Steam and condensate

Introduction

Steam is water which has taken in heat and passed through to the complete vaporization stage.

At atmospheric pressure, boiling water and steam have the same temperature, i.e., 100°C.

As in practice, a differential pressure is required to cause steam to flow along a pipe, steam is normally supplied at a pressure, some way above atmospheric pressure. Above atmospheric pressure the steam temperature rises; this temperature gradient makes the steam more useful as a heating agent.

There are three quantities of heat in steam:

1. Specific enthalpy of water (sensible heat) - this is the heat which is added to the water up to the point at which it is converted into steam.
2. Specific enthalpy of evaporation (latent heat) - which must be added to the water at the vapour change state to convert all the water into steam at the same temperature.
3. Specific enthalpy of steam - this is the sum of 1 and 2.

Steam tables

Owing to somewhat complex effects which occur at various steam pressures, the actual quantity of heat to be supplied or available in steam can only be determined from steam tables.

The steam table, Table 1, indicates the specific enthalpy of water, evaporation and steam available in steam at pressures up to 27 bar (1 bar = 14.5lb/in^2).

Design considerations

There are two methods of sizing pipework both of which have an unknown factor which must be assumed:

1. Pressure drop
2. Velocity.

Method 1 - Pressure drop

Steam will only flow along a pipeline when there is a sufficient pressure differential between the point of supply and the outlet. The first consideration therefore is distribution pressure. Per unit of weight, low pressure steam is a better heat carrier than high pressure steam and is easy to control. However, low pressure systems require larger diameter pipes than high pressure systems. High pressure systems utilising smaller distribution pipework with pressure reductions at the equipment inlet are generally preferred.

When undertaking the sizing of steam mains, a differential principle is expressed in the formula:

$$F = \frac{(P_1 - P_2)}{L}$$

and equates the necessary final pressure

required.

where:

P_1 = a factor based on the initial pressure

P_2 = a factor based on a final pressure

L = an effective length of service pipe which is inclusive of frictional allowance for fittings

F = pressure drop factor determined by above formula

Table 2 indicates the relationship between pressure factors and the working gauge pressure expressed in bar.

Required flow rates of steam over a wide range of pressures can be evaluated from Table 3. The pressure factors applicable to design can be determined from the following worked example:

Example 1

A steam main, after allowing for all resistances has an effective length of 165 metres. The initial gauge pressure (P-,) is 7 bar and the final outlet pressure (P_2) after due allowance for radiation loss, is 6.6 bar.

Using Table 2, we can calculate a suitable pipe diameter for a steam demand of 270kg per hour required by the unit above.

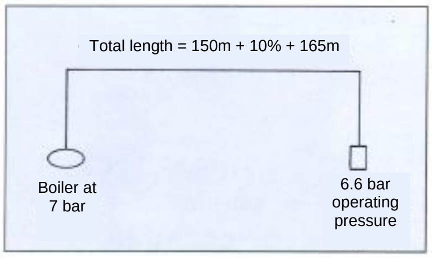


Figure 1 *Diagrammatic steam main*

P_1 at 7.0 bar has a pressure of 56.38

P_2 at 6.6 bar has a pressure of 51.05

$$F = \frac{(P_1 - P_2)}{L}$$

$$F = \frac{56.38 - 51.05}{165}$$

$$= 0.0323$$

At 0.0323 the steam flow rate from a 50mm (2in) diameter pipe read from Table 3 is 501.00kg/h.

Checking that the supply available in 40mm ($1^1/2$in) diameter pipe is below our needs, a 50mm (2in) diameter is the correct size and allows for a working margin.

Method 2 - Velocity

If a velocity is assumed then calculations are based on the specific volume of steam being carried, in relation to the cross sectional area of the pipe.

Practical experience shows that reasonable velocities for dry saturated steam mains are 25-35m/s. These velocities should be regarded as maximum values above which noise and erosion will take place, particularly if the steam is wet.

However, to avoid high pressure drops a steam velocity of no more than 15m/s should be used on long lengths of pipework.

Reading the specific volume of steam from the steam tables, pipe size can be determined from the following formula:

$$Wkg/h = 0.002827 \times \frac{D^2V}{U}$$

Where D= pipe diameter in mm

V = velocity, m/s

U = specific volume m^3/kg

Selection of a pipe size can be simplified by reference to Table 4 which has been compiled to give easy and convenient selection without the need to use the calculation method.

The method is clearly easy and convenient but it provides no guarantee of pressure at the using end.

Table 1 *Steam tables*

Pressure (bar)		Pressure (kPa)	Temperature (°C)	Specific enthalpy: Water (h_1) (kJ/kg)	Specific enthalpy: Evaporation (h_g) (kJ/kg)	Specific enthalpy: Steam (h_g) (kJ/kg)	Specific volume of steam (m^3/kg)
0.30		30.0	69.10	289.23	2336.1	2625.3	5.229
0.50	absolute -	50.0	81.33	340.49	2305.4	2645.9	3.240
0.75		75.0	91.78	384.39	2278.6	2663.0	2.217
0.95		95.0	98.20	411.43	2261.8	2673.2	1.777
0	gauge -	0	100.00	419.04	2257.0	2676.0	1.673
0.10		10.0	102.66	430.2	2250.2	2680.4	1.533
0.20		20.0	105.10	440.8	2243.4	2684.2	1.414
0.30		30.0	107.39	450.4	2237.2	2687.6	1.312
0.40		40.0	109.55	459.7	2231.3	2691.0	1.225
0.50		50.0	111.61	468.3	2225.6	2693.9	1.149
0.60		60.0	113.56	476.4	2220.4	2696.8	1.083
0.70		70.0	115.40	484.1	2215.4	2699.5	1.024
0.80		80.0	117.14	491.6	2210.5	2702.1	0.971
0.90		90.0	118.80	498.9	2205.6	2704.5	0.923
1.00		100.0	120.42	505.6	2201.1	2706.7	0.881
1.10		110.0	121.96	512.2	2197.0	2709.2	0.841
1.20		120.0	123.46	518.7	2192.8	2711.5	0.806
1.30		130.0	124.90	524.6	2188.7	2713.3	0.773
1.40		140.0	126.28	530.5	2184.8	2715.3	0.743
1.50		150.0	127.62	536.1	2181.0	2717.1	0.714
1.60		160.0	128.89	541.6	2177.3	2718.9	0.689
1.70		170.0	130.13	547.1	2173.7	2720.8	0.665
1.80		180.0	131.37	552.3	2170.1	2722.4	0.643
1.90		190.0	132.54	557.3	2166.7	2724.0	0.622
2.00		200.0	133.69	562.2	2163.3	2725.5	0.603
2.20		220.0	135.88	571.7	2156.9	2728.6	0.568
2.40		240.0	138.01	580.7	2150.7	2731.4	0.536
2.60		260.0	140.00	589.2	2144.7	2733.9	0.509
2.80		280.0	141.92	597.4	2139.0	2736.4	0.483
3.00		300.0	143.75	605.3	2133.4	2738.7	0.461
3.20		320.0	145.46	612.9	2128.1	2741.0	0.440
3.40		340.0	147.20	620.0	2122.9	2742.9	0.422
3.60		360.0	148.84	627.1	2117.8	2744.9	0.405
3.80		380.0	150.44	634.0	2112.9	2746.9	0.389
4.00		400.0	151.96	640.7	2108.1	2748.8	0.374
•4.50		450.0	155.55	656.3	2096.7	2753.0	0.342
5.00		500.0	158.92	670.9	2086.0	2756.9	0.315
5.50		550.0	162.08	684.6	2075.7	2760.3	0.292
6.00		600.0	165.04	697.5	2066.0	2763.5	0.272
6.50		650.0	167.83	709.7	2056.8	2766.5	0.255
7.00		700.0	170.50	721.4	2047.7	2769.1	0.240
7.50		750.0	173.02	732.5	2039.2	2771.7	0.227
8.00		800.0	175.43	743.1	2030.9	2774.0	0.215
8.50		850.0	177.75	753.3	2022.9	2776.2	0.204
9.00		900.0	179.97	763.0	2015.1	2778.1	0.194
9.50		950.0	182.10	772.5	2007.5	2780.0	0.185
10.00		1000.0	184.13	781.6	2000.1	2781.7	0.177
10.50		1050.0	186.05	790.1	1993.0	2783.3	0.171
11.00		1100.0	188.02	798.8	1986.0	2784.8	0.163
11.50		1150.0	189.82	807.1	1979.1	2786.3	0.157
12.00		1200.0	191.68	815.1	1972.5	2787.6	0.151
12.50		1250.0	193.43	822.9	1965.4	2788.8	0.148
13.00		1300.0	195.10	830.4	1959.6	2790.0	0.141
13.50		1350.0	196.62	837.9	1953.2	2791.1	0.136
14.00		1400.0	198.35	845.1	1947.1	2792.2	0.132
14.50		1450.0	199.92	852.1	1941.0	2793.1	0.128
15.00		1500.0	201.45	859.0	1935.0	2794.0	0.124
15.50		1550.0	202.92	865.7	1928.8	2794.9	0.119
16.00		1600.0	204.38	872.3	1923.4	2795.7	0.117
17.00		1700.0	207.17	885.0	1912.1	2797.1	0.110
18.00		1800.0	209.90	897.2	1901.3	2798.5	0.105
19.00		1900.0	212.47	909.0	1890.5	2799.5	0.100
20.00		2000.0	214.96	920.3	1880.2	2800.5	0.0949
21.00		2100.0	217.35	931.3	1870.1	2801.4	0.0906
22.00		2200.0	219.65	941.9	1860.1	2802.0	0.0868
23.00		2300.0	221.85	952.2	1850.4	2802.6	0.0832
24.00		2400.0	224.02	962.2	1840.9	2803.1	0.0797
25.00		2500.0	226.12	972.1	1831.4	2803.5	0.0768
26.00		2600.0	228.15	981.6	1822.2	2803.8	0.0740
27.00		2700.0	230.14	990.7	1813.3	2804.0	0.0714

Table 2 *Pressure factors for pipe sizing*

Pressure (bar abs)	Volume (m/kg)	Pressure factor
0.05	28.192	0.0301
0.10	14.674	0.0115
0.15	10.022	0.0253
0.20	7.649	0.0442
0.25	6.204	0.0681
0.30	5.229	0.0970
0.35	4.530	0.1308
0.40	3.993	0.1694
0.45	3.580	0.2128
0.50	3.240	0.2610
0.55	2.964	0.3140
0.60	2.732	0.3716
0.65	2.535	0.4340
0.70	2.365	0.5010
0.75	2.217	0.5727
0.80	2.087	0.6489
0.85	1.972	0.7298
0.90	1.869	0.8153
0.95	1.777	0.9053
1.013	1.673	1.025
bar gauge		
0	1.673	1.025
0.05	1.601	1.126
0.10	1.533	1.230
0.15	1.471	1.339
0.20	1.414	1.453
0.25	1.361	1.572
0.30	1.312	1.694
0.35	1.268	1.822
0.40	1.225	1.953
0.45	1.186	2.090
0.50	1.149	2.230
0.55	1.115	2.375
0.60	1.083	2.525
0.65	1.051	2.679
0.70	1.024	2.837
0.75	0.997	2.999
0.80	0.971	3.166
0.85	0.946	3.338
0.90	0.923	3.514
0.95	0.901	3.694
1.00	0.881	3.878
1.05	0.860	4.067
1.10	0.841	4.260
1.15	0.823	4.458
1.20	0.806	4.660
1.25	0.788	4.866
1.30	0.733	5.076
1.35	0.757	5.291
1.40	0.743	5.510
1.45	0.728	5.734
1.50	0.714	5.961
1.55	0.701	6.193
1.60	0.689	6.429
1.65	0.677	6.670
1.70	0.665	6.915
1.75	0.654	7.164
1.80	0.643	7.417
1.85	0.632	7.675
1.90	0.622	7.937
1.95	0.612	8.203
2.00	0.603	8.473
2.05	0.594	8.748
2.10	0.585	9.026
2.15	0.576	9.309
2.20	0.568	9.597
2.25	0.560	9.888
2.30	0.552	10.18
2.35	0.544	10.48
2.40	0.536	10.79
2.45	0.529	11.10
2.50	0.522	11.41
2.55	0.515	11.72
2.60	0.509	12.05
2.65	0.502	12.37
2.70	0.496	12.70
2.75	0.489	13.03
2.80	0.483	13.37
2.85	0.477	13.71
2.90	0.471	14.06
2.95	0.466	14.41
3.00	0.461	14.76
3.10	0.451	15.48
3.20	0.440	16.22
3.30	0.431	16.98
3.40	0.422	17.75
3.50	0.413	18.54
3.60	0.405	19.34
3.70	0.396	20.16
3.80	0.389	21.00
3.90	0.381	21.85
4.00	0.374	22.72
4.10	0.367	23.61
4.20	0.361	24.51
4.30	0.355	25.43
4.40	0.348	26.36
4.50	0.342	27.32
4.60	0.336	28.28
4.70	0.330	29.27
4.80	0.325	30.27
4.90	0.320	31.29
5.00	0.315	32.32
5.10	0.310	33.37
5.20	0.305	34.44
5.30	0.301	35.52
5.40	0.296	36.62
5.50	0.292	37.73
5.60	0.288	38.86
5.70	0.284	40.01
5.80	0.280	41.17
5.90	0.276	42.35
6.00	0.272	43.54
6.10	0.269	44.76
6.20	0.265	45.98
6.30	0.261	47.23
6.40	0.258	48.48
6.50	0.255	49.76
6.60	0.252	51.05
6.70	0.249	52.36
6.80	0.246	53.68
6.90	0.243	55.02
7.00	0.240	56.38
7.10	0.237	57.75
7.20	0.235	59.13
7.30	0.232	60.54
7.40	0.229	61.96
7.50	0.227	63.39
7.60	0.224	64.84
7.70	0.222	66.31
7.80	0.219	67.79
7.90	0.217	69.29
8 00	0 215	70 80
8 10	0 212	72.33
8.20	0.210	73.88
8.30	0.208	75.44
8.40	0.206	77.02
8.50	0.204	78.61
8.60	0.202	80.22
8.70	0.200	81.84
8.80	0.198	83.49
8.90	0.196	85.14
9.00	0.194	86.81
9.10	0.192	88.50
9.20	0.191	90.20
9.30	0.189	91.92
9.40	0.187	93.66
9.50	0.185	95.41
9.60	0.184	97.18
9.70	0.182	98.96
9.80	0.181	100.75
9.90	0.179	102.57
10.00	0.177	104.40
10.20	0.174	108.10
10.40	0.172	111.87
10.60	0.169	115.70
10.80	0.166	119.59
11.00	0.163	123.54
11.20	0.161	127.56
11.40	0.158	131.64
11.60	0.156	135.78
11.80	0.153	139.98
12.00	0.151	144.25
12.20	0.149	148.57
12.40	0.147	152.96
12.60	0.145	157.41
12.80	0.143	161.92
13.00	0.141	166.50
13.20	0.139	171.13
13.40	0.135	175.83
13.60	0.133	180.58
13.80	0.132	185.40
14.00	0.130	190.29
14.20	0.128	195.23
14.40	0.127	200.23
14.60	0.125	205.30
14.80	0.124	210.42
15.00	0.122	215.61
15.20	0.121	220.86
15.40	0.119	226.17
15.60	0.118	231.54
15.80	0.117	236.97
16.00	0.115	242.46
16.20	0.114	248.01
16.40	0.113	253.62
16.60	0.111	259.30
16.80	0.110	265.03
17.00	0.109	270.83
17.20	0.108	276.69
17.40	0.107	282.60
17.60	0.106	288.58
17.80	0.105	294.62
18.00	0.104	300.72

Table 3 Pipeline capacity and pressure drop factors

		15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm	175mm	200mm	225mm	250mm	300mm
F		**½"**	**¾"**	**1"**	**1¼"**	**1½"**	**2"**	**2½"**	**3"**	**4"**	**5"**	**6"**	**7"**	**8"**	**9**	**10"**	**12"**
0.00016	a						30.40	55.41	90.72	199.1	360.4	598.2	890.0	1275	1755	2329	3800
	v						4.30	4.86	5.55	6.82	7.90	9.16	10.05	10.94	11.94	12.77	14.54
0.00020	a					16.18	34.32	62.77	103.0	225.6	407.0	662.0	1005	1437	1966	2623	4276
	v					3.96	4.85	5.51	6.31	7.72	8.92	10.13	11.34	12.33	13.37	14.38	16.36
0.00025	a				10.84	17.92	38.19	69.31	113.2	249.9	450.3	735.5	1008	1678	2183	2904	4715
	v				3.74	4.39	5.40	6.08	6.92	8.56	9.87	11.26	12.5	14.40	14.85	15.92	18.04
0.00030	a				11.95	19.31	41.83	75.85	124.1	271.2	491.9	804.5	1209	1733	2390	3172	5149
	v				4 13	4.73	5.92	6.65	7.60	9.29	10.79	12.31	13.65	14.87	16.26	17.39	19.7
0.00035	a			6.86	12.44	20.59	43.76	80.24	130.0	285.3	519.2	845.3	1279	1823	2497	3346	5406
	v			3.88	4.30	5.04	6.21	7.04	7.96	9.77	11.38	12.94	14.44	15.64	17.00	18.34	20.69
0.00045	a		3.62	7.94	14.56	23.39	50.75	92.68	150.9	333.2	604.6	979.7	1478	2118	2913	3884	6267
	v		3.54	4.49	5.03	5.73	7.18	8.13	9.24	11.42	13.26	15.00	16.68	18.18	19.82	21.29	23.99
0.00055	a		4.04	8.99	16.18	26.52	57.09	103.8	170.8	337.1	674.2	1101	1663	2382	3281	4338	7057
	v		3.96	5.09	5.59	6.49	8.08	9.10	10.46	12.78	14.78	16.85	18.22	20.44	22.32	23.78	27.01
0.00065	a		4.46	9.56	17.76	29.14	62.38	113.8	186.7	409.8	739.9	1207	1823	2595	3597	4781	7741
	v		4.37	5.41	6.13	7.14	8.82	9.98	11.43	14.04	16.22	18.48	20.58	22.27	24.47	26.21	29.62
0.00075	a		4.87	10.57	19.31	31.72	68.04	124.1	203.2	445.9	804.5	1315	1977	2836	3908	5172	8367
	v		4.77	5.98	6.67	7.77	9.62	10.88	12.44	15.28	17.64	20.13	22.32	24.34	26.59	28.35	32.02
0.00085	a		5.52	11.98	21.88	35.95	77.11	104.7	230.2	505.4	911.8	1490	2240	3215	4429	5861	9482
	v		5.41	6.78	7.56	8.80	10.91	12.34	14.09	17.32	19.99	22.81	25.29	27.59	30.13	32.13	36.29
0.00100	a	1.96	5.84	12.75	23.50	38.25	81.89	148.6	245.2	539.4	968.5	1579	2403	3383	4707	6228	10052
	v	4.10	5.72	7.21	8.12	9.37	11.58	13.03	15.01	18.48	21.24	24.17	27.13	29.03	32.02	34.14	38.47
0.00125	a	2.10	6.26	13.57	24.96	40.72	87.57	159.8	261.8	577.9	1038	1699	2544	3634	5035	6655	10639
	v	4.39	6.13	7.68	8.62	9.97	12.39	14.02	16.03	19.80	22.76	26.01	28.72	31.19	34.26	36.48	40.71
0.00150	a	2.39	7.35	15.17	28.04	45.97	98.84	179.3	295.1	652.8	1172	1908	2896	4091	5631	7493	11999
	v	5.00	7.20	8.58	9.68	11.26	13.98	15.72	18.07	22.37	25.70	29.21	32.69	35.11	38.31	41.08	45.92
0.00175	a	2.48	7.51	16.30	29.61	49.34	103.4	188.8	311.1	686.5	1270	2017	3046	4291	5921	7852	13087
	v	5.19	7.36	9.22	10.23	12.08	14.63	16.56	19.05	23.52	27.85	30.88	34.39	36.83	40.28	43.04	50.08
0.0020	a	2.84	8.58	18.63	33.83	56.39	118.2	215.8	355.5	784.6	1451.	2305	3482	4904	6767	8974	14956
	v	5.94	8.40	10.54	11.68	>3.81	16.72	18.93	21.77	26.88	31.82	35.28	39.31	42.09	46.04	49.19	57.24
0.0025	a	3.16	9.48	20.75	37.25	61.30	132.0	240.5	391.3	881.7	1556	2546	3819	5422	7544	10090	16503
	v	6.61	9.29	11.74	12.86	15.01	18.67	21.09	23.96	30.21	34.12	38.97	43.11	46.53	51.33	55.31	63.16
0.0030	a	3.44	10.34	22.5	40.45	66.66	143.4	262.0	429.8	942.4	1701	2767	4183	6068	8275	11033	18021
	v	7.20	10.13	12.73	13.97	16.33	20.29	22.98	26.32	32.29	37.30	42.36	47.22	52.08	56.30	60.48	68.97
0.0040	a	4.17	12.50	26.97	48.55	80.91	173.1	313.8	514.9	1128	2040	3330	5051	7208	9905	13240	21625
	v	8.73	12.25	15.26	16.77	19.82	24.49	27.52	31.53	38.65	44.73	50.97	57.02	61.86	67.39	72.58	82.76
0.0050	a	4.71	14.12	30.40	54.92	90.23	196.1	354	578.6	1275	2305	3727	5737	8189	11278	14858	24469
	v	9.86	13.83	17.20	18.97	20.10	27.74	31.05	35.43	43.68	50.54	57.05	64.76	70.28	76.73	81.45	93.64
0.0060	a	5.25	15.69	35.80	60.31	99.05	215.8	392.3	647.3	1412	2550	4148	6277	9072	12406	16476	26970
	v	10.99	15.37	20.26	20.83	24.26	30.53	34.41	39.63	48.38	55.92	63.50	70.86	77.86	84.40	90.32	103.21
0.0080	a	6.08	18.34	39.23	70.12	116.2	251.5	456.0	750.3	1648	2976	4879	7355	10543	14417	19173	31384
	v	12.72	17.97	22.20	24.22	28.46	35.58	40.00	45.95	56.46	65.26	74.69	83.03	90.48	98.09	105.1	120.1
0.0100	a	6.86	20.64	44.13	79.44	130.4	283.9	514.9	845.9	1863	3334	5492	8336	11867	16280	21576	35307
	v	14.36	20.22	24.97	27.44	31.94	40.16	45.16	51.80	63.83	73.11	84.07	94.11	101.8	110.8	118.28	135.1
0.0125	a	7.35	22.20	47.28	81.00	140.1	302.1	547.3	901.9	1983	3589	5867	8844	2697	17426	23074	37785
	v	15.38	21.75	26.75	27.98	34.31	42.74	48.00	55.22	67.94	78.70	89.81	99.84	109.0	118.5	126.5	144.6
0.0150	a	8.27	25.00	53.33	95.62	157.2	342.0	620.6	1020	2230	4045	6620 .	10022	4251	19584	25974	42616
	v	17.31	24.49	30.18	33.03	38.50	48.38	54.43	62.46	76.40	88.70	101.3	113.1	22.3	133.2	142.4	163.09
0.0175	a	8.58	26.39	55.78	100.4	165.6	360.4	665.1	1073	2360	4291	6994	10512	5017	20595	27461	44194
	v	17.95	25.85	31.56	34.68	40.65	50.99	58.34	65.70	80.52	94.09	107.1	118.7	128.9	140.1	150.5	169.1
0.020	a	9.80	30.16	63.75	114.7	189.3	411.9	760.1	1226	2697	4904	7993	12014	7163	23538	31384	50508
	v	20.51	29.55	36.07	39.62	46.36	58.27	66.67	75.01	92.41	107.5	122.3	135.6	147.3	160.1	172.0	193.3
0.025	a	10.99	33.48	70.73	127.3	209.8	459.7	834.6	1367	2970	5422	8817	13296	9332	26357	34750	56581
	v	23.00	32.80	40.02	43.97	51.39	65.03	73.20	83.70	101.7	118.9	135.0	150.1	65.9	179.3	190.5	216.5
0.030	a	12.00	36.78	77.23	137.9	229.9	501.1	919.4	1480	3264	5884	9792	14481	20917	28595	37697	62522
	v	25.11	36.03	43.70	47.63	56.31	70.89	80.64	90.62	111.8	129.0	149.9	163.5	179.5	194.5	206.6	239.3
0.040	a	14.46	44.13	93.17	169.2	279.5	600.7	1093	1790	3923	7110	11622	17457	25254	34571	45604	75026
	v	30.26	43.23	52.72	58.44	68.46	84.98	95.87	109.6	134.4	155.9	177.9	197.2	216.7	235.2	250.0	287.1
0.050	a	16.43	49.53	104.4	191.2	313.8	676.7	1231	2020	4413	8042	13044	19370	23441	39229	51489	85324
	v	34.38	48.52	59.08	66.04	76.86	95.73	108.0	123.7	151.2	176.3	199.7	218.7	244.1	266.9	282.3	326.5
0.06	a	18.14	52.96	115.7	210.8	343.2	750.3	1373	2231	4855	8827	14368	21282	31384	43152	57373	
	v	37.96	51.88	65.47	72.81	84.06	106.1	120.4	136.6	166.3	193.5	219.9	240.2	269.3	293.6	314.5	
0.08	a	21.08	62.28	134.8	245.2	402.1	872.8	1594	2599	5688	10249	16672	24518	36532			
	v	44.11	61.02	76.28	86.69	98.49	123.5	139.8	159.1	194.9	224.7	255.2	276.8	313.5			
0.10	a	24.03	70.12	152.0	277.0	456.0	980.7	1804	2942	6424	11524	18879	27461				
	v	50.29	68 70	86.01	95.67	111.7	138.7	158.2	180.1	220.1	252.7	289.0	310.0				
0.12	a	25.99	77.48	167.7	306.5	500.2	1079	1986	3236	7110	12700	20841					
	v	54.39	75.91	94.90	105.9	122.5	152.6	174.2	198.1	243.6	278.5	319.0					
0.15	a	28.50	84.13	183.9	334.2	551.7	1195	2161	3494	7769							
	v	59.64	82.42	104.1	115.4	135.1	169.0	189.5	213.9	266.2							
0.20	a	34.32	102.0	220.7	402.1	662.0	1427	2599	4217	9317							
	v	71.82	99.93	124.9	138.9	162.1	201.9	228.0	258.2	319.2							
0.25	a	37.72	112.7	245.2	447.9	735.5	1565	2876	4668								
	v	78.94	110.4	138.7	154.7	180.1	221.4	252.3	285.8								
0.30	a	41.37	122.7	266.6	487.3	804.5	1710	3126	5057								
	v	86.58	120.2	150.9	168.3	197.0	241.9	274.2	309.6								
0.35	a	43.34	128.7	283.2	514.9	841.0	1802	3261									
	v	90.70	126.1	160.2	177.8	206.0	254.9	286.0									
0.40	a	49.93	147.1	323.6	588.4	961.1	2059	3727									
	v	104.5	144.1	183.1	203.2	235.4	291.3	326.9									
0.45	a	50.31	150.0	326.6	600.2	979.7	2083										
	v	105.3	146.9	184.8	207.3	239.9	294.7										
0.50	a	55.90	166.7	362.9	666.9	1089	2314										
	v	117.0	163.3	205.3	230.3	266.7	327.4										
0.6	a	62.28	185.3	402.1	735.5	1201											
	v	130.3	181.5	227.5	254.0	294.1											
0.7	a	63.07	188.8	407.6	750.9												
	v	132.0	185.0	230.6	259.3												
0.8	a	72.08	215.8	465.8	858.1												
	v	150.8	211.4	263.6	296.4												
0.9	a	73.28	218.4	476.6													
	v	153.3	214.0	269.7													

a = kg/h capacity v = m/s velocity with a volume of 1 m^3/kg

Table 4 *Pipeline capacities at specific velocities*

Pressure (bar)	Velocity (m/s)	kg/h										
		15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
0.4	15	7	14	24	37	52	99	145	213	394	648	917
	25	10	25	40	62	92	162	265	384	675	972	1457
	40	17	35	64	102	142	265	403	576	1037	1670	2303
0.7	15	7	16	25	40	59	109	166	250	431	680	1006
	25	12	25	45	72	100	182	287	430	716	1145	1575
	40	18	37	68	106	167	298	428	630	1108	1712	2417
1.0	15	8	17	29	43	65	112	182	260	470	694	1020
	25	12	26	48	72	100	193	300	445	730	1160	1660
	40	19	39	71	112	172	311	465	640	1150	1800	2500
2.0	15	12	25	45	70	100	182	280	410	715	1125	1580
	25	19	43	70	112	162	295	428	656	1215	1755	2520
	40	30	64	115	178	275	475	745	1010	1895	2925	4175
3.0	15	16	37	60	93	127	245	385	535	925	1505	2040
	25	26	56	100	152	225	425	632	910	1580	2480	3440
	40	41	87	157	250	357	595	1025	1460	2540	4050	5940
4.0	15	19	42	70	108	156	281	432	635	1166	1685	2460
	25	30	63	115	180	270	450	742	1080	1980	2925	4225
	40	49	116	197	295	456	796	1247	1825	3120	4940	7050
5.0	15	22	49	87	128	187	352	526	770	1295	2105	2835
	25	36	81	135	211	308	548	885	1265	2110	3540	5150
	40	59	131	225	338	495	855	1350	1890	3510	5400	7870
6.0	15	26	59	105	153	225	425	632	925	1555	2525	3400
	25	43	97	162	253	370	658	1065	1520	2530	4250	6175
	40	71	157	270	405	595	1025	1620	2270	4210	6475	9445
7.0	15	29	63	110	165	260	445	705	952	1815	2765	3990
	25	49	114	190	288	450	785	1205	1750	3025	4815	6900
	40	76	117	303	455	690	1210	1865	2520	4585	7560	10880
8.0	15	32	70	126	190	285	475	800	1125	1990	3025	4540
	25	54	122	205	320	465	810	1260	1870	3240	5220	7120
	40	84	192	327	510	730	1370	2065	3120	5135	8395	12470
10.0	15	41	95	155	250	372	626	1012	1465	2495	3995	5860
	25	66	145	257	405	562	990	1530	2205	3825	6295	8995
	40	104	216	408	615	910	1635	2545	3600	6230	9880	14390
14.0	15	50	121	205	310	465	810	1270	1870	3220	5215	7390
	25	85	195	331	520	740	1375	2080	3120	5200	8500	12560
	40	126	305	555	825	1210	2195	3425	4735	8510	13050	18630

Table 5 Flow of water in heavy grade steel pipes

Pa per m	mbar per m	kg/h								
		15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm
28	0.28	90	209	380	865	1320	2554	5194	8079	16511
29	0.29	92	214	400	878	1340	2590	5271	8196	16756
30	0.30	93	218	403	890	1361	2631	5348	8314	17000
33	0.33	97	226	414	930	1420	2744	5579	8677	17736
39	0.39	107	249	469	1028	1565	3025	6142	9526	19514
40	0.40	108	253	476	1040	1583	3062	6214	9639	19736
43	0.43	113	263	496	1079	1646	3180	6454	10024	20457
45	0.45	116	270	508	1107	1687	3261	6618	10297	21002
47	0.47	119	277	521	1134	1728	3338	6777	10523	21500
50	0.50	123	286	538	1172	1787	3447	6949	10859	22154
53	0.53	127	296	557	1211	1846	3565	7235	11249	22907
55	0.55	130	302	569	1238	1887	3638	7380	11476	23360
57	0.57	133	308	580	1261	1923	3710	7525	11703	23814
59	0.59	135	314	591	1288	1959	3783	7666	11884	24268
61	0.61	138	320	602	1311	1996	3851	7806	12111	24721
64	0.64	141	327	615	1338	2041	3933	7970	12383	25220
67	0.67	146	337	634	1379	2100	4051	8210	12746	25991
69	0.69	148	343	645	1402	2136	4119	8342	12973	26400
70	0.70	149	345	649	1411	2150	4146	8432	13041	26563
71	0.71	150	348	655	1424	2168	4182	8473	13154	26808
73	0.73	152	354	665	1447	2200	4246	8600	13336	27216
75	0.75	154	358	673	1458	2227	4291	8695	13517	27506
76	0.76	155	359	675	1465	2236	4305	8723	13563	27579
77	0.77	157	365	685	1488	2268	4368	8850	13744	27987
78	0.78	158	366	689	1497	2282	4390	8900	13812	28132
80	0.80	160	370	695	1510	2300	4427	8972	13925	28350
82	0.82	162	375	704	1529	2331	4491	9072	14407	28758
88	0.88	168	391	733	1590	2427	4536	9453	14651	29865
90	0.90	170	395	740	1606	2449	4717	9548	14787	30142
98	0.98	179	414	777	1696	2567	4944	10025	15513	31616
100	1.00	180	418	785	1701	2590	4990	10115	15649	31879
114	1.14	194	450	845	1832	2790	5366	10841	16828	34247
118	1.18	198	457	857	1860	2830	5443	11022	17055	34746
120	1.20	199	462	867	1880	2860	5502	11113	17282	35120
131	1.31	209	484	907	1996	2994	5761	11657	18053	36742
137	1.37	215	497	931	2018	3071	5906	11948	18507	37667
140	1.40	216	502	939	2037	3103	5965	12066	18688	38012
147	1.47	224	516	966	2096	3189	6128	12383	19187	39055
157	1.57	231	534	1002	2168	3298	6337	12814	19822	40361
160	1.60	234	541	1011	2195	3334	6409	12973	20049	40797
163	1.63	237	546	1025	2218	3370	6477	13109	20278	41232
176	1.76	246	570	1066	2309	3511	6740	13608	21092	42938
180	1.80	249	576	1075	2331	3547	6808	13744	21319	43364
196	1.96	261	603	1129	2440	3710	7130	14379	22317	45360
200	2.00	265	611	1143	2472	3760	7221	14560	22589	45931
212	2.12	273	629	1179	2549	3874	7434	15014	23270	47265
216	2.16	275	634	1188	2567	3905	7493	15132	23451	47637
220	2.20	278	641	1200	2595	3942	7570	15277	23678	48014
229	2.29	284	655	1225	2649	4028	7729	15604	24177	49125
235	2.35	288	664	1243	2689	4086	7843	15840	24522	49832
240	2.40	292	672	1256	2719	4129	7927	16017	24780	50363
245	2.45	295	679	1270	2749	4173	8010	16193	25039	50894
255	2.55	301	694	1297	2806	4260	8176	16520	25556	51928
260	2.60	304	701	1311	2834	4304	8260	16683	25814	52445
261	2.61	305	703	1315	2844	4318	8287	16738	25900	52618
274	2.74	313	721	1348	2917	4331	8501	17173	26554	54069
277	2.77	315	727	1356	2935	4459	8555	17282	26717	54432
280	2.80	317	730	1363	2948	4479	8593	17357	26839	54636
294	2.94	325	749	1402	3025	4595	8813	17781	27533	55793
300	3.00	328	757	1414	3055	4641	8900	17956	27803	56428
310	3.10	335	771	1438	3112	4726	9063	18280	28308	57507
314	3.14	336	775	1446	3129	4752	9074	18380	28459	57879
320	3.20	340	784	1462	3163	4825	9204	18579	28767	58424
327	3.27	344	792	1479	3198	4853	9299	18776	29076	58968
333	3.33	348	801	1495	3230	4904	9408	18979	29366	59612
340	3.40	351	809	1511	3263	4955	9516	19178	29656	60057
343	3.43	353	813	1520	3279	4980	9571	19278	29801	60329
353	3.53	358	825	1541	3328	5054	9707	19550	30237	61236
359	3.59	362	834	1556	3361	5103	9798	19732	30522	62143
360	3.60	363	835	1558	3365	5109	9809	19754	30564	62211

Alignment and drainage

Problems associated with a steam distribution system can be minimised if the correct consideration is given to the alignment and drainage of the pipework. Steam leaving a boiler is often much wetter than is appreciated, it starts to condense as heat losses take place from the pipework. The rate of condensation is heavy at plant start-up when the system is cold. During normal running, the rate is reduced but remains as small but finite amounts, however well insulated the pipework may be.

The condensate forms droplets on the inside of the pipe walls, these droplets can merge into a film as they are swept along by the steam flow. This film will gravitate to the bottom of the pipe so the water film will be greatest there.

Unless the condensed water is removed as quickly as possible, slugs of water will collect. These slugs of water carried down the pipework by the steam, build up considerable amounts of kinetic energy which reappear as pressure energy when the water is stopped at any obstruction.

The resultant shock waves created, cause water hammer, which in turn can damage both pipework and fittings.

If a few simple rules are observed, proper alignment and drainage will do much to ensure a trouble free system.

Pipework should be arranged with a fall in the direction of flow, a fall of around 40mm in 10m (1 in 250) in the direction of flow is considered adequate. The fall in the pipework ensures the condensate is carried by the steam to drain points located in the system.

Saturated steam pipework should be drained at regular intervals. The distance between drain points will depend on line size, location and the frequency of start-up, intervals of 30 to 50m between points is usual, any low point where condensate can collect should be drained.

Changes of direction on pipework are effective locations for drain points.

Due to the falls required on pipework, long horizontal lengths of pipe should have relay points, these points allow for the pipework to be raised to a higher level and fall again. Relay points are ideal drain points as the change in level helps to separate out entrained water droplets.

Drain points on long straight lengths of pipework should be as large as possible, full bore pockets are ideal on pipelines up to 100mm, above this size pockets can be one or more sizes smaller than the pipe, effectively.

Branch connections should always be taken from the top of any main to ensure the driest possible steam is supplied.

Branch connections from the side and particularly from the bottom of mains should be avoided, such branches would in effect become drain pockets, the result would be very wet steam reaching equipment.

Low points occur in branch pipework and drop legs to low level equipment with isolating or control valves are the most common occurrence. Condensate will build up in front of a closed valve, therefore a drain point with steam trap set is required as indicated in Figure 3.

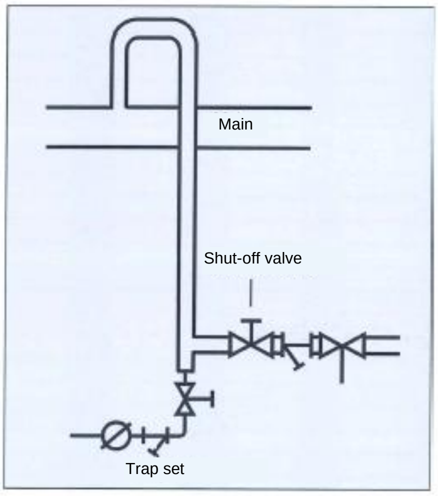
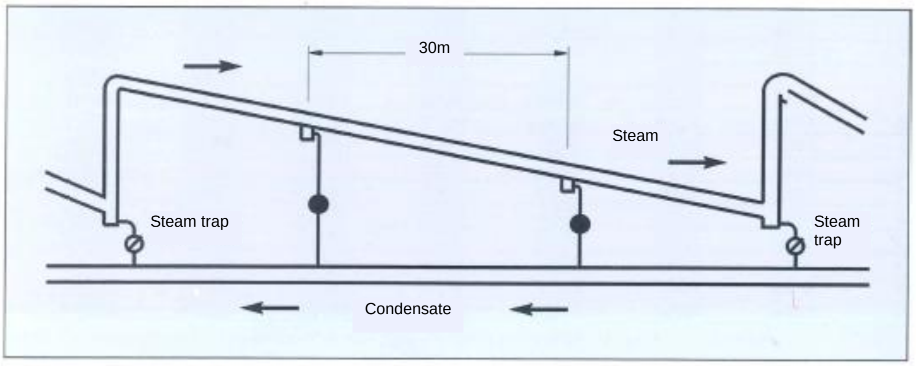


Figure 3 *Recommended take-off from main with branch drainage*

Figure 2 *Condensate removal from distribution main*



Steam and condensate traps

The steam traps used to drain steam mains must be suitable for use at the maximum steam pressure within the main, they should have sufficient capacity to pass the amounts of condensate reaching them with the pressure differentials which are present at the time.

A steam trap is an essential piece of equipment which must be fitted to the condense outlet of the steam heated equipment before discharging into the condensate return. The basic function of the steam trap is to release condensate and to hold back steam in the equipment.

There are three basic designs of steam trap which are most widely used:

Thermostatic traps (Figure 4)

These traps are bi-metallic devices or liquid-filled bellows which, because of their construction, are able to 'sense' the difference in temperature between condensate and steam. When condensate is flowing, the trap remains open but when the higher temperature steam enters the trap, it closes and will not allow the steam to pass through. When the steam condenses and loses temperature, the sensing element allows the trap valve to open and the cycle is repeated. Therefore these traps will cause a certain amount of water logging and allowance must be made for this.

Mechanical traps
(Figures 5 & 6)

This type of trap relies for its principle of action on the difference in density between steam and water acting on a ball float which rises in the presence of condensate and thus opens the valve which then permits condensate to pass through the trap. The inverted bucket in this type of trap floats when steam is admitted to the trap and thus this action closes the trap valve.

Thermodynamic traps
(Figure 7)

Some traps rely on the fact that when condensate at near steam temperature is reduced in pressure at an orifice, flash steam is produced. The most common trap of this type is the thermodynamic trap which uses the increased velocity of the flash steam to close a disc against a seat.

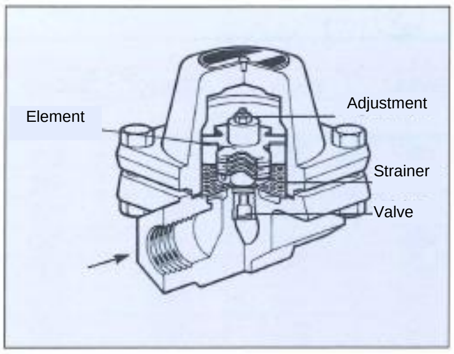


Figure 4 *Operation of bi-metal steam trap*

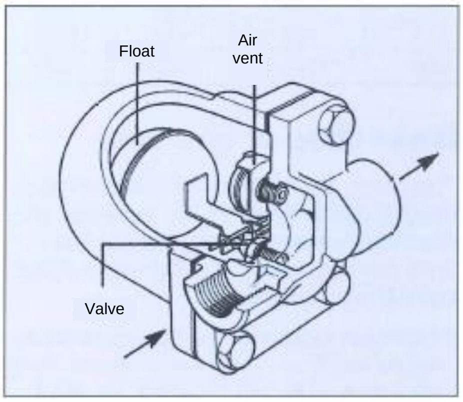


Figure 5 *Float trap with thermostatic air vent*

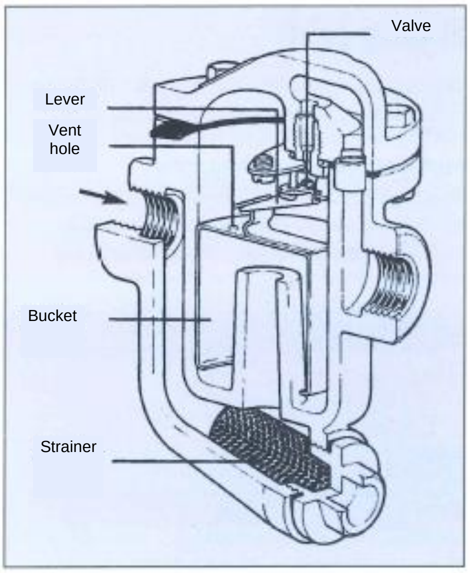


Figure 6 *Inverted bucket trap*

The trap opens on a cyclic basis when steam pressure in the control chamber is dissipated due to radiation. These traps discharge condensate as soon as it is formed and are therefore ideal for most trapping applications.

There are a number of other more complex designs of steam trap which can be used in special circumstances. These traps and their special functions lie within the realms of the specialist steam applications engineer.

Figures 4, 5, 6 and 7 indicate the working principles of the steam traps described.

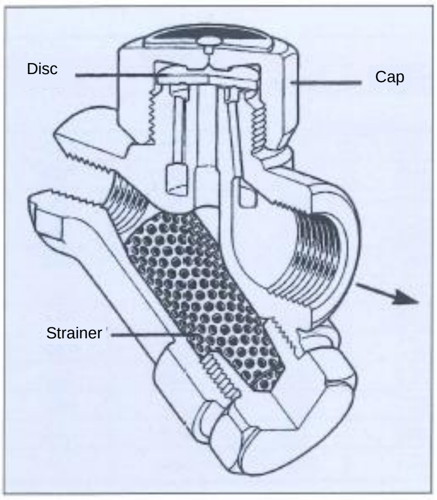


Figure 7 *Thermodynamic trap*

Steam separators

Although drain points are adequate to deal with condensate on pipeline walls, they cannot remove moisture form the steam itself. This is achieved by a series of simple baffle plates and are arranged to force the steam to change direction and are formed in an item of equipment called a separator. Dry steam passes through with little difficulty but allows the water droplets to drop to the bottom of the unit to a drain outlet and run to a drain point and a steam trap, thus providing better steam for power and process.

Strainers

The internal passageway of the pipework is continually confronted with deposits that cause blockages. These may take the form of rust, carbonate deposits in hard water districts and any general debris entering during installation. These deposits can easily block pipework and control equipment, jam open valves as well as scoring the face of valves and equipment due to the high velocity at which steam operates.

The most common practice is to provide and install a pipeline strainer upstream to any equipment, steam trap and valve set.

Steam trap checking

Even when adequately protected by a strainer, a steam trap may fail to operate for a number of reasons. Failure in the closed position would mean rapid reduction of plant output and remedial action must be taken. Conversely, if the trap fails in the open position or partially open position, output may not be affected but live steam could be passed to waste. The traditional method of checking for failure is the installation of a sight glass downstream of each trap to enable viewing of the flow discharge.

A recent development in trap checking is the advent of an electronic device which uses the electrical conductivity of the condensate to sense the conditions within the trap. The test points of a number of traps can be fitted remotely from their sensor chambers by suitable wiring, this is particularly advantageous where access is difficult.

Air venting

When steam is first admitted to the pipework on start-up or after a period of shutdown, the pipework is full of air. Further amounts of air and non-condensable gases are already mixed with the steam, and the air and gases must be removed from the system. This is achieved by the introduction of automatic air vents.

Balanced pressure air vents should be installed at the end of steam pipelines and large branch connections above the level of any condensate.

The discharge from the air vent should be piped to a safe place.

Reduction of heat losses

Reduction of heat losses within the steam distribution system is an important factor in the efficiency of the system.

Heat losses should be kept to an acceptable minimum so as much of the pipework and fittings within the distribution system as possible should be insulated. The thickness of insulation applied can vary significantly and the designer must make the most economical judgement on the thickness used.

Table 6 Heat emission from pipes

Temp. diff. steam to air	Pipe size									
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	150mm
°C	W/m									
56	54	65	79	103	108	132	155	188	233	324
67	68	82	100	122	136	168	198	236	296	410
78	83	100	122	149	166	203	241	298	360	500
89	99	120	146	179	205	246	289	346	434	601
100	116	140	169	208	234	285	337	400	501	696
111	134	164	198	241	271	334	392	469	598	816
125	159	191	233	285	321	394	464	555	698	969
139	184	224	272	333	373	458	540	622	815	1133
153	210	255	312	382	429	528	623	747	939	1305
167	241	292	357	437	489	602	713	838	1093	1492
180	274	329	408	494	556	676	808	959	1190	1660
194	309	372	461	566	634	758	909	1080	1303	1852

Table 7 Expansion of steel pipes

Final temperature (°C)	Expansion per 30m (mm)
66	19
93	29
121	41
177	61
204	74
232	84
260	97

Expansion (mm) =

1.25 x 1CT^5 x °C (diff) x 1000/m

External installations require weatherproofing as the heat losses of water saturated insulation, can be up to 50 times greater than from the same pipework in still air conditions.

Allowance for expansion

Allowance for expansion within the steam distribution system is required to give the necessary flexibility, as the system heats up to ensure no undue stresses are set up. Table 7 shows the approximate expansion of steel pipework installed at a temperature of 16°C, through a range of heat-up temperatures.

The distribution pipework where possible should be installed in reasonable lengths with sufficient bends, i.e., changes of direction to allow the expansion to be taken up ‘freely’.

Where ‘free’ movement is not possible other means of achieving the flexibility should be incorporated into the system.

Where practicable the expansion of the steam pipework and any expansion devices incorporated into it should be reduced by the inclusion of ‘cold draw’ or ‘cold stressing’ as it is alternatively known.

Expansion in long lengths of pipework can be taken up by nonmechanical means by the use of loops in the pipework.

Full loop

The full loop is achieved by one complete turn of the pipe, the ends being flanged for incorporation into the pipework system, the downstream side passes below the upstream side and should be fitted horizontally or a trapping set would be required to drain the build-up of condensate that would occur.

This type of loop has a tendency to unwind and can exert a force on the connecting flanges.

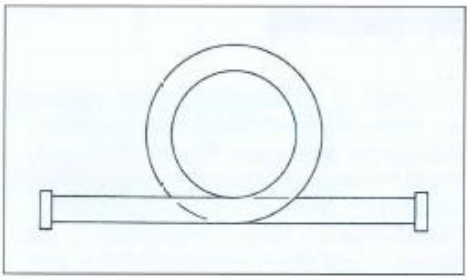
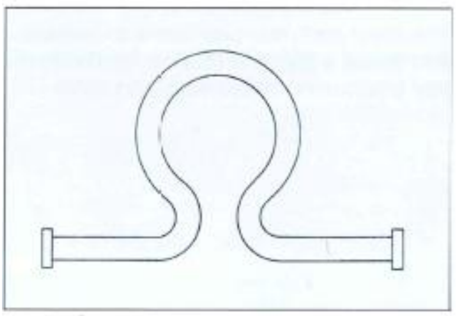


Figure 8 The full loop

Figure 9 The horse or lyre loop



Horse shoe or lyre loop

The horse shoe or lyre loop is commonly used. It has a tendency for the ends of the loop to straighten slightly but this does not cause any misalignment of the connecting flanges.

Expansion loops can be fabricated from straight lengths of pipes and bends, long radius bends should be used, as short radius bends restrict flexibility.

Sliding joint

Sliding joint expansion devices take up little space, however unless they are rigidly anchored they can develop problems of separating, any misalignment in pipework will cause the sleeve to bend, the joints also need regular maintenance, care should be taken in their use.

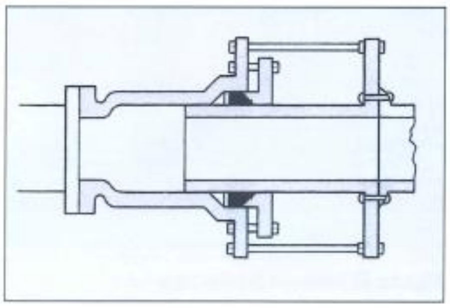


Figure 10 Sliding joint

Figure 11 Bellows joint

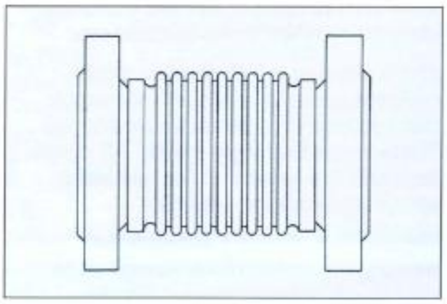


Table 8 *Flow of water in steel pipes (kg/h)*

Tube diameter (mm)	0.3 (30Pa)	0.5 (50Pa)	0.6 (60Pa)	0.8 (80Pa)	1.0 (100Pa)	1.4 (140Pa)
15	95	130	140	160	180	220
20	220	290	320	370	420	500
25	410	540	600	690	790	940
32	890	1180	1300	1500	1700	2040
40	1360	1790	2000	2290	2590	3100
50	2630	3450	3810	4390	4990	6000
65	5350	6950	7730	8900	10150	12100
80	8320	10900	12000	13800	15650	18700
100	17000	22200	24500	28200	31900	38000

Starting load i.e., running load x 2
Approx., frictional resistance (mbar per m of travel)
Heavy grade steel tube

Bellows

Bellows type devices are also in-line fittings but unlike the 'sliding joint' type require no packings, however pressure within the fitting can extend them, adequate anchoring and guiding is essential.

Articulated bellows

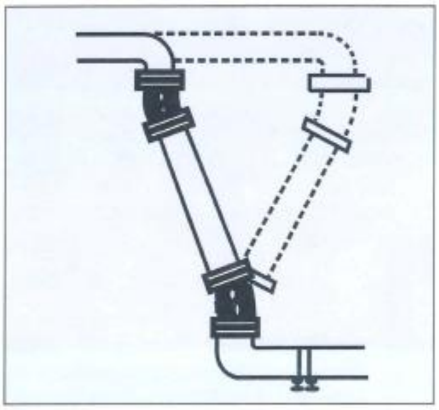
Articulated bellows are capable of absorbing the axial movement in the pipework and some of the lateral and angular displacement and have a number of advantages over other devices particularly at changes of direction. Anchoring and guiding are important with this type of device.

Heavy quality steel pipes have a linear coefficient of expansion of 1.25 x 10'5ºC per unit length. Table 7 gives the expansion in steel pipes.

Example 2

Assume a steam main 30 metres long has a temperature rise from 16°C to 260°C. Calculate the linear expansion to be taken up by an expansion unit.

Figure 12 *Articulated arrangement*



Expansion (mm) = $1.25 \times 10^{-5} \times 30 \times (260-16) \times 1000$
= 1.25x30x2.44
= 91.5mm

The heat emission from bare horizontal pipes with ambient temperatures between 10°C and 21 °C in still air conditions are shown in Table 8.

Condensate return

Design of the condensate return system is important. It should not impose any undue back pressure on the steam traps in the system.

The system should be adequately sized to carry maximum flow and be arranged with a fall to overcome the system resistance and flow under gravity conditions.

It is however rarely possible to return all the condensate produced in the distribution system all the way back to the boiler hotwell by gravity, some lifting will almost certainly be required.

It is therefore usual to direct the condensate to collecting receivers from which it can be pumped back to the boiler house.

At start up the plant is cold. Steam will condense rapidly and the steam consumption may be two or three times the normal running rate. Under these conditions, the condensate pipework will be required to pass two or three times the normal condensate rate. As the plant warms up, so the amount of condensate reduces to the running load.

Experience has shown that pipes sized for the above conditions will have an adequate capacity to handle the normal running conditions. For this kind of exercise the start-up load should be taken as not less than twice the running load. This provision will be sufficient for steam pressures up to 10 bar.

Above this pressure range, some additional capacity in the condense lines may however be desirable.

The flow rates and pressure drops given in Tables 5 and 8 may be found convenient for pipe sizing condensate lines.

Example 3

A plant having a normal running load of 1000kg/h and a starting load of 2000kg/h is to be adopted for condensate line sizing. Assuming a steam trap is fitted not more than 3m from the condensate receiver tank, determine a suitable diameter of pipe for the condensate pipeline.

Referring to Table 8, it will be seen that a 32mm pipe can handle 2040kg/h at a pressure drop of 1,40KPa (mbar) per metre of travel.

The overall pressure drop is therefore 1.40 x 3 = 4.20mbar and this small amount of back pressure would be acceptable. If, on the other hand, the condensate has to travel over a distance of say 500m, then the back pressure will be 500 x 1.4 = 700mbar and allowing for additional resistance, would impose a total back pressure in the region of 800mbar, to which must be added the back pressure caused by any lift in a line.

Condensate should run away from the trap by gravity but there are occasions when it is necessary to 'lift' it. This is achieved by the pressure available at the trap outlet and therefore, no steam trap will actually 'lift' the condensate.

It is handy to remember in initial design that for each 0.11 mbar (11 KPa) pressure at the trap, the condensate can be lifted 1 metre. It should be remembered when selecting steam traps that water hammer and attendant noise with the risk of mechanical damage are inevitable when lifting condensate.

Pumped condensate return pipe lines are generally flooded when running, these pipelines often follow the routing of the steam mains. Care should be taken not to connect the pipework from the traps draining the steam main to the flooded pumped condensate returns. Introducing condensate at higher pressure and temperature into flooded condensate pipework will cause re-evaporation where some of the condensate will flash-off into steam again, these steam bubbles will soon collapse in the cooler condensate causing severe water hammer.

Handling condensate

The receivers that collect condensate are usually at lower level than the boiler 'Hotwell' back at the boiler house, it will therefore be necessary to pump the condensate to higher levels than the collection receivers.

There are generally two accepted types of pump for condensate, one is positive displacement and the other uses electronically operated pumps.

Positive displacement pump

The positive displacement pump generally uses steam as the operating medium, compressed air can be used as an alternative, but due to aeration can have a corrosive effect.

In this type of set, a vented condensate receiver is located above the pump, the receiver ensures a constant head when the pump body is filling by gravity, whilst acting as a reservoir during the discharge stroke of the pump which ensures the flow of condensate from the plant to the receiver is not interrupted.

The advantages of this type of pump are that there is no cavitation and they can pump condensate at boiling point if required. Also because there are no electrics or motors they can continue to operate in damp or moisture laden conditions, they could continue to operate even if submerged in water.

Coupling two or more units together will increase the volume of condensate that can be handled.

Electronically operated pump

The electronically operated pump set has a much larger receiver, one or more motor driven pumps evacuate the condensate from the receiver back to the main plant Hotwell in the boiler house.

These sets can develop problems when dealing with hot condensate, at high temperatures it can flash to steam. This will severely reduce the efficiency of the unit and can also cause damage to the pump impellers.

Units that operate with low nett positive suction head cope with these conditions and will generally run trouble free.

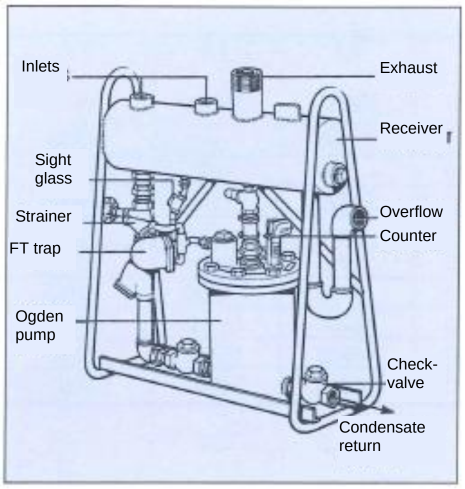


Figure 13 *Positive displacement pump*

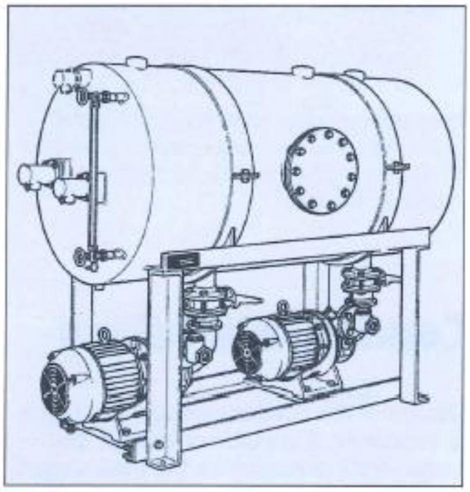


Figure 14 *Electronically operated condensate pump*

It should be remembered that both types of condensate sets do not discharge condensate on a continuous basis, therefore the discharge pipework should be sized to take account of this.

Due to the different operating design of the two sets, a good rule of thumb guide to sizing the discharge pipework is to allow three times the rated capacity of the positive displacement set and one and a half times for the electrically operated set.

Care should also be taken to reduce the amount of back pressure imposed on the units due to the frictional resistance in the pipework.

The design of the pipework is important, long horizontal runs should be avoided.

The most suitable arrangement is to have a vertical riser from the set followed by a gravity fall back to the boiler Hotwell. A long horizontal run followed by a final vertical lift would result in fully flooded return lines.