4.346	
		STD	40	40S	.280	6.065		19.05	28.89	18.97	12.51	1.50	8.496	
6	6.625	XS	80	80S	.432	5.761	20.81	18.10	26.07	28.57	11.29	1.35	12.22	6
		—	120	—	.562	5.501		17.28	23.77	36.39	10.30	1.24	14.98	
		—	160	—	.719	5.187		16.30	21.15	45.35	9.16	1.10	17.81	
		XXS	—	—	.864	4.897		15.38	18.84	53.16	8.16	.978	20.02	
		—	—	5S	.109	8.407		26.41	55.51	9.93	24.06	2.88	6.131	
		—	—	10S	.148	8.329		26.17	54.48	13.40	23.61	2.83	8.212	
		—	20	—	.250	8.125		25.53	51.85	22.36	22.47	2.69	13.39	
		—	30	—	.277	8.071		25.36	51.16	24.70	22.17	2.66	14.69	
		STD	40	40S	.322	7.981		25.07	50.03	28.55	21.70	2.60	16.81	
		—	60	—	.406	7.813		24.55	47.94	35.64	20.77	2.49	20.58	
8	8.625	XS	80	80S	.500	7.625	27.10	23.95	45.66	43.39	19.78	2.37	24.51	8
		—	100	—	.594	7.437		23.36	43.46	50.95	18.83	2.26	28.14	
		—	120	—	.719	7.187		22.58	40.59	60.71	17.59	2.11	32.58	
		—	140	—	.812	7.001		21.99	38.50	67.76	16.68	2.00	35.65	
		XXS	—	—	.875	6.875		21.60	37.12	72.42	16.10	1.93	37.56	
		—	160	—	.906	6.813		21.40	36.46	74.69	15.80	1.89	38.48	
		—	—	5S	.134	10.482		32.93	86.29	15.19	37.39	4.48	11.71	
		—	—	10S	.165	10.420		32.74	85.28	18.65	36.95	4.43	14.30	
		—	20	—	.250	10.250		32.20	82.52	28.04	35.76	4.29	21.15	
		—	30	—	.307	10.136		31.84	80.69	34.24	34.96	4.19	25.57	
		STD	40	40S	.365	10.020		31.48	78.86	40.48	34.20	4.10	29.90	
10	10.750	XS	60	80S	.500	9.750	33.77	30.63	74.66	54.74	32.35	3.88	39.43	10
		—	80	—	.594	9.562		30.04	71.84	64.43	31.13	3.73	45.54	
		—	100	—	.719	9.312		29.25	68.13	77.03	29.53	3.54	53.22	
		—	120	—	.844	9.062		28.47	64.53	89.29	27.96	3.35	60.32	
		XXS	140	—	1.000	8.750		27.49	60.13	104.13	26.06	3.12	68.43	
		—	160	—	1.125	8.500		26.70	56.75	115.64	24.59	2.95	74.29	

PIPE DATA TABLES CONT'D.

Pipe Size (in.)	Outside Diameter (in.)	Weight Class	Carbon Steel Sched.	Stainless Steel Sched.	Wall Thickness (in.)	Inside Diameter (in.)	Circum. (Ext.) (in.)	Circum (Int.) (in.)	Flow Area (sq. in.)	Weight of Pipe (lbs/Ft.)	Weight of Water (lbs/Ft.)	Gallons of Water per Ft.	Section Modulus	Pipe Size (in.)
		—	—	5S	.156	12.438		39.08	121.50	20.98	52.65	6.31	19.2	
		—	—	10S	.180	12.390		38.92	120.57	24.17	52.25	6.26	22.0	
		—	20	—	.250	12.250		38.48	117.86	33.38	51.07	6.12	30.2	
		—	30	—	.330	12.090		37.98	114.80	43.77	49.74	5.96	39.0	
		STD	—	40S	.375	12.000		37.70	113.10	49.56	49.00	5.88	43.8	
		—	40	—	.406	11.938		37.50	111.93	53.52	48.50	5.81	47.1	
12	12.750	XS	—	80S	.500	11.750	40.06	36.91	108.43	65.42	46.92	5.63	56.7	12
		—	60	—	.562	11.626		36.52	106.16	73.15	46.00	5.51	62.8	
		—	80	—	.688	11.374		35.73	101.64	88.63	44.04	5.28	74.6	
		—	100	—	.844	11.062		34.75	96.14	107.32	41.66	4.99	88.1	
		XXS	120	—	1.000	10.750		33.77	90.76	125.49	39.33	4.71	100.7	
		—	140	—	1.125	10.500		32.99	86.59	139.67	37.52	4.50	109.9	
		—	160	—	1.312	10.126		31.81	80.53	160.27	34.89	4.18	122.6	
		—	—	5S	.156	13.688		43.00	147.15	23.07	63.77	7.64	23.2	
		—		10S	.188	13.624		42.80	145.78	27.73	63.17	7.57	27.8	
		—	10	—	.250	13.500		42.41	143.14	36.71	62.03	7.44	36.6	
		—	20	—	.312	13.376		42.02	140.52	45.61	60.89	7.30	45.0	
		STD	30	—	.375	13.250		41.63	137.88	54.57	59.75	7.16	53.2	
		—	40	—	.438	13.124		41.23	135.28	63.44	58.64	7.03	61.3	
14	14.000	XS	—	—	.500	13.000	43.98	40.84	132.73	72.09	57.46	6.90	69.1	14
		—	60	—	.594	12.812		40.25	128.96	85.05	55.86	6.70	80.3	
		—	80	—	.750	12.500		39.27	122.72	106.13	53.18	6.37	98.2	
		—	100	—	.938	12.124		38.09	115.49	130.85	50.04	6.00	117.8	
		—	120	—	1.094	11.812		37.11	109.62	150.79	47.45	5.69	132.8	
		—	140	—	1.250	11.500		36.13	103.87	170.28	45.01	5.40	146.8	
		—	160	—	1.406	11.188		35.15	98.31	189.11	42.60	5.11	159.6	
		—	—	5S	.165	15.670		49.23	192.85	27.90	83.57	10.02	32.2	
		—	—	10S	.188	15.624		49.08	191.72	31.75	83.08	9.96	36.5	
		—	10	—	.250	15.500		48.69	188.69	42.05	81.74	9.80	48.0	
		—	20	—	.312	15.376		48.31	185.69	52.27	80.50	9.65	59.2	
		STD	30	—	.375	15.250		47.91	182.65	82.58	79.12	9.49	70.3	
		XS	40	—	.500	15.000		47.12	176.72	82.77	76.58	9.18	91.5	
16	16.00	—	60	—	.656	14.688	50.27	46.14	169.44	107.50	73.42	8.80	116.6	16
		—	80	—	.844	14.312		44.96	160.92	136.61	69.73	8.36	144.5	
		—	100	—	1.031	13.938		43.79	152.58	164.82	66.12	7.93	170.5	
		—	120	—	1.219	13.562		42.61	144.50	192.43	62.62	7.50	194.5	
		—	140	—	1.438	13.124		41.23	135.28	233.64	58.64	7.03	220.0	
		—	160	—	1.594	12.812		40.26	128.96	245.25	55.83	6.70	236.7	
		—	—	5S	.165	17.67		55.51	245.22	31.43	106.26	12.74	40.8	
		—	—	10S	.188	17.62		55.37	243.95	35.76	105.71	12.67	46.4	
		—	10	—	.250	17.50		54.98	240.53	47.39	104.21	12.49	61.1	
		—	20	—	.312	17.38		54.59	237.13	58.94	102.77	12.32	75.5	
		STD	—	—	.375	17.25		54.19	233.71	70.59	101.18	12.14	89.6	
		—	30	—	.438	17.12		53.80	230.30	82.15	99.84	11.96	103.4	
		XS	—	—	.500	17.00		53.41	226.98	93.45	98.27	11.79	117.0	
18	18.00	—	40	—	.562	16.88	56.55	53.02	223.68	104.87	96.93	11.62	130.1	18
		—	60	—	.750	16.50		51.84	213.83	138.17	92.57	11.11	168.3	
		—	80	—	.938	16.12		50.66	204.24	170.92	88.50	10.61	203.8	
		—	100	—	1.156	15.69		49.29	193.30	207.96	83.76	10.04	242.3	
		—	120	—	1.375	15.25		47.91	182.66	244.14	79.07	9.49	277.6	
		—	140	—	1.562	14.88		46.73	173.80	274.22	75.32	9.03	305.5	
		—	160	—	1.781	14.44		45.36	163.72	308.50	70.88	8.50	335.6	

PIPE DATA TABLES CONT'D.

Pipe Size (in.)	Outside Diameter (in.)	Weight Class	Carbon Steel Sched.	Stainless Steel Sched.	Wall Thickness (in.)	Inside Diameter (in.)	Circum. (Ext.) (in.)	Circum (Int.) (in.)	Flow Area (sq. in.)	Weight of Pipe (lbs/Ft.)	Weight of Water (lbs/Ft.)	Gallons of Water per Ft.	Section Modulus	Pipe Size (in.)
		—	—	5S	.188	19.62		61.65	302.46	39.78	131.06	15.71	57.4	
		—	—	10S	.218	19.56		61.46	300.61	46.06	130.27	15.62	66.3	
		—	10	—	.250	19.50		61.26	298.65	52.73	129.42	15.51	75.6	
		—	20	—	.375	19.25		60.48	290.04	78.60	125.67	15.12	111.3	
		STD	30	—	.500	19.00		59.69	283.53	104.13	122.87	14.73	145.7	
		XS	40	—	.594	18.81		59.10	278.00	123.11	120.46	14.44	170.4	
20	20.00	—	60	—	.812	18.38	62.83	57.73	265.21	166.40	114.92	13.78	225.7	20
		—	80	—	1.031	17.94		56.35	252.72	208.87	109.51	13.13	277.1	
		—	100	—	1.281	17.44		54.78	238.83	256.10	103.39	12.41	331.5	
		—	120	—	1.500	17.00		53.41	226.98	296.37	98.35	11.79	375.5	
		—	140	—	1.750	16.50		51.84	213.82	341.09	92.66	11.11	421.7	
		—	160	—	1.969	16.06		50.46	202.67	379.17	87.74	10.53	458.5	
		—	—	5S	.188	21.62		67.93	367.25	43.80	159.14	19.08	69.7	
		—	—	10S	.218	21.56		67.75	365.21	50.71	158.26	18.97	80.4	
		—	10	—	.250	21.50		67.54	363.05	58.07	157.32	18.86	91.8	
		STD	20	—	.375	21.25		66.76	354.66	86.61	153.68	18.42	135.4	
		XS	30	—	.500	21.00		65.97	346.36	114.81	150.09	17.99	117.5	
22	22.00	—	60	—	.875	20.25	69.12	63.62	322.06	197.41	139.56	16.73	295.0	22
		—	80	—	1.125	19.75		62.05	306.35	250.81	132.76	15.91	366.4	
		—	100	—	1.375	19.25		60.48	291.04	302.88	126.12	15.12	432.6	
		—	120	—	1.625	18.75		58.90	276.12	353.61	119.65	14.34	493.8	
		—	140	—	1.875	18.25		57.33	261.59	403.00	113.36	13.59	550.3	
		—	160	—	2.125	17.75		55.76	247.45	451.06	107.23	12.85	602.4	
		—	—	5S	.218	23.56		74.03	436.10	55	188.98	22.65	96.0	
		—	10	10S	.250	23.50		73.83	433.74	63	187.95	22.53	109.6	
		STD	20	—	.375	23.25		73.04	424.56	95	183.95	22.05	161.9	
		XS	—	—	.500	23.00		72.26	415.48	125	179.87	21.58	212.5	
		—	30	—	.562	22.88		71.86	411.00	141	178.09	21.35	237.0	
24	24.00	—	40	—	.688	22.62	75.40	71.08	402.07	171	174.23	20.88	285.1	24
		—	60	—	.969	22.06		69.31	382.35	238	165.52	19.86	387.7	
		—	80	—	1.219	21.56		67.74	365.22	297	158.26	18.97	472.8	
		—	100	—	1.531	20.94		65.78	344.32	367	149.06	17.89	570.8	
		—	120	—	1.812	20.38		64.01	326.08	430	141.17	16.94	652.1	
		—	140	—	2.062	19.88		62.44	310.28	483	134.45	16.12	718.9	
		—	160	—	2.344	19.31		60.67	292.98	542	126.84	15.22	787.9	
		—	—	5S	.250	29.50		92.68	683.49	79	296.18	35.51	172.3	
		—	10	10S	.312	29.38		92.29	677.71	99	293.70	35.21	213.8	
30	30.00	STD	—	—	.375	29.25	94.25	91.89	671.96	119	291.18	34.91	255.3	30
		XS	20	—	.500	29.00		91.11	660.52	158	286.22	34.31	336.1	
		—	30	—	.625	28.75		90.32	649.18	196	281.31	33.72	414.9	

SIZING STEAM LINES

SIMPLE SIZING CRITERIA

Proper detailed design of a steam system should be done using detailed calculations for frictional losses in steam piping. The following examples and rules are meant to provide simple guidelines to see if steam pipe sizes are possibly undersized. They do not imply any design liability by Nicholson. Undersizing of steam lines can lead to reduced pressure to process equipment and impaired performance of valves, heat exchangers and steam traps. Steam line sizing along with condensate return line sizing should always be checked when a system is not performing up to expectations.

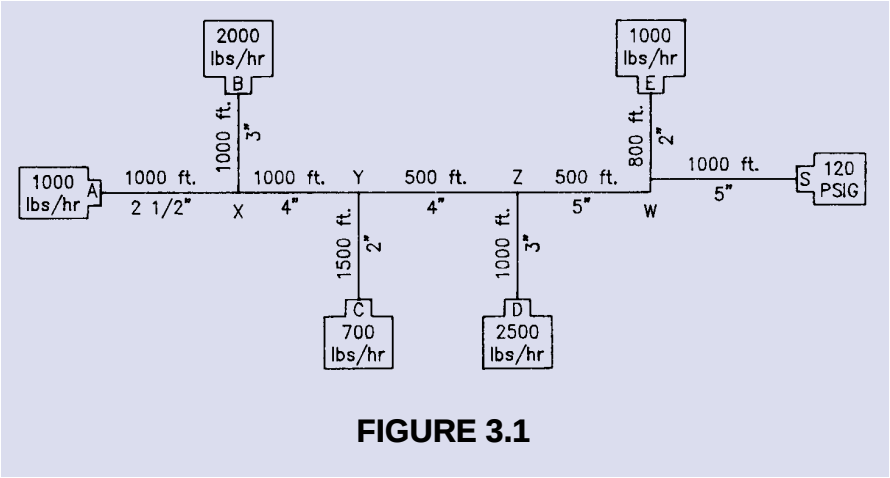


FIGURE 3.1

EXAMPLE: The system shown in Figure 3.1 will be used as our example. The Supply "S" at the right is 120 psig steam which is branching off to steam users A, B, C, D & E. The equipment usage is indicated in lbs/hr. The segments of piping will be addressed going backwards from the furthest end user A. The steam flow going through the pipe segment from the intersection X to equipment A is 1000 lb/hr (the usage of A). ***A simple rule of thumb*** for smaller steam piping (6" and below) is to keep steam velocities below 10,000 feet/minute (165 feet/second) for ***short lengths of pipe only***.

The length of the steam line between X and A is 1000 feet, so the simple rule of thumb can not be applied here because the pressure drop will be too high. The pressure drop should be kept to a minimum, or supply pressure to the equipment will droop.

SOLUTION BY CHART: The chart is a graphic solution to help select pipe sizes. The pressure values used for this chart are in psia (absolute). For values given in gage pressure (psig), you must add 15 psi (14.7 psi actual). The example we will use is for saturated steam flow, but this chart does have corrections for superheat. There will be an overall system pressure drop, so that the pressure is assumed to be 5 to 10 psig below the supply pressure of 120 psig (135 psia). Enter the chart at the top at a point representing 130 psia and proceed vertically downward. Enter the chart at the right at the value of the steam flow in Lb/minute (1000 lb/hr = 16.7 lb/min) and move horizontally across until the horizontal line intersects the vertical line. You will proceed along the diagonal, downward and to the right, parallel with the other diagonal lines.

This chart can be used two ways: either to determine the pressure drop of an existing pipe or to determine the correct pipe size for a specific pressure drop.

TO SIZE LINES: On the bottom of the chart is a pressure drop per 100 feet of pipe, select a value of 0.25 psi per 100 feet. This indicates 2.5 psi as the total loss for 1000 feet. Enter the chart at the bottom at .25 and move upward until you intersect the diagonal line. Proceed from the intersection horizontally left until you reach the actual pipe inside diameter to determine the pipe size. In this example, the pipe size for section X to A should be 2 1/2" pipe.

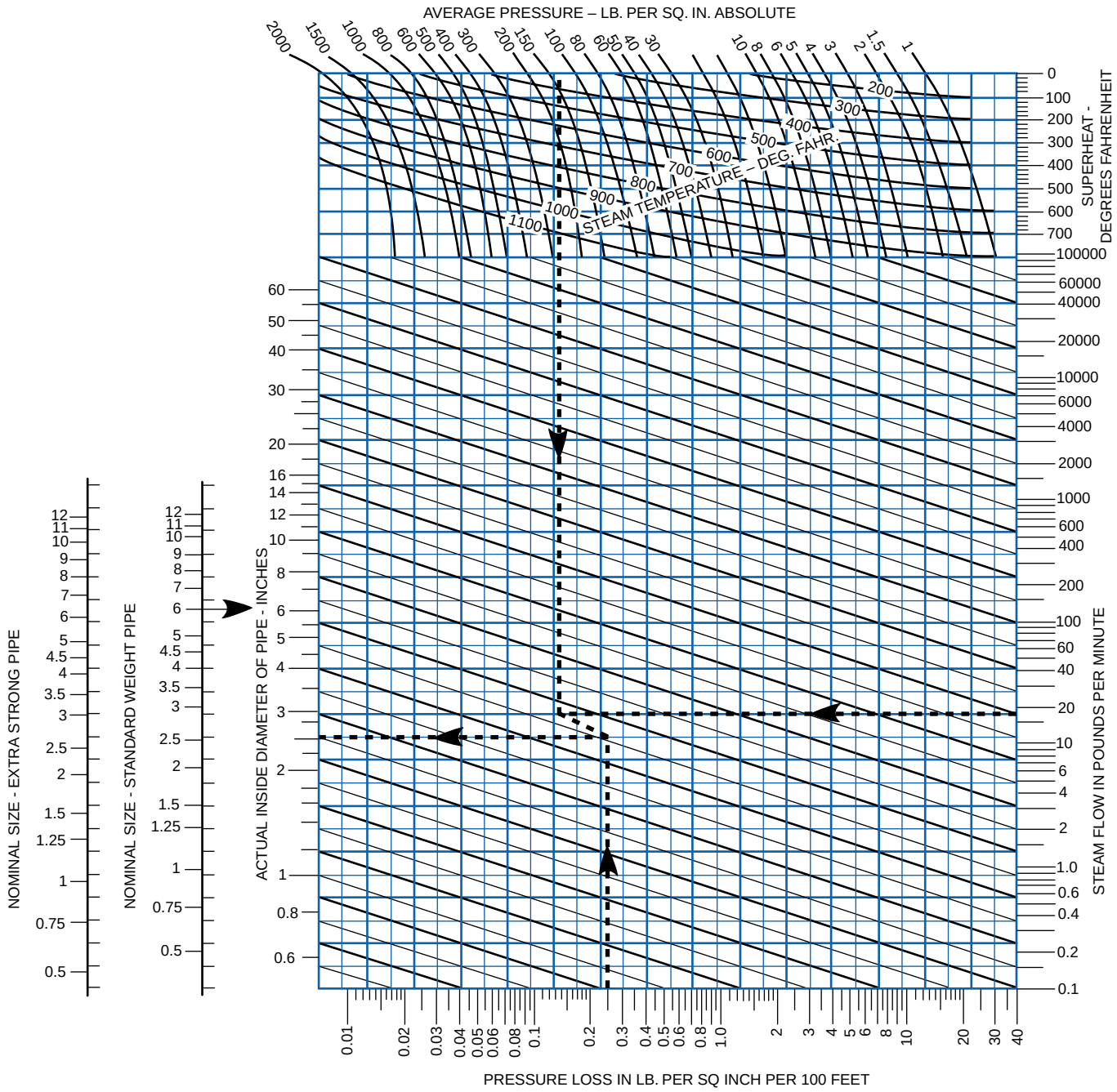
TO FIGURE PRESSURE DROP: Enter the chart on the left side at your pipe size and proceed horizontally until you intersect with the diagonal line. Proceed vertically downward to determine the pressure drop per 100 feet of pipe.

The next section of pipe to determine would be X to B. This would have the same pressure, but the intersection of the vertical line would be at the horizontal steam flow of 33 lb/min (2000 lb/hr) for user B. The choice of pipe sizes can be argued, a 4" will yield 0.1 psi/100 feet pressure drop (1.0 psi per 1000 feet), but the more economical solution of a 3" pipe yields a 0.4psi/100 feet pressure drop. ***Note***: when selecting the smaller more economical pipe size, there is less room for expansion and pressure drops will increase should additional process capacity arise.

For common sections of header such as Y to X, the steam flow for both steam users A and B must be combined. The vertical line will now intersect with the horizontal steam flow line coming across at 50 lb/min (3000 lb/hr). Using a 4" line will bring the pressure drop to a value of 0.22 psi/100 feet, or 2.2 psi for the 1000 foot section.

Remember that pressure drop figures from the bottom of the chart are per 100 feet, so segments such as Y to C have a larger total pressure drop because the distance is longer. Similarly, the total pressure drop from Z to Y is less because the distance is only 500 feet. The values for steam flow continue to be additive for each steam user; Z to Y is 3700 lb/hr (61.7 lb/min), W to Z is 6200 lb/hr (103.3 lb/min) and S to W is 7200 lb/hr (120 lb/min). Pipe sizes in Figure 3.1 are given for your reference and provide the user with reasonable pressure drops in the steam lines.

SIZING STEAM LINES CONT'D.



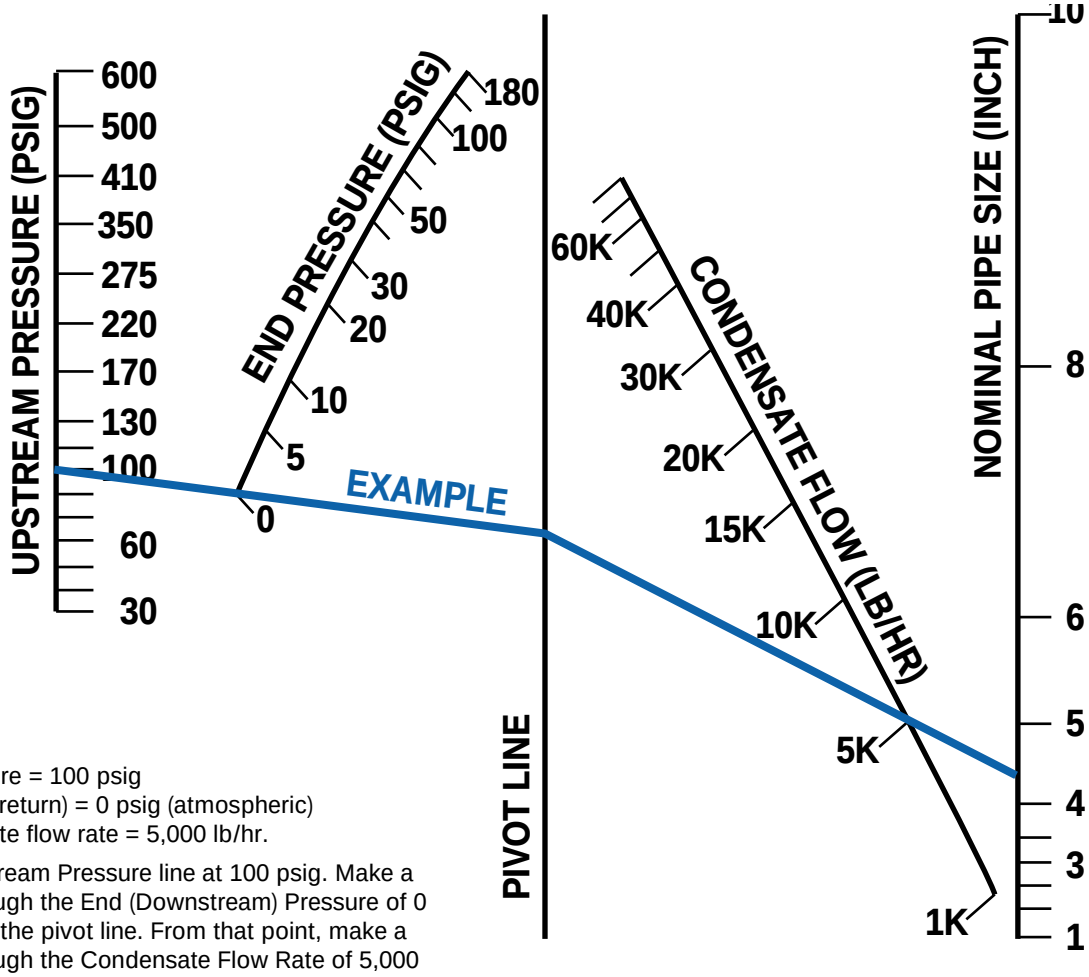
SIZING CONDENSATE RETURN LINES

SIZING CONDENSATE RETURN LINES

When condensate passes through a steam trap orifice, it drops from the upstream pressure in the heat exchanger to the downstream pressure in the condensate return line. The energy in the upstream condensate is greater than the energy in the downstream condensate. As the condensate passes through the steam trap, the additional energy from the upstream condensate forms a percentage of flash steam that changes based upon the upstream and downstream pressures (this percentage can be seen in Table 5 in the Condensate Commander section).

When sizing condensate return lines after the steam trap, it is important to take into account the amount of flash steam created when hot, saturated condensate undergoes a pressure drop. The flash steam has very large volume and can cause very high velocities if the return line is not sized properly. These high velocities can create high backpressure in the return line that often leads to poor steam trap performance.

We will size the condensate return line based upon flash steam velocities, The percentage of flash steam versus condensate (water) is usually on the order of 20 to 1, so the effect of the water in the system sizing is usually small. Choosing a velocity of flash steam is often subjective and different manufacturers will suggest different values. The nomograph below sizes return lines based upon 50 feet/second.



EXAMPLE:
Inlet Trap Pressure = 100 psig
Outlet Pressure (return) = 0 psig (atmospheric)
Actual condensate flow rate = 5,000 lb/hr.

Start at the Upstream Pressure line at 100 psig. Make a straight line through the End (Downstream) Pressure of 0 psig and stop at the pivot line. From that point, make a straight line through the Condensate Flow Rate of 5,000 and stop at the Nominal Pipe size line. It intersects slightly higher than 4". You may select the 4" line size without concern for undersizing the line because a low velocity of 50 ft/sec was used.

Note: If design requirements dictate using a velocity other than the 50 ft/sec value in the Nomograph, a ratio can be made of the pipe size because the velocity is proportional to the Pipe Diameter squared. For example, if you require a Pipe Diameter for 80 ft/sec, use the following equation:

$$\text{Nomograph Diameter} \times \sqrt{\frac{50\ \text{FT/SEC}}{\text{New Velocity (FT/SEC)}}}$$

Example: The Nomograph Diameter determined in the previous example is 4.2". Using the above formula, the Pipe Diameter for 80 ft/sec is 3.3".

SIZING STEAM TRAPS

HOW TO DETERMINE THE PROPER SIZE TRAP

Capacity tables that follow show maximum discharge rates in pounds per hour. To select the correct size trap from these tables, the normal condensing rate should be converted to a "pounds per hour" basis and multiplied by a safety factor.

REASON FOR SAFETY FACTORS

For steam applications, the condensation rate varies with:

(1) The starting or warming-up condition.

(2) The normal operating condition.

(3) Any abnormal operating condition.

Of these, the condensing rate for the normal condition is occasionally known, or it can be estimated with sufficient accuracy for trap selection; the loads imposed by warm-up and abnormal conditions are seldom known and practically impossible to predict.

During warm-up the trap load is heavy, since air as well as large quantities of condensate must be discharged. Condensate forms at a rapid rate as the cold equipment and connecting piping are brought up to temperature. This usually results in pressure drop at the trap inlet, thereby reducing its capacity during the period when the load is maximum.

Safety factors are therefore necessary, to compensate for start-up conditions, variation of steam pressure and product initial temperature, the process cycle speed required, and discrepancies between assumed and actual conditions which determine the normal condensing rate.

The selection of a safety factor depends on the type of trap and the operating conditions. If the known or calculated normal condensing rate is multiplied by the recommended factor from the pages which follow, efficient trapping will be assured.

EFFECT OF BACK PRESSURE ON TRAP CAPACITY

Most trap installations include piping the outlet into a common return system or to an available disposal location. In either case a constant static back pressure may exist, against which the trap must discharge. This back pressure may be unintentional or deliberately produced.

Unintentional back pressure in condensate return piping is caused by lifting the condensate to a higher level, piping which is too small for the volume of liquid conveyed, piping with insufficient or no pitch in the direction of flow, pipe and fittings clogged with rust, pipe scale or other debris, leaking steam traps, etc. In steam service an intentional back pressure is instigated by means of a pressure regulating or spring-loaded valve in the discharge system, when a supply of flash steam at a pressure less than the trap pressure is needed.

If very hot condensate is discharged to a pressure less than that existing in the trap body, some of it will flash into steam, with a tremendous increase in volume and consequent choking and build-up of pressure in the trap's discharge orifice and the passages and piping adjacent thereto. For condensate at or close to steam temperature, this flash pressure is quite high, usually considerably higher than any static back pressure existing in the trap outlet piping.

For this reason, capacity tables for thermostatic and thermodynamic traps are based on gage pressure at the trap inlet, instead of on the difference between trap inlet and discharge pressures. Experiments have shown that, for the temperatures applying to these tables, unless the static back pressure in the return piping exceeds 25% of the trap inlet pressure, no reduction of the trap capacity results. For back pressures greater than 25% of the trap inlet pressure there is a progressive decrease of trap capacity.

Thus, if the return piping static pressure is less than 25% of the trap inlet pressure, the capacities shown in these tables should be utilized for trap selection. If the return piping pressure is greater than 25% of the trap inlet pressure, reduce the table capacities by the percentage indicated in second line of Table A on the following pages.

Above data does not apply to float and thermostatic traps, capacities are based on differential pressure, obtained by subtracting any static back pressure from trap inlet pressure.

WHEN THE NORMAL CONDENSING RATE IS KNOWN

Normal condensing rate means the pounds of steam condensed per hour by the average conditions which prevail when the equipment drained is at operating temperature.

If this amount is known, simply multiply by the safety factor recommended for the service and conditions, obtained from the pages which follow, and determine size directly from the capacity tables for the type of trap selected.

Example: 4000 pounds per hour normal condensing rate from heat exchanger with submerged single coil, gravity drained, 80 PSIG constant steam pressure. What size thermostatic bellows trap to use?

Solution:

1. On page 3 recommended safety factor for single coil, gravity drained is 2. Multiplying, 4000 x 2 = 8000.
2. In Table G, page 5, the 3/4 Types B and C traps have a rated capacity of 8895 pounds per hour at 80 pounds pressure, and one of these should be specified.

WHEN THE NORMAL CONDENSING RATE IS UNKNOWN

Determine by utilizing proper formula from pages 2 thru 4 for the service and equipment to be trapped. Multiply the result by safety factor recommended for the operating conditions. See examples on the following pages.

SIZING STEAM TRAPS CONT'D.

EXPLANATION OF SYMBOLS USED IN NORMAL CONDENSING RATE FORMULAS

A = Heating surface area, square feet (see Table B)

B = Heat output of coil or heater, BTU per hour

C = Condensate generated by submerged heating surfaces, lbs/hr/sq ft (Table F)

D = Weight of material processed per hour after drying, pounds

F = Steam flow, lbs/hr

G= Gallons of liquid heated per unit time

H = Heat loss from bare iron or steel heating surface, BTU/sq ft/°F/hr

L = Latent heat of steam at pressure utilized, BTU/lb (see Table C or obtain from Steam Table)

M = Metal weight of autoclave, retort or other pressure vessel, pounds

Qh = Condensate generated, lbs/hr

Qu = Condensate generated, lbs/unit time (Always convert to lbs/hr before applying safety factor. See Examples using formulas 7 and 10 on next page).

S = Specific heat of material processed, BTU/lb/°F

Ta = Ambient air temperature, °F

Tf = Final temperature of material processed, °F

Ti = Initial temperature of material processed, °F

Ts = Temperature of steam at pressure utilized, °F (see Table C or obtain from Steam Table)

U = Overall coefficient of heat transfer, BTU/sq ft/°F/hr (see Table E)

V = Volume of air heated, cubic feet/minute

Wg= Liquid weight, lbs/gallon

Wh = Weight of material processed per hour, lbs

Wu = Weight of material processed per unit time, lbs

X = Factor for $\frac{Tf-Ti}{L}$ (obtain from Table D)

Y = Factor for $\frac{H(Ts-Ta)}{L}$, lbs/hr/sq ft (obtain from Table C)

AIR HEATING

Steam Mains; Pipe Coil Radiation; Convectors; Radiators; etc. (Natural Air Circulation)

(1) Qh = A Y

Recommended Safety Factors

For Steam Mains

Ambient Air Above Freezing:

1st Trap After Boiler..... 3
At End of Main..... 3
Other Traps 2

Ambient Air Below Freezing:

At End of Main 4
Other Traps 3

Steam mains should be trapped at all points where condensate can collect, such as at loops, risers, separators, end of mains, ahead of valves, where mains reduce to smaller diameters, etc., regardless of the condensate load. Installation of traps at these locations usually provides ample capacity.

For Pipe Coil Radiation, Convectors and Radiators

Single Continuous Coil 2
Multiple Coil 4

Damp Space Pipe Coil Radiation; Dry Kilns; Greenhouses; Drying Rooms; etc. (Natural Air Circulation)

(2) Qh = 2.5 A Y

Recommended Safety Factors

Single Continuous Coil 2
Multiple Coil 4

Steam Line Separators; Line Purifiers

(3) Qh = .10 F

Recommended Safety Factors

Indoor Pipe Line 2
Outdoor Pipe Line 3
If Boiler Carry-Over Anticipated... 4 to 6
(Depending on probable severity of conditions)

Unit Heaters; Blast Coils (Forced Air Circulation)

(4) When BTU Output is Known:

$$Qh = \frac{B}{L}$$

(5) When BTU Output is Unknown, Heat Transfer Area is Known:

Qh = 5 A Y

(6) When Volume of Air Heated is Known:

Qh = 1.09 V X

Recommended Safety Factors

Intake Air Above Freezing - Constant Steam Pressure 3
Intake Air Above Freezing - Variable Steam Pressure 4
Intake Air Below Freezing - Constant Steam Pressure 4
Intake Air Below Freezing - Variable Steam Pressure 5

Example: 11,500 cubic feet of air per minute heated by blast coil from 50°F to 170°F with 50 PSIG constant steam pressure.

Solution: By formula (6), Qh = 1.09 x 11,500 x .132 = 1655 lbs/hr. Recommended safety factor, 3 for intake air above freezing and constant steam pressure. 3 x 1655 = 4965 lbs/hr trap capacity required.

SIZING STEAM TRAPS CONT'D.

LIQUID HEATING

Submerged Coils; Heat Exchangers; Evaporators; Stills; Vats; Tanks; Jacketed Kettles; Cooking Pans; etc.

(7) When Quantity of Liquid to be Heated in a Given Time is Known:

$$Qu = G\ Wg\ S\ X$$

(8) When Quantity of Liquid to be Heated is Unknown:

$$Qh = A\ U\ X$$

(9) When Heating Surface Area is Larger than Required to Heat Known Quantity of Liquid in a Given Time:

$$Qh = A\ C$$

When maximum heat transfer efficiency is desired, or when in doubt, use formula (9) in preference to formulas (7) and (8).

Recommended Safety Factors

For Submerged Coil Equipment; Heat Exchangers; Evaporators; etc.

Constant Steam Pressure:

Single Coil, Gravity Drainage 2
Single Coil, Siphon Drainage 3
Multiple Coil, Gravity Drainage 4

Variable Steam Pressure:

Single Coil, Gravity Drainage 3
Single Coil, Siphon Drainage 4
Multiple Coil, Gravity Drainage 5

For Siphon Drained Equipment, specify traps with "Steam Lock Release Valve".

For Jacketed Equipment; Cooling Kettles; Pans; etc.

Slow Cooking:
Gravity Drainage 3
Siphon Drainage 4
Moderately Fast Cooking:
Gravity Drainage 4
Siphon Drainage 5
Very Fast Cooking:
Gravity Drainage 5
Siphon Drainage 6

For Siphon Drained Equipment, specify traps with "Steam Lock Release Valve".

Example: Heat exchanger with single submerged coil, gravity drained, heating 1250 gallons of petroleum oil of 0.51 specific heat, weighing 7.3 lbs/gal, from 50°F to 190°F in 15 minutes, using steam at 100 PSIG.

Solution: By formula (7), Qu = 1250 X 7.3 x .51 x .159 = 740 pounds of condensate in 15 minutes, or 4 x 740 = 2960 lbs/hr. Recommended safety factor is 2 for single coil, gravity drained. 2 x 2960 = 5920 lbs/hr trap capacity required.

DIRECT STEAM CONTACT HEATING

Autoclaves; Retorts; Sterilizers; Reaction Chambers; etc.

(10) $Qu = Wu\ S\ X + .12\ M\ X$

Recommended Safety Factors

Slow Warm-up Permissible 3
Fast Warm-up Desired 5

Example: An autoclave which weighs 400 pounds before loading is charged with 270 pounds of material having a specific heat of .57 and an initial temperature of 70°F. Utilizing steam at 50 PSIG, it is desired to bring the temperature up 250°F in the shortest possible time.

Solution: By formula (10), Qu = (270 x .57 x .198) + .12(400 x .198) = 40 pounds of condensate. Using safety factor of 5 recommended for fast warm-up and assuming 5 minutes as the time required to complete the reaction, a trap capacity of 40 x 12 x 5 = 2400 lbs/hr is required.

INDIRECT STEAM CONTACT HEATING

Cylinder Dryers, Drum Dryers, Rotary Steam Tube Dryers, Calenders; etc.

(11) $Qh = \frac{970\ (W - D)}{L} + Wh\ X$

Recommended Safety Factors

For Siphon or Bucket Drained Rotating Cylinder, Drum and Steam Tube Dryers; Cylinder Ironers; etc.

Small or medium Size,
Slow Rotation 4
Small or Medium Size,
Fast Rotation 6
Large Size, Slow Rotation 6
Large Size, Fast Rotation 8

For Siphon or Bucket Drained Equipment, specify traps with "Steam Lock Release Valve". Each cylinder should be individually trapped.

For Gravity Drained Chest Type Dryers and Ironers

Each Chest Individually Trapped... 2
Entire Machine Drained By Single Trap ..... 4 to 6
Depending on number of Chests

For Platen Presses

Each Platen Individually Trapped ... 2
*Entire Press Drained by Single Trap, Platens Piped in Series 3
*Entire Press Drained by Single Trap, Platens Piped in Parallel ..... 4 to 6
Depending on number of Platens

Example: A medium size rotary steam tube dryer with condensate lifted to a discharge passage in the trunion, dries 4000 lbs/hr of granular material to 3300 pounds, with 15 PSIG steam, initial temperature of material 70°F, final temperature 250°F.

Solution: By formula (11) Qh =

$$\frac{970\ (4000 - 3300)}{945} + (4000 \times .191)$$

= 1483 lbs/hr. Using safety factor of 4 recommended for medium size, slow rotation: 4 x 1483 = 5932 lbs/hr trap capacity required.

**A separate trap for each heating surface (coil, chest, platen, etc.) is recommended for maximum heating efficiency. Sluggish removal of condensate and air is certain when more than one unit is drained by a single trap, resulting in reduced temperatures, slow heating and possible water-hammer damage.*

TABLE A — EFFECT OF BACK PRESSURE ON STEAM TRAP CAPACITY

Back Pressure as Percent of Inlet Pressure	10	20	25	30	40	50	60	70	80	90
Percent Reduction of Trap Capacity	0	0	0	2	5	12	20	30	40	55

TABLE B – SQUARE FEET OF SURFACE PER LINEAL FOOT OF PIPE

Nominal Pipe Size (In.)	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"
Area, Sq. Ft. per Lineal Foot	.22	.28	.35	.44	.50	.63	.76	.92	1.18	1.46	1.74	2.26	2.81	3.34	3.67	4.19	4.71	5.24	6.28

TABLE C - FACTOR Y - H(Ts-Ta)/L - APPROXIMATE CONDENSING RATE FOR BARE IRON AND STEEL PIPE*

Steam Pressure - PSIG	1	2	5	10	15	20	25	50	75	100	150	200	250	300	350	400	450	500	600
Steam Temperature - °F	215	219	227	239	250	259	267	298	320	338	366	388	406	422	436	448	460	470	489
Latent Heat - BTU/lb	968	966	961	952	945	939	934	911	895	879	856	839	820	804	790	776	764	751	728
Factor Y Cond - lbs/hr/sq. ft	0.45	0.46	0.49	0.53	0.56	0.59	0.71	0.84	1.02	1.10	1.34	1.47	1.58	1.80	1.91	2.00	2.35	2.46	2.65

*Based on still air at 60F, recommended safety factors compensate for air at other temperatures. Used for steam trap selection only.

TABLE D — FACTOR X = (Tf–Ti)/L

Tf-Ti	STEAM PRESSURE - PSIG																		
°F	1	2	5	10	15	20	25	50	75	100	150	200	250	300	350	400	450	500	600
40	.041	.041	.042	.042	.042	.043	.043	.044	.045	.045	.047	.048	.049	.050	.051	.052	.052	.053	.055
60	.062	.062	.062	.063	.064	.064	.064	.066	.067	.068	.070	.072	.073	.075	.076	.077	.079	.080	.082
80	.083	.083	.083	.084	.085	.085	.086	.087	.089	.091	.093	.096	.098	.100	.101	.103	.105	.106	.110
100	.103	.103	.104	.105	.106	.106	.107	.110	.112	.114	.117	.120	.122	.124	.127	.129	.131	.133	.137
120	.124	.124	.125	.126	.127	.128	.129	.132	.134	.136	.140	.144	.146	.149	.152	.155	.157	.160	.165
140	.145	.145	.146	.147	.148	.149	.150	.154	.156	.159	.163	.167	.171	.174	.177	.180	.183	.186	.192
160	.165	.166	.167	.168	.169	.170	.172	.176	.179	.182	.187	.191	.195	.199	.203	.206	.210	.213	.220
180			.187	.189	.191	.192	.193	.198	.201	.204	.210	.215	.220	.224	.228	.232	.236	.240	.248
200				.211	.212	.213	.214	.219	.224	.227	.234	.239	.244	.249	.253	.258	.262	.266	.275
220						.235	.236	.242	.246	.250	.257	.262	.268	.274	.279	.283	.288	.293	.303
240								.263	.268	.273	.280	.286	.292	.299	.304	.309	.314	.319	.330
260									.290	.296	.304	.310	.317	.324	.329	.335	.340	.346	.357
280									.313	.319	.327	.334	.342	.349	.354	.361	.367	.373	.385
300											.350	.358	.366	.373	.380	.387	.393	.400	.412

TABLE E — FACTOR U, HEAT TRANSFER COEFFICIENTS BTU/HR/SQ FT/°F TEMP. DIFFERENTIAL

	AVERAGE DESIGN VALUES	
TYPE OF HEAT EXCHANGER	NATURAL CIRCULATION	FORCED CIRCULATION
STEAM TO WATER	125	300
STEAM TO OIL	20	45
STEAM TO MILK	125	300
STEAM TO PARAFFIN WAX	25	80
STEAM TO SUGAR & MOLASSES SOLUTIONS	75	150

Coefficients shown are suggested average design values. Higher or lower figures will be realized for many conditions. Use for

TABLE F — FACTOR C, APPROXIMATE CONDENSING RATE FOR SUBMERGED SURFACES, LBS/HR/SQ FT

HEATING SURFACE	DIFFERENCE BETWEEN STEAM TEMPERATURE AND MEAN WATER TEMPERATURE*											
	25	50	75	100	125	150	175	200	225	250	275	300
IRON OR STEEL	1.6	5	10	17	25	34	45	57	70	84	99	114
BRASS	2.6	8	16	27	40	54	72	91	112	134	158	182
COPPER	3.2	10	20	34	50	68	90	114	140	168	198	228

* Mean water temperature is 1/2 the sum of inlet temperature plus outlet temperature. Table based on heating surfaces submerged in water with natural circulation. Safety factor of 50% has been included to allow for moderate scaling. If surface will remain bright, multiply above figures by 2. Use for steam trap selection only.

STEAM TRACING DESIGN GUIDELINES

V.1.1 INTRODUCTION

Steam tracing is one of many ways to preheat, add heat and prevent heat loss from piping systems and their components. Some other ways are:

- ☛ Jacketed piping
- ☛ Hot water and oil tracing
- ☛ Dowtherm tracing

Jacketed piping systems are used primarily to maintain a constant high temperature. Due to its high cost of construction, jacketed systems are seldom used except where temperature control is critical. Hot water and oil must be pumped at a high velocity to maintain a desired temperature, and must have a separate return header as does Dowtherm. Hot water, oil or dowtherm are also an additional system which add to the cost of a plant.

Steam tracing is most often selected because:

- ☛ There is generally available a surplus of low and/or medium pressure steam.
- ☛ Steam has a high latent heat and heat-transfer-coefficient.
- ☛ Steam condenses at a constant temperature.
- ☛ Steam flows to end-point without the aid of pumps (when designed correctly).
- ☛ A small amount of return piping is needed due to existing condensate headers.

V.1.2 USES

Freeze Protection (winterizing)

- ☛ Adding sufficient heat to above-grade piping systems and equipment which are exposed to ambient temperatures below the freezing point of their media prevents freezing.

Maintaining A Desired Temperature

- ☛ The viscosity of some liquids becomes higher as their temperatures become lower causing more difficult and costly pumping and leading to down-time for cleaning.
- ☛ Condensation may occur in some gases if the ambient temperature falls below the dewpoint which is harmful and expensive in such systems as:

-Natural Gas where control valves freeze up and burners malfunction.

-Compressor Suction Lines where compressors can be damaged.

V.1.3 MATERIAL

Steam tracing material is normally as follows:

-Use the material specified for steam piping from the steam header (through the distribution manifold, if applicable) to and including the tracer block valve.

-Use 1/4” through 7/8” O.D. copper or stainless steel tubing (depending on the design conditions) from the block valve to the steam trap. Though sizes may vary with different applications, 3/8” and 1/2” O.D. are the most often used. Tube fittings and adapters are normally flareless compression type or 37 degree flared type.

-Use the material specified for condensate piping from the steam trap (through the collection manifold, if applicable) to the condensate header or end-point (drain or grade).

V.1.4 DESIGN GUIDELINES

1. Steam piping should be run within 12” of the line or equipment being traced to minimize exposed tubing.

2. Spiral tracing should be limited to vertical piping using multiple tracers on horizontal lines which require more heat.

3. Tracers should be designed so that the flow is always down. ***Avoid pockets! !*** Where vertical flow is unavoidable, steam pressure should be a minimum of 25 PSIG for every 10’ of rise.

4. Tracers should be a maximum of 100' long and continuous from the supply to the collection manifold or endpoint. For lines over 100’ long, provide another tracer and overlap the two 3 inches to avoid cold spots.

5. Tracers should have no branch tees except as indicated in *Section V.3.*

6. Provide each tracer with a separate strainer and steam trap.

7. Manifolds can be horizontal or vertical depending upon the design conditions.

8. Tracers should be attached to the pipe at 8” to 10” maximum intervals with stainless steel wire. Wire tension should be sufficient to hold the tracer secure and flush against the pipe.

9. Some piping materials, such as lined pipe, might require spacer blocks to avoid “hot spots”.

10. Tracer loops with unions are necessary:

- ☛ when joining tubing lengths.
- ☛ at all break flanges and unions.
- ☛ at all flanged valves.

11. Tracer discharge lines should be as short as possible since long discharge lines can freeze even with a fully functioning steam trap.

Clean Steam Design Guidelines

Clean Steam is a general term used to describe a range of steam pureness. It may be generated by such methods as:

- Filtration of plant steam typically requiring the removal of particles larger than 5 microns
- An independent steam generator. E.g. Stainless steel reboiler fed with distilled water.
- One stage of a multi-effect still within the overall water purification system.

Uses for Clean Steam vary by industry, however typical applications include:

- In-line sterilization of storage tanks and equipment
- Powering sterilizers and autoclaves
- Cleaning and sterilizing process piping systems without disassembling the piping system - commonly known as CIP (Clean in Place)
- Pasteurization utilizing Ultra High Temperature Processing (UHT)

The highest quality clean steam however, is typically used by the Pharmaceutical and Biotechnical industries. This steam, occasionally referred to as “Pure Steam”, is most often supplied by an independent steam generator utilizing Water for Injection (WFI) as feed water. WFI is typically produced by a Reverse Osmosis (RO) generator and then distilled thus removing any traces of organics, bacteria, and pyrogens. Pure steam is required for the sterilization of cell culture processing equipment such as incubators where contaminants could adversely affect cell growth. Other uses include pharmaceutical manufacture and direct steam injection pasteurization where contaminants could collect in products intended for human consumption.

Clean steam produced from high purity make up water is highly corrosive due to the minimal ion content. High purity water, pure steam and the resultant condensate will aggressively attempt to absorb or leach ions from their environment to achieve a more natural balance. Additionally, chemicals used to passivate steam and condensate in conventional systems are generally prohibited from clean steam system as such chemicals could contaminate or alter sensitive end products. Should corrosion begin, the oxidation byproducts may travel through the steam system catalyzing corrosion throughout in a process known as ‘rouging’.

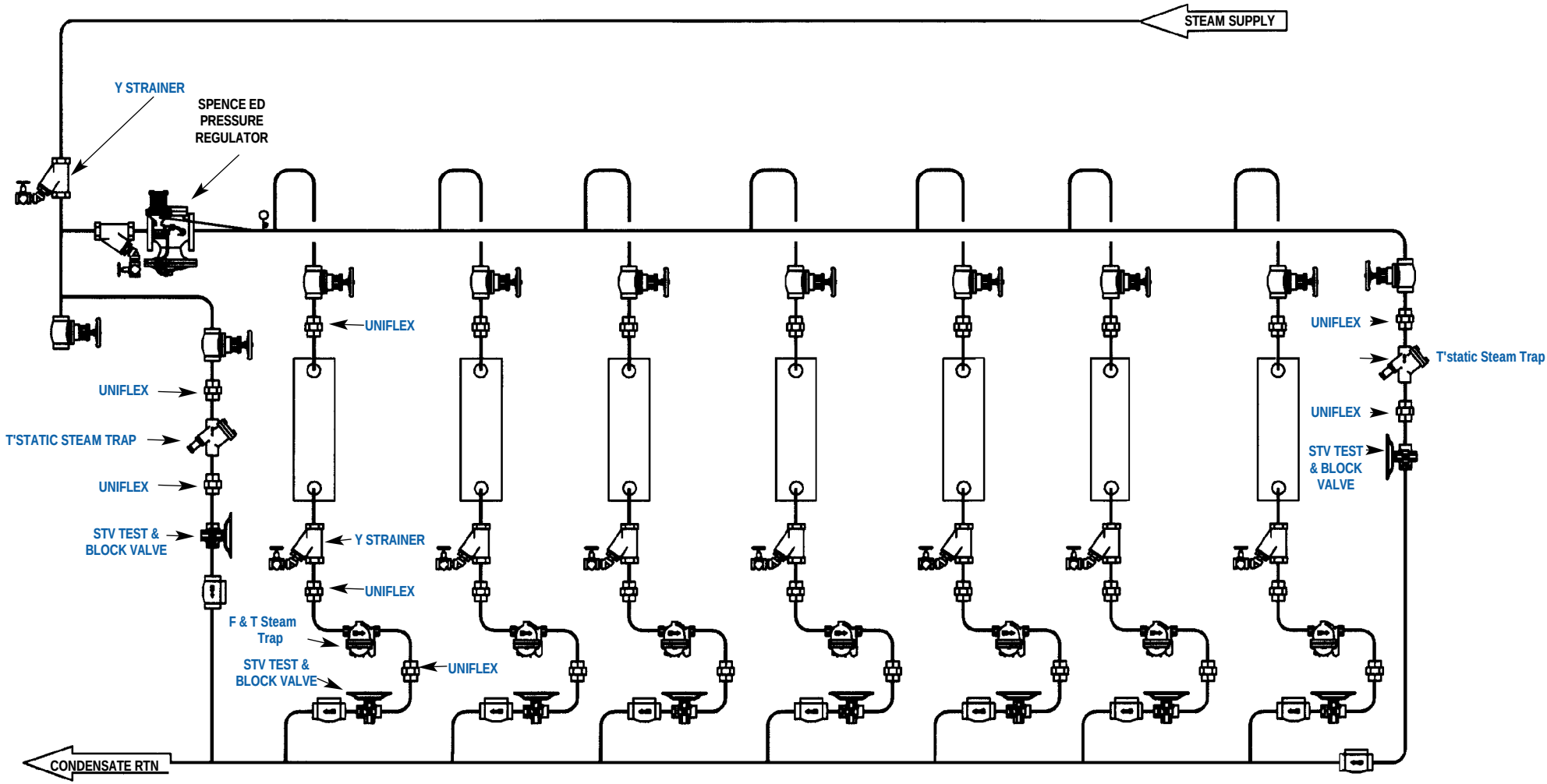
To combat the corrosive nature of clean steam, design practices require piping, fittings and valving to be comprised of corrosion resistant materials. Current industry accepted materials include 304L, 316 and 316L stainless steel and higher alloys such as Inconel. While these materials have proven themselves in practice, it should be noted that there are currently no U.S. governmental standards specifying materials for clean steam service. Regulatory agencies concern themselves with the purity and quality of the product, leaving the design standards entirely up to the manufacturer.

In addition to the use of corrosion resistant materials in sanitary systems, features designed to inhibit bacterial growth are often required. Piping, valves and fittings should be free draining and maintain industry standard surface finishes. Free draining valves and fittings are designed not to retain or ‘Puddle’ condensate when installed correctly. After shut down of the steam system, any puddled condensate could potentially promote bacterial growth. Inadequate surface finishes reduce the effectiveness of system sterilization techniques, increasing the possibility of bacterial contamination. Industry standard surface finishes are measured in micro inches, the lower the number the smoother, and are expressed as an arithmetic average (Ra). Typical industry specified surface finishes range from 32 to 10 µ in. Ra.

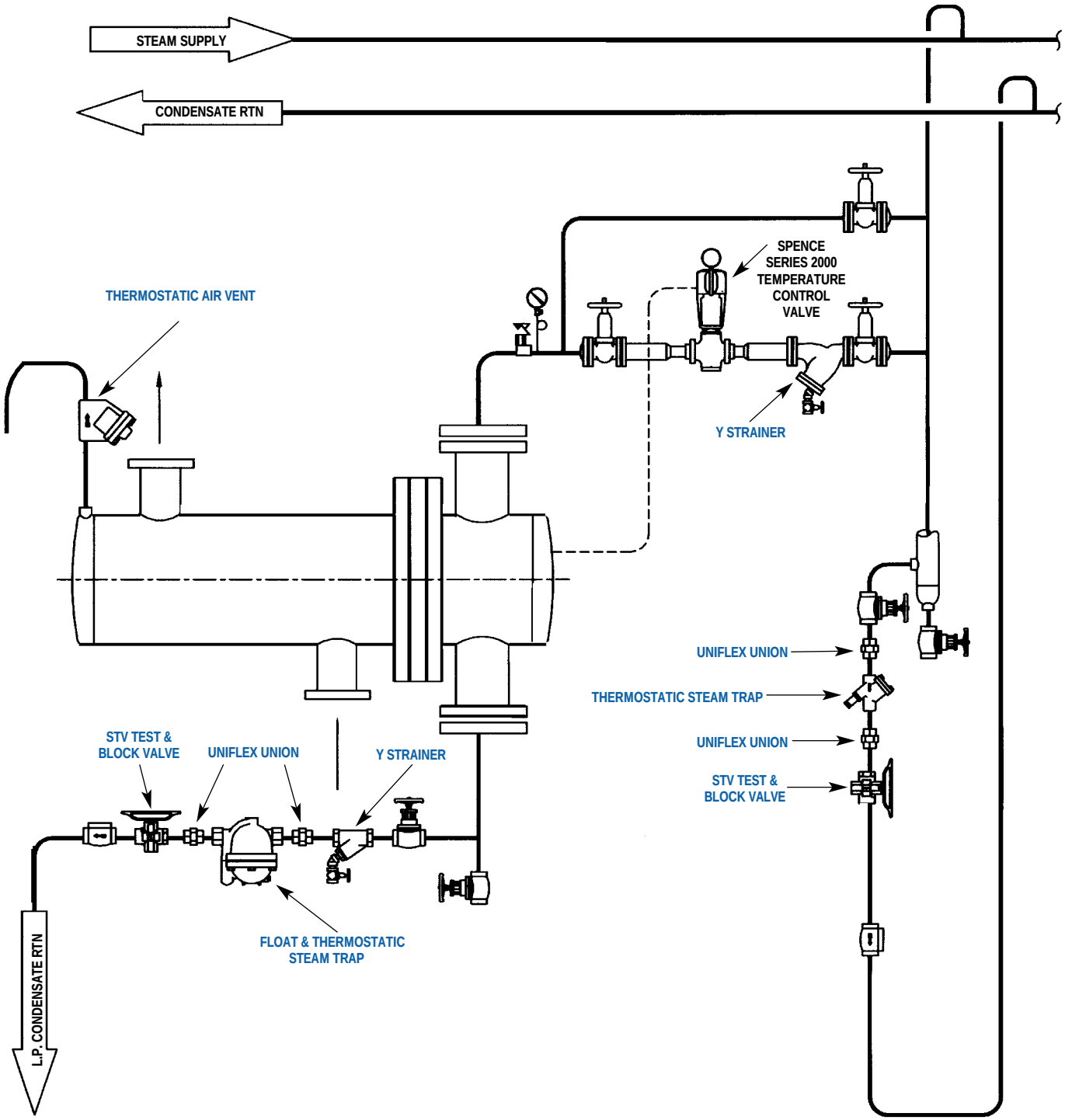
Piping & Trapping Design Guidelines

1. Extra care should be taken for expansion stresses due to the higher coefficient of expansion for stainless steel.
2. Branch connections are to be made from the top of headers with the block valve as close as possible to the header.
3. The recommended types of branch connections are tees and reducing tees.
4. Steam lines should slope down to traps (recommended 1% min.).
5. A dirt leg with trap station is recommended at every change of elevation (no undrainable pockets).
6. Extra care should be taken in pipe supports to eliminate sagging.
7. Instruments in general should be kept to a minimum. However, where required, it is recommended that:
   A) All are installed in tees.
   B) Pressure gauges be installed with diaphragm seals.
   C) Flow meters be installed in the vertical flow-up position to eliminate pockets
   D) Pressure reducing stations be kept to a minimum.
8. Traps should be installed in the vertical flow-down position to eliminate pockets.
9. Trap block valves should be located as close as possible to the user.
10. Condensate lines should be sloped (recommended 1% min.) to the end point. Note that contaminated condensate should always be piped to a process sewer. Uncontaminated condensate (from drip legs) may be recovered, if cost effective, and used elsewhere in the plant (not as Clean Steam make-up).
11. Condensate terminal points should contain an air break (2” or 2 pipe diameters, whichever is greater) between the end of the pipe and the drain, floor or grade.
12. Test connections for traps are recommended-trap efficiency is essential for Clean Steam.

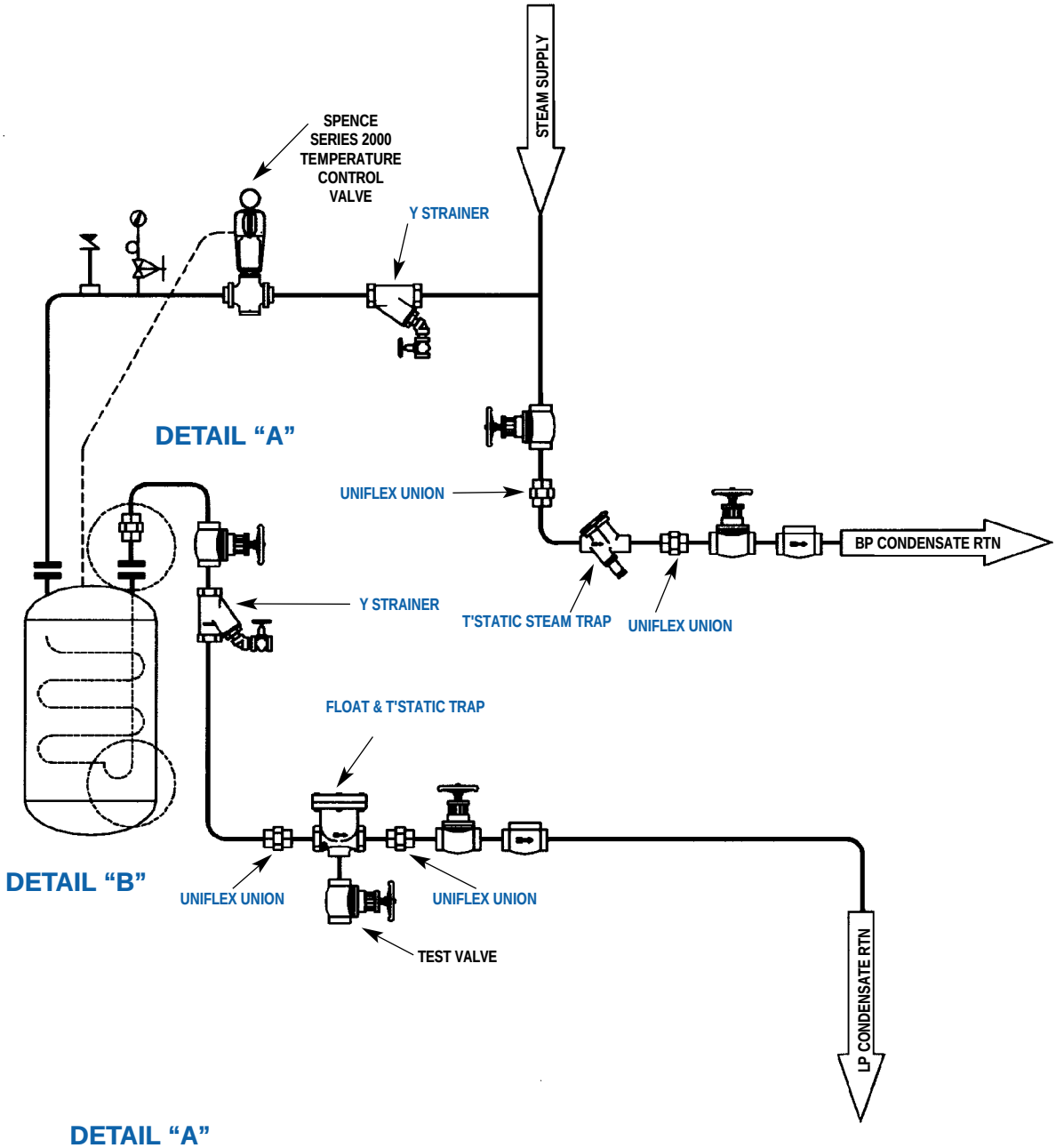
Oven Heating Coils



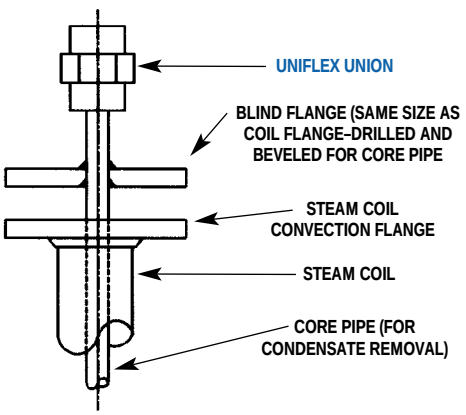
Shell & Tube Heat Exchanger



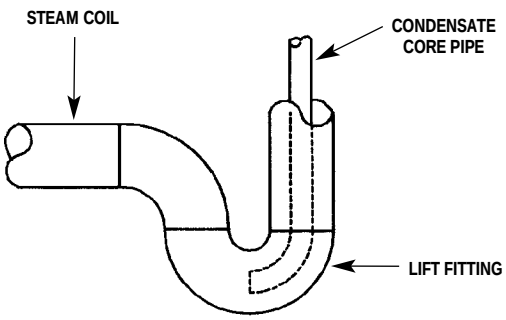
VESSEL WITH STEAM COIL OUTLET AT TOP



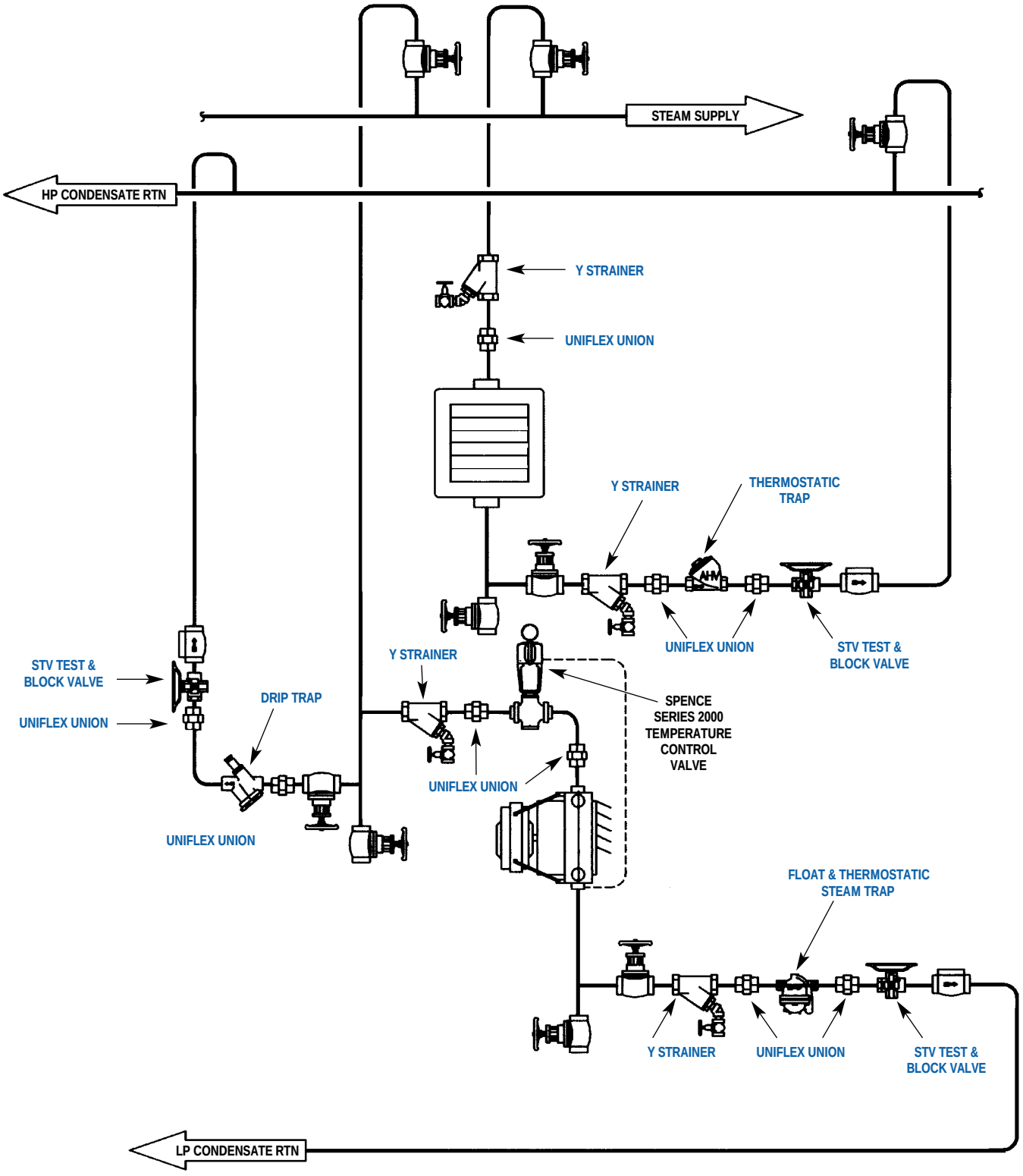
DETAIL "A"



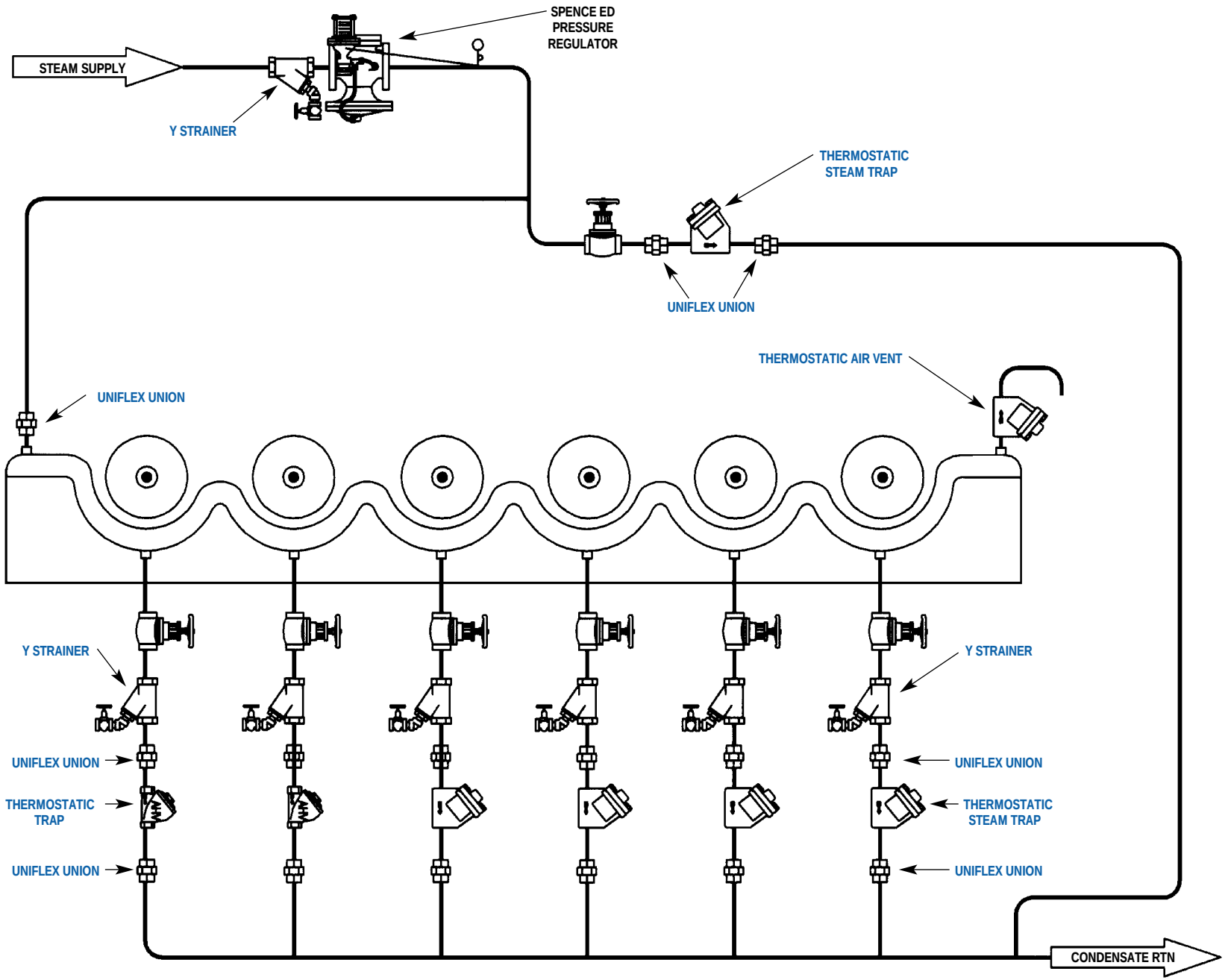
DETAIL "B"



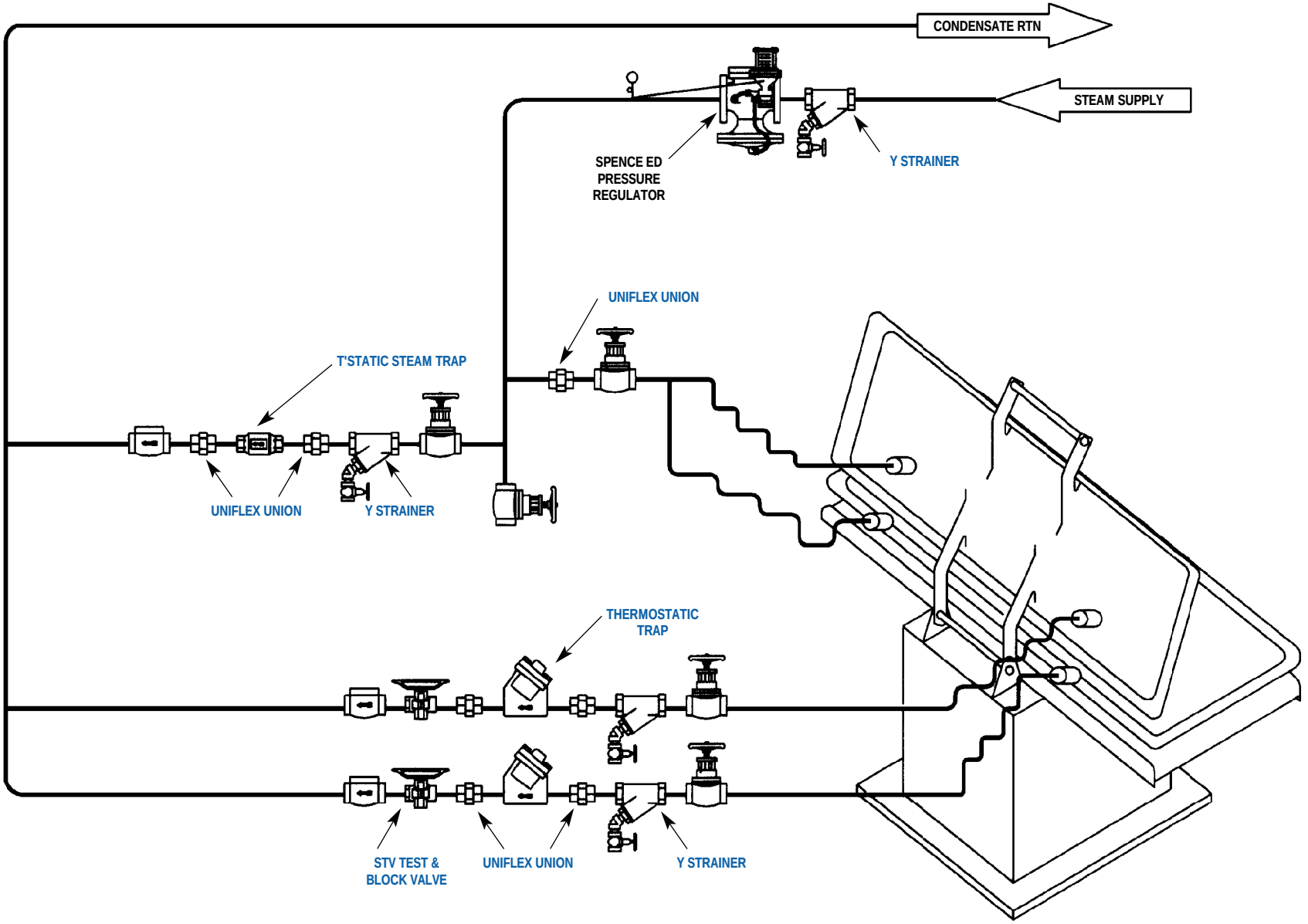
UNIT HEATER


STEAM SUPPLY
HP CONDENSATE RTN
Y STRAINER
UNIFLEX UNION
Y STRAINER
THERMOSTATIC TRAP
UNIFLEX UNION
STV TEST & BLOCK VALVE
STV TEST & BLOCK VALVE
UNIFLEX UNION
DRIP TRAP
UNIFLEX UNION
Y STRAINER
SPENCE SERIES 2000 TEMPERATURE CONTROL VALVE
UNIFLEX UNION
FLOAT & THERMOSTATIC STEAM TRAP
Y STRAINER
UNIFLEX UNION
STV TEST & BLOCK VALVE
LP CONDENSATE RTN

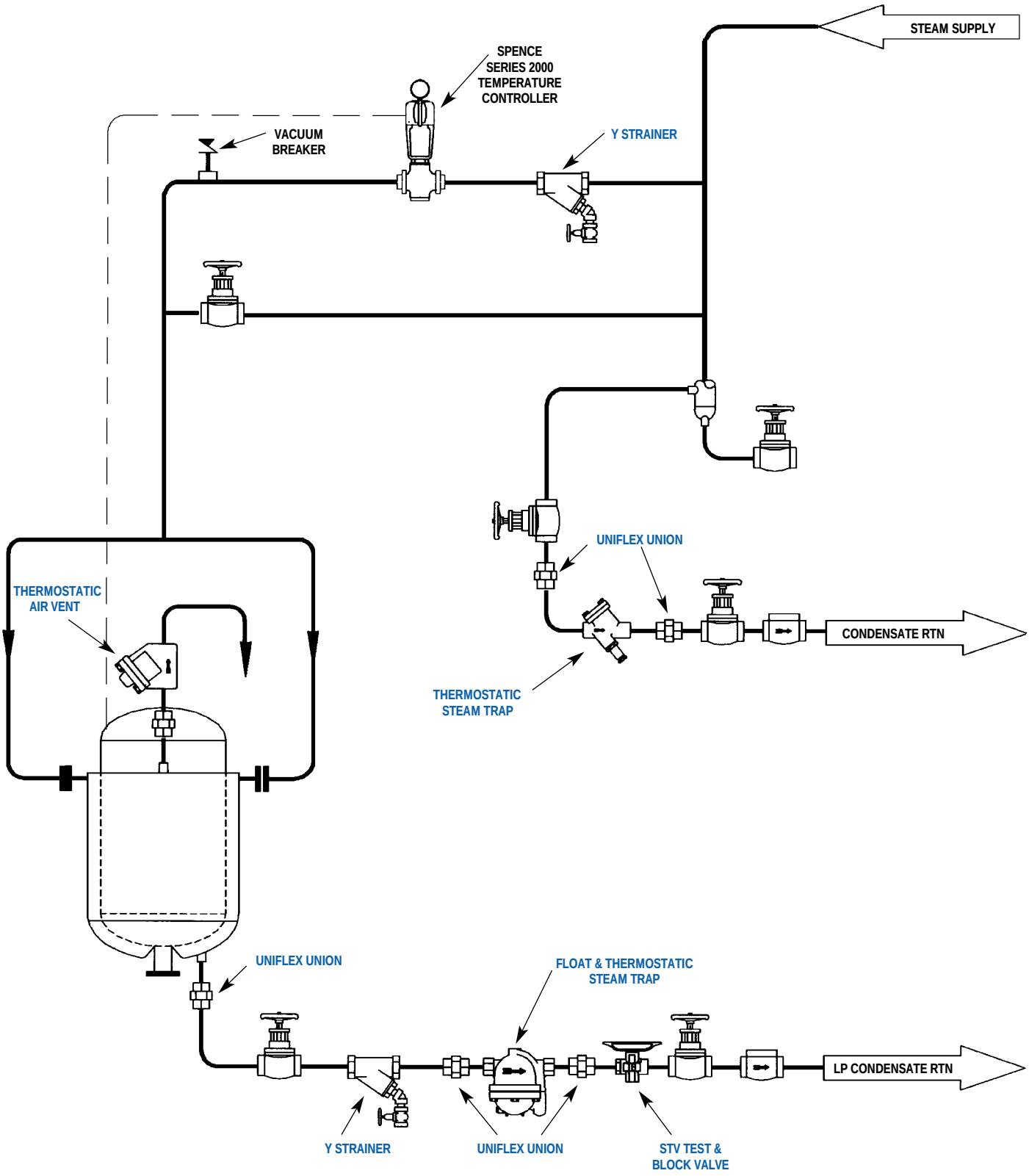
Flat Work Ironer



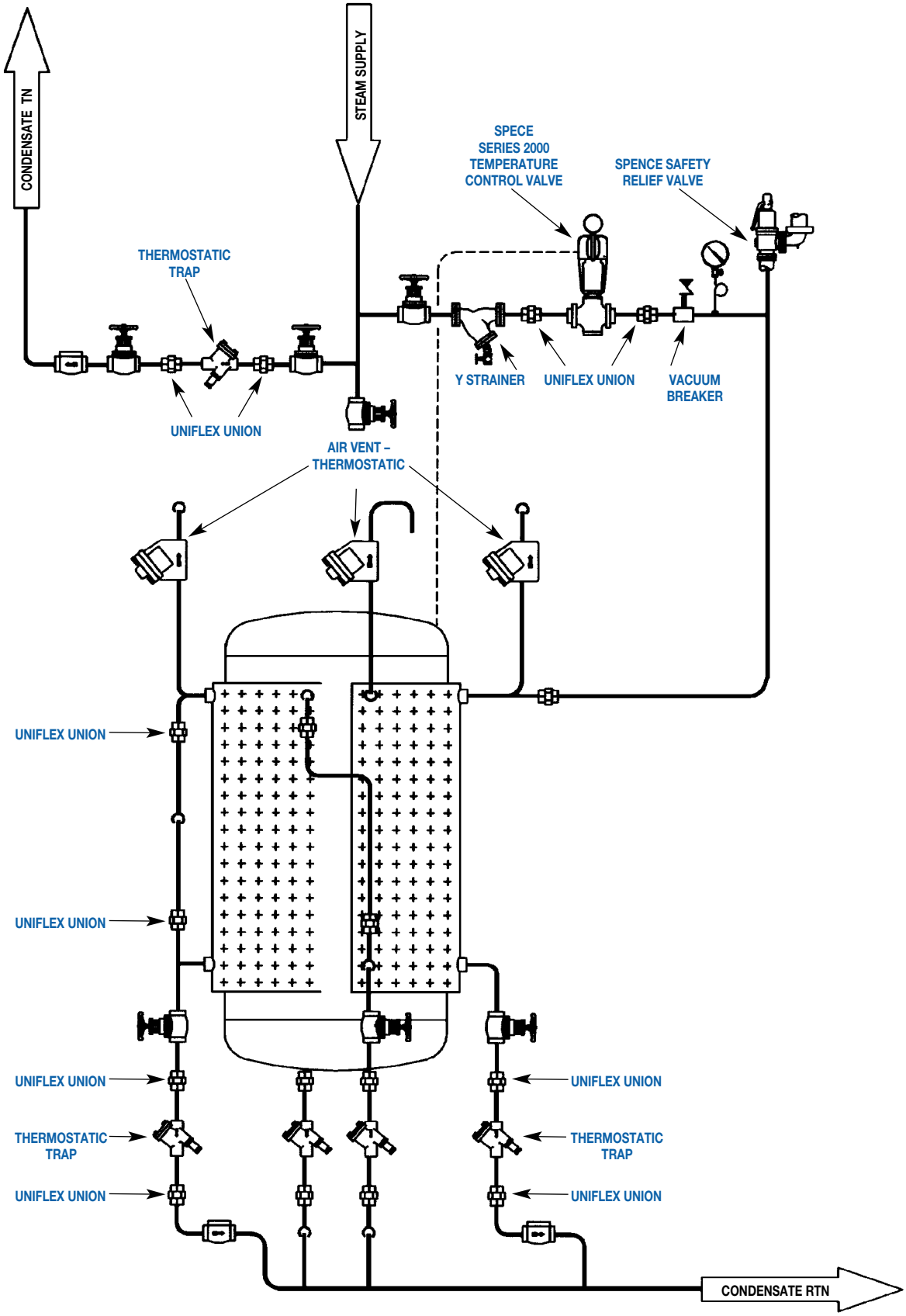
STEAM PRESS


CONDENSATE RTN
STEAM SUPPLY
SPENCE ED PRESSURE REGULATOR
Y STRAINER
UNIFLEX UNION
T'STATIC STEAM TRAP
UNIFLEX UNION
Y STRAINER
THERMOSTATIC TRAP
STV TEST & BLOCK VALVE
UNIFLEX UNION
Y STRAINER

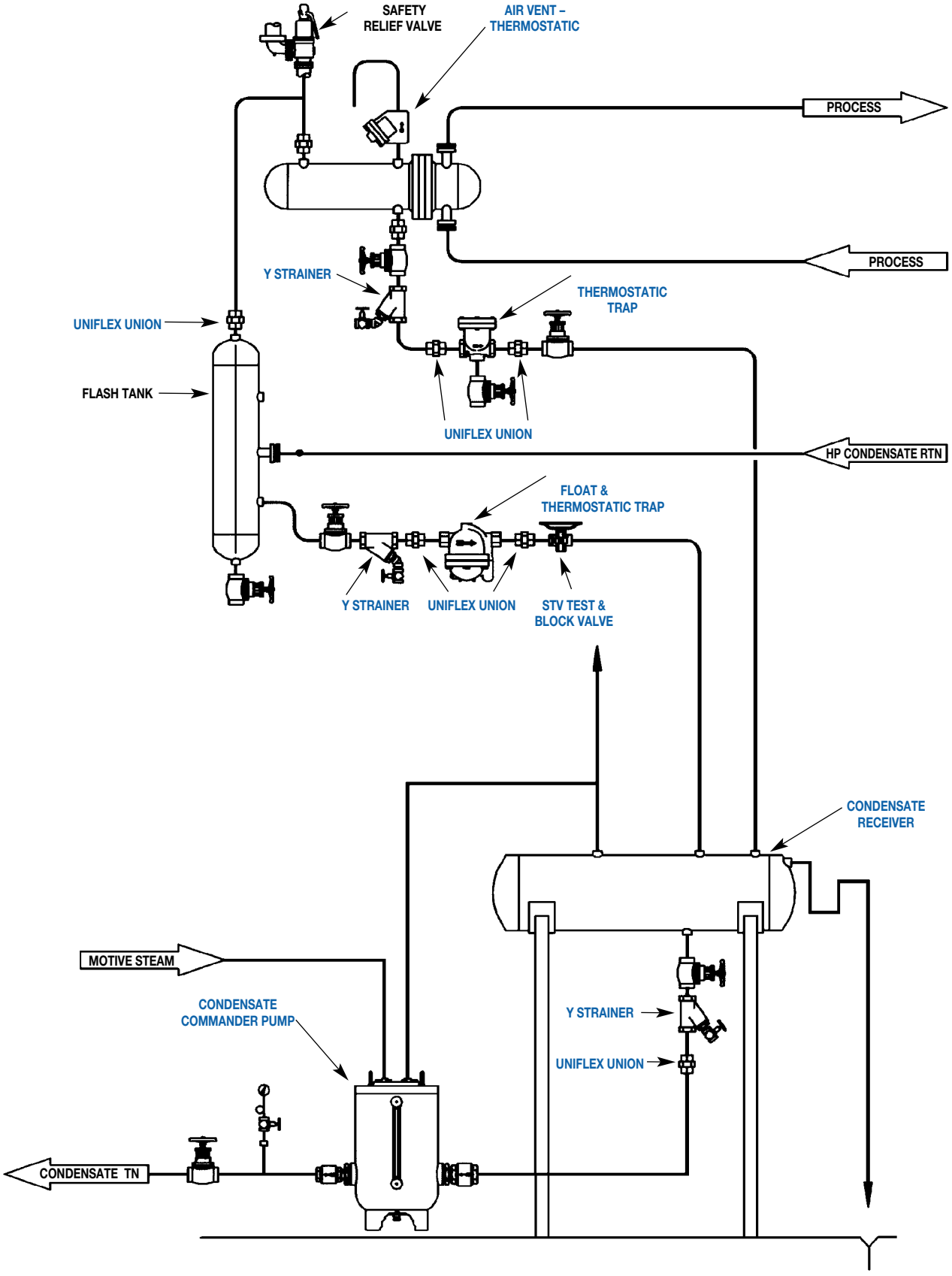
JACKETED PRESSURE VESSEL



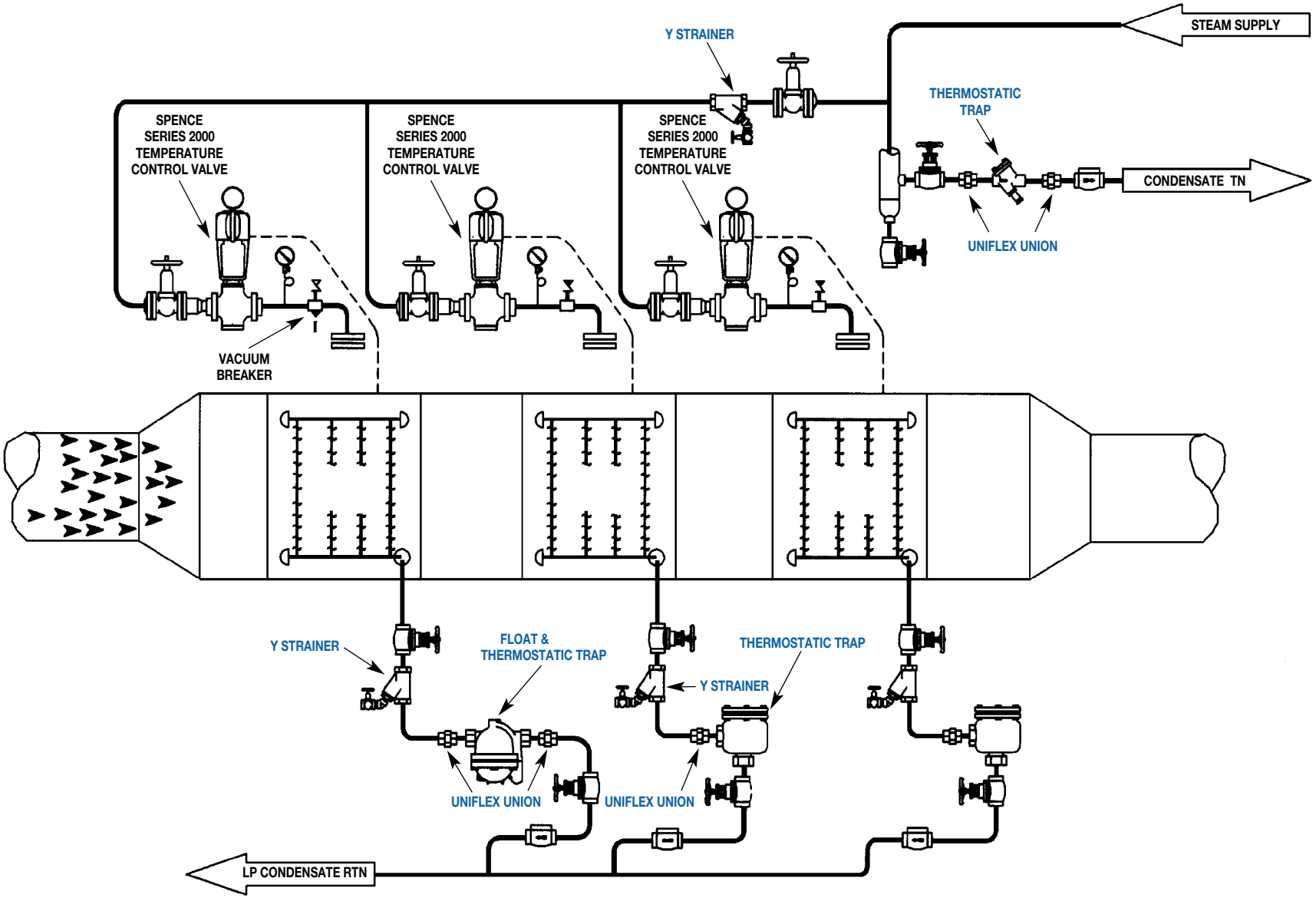
Pressure Vessel with Dimple Jacket



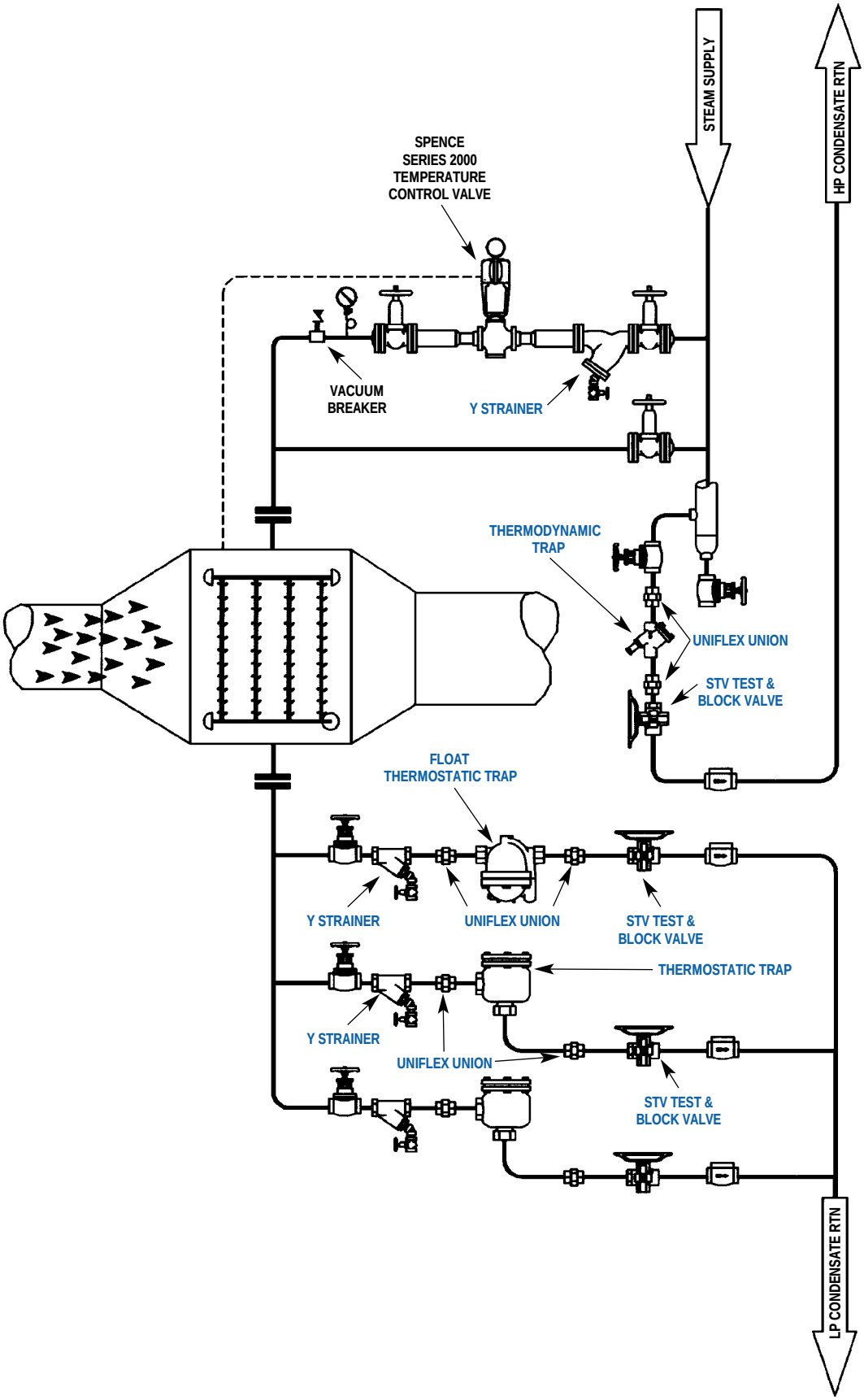
Flash Tank with condensate booster Pump



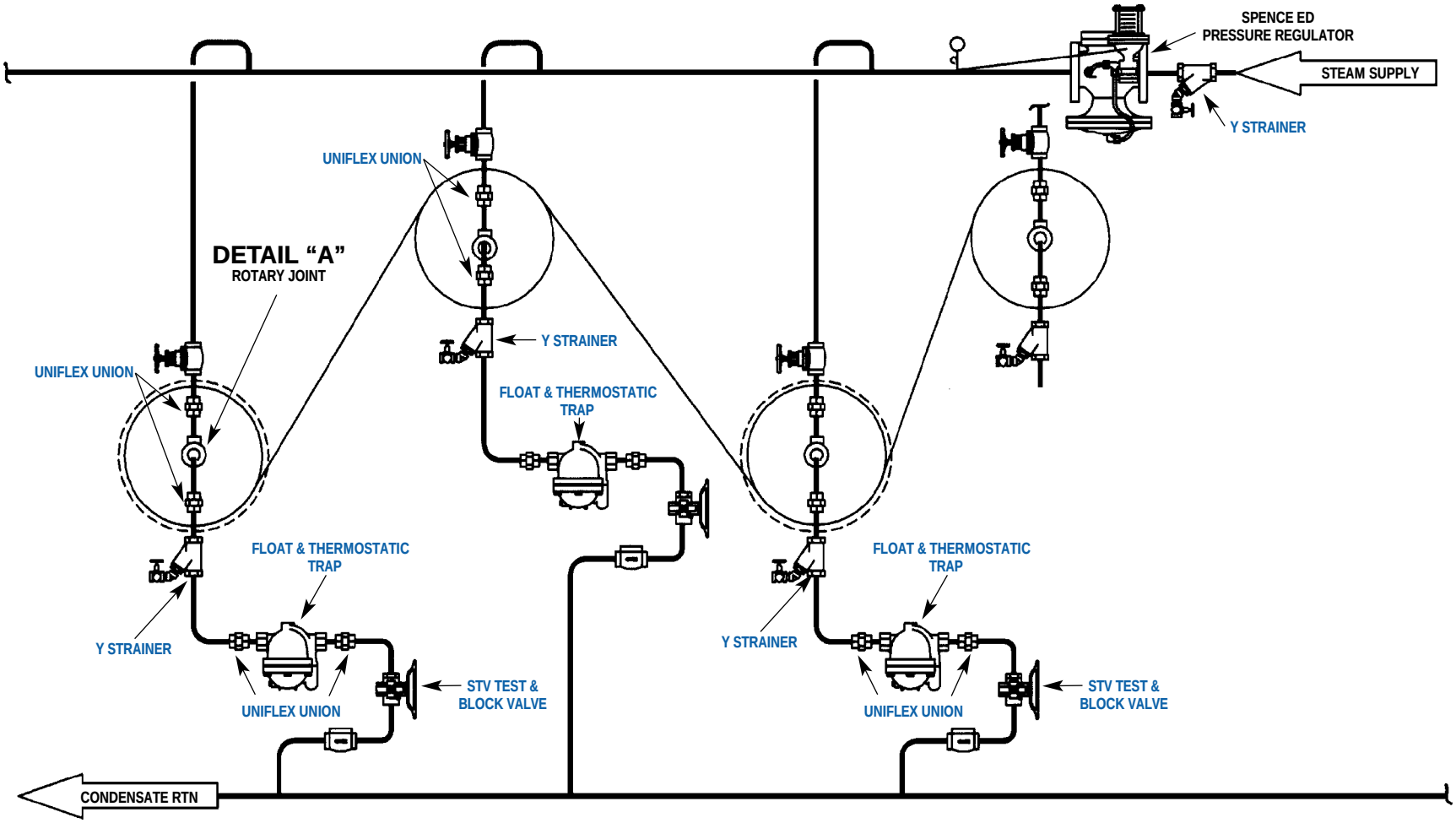
MULTI-COIL AIR HANDLER

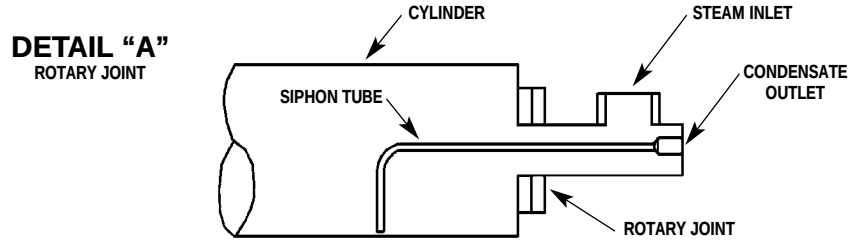


High Pressure Air Coil

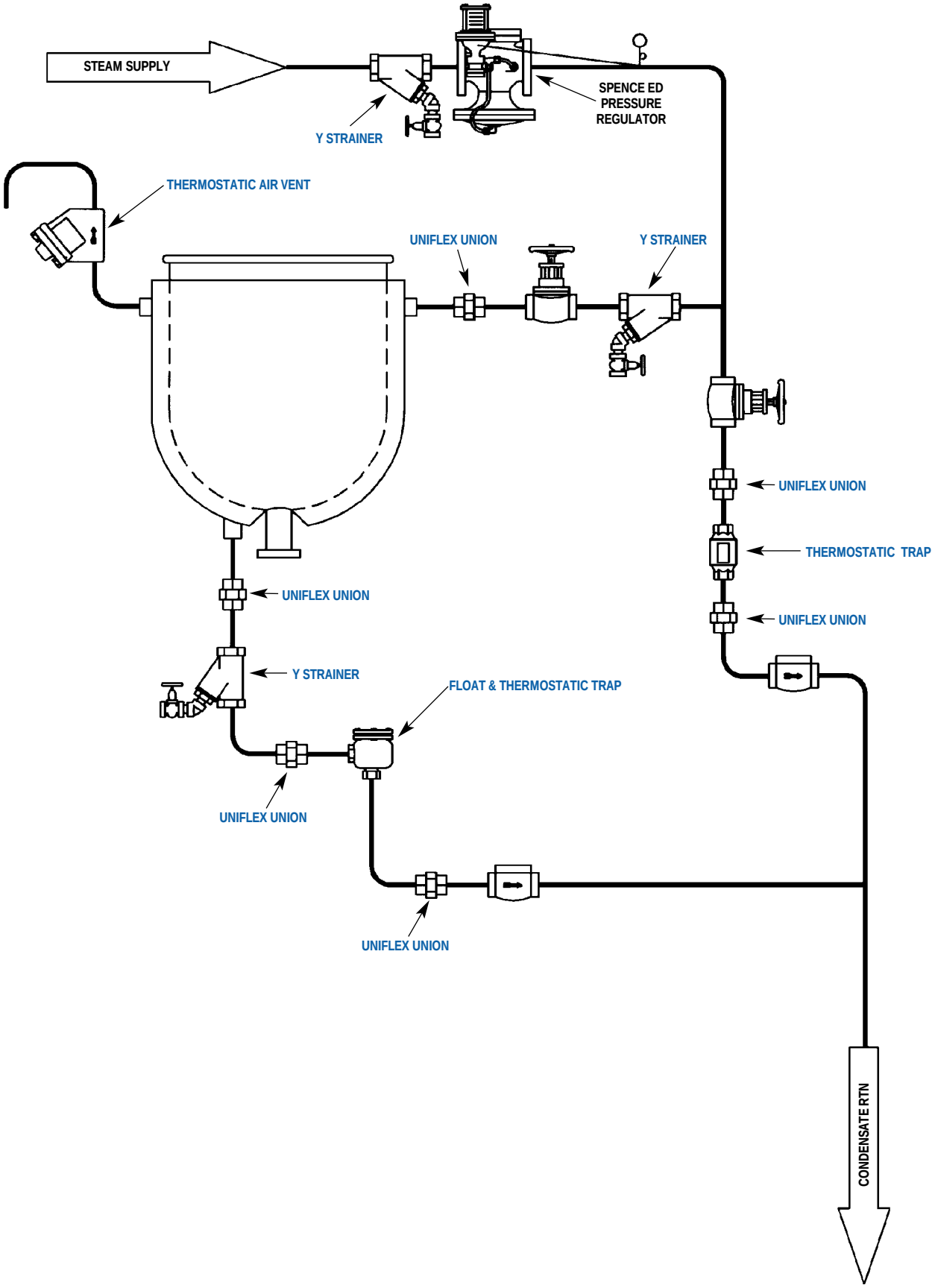


DRY CAN/CALENDER ROLL

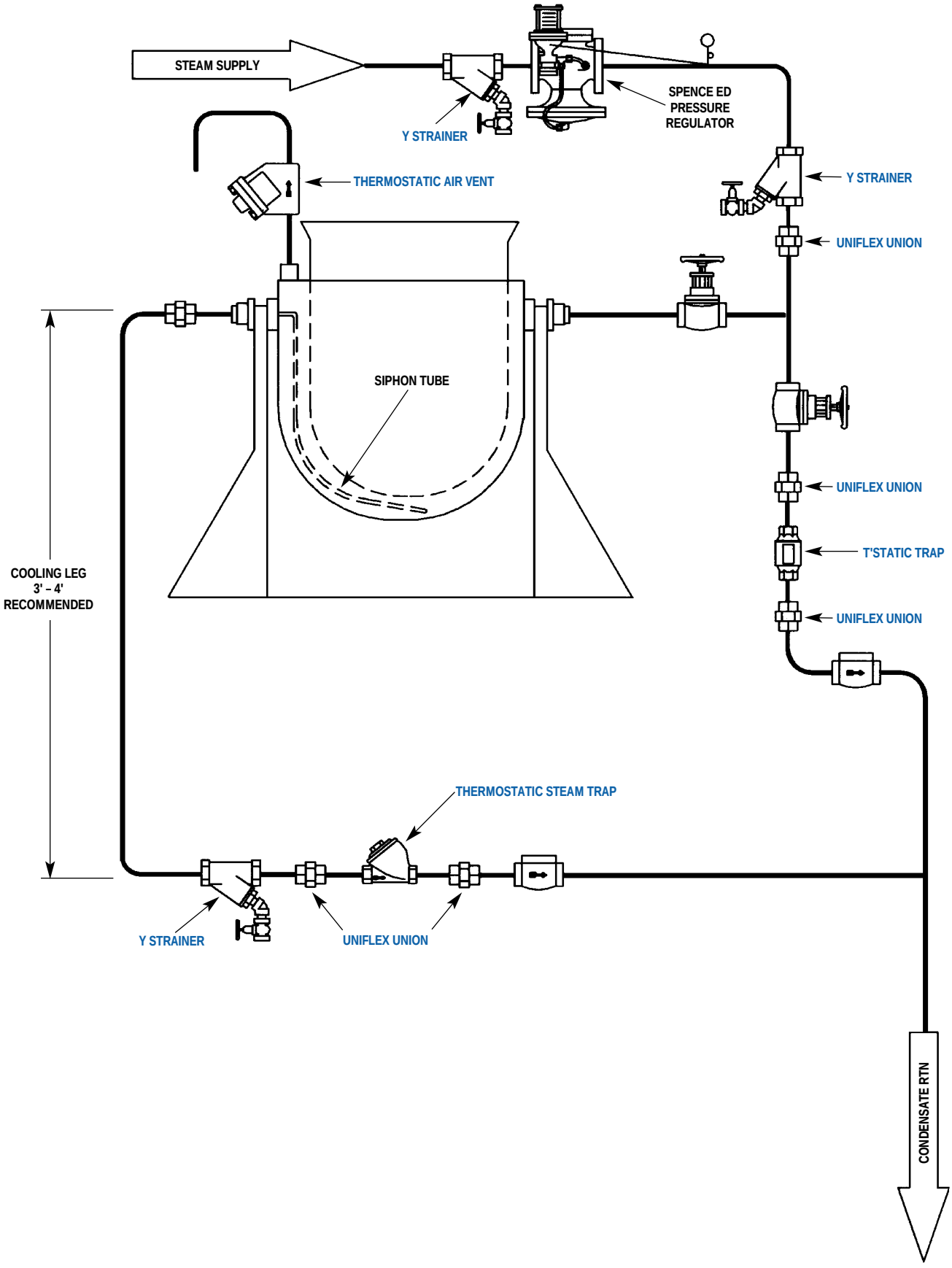




JACKETED KETTLE



TILTING JACKETED KETTLE



Domestic Hot Water