boiler bible

THERMODYNE

Dear Boiler Users,

With great pleasure and enthusiasm we present you with the maiden edition of our **Thermodyne boiler bible**. With an industrial presence of 24 years and serving a vast variety of clients the undersigned felt a special bond of respect and gratitude for all of you who made us grow with yourselves.

The technological progress and stiff competitions we experienced over the past few years have imbibed very strong values in our organization and enriched us with the experience gained.

In the times to come, the society and industry gears up for changes – and positive changes which will multiply human sustainability and innovation. We would be proud to write the success story of a new world along with you, based on stronger engineering ideas and trust in the same.

So that our presence is felt at your premises every moment, and our bond is witnessed by more things than only the machines we exchange, we heartily share with you the simple and subtle engineering facts of everyday usage through this handbook. Your valuable inputs to make subsequent editions more comprehensive will be received with due gratitude.

Keep the fire lighting!

Warm Regards,

Ashwani Setia

Thermodyne Engineering Systems

*Although we made best efforts to compile near accurate data, errors might have crept in. Designers are requested to verify the data from an authentic data source before making critical design calculations.

CONTENTS

THERMODYNE

SYSTEM OF UNITS AND CONVERSION FACTORS

A) System of Units :

Numerical calculations in engineering require a consistent system of units. Several systems exist and each is equally correct. Any of the systems may be chosen for use but confusions should be avoided. The following table summarises the relationship between mass and force in various systems of units. ($F = ma/g_c$)

Table A : Magnitude and Units of ge

System	Mass (m)	Length (l)	Time (t)	Force (F)	G_c
Absolute	Gm	Cm	Sec	dyne	1.0 gm cm/dyne sec^2
SI	Kg	M	Sec	newton	1.0 m kg/newton sec^2
MKS	Kg	M	Sec	kgf	9.806 m kg/kgf sec^2
English	Lbm	Ft	Sec	lbt	32.174 lbm ft/ibt sec^2
English (Engg)	Slug	Ft	Sec	lbt	1.0 slug ft/lbf sec^2
English (Absolute)	Lbm	Ft	Sec	poundal	1.0 lbm ft/poundal sec^2

B) SI Units:

It is the common system of units accepted by all countries of the world for international usage. This system is known as "System International Abbreviated as SI Units." It is the purest form of metric units and is an extension and refinement of traditional metric system. There are seven basic units as given in Table A, which are arbitrarily defined (Ref. IS : 5-1969) Internationally.

Table B : Basic Units in SI

Sr. No.	Physical Quantity	Unit	Symbol
1	Length	meter	m
2	Mass	kilogram	kg
3	Time	second	s
4	Electrical current	ampere	A
5	Luminous Intensity	candela	Cd
6	Thermodynamic temp.	kelvin	K
7	Amount	mole	Mole

Table C depicts the important derived units which are often used by mechanical engineers. In SI units, only decimal multiples and submultiples are used. The different factors may be abbreviated by use of prefix or symbols as shown in Table D

C) Writing of Units :

Some accepted recommendations for the representation of SI units and symbols are given below :

1. Full names of units or prefixes shall be written in upright roman, lower case letters. No capitals are used even if unit is named after a person, e.g. kelvin, newton , joule, watt, volt etc.
2. Symbols of units are written (i) in capitals if named after a person e.g. K, N, J and W etc (ii) otherwise in lower case letters e.g. m, s, kg etc. (see table B)
3. Algebraic quantities are written in italics say E for e.m.f. and I for current.
4. No Abbreviation be used for units. Write either as a symbol or full name.
5. Units remain unaltered in plurals. No 's' be sued either in full name or in symbol.
6. No full stop (period) or a punctuation mark be used e.g. 3 m; SI units ; 100.25 kg.
7. If a prefix is used with a symbol no space be left in between e.g. MJ and not M J.It is the common system of units accepted by all countries of the world for international usage.

For Table B : Basic Units in SI

8. Not more than one prefix be used e.g. for 10^{-9} m use nm and not mμm.
9. Power to base unit applies to whole and not to base alone e.g.

   $km^2 = (km)^2 = 10^6\,m^2$

   $= k(m)^2$ or $10^3\,m^2$
10. Leave a space between numeral and its unit. 64 kW and not 64kW.
11. In a combined unit a space may or may not be left. ISI has recommended that even a full stop may be used e.g. Nm, N m, N. m are correct but m N is not correct because it may imply milinewton. Hence it should be checked that it does not give some other meaning.
12. A solids or oblique may be used or a negative power may be used e.g. m , m/s or ms^{-1} are all correct but ms^{-1} may mean 'per milisecond'; but since no prefix should have been used in denominator, this complication may not occur.
13. For large numerals use groups of three without a coma (though in trade accounting it may continue). Grouping should start both sides from decimal. No grouping is done if figures are only 4.

Correct	Incorrect
234 869.739 45	23 486 9.7 394 5
40 000	40000
3456.72	3 456.7 2
0.123 457	0123457

Table C : Derived Units in SI

Physical Quantity	Unit	Symbol
Force	newton	N = kg m/s^2
Frequency	hertz	Hz = c/s
Work, energy or heat	joule	J = Nm
Power, Heat flow rate	watt	W = J/s
Torque, Bending moment	newton - meter	Nm = J
Pressure, stress or modulus of elasticity	newton per square meter	N/m^2
Dynamic viscosity	newton second per square meter	Ns/m^2
Thermal conductivity	watt per meter per degree kelvin	W/mK = J/s m K
specific heat	joule per kilogram per degree kelvin	

Table D : Multiples of Ten

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{12}	tera	T	10^{-1}	deci	d
10^{9}	giga	G	10^{-2}	centi	c
10^{6}	mega	M	10^{-3}	milli	m
10^{3}	kilo	k	10^{-6}	micro	μ
10^{2}	hecto	h	10^{-9}	nano	n
10^{1}	deca	da	10^{-12}	pico	p
			10^{-15}	femto	f
			10^{-18}	atto	a

CONVERSION OF MEASURES

Metric to British Units			British to Metric Units			
Length						
1 mm	=	0.03937 in.	1 in.	=	25.4mm	
1 m	=	3.281 ft.	1 ft.	=	0.3048 m.	= 12 in.
1 m	=	1.094 yd.	1 yd.	=	0.9144 m.	= 3 ft.
1 Km	=	0.6214 terrestrial mile	1 Statute mile	=	1.609 Km.	
1 Km	=	0.54 nautical mile	1 Sea mile	=	1.853 Km.	
Areas						
1 cm^2	=	0.1550 in^2.	1 in^2	=	6.45 cm^2	
1 m^2	=	10.764 $ft.^2$	1 $ft.^2$	=	0.0929 m^2	
1 m^2	=	1.196 sq. yd.	1 sq. yd.	=	0.836 m^2	
1 ha	=	2.471 acres	1 acre	=	0.4047 ha	
Volume						
1 cm^3	=	0.061 cu. in.	1 cu. in	=	16.387 cm^3	
1 m^3	=	35.32 $ft.^3$	1 $ft.^3$	=	0.0283 m^3	
1 m^3	=	1.308 cu. yd.	1 cu. yd.	=	0.7646 m^3	
Specific Volume & Weight						
1 m^3/kg.	=	16.01 ft^3/lb.	1 $ft.^3$/lb.	=	0.0624 m^3/kg	
1 kg/m^3	=	0.0624 lb./$ft.^3$	1 lb./$ft.^3$	=	16.01 kg/m^3	
Capacity						
1 L	=	0.26417 U. S. Gallon	1 U. S. Gallon	=	3.785 L	
1 L	=	0.21997 Imp. Gallon	1 Imp. Gallon	=	4.54 L	
1 L	=	0.0284 Bushel (U.S.)	1 Bushel (U.S.)	=	35.238 L	
1 L	=	0.0275 Bushel (Br.)	1 Bushel (Br.)	=	36.348 L	

1 gill = 0.142 L, 1 Pint = 0.568 L, 1 quart = 1.136 L

1 Bushel (US)	=	0.03524 m^3	1 Bushel (Br.)	=	0.03634 m^3
1 U.S. Gallon	=	0.833 Imp. Gallon	1 Imp. Gallon	=	1.2 U.S. Gallon

CONVERSION OF MEASURES

Metric to British Units			British to Metric Units		
Weights					
1 g.	=	15.43 grains	1 grain	=	64.8 mg.
1 g.	=	0.0351 oz.	1 oz.	=	28.35 g.
1 kg.	=	2.2046 lb.	1 lb.	=	0.4536 kg.
1 metric ton	=	1.102 U. S. short ton	1 U. S. short ton	=	907 kg.
1 metric ton	=	0.984 ton (Br.)	1 Br. long ton	=	1016 kg.

1 Metric ton = 1000 Kg., 1 Short ton = 2000 lb., 1 Long ton = 2240 lb.
1 Stone (St) = 6.35 Kg., 1 Pound = 7000 grains,

Pressure					
1 kg/cm^2	=	14.223 lb/sq. in (PSI)	1 lb/sq. in (PSI)	=	0.0703 kg/cm^2
1 mm WG	=	0.002937 in of Mercury	1 in. of Mercury	=	340.39 mm WG
			1 ounce/sq.in.	=	43.9 mm WG

Velocity					
1 m/sec	=	196.9 ft/min	100 ft/min	=	0.508 m/sec
1 m/sec	=	3.28 ft/sec	100 ft/sec	=	30.4 m/sec

1 nautical mile per hour = 1 knot

Flow					
1 m^3/hr	=	0.59.CFM (Cu. ft/min)	1 CFM	=	1.697 m^3/hr

Temperature

K = 273.16 + ^{0}C.

$$C = \frac{F - 32}{1.8}$$

^{0}F = (1.8 x ^{0}C) + 32

^{0}R = ^{0}F + 459.67

= 1.8 x ^{0}K

Force Units

1 newton (N)	=	10^5 gm-cm-sec^2 (dyne)
	=	1 kg-m/sec^2 = 0.012 kgf
	=	0.2481 lbf.
1 gm cm-sec^2 (dyne)	=	10^{-5} 1bm ft.sec^2 (poundal)
	=	7.233×10^{-5} lbm ft-sec^2 (poundal)
	=	2.481×10^{-6} lbf.
1 kg m sec^2	=	105 gm cm sec^{-2}
	=	1 newton
	=	7.233 1 bm ft sec^{-2}
	=	2.481×10^{-1} lbf
1 lbm-ft sec^2	=	1.3826×10^4 gm cm-sec^2
	=	1.3826×10^{-2} kg-m-sec^{-1}
	=	0.13826 N
	=	3.108×10^{-2} lbf
1 lbf	=	4.4482×10^5 gm-cm-sec^2
	=	4.482 kg m sec^{-2}
	=	4.482 N
	=	32.174 lbm-ft-sec^{-2}
1 kgf	=	2.205 lbf
	=	9.80665 N

CONVERSION OF PRESSURE UNITS

	PSI	kg/cm^2	Atmosphere	Bar	mmWC	Pascal	Pleze
PSI	1	0.07031	0.06804	0.069	703.1	6894.75	6.895
kg/cm^2	14.223	1	0.9678	0.981	10000	98066.5	98.08
Atmosphere	14.69	1.033	1	1.0133	10330	101325	101.32
Bar	14.5	1.019	0.986	1	10197.2	100000	100
mmWC	14.223×10^{-4}	1.0×10^{-4}	96.78×10^{-6}	9.81×10^{-5}	1	9.808	98.04×10^{-4}
Pascal (N/m^2)	145×10^{-6}	10.19×10^{-6}	9.869×10^{-6}	10^{-5}	0.1019	1	0.001
Pleze	0.145	0.01019	0.00986	0.01	102	1000	1

CONVERSION OF HEAT UNITS

1 BTU	=	0.252 kcal
1 BTU	=	107.7 kgm
1 BTU/sec.	=	1.055 KW
1 BTU/lb	=	0.5556 kcal/kg
1 BTU/cu ft.	=	8.900 kcal/m^3
1 BTU/sq.ft.h	=	2.71 kcal/m^{2}h
1 BTU/sq.ft.h^{0}F	=	4.886 kcal/m^{2}h^{0}C
1 BTU/ft h^{0}F	=	1.49 kcal/m h^{0}C
1 BTU in/sq.ft.hr^{0}F	=	0.124 kcal/mh^{0}C
1 BTU/lb^{0}F	=	1.001 kcal/kg^{0}C
1 BTU cu.ft^{0}F	=	16.2 kcal/m^3 ^{0}C
1 kcal	=	3.968 BTU
1 kgm	=	0.00930 BTU
1 KW	=	0.948 BTU/sec.
1 kcal/kg	=	1.80 BTU/lb
1 kcal/m^3	=	0.112 BTU/cu.ft
1 kcal/m^{2}h	=	0.369 BTU/sq.ft.h
1 kcal/m^{2}h^{0}C	=	0.205 BTU/sq.ft.h^{0}F
1 kcal/mh^{0}C	=	0.67 BTU/ft.h^{0}F
1 kcal m/h^{0}C m^2	=	8.07 BTU in/sq.ft.g^{0}F
1 kcal/kg^{0}C	=	0.999 BTU/lb^{0}F
1 kcal/m^3 ^{0}C	=	0.0624 BTU/cu ft^{0}F

CONVERSION OF ENERGY UNITS

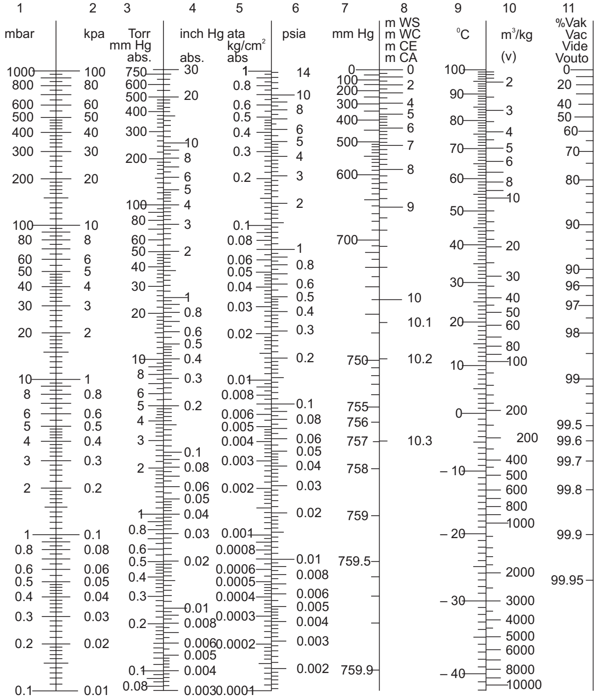
	kg.m.	kcal	Joule	kW hour	HP hour
kg.m.	1	0.00235	9.81	0.27×10^{-5}	0.365×10^{-5}
kcal	427	1	4186.8	0.001161	0.001556
Joule	0.102	0.000239	1	27.77×10^{-8}	37.25×10^{-8}
KW hour	3,67,098	860	3.600×10^{6}	1	1.3411
HP hour	2,73,745	641.18	26,84,519	0.74565	1

CONVERSION OF POWER UNITS

	kg.m/sec	kcal/sec	KW	HP	Ch
kg.m/sec	1	0.00234	0.00981	0.0131	0.0133
kcal/sec	427	1	4.17	5.59	5.67
KW	101.97	0.239	1	1.341	1.359
HP	76	0.178	0.746	1	1.014
Ch	75	0.176	0.736	0.986	1

VACUUM MEASUREMENT UNITS

- For the measurement of vacuum, a number of different units are used. Scales 1 and 2 show the current valid pressure units, which correspond to the International system of Units (SI).
- Scales 3 to 8 are the units previously used. Scales 1 to 8 give measures of absolute pressure.
- Scales 7 and 8 are units previously used for negative pressure.
- Scale 9 shows the boiling temperatures belonging to the pressures.
- In Scale 10, the specific volume of water vapor can be found
- Scale 11 gives vacuum percentage



CONVERSION OF ^{0}C to ^{0}F

The Conversion factors for both units into each other are:

$^0C = (^0F - 32) \times 5/9$ $^0F = (9/5 \times {}^0C) + 32$

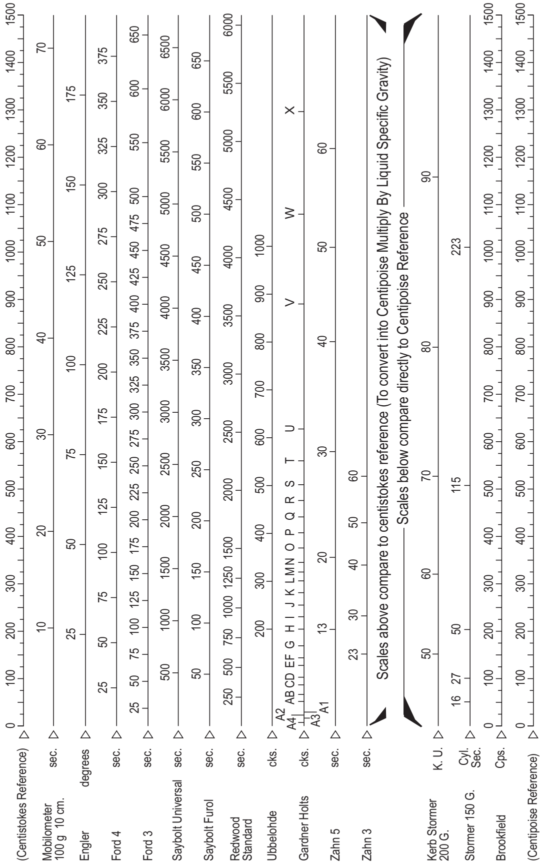
^{0}C	^{0}F	^{0}C	^{0}F
0	32	31	87.8
1	33.8	32	89.6
2	35.6	33	91.4
3	37.4	34	93.2
4	39.2	35	95
5	41	36	96.8
6	42.8	37	98.6
7	44.6	38	100.4
8	46.4	39	102.2
9	48.2	40	104
10	50	41	105.8
11	51.8	42	107.6
12	53.6	43	109.4
13	55.4	44	111.2
14	57.2	45	113
15	59	46	114.8
16	60.8	47	116.6
17	62.6	48	118.4
18	64.4	49	120.2
19	66.2	50	122
20	68	100	212
21	69.8	120	248
22	71.6	140	284
23	73.4	150	302
24	75.2	200	392
25	77	250	482
26	78.8	300	572
27	80.6	350	662
28	82.4	400	752
29	84.2	450	842
30	86	500	932

TABLE OF INTERNATIONAL GAUGES

No. of Gauges	British			U. S.		
	S.W.G. mm	B.W.G. mm	B.G. mm	B.S.G. mm	S.W.G. mm	B.S.G. Sheets mm
5/0	10.972	12.700	14.943	-	10.935	-
4/0	10.160	11.532	13.757	11.681	10.000	11.684
3/0	9.449	10.795	12.700	10.405	9.208	10.404
2/0	8.839	9.652	11.308	9.266	8.407	9.266
0	8.229	8.636	10.068	8.255	7.785	8.252
1	7.620	7.620	8.971	7.348	7.188	7.348
2	7.010	7.213	7.993	6.544	6.668	6.543
3	6.401	6.579	7.122	5.829	6.190	5.827
4	5.893	6.045	6.350	5.189	5.723	5.189
5	5.385	5.588	5.65	4.621	5.258	4.620
6	4.877	5.156	5.032	4.115	4.877	4.115
7	4.470	4.572	4.480	3.665	4.496	3.665
8	4.064	4.191	3.988	3.263	4.115	3.264
9	3.658	3.759	3.550	2.906	3.767	2.096
10	3.251	3.404	3.175	2.588	3.429	2.588
11	2.946	3.048	2.827	2.303	3.061	2.304
12	2.642	2.769	2.517	2.052	2.680	2.778
13	2.337	2.413	2.240	1.828	2.324	1.829
14	2.032	2.108	1.994	1.628	2.032	1.628
15	1.829	1.829	1.775	1.450	1.829	1.450
16	1.626	1.651	1.588	1.290	1.588	1.290
17	1.422	1.473	1.412	1.151	1.372	1.151
18	1.219	1.245	1.257	1.024	1.207	1.024
19	1.016	1.067	1.118	0.912	1.041	0.912
20	0.914	0.889	0.996	0.812	0.884	0.813
21	0.814	0.814	0.886	0.723	0.806	0.724
22	0.711	0.711	0.794	0.644	0.726	0.643
23	0.610	0.635	0.707	0.573	0.655	0.574
24	0.559	0.559	0.629	0.511	0.584	0.511
25	0.508	0.508	0.560	0.455	0.518	0.455

VISCOMETER COMPARISON CHART

For Newtonian Liquids



Note : This chart is intended to be an aid in comparing viscometer measurements of Newtonian liquids by referencing to absolute and Kinematic Viscosity.

APPROXIMATE CONVERSION OF VISCOSITIES

Engler	sec. Redwood No. 1	Centistokes	sec. Saybolt univ.
1.25	34.00	3.40	37.20
1.30	35.80	3.90	38.90
1.40	38.50	5.00	42.50
1.50	42.00	6.25	46.30
1.60	45.00	7.50	50.00
1.70	48.00	8.50	54.00
1.80	51.00	9.60	57.50
2.00	57.50	11.80	65.50
2.50	74.00	16.80	84.00
3.00	90.00	21.00	103.00
4.00	120.00	29.00	140.00
5.00	155.00	37.00	173.00
6.00	185.00	45.00	205.00
6.50	200.00	49.00	226.00
8.00	250.00	60.00	280.00
10.00	320.00	76.00	355.00
15.00	470.00	115.00	525.00
19.50	600.00	148.00	674.00
20.00	625.00	150.00	700.00
30.00	925.00	222.00	1080.00
32.50	1000.00	247.00	1120.00
40.00	1250.00	300.00	1400.00
50.00	1600.00	380.00	1780.00
52.00	1500.00	390.00	1800.00
60.00	1900.00	460.00	2180.00
70.00	2200.00	550.00	2500.00
80.00	2500.00	600.00	2800.00
90.00	2800.00	700.00	3200.00
97.50	3000.00	747.00	3370.00
100.00	3100.00	760.00	3500.00
150.00	4700.00	1150.00	5400.00
195.00	6000.00	1400.00	6840.00
200.00	6250.00	1500.00	7000.00
250.00	7500.00	1800.00	8500.00
300.00	9500.00	2200.00	-
350.00	11000.00	2500.00	-
450.00	14000.00	3250.00	-
550.00	16000.00	4000.00	-

VISCOSITY IN CENTISTOKES

FOR WATER

Temp. t^0C	Viscosity	Temp. t^0C	Viscosity
0	1.790	60	0.477
5	1.520	70	0.415
10	1.310	80	0.367
15	1.140	90	0.328
20	1.010	100	0.296
25	0.896	110	0.276
30	0.804	120	0.257
40	0.661	130	0.238
50	0.556	140	0.218

FOR WATER VAPOUR AT ATMOSPHERIC PRESSURE

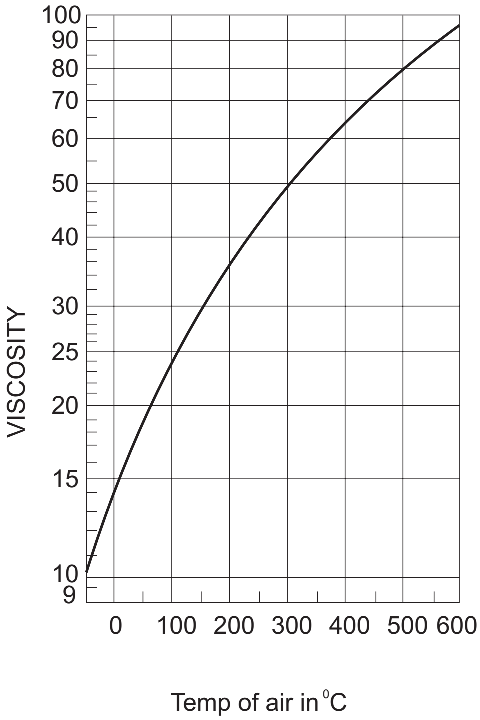
Temp. t^0C	Viscosity	Temp. t^0C	Viscosity
100	21.8	300	54.3
200	36.5	400	75.6

FOR DRY SATURATED STEAM

(Approximate Value)

kg/cm^2	Viscosity	kg/cm^2	Viscosity
1	22	8	3.8
1.5	15	10	3.1
2	12	15	2.2
3	8.6	20	1.7
5	5.9	30	1.2
6	4.9	40	0.9

VISCOSITY OF AIR
in Centistokes



CONVERSION OF BOILER CAPACITY

BRITISH AND US STEAM FROM WATER AT 100°C		COMMON MARKET STEAM FROM WATER AT 100°C	
Boiler HP	kg of steam/hr @540 kcal/kg	kg of steam/hr @640 kcal/kg	Power in kcal/hr x 1000
01	15.65	13.20	8.45
05	78.00	66.00	42.25
10	156.00	132.00	84.50
15	235.00	198.00	126.75
20	313.00	264.00	169.00
30	470.00	396.00	253.50
40	626.00	528.00	338.00
50	783.00	660.00	422.50
60	940.00	792.00	507.00
70	1096.00	924.00	591.50
80	1253.00	1056.00	676.00
100	1566.00	1320.00	845.00
150	2350.00	1980.00	1267.50
200	3130.00	2640.00	1690.00
250	3915.00	3300.00	2112.50
300	4700.00	3960.00	2535.00
350	5480.00	4620.00	2957.50
400	6260.00	5280.00	3380.00
450	7040.00	5940.00	3802.50
500	7830.00	6600.00	4225.00
550	8610.00	7260.00	4647.50
600	9390.00	7920.00	5070.00
650	10179.00	8580.00	5592.50
700	10962.00	9240.00	5915.00
750	11745.00	9900.00	6337.50
800	12528.00	10560.00	6760.00

Definition of Boiler Horse Power = Evaporation of 15.65 kg of water/hr from and at 100°C

1 Boiler HP = 33,479 BTU/hr = 8450 kcal/hr

PHYSICAL PROPERTIES OF WATER (LIQUID)

t (^0C)	ρ (kg/m^3)	C_p ($kcal/kg^0C$)	$k \times 10^2$ (cal/sm K)	$\alpha \times 10^4$ m^2/hr	$\mu \times 10^2$ (kg/hr m)	$\upsilon \times 10^6$ (m^2/sec)	Pr
0	999.9	1.003	13.117	4.71	644.093	1.789	13.67
10	999.7	0.998	13.671	4.94	469.818	1.306	9.52
20	998.2	0.996	14.252	5.16	361.892	1.006	7.02
30	995.7	0.994	14.695	5.35	288.668	0.805	5.42
40	992.2	0.994	15.082	5.51	235.602	0.659	4.31
50	988.1	0.994	15.414	5.65	197.771	0.556	3.54
60	983.2	0.995	15.691	5.78	169.305	0.478	2.98
70	977.8	0.997	15.885	5.87	146.370	0.415	2.55
80	971.8	0.999	16.051	5.96	127.924	0.365	2.21
90	965.3	1.002	16.189	6.03	113.507	0.326	1.95
100	958.4	1.005	16.245	6.09	101.910	0.295	1.75
110	951.0	1.008	16.300	6.13	93.215	0.272	1.60
120	943.1	1.012	16.328	6.16	85.448	0.252	1.47
130	934.8	1.016	16.328	6.19	78.744	0.233	1.36
140	926.1	1.021	16.300	6.20	72.475	0.217	1.26
150	917.0	1.027	16.272	6.22	66.792	0.203	1.17
160	907.4	1.035	16.245	6.23	62.206	0.191	1.10
170	897.3	1.043	16.161	6.22	58.623	0.181	1.05
180	886.9	1.052	16.051	6.20	54.976	0.173	1.00
190	876.0	1.062	15.940	6.17	51.921	0.165	0.96
200	863.0	1.073	15.774	6.14	49.266	0.158	0.93
220	840.3	1.099	15.359	5.99	44.823	0.148	0.89
240	813.6	1.132	14.944	5.84	41.356	0.141	0.87
260	784.3	1.178	14.390	5.61	38.274	0.135	0.87
280	750.7	1.245	13.671	5.27	35.596	0.131	0.90
300	712.5	1.336	12.841	4.75	32.835	0.129	0.97

THERMODYNE

PHYSICAL PROPERTIES OF SATURATED STEAM

t (^{0}C)	ρ (kg/m^3)	C_p (kcal/kg^{0}C	k x 10^2 (cal/sm K)	α x 10^3 m^2/hr	μ x 10^2 (kg/hr m)	υ x 10^6 (m^2/sec)	Pr
100	0.598	0.508	0.565	67.90	4.320	20.020	1.08
110	0.826	0.518	0.592	49.80	4.487	15.070	1.09
120	1.121	0.525	0.617	37.80	4.613	11.460	1.09
130	1.496	0.537	0.639	28.70	4.757	8.850	1.11
140	1.966	0.551	0.664	22.07	4.861	6.890	1.12
150	2.572	0.570	0.686	17.02	5.030	5.470	1.16
160	3.258	0.590	0.717	13.40	5.162	4.360	1.18
170	4.122	0.615	0.745	10.58	5.276	3.570	1.21
180	5.157	0.645	0.778	8.42	5.430	2.930	1.25
190	6.394	0.680	0.814	6.74	5.604	2.440	1.30
200	7.862	0.720	0.844	5.37	5.745	2.030	1.36
210	9.488	0.762	0.885	4.37	5.906	1.710	1.41
220	11.62	0.811	0.927	3.54	6.050	1.450	1.47
230	13.99	0.865	0.974	2.90	6.245	1.240	1.54
240	16.76	0.924	1.021	2.37	6.409	1.060	1.61
250	19.98	0.990	1.074	1.96	6.564	0.913	1.68
260	23.72	1.064	1.143	1.63	6.774	0.794	1.75
270	28.09	1.146	1.215	1.36	6.948	0.880	1.82
280	33.19	1.246	1.306	1.14	7.174	0.600	1.90
290	39.15	1.356	1.386	0.941	7.404	0.526	2.01
300	46.21	1.495	1.492	0.778	7.654	0.461	2.13
320	64.72	1.954	1.788	0.509	8.240	0.353	2.50
340	92.76	2.941	2.325	0.292	9.539	0.272	3.35
360	144.00	5.483	3.044	0.139	10.460	0.202	5.23

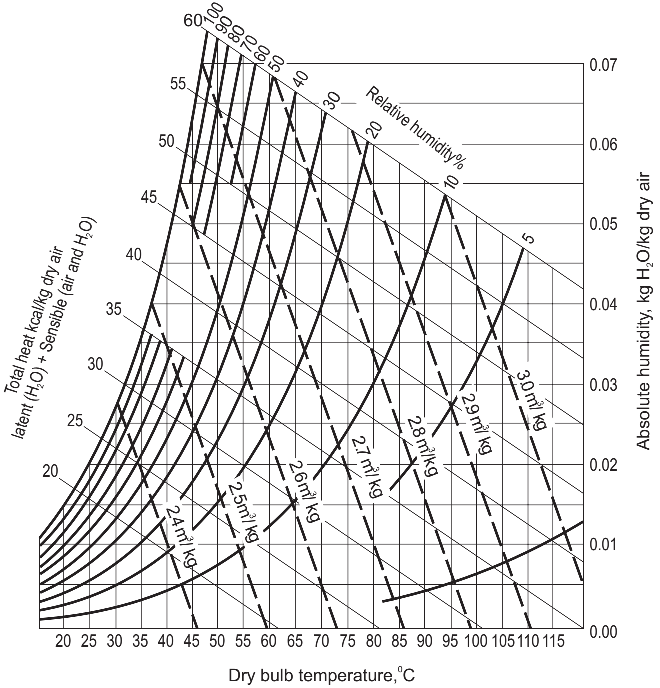
PROPERTIES OF WATER BETWEEN 0°C AND 250°C

Temp °C	Steam Pressure absolute kg/cm²	Specific Weight kg/m³ x 10³	Specific Volume m³/kg x 10⁻³
000	0.0062	0.9998	1.0002
010	0.0125	0.9996	1.0004
020	0.0238	0.9982	1.0018
030	0.0432	0.9956	1.0044
040	0.0752	0.9922	1.0079
050	0.1258	0.9880	1.0121
060	0.2031	0.9832	1.0171
070	0.3177	0.9777	1.0226
080	0.4829	0.9718	1.0290
090	0.7149	0.9653	1.0359
100	1.0332	0.9583	1.0435
110	1.4609	0.9510	1.0515
120	2.0245	0.9431	1.0603
130	2.7544	0.9348	1.0697
140	3.6850	0.9261	1.0798
150	4.8540	0.9169	1.0906
160	6.302	0.9074	1.1021
170	8.076	0.8973	1.1144
180	10.225	0.8869	1.1275
190	12.8	0.8760	1.1415
200	15.857	0.8647	1.1565
210	19.456	0.8528	1.1726
220	23.659	0.8403	1.19

PROPERTIES OF DRY AIR AT ATMOSPHERIC PRESSURE

Temp. t °C	Density ρ kg/m^3	Sp Heat C_p kcal/kgm °C	Viscosity $\mu \times 10^8$ $kgf\text{-}sec/m^2$	Thermal Conductivity K kcal/hr m°C	Prandtl No. Pr	Kinematic Viscosity $\upsilon \times 10^5$ m^2/sec
0	1.293	0.240	1.75	0.0210	0.707	13.28
10	1.247	0.240	1.80	0.0216	0.705	14.16
20	1.205	0.240	1.85	0.0223	0.703	15.06
30	1.165	0.240	1.90	0.0230	0.701	16.00
40	1.128	0.240	1.95	0.0237	0.699	16.96
50	1.093	0.240	2.00	0.0243	0.698	17.95
60	1.060	0.240	2.05	0.0249	0.696	18.97
70	1.029	0.241	2.10	0.0255	0.694	20.02
80	1.000	0.241	2.15	0.0262	0.692	21.09
90	0.972	0.241	2.19	0.0269	0.690	22.10
100	0.946	0.241	2.23	0.0276	0.688	23.13
120	0.898	0.241	2.33	0.0287	0.686	25.45
140	0.854	0.242	2.42	0.0300	0.684	27.80
160	0.815	0.243	2.50	0.0313	0.682	30.09
180	0.779	0.244	2.58	0.0325	0.681	32.49
200	0.746	0.245	2.65	0.0338	0.680	34.85
250	0.674	0.248	2.79	0.0367	0.677	40.61
300	0.615	0.250	3.03	0.0396	0.674	48.33
350	0.568	0.253	3.20	0.0422	0.676	55.46
400	0.524	0.255	3.37	0.0448	0.678	63.09
500	0.456	0.261	3.69	0.0494	0.687	79.38
600	0.404	0.266	3.99	0.0535	0.699	96.89
700	0.362	0.271	4.26	0.0577	0.706	115.4
800	0.329	0.276	4.52	0.0617	0.713	134.8
900	0.301	0.280	4.76	0.0656	0.717	155.1
1000	0.277	0.283	5.00	0.0694	0.719	177.1

DRY BULB TEMPERATURE v/s TOTAL HEAT



PHYSICAL PROPERTIES OF AIR

t (^0C)	ρ (kg/m^3)	Cp (kJ/kgK)	k x 10^2 (watt/m K)	α x 10^2 (m^2/hr)	μ x 10^2 (kg/hr m)	ν x 10^6 (m^2/sec)	Pr
– 50	1.584	1.013	2.034	4.57	5.264	9.23	0.728
– 40	1.515	1.013	2.115	4.96	5.475	10.04	0.728
– 30	1.453	1.013	2.197	5.37	5.645	10.80	0.723
– 20	1.395	1.009	2.278	5.38	5.822	12.09	0.716
– 10	1.342	1.009	2.360	6.28	5.996	12.43	0.712
0	1.293	1.005	2.441	6.77	6.188	13.28	0.707
10	1.247	1.005	2.511	7.22	6.346	14.16	0.705
20	1.205	1.005	2.592	7.71	6.533	15.06	0.703
30	1.165	1.005	2.673	8.23	6.717	16.00	0.701
40	1.128	1.005	2.755	8.75	6.704	16.96	0.699
50	1.093	1.005	2.824	9.29	7.067	17.95	0.698
60	1.060	1.005	2.894	9.79	7.221	18.97	0.696
70	1.029	1.009	2.964	10.28	7.344	20.02	0.694
80	1.000	1.009	3.045	10.87	7.523	21.09	0.692
90	0.972	1.009	3.127	11.48	7.701	22.10	0.690
100	0.946	1.009	3.208	12.11	7.880	23.13	0.688
120	0.898	1.009	3.336	13.26	8.170	25.45	0.686
140	0.854	1.013	3.4/87	14.52	8.479	27.80	0.684
160	0.815	1.017	3.638	15.80	8.786	30.08	0.682
180	0.779	1.022	3.778	17.10	9.070	32.49	0.681
200	0.746	1.026	3.929	18.49	9.380	34.85	0.680
250	0.674	1.038	4.266	21.49	10.020	40.61	0.677

SATURATED STEAM TABLES

(According to VDI Tables of Water Vapour Constants)

Absolute Pressure (Kg/cm^2)	Temperature t^0C	Specific volume of steam m^3/kg	Specific volume of steam kg/m^3	Enthalpy kcal/kg		Latent heat of vaporisation kcal/kg
				of Water	of Steam	
1	99.09	1.725	0.579	99.12	638.5	539.4
1.1	101.76	1.578	0.633	101.81	639.4	537.6
1.2	104.25	1.455	0.687	104.32	640.3	536
1.3	106.56	1.350	0.741	106.66	641.2	534.5
1.4	108.74	1.259	0.794	108.48	642	533.1
1.5	110.78	1.180	0.847	110.92	642.8	531.9
1.6	112.73	1.111	0.899	112.89	643.5	530.6
1.8	116.33	0.9952	1.005	116.54	644.7	528.2
2	119.62	0.9016	1.109	119.87	645.8	525.9
2.2	122.65	0.8246	1.213	122.90	646.8	523.9
2.4	125.46	0.7601	1.316	125.80	647.8	522
2.6	128.08	0.7052	1.418	128.50	648.7	520.2
2.8	130.55	0.6578	1.52	131	649.5	518.5
3	132.88	0.6166	1.622	133.40	650.3	516.9
3.2	135.08	0.5804	1.723	135.60	650.9	515.3
3.4	137.18	0.5483	1.824	137.80	651.6	513.8
3.6	139.18	0.5196	1.925	139.80	652.2	512.4
3.8	141.09	0.4939	2.025	141.80	652.8	511
4	142.92	0.4706	2.125	143.60	653.4	509.8
4.5	147.20	0.4213	2.374	148	654.7	506.7

SATURATED STEAM TABLES

(According to VDI Tables of Water Vapour Constants)

Absolute Pressure (Kg/cm^2)	Temperature t^0C	Specific volume of steam m^3/kg	Specific volume of steam kg/m^3	Enthalpy kcal/kg		Latent heat of vaporisation kcal/kg
				of Water	of Steam	
5	151.11	0.3816	2.624	152.1	655.8	503.7
5.5	154.71	0.3489	2.867	155.8	656.9	501.1
6	158.08	0.3213	3.112	159.3	657.8	498.5
6.5	161.15	0.2980	3.356	162.6	658.7	496.2
7	164.17	0.2778	3.6	165.6	659.4	493.8
7.5	166.96	0.2602	3.842	168.5	660.2	491.7
8	169.61	0.2448	4.085	171.3	660.8	489.5
8.5	171.11	0.2311	4.327	173.9	661.4	487.5
9	174.53	0.2189	4.568	176.4	662	485.6
9.5	176.82	0.2080	4.809	178.9	662.5	483.6
10	179.04	0.1981	5.049	181.2	663	481.8
11	183.20	0.1808	5.53	185.6	663.9	478.3
12	187.08	0.1664	6.01	189.7	664.7	475
13	190.71	0.1541	6.488	193.5	665.4	471.9
14	194.13	0.1435	6.967	197.1	666	468.9
15	197.36	0.1343	4.446	200.6	666.6	466
16	200.43	0.1262	7.925	203.9	667.1	463.2
17	203.35	0.1190	8.405	207.1	667.5	460.4
18	206.14	0.1126	8.886	210.1	667.9	457.8
19	208.81	0.1068	9.366	213	668.2	455.2

SATURATED STEAM TABLES

(According to VDI Tables of Water Vapour Constants)

Absolute Pressure (Kg/cm^2)	Temperature t^0C	Specific volume of steam m^3/kg	Specific volume of steam kg/m^3	Enthalpy kcal/kg		Latent heat of vaporisation kcal/kg
				of Water	of Steam	
20	211.38	0.1016	9.85	215.9	668.5	452.7
22	216.23	0.0925	10.81	221.2	668.9	447.7
24	220.75	0.0849	11.78	226.1	669.3	443.2
26	224.99	0.0784	12.75	230.8	669.5	438.7
28	228.98	0.0728	13.72	235.2	669.6	434.4
30	232.76	0.068	14.70	239.5	669.7	430.2
32	236.35	0.0637	15.69	243.6	669.7	426.1
34	239.77	0.0599	16.68	247.5	669.6	422.1
36	243.04	0.0565	17.68	251.2	669.5	418.3
38	246.17	0.0535	18.68	245.8	669.3	414.5
40	249.18	0.0507	19.69	258.2	669	410.8
42	252.07	0.0482	20.71	261.6	668.8	407.2
44	254.87	0.046	21.73	264.9	668.4	403.5
46	257.56	0.0439	27.76	268	668	400
48	260.17	0.042	23.80	271.2	667.7	396.5
50	262.70	0.0402	24.85	274.2	667.3	393.1
55	268.69	0.0363	27.50	281.4	666.2	384.8
60	274.29	0.331	30.21	288.4	665	376.6
65	279.54	0.0303	32.97	294.8	663.6	368.8
70	284.48	0.0279	35.78	300.9	662.1	361.2

SATURATED STEAM TABLES

(According to VDI Tables of Water Vapour Constants)

Absolute Pressure (Kg/cm^2)	Temperature t^0C	Specific volume of steam m^3/kg	Specific volume of steam kg/m^3	Enthalpy kcal/kg		Latent heat of vaporisation kcal/kg
				of Water	of Steam	
75	289.17	0.0260	38.7	307.0	660.5	353.5
80	293.62	0.0240	41.6	312.6	658.9	345.3
85	397.86	0.2240	44.6	318.2	657.0	338.8
90	301.92	0.2090	47.7	323.6	655.1	331.5
95	305.80	0.0196	50.9	328.8	653.2	324.4
100	307.53	0.0184	54.2	334.0	651.1	317.1
110	316.58	0.0163	61.1	344.0	646.7	302.7
120	323.15	0.0146	68.4	353.9	641.9	288.0
130	329.30	0.0131	76.2	363.0	636.6	373.6
140	335.09	0.0118	84.7	172.4	631.0	258.6
150	340.46	0.0106	93.9	381.7	624.9	243.2
160	345.74	0.0096	104.0	390.3	618.3	227.5
180	355.35	0.0078	128.0	410.2	602.5	192.3
200	364.08	0.0062	161.2	431.4	582.1	150.7
224	373.60	0.0038	262.0	477.5	526.0	48.5
225.65	374.15	0.0031	315.0	501.5	501.5	0

SUPERHEATED STEAM

Effective Pressure kg/cm^2	kcal/kg of Superheated Steam										
	200^0	220^0	240^0	260^0	280^0	300^0	320^0	340^0	360^0	380^0	400^0
0	686	675	705	714	724	734	744	753	763	772	782
1	685	676	704	714	723	733	743	752	762	772	782
2	684	694	703	713	723	732	742	752	762	772	782
3	683	693	702	712	722	732	742	752	761	771	781
4	682	692	702	711	721	731	741	751	761	771	781
5	681	691	701	711	721	731	741	751	761	771	781
6	679	690	700	710	720	730	740	750	760	770	780
8	677	688	698	708	719	729	739	749	759	770	779
9	675	687	697	708	718	728	739	749	759	769	779
10	674	685	696	707	717	728	738	748	759	769	779
11	672	684	395	706	717	727	738	748	758	769	779
12	671	683	694	705	716	727	737	747	757	768	778
13	669	682	693	705	715	726	737	747	457	768	778
14	668	680	692	704	715	725	736	746	757	767	777
15		680	691	703	714	725	735	746	757	767	777
17		677	689	701	712	723	734	745	756	767	776
19		674	687	699	711	722	733	744	755	766	776
21		671	685	696	709	721	732	743	754	765	775
23			682	697	708	720	731	742	753	764	774
25			680	694	706	718	730	741	752	764	773

TABLE OF SATURATED STEAM FLOW kg/hr

Absolute Steam Pressure (Kg/cm^2)	ø of pipe in mm													
	10	15	20	25	32	40	50	65	80	100	125	150	175	200
0.1	3	7.5	14	22	36	58	90	150	230	370	600	805	1,170	1,550
0.3	4	9.0	17	26	45	70	110	190	300	460	740	1,080	1,500	2,000
0.5	5	12.0	20	30	50	80	130	225	350	560	900	1,300	1,800	2,400
1.0	6	15.0	25	40	70	110	180	300	500	780	1,240	1,800	2,500	3,200
2.0	10	22.0	40	65	110	170	280	480	750	1,200	1,900	2,800	3,900	5,200
3.0	15	30.0	55	90	150	240	330	670	1,000	1,600	2,600	3,800	5,200	6,900
4.0	17	40	70	115	200	300	500	860	1,340	2,150	3,500	5,000	6,850	9,000
6.0	25	60.0	110	170	300	460	720	1,300	2,200	3,300	5,250	7,600	10,400	13,700
8.0	35	80.0	140	225	380	600	1,000	1,700	2,650	4,250	6,850	9,900	13,500	18,000
10.0	40	100.0	175	280	480	760	1,200	2,100	3,300	5,300	8,500	12,300	16,800	22,000
12.0	50	110.0	210	340	570	920	1,470	2,560	4,000	6,400	10,200	14,800	20,000	27,000
14.0	60	140.0	250	400	680	1,000	1,700	3,000	4,700	7,500	12,000	17,500	24,000	31,500
16.0	70	160.0	300	470	800	1,250	2,100	3,500	5,400	8,700	14,000	20,000	27,800	36,000
18.0	80	180.0	330	530	830	1,430	2,300	3,800	6,200	10,000	16,000	23,000	31,500	41,500
20.0	90	200.0	380	600	1000	1,650	2,650	4,550	7,000	11,000	18,000	26,000	38,000	48,000
25.0	115	260.0	500	800	1,300	2,100	3,400	5,900	9,200	15,000	23,500	34,500	47,000	63,000

PROBLEM : To expand 1000 kg. of saturated steam from 12kg/cm^2 to 1 kg/cm^2 : From the table, at 12 kg/cm^2 a 40 mm. pipe allows 920 kg/hr; at 1 kg/cm^2, a 100 mm. pipe allows 780 kg/hr, and 125 mm. pipe allows 1,240 kg/hr. Therefore a diameter between 100 and 125 mm will be required.

BULK WEIGHT OF STACKED SUBSTANCES – kg/m^3

Clay, gravel (dry)	1,800	Stacked Books	850
Clay, gravel (wet)	2,000	Lime and Sand Mortar	1,700 to 1,800
Oats	350 to 500	Eggs in case	3,600 pieces/m^3
Bananas	250	Domestic Garbage	200 to 250
Beet/root	570 to 650	Barley	530 to 750
Wheat	700 to 800	Paper	720
Coffee	720	Quarry Stone	200 to 2,700
Wood Coal	150 to 200	Planks	700 to 720
Coke	360 to 530	Pears & Plums	350
Pressed Cotton	390	Apples	300
Unpressed Cotton	200	Potatoes	650 to 700
Flour 500 to	600	Sand, Lime (dry)	1,600
Pressed Cotton Thread	200	Sand, Lime (wet)	2,000
Hay and Straw	100 to 120	Rye	600 to 800
Manure	750 to 950	Salt	745 to 785
Ice	670	Tobacco	420
Granite	2,500 to 3,050	Wet Pear	600
Beans, Peas, Lentils	710 to 850	Sheet Glass	2,600
Coal	770 to 860		

CONDUCTIVITY OF CONSTRUCTION MATERIALS

Material	Specific Weight kg/m^3	Conductivity kcal/m hr ^{0}C Temperatures of Materials 10^{0}C			
		Dry State	Partitions	External Walls	Damp Walls
Light Brick	1,200	0.22	-	-	-
Normal Brick	1,800	0.50	-	-	-
Walls of Light Brick	1,200	0.29	0.35	0.42	0.48
Walls of Normal Brick	1,800	0.52	0.62	0.75	0.86
Limestone	2,000	0.65	1.01	1.17	1.40
Sandstone	2,400	0.93	1.44	1.67	2.00
State perpendicular to strata	2,700	1.30	1.40	1.50	1.80
State parallel to strata	2,700	2.00	2.20	2.40	3.00
Mortar, Lime, Cement	1,800	0.44	0.58	0.72	0.85
Plaster Coat	1,200	0.37	0.48	0.60	0.80
Plaster Slabs	1,000	0.23	0.30	0.37	0.50
Grit Concrete	2,000	0.55	0.85	1.00	1.25
Compact reinforced concrete	-	0.90	1.20	1.40	1.60
Light aggregate concrete	1,000	0.16	0.24	0.28	0.33
Cellur Concrete	1,000	0.32	0.50	0.58	0.69
Isolated Isorel	400	0.04	0.044	0.045	0.047

CONDUCTIVITY OF MATERIALS

Material	Specific Weight kg/m^3	Conductivity (K) kcal/hr m ^{0}C	At ^{0}C
IS - 8 Bricks	2,200	1 - 1.2	1,000
Hysil Blocks	260	0.1	500
Mineral Wool (Rock)	100 - 150	0.08 - 0.1	300
Mineral Wool (Slag)	240 - 300	0.07 - 0.08	300
Mineral Wool (Glass)	150 - 300	0.070 - 0.08	300
Fibre Glass	400	0.06	10
Cork Plate	300	0.05	10
Asbestos (Wools)	300	0.05	10
Asbestos (Felt)	800	0.11	10
Asbestos (Plated Goods)	1,600	0.2	10
Sand	1,600	0.23	10
Gravel	2,000	0.33	10
Asphalt	2,150	0.8	10
Birtumen	1,050	0.14	10
Tiles	-	0.6	10
Cardboard	700	0.12	10
Ramming Mass (70% Al)	(Dry) 2,600	1.35 - 1.4	800
33% Alumina Fireclay	2,200	0.55	800
49% Alumina Fireclay	2,350	1.16	800
62% Alumina Fireclay	2,550	1.35	800
78% Alumina Fireclay	2,600	1.40	800

EMISSIVE POWER OF SOME MATERIALS

Material	Temperature °C	Emissive Power (e)
Lamp Black	130 - 230	0.957 - 0.952
Crude Brick	21	0.93
Unvarnished Silica	1,000	0.80
Oxidised Steel	1,000	0.79
Unpainted Steel Sheet	40 - 370	0.940 - 0.970
Polished Steel	430 - 1,030	0.144 - 0.377
Oxidised Brass	200 - 600	0.610 - 0.590
Polished Brass	245 - 355	0.028 - 0.031
Aluminium Cladding	225 - 575	0.039 - 0.057

Paint	Emissive Power (e)
Paint on rough material	0.906
Black or White lacquer	0.08 - 0.95
Dull black lacquer	0.96 - 0.98
Oil Paint in all Colours	0.92 - 0.96
Paint with Metalic Base	0.27 - 0.52

AVERAGE SPECIFIC HEAT FOR GASES AND STEAM AT CONSTANT PRESSURE PER 1 N m^3 BETWEEN 0^0C AND t^0C

Temp. T^0	Cp per N m^3				
	Air N_2 O_2 CO H_2	CH_4	C_2H_4	H_2O	CO_2 SO_2
0	0.312	0.343	0.420	0.272	0.397
100	0.314	0.379	0.469	0.373	0.410
200	0.316	0.414	0.518	0.375	0.426
300	0.318	0.450	0.567	0.376	0.442
400	0.320	0.486	0.616	0.378	0.456
500	0.322	0.522	0.666	0.380	0.467
600	0.324	0.557	0.715	0.383	0.477
700	0.326	0.593	0.764	0.385	0.487
800	0.328	0.629	0.813	0.389	0.497
900	0.330	0.664	0.862	0.394	0.505
1,000	0.332	0.700	0.911	0.398	0.511
1,100	0.334	0.736	0.760	0.402	0.517
1,200	0.336	0.771	1.009	0.407	0.521

AVERAGE SPECIFIC HEAT FOR GASES AND STEAM AT CONSTANT PRESSURE PER KG. BETWEEN 0^0 AND T^0C

Temp. T^0	Cp per kg. (kcal/kg.)						
	O_2	Air	N_2 CO	H_2	SO_2	CO_2	H_2O
0	0.218	0.241	0.249	3.445	0.139	0.202	0.462
100	0.219	0.243	0.251	3.467	0.144	0.209	0.464
200	0.221	0.244	0.252	3.490	0.149	0.217	0.466
300	0.222	0.246	0.254	3.512	0.155	0.225	0.468
400	0.224	0.247	0.255	3.534	0.159	0.232	0.470
500	0.225	0.249	0.257	3.557	0.164	0.238	0.473
600	0.226	0.250	0.259	3.579	0.167	0.243	0.476
700	0.228	0.252	0.261	3.601	0.170	0.248	0.479
800	0.229	0.253	0.262	3.624	0.174	0.253	0.484
900	0.231	0.255	0.264	3.646	0.177	0.257	0.490
1,000	0.232	0.256	0.266	3.668	0.179	0.260	0.495
1,100	0.233	0.258	0.267	3.690	0.181	0.263	0.500
1,200	0.235	0.260	0.266	3.713	0.182	0.265	0.506

RECOMMENDED INSULATION THICKNESS

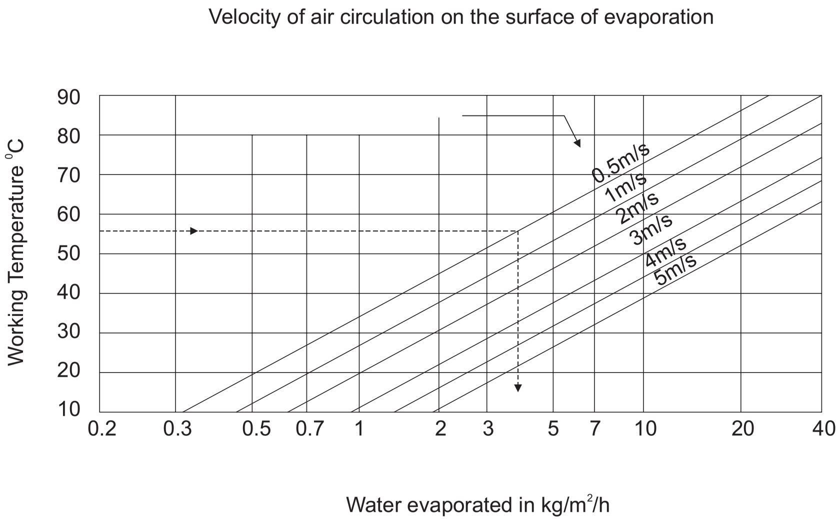
The table below gives recommended insulation thickness in mm required for different pipe sizes and different operating fluid temperatures.

Pipe dia (NB) mm	Operating / Fluid Temperature in ^{0}C					
	90	150	200	260	315	375
25	25	40	65	65	75	90
40	25	40	65	65	75	90
50	25	40	65	65	75	90
80	25	40	65	65	75	90
100	25	50	75	75	100	100
150	40	50	75	75	100	115
200	40	50	75	75	100	115
250	40	65	90	90	100	125
300	40	65	90	90	100	125
Flat	40	65	90	90	100	125

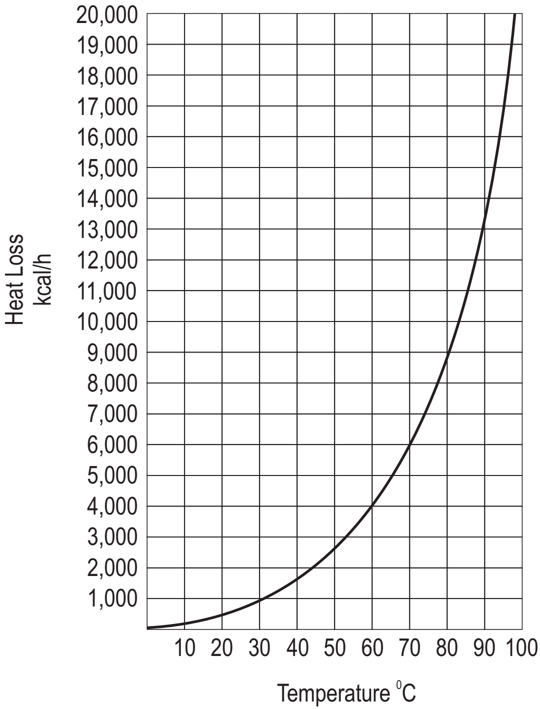
Please Note :

1. Insulation material assumed is Mineral wool having thermal conductivity 0.036 kcal/m hr^{0}C and average density about 100 - 200 kg/m^3
2. The surface temperature after insulation is 55 - 60^{0}C
3. Insulation upto 65 mm should be in single layer and above 65mm in multilayer e.g. for 80 mm two layers of 40 mm each, and for 90 mm inner layer of 40 mm and outer layer of 50 mm.

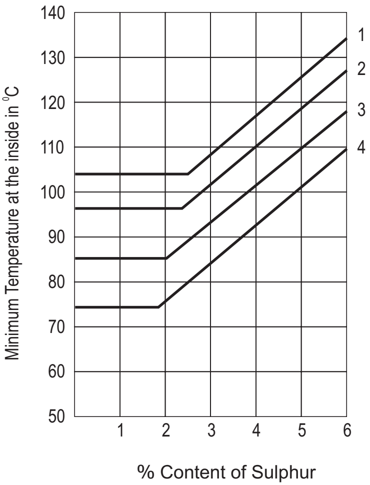
EVAPORATION OF WATER AT ATMOSPHERIC PRESSURE



HEAT LOSSES PER m^2 OF HOT WATER SURFACE AS A FUNCTION OF TEMPERATURE



DEW POINT T0 MINIMUM TEMPERATURE AT THE INSIDE OF THE CHIMNEY



1. Fuel Oil with high vanadium content
2. Natural Gas Containing H_2S
3. Fuel Oil with low vanadium content
4. Light Fuel Oil

HEAT EMMISSION RATES FROM PIPES SUBMERGED IN WATER

Published Overall Heat Transfer Rates	cal/s m^{2} ^{0}C	kcal/m^2h^{0}C
Tank Coil, Steam/Water (Temperature Difference 28^{0}C / 50^{0}F)	136-306	490 to 1100
Tank Coil, Steam/Water (Temperature Difference 56^{0}C / 100^{0}F)	238-408	855 to 1470
Tank Coil, Steam/Water (Temperature Difference 111^{0}C / 200^{0}F)	306-647	1100 to 2320
Reasonable Practical Heat Transfer Rates	**cal/s m^{2} ^{0}C**	**kcal/m^2h^{0}C**
Tank Coil, Low Pressure with natural circulation	136	490
Tank Coil, High Pressure with natural circulation	272	980
Tank Coil, Low Pressure with natural circulation	272	980
Tank Coil, High Pressure with natural circulation	408	1470

TYPICAL OVERALL HEAT TRANSFER COEFFICIENTS IN TUBULAR HEAT EXCHANGER

U = kcal/ ^{0}C m^2. hr.
NC = Non-condensable Gas Present
V = Vacuum
A = Atmospheric Pressure
FF = (or DIRT) units are (hr)(m^2)(^{0}C)/kcal

SHELL SIDE	TUBE SIDE	DESIGN U	INCLUDE TOTAL FF
LIQUID - LIQUID MEDIA			
Demineralized water	Water	1466-2443	0.20
Fuel Oil	Water	73-122	1.43
Heavy Oil	Water	73-244	1.02
Lube Oils (Low-viscosity)	Water	122-244	0.41
Lube Oils (High-			
viscosity)	Water	195-391	0.61
Organic Solvents	Water	244-732	0.61
Organic Solvent	Brine	171-440	0.61
Water	Caustic Soda		0.60
Water	Solution (10-30%) Water	489-1221 977-1221	0.61
CONDENSING VAPOUR - LIQUID MEDIA			
Alcohol Vapour	Water	489-977	0.61
Dowtherm vapour	Tall Oil And derivatives	293-391	0.82
Dowtherm vapour	Dowtherm Liquid	391-586	0.31
Origanic Solvent	Water	489-977	0.61
Origanic Solvent High NCV	Water or Brine	98-293	0.61
Origanic Solvent Low NC V	Water or Brine	244-587	0.01
Steam	Feed Water	1955-4887	0.61

TYPICAL OVERALL HEAT TRANSFER COEFFICIENTS IN TUBULAR HEAT EXCHANGER (CONTD.)

SHELL SIDE	TUBE SIDE	DESIGN U	INCLUDE TOTAL FF
Steam	No. 6 Fuel Oil	73-122	1.13
Steam	No. 2 Fuel Oil	293-440	0.51
Sulphur dioxide	Water	733-977	0.61
Water	Aromatic Vapour Stream azeotrope	195-391	1.02
GAS-LIQUID MEDIA			
Air N_2 etc. (compressed)	Water or Brine	195-391	1.02
Air N_2 etc. A	Water or Brine	49-244	1.02
Water Or Brine	Air N_2 etc. (Compressed)	98-195	1.02
Water Or Brine	Air N_2 etc. A	24.5-97	1.02
Water	Hydrogen containing natural gas mixtures	391-610	0.61
VAPORIZERS			
Water	Stem Condensing	1222-1955	0.31

OVERALL HEAT TRANSFER COEFFICIENT

CONDENSING

HOT FLUID	COLD FLUID	U kcal./hr.m^2 ^{0}C
Steam (Pressure)	Water	1710-3665
Steam (Vacuum)	Water	367-742
Saturated organic solvent near Atmospheric	Water	122-244
Saturated organic solvent vacuum with some non-condensables	Water, Brine	244-586
Organic solvent, atmospheric and high non-condensable	Water, Bine	24-98
Aromatic Vapours, atmospheric with non-condensable	Water	6-37
Organic solvent Vacuum And High non-condensable	Water, Bine	12-61
Low boiling atmospheric	Water	24-61
High boiling hydrocarbon, vacuum	Water	12.25-37
HEATERS		
Steam	Water	1222-3665
Steam	Light Oils	244-733
Steam	Heavy Oils	49-391
Steam	Organic solvent	489-977

Heat Loss :

Heat Loss for the insulated surface can be calculated by using following formula :

$$Q = \frac{(t_1 - t_2)}{T} K = (t_2 - t)f = \frac{(t_1 - t)}{\left\{ \frac{T}{K} + \frac{1}{t} \right\}}$$

Where Q = Heat loss (kcal/hr/metre run)

K = Thermal conductivity of insulation (kcal/hr/m/ ^{0}C)

t_1 = Temperature of hot surface (^{0}C)

t_2 = Temperature of cold surface (^{0}C)

t = Ambient temperature (^{0}C)

T = Thickness of insulation (m)
f = Surface coefficient (kcal/hr/m^2/^{0}C)

The temperature of surface of the covering can then be calculated as under :

$$t_2 = \frac{Q}{f} - t$$

For cylindrical surface

$$Q = \frac{(t_1 - t_2)}{R_i \left(\log_e \frac{R_0}{R_i}\right) x \frac{1}{KR_i} + \frac{R_0}{f}}$$

Where,
Q = Heat Loss (kcal/hr/m^2)
R_i = Inner radius of insulation (m)
R_o = Outer radius of insulation (m)
and the temperature of surface of the covering can than be calculated as under :

$$t_2 = \left(\frac{Q}{f} x \frac{R_i}{R_o}\right) + t$$

Effect of wind velocity on heat loss :

Wind velocity m/sec.	Bare Surface	Heat loss (Kcal/m/hr)			
		Thickness of insulation			
		25 mm	50 mm	75 mm	100 mm
0	3415	507	307	232	191
1	4197	537	319	238	198
5	7086	572	330	247	205
10	10490	576	336	248	206

Assumption for the above :

Pipe 150 mm at 300^{0}C
Ambient temp = 30^{0}C
Insulation K = 0.0515 Kcal/m/hr/^{0}C
Covering = Galvanised Iron

THERMODYNE

TYPICAL TEMPERATURES REQUIRED FOR VARIOUS PROCESSING INDUSTRIES ARE AS GIVEN BELOW:

Industry	Process	Typical Temperatures (°C)
Sugar	Raw juice heating	80-85
Dairy	Hot water generation	80
Plating	Metal deposition	70-85
Metal/Steel	Removal of rust/scale	90-95
Pharmaceutical	Wash tanks	70
Rubber	Heating caustic oil	140

HEAT TRANSFER THROUGH A STEEL TUBE

Material	Thickness 'x' (mm)	Conductivity 'k' (cal / s m^{0}C)	Resistance R=x/k (m^2 s^{0}C/cal)	Overall Conductance U = R^{-1} (cal / s m^2 ^{0}C)
Air	0.2	0.0060	0.0019	523.013
Condensate	0.2	0.0956	0.0001	8368.201
Scale steam side	0.2	0.1195	9.56x10^{-5}	10460.250
Steel tube	6.0	95.6	3.59x10^{-6}	278940
Water	0.05	0.1434	1.91 x10^{-5}	52301.260
Scale water side	0.1	0.1195	4.78 x10^{-5}	20920.500

HEAT TRANSFER THROUGH A COPPER TUBE

Material	Thickness 'x' (mm)	Conductivity 'k' (cal / s m^{0}C)	Resistance R=x/k (m^2 s ^{0}C/cal)	Overall Conductance U = R^{-1} (cal / s m^2 ^{0}C)
Air	0.2	0.025	0.008	125
Condensate	0.2	0.4	0.0005	2000
Scale steam side	0.2	0.5	0.0004	2500
Copper tube	6.0	400.0	0.000015	66666.67
Water	0.05	0.6	0.00008	12500
Scale waterside	0.1	0.5	0.0002	5000

OVERALL HEAT TRANSFER COEFFICIENTS 'U' FOR OIL TANKS

Tank Position	δT between oil and air	Overall heat transfer coefficients (cal/s m^2 ^0C)	
		Unlagged	Lagged
Sheltered	Up to 10^0C	1.625	0.406
	Up to 27^0C	1.768	0.430
	Up to 38^0C	1.912	0.478
Exposed	Up to 10^0C	1.912	0.478
	Up to 27^0C	2.031	0.502
	Up to 38^0C	2.175	0.549
Underground	Any temperature	1.625	--

HEAT EMISSION RATES FOR STEAM COILS SUBMERGED IN WATER

Customary overall heat transfer coefficients	U (cal/s m^2 °C)
Mean steam/water temperature difference around 30°C	135-310
Mean steam/water temperature difference around 60°C	240-410
Mean steam/water temperature difference around110°C	310-650
Recommended rates	**U (cal/s m^2 °C)**
Lower pressure coils (<2 bar gauge) with natural circulation of water	135
Higher pressure coils (>6 bar gauge) with natural circulation of water	265
Lower pressure coils (<2 bar gauge) with assisted circulation of water	265
Higher pressure coils (>6 bar gauge) with assisted circulation of water	410

HEAT EMISSION RATES FOR STEAM COILS SUBMERGED IN MISCELLANEOUS LIQUIDS

Medium Pressure steam	(2 - 6bar g) with natural liquid convection	**(cal/s m^2 °C)**
Light oils		42
Heavyoils		20-28
Fats		7-15
Medium Pressure steam	(2-6bar g) with forced liquid convection	**(cal/s m^2 °C)**
Light oils	(200sec Redwood at 38°C)	130
Medium oils	(1000sec Redwood at 38°C)	85
Heavy oils	(3500sec Redwood at 38°C)	40
Molasses	(10000sec Redwood at 38°C)	20
Fats	(50000sec Redwood at 38°C)	14

OVERALL HEAT TRANSFER COEFFICIENTS FOR STEAM JACKETS

Process fluid or product	Wall material	(cal/s m^2 °C)
Water	Stainless steel	205-410
	Glass-lined Carbon steel	95-135
Aqueous solution	Stainless steel	110-275
	Glass-lined carbon steel	70-95
Organics	Stainless steel	70-205
	Glass-lined carbon steel	40-95
Light oil	Stainless steel	80-215
	Glass-lined carbon steel	55-100
Heavy oil	Stainless steel	14-70
	Glass-lined carbon steel	14-55

NOMINAL SURFACE AREAS OF STEEL PIPES PER METER LENGTH

Nominal bore (mm)	15	20	25	32	40	50	65	80	100
Surface area (m^2/m)	0.067	0.085	0.106	0.134	0.152	0.189	0.239	0.279	0.358
Length/surface area (m/mm^2)	14.93	11.76	9.43	7.46	6.58	5.29	4.18	3.58	2.79

LINEAR EXPANSION OF PIPE LINES

If there is no provision for making up for the expansion in hot pipelines, they may get damaged. Following table presents the maximum possible expansion at the given temperatures, against which you must make sufficient accommodations and anchoring. Assumption - ambient temperature is 60°F and length at ambient temperature is 100 ft.

Temp of Steam/water °F	Liner Expansion Per 100 feet
60	0
80	0.15
100	0.31
150	0.70
200	1.11
250	1.52
300	1.92
350	2.39
400	2.83
450	3.29
500	3.75
550	4.22
600	4.71
650	5.21
700	5.71
750	6.22
800	6.75
850	7.27
900	7.82
950	8.37
1000	8.94

HEAT LOAD CALCULATIONS

$Q = mC_p\delta T$

Here, m = Total Mass of fluid to be heated

C_p = Specific Heat capacity of fluid at constant pressure

δT = Temperature difference as per process requirement

The above calculations give the heat load determination for your industry as per the fluid quantity and required working temperature.

Calculations of **Total Heat Requirement** of a tank/process equipment for fluid are based upon the following factors:

1. Heat needed to raise process fluid temperature from cold to operating temperature
2. Heat required to raise vessel temperature from ambient to its operating temperature
3. Heat lost from the solid surface of the vessel to atmosphere via cconvection
4. Heat lost by liquid surface to atmosphere (when exposed/open system) via convection
5. Heat absorbed by any cold articles dipped into process fluid

Heat Loss Calculations

$Q = U \times A \times \delta T$

U = Overall Conductivity of system (kcal/kgm^2 ^{0}C)

A = Heat transfer surface area (m^2)

δT = Temperature difference between process equipment and atmosphere (^{0}C)

HEAT LOSS FROM UNLAGGED STEEL PIPES FREELY EXPOSED TO AIR AT 20°C (cal/s m)

Temperature differential steam to air °C	Pipe size (mm)									
	15	20	25	32	40	50	65	80	100	150
50	13.38	16.25	19.60	23.90	27.01	32.50	40.15	45.65	57.60	79.35
60	16.49	20.31	24.37	29.87	33.46	40.63	49.71	56.88	71.22	98.47
70	20.08	24.38	29.64	36.33	40.63	49.23	60.23	69.07	86.04	119.50
80	23.90	29.16	35.37	43.02	48.28	58.55	71.46	81.98	102.29	141.97
100	32.26	39.20	47.56	58.08	65.01	78.87	96.32	110.90	137.90	192.16
120	41.35	50.19	61.18	74.81	83.89	101.81	124.76	143.40	178.29	249.04
140	51.62	62.62	76.24	93.45	104.92	127.39	156.07	179.49	223.70	312.61
160	62.86	76.24	92.97	113.76	127.86	155.59	190.96	219.40	273.65	383.12
180	74.81	91.06	110.90	135.99	152.96	186.42	228.96	262.90	328.39	460.07
200	87.95	107.07	130.49	160.13	180.21	219.64	270.31	309.98	387.89	543.96
220	102.05	124.28	151.52	185.94	209.60	255.49	315.00	360.89	452.19	634.54

APPROXIMATE INCREASE IN HEAT LOSS DUE TO AIR MOVEMENT OVER PIPES WITH A HIGH EMISSIVITY (MULTIPLY WITH GIVEN FACTOR)

Air velocity (m/s)	Emission factor
0.00	1.0
0.50	1.0
1.00	1.3
1.50	1.5
2.00	1.7
2.50	1.8
3.00	2.0
4.00	2.3
6.00	2.9
8.00	3.5
10.00	4.0

APPROXIMATE REDUCTION IN EMISSION OF LAGGED HORIZONTAL PIPES

Number of pipes	1	2	3	4	5	6	7	8	9	10
Emission factor	1.00	0.96	0.91	0.86	0.82	0.78	0.74	0.70	0.67	0.63

APPROXIMATE REDUCTION IN EMISSION OF LAGGED VERTICAL PIPES

Pipe size (mm)	15	20	25	32	40	50	65	80	100	150
Emission factor	0.76	0.80	0.82	0.84	0.86	0.88	0.91	0.93	0.95	1.00

EFFECT ON HEAT TRANSFER WITH AIR MOVEMENT (EXPOSED CONDITIONS)

Use the following multiplication factors for the overall Conductivity of the material while calculating heat losses to atmosphere.

Air Velocity (m/s)	0	0.5	1.0	2.0	3.0
Multiplying factor	1	1.3	1.7	2.4	3.1

AREA OF LAGGING IN m^2 PER 10m RUN OF STEAM LINE

NB of Pipe (in)	OD(mm)	25	50	75	100	125	150
1/8	10.29	1.89	3.46	5.04	6.61	8.18	9.75
1/4	13.72	2.00	3.57	5.14	6.71	8.28	9.86
3/8	17.14	2.11	3.68	5.25	6.82	8.39	9.96
1/2	21.34	2.24	3.81	5.38	6.95	8.52	10.10
3/4	26.67	2.41	3.98	5.55	7.12	8.69	10.26
1	33.40	2.62	4.19	5.76	7.33	8.90	10.47
1 1/4	42.16	2.90	4.47	6.04	7.61	9.18	10.75
1 1/2	48.26	3.09	4.66	6.23	7.80	9.37	10.94
2	60.32	3.47	5.04	6.61	8.18	9.75	11.32
2 1/2	73.02	3.86	5.44	7.01	8.58	10.15	11.72
3	88.90	4.36	5.93	7.51	9.08	10.65	12.22
3 1/2	101.60	4.76	6.33	7.90	9.48	11.05	12.62
4	114.30	5.16	6.73	8.30	9.87	11.44	13.02
5	141.30	6.01	7.58	9.15	10.72	12.29	13.86
6	168.27	6.86	8.43	10.00	11.57	13.14	14.71
8	219.07	8.45	10.02	11.59	13.17	14.74	16.31
10	273.07	10.15	11.72	13.29	14.86	16.43	18.00
12	323.85	11.74	13.32	14.89	16.46	18.03	19.60
14	355.60	12.74	14.31	15.88	17.45	19.03	20.60
16	406.40	14.34	15.91	17.48	19.05	20.62	22.19
18	457.20	15.93	17.50	19.08	20.65	22.22	23.79
20	508.00	17.53	19.10	20.67	22.24	23.81	25.38
22	558.80	19.13	20.70	22.27	23.84	25.41	26.98
24	609.60	20.72	22.29	23.86	25.43	27.01	28.58
26	660.40	22.32	23.89	25.46	27.03	28.60	30.17
28	711.20	23.91	25.48	27.06	28.63	30.20	31.77
30	762.00	25.51	27.08	28.65	30.22	31.79	33.36
32	812.80	27.11	28.68	30.25	31.82	33.39	34.96
34	863.60	28.70	30.27	31.84	33.41	34.98	36.56
36	914.40	30.30	31.87	33.44	35.01	36.58	38.15

HEAT LOSS FROM UNLAGGED HOT-WATER AND STEAM LINES

NB of Pipe (in)	Heat lost in kcal/ft.run / hour of hot water pipe in still air								
	Temperature difference between air & hot water (^{0}C)								
	80^0	85^0	90^0	95^0	100^0	105^0	110^0	115^0	120^0
0.5	34.72	37.20	39.69	42.17	46.30	48.78	52.09	55.39	58.70
0.75	43.82	46.30	49.61	52.91	57.87	62.01	66.14	69.45	72.76
1	49.61	52.91	57.87	61.18	66.14	70.28	74.41	79.37	83.50
1.25	60.35	64.49	70.28	74.41	81.02	85.16	90.94	96.73	101.69
1.5	67.80	71.93	79.37	84.33	90.94	95.91	102.52	109.13	114.92
2	80.20	85.16	93.43	99.21	107.48	113.27	119.88	128.15	134.76
2.5	95.08	100.87	111.61	117.40	128.15	136.42	144.69	152.95	160.39
3	115.75	124.02	136.42	144.69	155.43	165.35	175.28	185.20	195.94
4	143.86	152.95	167.83	177.76	191.81	202.56	216.61	229.02	241.42
5	175.28	186.02	204.21	219.09	233.15	248.03	262.91	277.80	292.68
6	206.69	223.23	239.76	256.30	272.83	289.37	310.04	326.57	343.11

RECOMMENDED THICKNESS OF GLASSWOOL INSULATION

Operating Temperature ^{0}F	100	200	300	400	500	600
Thermal Conductivity cal/s m ^{0}K	0.0115	0.0129	0.0146	0.0165	0.0186	0.0210
Pipe Dia (mm)	**Insulation Thickness (mm)**					
27	30	48	60	73	84	96
34	34	52	66	79	91	104
48	39	59	75	88	102	116
60	42	64	81	95	110	124
89	49	72	91	108	125	141
114	52	77	98	116	134	152
168	58	87	104	130	150	170
219	63	93	118	140	162	183
273	66	98	125	149	172	195
324	69	103	131	156	181	205
406	72	109	138	166	192	218

CHIMNEY CALCULATIONS

Up to a draft of 40 m and less, a chimney is more economical than mechanical draft. Also, beyond 40 m height, in situ concrete chimneys tend to be cheaper than steel chimneys.

a. Draft produced by Chimney

$$D = BH/7.6 \times [(352/Ta) - (366/Tg)]$$

where

D = Draft in mm of WG at the base of chimney

B = Barometric height (mm)

H = Height of chimney (m)

T_a = Ambient temperature ^0K

T_g = Mean gas temperature ^0K

Also, T_g = T_b - H/6; T_b = Flue gas temperature at base of chimney

When you have a barometer attached to your draft system and chimney height is known along with the flue temperature at base, the Draft produced is calculated from the above formula.

b. Diameter of Chimney

$$D = \sqrt{4Q / (0.6\rho V)}$$

D = Dia of chimney

Q = Volume of flue gas at working temperature, m^3/s

V = Velocity of flue gas, m/s

HOW TO SELECT A BOILER

The following points may be kept in view while selecting a boiler:

i) The shifting and evaluating the competing claims of different manufacturers is no longer a layman's job. It should be entrusted to a consultant.

ii) As of today, boilers are in buyers' market. Only a decade ago they were in sellers' market.

iii) Because a boiler is offered by a reputed firm it need not necessarily be good and because it is offered by a minor company just getting into business, it need not be bad.

Inviting Quotation

When writing to the boiler manufacturers, the following information should be furnished to them:

1. Lowest ambient temperature likely to be reached during a year at the proposed place of operation.
2. Elevation of the place above MSL.
3. Maximum steam demand at the working pressure of the boiler. Whether any superheat of steam is required.
4. Fuel to be used and its analysis report.
5. Whether the load on the boiler is likely to be steady or fluctuating and if fluctuating, then between what limits?
6. Analysis of the raw water to be used in the boiler after treatment.
7. In case of solid fuel fired boilers, whether mechanical firing is preferred.
8. In the event of any proposed standardization of both the HPs and the make of electric motors that fact should be intimated.

HOW TO SELECT A BOILER (Contd.)

Information the Manufacturer should be requested to furnish

The boiler manufacturer should be requested to include the following information in the quotation he sends -

i) Gross Thermal Efficiency of the boiler with the type of fuel cited

ii) Quality of steam - dryness fraction/superheat

iii) Flue gas temperature

iv) Grate area (for solid fuel fired boilers)

v) Expected evaporation (kg of steam at working pressure/kg of fuel)

vi) Overall dimensions of the boiler

vii) Heating surface area

viii) Weight of empty boiler and weight when water is at its full level

ix) Quality of boiler feed water required?

x) Accessories Included

xi) Delivery Period

BOILER LOG SHEET

A Boiler Log sheet is essential in monitoring proper boiler operation through documentation which the user maintains on an hourly/shift/daily basis. Following information is very crucial for regular monitoring of a boiler through the log sheet.

1. Steam

- ✓ Flow rate (kg/hour)
- ✓ Pressure (kg/cm^2)
- ✓ Temperature (^0C)
- ✓ Quantity consumed (kg)

2. a. Fuel - Oil

- ✓ Flow rate (liters/hr)
- ✓ Quantity consumed (kg)
- ✓ Temperature (^0C)
- ✓ Oil pressure to burner (kg/cm^2)

b. Fuel - Coal

- ✓ Quantity consumed

3. Air

- ✓ Ambient temperature (^0C)
- ✓ Temperature at air preheater outlet (^0C)
- ✓ FD fan discharge air pressure (mm WG)

4. Flue gases

- ✓ Boiler outlet temperature (^0C)
- ✓ Air preheater inlet temperature (^0C)
- ✓ Air preheater outlet temperature (^0C)
- ✓ Economizer inlet temperature (^0C)
- ✓ Economizer outlet temperature (^0C)
- ✓ CO_2 content in flue gas at base of chimney (%)
- ✓ CO content (%)
- ✓ Stack appearance (Description/Remarks)

BOILER LOG SHEET (CONTD.)

5. Feed Water

- ✓ Temperature at inlet to feed pumps (^{0}C)
- ✓ Quantity consumed (liters/hour)

6. Blowdown

- ✓ Duration (seconds)

7. Soot Blowing (duration)

8. Water Treatment (once a shift)

a. Feed water

- ✓ TDS content (ppm)
- ✓ Hardness (ppm)
- ✓ pH
- ✓ Alkalinity (ppm)

b. Boiler Water

- ✓ TDS content just before blowdown (ppm)
- ✓ Hardness (ppm)
- ✓ Phosphates (ppm)
- ✓ Sulphates (ppm)

Minimum instrumentation required in the boiler house

a. Steam flow and integrating meter
b. Steam pressure gauges on the steam line
c. Thermometer on the steam line
d. Oil flow and integrating meter
e. Thermometer on the oil line both before and after the heater
f. Pressure gauge on the oil line just before the burner
g. Weighing machine for coal
h. Room thermometer
i. Thermometers both before and after the air preheater to measure the air as well as flue gas temperature
j. Thermometers for water at the inlet and outlet of economizer
k. CO_2 meter - either Orsat or Fyrite type
l. Thermometers to measure the water temperatures at inlet to feed pump
m. Stop watch
n. Complete set of laboratory equipment in the laboratory to test the water samples

PER HOUR FUEL CONSUMPTION

Table below provides the measure of Fuel Consumption per 1000 kg steam/hour for all range of fuels (according to Calorific Values) and for the rated Boiler Efficiencies. All you need is to compare the values of fuel C.V and Boiler efficiency. The per hour fuel consumption (kg/hour) will be found out.

Efficiency of Boiler	Fuel Calorific Value C.V. (Kcal/hr)														
	2000	**2400**	**2800**	**3200**	**3600**	**4000**	**4500**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**	**11000**	**12000**
50%	540	450	386	338	300	270	240	216	180	154	135	120	108	98	90
55%	491	409	351	307	273	245	218	196	164	140	123	109	98	89	82
60%	450	375	321	281	250	225	200	180	150	129	113	100	90	82	75
65%	415	346	297	260	231	208	185	166	138	119	104	92	83	76	69
70%	386	321	276	241	214	193	171	154	129	110	96	86	77	70	64
75%	360	300	257	225	200	180	160	144	120	103	90	80	72	65	60
80%	338	281	241	211	188	169	150	135	113	96	84	75	68	61	56
85%	318	265	227	199	176	159	141	127	106	91	79	71	64	58	53
90%	300	250	214	188	167	150	133	120	100	86	75	67	60	55	50
95%	284	237	203	178	158	142	126	114	95	81	71	63	57	52	47

ACTUAL EVAPORATION RATE OF BOILER

For different feedwater and steam temperatures and pressures of operation, the evaporation rating of a boiler decreases. When we give Boiler capacity, it is always in terms of From & At 100 ^{0}C - means a 1000kg/hr rated boiler shall give 1000 kg/hr of steam only if water is fed at 100 ^{0}C and steam is taken out at 100 ^{0}C and 1 kg/cm^2. In case steam is taken out at 10.5 kg/cm^2 pressure and water is fed at various temperatures as under, the evaporation will be reduced as per the following factor of evaporation. Multiply the rated capacity with factors given below.

B.W.P kg/cm^2 / Temp ^{0}C	3	4	5	6	7	8	9	10	12	15	17.5
30	0.867	0.863	0.860	0.859	0.856	0.854	0.853	0.852	0.850	0.848	0.846
40	0.881	0.877	0.874	0.872	0.870	0.868	0.867	0.865	0.864	0.861	0.860
50	0.896	0.891	0.888	0.887	0.884	0.882	0.881	0.879	0.878	0.875	0.874
60	0.911	0.906	0.903	0.902	0.899	0.897	0.896	0.894	0.893	0.890	0.888
70	0.926	0.922	0.918	0.917	0.914	0.912	0.911	0.909	0.908	0.905	0.903
80	0.942	0.938	0.934	0.933	0.929	0.928	0.926	0.925	0.923	0.920	0.918
90	0.959	0.954	0.951	0.949	0.946	0.944	0.942	0.941	0.939	0.936	0.934
100	0.976	0.971	0.968	0.966	0.963	0.961	0.959	0.957	0.956	0.952	0.951

DE-RATING OF BOILERS AT HIGH ALTITUDE

A boiler designed to generate 5000 kg/hr steam for and at, 100^{0}C at Mean Sea Level (MSL) will not give the same quantity of steam if shifted to an elevated place. It will give less.

The blower in it will consume same volume of air for burning, but will not consume the same mass or weight of air at high altitudes. The reason lies in decreased air density at higher altitudes. This results in less fuel consumption and less steam generation rate.

Due to reduction of mass flow of gases through tubes of boiler, convective heat transfer is also reduced. This further reduces evaporation rates.

Altitude above MSL (ft)	De-rating Factor
1000	0.964
2000	0.930
3000	0.896
4000	0.864
5000	0.832
6000	0.801
7000	0.772
8000	0.743
9000	0.711
10000	0.688

HEATING WATER WITH IMMERSED STEAM COILS

Pipe Size (inch)	Length of Steel Pipe (meters) required for tank coil to heat one gallon of water from 15°C to 100°C in 1 Hour					
	1.5	3	7.5	15	30	45
	Steam Pressure in kg/cm²					
0.5	0.039	0.029	0.021	1.617	1.195	0.984
0.75	0.030	0.022	0.016	0.012	0.009	0.007
1	0.025	0.018	0.013	0.009	0.007	0.006
1.25	0.018	0.013	0.010	0.007	0.005	0.004
1.5	0.015	0.011	0.008	0.006	0.004	0.004
2	0.012	0.009	0.006	0.005	0.004	0.003
2.5	0.010	0.008	0.005	0.004	0.003	0.002

SELECTION OF STEAM TRAPS

Type of Trap	Type of Duty	Suited for Applications
Float	Continuous	Calorifiers, Cabinet heaters, Heater batteries, Jacketed Boiling Pans, Evaporators, Sizing Machines, Cylindrical Driers, Calenders, Cloth washing Tumblers, Dry-cleaning Machines, Process vats/retorts, digesters, outflow heaters on oil tanks, line heaters, bulk oil heating installations (LSHS)
Thermodynamic	Intermittent	Steam mains & branches, Hot air drying coils, Drying cylinders, Garment presses, Vulcanizing presses, platen presses, Pressure reducing stations
Balanced Pressure Expansion	Intermittent	Boiling plans, Autoclaves, Hospital sterilizers, Hot tables, Tracer lines, Jacketed pipes
Bucket	Intermittent	Storage tank heating coils

CONDENSATE LOAD FOR VARIOUS STEAM MAIN SIZES

Steam Trap Sizing for Steam Mains – Condensate Load in kilograms per hour per 1000 feet of insulated Steam Main – Ambient Temperature 70^{0}F – Insulation 80% Efficient, Steam Pressure in kg/cm^2

Steam Pressure	Steam Main Size													
	2"	2.5"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	24"
0.703	2.72	3.17	4.08	4.98	5.89	7.25	9.07	10.88	13.15	14.51	16.32	17.69	19.95	24.04
2.109	3.62	4.08	4.98	6.35	7.71	9.07	11.79	14.51	17.23	19.05	21.77	23.13	25.85	30.84
4.218	4.50	5.44	6.35	8.16	10.88	12.24	14.96	18.59	22.22	24.49	28.12	30.39	33.56	40.37
7.030	5.44	6.80	8.16	9.97	12.70	14.96	18.59	23.13	27.66	30.39	34.92	37.64	42.18	50.34
8.788	5.89	7.25	9.072	10.88	13.60	16.32	20.41	27.66	29.93	33.11	38.10	40.80	45.81	54.88
12.304	7.25	8.61	10.43	11.79	14.96	17.23	24.04	29.93	35.38	39.00	44.45	48.53	53.97	64.41
17.57	8.16	9.97	12.24	15.42	19.05	22.68	28.12	34.92	41.73	45.81	52.61	57.15	63.50	76.20
21.09	9.00	11.34	13.60	16.78	20.86	24.49	30.84	38.50	45.81	50.34	57.15	62.59	69.85	83.46
28.123	10.43	12.70	15.42	19.50	24.04	28.57	36.20	44.90	53.52	58.90	67.13	73.48	81.60	97.97
35.15	12.24	14.96	17.69	22.22	27.66	33.11	41.27	51.71	61.2	67.13	77.11	83.91	93.44	111.56
42.18	13.60	16.78	19.95	24.94	30.84	37.19	46.72	58.06	68.94	75.75	86.63	94.34	105.23	125.64

SPACING OF CONTROL PIPE SUPPORTS

NB of Pipe (inch)	OD of Pipe (inch)	Spacing of pipe supports				Dia of hanger rod for suspension (in)
		Normal Feet	Spacing Meters	Maximum Feet	Spacing Meters	
1	1.315	7	2.10	8.5	2.59	3/8
1.25	1.660	10	3.05	12	3.66	3/8
1.5	1.900	12	3.66	17	5.19	3/8
2	2.375	12	3.66	17	5.19	3/8
2.5	2.875	14	4.27	20	6.10	1/2
3	3.500	14	4.27	20	6.10	1/2
3.5	4.000	16	4.88	22	6.71	1/2
4	4.500	16	4.88	22	6.71	5/8
5	5.563	18	5.49	25	7.63	5/8
6	6.625	18	5.49	25	7.63	3/4
8	8.625	30	9.15	40	12.20	7/8
10	10.750	35	10.68	46	14.03	7/8
12	12.750	38	11.59	50	15.25	7/8
14	14.000	42	12.81	54	16.47	1
16	16.000	45	13.73	60	18.30	1

DURATION FOR WHICH THE BLOWDOWN SHOULD BE CARRIED OUT TO PURGE $1 m^3$ OF WATER (MINUTES)

Size of Blow down Valve (mm)	Boiler Pressure in kg/cm^2 at the time of Blowdown									
	10	15	20	25	30	40	50	60	80	100
5	23.00	9.00	17.00	15.00	13.50	13.00	10.50	9.50	8.50	7.00
8	9.50	7.60	6.70	6.00	5.40	4.70	4.20	3.80	3.30	3.00
10	5.80	4.80	4.20	3.70	3.40	2.90	2.60	2.10	1.85	1.68
15	2.60	2.10	1.85	1.67	1.52	1.30	1.12	0.92	0.83	0.75
20	1.52	1.23	1.08	0.95	0.88	0.75	0.67	0.53	0.48	0.43
25	0.92	0.77	0.67	0.60	0.53	0.13	0.42	0.33	0.30	0.27
30	0.67	0.55	0.48	0.43	0.38	0.33	0.30	0.23	0.22	0.18
40	0.37	0.30	0.25	0.23	0.20	0.18	0.17	0.13	0.12	0.10
50	0.23	0.20	0.17	0.15	0.13	0.12	0.10	0.08	0.07	0.07

VENTILATION (FANS AND BLOWERS)

Nomenclature :

Q	=	Volumetric Flow Rate m^3/s
P_s	=	Static Pressure in mm W. C.
P_t	=	Total Pressure in mm W. C.
P_n	=	Dynamic Pressure in mm W. C.
N	=	RPM (Revolution per min.)
HP	=	Power Absorbed (Horse Power)
v	=	Velocity of gas m/sec
ρ	=	Specific weight of gas kg/m^3
g	=	Acceleration due to gravity 9.81 m/sec^2
ηs	=	Static Efficiency of fan / blower

$$P_v = P_t - (\pm {}^{*}P_s)$$

$$n = \sqrt{\frac{2g\,P_v}{\rho}}$$

$$HP = \frac{Q \times Ps}{75 \times \eta s} \quad \text{OR} \quad HP = \frac{\text{cfm} \times \text{S. P. inches WC}}{6354 \times \eta s}$$

* Use + for Positive Pressure

and – for Negative Pressure

CORRECTION FACTORS FOR VENTILATION (FANS, BLOWERS)

Altitude	Temperature
At Sea Level $K = 1$ p = barometric pressure in mm of Hg $K = \frac{p}{760}$	At 20^0C $K' = 1$ t = temperature in ^{0}C $K = \frac{273 + 20}{273 + t}$

Altitude in (m)	K	Temperature ^{0}C	K'
0	1.00	– 30	1.20
100	0.98	– 20	1.15
200	0.97	– 10	1.11
300	0.96	0	1.07
400	0.95	20	1.00
500	0.94	50	0.90
1,000	0.88	200	0.78
1,500	0.83	150	0.69
2,000	0.78	200	0.61
3,000	0.69	250	0.56

EXAMPLE : FAN CHARACTERISTICS

Air at 20^0C : Q = 1,000 m^3/hr, Pt = 150 mm W. C. HP = 1

This fan (blower) handling 1,000 m^3/hr (Q) at a temperature of 50^0C and at an altitude 1,000 m will have the following characteristics :

Pressure 150 x 0.83 x 0.90 = 118.8 mm W. C.

Power Consumed : 1 x 0.88 x 0.90 = 0.79 HP

(Flow same in both cases)

LAWS OF CENTRIFUGAL FANS AND BLOWERS

Nomenclature :

Q	=	Volumetric Flow Rate
P	=	Pressure
HP	=	Horse Power
N	=	Speed of Impeller
D	=	Dia of Impeller
w	=	Width of Impeller
ρ	=	Gas Density at the inlet of Fan / Blower
Suffix 1	=	Initial Condition
Suffix 2	=	Final Condition

I - Change in Impeller Speed (N)

$$\frac{Q_2}{Q_2} = \frac{N_2}{N_1}$$

$$\frac{P_2}{P_1} = \left[\frac{N2}{N1}\right]^2$$

$$\frac{HP_2}{HP_1} = \left[\frac{N2}{N1}\right]^3$$

III - Change in Impeller Dia (D)

$$\frac{Q_2}{Q_1} = \left[\frac{D_2}{D_1}\right]^3$$

$$\frac{P_2}{P_1} = \left[\frac{D_2}{D_1}\right]^2$$

$$\frac{HP_2}{HP_1} = \left[\frac{D_2}{D_1}\right]^5$$

II - Change in Gas Density ρ

$$Q_2 = Q_1$$

$$\frac{P_2}{P_1} = \frac{P_2}{p_1}$$

$$\frac{HP_2}{HP_1} = \frac{P_2}{P_1}$$

II - Change in Gas Density ρ

$$P_2 = P_1$$

$$\frac{Q_2}{Q_1} = \frac{w_2}{w_1}$$

$$\frac{HP_2}{HP_1} = \frac{w_2}{w_1}$$

TABLE SHOWING LOSS IN FLOW DUE TO FRICTION

For a Length of 1m, with air at 20°C and 760 mm of Hg

ø	200mm		300mm		400mm		500mm		600mm	
Velocity m/sec	m^3/sec	P mm WG	m^3/sec	P mm WG	m^3/sec	P mm WG	m^3/sec	P mm WG	m^3/sec	P mm WG
2	0.063	0.031	0.14	0.019	0.25	0.013	0.39	0.010	0.72	-
4	0.125	0.113	0.28	0.068	0.50	0.048	0.78	0.036	1.44	0.029
6	0.188	0.240	0.42	0.150	0.75	0.104	1.18	0.076	2.16	0.062
8	0.250	0.390	0.56	0.235	1.00	0.170	1.57	0.130	2.88	0.106
10	0.314	0.640	0.70	0.385	1.25	0.270	1.96	0.200	3.60	0.163
12	0.377	0.900	0.85	0.540	1.51	0.375	2.36	0.280	4.32	0.230
14	0.440	1.200	0.99	0.720	1.76	0.510	2.75	0.385	5.04	0.310
16	0.502	1.550	1.13	0.930	2.01	0.670	3.14	0.500	5.75	0.410
18	0.565	1.950	1.27	1.180	2.26	0.830	3.54	0.620	6.48	0.500
20	0.625	2.400	1.41	1.460	2.51	1.020	3.93	0.770	7.20	0.610

For non-ferrous materials, the flow losses must be multiplied by the following factors :

Copper and Polished Aluminium	:	8
Smooth Cement	:	1.3
Plywood	:	1.5
Cement Fibre	:	1.25
Sawed Wood	:	1.5
Coated Masonry	:	1.2
Crude Concrete, Brick	:	2

Formula for equivalent diameter $D = \frac{2\,a\,b}{a + b}$

GENERALLY RECOMMENDED VELOCITIES

FOR DUCT / PIPING SYSTEM

SERVICE / APPLICATION	VELOCITY (m/sec)
Forced draft duct	12.5 - 17.5
Induced - Draft flues and breaching	10 - 15
Chimneys and stacks	10
Water line max.	30.5
Steam line	50-80
Compressed Air Lines	10
Refrigerant Vapour line - High Pressure	5 - 25
Refrigerant Vapour line - Low Pressure	10 - 25
Refrigerant Liquid	1
Brine lines	2
Ventilating ducts	6 - 15
Register Grills	2.5

VELOCITIES FOR PNEUMATIC CONVEYING

Materials	m/s	ft./min
Pulverised Coal	20 to 28	4000 - 5500
Sawdust	20 to 30	4000 - 6000
Wool, Jute, Cotton	22 to 30	4500 - 6000
Coffee Beans	15 to 20	3000 - 4000
Ashes, Powdered Clinker	30 to 43	6000 - 8500
Sand,	30 - 46	6000 - 9000
Lime	25 to 36	5000 - 7000
Flour	17 to 30	3500 - 6000
Come, Wheat, Rye	25 to 33	5000 - 7000

1 m/s = 197.25 ft/min

RECOMMENDED VELOCITY FOR EXHAUST VENTILATING SYSTEM

Service	Public Building		Industrial Pants	
	m/s	ft./min.	m/s	ft./min.
Risers	2.5-3.0	500-600	4.5-9.0	900-1800
Main Dust	4.5-8.0	900-1500	6-12	1200-2400

Air Change for Rooms, Occupancy known

Type of Building	Air change per cu. Ft. Per Person, Per hour
Hospitals - Ordinary	2500
Surgical Cases	3000
Contagious Diseases	6000
School, Theaters, Prisons, Assembly	1800
Hall	2000
Factories, Shops	1000
European Recommendation	
A. S. H. R. E. Recommendation	600

Air Change for Rooms, Occupancy unknown

Type of Building	Air change Per hour
Cinemas, Theatres	5-10
Assembly Rooms	5-10
Kitchens, large	10-20
Kitchens, Small	20-40
Lavatories	5-10
Restaurants	5-10
Office	3-8

Note : Also consider following

a) Permissible noise level and noise level expected to be generated by supply.

b) Duct sizes and shapes. Design limitations.

c) Heat generated/ to be removed.

d) Room Condition to be maintained.

DENSITY OF AIR WITH RESPECT TO ALTITUDE

All heights are in feet, above the Mean Sea Level

Elevation of Place (ft)	Weight of Air (kg/m^3)	Density Factor
0	4.675×10^3	1.000
500	4.588×10^3	0.981
1000	4.501×10^3	0.962
1500	4.413×10^3	0.944
2000	4.332×10^3	0.926
2500	4.251×10^3	0.909
3000	4.170×10^3	0.891
3500	4.089×10^3	0.874
4000	4.014×10^3	0.858
4500	3.939×10^3	0.842
5000	3.864×10^3	0.826
5500	3.789×10^3	0.810
6000	3.723×10^3	0.795
6500	3.652×10^3	0.780
7000	3.583×10^3	0.766
7500	3.514×10^3	0.751
8000	3.446×10^3	0.737

DENSITY OF AIR WITH RESPECT TO TEMPERATURE

Air Temperature °C	°F	Weight of Air (kg/m³)	Density Factor
-18	0	$5.393 x 10^3$	1.152
21	70	$4.675 x 10^3$	1.000
38	100	$4.426 x 10^3$	0.946
66	150	$4.064 x 10^3$	0.869
93	200	$3.758 x 10^3$	0.803
121	250	$3.496 x 10^3$	0.747
149	300	$3.258 x 10^3$	0.697
177	350	$3.059 x 10^3$	0.654
204	400	$2.884 x 10^3$	0.616
232	450	$2.722 x 10^3$	0.582
260	500	$2.584 x 10^3$	0.552
288	550	$2.453 x 10^3$	0.525
316	600	$2.341 x 10^3$	0.500
343	650	$2.235 x 10^3$	0.477
371	700	$2.135 x 10^3$	0.457
400	750	$2.047 x 10^3$	0.438
427	800	$1.966 x 10^3$	0.421

CHEMISTRY OF WATER

pH = Antilogarithm of the concentration H^+ ions of a solution, in which H^+ expresses acidity.

Acidic – ve water pH	<	7
Neutral water pH	=	7
Alkaline water pH	>	7
Total hardness (or TH)	=	Ca and Mg salts
Temporary hardness	=	bicarbonates and carbonates of Ca and Mg
Permanent hardness	=	neutral salts of Ca and Mg
Alkalinity of Phenolphthalein (or TA)	=	alkalies and carbonates
Alkalinity to methyl orange (or TC)	=	bicarbonates and carbonates

Hardness Conversion :

1 ppm	=	1 mg of $CaCO_3$ per litre
1 m equi./kg	=	50 mg of $CaCO_3$ per litre
1 deg French	=	10 mg of $CaCO_3$ per litre
1 deg Germany	=	10 mg of CaO per litre
1 deg English (Clark)	=	14.3 mg of $CaCO_3$ per litre
1 m mol/litre	=	100 mg of $CaCO_3$ per litre
1 grain/US gallon	=	17.1 mg of $CaCO_3$ per litre

1 ppm	=	0.02 m equi/kg = 0.056 deg German
	=	0.1 deg French = 0.07 deg of English
	=	0.01 m mol per litre = 0.0583 g.p.g.

Interpretation of TA and TAC values :

If $TA = \frac{TAC}{2}$ then only carbonate is present and carbonate content = TAC

If $TA < \frac{TAC}{2}$ then carbonate content = 2 TA
bicarbonate content = TAC – 2TA

If $TA > \frac{TAC}{2}$ then carbonate content = 2 (TAC – TA)
Alkaline + Caustic content = 2TA – TAC

IMPURITIES AND METHODS OF CORRECTION

Nature	Corrections
Turbidity	Coagulation - Decantation - Filtration
Organic matter	Coagulation - Decantation - Filtration - Chlorination
Micro - Organisms bacteria	Chlorination - Ozonation - Filtration - on sterilized candles
pH	Treatment by acid or alkali.
Hardness	Softening by ion exchanger. Internal treatment in boiler
Alkalinity	Softening with lime. Treatment with Acid. Decarbonisation by ion exchanger
Carbonic Acid	Aeration - Degassing - Neutralisation by alkalies - Protection or neutralisation by amines
Oxygen	Thermal degassing, sodium sulphite or hydrazine
Sulphates Chlorides	Total demineralisation
Silica	Precipitation of magnesium salts by heating, filtration through anthracite filters. Absorption by ion exchangers.
Iron	Aeration and filtration - Coagulation and filtration Softening with lime.
Manganese	Aeration and filtration. Coagulation and filtration.
Oil	Coagulation and filtration. Filtration on disatomic earths or active coal.

RECOMMENDED WATER CHARACTERISTICS FOR SHELL BOILERS

For pressure upto 25 bar g

Total hardness in feed water mg/lit. in terms of $CaCO_3$ max.	2
FEED WATER	
pH value	8.5 to 9.5
Oxygen	0.06
Total solids, alkalinity and silica	1.2
Organic matter	N.D
BOILER WATER	
Total hardness, mg/lit in terms of $CaCO_3$max.	ND
Sodium phosphate, mg/lit Na_3PO_4	50 - 100
Caustic Alkalinity, mg/lit in terms of $CaCO_3$min.	350
Total alkalinity, mg/lit in terms of $CaCO_3$max.	1200
Silica, mg/lit as SiO_2 max	< 0.4 of cuastic alkalinity
Sodium sulphite mg/lit as Na_2SO_3	30 - 70
or	
Hydrazine, mg/lit as N_2H_4	0.1 - 1
Suspended solids, mg/lit. max	50
Dissolved solids, mg/lit max.	3500

ND : Not Detectable

RECOMMENDED FEED WATER CHARACTERISTICS FOR WATER - TUBE BOILERS

FEED WATER			
Working Pressure range (kg/cm^2)	**20**	**40**	**60**
Total hardness, mg/lit as $CaCO_3$ max.	10	2	0.5
pH value	8.5 - 9.5	8.5 - 9.5	8.5 - 9.5
Oxygen, mg/lit as O_2 max.	0.05	0.02	0.01
(Fe + Cu + Ni), mg/lit max.	-	-	0.02
Total alkalinity	700	500	300
Silica	140	80	15
Oil	ND	ND	ND
Organic Matter	ND	ND	ND

ND : Not Detectable

RECOMMENDED BOILER WATER CHARACTERISTICS FOR WATER - TUBE BOILER

BOILER WATER				
Pressure at Boiler Outlet kg/cm^2	**20**	**40**	**60**	**80**
Sodium Phosphate, mg/lit as Na_3PO_4	50 - 100	30 - 70	20 - 50	10 - 40
Caustic alkalinity, mg/lit in terms of $CaCO_3$ max.	300	150	60	30
Total alkalinity, mg/lit in terms of $CaCO_3$ max.	700	500	300	200
Silica, mg/lit as SiO_3 max.	4 of Caustic alkalinity	20	10	3
Sodium Sulphite, mg/lit as Na_2SO_3	30 - 50	20 - 40	15 - 30	10 - 20
or Hydrazine, mg/lit as N_2H_4	0.1 - 1.0	0.1 - 0.5	0.05 - 0.30	0.05 - 0.1
Suspended solids, mg/lit max.	200	50	-	-
Dissolved solids, mg/lit max.	3000	2000	1200	700
Chloride, mg/lit as Cl max.	-	-	-	-

ND : Not Detectable

CONTINUOUS BLOWDOWN AS PERCENTAGE OF FEED WATER

$$\text{Blowdown Percentage} = \frac{\text{Feed Water Salts}}{\text{Boiler Water Salts} - \text{Feed Water Salts}} \times 100$$

Note : The following tables may be used as ready reckoners. They give the blowdown percentage to control boiler water salt content. Actual blowdown percentage will have to be worked out for each salt as per boiler water specifications. The highest blowdown value to be chosen.

Feed Water Salts ppm	Permissible Boiler Water Salts (ppm)					
	50	100	150	200	250	300
1	2.04	1.01	0.67	0.50	0.40	0.33
2	4.17	2.04	1.35	1.01	0.81	0.67
3	6.38	3.09	2.04	1.52	1.21	1.01
4	8.70	4.17	2.74	2.04	1.63	1.35
5	11.11	5.26	3.45	2.56	2.04	1.69
6	13.64	6.38	4.17	3.09	2.46	2.04
7	16.28	7.53	4.90	3.63	2.88	2.39
8	19.05	8.70	5.63	4.17	3.31	2.74
9	21.95	9.89	6.38	4.71	3.73	3.09
10	25.00	11.11	7.14	5.26	4.17	3.45

CONTINUOUS BLOWDOWN AS PERCENTAGE OF FEED WATER

Feed Water Salts (ppm)	Permissible Boiler Water Salts (ppm)					
	500	1000	1500	2000	2500	3000
10	2.04	1.01	0.67	0.50	0.40	0.33
20	4.17	2.04	1.35	1.01	0.81	0.67
30	6.38	3.09	2.04	1.52	1.21	1.01
40	8.70	4.17	2.74	2.04	1.63	1.35
50	11.11	5.26	3.45	2.56	2.04	1.69
60	13.64	6.38	4.17	3.09	2.46	2.04
70	16.28	7.53	4.90	3.63	2.88	2.39
80	19.05	8.70	5.63	4.17	3.31	2.74
90	21.95	9.89	6.38	4.71	3.73	3.09
100	25.00	11.11	7.14	5.26	4.17	3.45

Feed Water Salts (ppm)	Permissible Boiler Water Salts (ppm)			
	3000	3500	4000	5000
100	3.5	2.9	2.6	2.0
200	7.1	6.1	5.3	4.2
300	11.1	9.4	8.1	6.4
400	15.4	12.9	11.1	8.7
500	20.0	16.7	14.3	11.1
600	25.0	20.7	17.6	13.6
700	30.4	25.0	21.2	16.3
800	36.4	29.6	25.0	19.0
900	42.9	34.6	29.0	22.0
1000	50.0	40.0	33.3	25.0

SOLUBILITY OF VARIOUS COMPOUNDS

Product as Traded	Solubility (g) of waterfree substance in 1 litre of water	
	at 20°C	at 100°C
Aluminium Sulfate $Al_2(SO_4)_3$; 18 H_2O	363	895
Caustic Soda NaOH	1070	3410
Calcium Chloride $CaCl_2$; 6 H_2O	745	1590
Calcium Carbonate $CaCO_3$	0.015	0.037
Calcium Hydrogen Carbonate $Ca(HCO_3)_2$	1.100 (in CO_2 - saturated water)	
Calcium Sulfate $CaSO_4$; $2H_2O$	2.0	1.62
Iron Chloride $FeCl_3$; 6 H_2O	919	5370
Magnesium Chloride $MgCl_2$; 6 H_2O	542	727
Magnesium Carbonate $MgCO_3$	0.084	0.062
Magnesium Hydroxide $Mg(OH)_2$	0.009	2
Sodium Chloride NaCl	358	392
Diammon Hydrogen Phosphate $(NH_4)_2$ HPO_4	686	-
Sodium Hydrogen Phosphate Na_2HPO_4 ; 12 H_2O	77	104
Tri Sodium Phosphate Na_3PO_4 ; 10 H_2O	110	1080
Sodium Tripolyphosphate $Na_5P_3O_{10}$	150	-
Soda Ash Na_2CO_3 ; 10 H_2O	215	445
Sodium Hydrogen Carbonate $NaHCO_3$	95.7	-
Sodium Sulphate Na_2SO_4	532	423
Sodium Sulphite Na_2So_4	266	266
Potassium Permanganate $KMnO_4$	63.8	-

SOLUBILITY OF VARIOUS COMPOUNDS (Contd.)

$$\frac{1000 \text{ g} \times \rho}{1000 + \text{g}} = \text{g/l of solution} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

If percent by weight are to be found, the following formula has to be applied :

$$\frac{\text{g} \times 100}{1000 + \text{g}} = \text{\% b. w.} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The solubility of NaCl is 358 g. per 1000 g. of water.
The content of NaCl per 1 litre of solution is at a density (found hydrometrically) of 1.197 g/cm^3 :

$$\text{NaCl} = \frac{1000 \times 358 \times 1.197}{1000 - 358} = 315 \text{ g/l}$$

% b. w. of Nacl are :

$$\text{NaCl} = \frac{358 \times 100}{1000 + 358} = 26.4 \text{ \% b. w.}$$

ATOMIC WEIGHTS OF ELEMENTS

Element	Atomic No.	Symbol	Atomic Weight	Element	Atomic No.	Symbol	Atomic Weight
Actinium	89	Ac	226	Mercury	80	Hg	200.61
Aluminium	13	Al	26.97	Molybdenum	42	Mo	95.95
Antimony	51	Sb	121.76	Neodymium	60	Nd	144.27
Silver	47	Ag	107.88	Neon	10	Ne	20.183
Argon	18	Ar	39.944	Nickel	28	Ni	58.71
Arsenic	33	As	74.91	Niton or Radon	86	NitroRn	222
Nitrogen	7	N	14.008	Gold	79	Au	197.2
Barium	56	Ba	137.36	Osmium	76	Os	190.2
Bismuth	83	Bi	209.00	Oxygen	8	O	16
Boron	5	B	10.82	Palladium	46	Pd	106.70
Bromine	35	Br	79.916	Phosphorous	15	P	30.98
Cadmium	48	Cd	112.41	Platinum	78	Pt	195.23
Calcium	20	Ca	40.08	Lead	82	Pb	207.21
Carbon	6	C	12.01	Potassium	19	K	39.096
Celtium	72	Ct	178.6	Praseodymium	59	Pr	140.92
Cerium	58	Ce	140.13	Proto-actinium	91	Pa	231
Cesium	55	Cs	132.91	Radium	88	Ra	226.05
Chlorine	17	Cl	35.457	Rhenium	75	Re	186.31
Chromium	24	Cr	52.01	Rhodium	45	Rh	102.91
Cobalt	27	Co	58.94	Rubidium	37	Rb	85.48
Colombium	41	Cb	92.91	Ruthenium	44	Ru	101.07
Copper	29	Cu	63.57	Samarium	62	Sa	150.43
Dysprosium	66	Dy	162.46	Scandium	21	Sc	45.1
Erbium	68	Er	167.2	Selenium	34	Se	78.96
Tin	50	Sn	118.7	Silicon	14	Si	28.06
Europium	63	Eu	152	Sodium	11	Na	22.997
Iron	26	Fe	55.86	Sulphur	16	S	32.06
Fluorine	9	F	19	Strontium	38	Sr	87.63
Gadolinium	64	Gd	157.25	Tantalum	73	Ta	180.88
Gallium	31	Ga	69.72	Tellurium	52	Te	127.61
Germanium	32	Ge	72.6	Terbium	65	Tb	159.2
Glucinium(1)	4	Gl	9.02	Thallium	81	Tl	204.39
Helium	2	He	4.003	Thorium	90	Th	232.12
Holmium	67	Ho	162.98	Thulium	69	Tm	168.9
Hydrogen	1	H	1.008	Titanium	22	Ti	47.9
Indium	49	In	114.76	Tungsten	74	W	183.85
Iodine	53	I	126.92	Uranium	92	u	238.07
Iridium	77	Ir	192.2	Vanadium	23	V	50.95
Krypton	36	Kr	83.7	Xenon	54	X	131.3
Lanthanum	57	La	138.9	Ytterbium	70	Yb	173.04
Lithium	3	Li	6.94	Yttrium	39	Y	88.92
Lutesium	71	Lu	174.99	Zinc	30	Zn	65.38
Magnesium	12	Mg	24.32	Zirconium	40	Zr	91.22
Manganese	25	Mn	54.93				

PHYSICAL PROPERTIES OF METALS AND ALLOYS

Material	Sp. wt. at 20°C	Melting Point 0°C	Boiling Point 0°C	Sp. heat at ± 50°C c kcal/kg°C	Thermal Conductivity at temperature *t* kcal / m hr°C	*t*°C
Mild Steel	7.65	1400	-	0.114	39.4	20
Aluminium	2.7	660	2270	0.2122	174	0
Antimony	6.7	630.5	1645	0.052	15.9	0
Silver	10.5	960.5	1927	0.0058	365	20
Barium	3.59	710	1537	-	-	-
Bismuth	9.8	271	1560	0.03	6.82	0
Bronze	8.7	900	-	-	51	20
Cadmium	8.64	320.9	767	0.549	80.3	0
Calcium	1.55	810	1439	10.149	-	-
Carbon (graphite)	2.26	3845	3927	0.31	-	-
Chromium	7.188	1765	2600	0.128	77.3	100
Cobalt	8.9	1490	2900	0.1041	-	-
Copper	8.94	1083	2336	0.0928	333	18
White Tin	7.3	231.85	2260	0.0538	56.5	20
Iron	7.9	1535	Varying according to composition	0.1096	58.1	18
Wrought Iron	7.78	2100		-	45	20
White Cast Iron	7.4 to 7.8	1100		0.1298	-	-
Grey Cast Iron	6.7 to 7.1	1225		-	48	0
Brass	8600	900	-	0.094	83.5	0
Lithium	0.530	186	1336	1.092	60.2	0
Magnesium	1.736	650	1110	0.2469	137	50
Manganese	7.2	1247	2032	0.1211	-	-
Mercury	13.6	– 38.83	356.9	0.03325	5.4	18
Molybdenum	10.22	2625	4540	0.0647	126	0
Nickel	8.9	1455	2340	0.1086	51.5	18
Gold	19.3	1063	2600	0.0316	254	0
Platinum	21.45	1773	4300	0.032	60.2	10
Lead	11.34	327.4	1740	0.039	30.2	2
Potassium	0.85	63.5	762.2	0.1921	85.1	0
Silicium	2.326	1430	2355	0.1712	72.2	30
Sodium	0.954	97.8	880	0.297	121	0
Stainless Steel Gr. 316	8.0			0.120	14	100
Sulphur	2.07	112.8	444.55	0.1751	0.181	0
Strontium	2.577	770	1366	0.055	-	-
Tantalum	16.6	3027	>4100	0.033	48	20
Crystaline Tetturium	6.27	449.8	989.8	0.0487	-	-
Thallium	11.82	302	1457	0.0326	33.6	0
Thorium	11.7	(1827)	(>3000)	0.0276	-	20
Titanium	4.5	1725	>3000	0.1125	-	-
Tungsten	19.3	3370	(6700)	0.0375	149	99.8
Uranium	18.97	1090	(3500)	0.0619	-	-
Vanadium	6015	1715	-	0.1153	-	-
Zinc	7.14	419.44	907	0.0938	96	

PHYSICAL PROPERTIES OF CERTAIN LIQUIDS

Liquid	Specific Wt. kg/m^3	Specific Heat kcal/kg °C	Thermal Conductivity kcal/hr.m °C
Acetic acid 100%	1050	0.49	0.148
Sulphuric acid 5%	1030	0.95	0.445
Sulphuric acid 10%	1070	0.92	0.445
Sulphuric acid 15%	1100	0.88	0.445
Nitric acid 10%	1050	0.90	0.445
Nitric acid 20%	1120	0.81	0.445
Ethyl alcohol 100%	700	0.65	0.150
Hydrochloric acid 10%	1050	0.75	-
Asphalt	1100 - 1500	0.22 - 0.40	0.640
Aniline	1020	0.50	0.148
Benzene	730 - 780	0.45	0.137
Cellulose	1300 - 1600	0.32	0.030
Vulcanised rubber	1100	0.42	0.148
Dowtherm A	995	0.63	0.118
Ether	736	0.50	0.117
Water	1000	1.00	0.510
Gasoline	700 - 750	0.53	0.116
Gelatin	1100	0.90	-
Glycerine	1250	0.58	0.245
Coal tar	1200	0.35	-
Cotton Oil	950	0.47	0.148
Machine Oil	920	0.40	0.148
Olive Oil	920	0.47	0.146
Melted Paraffin	890	0.70	0.208
25% Solution NaCl	1180	0.63	0.416
25% Solution CaCl	1240	0.65	0.4162
Carbon Tetrachloride	1600	0.20	0.159
Turpentine	860	0.42	0.100

Note : All the properties given above are at 30°C

CHARACTERISTICS OF THERMIC FLUIDS

Properties	Petroleum Oils	Therminol 66	Marlotherm S	Dowtherm A
Density (Kg/m^3)				
20^{0}C	880	1005.5	1029	1059
100^{0}C	830	952.7	974	995
200^{0}C	765	884.6	904	907
300^{0}C	700	816.6	834	8.7
Kinematic Viscosity (Centistokes)				
20^{0}C	50.17	117.27	39.94	3.77
100^{0}C	5.31	3.97	3.0	1.01
200^{0}C	1.33	0.99	0.95	0.44
300^{0}C	0.6	0.52	0.51	0.27
Vapour Pressure absolute (kg/cm^2)				
200^{0}C	0.012	0.028	0.0041	0.25
250^{0}C	0.078	0.11	0.026	0.9
300^{0}C	0.34	0.46	0.12	2.42
Specific Heat (kcal/kg^{0}C)				
25^{0}C	0.47	0.39	0.38	0.38
100^{0}C	0.53	0.45	0.44	0.43
300^{0}C	0.74	0.62	0.61	0.57
Thermal Conductivity (kcal/hr m^{0}C)				
20^{0}C	0.113	0.103	0.114	0.119
100^{0}C	0.108	0.099	0.106	0.113
200^{0}C	0.102	0.092	0.097	0.102
300^{0}C	0.095	0.083	0.088	0.092
Recommended maximum				
Bulk Temperature ^{0}C)	280	343	340	380
Freezing Point (^{0}C)	–	– 26.1	– 35	12
Flash Point (^{0}C)	204	177	190	124

MECHANICAL PROPERTIES OF SOME COMMON METALS AND ALLOYS

Material	Working Stress kg/mm²			Ultimate Stress kg/mm²			Modulus of elasticity kg/mm²	
	Tension	Compression	Sheer	Tension	Compression	Sheer	Longitudinal	Transversal
Extra mild steel	8	8	4	35-40	35-40	20	20,000	8,000
Mild Steel	9	9	4.5	40-45	40-45	23	20,000	8,000
Semi-mild steel	11	11	5.5	50-55	50-55	28	20,000	8,000
Semi-hard steel	13	13	6.5	60-65	60-65	33	20,000	8,000
Hard steel	15	15	7.5	70-75	70-75	38	22,000	8,800
Very hard steel	17	17	8.5	80-85	80-85	43	22,000	8,800
Extra hard steel	20	20	10	90-100	90-100	50	22,000	8,800
Cast steel	30	30	15	130	130	65	27,500	11,000
Cast aluminium	5	5	2.5	20	-	10	6,750	2,700
Rolled aluminium	4	4	2	25	-	13	7,500	3,000
Bronze	2	2.5	2	25	-	12	6,000	2,400
Aluminium bronze	12	12	6	60	60	30	12,000	4,800
Pure rolled copper	3	6.5	1.5	21	-	11	11,000	4,400
Non-annealed copper wire	6	6	3	40	-	20	13,000	5,200
Hard state duralumin	9	9	7.5	50	50	40	7,500	3,000
Normal duralumin	7.5	7.5	4	43	43	22	7,500	3,000
Annealed duralumin	4	4	2	23	23	12	7,500	3,000
Tin	0.6	0.6	0.3	3.5	3.5	2	3,200	1,280
White cast iron	3	9	3	15	90	15	10,000	4,000
Grey cast iron	2.5	7	2.5	12.5	75	12.5	10,000	4,000
Cast brass	3	3	3	13	70	13	8,000	3,200
Rolled brass	3	3	1.5	20	-	10	6,500	2,600
Non-annealed brass wire	6	6	3	50	-	25	10,000	4,000
Lead	0.2	0.2	0.1	1.35	5	0.7	500	200
Lead wire	0.25	0.25	0.12	2.2	-	1.1	700	280
Zinc	1.5	1.5	1.75	5.5	-	3	9,500	3,800

COEFFICIENT OF LINEAR EXPANSION

Metal/ Plastic	Temperature °C	Linear Expansion per unit length per °C x 10^{-5}
Aluminum	20	2.23
Brass	25 - 100	1.80
Copper	20	1.62
Cast Iron	20	1.17
Wrought Iron	20	1.19
Lead	100	2.93
Magnesium	25 - 100	2.59
Nickel	20	1.26
Carbon Steel	20	1.13
Tin	18 - 100	2.68
Zinc	20	3.06
Epoxy	25	3.06 to 9
Polystyrene	25	5.94 to 8.64
Polyester	25	5.04 to 10
SS AISI 304	0 - 500	1.85
SS AISI 410	0 - 500	1.30

PROPERTIES OF FLUE GASES AT ATMOSPHERIC PRESSURE (11% WATER VAPOUR AND 13% CARBON DIOXIDE)

Temp. t °C	Density kg/m³ ρ	Sp Heat C_p kcal/kg °C	Viscosity μ x 10^6 kg-sec/m²	Thermal Conductivity K K x 10^3 kcal/hr m °C	Prandtl No. Pr	Kinematic Viscosity v x 10^6 m² /sec
100	0.950	0.255	2.082	26.90	0.69	21.50
200	0.748	0.262	2.501	34.47	0.67	32.80
300	0.617	0.268	2.880	41.61	0.65	45.80
400	0.525	0.275	3.232	49.00	0.64	60.40
500	0.457	0.283	3.554	56.31	0.63	76.30
600	0.405	0.290	3.864	63.79	0.62	93.60
700	0.363	0.296	4.144	71.09	0.61	112.00
800	0.329	0.302	4.427	78.66	0.60	132.00
900	0.301	0.308	4.664	85.96	0.59	152.00
1000	0.275	0.312	4.878	93.70	0.58	174.00
1100	0.257	0.316	5.161	101.00	0.57	197.00
1200	0.240	0.320	5.407	107.88	0.56	221.00

GASES-PROPERTIES AND COMBUSTION REQUIREMENTS

Substance		Molecular Weight	Relative Density (Air = 1)	Specific Volume m^3/kg at 0^0C	G. C. V. $kcal/m^3$
Air		-	1	0.773	-
Oxygen	O_2	32.000	1.105	0.699	-
Hydrogen	H_2	2.016	0.069	11.12	2900
Nitrogen (Atmos)	N_2	28.016	50.972	0.795	-
Carbon Monoxide	CO	28.010	0.967	0.800	2865
Carbon Dioxide	CO_2	44.010	1.529	0.510	-
Methane	CH_4	16.040	0.555	1.390	9015
Acetylene	C_2H_2	26.040	0.906	0.853	1499
Ethylene	C_2H_4	28.050	0.975	0.793	13350
Ethane	C_2H_4	30.070	1.049	0.737	15950
Sulphur Dioxide	SO_2	64.060	2.264	0.341	-
Hydrogen Sulphide	H_2S	34.080	1.191	0.649	5760
					kcal/kg
Carbon	C	12.010	-	-	7830
Sulphur	S	32.060	-	-	2200

Air :- BY Weight 76.8% Nitrogen, 23.2% Oxygen.

GASES-PROPERTIES AND COMBUSTION REQUIREMENTS (CONTD.)

Combustion Requirements				Combustion Products with Theoretical Air Quantity							
kg/kg		Mol/mol		kg/kg				Mol/mol			
O_2	Air	O_2	Air	CO_2	H_2O	N_2	SO_2	CO_2	H_2O	N_2	SO_2
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
7.94	34.34	0.5	2.38	-	8.94	26.41	-	-	1.0	1.88	-
-	-	-	-	-	-	-	-	-	-	-	-
0.57	2.47	0.5	2.38	1.57	-	1.9	-	1.0	-	1.88	-
-	-	-	-	-	-	-	-	-	-	-	-
3.99	17.27	2.0	9.53	2.74	2.25	3.28	-	1.0	2.0	7.53	-
3.07	13.3	2.5	11.91	3.38	0.69	10.22	-	2.0	1.0	9.41	-
3.42	14.81	3.0	14.29	3.14	1.29	11.39	-	2.0	2.0	11.29	-
3.73	16.12	3.5	16.68	2.93	1.80	12.39	-	2.0	3.0	13.18	-
-	-	-	-	-	-	-	-	-	-	-	-
1.41	6.10	1.5	7.15	-	0.53	4.69	1.88	-	1.0	5.65	1.0
2.66	11.53	1.0	4.76	3.66	-	8.86	-	1.0	-	3.76	-
1.0	4.29	1.0	4.76	-	-	3.29	2.0	-	-	3.76	1.0

Air :- BY Volume 79.0% Nitrogen, 21.0% Oxygen.

CHARACTERISTICS OF FUEL OILS

Properties	Fuel Oils			
	F. O.	L. S. H. S.	H. P. S.	L. D. O.
Density (Approx. kg/lit at 15°C)	0.89 - 0.95	0.88 - 0.98	0.85 - 0.98	0.85 - 0.87
Flash Point (°C)	66	93	93	66
Pour Point (°C)	20	72	72	12 (Winter) 18 (Summer)
G.C.V., (kcal/kg)	10,200	10,300	9,500	10,700
Sediment.% Wt. Max.	0.25	0.25	0.25	0.1
Sulphur Total, % Wt. Max.	4.0	1.0	1.5	1.8
Water Content, % Vol. Max.	1.0	1.0	1.0	0.25
Ash, % Wt. Max.	0.1	0.1	0.1	0.02

TYPICAL COMPOSITION OF FUELS

Fuels	Percentage Composition							NCV kcal/kg.
	C	H_2	S	N	O_2	H_2O	ASH	
Wood	45.60	3.96	0.07	0.45	37.45	9.33	3.14	4400
Lignite	52.21	3.83	0.88	0.46	17.06	18.39	7.17	4700
Coal - 4000	44.03	3.10	0.32	0.82	4.77	3.84	43.13	3800
Coal - 4500	48.92	3.79	0.51	1.00	5.36	6.04	34.38	4250
Coal - 5500	59.38	3.15	0.38	1.04	4.86	6.00	25.19	5300
Husk	36.14	3.70	0.08	0.46	29.34	8.92	19.40	3100
Bagasse	40.94	4.58	0.04	0.23	36.65	10.53	7.03	3550
F. O.	84.00	11.00	3.50	-	-	1.00	0.50	9650
L. D. O.	85.50	11.50	3.00	-	-	-	-	10100
L. S. H. S.	86.70	11.80	1.00	-	-	0.50	-	9670
L. P. G.	81.50	17.00	-	-	-	1.50	-	10750
N. Gas	66.00	2300	-	-	-	1.50	-	8850
Petcoke	88.00	3.80	5.00	1.65	1.20	8-12%	0.35	7800

Note : 1. The above compositions can vary widely depending on the mine, location, source etc.

2. Solid Fuels in air dried condition.

† L.P.G. is assumed to be composed of (by volume) 10 - 40% of Propane and 70 - 60% of Butane Density - 2.32 kg/Nm^3

‡ Natural Gas is assumed to be composed of (by volume) 76% of Methane, 10% of Ethane, 2% of Propane, 6% of CO_2 and 4% of N_2. Density - 0.83 kg/Nm^3

VISCOSITY IN ENGLER DEGREES AS A FUNCTION OF TEMPERATURE

°C	Gas Oil 28 Sec. Red. 1	Light 42 Sec. Red. 1	Medium 200 Sec. Red. 1	Heavy 600 Sec. Red. 1	Heavy 1500 Sec. Red. 1	Extra Heavy 3500 Sec. Red. 1
0	1.9	3.5	115	620	1,700	6,000
10	1.6	2.6	42	170	500	1,600
20	1.4	2	17.5	62	200	540
30	1.3	1.7	9.5	29	88	210
40	1.22	1.556	6	16	42	95
50	-	1.5	4	9.5	23	46
60	-	-	2.9	6	13	26
70	-	-	2.4	4.2	8.4	15
80	-	-	2	3.2	5.6	9.5
90	-	-	1.8	2.5	3.9	6.5
100	-	-	-	2.1	2.9	4.5
110	-	-	-	1.8	2.4	3.5
120	-	-	-	-	2	2.8
130	-	-	-	-	-	2.4

KINEMATIC VISCOSITY OF LIQUID FUELS AS A FUNCTION OF TEMPERATURE (CENTISTOKES)

°C	Kerosene	H. S. D.	L. D. O.	F. O.
15	2.1	-	-	-
20	1.95	5.8	33	1,500
25	1.8	4	25	1,000
30	1.7	3	20	670
40	1.44	2.5	13	300
60	-	-	5.5	150
80	-	-	-	60
100	-	-	-	30
120	-	-	-	13
140	-	-	-	6

COMBUSTION REACTIONS

		Water in Vapor Form	Water in Liquid Form
Carbon	$C + O_2 + 4\ N_2 = CO_2 + 4\ N_2$	+ 97.6 kcal	-
	$2C + O_2 + 4\ N_2 = 2CO + 4\ N_2$	+ 58.8 kcal	-
Sulphur	$S_2 + 2\ O_2 + 8\ N_2 = 2\ SO_2 + 8\ N_2$	+ 183.6 kcal	-
	$S_2 + 3\ O_2 + 12\ N_2 = 2\ SO_3 + 12\ N_2$	+ 186.6 kcal	
Hydrogen Carbon	$2H_2 + O_2 + 4\ N_2 = 4\ N_2 + 2H_2O$	+ 116.4 kcal	(+ 138.2)
Monoxide	$2CO + O_2 + 4\ N_2 = 2CO_2 + 4\ N_2$	+ 136.4 kcal	-
Methane	$CH_4 + 2\ O_2 + 8\ N_2 = CO_2 + 8\ N_2 + 2\ H_2O$	192.5 kcal	(+ 214.3)
Ethylene	$C_2H_4 + 3\ O_2 + 12\ N_2 = 2\ CO_2 + 12\ N_2 + 2\ H_2O$	+ 319.7 kcal	(+341.5)
Acetylene	$2C_2H_2 + 5\ O_2 + 20\ N_2 = 4\ CO_2 + 20\ N_2 + 2H_2O$	+ 609.6 kcal	(+631.4)
Propane	$C_3H_3 + 5\ O_2 + 20\ N_2 = 3\ CO_2 + 20\ N_2 + 4\ H_2O$	+ 485.1 kcal	(528.7)
Butane	$C_4H_{10} + 13/2\ O_2 + 26\ N_2 = 4\ CO_2 + 26\ N_2 + 5\ H_2O$	+625.7 kcal	(+680.2)

Note : The reactions are considered with substances at 0^0C, the products of reaction brought to 0^0C and the pressure 760 mm Hg.

THERMAL EFFICIENCY CALCULATIONS OF HEATING EQUIPMENT

Various methods are adopted in testing the performance and evaluating the efficiency of heating equipment such as boilers, thermic fluid heaters, air heaters etc. Here is the direct method.

Direct Method:

Total heat input = Heat contained in the fuel input

= Fuel firing rate x C. V. of fuel

Total heat output = Heat contained in absorbing fluid output

Efficiency = $\frac{\text{Heat output} \times 100}{\text{Heat input}}$

= $\frac{\text{Steam produced} \times \text{Change in Enthalpy}}{\text{Fuel Burnt} \times \text{G.C.V}}$

However, this direct approach presents considerable difficulties due to the following reasons,

a) Evaluation of the correct dryness fraction is not possible due to fluctuations in it. Hence boiler output will be incorrect.

b) Correct measurement of steam flow rate encounters unreliability.

Thus the indirect evaluation of the output by deducting the losses from the input has become quite popular and the method is given, among others, in BS 845.

Indirect Method:

Efficiency of the equipment = 100 - Total percentage losses either on the basic of L.C.V. & G. C. V.

Calculation of individual losses can be done by referring to the tables given on the following pages and generally follows the principles used to formulae BS 845

Total percentage loss = dry flue gas loss + loss due to refuse + hydrogen & Moisture loss + Surface loss

All these values have to be separately calculated and added together to calculate total loss. The methods and useful tables to assist you in calculations have been detailed in the following pages.

1. Dry flue gas loss

This type of loss is calculated differently for solid and liquid/gaseous fuels. There are different formulae and bases.

(a) For Solid Fuels

T_s = Stack Temperature ^0C

T_a = Ambient Temperature ^0C

$\%CO_2$ = Dry $CO_2\%$ in stack gas

Cc = Corrected Carbon available per kg of fuel.

= (C% + 3/8 S%) 100

Cr = Carbon rejected in refuse per kg of fuel

Loss due to dry flue gas

$$= \frac{K(T_s - T_a)}{\%\,CO_2 \times G.C.V.} \quad \%\text{..... as per G.C.V. basis}$$

$$= \frac{K(T_s - T_a)}{\%\,CO_2 \times L.C.V} \quad \%\text{..... as per L.C.V. basis}$$

Cc x 100 \ Cr	3	5	7	9	11
25	1355	1232	1108	985	862
30	1663	1540	1416	1293	1170
35	1971	1847	1724	1601	1478
40	2278	2155	2032	1909	1786
45	2586	2463	2340	2217	2094
50	2894	2771	1648	2525	2402
55	3202	3079	2956	2833	2710
60	3510	3387	3264	3141	3017
65	3818	3695	3572	3448	3325
70	4126	4003	3880	3756	3633
75	4434	4311	4187	4064	3741

*Values of G. C. V. and L. C. V. should be in kcal/kg

Dry Flue Gas Loss (Continued)

(b) For Liquid/Gaseous Fuels

T_s = Stack Temperature ^0C

T_a = Ambient Temperature ^0C

CO_2 = Dry CO_2% in Stack Gas.

$$\text{Dry Flue Gas Loss} = \frac{K(T_s - T_a)}{\% CO_2}\%$$

Fuel	K based on G. C. V.	K based on L. C. V.
L. S. H. S.	0.53	0.56
F. O.	0.53	0.56
L. D. O.	0.50	0.53
N. Gas	0.40	0.45
L. P. G.	0.43	0.45

Note : a) The above formulae are approximate. For correct values, fuel and ash analysis are essential and the losses are to be worked out in detail, say as in BS - 845.

b) BS - 845 indicates that a value of 0.56 can be taken on L. C. V. basis for all liquid petroleum fuels.

2. Losses Due To Refuse

A = Percentage of ash in fuel by weight.

Rc = Percentage of combustible in refuse by weight

$$Rc = \frac{\text{C. V. of refuse}}{80.55}$$ % as a rough approximation.
if the actual value by analysis is not available.

$$\text{Quantity of refuse per kg of fuel} = R = \frac{A}{100 - R_c}$$

Losses due to combustible in refuse

$$= \frac{\text{R x C. V. of refuse}}{\text{G. C. V.}} \text{ x 100 ... as per G. C. V. basis}$$

$$= \frac{\text{R x C. V. of refuse}}{\text{L.C.V.}} \text{ x 100... as per L. C. V. basis}$$

† Units of G. C. V. & L. C. V should be in kcal/kg.

LOSS DUE TO INHERENT MOISTURE IN FUEL : G.C.V. BASIS

Note : 1) Following values are applicable for air dried fuels only.

2) Ambient temp. is assumed to be 25^{0}C

Moisture Loss% = K/G.C.V.%

Values of K as per following table

Stack	Percent Moisture in Fuel									
	1	2	3	4	5	6	7	8	9	10
150	625	1250	1875	2500	3125	3750	4375	5000	5025	6250
175	638	1275	1913	2550	3188	3825	4463	5100	5738	6375
200	650	1300	1950	2600	3250	3900	4550	5200	5850	6500
225	663	1325	1988	2650	3313	3975	4638	5300	5963	6625
250	675	1350	2025	2700	3375	4050	4725	5400	6075	6750
275	688	1375	2063	2750	3438	4125	4813	5500	6188	6875
300	700	1400	2100	2800	3500	4200	5900	5600	6300	7000
325	713	1425	2138	2850	3563	4275	4988	5700	6413	7125
350	725	1450	2175	2900	3625	4350	5075	5800	6525	7250
375	738	1475	2213	2950	3688	4425	5163	5900	6638	7375
400	750	1500	2250	3000	3750	4500	5250	6000	6750	7500

LOSS DUE TO HYDROGEN IN FUEL : G.C.V. BASIS

Note : 1) Following values are applicable for air dried fuels only.
2) Ambient temp. is assumed to be 25°C
Hydrogen Loss% = K/G.C.V.%
Values of K as per following table

Stack Temp °C	Percent Moisture in Fuel												
	2.00	3.00	3.10	3.25	3.50	3.75	4.00	6.00	8.00	10.00	12.00	15.00	17.00
150	11170	16755	17314	18151	19548	20944	22340	33510	44680	55850	67020	83775	94945
175	11393	17090	17660	18514	19939	21363	22787	34180	45574	56967	68360	85450	96844
200	11617	17425	18006	18877	20329	21782	23234	34850	46467	58084	69701	87126	98743
225	11840	17760	18352	19240	20720	22200	23680	35521	47361	59201	71041	88802	100642
250	12064	18095	18699	19603	21111	22619	24127	26191	48254	60318	72382	90477	102541
275	12287	18431	19045	19966	21502	23038	24574	26861	49148	61435	73722	92153	104440
300	12510	18766	19391	20329	21893	23457	25021	37531	50042	62552	75062	93828	106338
325	12734	19101	19737	20692	22284	23876	25468	38201	50935	63669	76403	95504	108237
350	12957	19436	20084	21056	22675	24295	25914	38872	51829	64786	77743	97179	110136
375	13181	19771	20430	21419	23066	24714	16361	39542	52722	65903	79084	98855	112035
400	13404	20106	20776	21782	23457	25133	26808	40212	53616	67020	80424	100530	113935

LOSS DUE TO INHERENT MOISTURE IN FUEL : L.C.V. BASIS

Note : 1) Following values are applicable for air dried fuels only.
2) Ambient temp. is assumed to be 25°C
Moisture Loss% = K/L.C.V.%
Values of K as per following table

Stack Temp °C	Percent Moisture in Fuel									
	1	2	3	4	5	6	7	8	9	10
150	85	170	225	340	425	510	595	680	765	850
175	98	195	293	390	488	585	683	780	878	975
200	110	220	330	440	550	660	770	880	990	1100
225	123	245	368	490	613	735	858	980	1103	1225
250	135	270	405	540	675	810	945	1080	1215	1350
275	148	295	443	590	738	885	1033	1180	1328	1475
300	160	320	480	640	800	960	1120	1280	1440	1600
325	173	345	518	690	863	1035	1208	1380	1553	1725
350	185	370	555	740	925	1110	1295	1480	1665	1850
375	198	395	593	790	988	1185	1383	1580	1778	1975
400	310	420	630	840	1050	1260	1470	1680	1890	2100

LOSS DUE TO HYDROGEN IN FUEL : L.C.V. BASIS

Note : 1) Following values are applicable for air dried fuels only.
2) Ambient temp. is assumed to be 25^{0}C
Hydrogen Loss% = K/L.C.V.%
Values of K as per following table

Stack Temp ^{0}C	Percent Moisture in Fuel												
	2.00	3 .00	3.10	3.25	3.50	3.75	4.00	6.00	8.00	10.00	12.00	15.00	17.00
150	1519	2279	2355	2469	2658	2848	3038	4557	6076	7596	9115	11393	12913
175	1743	2614	2701	2832	3049	3267	3485	5228	6970	8713	10455	13069	14841
200	1966	2949	3047	3195	3440	3686	3932	5898	7864	9830	11796	14744	16710
225	2189	3284	3393	3558	3831	4105	4379	6568	8757	10947	13136	16420	18609
250	2413	3619	3740	3921	4222	4524	4825	7238	9651	12064	14476	18095	20508
275	2636	3954	4086	4284	4613	4943	5272	7908	10545	13181	15817	19771	22407
300	2860	4289	4432	4647	5004	5362	5719	8579	11438	14298	17157	21446	24306
325	3083	4624	4779	5010	5395	5780	6166	9249	12332	15415	18498	23122	26205
350	3306	4959	5125	5373	5786	6199	6613	9919	13225	16532	19838	24797	28104
375	3530	5295	5471	5736	6177	6618	7059	10589	14119	17649	21178	26473	30003
400	3753	5630	5817	6099	6568	7037	7506	11259	15013	18766	22519	28148	31902

SURFACE LOSSES IN STILL AIR
(Radiation and Natural Convection only)

Loss due to Radiation and Convection

$$= K \frac{A}{F.F. \times G.C.V.} \times 100 \text{...as per G. C. V. basis}$$

$$= K \frac{A}{F.F. \times L.C.V.} \times 100 \text{...as per L. C. V. basis}$$

Where A = Surface area loosing heat (m^2)

F. F. = Fuel firing rate (kg/hr)

K = Value to be read from following table

Surface Temp°C	Mild Steel Surface			Aluminium Clad Surface		
	Ambient Temp. (°C)			Ambient Temp. (°C)		
	25	30	35	25	30	35
50	178	140	103	102	78	55
60	267	227	187	155	128	103
70	364	321	279	212	184	156
80	467	423	380	273	243	213
90	577	532	487	336	305	275
100	694	648	602	402	370	338
150	1381	1331	1280	767	731	674
200	2254	2201	2147	1181	1141	1102
250	3342	3286	3229	1638	1596	1554
300	4681	4623	4564	2138	2093	2049
350	6314	6254	6193	2680	2634	2588

Note : The actual loss depends also on whether the areas are horizontal, vertical, upwards, downwards etc. An approximate value is taken considering normal mix of types of surfaces found in boiler equipment and ducting.

1. EXCESS AIR FOR COMBUSTION AS A FUNCTION OF % OF CO_2

% CO_2	COAL		WOOD		PADDY HUSK		FUEL OIL	
	% Excess Air	Combustion Air m^3	% Excess Air	Combustion Air m^3	% Excess Air	Combustion Air m^3	% Excess Air	Combustion Air m^3
22.0	-	-	-	-	10.8	2.8	-	-
21.0	-	-	-		16.0	3.0	-	-
20.0	-	-	2.5	4.0	22.0	3.15	-	-
19.0	-	-	8.0	4.25	28.5	3.35	-	-
18.7	0.0	8.81	9.0	4.30	-	-	-	-
18.0	2.9	9.08	13.0	4.45	36.0	3.5	-	-
17.0	9.7	9.66	16.0	4.60	44.0	3.7	-	-
16.0	-	-	27.5	5.0	53.0	4.0	-	-
15.4	-	-	-	-	-	-	0	11.01
15.0	24.0	10.92	35.0	5.3	63.0	4.25	2.4	11.28
14.0	32.0	11.62	45.0	5.7	75.0	4.55	9.4	12.06
13.0	43.0	12.60	56.0	6.1	90.0	4.95	17.0	12.9
12.0	55.0	13.65	70.0	6.6	105.0	5.3	26.0	13.9
11.0	68.0	14.8	84.0	7.2	125.0	5.9	37.0	15.1
10.0	84.0	16.2	103.0	8.0	147.0	6.4	53.0	16.85
9.0	105.0	18.05	126.0	8.8	175.0	7.2	74.0	19.2
8.0	130.0	20.25	154.0	9.9	210.0	8.1	87.0	20.6
7.0	162.0	23.1	188.0	11.3	-	-	112.0	23.4
6.0	203.0	26.7	-	-	-	-	146.0	27.1
5.0	265.0	32.3	-	-	-	-	194.0	32.4
4.0	350.0	39.6	-	-	-	-	267.0	40.5

2. EXCESS AIR FOR COMBUSTION AS A FUNCTION OF % OF CO_2

% CO_2	Natural Gas		Blast Furnace Gas		Butane		Propane	
	% Excess Air	Combustion Air m^3	% Excess Air	Combustion Air m^3	% Excess Air	Combustion Air m^3	% Excess Air	Combustion Air m^3
25.1	-	-	0.0	0.687	-	-	-	-
25.0	-	-	1.0	0.693	-	-	-	-
23.0	-	-	21.0	0.825	-	-	-	-
21.0	-	-	43.0	0.980	-	-	-	-
19.0	-	-	70.0	1.170	-	-	-	-
17.0	-	-	105.0	1.400	-	-	-	-
15.0	-	-	148.0	1.700	-	-	-	-
13.97	-	-	-	-	0.0	31.1	-	-
13.71	-	-	-	-	-	0.0	0.0	23.76
13.0	-	-	205.0	2.090	7.0	33.25	5.0	24.95
12.0	-	-	240.0	2.400	13.0	35.21	13.0	26.86
11.55	0.0	8.06	-	-	-	-	-	-
11.0	5.0	8.46	281.0	2.620	24.0	38.36	24.0	29.51
10.0	12.0	9.3	332.0	2.970	37.0	42.65	34.0	31.84
9.0	28.0	10.34	393.0	3.387	51.0	47.00	48.0	35.15
8.0	44.0	11.63	470.0	3.920	69.0	52.64	65.0	39.31
7.0	65.0	13.3	567.0	4.580	92.0	59.61	88.0	44.66
6.0	93.0	15.52	700.0	5.490	122.0	69.05	118.0	51.69
5.0	131.0	18.61	883.0	6.750	165.0	82.45	159.0	61.66
4.0	189.0	23.31	1160.0	8.640	229.0	102.3	223.0	76.66

INTENSITY OF DRAFT FOR METALLIC CHIMNEYS

(Draft in mm Wg at 27^{0}C and 760 mm of Hg.

Average Temp. in Chimney ^{0}C	Induced Draft per m height Z	* (Useful) Height of Chimney in m									
		3	5	7.5	10	15	20	30	40	50	60
120	0.277	0.83	1.38	2.07	2.77	4.15	5.5	8.3	11.0	13.8	16.6
140	0.317	0.95	1.58	2.37	3.17	4.75	6.3	9.5	12.6	15.8	19.0
160	0.360	1.08	1.80	2.70	3.60	5.40	7.2	10.8	14.4	18.0	21.6
180	0.395	1.18	1.97	2.96	3.95	5.92	7.9	11.8	15.8	19.7	23.7
200	0.425	1.27	2.11	3.18	4.25	6.36	8.5	12.7	17.0	21.1	25.5
220	0.458	1.37	2.29	3.43	4.58	6.87	9.1	13.7	10.3	22.9	27.4
240	0.486	1.45	2.43	3.64	4.86	7.29	9.7	14.5	19.4	24.3	29.1
260	0.515	1.54	2.57	3.86	5.15	7.72	10.3	15.4	20.6	25.7	30.9
280	0.535	1.60	2.67	4.01	5.35	8.02	10.7	16.0	21.4	26.7	32.1
300	0.557	1.67	2.78	1.17	5.57	8.35	11.1	16.7	22.2	27.7	33.4
320	0.577	1.73	2.88	4.32	5.77	8.65	11.5	17.3	23.0	28.8	34.6
340	0.599	1.80	3.00	4.49	5.99	8.98	11.9	17.9	23.9	29.9	35.9

1. For other barometric pressures (b), draft = Z b/760
2. Since the loss of temperature per m height of chimney is approx. 0.5^{0}C, Average temperature of chimney = Foot Temperature - 1/4 chimney height.
3. Useful (*) height above the plans of hearth, for instance above the grating level.

COEFFICIENT OF HEAT TRANSFER (kcal/hr m^{0}C)

Heating	Heated Fluid	Convection		Fluid	Equipment
		Free	Forced		
Liquid	Liquid	125 - 300	750 - 1500	Water	Heat Exchanger
		25 - 50	75 - 200	Oil	between liquids
	Gas	5 - 15	10 - 50	Water to Oil	Hot Water Radiators
	Boiling Liquid	500 - 1500	1000 - 2000	Water	Saline Water Cooler
		25 - 100	100 - 250	Oil	
Gas	Liquid	5 - 15	10 - 50	Air to Water	Air Cooled Economisers
	Gas	3 - 10	10 - 30	Smoke to Steam	Super Heaters
	Boiling Liquid	5 - 15	10 - 50	Smoke to boiling Water	Boilers
Condensed Vapor	Liquid	250 - 1000	750 - 4000	Steam to Water	Condenser Feed Water
		50 - 150	100 - 300	Steam to Oil	Heaters, Oil Reheaters
	Gas	5 - 10	10 - 50	Steam to Air	Steam Pipe in Air, Air Reheaters
	Boiling Liquid	1500 - 12000	-	Steam to Water	Evaporation under
		250 - 7500	-	Steam Oil	Vaccum

PROPERTIES OF VARIOUS FUEL OILS

Properties	Fuel Oils				
	F. O.	L. S. H. S.	H. P. S.	L. D. O.	H.S.D
Density (Approx. kg/lit at 15°C)	0.89 - 0.95	0.88 - 0.98	0.85 - 0.98	0.85 - 0.87	0.82-0.845
Flash Point (°C)	66	93	93	66	66
Pour Point (°C)	20	72	72	12 (Winter)	3 (Winter)
	-	-	-	18 (Summer)	15 (Summer)
G.C.V. (kcal/kg)	10,200	10,300	9,500	10,700	10,900
Sediment.% Wt. Max.	0.25	0.25	0.25	0.1	0.1
Sulphur Total, % Wt. Max.	4.0	1.0	1.5	1.8	
Water Content, % Vol. Max.	1.0	1.0	1.0	0.25	1.0
Ash % Wt. Max.	0.1	0.1	0.1	0.02	0.01

PROPERTIES OF FUELS

Fuel	Ignition Temp (°C)	Sp. Gravity (kg/m³)	Average Viscosity	G.C.V (Kcal/kg)	Flame Temperature (°C)
Coal	450	0.64-0.93	–	7,775	1100-1200
Fuel Oil	250	0.82-1.08	Min 3, Max 650	10,275	1900
Natural Gas	580	0.65	1.02 Ns/m^2	9,050	–
Paddy Husk	340	0.70	–	3,350	800-1000
Bio Gas	680	1.227	–	4,800	1200
Blast Furnace Gas	640	1.0	–	655	1460
Producer Gas	750	0.87	–	1,430	1600
Butane	420	2.09	–	12,000	2000
Town Gas	480	0.50	–	4,300	2045
Coke	700	–	–	7900	–
Hydrogen	400	0.07	8.75	33,800	–
Diesel	210	0.82-1.08	6 centstoke	10,800	–

*The entries left blank are for gases whose average viscosity varies at different temperatures. Viscosity of solids is irrelevant until put to lubricating applications.

NATURAL GAS & TOWN GAS COMPARED

Property	Natural Gas	Town Gas
Maximum Flame Velocity (m/s)	0.34	1.0
Maximum Flame Temperature (^{0}C)	1955	2045
Wobble Number	54	29
Calorific Value (mega cal/m^3)	9.8	4.8
Density (kg/m^3)	0.7	0.6
Specific Gravity w.r.t Air	0.55	0.47
Sulphur compounds (mg of sulphur/m^3)	0-20	122-392
Theoretical volume of air required(m^3/ m^3 of gas)	9.8	4.5
Toxicity	Non-toxic	Toxic

HORIZONTAL STORAGE TANKS

Storage Capacity (liters)	Internal Dia (mm)	Length (mm)
3000	1350	2135
3375	1350	2590
4500	1350	3350
6750	1525	4120
6750	1830	3815
9000	1830	3815
9000	2015	3280
11250	2015	4040
13500	2135	4115
18000	2135	5415
22500	2290	5950
27000	2745	5030
31500	2595	6405
36000	2745	6560
40500	2595	8235
40500	2745	7320
45000	2595	9150
45000	2745	8235
50000	2745	9075

Note : Thickness of plate for cylindrical side is 6mm for all the tanks listed above except the last two for which it is 8mm. The flat ends should always be fabricated from plate at least 2mm thicker than the plate used for the cylindrical side.

FLUID FLOW

Pressure drop in pipes (meters of W.C.)

For 100 meter length of commercial pipe carrying water.

Pipe dia NB Medium (mm)	Flow Rate m^3/hr									
	5	10	15	20	25	30	35	40	45	50
25	20.75	83.0								
32	5.10	20.35	45.79	81.41						
40	2.35	9.43	21.23	31.74	58.97	84.92				
50	0.72	2.9	6.5	11.6	18.15	26.14	35.18	46.47	58.8	72.6

Pipe dia NB Medium (mm)	Flow Rate m^3/hr									
	25	50	75	100	150	200	250	300	350	400
65	4.93	19.7	44.4							
80	2.20	8.81	19.82	35.24						
100	0.58	2.34	5.28	9.38	21.12					
125	0.20	0.80	1.8	3.23	7.28	12.94	20.23	29.13		
150	-	0.3	0.74	1.3	2.96	5.26	8.22	11.84	16.12	21.06

Pipe dia NB ASA Sch 40 inches	Flow Rate m^3/hr									
	5	10	15	20	25	30	35	40	45	50
1"	21.38	85.5								
1 ¼ "	5.43	21.72	48.88	86.90						
1 ½ "	2.51	10.05	22.61	40.20	62.82					
2"	0.72	2.87	6.46	11.5	17.96	25.87	35.21	45.99	58.21	
2 ½"	0.3	1.18	2.66	4.73	7.39	10.64	14.49	18.93	23.96	29.58

Pipe dia NB ASA Sch 40 inches	Flow Rate m^3/hr									
	25	50	75	100	150	200	250	300	350	400
3"	3.47	13.91	31.30							
3 ½"	1.20	4.82	10.85	19.30						
4"	0.64	2.56	5.77	10.26	23.09					
5"	0.20	0.83	1.86	3.31	7.45	13.25	20.71			
6"	-	0.33	0.74	1.32	2.97	5.28	8.26	11.9	16.19	21.15

EQUIVALENT LENGTH (m) FOR ADDITIONAL PRESSURE DROP DUE TO VALVES AND BENDS

Pipe Dia NB Medium	Gate Valve	Angle Volve	Globe Volve	Std. T	Bend 90^0	Bend 45^0
10	0.099	2.79	5.33	1.116	0.434	0.23
15	0.122	3.30	6.44	1.369	0.483	0.277
25	0.204	5.04	9.81	2.180	0.763	0.436
40	0.314	7.53	14.65	2.930	1.130	0.628
65	0.515	12.36	24.03	4.806	1.716	1.030
80	0.605	14.52	28.23	5.646	2.016	1.200
100	0.788	18.91	36.77	7.354	2.626	1.576
125	0.975	23.39	45.48	9.097	3.249	1.950
150	1.167	27.99	54.43	10.885	3.888	2.333

BOILER FEED PUMPS – MAXIMUM SUCTION LIFT

As the temperature of the feed-water rises, the suction that can be handled by a centrifugal boiler feed pump falls due to cavitation problems.

Temperature of feedwater °C	Maximum Suction Feed pump handles (feet)	NPSH required at this temperature (feet)
55	10	-
65	7	-
75	2	-
80	0	0
88	-	5
95	-	10
98	-	15
100	-	17

VOLUMETRIC CONTENTS OF PIPELINES

Internal pipe dia		Liters/m run
0.5 inch	15mm	0.21
0.75 inch	20mm	0.37
1 inch	25mm	0.58
1.25 inch	32mm	1.01
1.5 inch	40mm	1.37
2 inch	50mm	2.20
2.5 inch	65mm	3.71
3 inch	80mm	5.11
4 inch	100mm	8.70
5 inch	125mm	13.26
6 inch	150mm	18.90

AIR REQUIRED FOR COMBUSTION OF VARIOUS ELEMENTS – BY WEIGHT

1 kg of	Kg of O_2 required	Weight of product of combustion (kg)	Kg of N_2 needed	Total weight of air required (kg)	Total weight of combustion products (kg)
H_2	7.937	8.937 H_2O	26.270	34.210	35.210
C	1.332	2.332 CO	4.410	5.742	6.742
C	2.664	3.664 CO_2	8.820	11.480	12.480
S	0.998	1.998 SO_2	3.303	4.301	5.301

AIR REQUIRED FOR COMBUSTION OF VARIOUS ELEMENTS – BY VOLUME

1 kg of	m^3 of O_2 required	Volume of product of combustion (m^3)	m^3 of N_2 needed	Total volume of air required (m^3)	Total volume of combustion products (m^3)
H_2	10.70	6.76 H_2O	31.18	42.04	37.94
C	1.80	2.77 CO	5.23	7.06	8.00
C	3.59	6.84 CO_2	10.47	14.10	17.31
S	1.35	5.54 SO_2	3.92	5.28	9.46

FRICTION LOSS FOR WATER PER 100 FEET OF SCHEDULE 40 STEEL PIPE

1/2" Pipe			1" Pipe		
l/min	m/sec	hf Friction	l/min	m/sec	hf Friction
7.60	0.640	5.50	22.71	0.68	3.10
9.50	0.803	8.24	30.28	0.91	5.20
11.30	0.964	11.50	37.85	1.13	7.90
13.25	1.125	15.30	45.42	1.35	11.10
15.20	1.283	19.70	52.99	1.58	14.70
19.00	1.605	29.70	60.56	1.81	19.00
22.75	1.927	42.00	75.7	2.25	28.90
26.50	2.246	56.00	83.27	2.48	34.80
30.25	2.568	72.10	90.84	2.71	41.00
34.00	2.888	90.10	98.41	2.93	47.80
38.00	3.210	110.60	105.98	3.16	55.10
52.99	4.499	211.00	113.55	3.37	62.90
60.56	5.140	270.00	132.48	3.95	84.40
			151.4	4.5	109.00
			170.32	5.08	137.00
			89.25	5.65	168.00

1½" Pipe			2" Pipe		
l/min	m/sec	hf Friction	l/min	m/sec	hf Friction
60.56	0.77	2.26	94.63	0.73	1.48
68.13	0.86	2.79	113.55	0.87	2.10
75.70	0.96	3.38	132.48	1.02	2.79
83.27	1.05	4.05	151.40	1.16	3.57
90.84	1.15	4.76	170.33	1.31	4.40
98.41	1.25	5.54	189.25	1.45	5.37
105.98	1.34	6.34	227.10	1.74	7.58
113.55	1.44	7.20	264.95	2.03	10.20
132.48	1.68	9.63	302.80	2.33	13.10
151.40	1.92	12.41	340.65	2.61	16.30
170.33	2.14	15.49	378.50	1.32	2.72
189.25	2.40	18.90	454.20	3.50	28.50
208.18	2.64	22.70	529.90	4.07	38.20
227.10	2.88	26.70	605.60	4.65	49.50
246.03	3.11	31.20			
264.95	3.35	36.00			
283.88	3.59	41.20			
302.80	3.83	46.60			
321.73	4.07	52.40			
340.65	4.32	58.70			
359.58	4.56	65.00			
378.50	4.80	71.60			

3" Pipe			4" Pipe		
l/min	m/sec	hf Friction	l/min	m/sec	hf Friction
189.25	0.66	0.76	378.50	0.76	0.72
227.10	0.79	1.06	454.20	0.92	1.01
264.95	0.92	1.40	529.90	1.07	1.35
302.80	1.05	1.81	605.60	1.22	1.71
340.65	1.18	2.26	681.30	1.38	2.14
378.50	1.01	2.75	757.00	1.53	2.61
454.20	1.58	3.88	832.70	1.68	3.13
529.90	1.85	5.19	908.40	1.84	3.70
605.60	2.11	6.68	984.10	1.99	4.30
681.30	2.37	8.38	1059.80	2.15	4.95
757.00	2.64	10.2	1135.50	2.29	5.63
832.70	2.90	12.3	1324.75	2.68	7.54
908.40	3.16	14.5	1514.00	3.07	9.75
984.10	3.43	16.9	1703.25	3.46	12.30
1059.80	3.70	19.5	1892.50	3.83	14.40
1135.50	3.95	22.1	2081.75	4.22	18.10
1324.75	4.62	30.0	2271.00	4.59	21.40

WARM UP LOAD IN KILOGRAMS OF STEAM PER 100M OF STEAM MAIN LINE

Ambient temperature = 21°C

Steam Pressure (kg/cm²)	Main Line Size (mm)													
	50	65	80	100	125	150	200	250	300	350	400	450	500	600
0.36	9.2	14.4	19.0	27	37	47	71	101	134	159	208	262	308	309
0.72	10.0	15.9	20.8	29	40	52	69	112	146	174	227	287	338	470
1.02	11.3	17.8	23.4	33	45	58	88	125	165	196	255	322	379	529
2.55	12.2	19.5	25.4	36	50	64	96	135	179	212	277	350	412	575
4.08	13.4	21.3	27.8	39	53	70	105	148	195	232	303	383	450	627
5.60	15.8	25.2	33	47	63	82	123	175	233	276	360	454	535	745
7.13	17.8	28.0	37	52	71	92	138	196	260	308	402	507	598	832
8.66	19.3	30.6	40	57	77	100	151	214	284	335	438	553	651	906
10.19	20.1	31.8	42	59	80	104	157	223	293	349	455	574	676	942
12.23	20.8	33.1	43	62	83	108	162	230	305	361	472	595	700	997
14.27	22.6	35.8	47	67	90	117	176	250	331	392	513	646	760	1059
16.3	24.2	38.2	50	71	96	125	189	267	353	418	546	689	811	1130
20.38	28.1	45.0	58	83	113	146	219	312	412	489	638	805	947	1320
25.47	36.0	55.0	74	108	150	205	312	463	637	764	981	1228	1503	1700
30.57	39.0	59.0	80	117	162	222	338	502	692	282	1065	1362	1631	2315
40.76	41.5	64.0	85	124	173	237	360	534	735	882	1134	1420	1735	2464
0.36	44.3	68.0	91	132	184	253	385	570	784	940	1210	1514	1852	2627

CONDENSATE LOAD IN KILOGRAMS PER HOUR PER 100M OF INSULATED STEAM MAIN LINE

Ambient temperature 21^{0}C – Insulation 80% Efficient

Steam Pressure (bar)	Main Size (mm)													
	50	65	80	100	125	150	200	250	300	350	400	450	500	600
0.71	9	10	13	16	19	24	30	36	44	48	54	59	66	80
2.04	11	13	16	20	24	29	37	46	55	60	69	73	82	128
4.10	15	18	21	28	37	42	51	63	75	83	95	103	114	137
7.13	18	22	26	32	41	48	60	75	89	98	113	122	136	163
12.23	24	28	34	39	49	57	79	99	117	129	147	160	178	212
16.30	29	35	43	54	67	80	9	123	147	162	186	202	224	269
20.38	31	38	46	57	71	83	105	131	155	170	194	212	237	283
28.50	34	41	50	63	78	92	117	145	173	191	217	237	264	317
35.66	41	50	59	74	92	110	137	172	204	223	257	279	311	371
42.80	45	59	66	83	103	124	155	193	229	252	288	314	350	418

COVERAGE OF PAINTS

With hand-brushing on steel, the following coverage may be expected with different paints:

Ordinary Enamel paint	-	10m^2/liter	(25 microns)*
Red Oxide	-	10m^2/liter	(25 microns)
Coal tar Epoxy	-	5 m^2/liter	(90 microns)
Epoxy zinc coat primer	-	7 m^2/liter	(30 microns)

* - Thickness of each coat

If a person covers 60 m^2 of one coat in 8 hours by spray painting, the finishing will be good. But 40% wastage will be inevitable.

SELECTION TABLE

For Fuses / Cables for Star - Delta Motors

HP, 3ø 415V, 50Hz	FLC Amp.	Phase C Amp.	Back up HRC Fuse Amps.				Isolating Switch Amps.	Typical Cable Size mm² Al	
			Siemens	L & T	Std. Wickman	English Electric		Supply Side	Motor Side
3	5.0	2.9	10	16	10	16	25	2.5	2.5
5	7.5	4.3	16	20	15	20	25	2.5	2.5
7.5	11.0	6.3	16	25	20	20	25	2.5	2.5
10	14.0	8.1	25	25	20	32	25	4	2.5
12.5	18	10.4	25	35	32	32	63	4	2.5
15	21	12.1	32	35	32	50	63	6	2.5
20	28	16.2	50	63	50	63	63	10	4
25	35	20.2	50	63	50	63	63	16	6
30	40	23.0	63	63	63	63	100	16	6
40	53	30.6	63	100	80	100	100	25	16
50	66	38.2	80	100	80	100	100	35	16
60	80	46.2	100	120	100	125	100	50	25
75	100	57.5	125	160	125	160	250	70	35
100	135	77.9	160	200	160	200	250	95	50
125	165	95	200	250	200	250	250	120	70
150	200	115	200	250	200	250	250	185	70
175	230	132.8	250	320	250	-	400	225	120
200	275	159	-	350	250	-	400	400	150
250	325	187	-	350	355	-	400	400	185
275	360	208	-	400	400	-	400	400	185
300	385	222	-	400	400	-	400	500	225
400	500	289	-	500	400	-	630	625	400

SELECTION TABLE
For Fuses / Cables for Dol Motors

HP, 3 Phase 415V, 50Hz	Back up HRC Fuse Amps. FLC Amp.	Siemens	L & T	Std. Wickman	English Electric	Isolating Switch Amps.	Typical Cable Size mm^2 Al
0.5	1.2	4	6	6	6	25	2.5
0.75	1.6	6	6	6	6	25	2.5
1	1.8	6	6	6	10	25	2.5
1.5	2.6	6	10	6	10	25	2.5
2	3.5	10	15	6	16	25	2.5
3	5	16	15	10	16	25	2.5
5	7.5	16	20	16	20	25	2.5
7.5	11	25	25	20	32	25	4
10	14	25	35	20	50	63	4
12.5	18	32	50	32	50	63	6
15	21	32	50	32	50	63	6
20	28	50	63	50	63	63	10
25	35	63	80	50	80	100	16
30	40	63	100	50	100	100	25
40	55	100	120	80	100	100	25
50	65	100	160	80	125	250	35
60	80	160	200	125	200	250	50
75	100	160	200	125	200	250	70
100	135	200	320	160	250	400	95
150	200	-	350	200	-	400	185
200	275	-	500	250	-	400	400
225	300	-	500	315	-	500	400

ELECTRIC MOTOR – FULL LOAD CURRENT

440V, 3 phase, 50Hz current in amperes

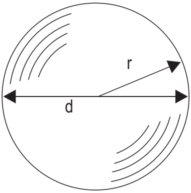
KW	HP	Revolutions per Minute (speed of motor)				
		3000	1500	1000	750	600
0.12	1/6	0.4	0.5	0.5	0.6	0.7
0.18	1/4	0.5	0.6	0.8	1.0	1.3
0.25	1/3	0.7	0.9	1.0	1.2	1.4
0.37	1/2	0.9	1.1	1.3	1.6	1.8
0.55	3/4	1.3	1.5	1.8	2.1	2.4
0.75	1	1.8	2.0	2.3	2.7	3.2
1.10	1.5	2.6	2.8	3.1	3.6	4.2
1.50	2	3.3	3.6	4.0	4.7	5.4
2.20	3	4.6	5.0	5.6	6.3	7.0
3.70	5	7.5	8.0	8.8	9.5	11.0
5.50	7.5	11.0	11.5	12.5	13.5	15.0
7.50	10	14.0	15.0	16.5	18.0	20.0
11.00	15	21.0	22.0	23.0	25.0	27.0
15.00	20	28.0	30.0	31.0	33.0	35.0
18.50	25	34.0	36.0	38.0	40.0	43.0
20.00	30	40.0	43.0	45.0	47.0	50.0
30.00	40	54.0	57.0	60.0	63.0	67.0
37.00	50	65.0	68.0	71.0	75.0	80.0

THERMODYNE

BUS BAR RATINGS

APPROX CURRENT CAPACITY	COPPER		ALUMINIUM	
Amps	mm	inch	mm	inch
425	25x6	1x(1/4)	32x6	1.25x(1/4)
690	38x6	1.5x(1/4)	38x8	1.5x(5/16)
775	51x6	2x(1/4)	51x8	2x(5/16)
1125	76x6	3x(1/4)	76x8	3x(5/16)

SPHERE



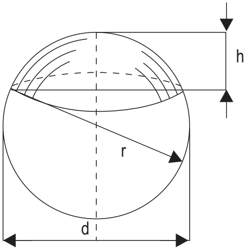
$$S.A. = \pi d^2 = 4\pi r^2 = 12.566\ r^2$$

$$V = \frac{4}{3}\pi r^3 = 4.189 r^3$$

$$= \frac{\pi d^3}{6}$$

$$= 0.5236\ d^3$$

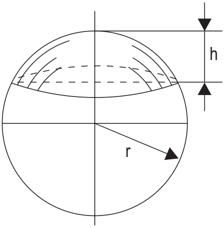
SPHERICAL SECTOR



$$S.A. = \pi r \frac{4h + d}{2}$$

$$V = \frac{2}{3}\pi r^2 h = 2.094\ r^2 h$$

SPHERICAL SEGMENT



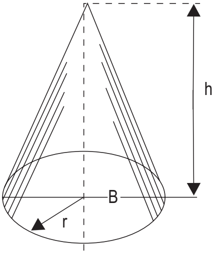
S.A. = Spherical Surface

$$= 2\pi rh = \frac{\pi}{4}(d^2 + 4h^2)$$

$$V = \pi h^2 \left(r - \frac{1}{3} h \right)$$

$$= \pi h \left(\frac{d^2}{8} + \frac{h^2}{6} \right)$$

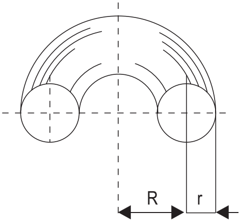
RIGHT CIRCULAR CONE



$$S.A. = \pi rl = \pi r^2 = \pi r^2 \sqrt{r^2} = h^2$$

$$V = \frac{1}{3} Bh = \frac{1}{3}\pi hr^2$$

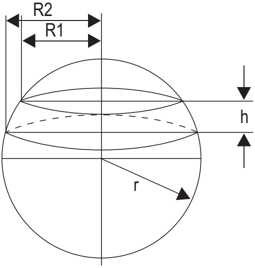
CIRCULAR RING



S.A. = $4\pi r^2 R$

V = $2\pi^2 r^2 R = 2.467\alpha^2 D$

SPHERICAL ZONE



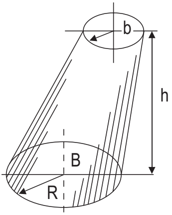
r = radius of sphere

S.A. = area of spherical part

S.A. = $2\pi rh$

V = $\frac{1}{6}\pi h\,(R^2_1 + 3R^2_2 + h^2)$

FRUSTUM OF CONE WITH PARALLEL BASES



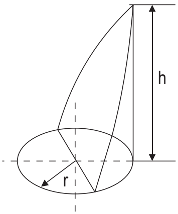
B = area large base

b = area small base

h = distance between two bases

V = $\frac{1}{3}h\,(B + b + \sqrt{Bb})$

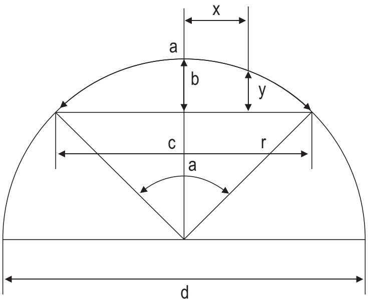
CYLINDRICAL ANGULAR WITH NORMAL CYLINDRICAL BASE



S.A.= cylindrical surface

V = $\frac{2}{3}r^2 h$

SEGMENT OF A CIRCLE



$$S = \frac{1}{2} r^2 \left(\frac{\alpha^0}{180} \pi - \text{Sin } \alpha \right)$$

$$\text{Rise } b = r - \frac{1}{2} \sqrt{4r^2 - c^2} = \frac{c}{2} \text{tg } \frac{\alpha}{4}$$

$$Y = b - r + \frac{1}{2} \sqrt{r^2 - x^2}$$

COLOUR CODE FOR GENERAL SERVICES (PIPES)

Pipe Contents	Basic Colour (approx 150 mm)	Colour Code Indication			Basic Colour (approx 150 mm)
Water					
Drinking	green		blue		green
Cooling (Primary)	green		white		green
Boiled feed	green	crimson	white	crimson	green
Condensate	green	crimson	emgreen	crimson	green
Chilled	green	white	emgreen	white	green
Central htg 100°C	green	blue	crimson	blue	green
Central htg 100°C	green	crimson	blue	crimson	green
Cold, down service	green	white	blue	white	green
Hot water supply	green	white	crimson	white	green
Hydraulic power	green		salmon pink		green
Sea, river, untreated			green		
Fire extinguishing	green		safety red		green
Compressed air			light blue		
Vacuum	light blue		white		light blue
Steam			Silver grey		
Drainage			black		
Electrical conduits & ducts			orange		
Town gas					
Manufactured gas	yellow ochre		emerald green		yellow ochre
Natural gas			yellow ochre		
Oils					
Diesel fuel			brown		
Lubricating power	brown		emerald green		brown
Hydraulic power	brown		salmon pink		brown
Transformer	brown		crimson		brown
Acid and alkalis			violet		

Code indication colours (if other and safety colours)

Colour	BS 381C	BS 2660
Crimson	540	1 - 025
Emerald Green	228	0 - 010
Salmon Pink	447	2 - 031

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