BYWORTH BOILERS LTD

SATURATED STEAM TABLES

PRESSURE		TEMPERATURE		SPECIFIC ENTHALPY						SPECIFIC VOLUME STEAM	
				WATER Sensible Heat h_f		EVAPORATION Latent Heat h_{fg}		STEAM Total Heat h_g			
bar g	psi	°C	°F	kJ/kg	btu/lb	kJ/kg	btu/lb	kJ/kg	btu/lb	m^3/kg	ft^3/lb
0.00	0.0	100.0	212.0	419.0	180.2	2257.0	970.3	2676.0	1150.5	1.673	26.80
0.10	1.5	102.7	216.8	430.2	185.0	2250.2	967.4	2680.4	1152.4	1.533	24.56
0.20	2.9	105.1	221.2	440.8	189.5	2243.4	964.5	2684.2	1154.0	1.414	22.65
0.25	3.6	106.3	223.3	445.7	191.6	2240.3	963.2	2686.0	1154.8	1.361	21.80
0.30	4.4	107.4	225.3	450.4	193.6	2237.2	961.8	2687.6	1155.5	1.312	21.02
0.40	5.8	109.6	229.2	459.7	197.6	2231.3	959.3	2691.0	1156.9	1.225	19.62
0.50	7.3	111.6	232.9	468.6	201.5	2225.6	956.8	2694.2	1158.3	1.149	18.41
0.75	10.9	116.3	241.3	487.9	209.8	2213.0	951.4	2700.9	1161.2	0.997	15.97
1.00	14.5	120.4	248.8	505.6	217.4	2201.1	946.3	2706.7	1163.7	0.881	14.11
1.50	21.8	127.6	261.7	536.1	230.5	2181.0	937.7	2717.1	1168.1	0.714	11.44
2.00	29.0	133.7	272.6	562.2	241.7	2163.3	930.1	2725.5	1171.8	0.603	9.66
2.50	36.3	139.0	282.2	585.0	251.5	2147.6	923.3	2732.6	1174.8	0.522	8.36
3.00	43.5	143.8	290.8	605.3	260.2	2133.4	917.2	2738.7	1177.4	0.461	7.38
3.50	50.8	148.0	298.4	623.6	268.1	2120.3	911.6	2743.9	1179.7	0.413	6.62
4.00	58.0	152.0	305.5	640.7	275.5	2108.1	906.3	2748.8	1181.8	0.374	5.99
4.50	65.3	155.6	312.0	656.3	282.2	2096.7	901.4	2753.0	1183.6	0.342	5.48
5.00	72.5	158.9	318.1	670.9	288.4	2086.0	896.8	2756.9	1185.3	0.315	5.05
5.50	79.8	162.1	323.7	684.6	294.3	2075.7	892.4	2760.3	1186.7	0.292	4.68
6.00	87.0	165.0	329.1	697.5	299.9	2066.0	888.2	2763.5	1188.1	0.272	4.36
6.50	94.3	167.8	334.1	709.7	305.1	2056.8	884.3	2766.5	1189.4	0.255	4.08
7.00	101.5	170.5	338.9	721.4	310.1	2047.7	880.4	2769.1	1190.5	0.240	3.84
7.50	108.8	173.0	343.4	732.5	314.9	2039.2	876.7	2771.7	1191.6	0.227	3.64
8.00	116.0	175.4	347.8	743.1	319.5	2030.9	873.1	2774.0	1192.6	0.215	3.44
8.50	123.3	177.8	352.0	753.3	323.9	2022.9	869.7	2776.2	1193.6	0.204	3.27
9.00	130.5	180.0	355.9	763.0	328.0	2015.1	866.3	2778.1	1194.4	0.194	3.11
9.50	137.8	182.1	359.8	772.5	332.1	2007.5	863.1	2780.0	1195.2	0.185	2.96
10.00	145.0	184.1	363.4	781.6	336.0	2000.1	859.9	2781.7	1195.9	0.177	2.84
10.50	152.3	186.0	366.8	790.0	339.6	1993.0	856.8	2783.0	1196.5	0.171	2.74
11.00	159.5	188.0	370.4	798.2	343.2	1986.0	853.8	2784.2	1197.0	0.163	2.61
11.50	166.8	190.0	374.0	807.0	346.9	1979.0	850.8	2786.0	1197.8	0.157	2.51
12.00	174.0	191.7	377.0	815.1	350.4	1972.5	848.0	2787.6	1198.5	0.151	2.42
12.50	181.3	193.0	379.4	823.0	353.8	1966.0	845.2	2789.0	1199.1	0.146	2.34
13.00	188.5	195.1	383.2	830.4	357.0	1959.6	842.5	2790.0	1199.5	0.141	2.26
13.50	195.8	197.0	386.6	838.0	360.3	1953.0	839.6	2791.0	1199.9	0.136	2.18
14.00	203.1	198.4	389.0	845.1	363.3	1947.1	837.1	2792.2	1200.4	0.132	2.11
14.50	210.3	200.0	392.0	852.0	366.3	1941.0	834.5	2793.0	1200.8	0.128	2.05
15.00	217.6	201.5	394.6	859.0	369.3	1935.0	831.9	2794.0	1201.2	0.124	1.99
16.00	232.1	204.4	399.9	872.3	375.0	1923.4	826.9	2795.7	1201.9	0.117	1.87
17.00	246.6	207.2	404.9	885.0	380.5	1912.1	822.1	2797.1	1202.5	0.110	1.76
18.00	261.1	209.9	409.8	897.2	385.7	1901.3	817.4	2798.5	1203.1	0.105	1.68
19.00	275.6	212.5	414.4	909.0	390.8	1890.5	812.8	2799.5	1203.6	0.100	1.60
20.00	290.1	215.0	418.9	920.3	395.7	1880.2	808.3	2800.5	1204.0	0.095	1.52
21.00	304.6	217.4	423.2	931.3	400.4	1870.1	804.0	2801.4	1204.4	0.091	1.45
22.00	319.1	219.7	427.4	941.9	404.9	1860.1	799.7	2802.0	1204.6	0.087	1.39
23.00	333.6	221.9	431.3	952.2	409.4	1850.4	795.5	2802.6	1204.9	0.083	1.33
24.00	348.1	224.0	435.2	962.2	413.7	1840.9	791.4	2803.1	1205.1	0.080	1.28
25.00	362.6	226.1	439.0	972.1	417.9	1831.4	787.4	2803.5	1205.3	0.077	1.23
26.00	377.1	228.2	442.7	981.6	422.0	1822.2	783.4	2803.8	1205.4	0.074	1.19
27.00	391.6	230.1	446.3	990.7	425.9	1813.3	779.6	2804.0	1205.5	0.071	1.14
28.00	406.1	232.1	449.7	999.7	429.8	1804.4	775.8	2804.1	1205.5	0.069	1.10
29.00	420.6	233.9	453.1	1008.6	433.6	1795.6	772.0	2804.2	1205.6	0.067	1.07
30.00	435.1	235.8	456.4	1017.0	437.2	1787.0	768.3	2804.0	1205.5	0.065	1.03
31.00	449.6	237.6	459.6	1025.6	440.9	1778.5	764.6	2804.1	1205.5	0.063	1.00
32.00	464.1	239.3	462.7	1033.9	444.5	1770.0	761.0	2803.9	1205.5	0.061	0.97
33.00	478.6	241.0	465.7	1041.9	447.9	1761.8	757.4	2803.7	1205.4	0.059	0.94
34.00	493.1	242.6	468.7	1049.7	451.3	1753.8	754.0	2803.5	1205.3	0.057	0.91
35.00	507.6	244.3	471.7	1057.7	454.7	1745.5	750.4	2803.2	1205.2	0.055	0.89
36.00	522.1	245.9	474.5	1065.7	458.2	1737.2	746.9	2802.9	1205.0	0.054	0.86
37.00	536.6	247.4	477.4	1072.9	461.3	1729.5	743.6	2802.4	1204.8	0.052	0.84
38.00	551.1	249.0	480.1	1080.3	464.4	1721.6	740.2	2801.9	1204.6	0.051	0.82
39.00	565.6	250.4	482.8	1087.4	467.5	1714.1	736.9	2801.5	1204.4	0.050	0.80
40.00	580.2	251.9	485.5	1094.6	470.6	1706.3	733.6	2800.9	1204.2	0.049	0.78

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SOME USEFUL CALCULATIONS

To calculate actual steam production from the "from & at" rating

$$\text{Actual Output} = \frac{M \times 2257}{Ah_g - (T_F \times 4.19)}$$

Where;

M	The "from & at" rating of the boiler shown on the nameplate in kg/h
Ah_g	h_g at the working pressure of the boiler in kJ/kg
T_F	Feed tank / howell temperature in °C

for example;
to calculate the actual steam produced by a 5000 kg/hr steam boiler operating at 7 bar with feed water supplied at 85°C

M	5000	kg/hr		$\frac{5000 \times 2257}{2769.1 - (85 \times 4.19)}$	=	4677 kg/hr
Ah_g	2769.1	kJ/kg	(from the table overleaf)			
T_F	85	°C				

To calculate the required blowdown rate of a boiler

$$\text{Blowdown rate} = \frac{F \times S}{B - F}$$

Where;

F	Feed tank TDS in ppm
S	Actual boiler steam production in kg/hr
B	Maximum TDS allowable in the boiler in ppm

for example;

The steam boiler in the previous example has a feed tank with a TDS of 80ppm, in order to stay below 3500ppm it will need to blowdown at least;

F	80	ppm	$\frac{80 \times 4677}{3500 - 80}$	=	109 kg/hr
S	4677	kg/hr			
B	3500	ppm			

To calculate the energy lost as a result of boiler blowdown as a percentage of overall fuel costs

$$\text{Energy lost} = \frac{\Delta H_f \times BR \times 100}{(Ahg + \Delta H_f) \times S}$$

Where;

T_F	Temperature of feed water in °C
T_B	Temeprature of steam at boiler pressure in °C
ΔH_f	(TF - TB) x 4.19 kJ/kg
BR	Blowdown Rate in kg/hr
AH_g	h_g at the working pressure of the boiler in kJ/kg
S	Actual boiler steam production in kg/hr

To continue the example above;

T_F	85	°C		$\frac{358.2 \times 109 \times 100}{(2769.1 + 358.2) \times 4677}$	=	0.27%
T_B	170.5	°C	(from the table overleaf)			
ΔH_f	(170.5 - 85) x 4.19 =	358.2	kJ/kg			
BR	109	kg/hr				
AH_g	2769.1	kJ/kg	(from the table overleaf)			
S	4677	kg/hr				

To calculate the amount of energy required to raise a mass of steam at a given pressure from a given feed water temperature

$$\text{Energy Required} = \frac{Ah_g - (T_F \times 4.19) \times S}{\text{Eff.}}$$

Where;

AH_g	h_g at the working pressure of the boiler in kJ/kg
T_F	Temperature of feed water in °C
Eff.	Boiler efficiency expressed as a decimal
S	Actual boiler steam production in kg/hr

For example
To raise an ACTUAL 5000 kg/hr of steam at 7 bar from 85°C feed water will require;

AH_g	2769.1	kJ/kg	(from the table overleaf)	$\frac{2769.1 - (85 \times 4.19) \times 5000}{0.8}$	=	15,081	MJ/hr
T_F	85	°C					
Eff	0.8		(i.e. 80%)		or	4189	kW
S	5000	kg/hr					

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