Volume II

Reference Book

on

Chemical
Engineering

D. Sen

Reference Book
on
Chemical Engineering

THIS PAGE IS BLANK

Reference Book
on
Chemical
Engineering

Volume II

D. Sen
  B.Ch.E.
Fellow of the Institution of Engineers (India)
Former Listed IDBI Consultant
and
Retired Chief Engineer (Chem.) of BVFCL, (Formerly HFCL)
Namrup Unit, Assam

To My Mother

Who has taken much interest
in progress of the book ,
the book is dedicated

THIS PAGE IS BLANK

PREFACE

This volume II contains a large number of data tables and graphs in Part A whereas in Part B essential information on other engineering disciplines viz. civil, mechanical, electrical, instrumentation and general matters were given for Chemical Engineering students as well as for professionals. Some of the information on other engg. areas and finance were written by experienced senior engineers and finance executives from industry to make this volume more interesting. This volume was also reviewed by Professor U.P. Ganguly (retd.) of Chemical Engg. Deptt. of IIT, Kharagpur. I thank to all who have assisted in this work.

Kolkata   **D. SEN**

THIS PAGE IS
BLANK

CONTENTS

THIS PAGE IS BLANK

PART I
Data Tables and Graphs

THIS PAGE IS
BLANK

TABLES

Table 1 : Chemical and physical Data of Various Elements

	Symbol	Atomic Mass $^{12}C = 12$	Density[6] g/cm^3 (20°C)	Melting Point °C	Boiling Point at 760 Torr °C	Brinell Hardness HB
Aluminium.......	Al	26.98	2.70	659	2447	16
Antimony.......	Sb	121.75	6.69	630.5	1637	30
Arsenic.......	As	74.92	5.72[1]	815	613	–
Barium.......	Ba	137.34	3.61	710	1637	42
Beryllium.......	Be	9.01	1.85	1283	2477	60
Boron.......	B	10.81	2.33	2030	3900	–
Cadmium.......	Cd	112.40	8.64	321	765	35
Calcium.......	Ca	40.08	1.54	850	1487	13
Carbon[3]).......	C	12.01	2.20	3800	–	–
Cerium.......	Ce	140.12	6.77	797	3470	21
Chromium.......	Cr	52.00	7.20	1903	2642	70
Cobalt.......	Co	58.93	8.90	1492	2880	125
Copper.......	Cu	63.54	8.96	1083	2595	50
Fluorine.......	F	19.00	1.70	–219.6	–188	–
Gold.......	Au	196.97	19.30	1064.8	2707	–
Iodine.......	I	126.90	4.93[2]	113.6	182.8	–
Iron.......	Fe	55.85	7.87	1536	3070	45
Lead.......	Pb	207.19	11.34	327.4	1751	3
Magnesium.....	Mg	24.31	1.74	649.5	1120	–
Manganese.....	Mn	54.94	7.43	1244	2095	–
Mercury.......	Hg	200.61	13.55	– 38.9	356.7	–
Molybdenum....	Mo	95.94	10.22	2620	4800	160

Nickel.......	Ni	53.71	8.91	1455	2800	70
Nioblum.......	Nb	92.91	8.55	2468	~4900	250
Phosphorus.....	P	30.97	2.69[4])	44.2[5])	281	–
Potassium.......	K	39.10	0.86	63.2	753.8	0.037
Rhodium.......	Rh	102.91	12.50	1960	3960	110
Silicon.......	Si	23.09	2.33	1423	2355	–
Silver.......	Ag	107.87	10.50	961.3	2180	20
Sodium.......	Na	22.99	0.97	97.8	890	0.07
Sulphur.......	S	32.06	2.07	115.2	444.6	–
Tantalum.......	Ta	180.95	16.60	2996	5400	30
Titanium.......	Ti	47.90	4.51	1668	3280	160
Uranium.......	U	233.03	19.10	1130	3930	–
Vanadium.......	V	50.94	6.12	1890	≈ 3380	260
Bismuth.......	Bi	203.98	9.79	271	1560	9
Tungsten.......	W	183.85	19.27	3390	5500	250
Zinc........	Zn	65.37	7.13	419.5	907	35
Tin.......	Sn	113.69	7.29	231.9	~2687	4
Zirconium.......	Zr	91.22	6.50	1855	≈ 4380	160
Chlorine	Cl	35.46	2.49[6]	–101.6	–34.6	–
Helium	He	4.00	0.137	–272.2	–268.9	–
Hydrogen	H	1.008	0.069	–259.1	–252.7	–
Krypton	Kr	83.70	2.818	–169	–151.8	–
Neon	Ne	20.183	0.674	–248.6	–245.9	–
Nitrogen	N	14.00	12.5[7]	–209.8	–195.8	–
Oxygen	O	16.00	1.105	–218.4	–183	–
Radium	Ra	226.05	5.0	960	1140	–

(1) For the rhombic modification. (2) At 25°C. (3) For graphite. (4) For black phosphorus. (5) For white phosphorus. (6) At. 20°C (7) At 0°C and H_2O = 1

Source : D ANS Lax, Chemists and Physicists Pocket Book, 3rd edn 1967 except B.H.

Table 2 : Groups of chemicals

There are about 70, 000 chemicals in use through out the world. The chemicals can be classified in three groups as below :

Group A

1. Adhesive chemicals

2. Pesticides

3. Fertilisers (agro chemicals)

4. Basic chemicals

5. Bulk drugs

6. Catalytic chemicals

7. Cosmetics and detergents

8. Dyes and Pigments

9. Lab. reagents

10. Fine chemicals

Group B

11. Perfume chemicals

12. Food preservatives (additives)

13. Food Processing Chemicals

14. Heavy chemicals

15. Intermediates

16. Leather chemicals

17. Metal Processing chemicals

18. Organic chemicals

19. Oil and drilling chemicals.

20. Paper processing chemicals.

Group C

21. Petrochemicals

22. Plastic Polymers
    (straight, addition and condensation)

23. Pharma chemicals

24. Speciality chemicals

25. Textile processing chemicals

26. Printing and Writing ink

27. Optical whiteners

28. Oils & fats

29. Rubber chemicals

30. Photographic chemicals.

N. B. Some chemicals have overlapping existence in other groups.

Table 3 : Physical Data of various Elements and Compounds

Substance	For-mula $^{12}C=12$	Molecular Weight	Density kg/m^3 gaseous	Density kg/m^3 liquid	Boiling Point 760 Torr °C	Heat of Vapor-isation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temper-ature °C	Critical Pressure kp/cm^2
Hydrogen......	H_2	2.016	0.09	71 (−253)	−252.8	108.4 (18)	3.424	−259.2	−239.9	13.2
Oxygen.........	O_2	32.00	1.43	1195 (−195)	−183.0	50.9	0.22 (48)	−218.8	−118.3	51.8
Nitrogen........	N_2	28.02	1.25	812 (−196)	−195.8	47.3	0.25	−210.0	−146.9	34.5
Air...............		28.96	1.29	520 (−146)	−191.4	47	0.240	−213.0	−140.7	38.5
Chlorine........	Cl_2	70.91	3.21	1574 (−40)	−34.1	68.8	0.114	−101.0	144	78.5
Water...........	H_2O	18.01	0.804	1000 (4)	100.00	539	1.007	0.000	374.2	225.6
Hydrochloric acid............	HCl	36.47	1.63	1194 (−86)	−85.0	105.8	0.19	− 114.2	51.5	84.7
Hydrogen sulphide........	H_2S	34.08	1.54	964 (− 60)	−60.2	131.0	0.24	− 85.7	100.4	91.9
Sulphur dioxide..........	SO_2	64.07	2.93	1460 (−10)	−10.0	93.1	0.145	− 75.5	157.5	80.4
Ammonia.......	NH_3	17.03	0.77	650 (−10)	−31.0	288.8	0.50	− 77.4	132.4	115.2
Carbon monoxide.CO	28.01	1.250	791 (−191)	−191.6	51.6	0.243	− 205.1	− 140.2	35.7
Carbon dioxide....CO_2	44.01	1.98	960 (− 6)	−78.5	137	0.202	− 56.6	31.0	75.3

See notes to Table 1 for Tables 3 to 15

Source : Chemists and Physicists pocket book-D Ans Lax 3rd edn. 1967.

Where the liquid-state density shown does not refer to 20°C, the relevant temperature is indicated in brackets.

Where the heat of evaporation does not refer to the boiling point at 760 Torr (760 mm Hg), the relevant temperature is added in brackets.

Specific heat at constant pressure C_p. Where the information shown does not refer to 20°C for liquids or 25°C for vapours or gases, the relevant temperature is given in brackets.

Table 4 : Physical Data of Various Hydrocarbons

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Normal Paraffins									
Methane..........	CH_4	16.04	0.717^1	−164	121.9	0.532	−184	−82.5	47.3
Ethane...........	$CH_3{-}CH_3$	30.07	1.356^1	−88.5	116.7	0.419	−172.1	32.1	50.0
Propane..........	$CH_3{-}CH_2{-}CH_3$	44.10	2.02^1	−44.5	101.8	0.399	−189.9	96.8	43.5
n-Butane........	$CH_3{-}CH_2{-}CH_2{-}CH_3$	58.12	2.703^1	−0.5	92.1	0.406	−135	152.0	38.6
i-Butane........	$CH_3{>}CH{-}CH_3$ (CH_3)	58.12	2.673^1	−10.2	87.5	0.39	−145	133.7	37.7
n - Pentane....	$CH_3{-}(CH_2)_3{-}CH_3$	72.15	626	36.15	85.4	0.543	−130.8	197.2	34.1
2-Methyl butane (isopentane)	$CH_3{-}CH{-}CH_2{-}CH_3$ $|$ CH_3	72.15	625(15)	28.0	81.5	0.541	−159.6	194.8	34.4
n-Hexane.........	$CH_3{-}(CH_2)_4{-}CH_3$	86.18	664(15)	68.8	80	0.532	−93.5	234.7	31.9
2-Methyl pentane..	$CH_3{-}CH{-}CH_2{-}CH_2{-}CH_3$ $|$ CH_3	86.18	669(15)	63.2	76.5 (60)	0.523	−153.7	224.9	30.9
n-Heptane........	$CH_3{-}(CH_2)_5{-}CH_3$	100.21	684	98.3	75.6	0.525	−90.5	267.2	28
n-Octane.........	$CH_3{-}(CH_2)_6{-}CH_3$	114.23	702	125.8	71.9	0.522	−57.0	296.2	25.5
n-Nonane.........	$CH_3{-}(CH_2)_7{-}CH_3$	128.26	718	140.6	68.8	0.52	−51.0	322.0	23.7

(1) kg/nm^3 (at 0°C and 760 Torr)

Table 5

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Naphthenes) (Cycloparaffins)									
Cyclobutane.........	CH_2—CH_2 / CH_2—CH_2	56.11	703 (0)	–7.5	103	0.31	– 80		
Cyclopentane........	CH_2—CH_2 CH_2 / CH_2—CH_2	70.14	745	49.5	94	0.43	–93.3	238.6	46.1
Cyclohexane........	CH_2—CH_2—CH_2 / CH_2—CH_2—CH_2	84.16	773	80.8	86	0.497	6.4	281	41.9
Cycloheptane.........	CH_2—CH_2—CH_2 CH_2 / CH_2—CH_2—CH_2	98.19	812	118		0.44	–12		
Cyclooctane.........	CH_2—CH_2—CH_2—CH_2 / CH_2—CH_2—CH_2—CH_2	112.12	834	148.5			14.3		

Table 5A

Aromatic Hydrocarbons

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Benzene.........	C_6H_6	78.11	879	80.2	94.2	0.413	5.5	288.9	49.9
Methyl benzene (toluene).........	$C_6H_5CH_3$	92.14	872(15)	110.8	85	0.41	–95	319.9	41.6
1, 2-Dimethyl benzene (O-Xylene).........	$C_6H_4(H_3)_2$	106.17	881	143.6	83	0.414	–27.9	358.0	37.3
m-Xylene.........	$C_6H_4(CH_3)_2$	106.17	866	139	82	0.410	–49.3	353	37.7

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
p-Xylene........	$C_6H_4(CH_3)_2$	106.17	861	138.4	81	0.406	13.3	343	37.2
Ethyl benzene....	C_6H_5—CH_2—CH_3	106.17	867	136.1	81.1	0.415	−94.4	346.4	38.1
1, 3, 5-Trimethyl benzene (Mesitylene).........	$C_6H_3(CH_3)_3$	120.2	864	164.4	77.5	0.42	−52.7	388	34.3
n-Propylbenzene.....	C_6H_5—CH_2—CH_2—CH_3	120.12	862	159.6	76.0		99.2	363	33.1
Diphenyl...........	C_6H_5—C_6H_5	154.2	989(77.1)	255.9	74	0.295	70	528	42.7

Table 6

Condensed Aromatics

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Naphthalene		128.18	976(85.3)	218	75	0.306	80	478.5	41.9
1, 2, 3, 4-Tetrahydronaphthalene (Tetraline)........		132.21	973	207	79.3	0.40	−35		
Cis-Decahydronaphthalene (Decalin).....		138.25	894	193	71.0 (120)	0.41	−51		
Anthracene......		178.24	1252 (0°)	342		0.28	218		
Phenanthrene...		178.24	1041 (131.1)	332		0.31	101		

Table 7

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Mono-olefines									
Ethylene	$CH_2 = CH_2$	28.05	1.26'	−103.9	125	0.371	−170	9.5	51.7
Propylene	$CH = CH_2—CH_3$	42.08	647 (−79)	− 47	104.7	0.363	−185	91.8	47.1
Butylene-(1)	$CH_2 = CH—CH_2—CH_3$	56.11	607 (9.8)	− 6.1	96.1	0.38	− 190	146.4	37.5
Isobutylene		56.1	626.8(−6.6)	−6.6	92.8	0.38	−146.8	144.0	40.0
Pentene-(1)	$CH_2 = CH—CH_2—CH_2—CH_3$	70.14	637 (18)	39.5	75	0.530	−166.2	202.6	41.7
Hexene-(1)	$CH_2 = CH—(CH_2)_3—CH_3$	84.16	679 (15)	63.4	79.5	0.50	−139.0	230	31.5
Heptene-(1)	$CH_2 = CH—(CH_2)_4—CH_3$	98.19	705	98.5		0.49	−119.4	262	28.7

Table 8

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Diolefines									
Propadiene	$CH_2 = C = CH_2$	40.07	652 (−25)	32	125	0.35	−146	120.8	53.5
Butadiene-(1, 3)	$CH_2 = CH—CH = CH_2$	54.09	650 (−6)	4.75	108.0	0.561 (0)	−108.9	152	44.1
Pentadiene-(1, 3)	$CH_2 = CH—CH = CH—CH_3$	68.12	683.0 (15)	42.1		0.36	− 87.5		
2-Methyl butadiene (1, 3) (Isoprene)	$CH_2 = C—CH = CH_2$ $|$ CH_3	68.12	681	34.3	92.1 (25)	0.58 (25)	−120		

(1) kg/nm³ (at 10°C and 760 Torr)

Source : Chemists and Physicists pocket book-D Ans Lax 3rd edn. 1967

Table 9

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Acetylenes									
Acetylene	$CH \equiv CH$	26.04	618 (−81.8)	−83.6	198	0.403	−81.8	35.5	63.7
Methyl acetylene ...	$CH_3 — C \equiv CH$	40.07	713 (−55)	− 27.5		0.362	− 105	127.9	
Ethyl acetylene	$CH_3 — CH_2 — C \equiv CH$	54.09	668 (0)	18			−137		
Dimethyl acetylene ...	$CH_3 — C \equiv C — CH_2$	54.09	650	27.2	119	0.552	−32.3	215.5	

Table 10

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Halogenated Hydrocarbons									
Methyl chloride	CH_3Cl	50.49	2.307[1]	−23.7	102	0.193	−97.7	142.8	68.2
Methyl fluoride	CH_3F	34.03	1.545[1]	−78.2	124	0.26	−141.8	44.5	59.9
Methylene chloride..	CH_2Cl_2	84.93	1336	40.7	78.7	0.276	−96	237	62
Chloroform	$CHCl_2$	119.38	1482	60.7	60.6	0.237	−63.5	262.5	56.7
Carbon tetrachloride	CCl_4	153.82	1592	76.7	46.6	0.203	−22.9	283.1	46.5
Trichloro-monofluoro methane (Freon 11)	$CFCl_3$	137.37	1494 (17.2)	24.9	43.6	0.211	−111	198.0	44.6
Dichloro-difluoro methane (Freon 12)	CF_2Cl_2	120.91	1486 (−30)	− 29.8	40	0.137	−111	115.5	40.9

(1) kg/nm³ (at 0 and 760 Torr)

Table 10 (contd.)

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Chloro-trifluoro methane (Freon 13)	CF_3Cl	104.47	927	−81.5	36	0.15	−181.0	28.7	39.4
Ethyl chloride..........	C_2H_5Cl	64.52	917 (6)	13.1	91.3	0.382	−142.5	189	56.8
Ethylene dichloride (1,2)...........	$CH_2Cl—CH_2Cl$	98.96	1253	83.7	84.1	0.31 (30)	−35.5	288	54.8
Ethylene dichloride (1,1)...........	$CHCl_2—CH_3$	98.96	1184 (15)	57.3	57.3	0.21	−96.6	250	51.7
1,1-Dichloro ethylene	$CH_2 = CCl_2$	96.94	1218	37	65	0.28	−122.5		
1,1,1-Tichloro-ethane.........	$CCl_3—CH_3$	133.41	1311 (25)	74		0.257	−32.6		
1,1,2-Trichloro-ethane...........	$CHCl_2—CH_2Cl$	133.41	1443	113.7	67		−35.5		
Trichloro ethylene...........	$CCl_2 = CHCl$	131.39	1470 (15)	86.9	57.8	0.277	−83		
Tetrachloro ethane............	$CHCl_2—CHCl_2$	167.85	1603 (15)	146.4	55.0	0.27 (16)	−42.5		
Tetrachlorethy-lene	$CCl_2 = CCl_2$	165.83	1624 (15)	121.1	50.0	0.210	−23.5		
Fluroro benzene............	C_6H_5F	96.11	1024	85.1	77	0.364	−40.5	286.5	46.1
Chloro benzene	C_6H_5Cl	112.56	1112 (15)	132	77.6	0.31	−45	359.2	46.1

Table 11

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat Cp kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Alcohols									
Methanol (methyl alcohol)......	CH_3OH	32.04	795 (15)	64.7	263	0.596	−97.9	239.4	82.6
Ethanol (ethyl alcohol)......	C_2H_5OH	46.07	794 (15)	78.3	202	0.572	−114.5	234.1	65.1
Glycol..........	$HO \cdot CH_2{-}CH_2 \cdot OH$	62.07	1113	197.4	194	0.563	−12.4		
n-Propyl alcohol.......	$C_2H_5CH_2OH$	60.10	804	97.4	180	0.560	−126.2	263.7	51.8
i-Propyl alcohol.......	$CH_3CH(OH)CH_3$	60.10	785	82.4	160	0.576	−89.5	243.5	54.9
Glycerine..........	$CH_2OH \cdot CHOH \cdot CH_3OH$	92.10	1261	290	197	0.65	18		
n-Butyl alcohol........	$C_3H_7CH_2OH$	74.12	810	117.5	141	0.560	−89.3	289.7	45
i-Butyl alcohol........	$(CH_3)_2CHCH_2OH$	74.12	803	108	138	0.552	−108	277.6	49.8
n-Amyl alcohol.......	$C_5H_{11}OH$	88.15	824 (15)	138	123	0.553	−78.5	315	
i-Amyl alcohol	$(CH_3)_2CHCH_2CH_2OH$	88.15	808 (25)	131.5	120	0.560		306.6	
Cyclohexanol (Hexalin)........	$CH_2\!\!\begin{smallmatrix} CH_2{-}CH_2 \\ \\ CH_2{-}CH_2 \end{smallmatrix}\!\!CHOH$	100.16	938 (36.6)	160	108	0.418	23		
Phenol	C_6H_5OH	94.11	1071 (25)	182.2	122	0.333	40.8	419.2	62.5
o-Cresol........	$C_6H_4(OH)CH_3$	108.14	1047	191	103	0.50	32	422	51

Table 12

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m³	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Aldehydes, Ketones									
Acetone..........	CH_3COCH_3	58.08	791	56.2	125	0.515	−95.6	235.0	48.6
Diethyl ketone.....	$C_2H_5COC_2H_5$	86.13	816 (25)	101.7	90.8	0.55 (50)	−39.9		
Furfural	HC—CH ‖ ‖ HC·O·C·CHO	96.09	1160	161.7	108	0.418 (50)	−36.5		
Methyl furfural....	CH — CH ‖ ‖ CH_3·C.O.C— CHO	110.11	1107.2 (18)	187.0					

Table 13

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m³	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm²
Ethers									
Dimethyl ether	CH_3—O—CH_3	46.07	2.11[1]	−24.9	111.6	0.33	−140	126.9	53.7
Methylethyl ether........	CH_3—O—C_2H_5	60.10	726.0 (0)	6.4/724[2]	98	0.32		164.7	44.8
Diethyl ether.....	C_2H_5—O—C_2H_5	74.12	714	34.6	86	0.371	−116.4	193.4	37.2
Diphenylene oxide............		168.2	1089 (99.3)	287.0			83		

(1) kg/nm³ (at 0°C and 760 Torr) (2) 6.4 at 724 Torr

Table 14

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Esters									
Formic acid ethyl ester......	$HCOOC_2H_5$	74.08	912 (25)	54.1	97.2	0.48	–80.5	235.3	48.4
Acetic acid ethyl ester......	$CH_3COOC_2H_5$	88.11	901	77.1	87.6	0.46	–83.6	250.1	39.3
Butyric acid ethyl ester.....	$C_3H_7COOC_2H_5$	116.16	872 (25)	121.2	74.7	0.45	–97.9	292.8	31.3

Table 15

Sulphur and Nitrogen Compounds

Substance	Formula	Molecular Weight $^{12}C = 12$	Density kg/m^3	Boiling Point 760 Torr °C	Heat of Evaporation kcal/kg	Specific Heat C_p kcal/kg deg C	Melting Point °C	Critical Temperature °C	Critical Pressure kp/cm^2
Methyl amine....	CH_3NH_2	31.06	769 (–79)	–7.55[1]	198.6	0.416	–92.5	156.9	76.0
Ethyl amine......	$C_2H_5NH_2$	45.08	742 (–33.5)	16.6	149	0.69	–83.3	183.2	57.4
Aniline.............	$C_6H_5NH_2$	93.13	1013 (30)	184.4	107	0.49	–6.5	425.6	54.1
O-Toluidine.....	$CH_3 \cdot C_6H_4 \cdot NH_2$	107.16	996 (45)	200.5	90.5	0.45	43.5	395.5	31.8
Nitro-benzene..	$C_6H_5NO_2$	123.11	1204	210.9	94.7	0.36	5.7		
Pyridine..........	$\begin{smallmatrix}HC\!\!-\!\!CH\!\!-\!\!CH\\ \quad\quad\quad\quad N\\ HC\!\!-\!\!CH=CH\end{smallmatrix}$	79.10	988 (15)	115.5	102	0.42	–41.8	346.8	57.9
Thiophene........	$\begin{smallmatrix}HC\;-\;CH\\ \parallel\quad\quad\parallel\\ HC\!-\!S\!-\!CH\end{smallmatrix}$	84.14	1067 (16.8)	84.0	90	0.35	–29.8	317.3	49.3

(1) At 719 Torr

Table 16 : Density, Dynamic and Kinematic Viscosity of Pure Water at different Temperatures as per DIN 51 550

Temperature °C	Density g/cm³	Dynamic Viscosity Centipoise (cP)	Kinematic Viscosity Centistokes (cSt)
0	0.99984	1.792	1.792
5	0.99996	1.520	1.520
10	0.99970	1.307	1.307
15	0.99910	1.138	1.139
20	0.99820	1.002	1.0038
25	0.99705	0.890	0.893
30	0.99565	0.797	0.801
35	0.99403	0.719	0.724
40	0.99221	0.653	0.658
45	0.99022	0.598	0.604
50	0.98805	0.548	0.554
55	0.98570	0.505	0.512
60	0.98321	0.467	0.475
65	0.98057	0.434	0.443
70	0.97778	0.404	0.413
75	0.97486	0.378	0.388
80	0.97180	0.355	0.365
85	0.96862	0.334	0.345
90	0.96532	0.315	0.326
95	0.96189	0.298	0.310
100	0.95835	0.282	0.295

Table 17 : Conversion of Baume Scale (+°Bé) into density ρ (kg/dm³) for liquids heavier than water at 15°C.

+°Bé	Density Kg/dm³	+°Bé	Density Kg/dm³
0	1.000	34	1.308
1	1.008	35	1.320
2	1.014	36	1.332
3	1.022	37	1.345
4	1.029	38	1.357
5	1.037	39	1.370
6	1.045	40	1.383
7	1.052	41	1.387
8	1.060	42	1.410
9	1.067	43	1.424

10	1.075	44	1.438
11	1.083	45	1.453
12	1.091	46	1.468
13	1.100	47	1.483
14	1.108	48	1.498
15	1.116	49	1.514
16	1.125	50	1.530
17	1.134	51	1.540
18	1.142	52	1.563
19	1.152	53	1.580
20	1.162	54	1.597
21	1.171	55	1.615
22	1.180	56	1.634
23	1.190	57	1.652
24	1.200	58	1.672
25	1.210	59	1.691
26	1.220	60	1.711
27	1.231	61	1.732
28	1.241	62	1.753
29	1.252	63	1.774
30	1.263	64	1.796
31	1.274	65	1.819
32	1.285	66	1.842
33	1.297		

The Baumé Scale is a measurement of density for liquids heavier (+°Bé) or lighter (−°Bé) than water.

If n is the hydrometer reading in °Bé and ρ_h, ρ_i are the densities in kg/dm^3 of liquids respectively heavier and lighter thatn water, then at 15°C

$$\rho_h = 144.30/(144.30 - n) \text{ and } \rho_i = 144.30/(144.30 + n).$$

°API (American Petroleum Institute) are used in the U.S.A. for indicating the density of fuels and oils:

$$\text{Density (g/cm}^3) = 141.5/(°API + 131.5).$$

Source : Borsig pocket book 3rd edn. 1970.
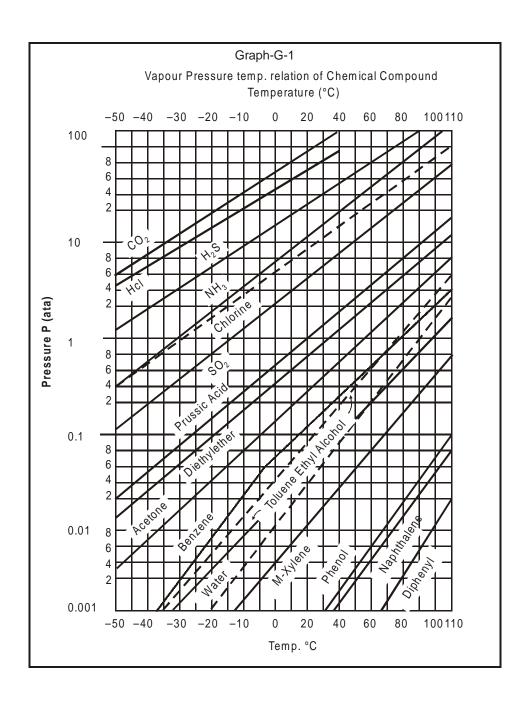
Table 18 : Standard oxidation-reduction potentials, E° and equilibrium constants, K
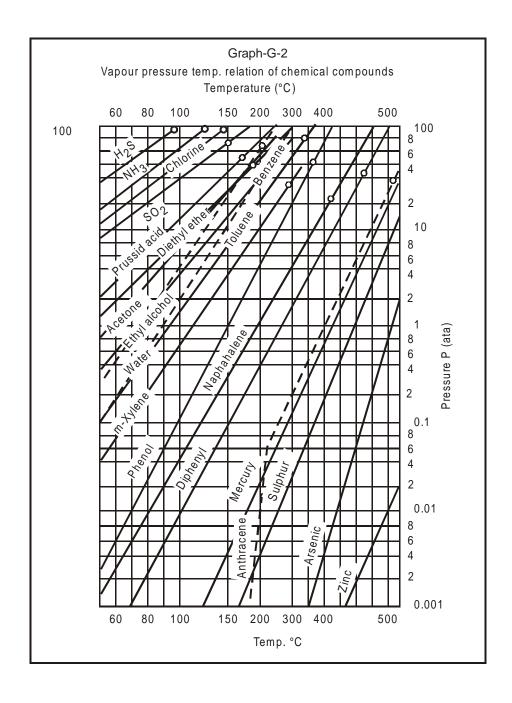
Elements/Compounds	E°	K
Li $\longrightarrow$ Li$^+$ + e$^-$	3.05	4×10^{50}
Cs $\longrightarrow$ Cs$^+$ + e$^-$	2.92	1×10^{49}
Rv $\longrightarrow$ R$_v^+$ + e$^-$	2.92	1×10^{49}
K $\longrightarrow$ K$^+$ + e$^-$	2.92	1×10^{49}
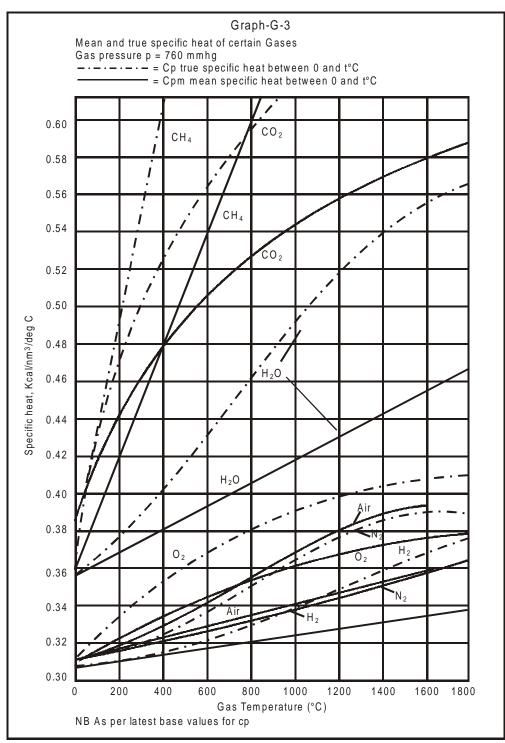
$\frac{1}{2}$ Ba $\longrightarrow$ $\frac{1}{2}$ Ba$^+$ + e$^-$	2.90	5×10^{48}
$\frac{1}{2}$ Sr $\longrightarrow$ $\frac{1}{2}$ Sr^{++} + e$^-$	2.89	4×10^{48}
$\frac{1}{2}$ Ca $\longrightarrow$ $\frac{1}{2}$ Ca^{++} + e$^-$	2.87	2×10^{48}
Na $\longrightarrow$ Na$^+$ + e$^-$	2.712	4.0×10^{45}
$\frac{1}{3}$ Al + $\frac{4}{3}$ OH$^-$ $\rightarrow$ $\frac{1}{3}$ Al (OH)$^-_4$ + e$^-$	2.35	3×10^{39}
$\frac{1}{2}$ Mg $\longrightarrow$ $\frac{1}{2}$ Mg^{++} + e$^-$	2.34	2×10^{39}
$\frac{1}{2}$ Be $\longrightarrow$ $\frac{1}{2}$ Be^{++} + e$^-$	1.85	1×10^{31}
$\frac{1}{3}$ Al $\longrightarrow$ Al^{+++} + e$^-$	1.67	1×10^{28}
$\frac{1}{2}$ Zn + 2OH$^-$ $\longrightarrow$ $\frac{1}{2}$ Zn(OH)$^=_4$ + e$^-$	1.216	2.7×10^{20}
$\frac{1}{2}$ Mn $\longrightarrow$ $\frac{1}{2}$ Mn^{++} + e$^-$	1.18	7×10^{19}
$\frac{1}{2}$ Zn + 2NH$_3$ $\longrightarrow$ $\frac{1}{2}$ Zn(NH$_3$)$_4^{++}$ + e$^-$	1.03	2×10^{17}
Co(CN)$_6$ $\longrightarrow$ Co(CN)$_6^{---}$ + e$^-$	0.83	1×10^{14}
$\frac{1}{2}$ Zn $\longrightarrow$ $\frac{1}{2}$ Zn^{++} + e$^-$	.762	6.5×10^{12}
$\frac{1}{3}$ Cr $\longrightarrow$ $\frac{1}{3}$ Cr^{+++} + e$^-$	.74	3×10^{12}
$\frac{1}{2}$ H$_2$C$_2$O$_4$(aq) $\longrightarrow$ CO$_2$ + H$^+$ + e$^-$	.49	2×10^8
$\frac{1}{2}$ Fe $\longrightarrow$ $\frac{1}{2}$ Fe^{++} + e$^-$	.440	2.5×10^7
$\frac{1}{2}$ Cd $\longrightarrow$ $\frac{1}{2}$ Cd^{++} + e$^-$	.402	5.7×10^6
$\frac{1}{2}$ Co $\longrightarrow$ $\frac{1}{2}$ Co^{++} + e$^-$	.277	4.5×10^4
$\frac{1}{2}$ Ni $\longrightarrow$ Ni^{++} + e$^-$	.250	1.6×10^4
I + Cu $\longrightarrow$ CuI(s) + e$^-$	.187	1.4×10^3
$\frac{1}{2}$ Sn $\longrightarrow$ $\frac{1}{2}$ Sn^{++} + e$^-$	.136	1.9×10^2
$\frac{1}{2}$ Pb $\longrightarrow$ $\frac{1}{2}$ Pb^{++} + e$^-$	.126	1.3×10^2
$\frac{1}{2}$ H$_2$ $\longrightarrow$ H$^+$ + e$^-$	0.000	1
$\frac{1}{2}$ H$_2$S $\longrightarrow$ $\frac{1}{2}$ S + H$^+$ + e$^-$	–0.141	4.3×10^{-3}
Cu$^+$ $\longrightarrow$ Cu^{++} + e$^-$	–0.153	2.7×10^{-3}
$\frac{1}{2}$ H$_2$O + $\frac{1}{2}$ H$_2$SO$_3$ $\longrightarrow$ $\frac{1}{2}$ SO$^=_4$ + 2H$^+$ + e$^-$	–0.17	1×10^{-3}
$\frac{1}{2}$ Cu $\longrightarrow$ Cu^{++} + e$^-$	–0.345	1.6×10^{-6}
Fe(CN)$_6$ $\longrightarrow$ Fe(CN$_6$)$^{---}$ + e$^-$	0.36	9×10^{-7}
I $\longrightarrow$ $\frac{1}{2}$ I$_2$(S) + e$^-$	–0.53	1×10^{-9}
MnO$^=_4$ $\longrightarrow$ MnO$^-_4$ + e$^-$	–0.54	1×10^{-9}
$\frac{4}{3}$ OH$^-$ + $\frac{1}{3}$ MnO$_2$ $\longrightarrow$ $\frac{1}{3}$MnO$^-_4$ + $\frac{2}{3}$ H$_2$O + e$^-$	–0.57	3×10^{-10}
$\frac{1}{2}$ H$_2$O$_2$ $\longrightarrow$ $\frac{1}{2}$ O$_2$ + H$^+$+ e$^-$	–0.682	3.5×10^{-12}
Fe^{++} $\longrightarrow$ Fe^{+++} + e$^-$	–0.771	1.1×10^{-13}
Hg $\longrightarrow$ $\frac{1}{2}$ Hg$_2^{++}$ + e$^-$	–0.799	3.7×10^{-14}
Ag $\longrightarrow$ Ag$^+$ + e$^-$	–0.800	3.5×10^{-14}
H$_2$O + NO$_2$ $\longrightarrow$ NO$^-_3$ + 2H$^+$ + e$^-$	–0.81	3×10^{-14}

$1/2\ Hg \longrightarrow 1/2\ Hg^{++} + e^-$	−0.854	4.5×10^{-15}
$1/2 HNO_2 + 1/2\ H_2O \longrightarrow 1/2\ NO_3^- + H^+ + e^-$	−0.94	5.0×10^{-16}
$1/2\ Hg_2^{++} \longrightarrow Hg^{++} + e^-$	−0.910	2×10^{-16}
$NO + H_2O \longrightarrow HNO_2 + H^+ + e^-$	−0.99	2×10^{-17}
$1/2\ ClO_3^- + 1/2\ H_2O \longrightarrow 1/2\ ClO_4^- + H^+ + e^-$	−1.00	
$Br^- \longrightarrow 1/2\ Br_2 + e^-$	−1.065	1.3×10^{-18}
$H_2O + 1/2\ Mn^{++} \longrightarrow 1/2\ MnO_2 + 2H^+ + e^-$	−1.23	2×10^{-21}
$Cl^- \longrightarrow 1/2\ Cl_2 + e^-$	−1.358	1.5×10^{-23}
$7/6\ H_2O + 1/3\ Cr^{+++} \longrightarrow 1/6\ Cr_2O_7^= + 7/3\ H^+ + e^-$	−1.36	1×10^{-23}
$1/2\ H_2O + 1/6\ Cl^- \longrightarrow 1/6\ ClO_3^- + H^+ + e^-$	−1.45	4×10^{-25}
$1/3\ Au \longrightarrow 1/3\ Au^{+++} + e^-$	−1.50	6×10^{-26}
$4/3\ H_2O + 1/5 Mn^{++} \longrightarrow 1/5\ MnO_4 + 8/5\ H^+ + e^-$	−1.52	3×10^{-26}
$1/2\ Cl_2 + H_2O \longrightarrow HClO + H^+ + e^-$	−1.63	4×10^{-28}
$H_2O \longrightarrow 1/2\ H_2O_2 + H^+ + e^-$	−1.77	2×10^{-30}
$Co^{++} \longrightarrow Co^{+++} + e^-$	−1.84	1×10^{-31}
$F^- \longrightarrow 1/2\ Fe + e^-$	−2.65	4×10^{-44}

Note : Values at 25°C, std. press of gases at 1 atmosphere and standard conc. of 1M.

Graph-G-1

Vapour Pressure temp. relation of Chemical Compound

Temperature (°C)

Temp. °C

Graph-G-2
Vapour pressure temp. relation of chemical compounds
Temperature (°C)

Graph-G-3

Mean and true specific heat of certain Gases
Gas pressure p = 760 mmhg
— · — · — · — = Cp true specific heat between 0 and t°C
————————— = Cpm mean specific heat between 0 and t°C
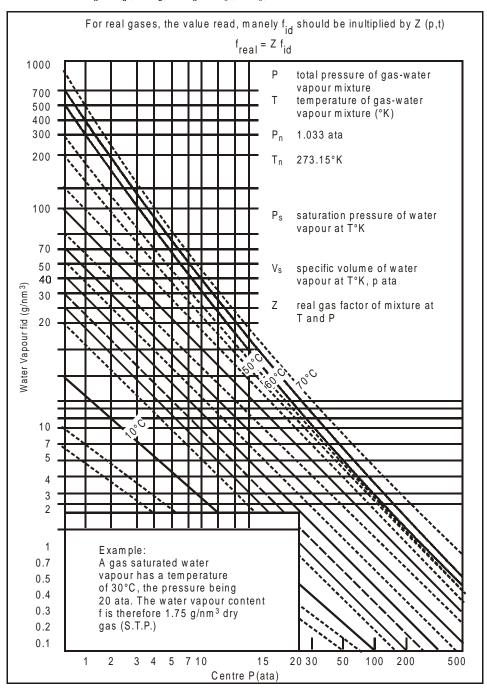
Source: Borsig pocket book 3rd edn. 1970.

Graph G-4

Maximum Water vapour content of Gases

For ideal gases $f_{id} = \dfrac{P_n}{T_n} - \dfrac{P_s}{R_d(P - P_2)} = \dfrac{P_n}{T_n} - \dfrac{T}{V_s(P - P_s)}$ [(g/m^3 dry gas (S.T.P.)]

For real gases, the value read, manely f_{id} should be inultiplied by Z (p,t)

$f_{real} = Z\, f_{id}$

P	total pressure of gas-water vapour mixture
T	temperature of gas-water vapour mixture (°K)
P_n	1.033 ata
T_n	273.15°K
P_s	saturation pressure of water vapour at T°K
V_s	specific volume of water vapour at T°K, p ata
Z	real gas factor of mixture at T and P

Water Vapour fid (g/nm^3)

Centre P(ata)

Example:
A gas saturated water vapour has a temperature of 30°C, the pressure being 20 ata. The water vapour content f is therefore 1.75 g/nm^3 dry gas (S.T.P.)

Source : Borsig pocket book 3rd edn. 1970

Table 19 : Density and Concentration of Ethyl Alcohol-Water Mixtures

Density at $\frac{15°C}{4°C}$ kg/l	Wt. % of ethyl alcohol	Density at $\frac{15°C}{4°C}$ kg/l	Wt. % of ethyl alcohol
0.9954	2	0.9134	52
0.9920	4	0.9089	54
0.9887	6	0.9044	56
0.9858	8	0.8999	58
0.9830	10	0.8952	60
0.9804	12	0.8906	62
0.9779	14	0.8859	64
0.9755	16	0.8813	66
0.9731	18	0.8766	68
0.9707	20	0.8719	70
0.9682	22	0.8671	72
0.9656	24	0.8623	74
0.9628	26	0.8575	76
0.9599	28	0.8527	78
0.9568	30	0.8478	80
0.9536	32	0.8428	82
0.9501	34	0.8378	84
0.9465	36	0.8327	86
0.9427	38	0.8276	88
0.9488	40	0.8223	90
0.9348	42	0.8169	92
0.9307	44	0.8113	94
0.9265	46	0.8056	96
0.9222	48	0.7997	98
0.9178	50	0.7935	100

Table 20 : Density and Concentration of Aqueous Solutions of Ammonia

Density at 20°C Kg/l	Concentration		Density at 20°C Kg/l	Concentration	
	Wt.%	Mol/l		Wt.%	Mol/l
0.998	0.0465	0.0273	0.930	17.85	9.75
0.990	1.89	1.10	0.920	20.88	11.28
0.980	4.27	2.46	0.910	24.03	12.84
0.970	6.75	3.84	0.900	27.33	14.44
0.960	9.34	5.27	0.890	30.69	16.04
0.950	12.03	6.71	0.880	34.35	17.75
0.940	14.88	8.21			

Table 21 : Density and Concentration of Aqueous Solutions of Caustic Soda

Density at 20°C kg/l	Concentration Wt.%	Mol/l	Density at 20°C kg/l	Concentration Wt.%	Mol/l
1.000	0.159	0.041	1.270	24.65	7.824
1.010	1.045	0.264	1.280	25.56	8.178
1.020	1.94	0.494	1.290	26.48	8.539
1.030	2.84	0.731	1.300	27.41	8.906
1.040	3.75	0.971	1.310	28.33	9.278
1.050	4.66	1.222	1.320	29.26	9.656
1.060	5.56	1.474	1.330	30.20	10.04
1.070	6.47	1.731	1.340	31.14	10.43
1.080	7.38	1.992	1.350	32.10	10.83
1.090	8.28	2.257	1.360	33.06	11.24
1.100	9.19	2.527	1.370	34.03	11.65
1.110	10.10	2.802	1.380	35.01	12.08
1.120	11.01	3.082	1.390	36.00	12.51
1.130	11.92	3.367	1.400	36.99	12.95
1.140	12.83	3.655	1.410	37.99	13.39
1.150	13.73	3.947	1.420	38.99	13.84
1.160	14.64	4.244	1.430	40.00	14.30
1.170	15.54	4.545	1.440	41.03	14.77
1.180	16.44	4.850	1.450	42.07	15.25
1.190	17.35	5.160	1.460	43.12	15.74
1.200	18.26	5.476	1.470	44.17	16.23
1.210	19.16	5.796	1.480	45.22	16.73
1.220	20.07	6.122	1.490	46.27	17.23
1.230	20.98	6.451	1.500	47.33	17.75
1.240	21.90	6.788	1.510	48.38	18.26
1.250	22.82	7.129	1.520	49.44	18.78
1.260	23.73	7.475	1.530	50.50	19.31

Table 22 : Densities of Solid and Liquid materials in kg/dm^3, g/cm^3

Densities of Solid and Liquid Substances (at 15 to 20°C) in relation to water = 1

Akrite cutting alloy	9.0	Delta Metal	8.6
Alum	1.71	Dolomite	2.1 to 2.9
Aluminium (700°C)	2.38	Dynamo sheet iron	
Aluminium (1000°C)	2.30	(high-alloyed, 4% Si)	7.6
Aluminium bronze	7.7	Feldspar	2.5 to 2.6
Aluminium (cast)	2.56	Ferromanaganese	
Aluminium (hammered)	2.75	(with 80% Mn)	7.5
Aluminium (pure)	2.70	Fluorspar	3.15

Antimony	6.69	Foundry coke	1.6 to 1.9
Anthracite	1.4 to 1.7	Glass	2.4 to 3.9
Arsenic, grey (metallic)	5.72	Gold (at 1100°C)	19.25
Barium	3.6 to 3.8	Gold (at 1300°C)	19.0
Bell metal	8.8	Gold (cast)	19.25
Benzene (at 0°C), liquid	0.88	Gold (coined)	19.50
Beryllium	1.86	Greases (at 15°C)	0.92 to 0.94
Blast-furnace slag	2.6 to 3.0	Grey cast iron	7.0 to 7.25
Boron (amorphous)	2.34	High-temperature Cr-Ni	
Boron (crystalline)	3.33	resistance metal	8.4
Bronze (with 6–20%	8.7 to 8.9	Iodine	4.95
tin content)		Iron oxide	5.25
Brown coal	1.2 to 1.5	Iron (pure)	7.87
Brown coal (in bulk)	0.7	Iron (pure, at 1550°C)	7.207
Brown hematite	3.4 to 4.0	Iron (pure, at 1600°C)	7.158
Cadmium	8.64	Iron (pure, at 1700°C)	7.057
Cast iron (cf. grey cast		Lead	11.34
iron)		Lead (at 327°C)	10.65
Cast steel	7.85	Lead (at 731°C)	10.19
Caustic potash, 11%		Lead (rolled)	11.4
solution	1.1	Marsh gas (fire damp)[1]	0.56
Cerium	6.8	Mild steel	7.70 to 7.85
Charcoal	0.3 to 0.5	Moulding sand	2.1 to 2.2
Chromium	7.14	Petrol (at 15°C)	0.68 to 0.72
Cr-Ni Steel (stainless)	7.85	Potassium	0.87
Cr Steel (stainless)	7.7	White lead	6.7

Density of Solid and Liquid Materials

Air (760 Torr, 0°C)	1.00	Kaolin	2.2
Bearing metal, white		Kidney Iron ore	4.9 to 5.3
metal	7.1	Limestone	2.5 to 2.8
Bog iron ore	2.6	Magnesite	3.0
Brass (cast)	8.4 to 8.7	Magnesium	1.74
Brass (drawn)	8.5 to 8.8	Magnetite	4.9 to 5.2
Carbon, diamond	3.51	Manganese	7.3
Carbon dioxide		Mercury	13.55
gaseous[1]	1.52	Mineral oils	0.90 to 0.93

---

(1) Reforred to air = 1 (at 760 Torr and 0°C)
Source : Borsig pocket book 3rd edn. 1970.

Carbon, graphite	2.25	Molybdenum	10.2
Carbonic acid (0°C, liquid)	0.94	Nickel	8.85
Carbon monoxide	0.97	Nickel (1500°C)	7.76
Carbon, soot	1.75	Ni Steel with minimum expansion (36% Ni)	8.13
Caustic potash, 31% solution	1.3	Ni Steel with high initial permeability (50% Ni)	8.19
Caustic potash 63% solution	1.7		
Caustic soda, 9% NaOH	1.1	Ni-Mn Steel (nonmagnetic, 15% Ni, 5% Mn)	8.03
Caustic soda, 18% NaOH	1.2		
Caustic soda, 37% NaOH	1.4	Niobium	8.56
Caustic soda, 47% NaOH	1.5	Nitric acid	1.513
Cobalt	8.71	Oxygen[1]	1.10
Cabalt magnet steel (hardened)	7.75	Oxygen (liquid −182.8°C)	1.142
Coke in lumps	0.6	Palladium	11.9
Common salt solution, 14% NaCl	1.1	Petroleum	0.79 to 0.82
		Phosphorus, red	2.20
Common salt solution 26% NaCl	1.2	Phosphorus, yellow	1.83
		Phosphor bronze	8.8
Copper (at 1100°C)	7.92	Platinum	21.4
Copper (at 1600°C)	7.53	Pig iron, dark grey	7.58 to 7.73
Copper, cast	8.63 to 8.80	Pig iron, light grey	7.20
Copper, rolled	8.82 to 8.95	Pig iron, white	7.0 to 7.13
Cupola-furunace slag	2.8 to 3.0	Quicklime	2.8 to 3.2
Fireclay	1.8 to 2.2	Rhodium	12.5
Hydrochloric acid, 10%	1.05	Sand, dry	1.4 to 1.6
Hydrochloric acid, 20%	1.10	Sandstone	2.2 to 2.5
Hydrochloric acid, 30%	1.15	Sea-water (at 4°C)	1.026
Hydrochloric acid, 40%	1.20	Slaked lime	1.2 to 1.3
High-speed steel Cr-Co-W base	8.3 to 9.3	Sodium	0.98
		Town gas	0.38 to 0.45
Bismuth	9.82	Silicon, graphitic	2.00
Cast steel	7.8	Silver	10.51
Cement	2.7 to 3.0	Silver (at 970°C)	9.32
Cement, set	2.3	Silver (at 1302°C)	9.00
Cinnabar	8.09	Spiegel with 10% Mn	7.60
Clay, dry	1.8	Sulphur dioxide	2.23
Clay, fresh	2.4 to 2.6	Sulphur, monoclinic	1.96
Coal tar	1.1 to 1.26	Sulphur, rhombic	2.07
Cruicible steel	7.85	Sulphuretted hydrogen	

(1) Referred to air = 1 (at 760 Torr and 0°C)

Ferrosilicon, 7.5% Si	7.35	(760 Torr, 0°C)[2]	1.19
Ferrosilicon, 20% Si	6.70	Sulphuric acid	
Ferrosilicon, 46% Si	4.87	(760 Torr, 0°C)[1]	2.15
Ferrosilicon, 95% Si	2.32	Tantalum	16.6
Hard coal	1.2 to 1.5	Thomas slag	2.6 to 3.2
High-speed steel,		Tin (cast)	7.2
tungsten carbide base	13.5 to 14.5	Tin (at 232°C)	6.99
Hydrogen	0.089	Tin (rombic)	5.75
Hydrogen (liquid,		Tin (tetragonal)	7.28
−252.5°C)	0.070	Titanium	4.50
Nitrogen	0.97	Tungsten	19.1
Nitrogen, liquid		Uranium	19.1
(−196°C)	0.811	Vanadium	6.07
Nitric oxide		Water vapour	
(760 Torr, 0°C)	1.04	(760 Torr, 0°C)[1]	0.62
Nitrous oxide	1.53	Welding steel	7.8
Open-hearth slag	2.5 to 3.0	Widia (tungsten carbide)	
Peat	0.4	cutting metal	14.4
Rock salt	2.28	Zinc	7.14
Siderite	3.7 to 3.9	Zinc (at 419°C)	6.92
Silicon, crystalline	2.34	Zirconium	6.49

Table 23 : Properties of Anhydrous Ammonia

Wt./gallon (US) at 15.6°C	–	5.14 1b
B.P. at 760 mm Hg	–	−33.35°C
Freezing pt. at 760 mm Hg	–	−77.7°C
Heat of Fusion	–	108.19 cal/gm
Heat of vaporisation at		
760 mm Hg	–	327.4 cal/gm
Critical temperature	–	132.4°C
Critical pressure	–	111.5 atm. abs.
Dielectric constant of vapour		
at 0°C and 1×10^6 cps	–	1.0072
Vapour for liquid at −34°C		
and 4×10^8 cps	–	22
Solid at −90°C and 4×10^8 cps	–	44.01
Viscosity, liquid at −33.5°C	–	0.266 cp

(1) Referred to air = 1 (at 760 Torr and 0°C)

Vapour at −78.5°C	–	0.00672 cp
Vapour at 0°C	–	0.00926 cp
Vapour at 20°C	–	0.01080 cp
Vapour at 100°C	–	0.01303 cp

N.B. Dielectric constant refers to frequency in cycles per sec.

Table 24 : Acetic anhydride, specification

Purity	=	99% wt. (min)
Phosphate	=	1.0 ppm (max)
Chloride	=	1.0 ppm (max)
Sulphate	=	1.0 ppm (max)
Al	=	1.0 ppm (max)
Iron	=	1.0 ppm (max)
Nonvolatiles	=	30 ppm (min)
Colour (pt-cobalt) index	=	10
Permanganate time	=	A ml. sample will not reduce more than 0.1 ml of 0.1N $KMnO_4$ in 5 mins.
Sp. gravity (20/20°C)	=	1.08–1.085

N.B. Process of manufacture of Acetic anhydride:

1. Ketone process
2. Acetaldehyde process
3. Mehyl acetate carbonylation.

Table 25 : Leather Chemicals

1. Synthetic tanning agents
2. Vegetable tanning agents
3. Chrome extracts
4. Fat liquors
5. Acrylic binders
6. Casein binders
7. Pigment dispersants
8. Lacquer and Lacquer emulsions
9. Drum dyes
10. Dye solutions.

Table 26 : Molecular diameter of common gases

CO_2	=	0.28 nm
CH_4	=	0.44 nm
CCl_4	=	0.69 nm
Oxygen	=	0.28 nm
Water Vapour	=	0.315 nm
Nitrogen	=	0.3 nm
CO	=	0.28 nm
Hydrogen	=	0.24 nm

Table 27 : Battery grade Sulphuric acid

		Specification (IS)
H_2SO_4 conc.	=	29.7% wt.) - min
	Impurities	
Iron as Fe	=	0.0006% wt.
Chlorides	=	0.0003% wt.
Arsenic	=	0.0001% wt.
Selenium	=	0.0006% wt.
Manganese	=	0.00003% wt.
Copper	=	0.001% wt.
Zinc	=	0.001% wt.
Ash	=	0.02% wt.

Table 28 : H_2SO_4 and SO_3 content in sulphuric acid at 15.5°C

Sp. gravity	H_2SO_4 100 parts (wt.) contain H_2SO_4 wt. part	(wt.) SO_3 part	1 lit contains Kg of H_2SO_4
(1)	(2)	(3)	(4)
1.885	99.31	81.08	1.826
1.8390	99.12	80.9	1.823
1.8395	98.77	80.63	1.817
1.84	98.72	80.59	1.816
1.8405	98.52	80.43	1.814
1.8410	98.20	80.16	1.808
1.61	69.06	57.49	1.141
1.63	71.27	55.18	1.162
1.64	72.12	58.88	1.182
1.65	72.96	59.57	1.204
1.66	73.81	60.26	1.225
1.68	75.92	61.97	
1.71	77.7	63.42	
1.72	79.37	64.79	
1.74	81.16	65.06	
1.80	87.69	71.58	

1.82	91.11	74.37
1.828	93.03	75.94
1.832	94.32	76.99
1.50	60.17	49.12
1.52	62.00	50.61
1.54	63.81	52.09
1.56	65.59	53.54
1.58	67.35	54.98

Table 29 : Sp. gravity of aq. soln. of Sulphuric acid at 15.5°C

% H_2SO_4 (wt.)	Sp. gravity
55%	1.449
60%	1.502
65%	1.558
70%	1.615
75%	1.674
80%	1.732
85%	1.784
90%	1.819
95%	1.839
97%	1.841
98%	1.841

Table 30 : Oleum

% Free SO_3 (wt.)	Sp. gravity at 15.5°C
10%	1.888
20%	1.920
30%	1.959

Table 31 : Heats of soln. of SO_3 in water

n (moles of H_2O)	Heat of soln. kcal
1	21.3
2	28.04
3	31.31
5	34.14
1600	40.34

Table 32 : Benzene Physical Properties

Formula	=	C_6H_6
Mol. wt	=	78.115
B.P	=	80.1°C
F.P	=	5.5°C
M.P	=	5.533°C
Density at 20°c	=	0.87901
n_D 20	=	1.50112
Critical density	=	0.0309 gm/cc
Critical press.	=	48.9 bar
Critical temp.	=	288.9°C
Flash point	=	– 11°C
Ignition temp.	=	595°C
Explosive limit	=	1.4% (lower)
	=	6.7% (higher)
Heat of fusion	=	125.9 j/gm
Heat of combustion	=	3275.3 kg/mole
Gross heating value	=	41932 j/gm
Spec. electrical conductivity	=	3.8×10^{-14} per cm per ohm
V.P. at 273°K	=	3.466 KPa
Specific heat at 273°K	=	1.492 j/gm
Heat of vaporisation	=	448 cal/gm
Viscosity	=	0.906 j/gm
Benzene water azeotrope		
mix. (B.P = 69.25°C) Benzene	=	91.17% wt
water	=	8.83 wt.

Benzene is available in 3 grades viz Industrial grade (ASTM D 836–84), Refined benzene 535(ASTM D 2359–69) and Refined benzene -485- nitration grade ASTM D835–85

Azeotropes of benzene:

Component	BP°C	Azeotrope, BP°C	wt% benzene
Cyclohexane	80.75	77.56	51.9
Methyl cyclopentane	71.8	71.5	9.4
_n_ heptane	98.4	80.1	99.3

Table 33 : Physical properties of Toluene

Mol. wt.	=	92.13
B.P (100 KPa)	=	110.635°C
Critical temp.	=	320.8°C
Critical Press.	=	4.133 Mpa

Critical compressibility	=	0.26
Density at 100 KPa & 25°C	=	0.863 gm/cc
Surface tension at 100 Kpa & 25°C	=	20.75 m N/m
Viscosity at 100 KPa & 25°C	=	0.586 Mpa sec.

Thermal conductivity at

100 KPa & 18°C	=	0.1438 W/m°K
LCV – gas	=	40.97 Kj/gm
– liquid	=	40.52 Kj/gm
Flash point	=	4°C
Ignition temp.	=	552°C
Explosion limit – upper	=	27% (vol)
– Lower	=	6.75% (vol)
Refractive index ND^{20}	=	1.497.

Table 34 : Reagent grade benzene (American chem. society)

Colour (APHA)	–	not more than 10
Boiling range	–	within±1°C of 80.1°C
F.P	–	not below 5.2°C
Residue after evaporation	–	not more than 0.001% wt.
Thiophene	–	not more than 0.005% wt.
Water	–	not more than 0.05% wt.

Substance darkened by H_2SO_4 to pass test safety.

Permissible exposure limit (TLV) = 1 ppm (1 hr.)
                         (OSHA-71)

Benzene should be free from non-aromatics (for 5.5°C FP, maxm allowable is 0.01% wt).

Packing in steel drums for transportation

Table 35 : Physical properties of Naphthalene

Density at 20°C	=	1.1789 gm/cm^3
Ref. index (99.5°C)	=	1.5829
Heat capacity at 25°C	=	1.294 kj/kg
Heat of fusion	=	148 kj/kg
Heat of vaporisation	=	352 kj/kg
V.P. at 70°C	=	0.525 KPa
V.P. at 88°C	=	1.33 KPa
V.P. at 101°C	=	40 KPa
Critical temp.	=	475°C
Critical press	=	41.9 KPa/cm^2
Ignition temp.	=	540°C

Flash point (closed cup)   =   80°C

Dielectric constant at 20°C   =   2.47

Lower limit of explosion   =   0.88% (vol)

Higher limit of explosion   =   5.9% (vol)

Odour threshold limit   =   0.004 mg/m^3

LD$_{50}$ =   1100–2400 mg/kg rat, orl

N.B. Phthalic anhydride is produced by catalylic gas phase oxdn. of naphthalene.

Table 36 : Nitration grade Toluene specification

		ASTM D841	Test ASTM Code
Density at 20°C, gm/ml	=	0.869–0.873	D891
Colour (Hazen)	=	< 20	D1209
Boiling range	=	± 1°C	D850, D1078
Acidity	=	–	
Colour after acid treatment	=	≤ no.2	
Sulphur content	=	nil	

Table 37 : Physical Characteristics of Pure Gases

Substance	Molar weight M $\left[\dfrac{kg}{k\ mol}\right]$	Standard Density ρ_n [1] $\left[\dfrac{kg}{n\ m^3}\right]$	Gas Constant R $\left[\dfrac{mkp}{kg\ °K}\right]$	Specific Heat in Standard State [kcal/kg deg C]		Molar Volume V_n [1] $\left[\dfrac{n\ m^3}{k\ mol}\right]$
				C_p	C_v	
Chlorine................	70.914	3.214	11.956	0.120	0.0895	22.064
Oxygen	32.000	1.42895	26.495	0.2184	0.1562	22.394
Nitrogen	28.016	1.25046	30.262	0.2482	0.1774	22.405
Hydrogen	2.016	0.08989	420.551	3.403	2.417	22.427
Nitric oxide	30.008	1.3402	28.254	0.2384	0.1722	22.391
Carbon monoxide	28.011	1.25001	30.268	0.2486	0.1775	22.408
Hydrochloric acid	36.465	1.6392	23.251	0.191	0.136	22.246
Carbon dioxide...	44.011	1.9769	19.264	0.1957	0.1505	22.263
Sulphur dioxide ..	64.066	2.9262	13.234	0.1453	0.1143	21.894
Nitrous oxide	44.016	1.9804	19.262	0.2131	0.1680	22.226
Water vapour	18.016	(0.80378)	47.060	0.443 (100°)	0.332 (100°)	(23.45)
Ammonia	17.032	0.77142	49.779	0.491	0.374	22.078
Methane	16.043	0.7168	52.847	0.515	0.390	22.381

Acetylene	26.038	1.1747	32.561	0.3613	0.2904	22.166
Ethylene	28.054	1.2604	30.221	0.385	0.308	22.258
Ethane	30.070	1.3566	28.195	0.413	0.345	22.166
Propylene	42.081	1.9149	20.148	0.340		21.976
Propane	44.097	2.00963	19.227	0.360	0.313	21.943
n-Butane	58.214	2.73204	14.587	0.382		21.275
n-Pentane	72.151	3.21901	11.751	0.384		20.877
Benzene	78.114	3.48505	10.853	0.229	0.272	
...				(100°)	(100°)	
Hexane	86.178	3.84483	9.838	0.384		
Air Hydrogen	28.964	1.2928	29.272	0.240	0.171	22.401
Sulphide	34.082	1.5362	24.876	0.23	–	22.186

(1) nm^3 = normal cubic metre, i.e. at 0°C and 760 Torr

Note :

R individual gas constant = $\dfrac{847.84}{M}$ [mkp/kg °K]

$C_p - C_v = \dfrac{1.987}{M}$

ρ_n standard density = $\dfrac{M}{V_n}\left[\dfrac{kg}{nm^3}\right]$

Adiabatic exponent $x = C_p/C_v$

Molar volume V_n in stnadard state nm^3/kg mol.

Standard state is at 0°C and 760 Torr

For liquids the data refer to the vaporised state,

Source : Borsig pocket book 3rd edn.

Table 38 : Density and Concentration of Aqueous Hydrochloric Acid soln.

Density at 20°C kg/l	Concentration		Density at 20°C	Concentration	
	Wt. %	Mol/l		Wt. %	Mol/l
1.000	0.3600	0.09872	1.105	21.36	6.472
1.005	1.360	0.3748	1.110	22.33	6.796
1.010	2.364	0.6547	1.115	23.29	7.122
1.015	3.374	0.9391	1.120	24.25	7.449
1.020	4.388	1.227	1.125	25.22	7.782
1.025	5.408	1.520	1.130	26.20	8.118
1.030	6.433	1.817	1.135	27.18	8.459
1.035	7.464	2.118	1.140	28.18	8.809
1.040	8.490	2.421	1.145	29.17	9.159
1.045	9.510	2.725	1.150	30.14	9.505
1.050	10.52	3.029	1.155	31.14	9.863

1.055	11.52	3.333	1.160	32.14	10.23
1.060	12.51	3.638	1.165	33.16	10.60
1.065	13.50	3.944	1.170	34.18	10.97
1.070	14.50	4.253	1.175	35.20	11.34
1.075	15.49	4.565	1.180	36.23	11.73
1.080	16.47	4.878	1.185	37.27	12.11
1.085	17.45	5.192	1.190	38.32	12.50
1.090	18.43	5.510	1.195	39.37	12.90
1.095	19.41	5.829	1.198	40.00	13.14
1.100	20.39	6.150			

Table 39 : Density and Concentration of Aqueous Nitric Acid soln.

Density at 20°C kg/l	Concentration		Density at 20°C	Concentration	
	Wt. %	Mol/l		Wt. %	Mol/l
1.000	0.3333	0.05231	1.300	48.42	9.990
1.020	3.982	0.6445	1.320	51.72	10.83
1.040	7.530	1.243	1.340	55.13	11.72
1.060	10.97	1.845	1.360	58.78	12.68
1.080	14.31	2.453	1.380	62.70	13.73
1.100	17.58	3.068	1.400	66.97	14.88
1.120	20.79	3.696	1.420	71.63	16.14
1.140	23.94	4.330	1.440	76.71	17.53
1.160	27.00	4.970	1.460	82.39	19.09
1.180	30.00	5.618	1.480	89.07	20.92
1.200	32.94	6.273	1.500	96.73	23.02
1.220	35.93	6.956	1.504	97.74	23.33
1.240	39.02	7.679	1.508	98.76	23.63
1.260	42.14	8.426	1.513	100.00	24.01
1.280	45.27	9.195			

Source : Borsig pocket book 3rd edn. 1970.

Table 40 : Density and Concentration of Aqueous Solutions of Sulphuric Acid

Density at 20°C kg/l	Concentration		Density at 20°C	Concentration	
	Wt. %	Mol/l		Wt. %	Mol/l
1.000	0.2609	0.02660	1.460	56.41	8.397
1.020	3.242	0.3372	1.480	58.31	8.799
1.040	6.237	0.6613	1.500	60.17	9.202
1.060	9.129	0.9865	1.520	62.00	9.603
1.080	11.96	1.317	1.540	63.81	10.02
1.100	14.73	1.652	1.560	65.59	10.43
1.120	17.43	1.990	1.580	67.35	10.85
1.140	20.08	2.334	1.600	69.09	11.27

1.160	22.67	2.681	1.620	70.82	11.70
1.180	25.21	3.033	1.640	72.52	12.13
1.200	27.72	3.391	1.660	74.22	12.56
1.220	30.18	3.754	1.680	75.92	13.00
1.240	32.61	4.123	1.700	77.63	13.46
1.260	35.01	4.498	1.720	79.37	13.92
1.280	37.36	4.876	1.740	81.16	14.40
1.300	39.68	5.259	1.760	83.06	14.90
1.320	41.95	5.646	1.780	85.16	15.46
1.340	44.17	6.035	1.800	87.69	16.09
1.360	46.33	6.424	1.820	91.11	16.91
1.380	48.45	6.817	1.824	92.00	17.11
1.400	50.50	7.208	1.828	93.03	17.34
1.420	52.51	7.603	1.832	94.32	17.62
1.440	54.49	8.000	1.838	95.00	–

Table 41 : Density and Concentration of Aqueous Solutions of Caustic Potash

Density at 20°C kg/l	Concentration		Density at 20°C	Concentration	
	Wt. %	Mol/l kg/l		Wt. %	Mol/l
1.000	0.197	0.0351	1.280	29.25	6.67
1.020	2.38	0.434	1.300	31.15	7.22
1.040	4.58	0.848	1.320	33.03	7.77
1.060	6.74	1.27	1.340	34.90	8.34
1.080	8.89	1.71	1.360	36.74	8.91
1.100	11.03	2.16	1.380	38.56	9.48
1.120	13.14	2.62	1.400	40.37	10.07
1.140	15.22	3.09	1.420	42.16	10.67
1.160	17.29	3.58	1.440	43.92	11.28
1.180	19.35	4.07	1.460	45.66	11.88
1.200	21.38	4.57	1.480	47.39	12.50
1.220	23.38	5.08	1.500	49.10	13.13
1.240	25.36	5.60	1.520	50.80	13.76
1.260	27.32	6.14	1.535	52.05	14.24

Table 42 : Specification of lactic acid

	Pharma	Food chemicals	Edible grade
Assay %	88	94–105	80
Sulphites %	0.02	0.25	0.05
Arsenic, ppm	4	3	0.2
Chloride %	0.008	0.2	0.02
Iron, ppm	10	10	10
Heavy metals, ppm	33	10	10
Ash %	0.1	0.1	0.1
Calcium %	0.02	–	–

Uses

(*i*) Buffered lactic acid-sod. lactate is used in confectionary.

(*ii*) In cheese making.

(*iii*) For Antimicrobial treatment of meat and poultry.

N.B. In Europe lactic acid specification is laid down in EEC council directives. It is coded in Food Chemicals code in U.S.A. for edible grade lactic acid.

Properties

Lactic acid produced synthetically is optically inactive (recemic), where as when produced by fermentation using specific microorganism, optically active lactic acid is produced. It forms L(+) lactic acid and D(–) lactic acid due to optical rotation in the molecule. The acid is mono hydroxy carboxylic acid with an asymetrical carbon atom.

$$
\begin{array}{cc}
\text{COOH} & \text{COOH} \\
| & | \\
\text{HO} - \text{C} - \text{H} \qquad\qquad & \text{HO} - \text{C} - \text{OH} \\
| & | \\
\text{CH}_3 & \text{CH}_3 \\
\text{L (+) lactic acid} & \text{D(–) lactic acid}
\end{array}
$$

Lactic acid is very hygroscopic and is obtained as 90% conc. solution (wt.). Pure acid is white crystalline solid produced by careful distillation and undergoes internal esterification to produce lacto γ lactic acid. M.P. of isomers is 52.7–52.8°C and B.P. of anhydrous lactic acid is 125–140°C at 27.9 Kp_a and its M.P. is 18–33°C and molecular wt. is 90.08. Lactic acid products viz. α, β, γ and δ hydroxy carboxylic acids have M.P. of 23–33°C, B.P. 119–123°C at 1.6–2 Kp_a, density at 25°C is 1.206 and R.I. is 1.4392.

Table 43 : Sodium Chloride data

Source   : Salt lagoons for sea water and salt mines

Impurities : Salt lagoons (1–10% $CaSO_4$ and others) and

           Mined salt (1–4% $CaSO_4$ and others-$CaCl_2$ $Mgcl_2$)

Physical data (Sodium chloride)

Density	=	2.165 gm/cc
Refractive index ND^{20}	=	1.544
sp. heat	=	0.853 J/gm
Heat of fusion	=	517.1 J/gm
M.P.	=	800.8°C
Heat of soln.	=	3.757 Kj/mol

Uses – Leather tanning to prevent bacterial decomposition.

– Textile dyeing for dye fixation and die standardisation.

– Soap making for separation of soap.

– Pulp and paper for precipitation of water proofing compounds and generation of Cl_2 bleach.

– Ceramics for surface vitrification of heated clays.

– Rubber manufacture for salting out of rubber from latex.

– Refrigerant cooling media (saltice mixture).

– Oil well operation to prevent foamability of drilling mud chemicals.

– Pigment as a grinding agent.

Table 44 : Spec. of Sod. nitrite

	USP	Food grade	Tech-grade
Sod. nitrite, wt% min	97	97	97
Loss or drying wt% max	0.25	0.25	–
Heavy metals (as Pb) wt% max	0.002	0.002	–
Arsenic (as As)– ppm max	–	3	–
Pb as Pb, ppm (max)		10	–
Sod. Sulphate, wt% max	–	–	0.2
Sod. Chloride, wt% max	–	–	0.2
Insolubles, wt% max	–	–	0.5

Remarks : Sod. nitrite and an acid – reacts to form NOX.

Packaging norms – Multiwal plastic bag or fibre drum for Hazardous chemical and an appropriate oxidiser to be indicated.

Toxicity   – Inhalation of salt dust, liquid mist or direct injestion can cause acute toxic effect leading to death. Sod. nitrite can cause meglobinemia in children. Oral limit is 10 ppm. B.P. loss and irritation of throat and nose due to sod. nitrite poisoning.

Table 45 : Analysis of Sponge iron

Total Fe	=	88% min
Metalisation	=	86
Carbon	=	1.4
Sulphur	=	0.02
Residue	=	0.10
Total gangue	=	6
Size : 5mm = 5% (max), +16 mm =		10%

Table 46 : Physical properties of isocyanuric acid

Formula	=	NHCONHCONHCO
Mol. wt.	=	129.08
Phy. form	=	Crystialline, white solid
Decomposition point	=	330°C.
Bulk density	=	0.6 − 0.85 cm/cc
pH of 1% soln.	=	3.5 − 5.1.
Solubility at 25°C	=	0.3 gm/100 gm mole.

Manufacture – By heating urea above its M.P.

Uses   – Chlorine stabiliser for chlorine compounds based disinfectants or other disinfectants for swimming pool stabilisation, laundry bleaching agent, plasticiser, varnish (elec) etc.

Table 47 : Properties of MEA, DEA & TEA

	Mol. wt.	M. p°C	B. p°C	Density 20°C	Heat of vaporisation kj/kg.	Sp. Heat	Viscosity MPa.s
MEA	61.08	10.35	170.3	20°C	848	2.72	23
DEA	105.1	27.4	268.5	1.0012	638.4 (30°C)	2.73	389
TEA	149.2	21.6	336.1	1.248	517.8	2.33	930

Uses :

MEA – For intermediates in the preparation of surfactants (Textiles, detergents, leather chemicals for dressing, dyeing and finishing and emulsions. Drilling and cutting oils, medicinal soaps and high quality soaps from stearic acid, lanonic and oleic acid or carpolytic acid used as cosmatics, polishes, shoe creams, ethanol amines soaps with wax and resins and used as impregnating material, protective coatings for textile and leather goods. Ethyl amine soaps from alkyl benzene sulphonic acids are used as detergents (having better biodegradibility. MEA is also used in paints.

DEA – As corrosion inhibitor in coolant for auto engines. It is also made from coconut fatty acids and oleic acid are also used industrially, liquid detergents are also based on TEA. TEA is also used as cement milling additive.

Table 48 : Physical properties of ethylene

Formula	=	$CH_2 = CH_2$
Mol. wt.	=	28.052
Lower/higher limits of inflamability	=	2.75/28.6%
Ignition temperature	=	425–527°C
Critical temperature	=	9.9°C
Critical pressure	=	5.117 MPa
M.P.	=	−169°C
Density at 0°C	=	0.34 gm/cc
Gas density at STP	=	1.263 gm/lit
Heat of fusion	=	119.5 Kj/Kg.
Heat of combusion	=	47.183 Kj/Kg.
Heat of vaporisation at B.P.	=	488 Kj/Kg.

Table 48A : Adhesives

1. Classified as natural and synthetic adhesives.

2. Natural adhesives are resinous secretions of certain trees viz. guar gum, suitable for light bonding press.

3. Synthetic adhesives are made from several polymerisable resins viz. epoxy, vinyl, acetate, urethene and acrylic structural resins.

4. Adhesives function in two ways. Firstly, initially in liquid state, have to wet the adehereants and the adhesive in second stage to form the bondline which must be solid high molecular wt. polymer that is able to carry out and transfer mechanical forces to seal the adherents. The second stage is called "curing".

5. There are three types curing processes for synthetic adhesives:

    (*i*) Adhesive is applied in liquid state and allowed to dry or cool for solidification for bonding.

    (*ii*) Adhesive is applied as a solution containing a carrier liquid or an emulsifier containing emulsifying agent and the carrier liquid which evaporates leaving behind high molecular weight polymer.

    (*iii*) Adhesives containing a low viscisity fluid having reactive group that undergoes Polymerisation in bondline between adhereanants to build the molecular wt. suitable to carry load of adherents. This curing process is commonly used in structural adhesives viz. epoxy. vinyls, urethene and acrylic adhesives.

6. Adhesion of adhesives is due to :

    (*i*) mechanical interlocking due to pressure,

    (*ii*) Electrostatic attraction between polar groups in the adhesive as well as in adherants surface and

    (*iii*) Formation of chemical bonds across the interface due to presence of chemically reactive group.

7.   Reaction of Epoxy adhesive in two parts viz. curing agent (active H) and epoxy resin :

8.   Properties format for adhesives :

   (*i*) Physical form.

  (*ii*) Closed assembly time at 20°C.

 (*iii*) Setting process.

  (*iv*) Processing condition.

   (*v*) Coverage.

  (*vi*) Shelf life at 20°C.

 (*vii*) Working life.

(*viii*) Performance.

  (*ix*) Application.

Table 49 : pH test indicators to determine end pt. in titration

		pH range	colour change
Litmus	=	4.5 – 8.3	Red to blue
Methyl orange	=	3.1 to 4.4	Orange red to yellow
Methyl red	=	4.2 to 6.3	Red to yellow
Phenolphthalein	=	8.3 to 10	Colourless to red
Phenol red	=	6.6 to 8.2	Yellow to red
Alizarin red	=	5.0 to 6.8	Yellow to red
Congo red	=	3.0 to 5	Blue to red
Bromocresol green	=	4.0 to 5.6	Yellow to blue

Buffers – Mix of either weak acids with their salts of strong bases or strong acids with their salt of weak bases.

Table 50 : Physical data – Liquefaction and Fractionation of Air

Constituents	Conc. vol%	B.P. at atm. press, 0°C	Latent heat B.T.U/1b mole	Critical temp. 0°C	Sp. Gr. of liq phase
N_2	78.08	−195.8	2399	−117	0.808
O_2	20.95	−183	2938	−83	1.14
Ar	0.932	−185.7	2800	−120.2	1.39
CO_2	0.03	−78.5	10853	31.0	1.562
He	5.24	−268.9	39.3	—	0.126
H_2	<lppm	−252	391.9	—	0.708
Hydrocarbons	<1.5 ppm	—	—	—	—

Table 51 : n-pentane specification

	Grade-1	Grade-2	Remarks
Purity, %	99	90	Grade-1=0.5% isopentane and 0.5% isomers and homologues
Sp. gravity, 15.6°C	0.63	0.63	
Distillation range	35.5–36.5°C	34.5–38°C	Grade-2 = 8% isopentane and 2% isomers.
Residue, % max	0.005	0.005	
Acidity	neutral	neutral	

The mixed pentanes in grade-2 can be separated into constituents by selective adsorption over molecular sieves crystalline zeolites when n-pentanes pass through pores in molecular sieves pore openings. The n-pentane is then recovered from adsorbed molecular sieves by desorption using a purge material gas.

Table 52 : Metallurgical coke specification

Reactivity	=	24% (max) - by CRI method
Ash	=	14% (max)
Volatility	=	1.25% (max)
Sulphur	=	1% (max)
Moisture	=	5% (max)
Strength – M-10	=	10% (max)
– M-40	=	75% (max)
Size of coke :		
+ 40 – 80 mm	=	90% min
+ 65 mm	=	30% $\pm$ 15%
+ 80 mm	=	5% (max)
– 40 and + 80	=	10% max

Shatter index-Related to hard coke. It should not be less than 90 (min. requirement for metallurgical coke).

Table 53 : Butadiene Specification

Group : Unsaturated C-4 hydrocarbon

Formula: 1, 3-butadiene, $CH_2 = CH–CH=CH_2$

B.P. at 0.1013 Mpa	=	–4.411°C
M. wt.	=	54.092
MP at 0.1013 Mpa	=	–108.902
Critical temperature	=	152.0°C
Critical press	=	4.32 Mpa
Critical density	=	0.245 gm/c.c.
Liq. density at °C	=	0.6452 gm/c.c.
Liq. density at 25°C	=	0.6194 gm/c.c.

Gas density (air = 1)   =   1.9
Liq. viscosity at 4°C   =   0.2 m.Pa.S
Enthalpy of vapour at 25°C   =   20.88 Kj/mol
Enthalpy of combustion of
  gases at 298°K, 0.1013 Mpa   =   2541.74 Kj/mol
Vapour press at 20°C   =   0.2351 Mpa
Vapour press at 40°C   =   0.4288 Mpa

Explosion Limits

Upper	Lower
22% (Vol.)	1.4 % (Vol.) at 0.4904 MPa, 30°C
(density 2400 gm/m^3)	
16.3%	1.4% (density at 31 gm/m^3)
(density = 365 gm/m^3)	

Uses of butadiene: PBR, SBR/latex, chloroprene adipic acid by BASF process, acrylonitrile butadiene rubber, chloroprene rubber, Azeotropic extraction by liq-liq extraction and hexamethylene diamine production.

Table 54 : Vacuum Scales, Comparative Data

Torr	ata	% Vacuum	Torr	ata	% vacuum	Torr	ata	% vacuum
760	1.033	0	62	0.0844	91.84	4.2	0.00571	99.450
720	0.9785	5.26	58	0.0788	92.37	4.0	0.00544	99.475
680	0.9243	10.53	54	0.0734	92.89	3.8	0.00516	99.502
640	0.8699	15.71	50	0.0679	93.42	3.6	0.00489	99.527
600	0.8155	21.05	46	0.0625	93.96	3.4	0.00462	99.555
575	0.7816	24.34	43	0.0584	94.34	3.2	0.00435	99.580
550	0.7476	27.63	40	0.0544	94.74	3.0	0.00408	99.608
525	0.7136	30.92	37	0.0503	95.13	2.8	0.00381	99.632
500	0.6796	34.21	34	0.0462	95.53	2.6	0.00353	99.660
475	0.6456	37.50	32	0.0435	95.79	2.4	0.00326	99.685
450	0.6116	40.79	30	0.0408	96.05	2.2	0.00299	99.710
425	0.5777	44.08	28	0.0381	96.32	2.0	0.00272	99.738
400	0.5437	46.39	26	0.0353	96.58	1.8	0.00245	99.762
380	0.5164	50.00	24	0.0326	96.84	1.6	0.00217	99.790
360	0.4892	52.63	22	0.0299	97.11	1.4	0.00190	99.840
340	0.4621	55.26	20	0.0272	97.37	1.2	0.00163	99.845
320	0.4349	57.89	19	0.0258	97.50	1.0	0.00136	99.868
300	0.4080	60.53	18	0.0245	97.63	0.9	0.00122	99.882
280	0.3806	63.16	17	0.0231	97.76	0.8	0.00109	99.897
260	0.3534	65.79	16	0.0217	97.89	0.7	0.000952	99.907
240	0.3262	68.42	15	0.0204	98.03	0.6	0.000816	99.922

220	0.2991	71.05	14	0.0190	98.16	0.5	0.000680	99.935
200	0.2718	73.76	13	0.0177	98.29	0.4	0.000544	99.947
190	0.2582	75.00	12	0.0163	98.42	0.3	0.000408	99.960
180	0.2447	76.32	11	0.0149	98.55	0.2	0.000272	99.975
170	0.2311	77.63	10	0.0136	98.68	0.1	0.000136	99.987
160	0.2175	78.95	9.6	0.01305	98.74	0.08	0.000108	99.990
150	0.2039	80.26	9.3	0.01264	98.78	0.06	0.0000816	99.992
140	0.1903	81.58	9.1	0.01223	98.82	0.04	0.0000544	99.995
130	0.1767	82.90	8.5	0.01155	98.88	0.02	0.0000272	99.9974
120	0.1631	84.21	8.0	0.01087	98.93	0.01	0.0000136	99.9987
110	0.1495	85.53	7.5	0.01019	99.015	0.008	0.0000108	99.99895
100	0.1359	86.84	7.0	0.00952	99.080	0.006	0.0000081	99.99921
95	0.1291	87.80	6.5	0.00884	99.145	0.004	0.0000054	99.99934
90	0.1223	87.75	6.0	0.00816	99.145	0.004	0.0000027	99.99974
85	0.1155	88.82	5.5	0.00748	99.280	0.0018	0.0000024	99.99976
80	0.1087	89.47	5.0	0.00680	99.345	0.0016	0.0000022	99.99979
75	0.1019	90.13	4.8	0.00668	99.262	0.0014	0.0000019	99.999816
70	0.0952	90.79	4.6	0.00625	99.398	0.0012	0.0000016	99.999842
66	0.0897	91.32	4.4	0.00598	99.422	0.001	0.0000013	99.999868

Source : Borsig pocket book 3rd edn. 1970.

Table 55 : Temperature and Density of Dry and Saturated Air, partial Pressure (saturation press) of Water Vapour, Water-Vapour Content of Saturated Air, at 760 mm Hg

Temperature	Density of		Partial Pressure of Water Vapour in Saturated Air		Water-Vapour Content of Saturated Air	
	Dry Air	Saturated Air			per m^3 of this air	per kg dry air in this saturated air
°C	kg/m^3	kg/m^3	kg/m^2	Torr	g/m^3	g/kg dry air
−20	1.396	−	12.6	0.927	1.06	0.76
−15	1.369	−	19.44	1.429	1.62	1.17
−10	1.342	−	28.5	2.093	2.30	1.72
−5	1.317	−	39.8	2.929	3.37	2.56
+0	1.293	1.290	62.5	4.600	4.88	3.8
5	1.270	1.267	89.0	6.550	6.82	5.5
10	1.248	1.242	125.1	9.200	9.37	7.6
15	1.226	1.218	173.8	12.800	12.78	10.6
20	1.205	1.194	238.3	17.530	17.18	14.4
25	1.185	1.170	322.9	23.75	22.87	20.0
30	1.165	1.146	432.5	31.80	30.13	27.1

35	1.146	1.122	573.3	42.20	39.6	36.4
40	1.128	1.097	752.0	55.4	51.1	48.7
45	1.110	1.070	977.1	71.9	65.3	64.7
50	1.093	1.044	1257.8	92.50	82.7	86.2

(1) at saturation pressure see page 45.

Table 56 : Properties of Water in Saturated State

Temperature °C	Pressure ata	Enthalpy kcal/kg	Specific Volume m^3/kg	Density kg/m^3
0	0.0062	0.0	0.001 000	1000
5	0.0089	5.0	0.001 000	1000
10	0.0125	10.0	0.001 000	1000
15	0.0174	15.0	0.001 001	999
20	0.0238	20.0	0.001 002	998
25	0.0323	25.0	0.001 003	997
30	0.0433	30.0	0.001 004	996
35	0.0573	35.0	0.001 006	993
40	0.0752	40.0	0.001 008	992
45	0.0977	45.0	0.001 010	990
50	0.1258	50.0	0.001 012	988
60	0.2031	60.0	0.001 017	982
70	0.3177	70.0	0.001 023	978
80	0.4829	80.0	0.001 029	972
90	0.7149	90.0	0.001 036	965
100	1.033	100.0	0.001 044	959
110	1.461	110.1	0.001 052	952
120	2.025	120.3	0.001 060	943
130	2.754	130.4	0.001 070	934
140	3.685	140.6	0.001 080	926
150	4.850	150.9	0.001 091	918
160	6.802	161.3	0.001 102	909
170	8.076	171.7	0.001 114	898
180	10.23	182.2	0.001 128	887
190	12.80	192.8	0.001 142	876
200	15.86	203.5	0.001 157	865
210	19.46	214.3	0.001 173	853
220	23.66	225.3	0.001 190	840
230	28.53	236.4	0.001 209	827
240	23.14	247.7	0.001 229	815

250	40.56	259.2	0.001 251	800
260	47.87	271.0	0.001 276	784
270	56.14	283.0	0.001 302	763
280	65.46	295.3	0.001 332	750
290	75.92	308.0	0.001 366	731
300	87.61	321.1	0.001 404	712
310	100.6	334.6	0.001 448	690
320	115.1	349.0	0.001 499	667
330	131.2	364.2	0.001 562	640
340	149.0	380.7	0.001 641	610
350	168.6	398.9	0.001 746	572

From VDI Steam Tables, 6th Edn. 1963

Table 57 : Oxygen index (OI) of manmade/natural fabrics

OI index

Acrylic	=	0.182
Acetate	=	0.186
Rayon	=	0.197
Nylon	=	0.201
Polyester	=	0.206
P.P.	=	0.186
Wool	=	0.252
Cotton	=	0.201
Treated (flame retardant)		
Cotton	=	0.270

Note : 1. Higher OI index means a less flammable material. Material (untreated) which barely burns is having a OI of 0.201.

2. There are 3 types textile flame retardants viz. syn. Polymer, antimony flame retardants and halogenated flame retardents.

Table 58 : Coefficient of Thermal conductivity λ and Density of some Substances

Insulating and Building Maetrials	ρ kg/m3	γ kcal/m h deg C, at			
		100°C	300°C	600°C	800°C
Asbestos	540	0.167	0.18	0.186	0.19
Boiler scale (high calcium sulphate)	2000 to 2500	0.5	2.0	–	–
Boiler scale (high silicate)	300 to 1000	0.07	0.15	–	–
Brickwork	1420 to 1460	0.22	0.31	0.4	0.45
Diatomite filter bricks	700	0.17	0.2	0.245	0.27

Firebricks	1800 to 2000	0.76	0.87	0.95	1.2
Glass fibre	90	0.045	0.085	–	–
Glass wool	100	0.051	0.087	–	–
Lightweight refractory bricks	900	0.189	0.229	0.28	0.31
Mineral wool	200 to 220	0.046	0.066	0.08	0.1
Oil film (burnt on)	–	0.1	–	–	–
Pumice	600	0.15	0.2	0.25	–
Sand	1200 to 1650	0.3	–	–	–
Slag (liquid)	3500	–	4.2 at 1400°C	–	–
Slag (Solid)	2700	0.66	0.82	1.02	1.2
Slag wool	180 to 200	0.045	0.076	0.1	–
Sterchamol 23	380	0.07	0.099	0.139	0.168
Vitreous porcelain	2300 to 2500	0.9	–	–	–

Table 59

Metals and Alloys	ρ	λ, kcal/m h deg C, at			
	kg/m³	100°C	200°C	400°C	600°C
Aluminium, 99.5%	2 700	185	196	220	245
Austenitic steel	7 850	12	11.5	10	9.5
Brass (30% Zn)	8 500	93	97	101	–
Copper	8 930	325	320	315	–
Carbon steel	7 850	42	38	36	–
Cr- Mo steel	7 850	28	26	22	18
Cr-Ni-Mo steel	7 850	14	13	12	10
Electron metal	1 820	120	115	115	–
Grey cast iron	7 250	32 to 50	30 to 40	–	–
Mercury	13 596	9 at 0°C		–	–
Molybdenum steel	7 850	32	30	26	–
Nickel	8 800	46	45	42	–
Silumin, cast	2 650	133	–	–	–
Silver	10 500	360 at – 160°C to + 100°C			
Steel, cast	7 650	28	26	25	–
Tin	7200 to 7500	54	–	–	–
Zinc	7 100	95	90	80	–
Scale on steel:	at 900°	1000°C	1100°C	1200°	
	λ = 1.25	1.4	1.6	1.8	

Source : Borsig pocket book 3rd edn. 1970.

Table 60 : Thermal expansion, co-eff. of various materials

Material	Linear Thermal Expansion Coefficient $\times 10^{-6}$ m/m°C	At°C
A Refractory Bricks		
Bauxite bricks	5.2 to 6.5	20 to 1000
Carborundum bricks	4.4 to 5.4	20 to 1000
Chromite bricks	9.3 to 9.1	20 to 1000
Corundum bricks	5.6 to 7.0	20 to 1000
Fireclay bricks (firebricks), commercial	5.5 to 6.8	20 to 1000
Ganister bricks	5.0 to 6.3	20 to 1000
Magnesite bricks	13.7 to 14.5	20 to 1000
Magnesia ramming mix	13.9 to 14.5	20 to 1000
Silica bricks	12.7 to 15.4	20 to 1000
Silicon carbide bricks	4.7	0 to 900
Sillimanite bricks	4.9	20 to 1000
Zirconium oxide bricks	5.0 to 5.7	20 to 1000
Other Materials		
Bakelite	29.5	0 to 100
Glass, Thuringia	9.3 to 9.8	0 to 100
Glass, Jena	3.5	0 to 100
Marble	11.7	15 to 100
Porcelain	3.9 to 5.0	0 to 600
Porcelain	4.7 to 5.9	0 to 1200
Quartz glass	4.8	0 to 1000
Wood, along grain	3.7 to 5.4	0 to 35
Wood, across grain	54.4 to 34.0	0 to 35
Fluids		
Coal tar	500 to 700	
Lubricating oil	600 to 700	
Mercury	181	
Mineral oil	650 to 1200	
Petroleum	900 to 1000	

Examples : (1) Aluminium bar: L_0 at 20 °C = 1.650 m

β = 28.5 $\times$ 10^{-6} m/m °C. What is L at 600 °C?

L = 1.650 [1 + 28.5 $\times$ 10^{-6} (600 − 20)] = 1.677 m.

(2) Firebrick lining: V_0 at 0 °C = 1.0 m^3

β = 6.2 × 10^{-6} m/m °C. What is V at 1000 °C?

V = 1.0 [1 + 3 × 6.2 × 10^{-6} × 1000] = 1.019 m^3.
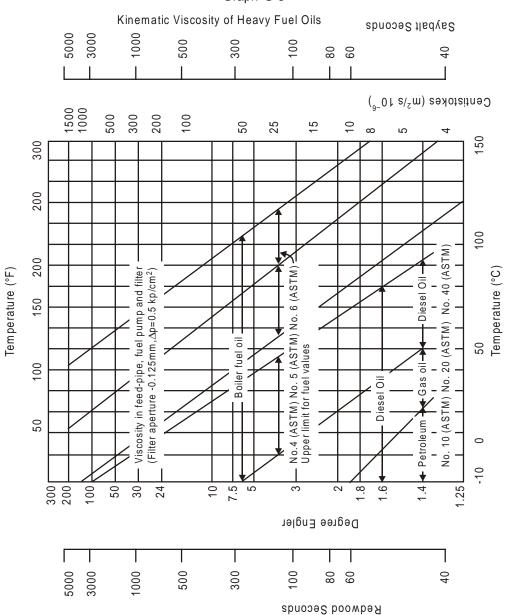
Table 60 : Thermal Expansion Coefficients of various materials (contd.)

Material	Linear Thermal Expansion Coefficient	
	x 10^{-6} m/m °C	At °C
B Metals		
Aluminium, 99.5%	24.0	20 to 100
Aluminium, 99.5%	28.5	20 to 600
Brass	19.0	0 to 100
Brass	21.6	0 to 500
Constantan	15.2	0 to 100
Constantan	16.8	0 to 500
1– Copper	16.2	0 to 100
2– Copper	18.1	0 to 500
Grey cast iron	10.4	0 to 100
Grey cast iron	12.8	0 to 500
Iron, pure	11.7	0 to 100
Iron, pure	22.2	900 to 1000
Magnesium	24.5	0 to 100
Magnesium	29.8	0 to 500
Mercury	181.0	
Nickel	13.0	0 to 100
Nickel	16.8	0 to 1000
Silumin, cast (Al–Si alloy)	22.0	
Silver	19.7	0 to 100
Silver	22.1	0 to 800
Steel, chromium–mdyldenum	11.3	
Steel, high–grade	12.0	0 to 100
Steel, high–grade	14.1	0 to 500
Steel, nickel	5 to 12	0
Steel, special	11.7	0 to 100
Steel, special	13.8	0 to 500
Steel, stainless	9.2	

Steel, welding	12.2	0 to 100
Steel, welding	14.0	0 to 500
Zinc	16.5	0 to 100

Source : Borsig pocket book 3rd edn. 1970

Graph G-5

Kinematic Viscosity of Heavy Fuel Oils
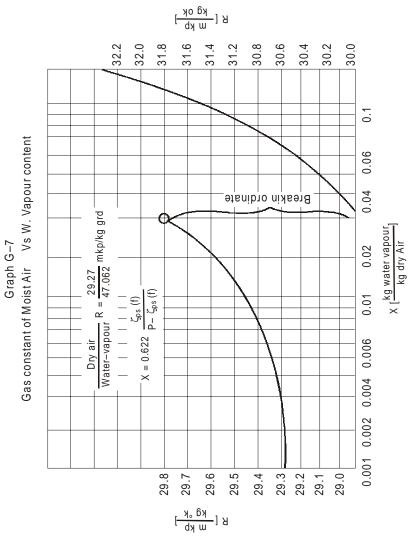
Source : Borsig pocket book 3rd edn. 1970.

Graph G-6

Kinematic Viscosity values γ of some Oils
Specific gravity (kp/dm^3)
1 cst = 10^{-6}m^2/s

Source : Borsig pocket book 3rd edn. 1970.

Graph G–7   Gas constant of Moist Air   Vs W. Vapour content

N.B. kp stands for kgf (kilopond)

Source : Borsig pocket book 3rd edn. 1970.

Graph G–8
Thermal Insulation thickness for Insulating materials

Wall thickness (mm)

γ stands for the density of insultating matieral

Heat loss 450 Kcal/m^3/h, corresponding to an overall coefficient of heat transfer of 15 kcal/m^{2}h deg C and an excess temperature of 30 deg C. For a different heat loss q. multiply the wall thickness by 450 q.

Example : t_1 = 1100°C, t_2 = 50°C
Insulating layers selected from the table
1. 200 mm fireclay:
2. 200 mm light diatomite :
3. 400 mm slag wool.
The layer of fireclay must be of such thickness that the subsequent layer can accept the temperature
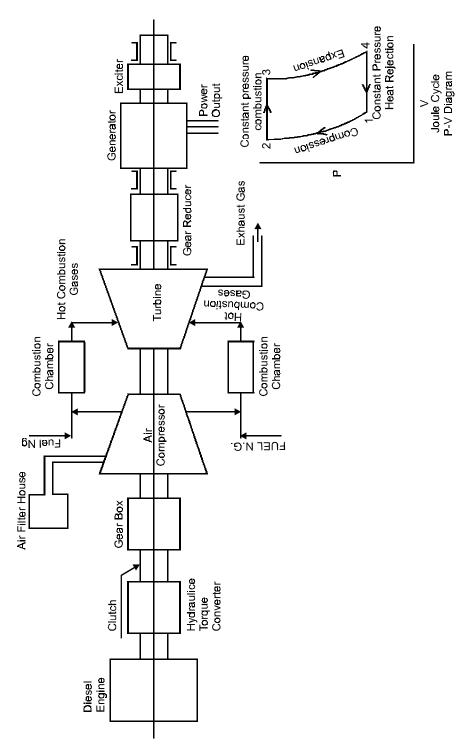
Fig. 1. Open Cycle Gas Turbine Generator Diagram.

Table 61 : Bulk Weight storage volume of Bulk Materials
(rough estimation)

	$1m^3$ weighs kg	$1ton$ occupies m^3		$1m^3$ weighs kg	$1ton$ occupies m^3
Aluminium chips	750	1.33	Echte	1800	0.55
Aluminium ingots	1500	0.67	Geislingen (fine)	1820	0.55
Blasting sand	1350	0.74	Kahlenberg	1620	0.62
Calcined pyrites:			Kalaa–Djerda	1750	0.57
fine (Hamborn)	1170	0.85	Echte (fine)	1800	0.56
Cast iron chips	2500	0.4	Klippenfloz (coarse)	1760	0.57
Cast iron scrap	3300	0.3	Lenglern (coarse)	1400	0.72
Cement	1200	0.8	Minette	1580	0.63
Charcoal	200	5.00	Peiner	1850	0.54
Clay bricks:			Pegnitz (fine)	1470	0.68
heaped	1200	0.8	Phosphate (fine)	1570	0.64
stacked	1400	0.7	Porta (coarse)	1720	0.58
Coke:			Steinberg	1470	0.68
Blast–furnace coke	420	2.39	Pig iron	3300	0.3
Broken coke I, II*	486	2.05	stacked	4000	0.25
Broken coke III, IV*	514	1.95	Sinter	1000	1.0
Coke breeze*	595	1.69	to	1800	0.56
Concentrates	1900	0.53	Moulding sand	1500	0.67
Dolomite	2000	0.5	Slag:		
Fire–clay	1500	0.8	Blast–furnace, ⎫	600	1.6
Fluorspar	2200	0.45	Cupola furnace ⎭		
Insulating bricks	700	1.43	Open–hearth furnace	2100	0.48
Limestone	1700	0.59	Basic converter	2000	0.5
Loam	1500	0.67	Rolling mill	3000	0.33
Magnesite	2200	0.45	Soft coal:		
Ore, high–grade:			Raw	580	1.72
Afrau	2150	0.47	Briquettes, heaped	770	1.30
Buchenberg	2240	0.445	Briquettes, stacked	1030	0.97
Brazil	3540	0.28	Dust	500	2.0
Itabira	3930	0.25	Steel chips	1500	0.67
Kiruna	3100	0.32	Hard coal:		
Königszug	2560	0.39	Coking coal'		
Malaespera roasted	2500	0.4	unstamped	800	1.25
Spathic iron ore			stamped	950	1.05
Rif fine	2720	0.37			

			Run–of–mine	860	1.16
Roasted spathic			Lump coal	790	1.27
iron ore (Bilbao)	2100	0.48	Nuts, I, II	760	1.32
Roasted spathic			Nuts, III, IV, V	735	1.36
iron ore (Siegen)	2500	0.40	Fines	840	1.19
Hematite (Brazil)	2800	0.36	Dust	600	1.67
Crude siderite	2400	0.42	Silica bricks	1700	0.59.
Wabana	2270	0.44	Rolling–mill scale	1000	1.0
Ställberg	2980	0.34	to	1800	0.53
Ore, low grade:			—		
Bulten	1790	0.56	[1]10% water, 80%		
Dogger	1820	0.55	grain size < 2mm		

Source : Borsig pocket book 3rd edn. 1970, *German and British coke sizes are different.

Table 62 : Henry's law constant

Chemical/gas	*Henry's law constant at 20°C*
Oxygen	4.3×10^4
Nitrogen	8.6×10^4
Hydrogen sulphide	5.15×10^2
Sulphor dioxide	38×10^2
Ammonia	0.76×10^2
Ozone	3.9×10^4
Carbon dioxide	1.51×10^3
Benzene	2.4×10^2
Toluene	3.4×10^2
Carbon tetrachloride	1.29×10^3
Chloro–form	1.7×10^2
Tichloroethylene	1.1×10^3
Vinyl Chloride	3.55×10^5
Pentachlorophenol	0.12×10^2
1–4 dichlorobenzene	1.9×10^2

Note: 1. Henry's law, $P_a = H_a \times X_a$ where

P_a = Partial Pr. of solute in soln.

X_a = Conc. of solute a in soln.

H_a = Henry's law constant for item a.

2. Larger the H_a, greater will be the equilibrium concentration (Y_a) in air and constituents having larger Henry's law constant are, therefore, easier to remove by air stripping. At equilibrium, $Y_a = X_a$

Table 63 : Fouling factor for various cooling water

$\dfrac{10^{-4}.m^2 {}^\circ K}{w}$		
C. W. Velocity	< 0.9m/sec	>0.9m/sec
C. T. circulating water	2	2
Stream water	4	2
Brackish water (Salty water)	4	2
Sea water	1	1

Table 64 : Molecular sieve specification

Major component	=	SiO_2
Grain size, nm	=	1 – 5
True density, kg/m^3	=	2600
Apparent density, kg/m^3	=	400 – 1500
Packing density, kg/m^3	=	600 – 900
Micropore vol. cm^3/gm	=	0.25 – 0.30 to 0.30 – 0.40
Specific surface area, m^2/gm	=	500 – 1000
Specific heat capacity	=	0.92
Thermal conductivity	=	0.13
Pore size, nm	=	0.2 – 0.3

Mol sieve formula:

$M_2/n^0 : Al_2O_3 : XSiO_2 : yH_2O$ where M = metal ion and n its valency

Table 65 : Filtering media for water vapour and others in gaseous state

	Mol. Sieve	Silica gel (Wide pore dia)	Active Carbon (wide pore)
Mazor Component	$SiO_2Al_2O_3$	SiO_2	C
Grain size, nm	1–5	1–5	3–10
Apparent density, kg/m^3	1100–1500	1100	600–700
True density kg/m^3	2600	2200	2200
Packing density kg/m^3	600–900	400–800	300–500
Micropore Vol. Cm^3/g (<50nm)	0.25 – 0.30	0–30 – 0.45	0.20–0.30
Micropore Vol. cm^3/g (>50nm)	0.30 – 0.4	0.25 – 0.10	0.30 – 0.50
Spec. heat capacity kj^{-1}k^{-1}	0.92	0.92	0.76 – 0.84
Spec. surface area, m^2/gm	500–1000	250–350	1000–1500

(Contd.)

Thermal Conductivity, $Wm^{-1}k^{-1}$	0.13	0.20	0.1
Regeneration temperature °C	200–300	120–150	
*Heat reqd/kg of			
water removed, kj/kg	12000	8000	–

Table 66 : Galvanic series of metals and graphite

Metal Active End

1. Magnesium
2. Magnesium alloys
3. Zinc
4. Aluminium
5. Cadmium
6. Steel or iron
7. Cast iron
8. Chromium iron
9. Nickel
10. 18–8 Stainless steel
11. 18–8–3 Stainless steel
12. Pb – Tin solders
13. Pb
14. Tin
15. Brases
16. Copper
17. Bronzes
18. Cu–Nickel Alloys
19. Silver solder
20. Silver
21. Graphite
22. Gold
23. Platinum
    Metal–noble end

Criteria of selection of metals to limit Galvanic corrosion:

(*i*) The metals selected should be in the same or at least adjacent group in the Galvanic series.

(*ii*) Insulating materials fittings, inserts or nipples may be used to isolate components in the desimiliar metal component of the Galvanic series.

Table 67 A : Microorganisms used for fermentation

Item	Microorganism name
Lactic Acid	L. Buchneri
	Lacto bacillus urevis L. fifidus
Ethanol	S. Cerevisiae, Zynosores
Salicylic Acid	Corynobacterium Species
Poly Alcohols	Onmophillic Yeasts
(Erythritol, arabitol)	
Glycerol	S.Cerevisiae and Others related
Methane	Methano–coccus
Lipids	Yeasts, Molds, Algae and Bacteria
Hydrogen	Bacteria, Algae
Vit.C (Sorbitol)	Acetobacter Species
Vit. B_{12}	Propionibacterium
Biotin	Streptomyces
Antibiotics	Various Microorganism
Lysine	Mutants of Corynebacterium

Table 67 B : Micro organisms (bio fertilisers) used for seed inocculation and nitrifying bacteria in soils

1. Legume (Soyabean groundnut and pulses) seeds inocculation is done by Rhizobium microbe which increases yield by 10–25%.

2. Nitrifying microbes : Rhizobium, Azetobacter, Azospivillum

3. In India NAFED is the agency for biofertiliser production; culture is obtained from agricultural universities who are also doing R and D work.

Table 68 A : State Variables of Saturated Steam

P ata	Ts C	v' m³/kg	v'' m³/kg	ρ'' kg/m³	i' kcal/kg	i'' kcal/kg	r
0.01	6.7	0.00100	131.6	0.00760	6.7	600.2	593.5
0.02	17.2	0.001001	68.27	0.01465	17.2	604.8	587.6
0.04	28.6	0.001004	35.46	0.02820	28.7	609.8	581.1
0.06	35.8	0.001006	24.19	0.04134	35.8	612.9	577.1
0.08	41.2	0.001008	18.45	0.05421	41.1	615.2	574.1
0.10	45.5	0.001010	14.95	0.06688	45.4	617.0	571.6
0.15	53.6	0.001014	10.21	0.09792	53.5	620.4	566.9
0.20	59.7	0.001017	7.794	0.1283	59.6	623.0	563.4
0.30	68.7	0.001022	5.328	0.1877	68.6	626.6	558.0
0.40	75.4	0.001026	4.068	0.2458	75.4	629.3	553.9
0.50	80.9	0.001030	3.301	0.3030	80.8	631.5	550.7
0.60	85.5	0.001033	2.782	0.3594	85.4	633.3	547.9
0.80	93.0	0.001039	2.125	0.4705	93.0	636.2	543.2
1.00	99.1	0.001043	1.725	0.5798	99.1	638.4	539.4
1.20	104.3	0.001047	1.454	0.6876	104.3	640.3	536.0
1.4	108.7	0.001051	1.259	0.7944	108.9	641.9	533.0
1.6	112.7	0.001054	1.111	0.9001	112.9	643.4	530.5
1.8	116.3	0.001058	0.995	1.005	116.6	644.6	528.0
2.0	119.6	0.001060	0.9015	1.109	119.9	645.8	525.9
2.5	126.8	0.001067	0.7315	1.367	127.2	648.2	521.0
3.0	132.9	0.001073	0.6165	1.622	133.4	650.2	516.8
3.5	138.2	0.001078	0.5335	1.874	138.8	651.9	513.1

P ata	Ts C	v' m³/kg	v'' m³/kg	ρ'' kg/m³	i' kcal/kg	i'' kcal/kg	r
16	200.4	0.001158	0.1262	7.926	203.9	667.3	463.4
17	203.4	0.001162	0.1190	8.405	207.1	667.8	460.7
18	206.1	0.001167	0.1125	8.885	210.1	668.2	458.1
19	208.8	0.001171	0.1068	9.365	213.0	668.5	455.5
20	211.4	0.001175	0.1016	9.846	215.8	668.8	450.0
22	216.2	0.001184	0.09250	10.81	221.1	669.3	448.2
24	220.8	0.001192	0.08490	11.78	226.1	669.6	443.5
26	225.0	0.001199	0.07843	12.75	230.8	669.9	439.1
28	229.0	0.001207	0.07285	13.73	235.2	670.0	434.8
30	232.8	0.001215	0.06799	14.71	239.5	670.1	430.6
32	236.4	0.001222	0.06371	15.70	243.5	670.1	426.6
34	239.8	0.001229	0.05992	16.69	247.4	670.0	422.6
36	243.0	0.001236	0.05653	17.69	251.1	669.9	418.8
38	246.2	0.001243	0.05349	18.69	254.7	669.7	415.0
40	249.2	0.001250	0.05074	19.71	258.2	669.5	411.3
45	256.2	0.001266	0.04490	22.27	266.5	668.7	402.2
50	262.7	0.001283	0.04019	24.88	274.1	667.7	393.6
55	268.7	0.001299	0.03631	27.54	281.3	666.5	385.2
60	274.3	0.001315	0.03305	30.25	288.2	665.2	377.0
65	279.5	0.001331	0.03028	33.02	294.7	663.8	369.1
70	284.5	0.001347	0.02789	35.85	300.9	662.3	361.4
80	293.6	0.001379	0.02399	41.69	312.6	659.0	346.4

(Contd.)

P	Ts	v'	v"	ρ"	i'	i"	r
4.0	142.9	0.001083	0.4706	2.125	143.6	653.4	509.8
4.5	147.2	0.001088	0.4213	2.373	148.0	654.7	506.7
5.0	151.1	0.001092	0.3816	2.621	152.1	655.9	503.8
6.0	158.1	0.001100	0.3213	3.112	159.3	657.9	498.6
7.0	164.2	0.001108	0.2778	3.600	165.6	659.5	493.9
8.0	169.6	0.001114	0.2448	4.085	171.3	660.9	489.6
9.0	174.5	0.001121	0.2189	4.568	176.4	662.1	485.7
10.0	179.0	0.001127	0.1980	5.050	181.2	663.2	482.0
11.0	183.2	0.001132	0.1808	5.530	185.5	664.1	478.6
12.0	187.1	0.001138	0.1664	6.010	189.7	664.9	475.2
13.0	190.7	0.001143	0.1541	6.489	193.5	665.6	472.1
14.0	194.1	0.001148	0.1435	6.968	197.2	666.3	469.1
15.0	197.4	0.001153	0.1343	7.447	200.6	666.8	466.2

P	Ts	v'	v"	ρ"	i'	i"	r
90	301.9	0.001411	0.02093	47.78	323.6	655.5	331.9
100	309.5	0.001445	0.01846	54.16	334.1	651.7	317.6
110	316.6	0.001480	0.01642	60.89	344.0	647.7	303.7
120	323.2	0.001516	0.01467	68.18	353.7	643.0	289.3
130	329.3	0.001555	0.01315	76.05	363.1	637.5	274.4
140	335.1	0.001597	0.01183	84.57	372.4	631.6	259.2
150	340.6	0.001644	0.01066	93.82	381.6	625.1	243.5
160	345.7	0.001695	0.00962	104.0	390.8	618.3	227.5
180	355.4	0.001822	0.00781	128.0	410.2	603.0	192.8
200	364.1	0.00201	0.00622	160.9	431.5	582.2	150.7
220	372.1	0.00238	0.00444	225.0	463.6	545.5	81.9
224	373.6	0.00261	0.00389	257.0	478.5	530.8	52.3

P = absolute pressure

T_s = saturation temperature

v = Specific volume

ρ = 1/v density

i = enthalpy

r = i" – i' = latent heat of evaporation

Indices : ' for boiling state

" for dry saturated state

In the wet steam range $v = v' + x \cdot (v" - v')$

$i = i' + x \cdot r$

*From VDI Steam Tables by Ernst Schmidt
and R. Oldenbourg. 6th Edn. 1963

Table 68 B : Enthalpy at Superheated Steam and Water, Kcal/kg

P ata	Temperature, °C															
	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400
1	710.3	715.0	719.8	724.5	729.3	734.1	738.9	743.7	748.6	753.4	758.3	763.1	768.0	772.9	777.8	782.8
2	709.5	714.3	719.1	723.9	728.7	733.5	738.3	743.2	748.0	752.9	757.8	762.7	767.6	772.5	777.4	782.4
3	708.7	713.5	718.4	723.2	728.1	732.9	737.8	742.6	747.5	752.4	757.3	762.2	767.2	772.1	777.1	782.0
4	707.9	712.8	717.7	722.5	727.4	732.3	737.2	742.1	747.0	751.9	756.8	761.8	766.7	771.7	776.7	781.6
5	707.1	712.1	717.0	721.9	726.8	731.7	736.6	741.6	746.5	751.4	756.4	761.3	766.3	771.3	776.3	781.2
6	706.4	711.3	716.3	721.2	726.2	731.1	736.1	741.0	746.0	750.9	755.9	760.9	765.9	770.9	775.9	780.9
7	705.6	710.6	715.6	720.5	725.5	730.5	735.5	740.5	745.4	750.4	755.4	760.4	765.4	770.4	775.5	780.5
8	704.8	709.8	714.8	719.9	724.9	729.9	734.9	739.9	744.9	749.9	755.0	760.0	765.0	770.0	775.1	780.1
9	704.0	709.1	714.1	719.2	724.2	729.3	734.3	739.4	744.4	749.4	754.5	759.5	764.6	769.6	774.7	779.7
10	703.1	708.3	713.4	718.5	723.6	728.7	733.8	738.8	743.9	748.9	754.0	759.1	764.1	769.2	774.3	779.3
11	702.3	707.5	712.7	717.8	723.0	728.1	733.2	738.3	743.4	748.4	753.5	758.6	763.7	768.8	773.9	779.0
12	701.5	706.7	712.0	717.1	722.3	727.5	732.6	737.7	742.8	747.9	753.0	758.1	763.3	768.4	773.5	778.6
13	700.6	706.0	711.2	716.5	721.7	726.8	732.0	737.2	742.3	747.4	752.6	757.7	762.8	767.9	773.1	778.2
14	699.8	705.2	710.5	715.8	721.0	726.2	731.4	736.6	741.8	746.9	752.1	757.2	762.4	767.5	772.7	777.8
15	698.9	704.4	709.7	715.1	720.3	725.6	730.8	736.0	741.2	746.4	751.6	756.8	761.9	767.1	772.3	777.4
16	698.0	703.5	709.0	714.4	719.7	725.0	730.2	735.5	740.7	745.9	751.1	756.3	761.5	766.7	771.9	777.0
17	697.1	702.7	708.2	713.6	719.0	724.3	729.6	734.9	740.2	745.4	750.6	755.9	761.1	766.3	771.5	776.7
18	696.2	701.9	707.4	712.9	718.3	723.7	729.1	734.4	739.6	744.9	750.2	755.4	760.6	765.8	771.1	776.3
19	695.3	701.0	706.7	712.2	717.7	723.1	728.4	733.8	739.1	744.4	749.7	754.9	760.2	765.4	770.7	775.9
20	694.3	700.2	705.9	711.5	717.0	722.4	727.8	733.2	738.6	743.9	749.2	754.5	759.7	765.0	770.2	775.5
22	692.4	698.4	704.2	710.0	715.6	721.1	726.6	732.1	737.5	742.9	748.2	753.5	758.9	764.2	769.4	774.7
24	690.3	696.6	702.6	708.4	714.2	719.8	725.4	730.9	736.4	741.8	747.2	752.6	758.0	763.3	768.6	773.9
26	688.2	694.7	700.9	706.9	712.7	718.5	724.1	729.7	735.3	740.8	746.2	751.7	757.1	762.5	767.8	773.2
28	686.0	692.7	699.1	705.3	711.2	717.1	722.9	728.5	734.2	739.7	745.2	750.7	756.2	761.6	767.0	772.4

(Contd.)

30	683.7	690.7	697.3	703.6	709.7	715.7	721.6	727.3	733.0	738.7	744.2	749.8	755.3	760.7	766.2	771.6
35	677.4	685.2	692.4	699.3	705.8	712.1	718.2	724.2	730.1	735.9	741.7	747.4	753.0	758.6	764.1	769.6
40	670.2	679.1	687.2	694.6	701.6	708.3	714.8	721.0	727.2	733.2	739.1	744.9	750.7	756.4	762.0	767.6
45	259.2	672.4	681.4	689.5	697.1	704.3	711.1	717.7	724.1	730.3	736.4	742.4	748.3	754.1	759.9	765.6
50	259.2	270.9	675.0	684.0	692.3	700.0	707.2	714.2	720.8	727.3	733.6	739.8	745.9	751.8	757.7	763.6
60	259.2	270.8	282.9	671.5	681.4	690.5	698.8	706.6	713.9	721.0	727.8	734.4	740.8	747.1	753.3	759.4
70	259.2	270.8	282.8	295.1	668.8	679.6	689.2	698.1	706.4	714.2	721.6	728.7	735.5	742.2	748.7	755.1
80	259.2	270.8	282.8	295.0	307.8	667.1	678.5	688.7	698.0	706.7	714.8	722.5	729.9	737.0	743.9	750.6
90	259.2	270.8	282.7	294.9	307.7	321.0	666.2	678.1	688.8	698.5	707.5	716.0	723.9	731.5	738.8	745.9
100	259.2	270.7	282.6	294.8	307.5	320.7	334.7	666.3	678.6	689.6	699.6	708.9	717.5	725.7	733.5	741.0
110	259.2	270.7	282.6	294.7	307.3	320.4	334.3	653.2	667.3	679.8	691.0	701.2	710.7	719.6	727.9	735.8
120	259.2	270.7	282.5	294.6	307.1	320.2	334.0	348.7	654.7	669.0	681.6	693.0	703.4	713.0	722.0	730.4
130	259.3	270.7	282.5	294.5	307.0	320.0	333.6	348.2	638.8	657.0	671.5	684.1	695.5	706.0	715.7	724.7
140	259.3	270.7	282.4	294.4	306.8	319.7	333.3	347.7	363.5	642.1	660.5	674.5	687.1	698.6	709.0	718.8
150	259.3	270.7	282.4	294.3	306.7	319.5	333.0	347.2	362.7	380.4	647.4	664.0	678.2	690.6	702.0	712.4
160	259.3	270.7	282.3	294.2	306.6	319.3	332.7	346.7	362.0	379.2	630.6	651.9	668.7	682.2	694.6	705.8
180	259.4	270.7	282.3	294.1	306.3	318.9	332.1	345.9	360.7	377.1	396.4	620.0	645.6	663.5	678.4	691.5
200	259.4	270.7	282.2	294.0	306.1	318.6	331.6	345.2	359.6	375.3	393.1	416.8	610.8	639.6	660.2	675.7
220	259.5	270.7	282.2	293.8	305.9	318.3	331.1	344.5	358.6	373.8	390.7	411.0	443.6	609.0	637.6	658.3
250	259.6	270.7	282.1	293.7	305.6	317.9	330.5	313.6	357.3	371.9	387.6	405.7	428.0	471.4	585.6	623.0
300	259.8	270.8	282.1	293.5	305.3	317.3	329.6	342.3	355.6	369.4	384.1	399.9	117.8	439.5	470.4	523.4
350									354.2	367.5	381.3	396.2	412.1	430.0	451.2	477.7
400									353.0	365.9	379.3	393.3	408.2	424.4	442.1	462.3
450									352.1	364.6	377.6	391.1	405.3	420.3	436.3	453.9
500									351.3	363.6	376.2	389.1	402.7	416.9	431.8	447.8

Table 68 C : Enthalpy of Superheated steam and Water, kcal/kg

P ata	410	420	430	440	450	460	470	480	P ata	490	500	510	520	530	540	550	560
				Temperature, °C									*Temperature, °C*				
1	787.7	792.7	797.7	802.6	807.7	812.7	817.7	822.8	1	827.8	832.9	838.0	843.1	848.3	853.4	858.6	863.8
2	787.4	792.3	797.3	802.3	807.3	812.4	817.4	822.5	2	827.6	832.7	837.8	842.9	848.0	853.2	858.4	863.5
3	787.0	792.0	797.0	802.0	807.0	812.1	817.1	822.2	3	827.3	832.4	837.5	842.6	847.8	853.0	858.1	863.3
4	786.6	791.6	796.6	801.7	806.7	811.8	816.8	821.9	4	827.0	832.1	837.3	842.4	847.6	852.7	857.9	863.1
5	786.3	791.3	796.3	801.3	806.4	811.5	816.5	821.6	5	826.8	831.9	837.0	842.2	847.3	852.5	857.7	862.9
6	785.9	790.9	796.0	801.0	806.1	811.2	816.3	821.4	6	826.5	831.6	836.8	841.9	847.1	852.3	857.5	862.7
7	785.5	790.6	795.6	800.7	805.8	810.9	816.0	821.1	7	826.2	831.4	836.5	841.7	846.9	852.1	857.3	862.5
8	785.2	790.2	795.3	800.4	805.5	810.6	815.7	820.8	8	825.9	831.1	836.3	841.4	846.6	851.8	857.0	862.3
9	784.8	789.9	795.0	800.0	805.1	810.3	815.4	820.5	9	825.7	830.8	836.0	841.2	846.4	851.6	856.8	862.1
10	784.4	789.5	794.6	799.7	804.8	810.0	815.1	820.2	10	825.4	830.6	835.8	840.9	846.2	851.4	856.6	861.9
11	784.1	789.2	794.3	799.4	804.5	809.7	814.8	820.0	11	825.1	830.3	835.5	840.7	845.9	851.1	856.4	861.6
12	783.7	788.8	793.9	799.1	804.2	809.4	814.5	819.7	12	824.9	830.1	835.3	840.5	845.7	850.9	856.2	861.4
13	783.3	788.5	793.6	798.7	803.9	809.1	814.2	819.4	13	824.6	829.8	835.0	840.2	845.5	850.7	855.9	861.2
14	783.0	788.1	793.3	798.4	803.6	808.8	813.9	819.1	14	824.3	829.5	834.8	840.0	845.2	850.5	855.7	861.0
15	782.6	787.7	792.9	798.1	803.3	808.5	813.6	818.8	15	824.1	829.3	834.5	839.7	845.0	850.2	855.5	860.6
16	782.2	787.4	792.6	797.8	803.0	808.2	813.4	818.6	16	823.8	829.0	834.2	839.5	844.7	850.0	855.3	860.6
17	781.8	787.0	792.2	797.4	802.6	807.9	813.1	818.3	17	823.5	828.8	834.0	839.3	844.5	849.8	855.1	860.4
18	781.5	786.7	791.9	797.1	802.3	807.5	812.8	818.0	18	823.2	828.5	833.7	839.0	844.3	849.6	854.9	860.2
19	781.1	786.3	791.6	796.8	802.0	807.2	812.5	817.7	19	823.0	828.2	833.5	838.8	844.0	849.3	854.6	859.9
20	780.7	786.0	791.2	796.5	801.7	806.9	812.2	817.4	20	822.7	828.0	833.2	838.5	843.8	849.1	854.4	859.7
22	780.0	785.3	790.5	795.8	801.1	806.3	811.6	816.9	22	822.2	827.4	832.7	838.0	843.3	848.7	854.0	859.3
24	779.3	784.6	789.9	795.1	800.4	805.7	811.0	816.3	24	821.6	826.9	832.2	837.6	842.9	848.2	853.5	858.9
26	778.5	783.8	789.2	794.5	799.8	805.1	810.4	815.8	26	821.1	826.4	831.7	837.1	842.4	847.7	853.1	858.5
28	777.8	783.1	788.5	793.8	799.2	804.5	809.9	815.2	28	820.5	825.9	831.2	836.6	841.9	847.3	852.7	858.0
30	777.0	782.4	787.8	793.2	798.5	803.9	809.3	814.6	30	820.0	825.4	830.7	836.1	841.5	846.8	852.2	857.6
35	775.1	780.6	786.1	791.5	797.0	802.4	807.8	813.2	35	818.6	824.1	829.5	834.9	840.3	845.7	851.1	856.5

40	773.2	778.8	784.3	789.9	795.4	800.9	806.3	811.8
45	771.3	777.0	782.6	788.2	793.8	799.3	804.9	810.4
50	769.4	775.1	780.8	786.5	792.2	797.8	803.4	809.0
60	765.4	771.4	777.3	783.1	788.9	794.7	800.4	806.1
70	761.3	767.5	773.6	779.6	785.6	791.5	797.4	803.2
80	757.1	763.5	769.8	776.1	782.2	788.3	794.3	800.3
90	752.8	759.4	766.0	772.4	778.8	785.0	791.2	797.3
100	748.2	755.2	762.0	768.7	775.2	781.7	788.0	794.3
110	743.5	750.8	757.9	764.8	771.6	778.2	784.8	791.2
120	738.5	746.2	753.7	760.9	767.9	774.7	781.5	788.1
130	733.3	741.4	749.2	756.8	764.1	771.2	778.1	784.9
140	727.9	736.5	744.7	752.5	760.1	767.5	774.6	781.6
150	722.2	731.3	739.9	748.2	756.1	763.7	771.1	778.3
160	716.2	725.9	735.0	743.6	751.9	759.8	767.5	774.9
180	703.4	714.3	724.5	734.1	743.1	751.7	759.9	767.9
200	689.4	701.8	713.2	723.8	733.7	743.1	752.0	760.5
220	674.0	688.2	701.1	712.8	723.8	734.0	743.6	752.7
250	646.0	665.5	681.0	695.0	707.7	719.4	730.2	740.4
300	578.0	615.0	641.1	661.1	677.8	692.4	705.8	718.1
350	511.4	552.0	591.0	620.0	643.2	662.4	679.0	693.9
400	485.6	513.0	545.7	577.1	604.9	629.6	650.5	668.2
450	473.1	494.5	518.7	545.1	571.3	597.4	620.9	641.9
500	464.9	483.5	503.5	525.3	548.6	572.2	595.2	617.2

40	817.3	822.7	828.2	833.7	839.1	844.6	850.0	855.5
45	815.9	821.4	826.9	832.4	837.9	843.4	848.9	854.4
50	814.5	820.1	825.7	831.2	836.8	842.3	847.8	853.4
60	811.8	817.5	823.1	828.8	834.4	840.0	845.6	851.2
70	809.0	814.8	820.5	826.3	832.0	837.7	843.4	849.1
80	806.2	812.1	818.0	823.8	829.6	635.4	841.2	846.9
90	803.4	809.4	815.3	821.3	827.2	833.1	838.9	844.8
100	800.5	806.6	812.7	818.8	824.8	830.7	836.7	842.6
110	797.5	803.8	810.0	816.2	822.3	828.4	834.4	840.4
120	794.6	801.0	807.3	813.6	819.8	826.0	832.1	838.2
130	791.6	798.1	804.6	811.0	817.3	823.6	829.8	836.0
140	788.5	795.2	801.8	808.4	814.8	821.2	827.5	833.8
150	785.3	792.2	799.0	805.7	812.2	818.7	825.2	831.5
160	782.1	789.2	796.1	803.0	809.7	816.3	822.8	829.3
180	775.5	783.0	790.3	797.4	804.4	811.3	818.0	824.7
200	768.6	776.5	784.2	791.7	799.0	806.1	813.1	820.0
220	761.5	769.8	777.9	785.8	793.4	800.8	808.1	815.2
250	750.1	759.3	768.1	776.5	784.7	792.6	800.4	807.9
300	729.6	740.4	750.5	760.2	769.4	778.3	786.8	795.1
350	707.4	720.0	731.7	742.7	753.2	763.1	772.6	781.7
400	684.2	698.7	712.1	724.5	736.2	747.3	757.8	767.8
450	660.7	677.2	692.3	706.2	719.1	731.3	742.8	753.7
500	637.7	656.4	673.2	688.4	702.7	715.7	728.1	739.8

Table 68 D : Enthalpy of Superheated Steam and Water, kcal/kg

P ata	Temperature, °C															
	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720
1	869.0	874.2	879.4	884.7	889.9	895.2	900.5	905.8	911.1	916.5	921.9	927.2	932.6	938.0	943.5	948.9
2	868.8	874.0	879.2	884.5	889.7	895.0	900.3	905.6	911.0	916.3	921.7	927.1	932.5	937.9	943.2	948.8
3	868.5	873.8	879.0	884.3	889.6	894.8	900.2	905.5	910.8	916.2	921.5	926.9	932.3	937.8	943.2	948.7
4	868.3	873.6	878.8	884.1	889.4	894.7	900.0	905.3	910.7	916.0	921.4	926.8	932.2	737.6	943.1	948.5
5	868.1	873.4	878.6	883.9	889.2	894.5	899.8	905.1	910.5	915.9	921.2	926.6	932.1	937.5	942.9	948.4
6	867.9	873.2	878.4	883.7	889.0	894.3	899.6	905.0	910.3	915.7	921.1	926.5	931.9	937.3	942.8	948.3
7	867.7	873.0	878.2	883.5	888.8	894.1	899.5	904.8	910.2	915.5	920.9	926.3	931.8	937.2	942.7	948.1
8	867.5	872.8	878.1	883.3	888.6	894.0	899.3	904.6	910.0	915.4	920.8	926.2	931.6	937.1	942.5	948.0
9	867.3	872.6	877.9	883.2	888.5	893.8	899.1	904.5	909.8	915.2	920.6	926.0	931.5	936.9	942.4	947.9
10	867.1	872.4	877.7	883.0	888.3	893.6	899.0	904.3	909.7	915.1	920.5	925.9	931.3	936.8	942.2	947.7
11	866.9	872.2	877.5	882.8	888.1	893.4	898.8	904.1	909.5	914.9	920.3	925.7	931.2	936.6	942.1	947.6
12	866.7	872.0	877.3	882.6	887.9	893.3	898.6	904.0	909.4	914.8	920.2	925.6	931.0	936.5	942.0	947.5
13	866.5	871.8	877.1	882.4	887.7	893.1	898.4	903.8	909.2	914.6	920.0	925.5	930.9	936.4	941.8	947.3
14	866.3	871.6	876.9	882.2	887.6	892.9	898.3	903.7	909.0	914.4	919.9	925.3	930.8	936.2	941.7	947.2
15	866.1	871.4	876.7	882.0	887.4	892.7	898.1	903.5	908.9	914.3	919.7	925.2	930.6	936.1	941.6	947.1
16	865.9	871.2	876.5	881.8	887.2	892.6	897.9	903.3	908.7	914.1	919.6	925.0	930.5	935.9	941.4	946.9
17	865.7	871.0	876.3	881.7	887.0	892.4	897.8	903.2	908.6	914.0	919.4	924.9	930.3	935.8	941.3	946.8
18	865.5	870.8	876.1	881.5	886.8	892.2	897.6	903.0	908.4	913.8	919.3	924.7	930.2	935.7	941.1	946.7
19	865.3	870.6	875.9	881.3	886.7	892.0	897.4	902.8	908.2	913.7	919.1	924.6	930.0	935.5	941.0	946.5
20	865.1	870.4	875.7	881.1	886.5	891.9	897.2	902.7	908.1	913.5	919.0	924.4	929.9	935.4	940.9	946.4
22	864.6	870.0	875.4	880.7	886.1	891.5	896.9	902.3	907.8	913.2	918.7	924.1	929.6	935.1	940.6	946.1
24	864.2	869.6	875.0	880.4	885.7	891.2	896.6	902.0	907.4	912.9	918.3	923.8	929.3	934.8	940.3	945.9
26	863.8	869.2	874.6	880.0	885.4	890.8	896.2	901.7	907.1	912.6	918.0	923.5	929.0	934.5	940.1	945.6
28	863.4	868.8	874.2	879.6	885.0	890.4	895.9	901.3	906.8	912.3	917.7	923.2	928.7	934.3	939.8	945.3
30	863.0	868.4	873.8	879.2	884.7	890.1	895.5	901.0	906.5	911.9	917.4	922.9	928.4	934.0	939.5	945.1
35	862.0	867.4	872.8	878.3	883.8	889.2	894.7	900.2	905.7	911.2	916.7	922.2	927.7	933.3	938.8	944.4
40	860.9	866.4	871.9	877.4	882.8	888.3	893.8	899.3	904.9	910.4	915.9	921.5	927.0	932.6	938.1	943.7

45	859.9	865.4	870.9	876.4	881.9	887.5	893.0	898.5
50	858.9	864.4	870.0	875.5	881.0	886.6	892.1	897.7
60	856.8	862.4	868.0	873.6	879.2	884.8	890.4	896.0
70	854.8	860.4	866.1	871.7	877.4	883.1	888.7	894.4
80	852.7	858.4	864.1	869.9	875.6	881.3	887.0	892.7
90	850.6	856.4	862.2	868.0	873.8	879.5	885.3	891.1
100	848.5	854.4	860.2	866.1	871.9	877.8	883.6	889.4
110	846.4	852.4	858.3	864.4	870.1	876.0	881.9	887.7
120	844.3	850.3	856.3	862.3	868.3	874.2	880.1	886.1
130	842.2	848.3	854.3	860.4	866.4	872.4	878.4	884.4
140	840.0	846.2	852.2	858.5	864.6	870.6	876.7	882.7
150	837.9	844.1	850.4	856.6	862.7	868.8	874.9	881.0
160	835.7	842.0	848.4	854.6	860.8	867.0	873.2	879.3
180	831.3	837.8	844.3	850.7	857.1	863.4	869.7	876.0
200	826.8	833.5	840.2	846.8	853.3	859.8	866.2	872.6
220	822.3	829.2	836.0	842.8	849.5	856.1	862.6	869.1
250	815.3	822.5	829.7	836.7	843.6	850.4	857.2	863.9
300	803.2	811.0	818.7	826.2	833.6	840.9	848.0	855.1
350	790.5	799.0	807.3	815.4	823.3	831.0	838.6	846.1
400	777.4	786.7	795.6	804.3	812.7	820.9	829.0	836.9
450	764.1	774.1	783.7	793.0	801.9	810.7	819.2	827.5
500	750.9	761.6	771.8	781.7	791.2	800.4	809.4	818.1

45	904.1	909.6	915.2	920.7	926.3	931.9	937.5	943.1
50	903.2	908.8	914.4	920.0	925.6	931.2	936.8	942.4
60	901.6	907.3	912.9	918.5	924.1	929.8	935.4	941.1
70	900.0	905.7	911.4	917.0	922.7	928.4	934.1	939.7
80	898.4	904.1	909.8	915.5	921.3	927.0	932.7	938.4
90	896.8	902.6	908.3	914.1	919.8	925.6	931.3	937.1
100	895.2	901.0	906.8	912.6	918.4	924.2	930.0	935.8
110	893.6	899.4	905.3	911.1	916.9	922.8	928.6	934.5
120	892.0	897.9	903.8	909.6	915.5	921.4	927.3	933.1
130	890.3	896.3	902.2	908.2	914.1	920.0	925.9	931.8
140	888.7	894.7	900.7	906.7	912.6	918.6	924.5	930.5
150	887.1	893.1	899.2	905.2	911.2	917.2	923.2	929.2
160	885.5	891.6	897.6	903.7	909.8	915.8	921.8	927.8
180	882.2	888.4	894.6	900.7	906.9	913.0	919.1	925.2
200	878.9	885.2	891.5	897.7	904.0	910.2	916.4	922.6
220	875.6	882.0	888.4	894.7	901.1	907.4	913.6	919.9
250	870.6	877.2	883.7	890.2	896.7	903.1	909.5	915.9
300	862.1	869.0	875.8	882.6	889.3	896.0	902.7	909.2
350	853.4	860.7	867.8	874.9	881.9	888.8	895.7	902.5
400	844.6	852.2	859.7	867.1	874.4	881.6	888.7	895.8
450	835.6	843.6	851.4	859.3	866.7	874.2	881.6	888.9
500	826.6	835.0	843.2	851.2	859.1	866.9	874.5	882.1

Table 68 E : Enthalpy of Superheated Steam, kcal/kg

P	Temperature, °C							
ata	730	740	750	760	770	780	790	800
1	954.4	959.9	965.4	970.9	976.4	982.0	987.5	993.1
2	954.3	959.7	965.2	970.8	976.3	981.8	987.4	993.0
3	954.1	959.6	965.1	970.6	976.2	981.7	987.3	992.9
4	954.0	959.5	965.0	970.5	976.1	981.6	987.2	992.8
5	953.9	959.4	964.9	970.4	975.9	981.5	987.1	992.7
6	953.7	959.2	964.8	970.3	975.8	981.4	987.0	992.6
7	953.6	959.1	964.6	970.2	975.7	981.3	986.9	992.4
8	953.5	959.0	964.5	970.0	975.6	981.2	986.7	992.3
9	953.3	958.9	964.4	969.9	975.5	981.0	986.6	992.2
10	953.2	958.7	964.3	969.8	975.4	980.9	986.5	992.1
11	953.1	958.6	964.1	969.7	975.2	980.8	986.4	992.0
12	953.0	958.5	964.0	969.6	975.1	980.7	986.3	991.9
13	952.8	958.3	963.9	969.4	975.0	980.6	986.2	991.8
14	952.7	958.2	963.8	969.3	974.9	980.5	986.1	991.7
15	952.6	958.1	963.6	969.2	974.8	980.3	985.9	991.6
16	952.4	958.0	963.5	969.1	974.6	980.2	985.8	991.5
17	952.3	957.8	963.4	969.0	974.5	980.1	985.7	991.3
18	952.2	957.7	963.3	968.8	974.4	980.0	985.6	991.2
19	952.0	957.6	963.1	968.7	974.3	979.9	985.5	991.1
20	951.9	957.5	963.0	968.6	974.2	979.8	985.4	991.0
22	951.7	957.2	962.8	968.3	973.9	979.5	985.2	990.8
24	951.4	957.0	962.5	968.1	973.7	979.3	984.9	990.6
26	951.1	956.7	962.3	967.9	973.5	971.1	984.7	990.4
28	950.9	956.4	962.0	967.6	973.2	978.9	984.5	990.1
30	950.6	956.2	961.8	967.4	973.0	978.6	984.3	989.9
35	950.0	955.6	961.2	966.8	972.4	978.0	983.7	989.4
40	949.3	954.9	960.5	966.2	971.8	877.5	983.1	988.8
45	948.7	954.3	959.9	965.6	971.2	976.9	982.6	988.3
50	948.0	953.7	959.3	965.0	970.6	976.3	982.0	987.7
60	946.7	952.4	958.1	963.8	969.5	975.2	980.9	986.6
70	945.4	951.1	956.9	962.6	968.3	974.0	979.8	985.5
80	944.2	949.9	955.6	961.4	967.1	972.9	978.7	984.5
90	942.9	948.6	954.4	960.2	966.0	971.8	977.6	983.4
100	941.6	947.4	953.2	959.0	964.8	970.6	976.5	982.3
110	940.3	946.1	952.0	957.8	963.6	969.5	975.3	981.2
120	939.0	944.9	950.7	956.6	962.5	968.4	974.2	980.1

(Condt.)

130	937.7	943.6	949.5	955.4	961.3	967.2	973.1	979.0
140	936.4	942.4	948.3	954.2	960.2	966.1	972.0	978.0
150	935.1	941.1	947.1	953.0	959.0	965.0	970.9	976.9
160	933.9	939.9	945.9	951.9	957.9	963.8	969.8	975.8
180	931.3	937.4	943.4	949.5	955.5	961.6	967.6	973.7
200	928.7	934.9	941.0	947.1	953.2	959.3	965.5	971.6
220	926.1	932.4	938.6	944.8	950.9	957.1	963.3	969.4
250	922.3	928.6	934.9	941.2	947.5	953.7	960.0	966.2
300	915.8	922.3	928.8	935.3	941.7	948.2	954.6	961.0
350	909.3	916.0	922.7	929.4	936.0	942.6	949.2	955.7
400	902.8	909.7	916.6	923.4	930.3	937.0	943.7	950.4
450	896.2	903.4	910.5	917.5	924.5	931.4	938.3	945.2
500	889.6	897.0	904.3	911.6	918.7	925.9	933.0	940.0

Table 68 F : Specific Volume of Superheated Steam and Water, m^3/kg

| P | Temperature, °C | | | | | | | | | | |
ata	240	260	280	300	320	340	360	380	400	420	440
1	2.406	2.501	2.596	2.690	2.785	2.880	2.974	3.069	3.163	3.258	3.352
2	1.198	1.246	1.294	1.342	1.390	1.437	1.485	1.532	1.580	1.627	1.674
3	0.796	0.828	0.860	0.892	0.924	0.956	0.988	1.020	1.052	1.033	1.115
4	0.595	0.619	0.643	0.668	0.692	0.716	0.740	0.764	0.788	0.812	0.835
5	0.474	0.494	0.513	0.533	0.552	0.572	0.591	0.610	0.629	0.648	0.668
6	0.393	0.410	0.426	0.443	0.459	0.475	0.492	0.508	0.524	0.540	0.556
7	0.336	0.350	0.364	0.379	0.393	0.407	0.421	0.434	0.448	0.462	0.476
8	0.293	0.305	0.318	0.330	0.343	0.355	0.367	0.380	0.392	0.404	0.416
9	0.259	0.271	0.282	0.293	0.304	0.315	0.326	0.337	0.348	0.359	0.369
10	0.232	0.243	0.253	0.263	0.273	0.283	0.293	0.303	0.313	0.322	0.332
12	0.192	0.201	0.209	0.218	0.227	0.235	0.243	0.252	0.260	0.268	0.276
14	0.163	0.171	0.178	0.186	0.193	0.201	0.208	0.215	0.222	0.229	0.236
16	0.141	0.148	0.155	0.162	0.168	0.175	0.181	0.187	0.194	0.200	0.206
18	0.125	0.131	0.137	0.143	0.149	0.155	0.160	0.166	0.172	0.177	0.183
20	0.111	0.117	0.123	0.128	0.133	0.139	0.144	0.149	0.154	0.159	0.164
22	0.100	0.105	0.111	0.116	0.121	0.126	0.130	0.135	0.140	0.144	0.149
24	0.091	0.096	0.101	0.106	0.110	0.115	0.119	0.123	0.128	0.132	0.136
26	0.083	0.088	0.092	0.097	0.101	0.105	0.110	0.114	0.118	0.122	0.126
28	0.076	0.081	0.085	0.089	0.093	0.097	0.101	0.105	0.109	0.113	0.116
30	0.070	0.075	0.079	0.083	0.087	0.091	0.094	0.098	0.101	0.105	0.108
35	0.001	0.062	0.066	0.070	0.073	0.077	0.080	0.083	0.036	0.089	0.092
40	0.001	0.053	0.057	0.060	0.063	0.066	0.069	0.072	0.075	0.078	0.080
45	0.001	0.046	0.049	0.053	0.056	0.058	0.061	0.064	0.066	0.069	0.071

(Condt.)

50	0.001	0.001	0.043	0.046	0.049	0.052	0.054	0.057	0.059	0.061	0.063
60	0.001	0.001	0.034	0.037	0.040	0.042	0.044	0.046	0.048	0.050	0.052
70	0.001	0.001	0.001	0.030	0.033	0.035	0.037	0.039	0.041	0.043	0.044
80	0.001	0.001	0.001	0.025	0.028	0.030	0.032	0.033	0.035	0.037	0.038
90	0.001	0.001	0.001	0.001	0.023	0.026	0.027	0.029	0.031	0.032	0.034
100	0.001	0.001	0.001	0.001	0.020	0.022	0.024	0.026	0.027	0.028	0.030
110	0.001	0.001	0.001	0.001	0.017	0.019	0.021	0.023	0.024	0.025	0.027
120	0.001	0.001	0.001	0.001	0.001	0.017	0.019	0.020	0.022	0.023	0.024
130	0.001	0.001	0.001	0.001	0.001	0.015	0.017	0.018	0.020	0.021	0.022
140	0.001	0.001	0.001	0.001	0.001	0.013	0.015	0.016	0.018	0.019	0.020
150	0.001	0.001	0.001	0.001	0.001	0.002	0.013	0.015	0.016	0.017	0.018
160	0.001	0.001	0.001	0.001	0.001	0.002	0.012	0.013	0.015	0.016	0.017
180	0.001	0.001	0.001	0.001	0.001	0.002	0.009	0.011	0.012	0.013	0.015
200	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.009	0.010	0.012	0.013
220	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.007	0.009	0.010	0.011
250	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.006	0.008	0.009
300	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.005	0.007
350	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.005
400	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.003
450	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.003
500	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002

Table 69 : Proximate Analysis of Bituminous Coals
(various countries)

Fuel	Net Calorific Value kcal/kg	Ash %	Water %	Volatile Matter %	CO_2 Max. %
Bituminous Coals:					
Aachen					
Dry steam coal (nuts)	7580	6.0	4.0	10–13	19.25
Medium volatile coal					
(nuts)	7530	6.0	4.0	24–30	19.1
Lower Silesia					
Medium volatile coal	7000	5–7	2–8	25–33	18.7
Lower Saxony					
Dry steam coal	6500–7000	5–10	5–9	6–12	19.25
Low volatile coal	6900–7200	8–11	4–8	12–19	18.9
Medium volatile coal	6600	11–15	1–3	28–31	17.95

(Condt.)

Upper Bavaria					
Sub-bituminous coal	5370	11.0	10.0	35–40	18.25
Upper Silesia					
Gas and open-burning coal	6800–7100	4–9	3–7	30–35	18.8
Ruhr					
Gas and open-burning coal	7000–7600	4–6	2–5	30–36	18.65
Medium volatile coal	7500–7900	4–7	2–5	22–30	18.75
Low volatile coal	7500–7900	3–7	2–6	13–17	19.25
Dry steam coal	7100–7400	7–9	2–7	10–15	19.25
Saxony					
Gas and open-burning coal	6700	5–6	8	30–36	18.6
Saar					
Gas and open burning coal	7000	3–7	3–5	38	18.9
Belgium					
Low volatile coal	7600	5–7	4–6	14–18	18.85
Dry steam coal	7500	7–9	3–6	8–10	19.15
China					
Chihli Kaiping	7423	13.3	0.6	26	
Chihli Penchihu	7508	11.2	0.7	24	19.1
Great Britain					
Cumberland	7400–7600	5.5–8.0	2.5–3.5	30–36	
Derbyshire	6500–7500	2.0–7.0	4.5–12	31–39	
Durham	6700–7600	3.0–10.0	2–8	25–35	18.55
Midland	6700–7600	3–7	2–10	31–37	
North Wales (Ruabon					
seven–feet)	7770	2.9	3.7	35.5	
South Wales (Cardiff)	7500–8000	3–8	1–3	15–25	

Source : Borsig pocket book 3rd edn. 1970

Table 70 : Detail of Solid Fuels (based on german coals)

Fuel (Commercial Designation)	Coke (not L.T. coke)	Bituminous Coal							Brown Coal or Lignite		Peat	Wood
		An-thra-cite	Dry Steam Coal (Semian-thracite)	Low volatile Steam Coal	Medium Volatile or Coking Coal	Gas Coal	Open-burning Gas Coal	Sintering, Cannel and Subbituminous Coals	Glance Brown Coal	Earthy Brown Coal		
Volatile Matter %	1–4	6–8	8–13	13–19	19–30	30–35	35–40	36–50	40–50	50–60	60–70	70–85
Carbon content %	95–97	92–24	90–93	87–92	84–90	82–88	78–86	74–82	70–76	62–70	55–65	40–50
Hydrogen content%	0.4–1	3.8	4.3	4.3–4.7	4.7–5.4	5.4	5.4–5.8	5.6–6.0	5.7–6.5	6–6.7	6	5.5
Net calorific value kcal/kg	7950	8300	8400	8450	8350	8100	7900	7400–7800	6400–6800	6000–6400	5400–6000	4300–5300
CO_2 content max.%	19.4–20.7	19.1	18.9	18.8	18.6	18.5	18.5	18.6	19.0	19.5	20.0–20.5	20.6
Water content %	1	3–5	5–6	2–7			7–9	9–18	20–40	40–60	25–75	15–50
Ash content %	5–10			6	6–7		7	6–7	5–6	5	1–20	0–2
Net calorific value kcal/kg	7200	7800	7500	7600	7500	7400	7200	6500	4800	2200	1500–3500	2000–3800
Densty kg/m³	700–900	1350	1280	1275		1270		1240	1220	1150–1200	600–900	400–950
Mean spec. heat of dry coal between 0 and 100°C, kcal/kg °C	0.201	0.26	0.267	0.28	0.29	0.302	0.312	0.34	0.45	0.68–0.76	0.45	0.33–0.65
Thermal conductivity at 30 °C, kcal/m h °C	0.62	0.2	0.18	0.17	0.18	0.19	0.20	0.22	0.25	0.3	0.07	0.14–0.3

Clean Coal

Raw Coal

Flame when burnt on grate	Small flames Non–luminous Soot–free	Short flames Slight soot	Medium long Luminous Heavy soot	Long flames Dull slight soot		
					None (Bohe–mia)	Central Ger–many, Rhine–land	North German plain, South Germany
Principal source in Germany	Ruhr	Ruhr, Lower Saxony	Ruhr, Lower Silesia	Ruhr, Silesia		

Source : Borsig pocket book 3rd edn. 1970

Table 71: Distillation of Coke oven tar (HTC) to med. soft pitch

Sl. No.	Name of Fractions	Boiling range °C	Wt% of crude tar
1.	Crude benzol/light oil	99–160	0.6
2.	Naphtha	168–196	2.9
3.	Naphthalene oil	198–230	14.6
4.	Wash oil or Benzole absorbing oil or Light creosote oil	224–286	2.8
5.	Anthracene oil and Heavy creosote oil	247–355	8
6.	Heavy oil	323–372	9.5
7.	Residue (medium soft pitch)	–	56.6
8.	Liquor and losses	–	5

N.B. Low temperature carbonisation of coal (600–800°C) yields more tar (75–135 lit/te)

Table 72 : Densities of Bituminous substances

	kg/m^3
Coal	1300–1500
Foundry Coke	1600–1900
Anthracite	1350–1400
Lignite	1200–1300
Raw coal	700–900
Heavy charcoal	330–500
Graphite	500
Crude oil (M. E)	880–890
Pitch	1100
Coal tar	1100

Table 73 : Densities of Fuels and Grease

Fuel	kg/m^3
ATF	707–773
L.P.G	890
Naptha	718
Petrol	739.3
Kerosene	810
N.G	83
Diesel oil	850
Grease	998.4

Paraffin Wax	800.1
Residual Fuel oil	944
LSHS	949
Light Fuel Oil	920

Table 74 : Power plant energy requirement

1. About 10,000 B. T. U/Kwh or 2,500 kcl/kwh is required in steam power plant.

2. Incremental B. T. U requirement in by–product Power generation is 4,250 B. T. U/kwh.

$$\text{Equation for heat to power BTU/kwh} = \frac{3412}{\text{Boiler eff.} \times \text{Generation eff.}}$$

3. Theoretical energy required in steam Power Plant is 859 kcal/kwh.

4. Energy required in gas turbine (NG firing) generators with auxiliary boiler = 3500–3700 kcal/kwh.

Table 75 : Range of heat output in burners

Chemical process industries	=	12600 kcal/hr – 1.26 m. kcal/hr
Industrial plants	=	5.04 – 20.16 m. kcal/hr.
Petroleum refineries	=	1.008 – 15 m. kcal/hr.
Power plants	=	30.24 m. kcal/hr.

Table 76 : Energy equivalent

1 MT coal	=	7×10^6 kcal
1 Barrel of crude oil (US)	=	1.462×10^6 kcal = 0.21 MT coal
1 MT furnace oil	=	10.7×10^6 kcal = 1.53 MT coal
1 SM^3 NG	=	8.905×10^3 kcal
1 KWH (Hydropower)	=	39.7×10^3 kcal = 0.4 kg coal.
	=	0.076 gallon (US) crude oil
	=	10.4 cft NG.

Table 77 : Non I B R boilers and others

Capacity	=	600 – 800 kg/hr at atmosphere press.
Vol. of Helical Coil in boiler	=	22 lit
Hot water generation can be by wood or coal		
Flue gas exit temperature	=	230 – 250°C
Operation press. limit below 1.5 kg/cm^{2}g.		
Tubes projecting	=	2 – 3 mm
**Chimney	=	Maxm. two boilers/chimney
CO_2 in exit smoke	=	12 – 13.5%
Fuel oil consumption for oil fired boiler	=	12 – 14.5 kg steam/lit fuel oil
Refractory curing	=	48 – 60 hrs.
Soot blowing	=	at regular interval

**Oversized chimney should be avoided as it reduces draft and increases tendency to back fire.
Chimney height is specified by central pollution board limit of chimney for large boilers.

Table 78 : Light Reflection factors for paints

Colour	Reflection factor
	ρ
White	0.80
Light Grey	0.66
Primrose yellow	0.65
Pale pink	0.50
Pale blue	0.44
Light green	0.45
Medium Grey	0.42
Sky blue	0.34
Olieve green	0.21
Medium brown	0.17
Cordial red	0.19
Dark grey	0.17

N.B. Absorption factor is $1 - \rho$

Table 79 : Composition of green paste, baked for electrodes in submerged arc smelting furnace for charge chrome industry.

F. C	=	85 − 87% wt
Volatile matter	=	13 − 14
Moisture	=	1 (max)
Ash	=	0.5
Plasticity	=	20 − 30%
Solidification setting temperature	=	300°C
Solidification completion temperature	=	700°C

The green paste consisting 75% anthracite or petro. Coke and 25% tar pitch is put into C. R sheets, 1–2mm thick and 1100–2500 mm long. The outer casing melts on heat of furnace.

Continuous self Baked electrode properties

Density	=	1–4 gm/cc
True density	=	1–2 gm/cc
Porosity	=	25 − 30%
Resistivity	=	60–122 ohm/mm^2 /m (usually above 80)
Current density allowed	=	5–7 amps/cm^2

N.B. The arc initially supplies melting heat and followed by resistance heating.

Table 80 : Velocity for heat transfer media

	Velocity range	*Remarks*
Dowtherm A		Temperature 230–276°C
Dowtherm G	1.23 m/sec	
Dowtherm LF	1.88 m/sec	Temperature range 100–300°C
Dowtherm J		

Table 81 : Heat Transfer Media (HTM)

Type	*Temperature range*	*Fluid life*
Silicones (poly dimethyl siloxanes)	– 40 –376 °C	10 years
Organic dowtherm, A230 (diphenyl oxide eutectic)	230–400 °C	3–12 years
Organic dowtherm SR_1 (inhibited by MEG)	–40 – 165 °C	3–12 years

Table 82 : Pitch types and softening points

Types of Pitch	*Softening Point*
Refined or base tar	Below 50°C
Soft pitch	50 – 60°C
Medium soft pitch	60 – 75°C
Medium hard pitch	75 – 110°C
Hard pitch	above 110°C.

1. Electrode binder pitch usually contains 8–10% quinoline insoluble matter and 30–35% toluene insoluble matter.

2. Pitch is a complex hetrogeneous mix of H resins (2.8 –14.4%) vol and M resins (3.8 – 28.2%) vol.

3. Modern trend is to use tar–bitumen mixer as binder. BS 1964 mentions type A–surface dressing tar and type B for tar macadam.

4. For road construction, hot blown bitumen at 60–78 °C is used. Molten bitumen is blown with hot air at 50–60°C to remove volatile matters.

Table 83 : Chromite ore analysis for charge chrome

$$Cr_2O_3 \quad\quad = \quad 40 - 48\% \text{ wt}$$
$$Feo \text{ and } Fe_2O_3 \quad = \quad 15 - 21$$
$$SiO_2 \quad\quad = \quad 3 - 5$$
$$Al_2O_3 \quad\quad = \quad 14 - 17$$
$$MgO \quad\quad = \quad 9 - 12$$
$$Cao \quad\quad = \quad 0.3 - 2.9$$
$$P_2O_5 \quad\quad = \quad 0.023$$
$$L \ O \ I \quad\quad = \quad 3$$
$$\frac{Cr}{Fe} \text{ ratio} \quad = \quad 1.8 - 2.0$$

Table 84 : Analysis of quartzite

SiO_2	=	98% wt (min)
Al_2O_3	=	0.5 − 1.5 (max)
Fe_2O_3	=	0.5 − 1.5 (max)
Phosphorus as P_2O_5	=	0.005 (max)
MgO	=	0.2 − 0.5

N.B. quartzite is available in different grades suitable for refractory, ceramic and Pottery, fluxes and other uses.

Table 85 : Analysis of alloying material–Ferrochrome

Chromium	=	60 − 67%
Carbon	=	0.05 (max)
Phosphorous	=	0.05 (max)
Manganese	=	0.75 (max)
Sulphur	=	0.04 (max)
Aluminium	=	0.1% (max)

Size = 50 − 125 mm. with $\pm$ 10% over size upto 150mm

Also 10–30 mm size (over size = 40 mm)

Table 86 : Hardness scale for minerals

	Moh scale
Talc	1
Rocksalt or gypsum	2
Calcite	3
Flourite	4
Apatite	5
Feldspas	6
Quartz	7
Topaz	8
Corrundum	9
Diamond	10

P.S. Greater is the no, higher the hardness.

Table 87 : Analysis of magnesite

MgO	=	45 − 48% wt.
SiO_2	=	3 − 5
CaO	=	0.8 − 1.4
Fe_2O_3	=	1 − 3
Al_2O_3	=	1 − 2
L. O. I	=	47 − 49

Table 88 : Limestone Analysis

CaO	=	48 – 54% wt
MgO	=	1 – 3
SiO_2	=	2 – 6
Al_2O_3 + Fe_2O_3	=	1 – 3
Total insoluble	=	4 – 7
L.O.I.	=	40 – 44
Size	=	20 – 60 mm

Table 89 : Dolomite Analysis

CaO	=	22 – 25% wt
MgO	=	18 – 20.5
SiO_2	=	4 – 6
Al_2O_3	=	1 – 2
Phosphorous	=	0.02
Sulphur	=	0.05
Type	=	amorphous

Table 90 : Analysis of bentonite

Na	=	1.7 – 1.9% wt
K	=	0.09 – 0.11
Fe	=	7.6 – 7.9
Al_2O_3	=	18.5 – 20
CaO	=	1.5 – 1.70
TiO_2	=	1.2
SiO_2	=	53 – 56
L.O.I.	=	7 – 8

N.B. The above is for pelletisation

Table 91 : Analysis of Porcessed Bauxite

Al_2O_3	=	50 – 68% wt
Fe_2O_3	=	3.0 (max)
TiO_2	=	2 – 4 (max)
SiO_2	=	3 – 4
CaO	=	1 (max)
MgO	=	1 – 2

Table 92 : Analysis of Kiselghur

SiO_2	=	73 – 88%
Al_2O_3	=	2.4 – 9
Fe_2O_3	=	0.9 – 3
CaO	=	0.87 – 3.5
MgO	=	0.28 – 1.21
Organic matter and combined water	=	4.8 – 7.7

Table 93 : Physical data of Hydrogen

Density at STP	=	0.084 kg/m^3
Heat of vaporisation of liq H_2	=	445.6 joules/gm
Lower heating value	=	28547 Kcal/kg.
Higher heating value	=	33875 kcal/kg
Conductivity at STP	=	1.897 mW cm^{-1} K^{-1}
Flammability limits, lower	=	4% (vol) in air
Flammbility limits, higher	=	75% (vol) in air
Detonability limits in air :		
Lower	=	18.3% (vol)
Higher	=	59% (vol)
Limiting O_2 index	=	5% (vol)
Auto ignition temperature in air	=	858°K
Min. energy for ignition in air	=	0.02 mj
Flame temperature in air	=	2318°k
Maxm. burning velocity in air at STP	=	3.46 m/s
Detonation velocity in air at STP	=	2–15 km/s
Energy of explosion	=	2.02 gm TNT equiv/m^3 (STP)

Table 94 : Electrolysis of water for pure H_2 through H_2 Cell

Eth	=	Theoretical min. decomposition potential at std conditions = 1.48v
A$_c$	=	Actual cell voltage
E$_2$	=	Anodic over voltage
E$_3$	=	Cathodic over voltage
E$_4$	=	Voltage drop due to resistance of electrolyte in H_2 cell.
Electrolyte in cell	=	pure water with 26–30% NaoH or KoH
Combination of E$_2$ + E$_3$	=	0.37v to 0.57v.
A$_c$ = 1.48 + 0.37	=	1.85v.
Cell current density	=	2 – 3 KA/m^2
Specific Power consumption	=	4–5 kwh/m^3 at STP
H_2 gas purity at cathode	=	99.8% H_2 (vol)
O_2 gas purity at anode	=	99.6% O_2 (vol)

N.B. 1. H_2–cell of std manufacture is to be used.

2. Process suitable when power cost is lower

3. H_2 generated can be used for H_2 Plasma generation:

$$H_2 \xrightarrow[500°K]{\text{dissociation}} 2 H^+ \text{ H.T (3000–3500 °K)}$$

Use: Oxy–hydrogen welding torches.

Table 95 : Hydrogen Burner

Special design feature must be included in hydrogen burner due to differences in combustion properties, flame speed, flame stability, density and heating values than the conventional gas (e.g NG) burners. The geometry of H_2 burners, are therefore different. The flame speed reqd. for H_2 air mixture in 7 times higher than that of rich methane N.G due to flash back phenomenon over a wide range of such mixtures (H_2–air) . As such secondary and primary air ratio is higher.

Most recent Hydrogen burners are of H_2 – air premix burners or nozzle mix burners with high mix velocities. Flameless Pt or Palladium H_2 burners have working press. of 10 KPa.

Table 96 : Units of hardness in water

Unit of measurement for hardness of water is milli equivalent per lit (mval/l) or the calcium equivalent of the compounds. units:

1 mval/l	=	28 mg CaO/lit or 50 mg $CaCO_3$/lit
1°dH (German Hardness)	=	10 mg CaO/lit
1°eH (English Hardness)	=	14.3 mg $CaCO_3$/lit
1 ppm (American Hardness	=	1 mg $CaCO_3$/lit
1 °fH (French Hardness)	=	10 mg $CaCO_3$/lit

Therefore,

1 mval/lit	=	2.8°dH	5.0°fH	3.5°eH	50ppm
1°eH(0.286 mval)	=	0.8°dH	1.43°fH	1.0°eH	14.3 ppm
1 ppm (0.02 mval)	=	0.056°dH	0.1°fH	0.07°eH	1.0 ppm

Table 97 : W. H. O drinking water standard

pH	=	*6.5 – 8.5*
Colour index	=	15 APHA
Conductivity	=	– µs/cm
Total solid	=	– mg/1
Total hardness* (as $CaCO_3$)	=	500 mg/1
Alkalinity as $CaCO_3$	=	– mg/1
Chloride as C1$^-$	=	250 mg/1
Sulphate as $SO_4^=$	=	400 mg/1
Flouride as F$^-$	=	1.5 mg/1
COD	=	nil mg/1

(Contd.)

NO_2 as N	=	–
NO_3 as N	=	0.01 mg/1
NH_4 as N	=	nil
Total coliform		
Bacteria	=	– MPN/100 ml
Sodium as Na	=	200 mg/1
Iron as Fe	=	0.3 mg/1
Calcium as Ca	=	mg/1
Magnesium as Mg	=	– mg/1
Zinc as Zn	=	5000 µg/1
Arsenic as As	=	0.05 µg/1
Lead as Pb	=	0.05 µg/1
Copper as Cu	=	1000 µg/1
Manganese as Mn	=	50 µg/1
Potassium as K	=	2 mg/1

N.B*. Includes non carbonate hardness

US mineral water std. minerals. = > 500 ppm

EU mineral water std. minerals. = > 1000 ppm

Table 98 : Allotropic forms of iron

Pure iron   –   Alpha iron is stable below 906°C with a body centered cubic structure. It is ferromagnetic upto curie point (768°C).

Gamma iron –   This is stable between 906°C and 403°C with non–magnetic face–centered cubic structure. Occurs as + 3 oxdn. stage. Suitable for longitudinal recording on tapes and disc.

Delta iron   –   Delta iron has body centered cubic structure above 1403°C.

Iron is 4th abundant element found in nature. It has 9 isotopes. It has oxidation stages of Fe^{+2}, Fe^{+3}, Fe^{+4} and Fe^{+6}. Fe^{+3} oxide exists as hydrated form (red brown powder) with M.P of 1565°C. Hydrated iron oxides are more magnetic.

N.B. Gamma–Fe_2O_3 iron does not crystallise directly as needles because in crystal lattice process curic symmetry. Such particles can be synthesised only in a round about way as stated below:

$$Fe^{+2} + 2OH^- = Fe\,(OH)_2 \xrightarrow[O_2]{\text{Oxdn.}} FeOOH \text{ needle shaped yellow crystals.} \qquad ...(1)$$

$$2\ FeOOH \xrightarrow[250°\,C]{\text{dehydration}} Fe_2O_3 + H_2O \xrightarrow[\text{with } H_2\ 400°\,C]{\text{Reduction}} Y\ Fe_3O_4 \qquad ...(2)$$

$$Y\ Fe_3O_4 \xrightarrow[O_2]{\text{Oxidation}} Y\ Fe_2O_3 \qquad ...(3)$$

Table 99 : Characteristics of solvents used in plastics emulsions

Solvent	Mol.Wt	BP°C	Solubility parameter	H.B. index	Relative evaporation rate	Flash Point °F	Viscocity $\frac{C_p}{25°C}$ at	MAC
Acetone	58.08	56	10	5.9	1160	15	0.35	1000
Cyclohexane	84.16		8.2	2.2	720	40	1.06	300
O–dichloro benzene	147.01		10.0	3.1	15	174	1.27	50
M E K	72.10	80	9.3	5.4	572	35	0.42	200
Toluene	92.13	110.6	8.9	3.3	240	44	0.59	100
Naptha	–		7.6	2.5	275	48	–	500
Isopropyl alcohol	60.09		11.5	8.7	300	70	2.41	400
Ethyl acetate	88.10		9.1	5.2	615	45	0.44	400
Hexane	86.17		7.3	2.1	1000	–25	0.29	500
Heptane	100.2		7.4	2.2	386	25	0.47	500
Benzene	80.1							

N. B.   Other industrial organic solvents– Butyl alcohol and Ethyl acetate. Zylol (b.p 138°C), coal tar naphtha, (b.p 149–177°C), Petrol, Diesel, Benzol, Butyl acetate and Ethyl alcohal.

Table 100 : International Specifications of iron oxide

	ISO	ASTM	DIN
Black ironoxide	1248	D769	ISO1248
Red ironoxide	1248	D3721	55913T1
Yellow iron oxide	1248	D768	ISO1248
Brown iron oxide	1248	D3722	ISO1248
FeO Content	–	D3872	–

Table 100 A : Rustproof Lubricating Oil

Lube oil (light)	–	97.5 – 87%
Lard oil	–	2 – 10
Lecithin	–	0.5 – 3
	or	
White oil	–	98%
Naphthalene	–	2

Table 100 B : Percentage Excess Air Requirement in Furnaces

Type	Fuel oil firing	NG fired
Natural draft	25 – 15% (vol)	20 – 10% (vol)
Forced draft	15 – 10	10 – 5
Forced draft	10 – 5	5
(preheated air)		

Table 101 : Solvents for plastics and Synthetic rubbers

Plastics	Solvent
Polypropylene	O–chloronaphthalate
Polybutylene	Toluene
Cis 1,4 Poly butadiene	Benzene
Poly–isobutylene	Benzene, cyclohexane
Polyethyl acrylate	Acetone
Poly n–butyl methacrylate	M E K
P V C	Cyclohexane, Benzene, Tetra Hydrofuran
P V A	Ketones (low m.wt Carbolic esters)
Poly methyl methacrylate	Benzene/MEK
M M A	Xylenes
Polystyrene	Benzene/MEK/Cyclohexane
XLPE	—
PET	meta cresol, orthocresol chlorophenol
Polyacrylonitrile	Dimethyl formaldehyde
Melamine formaldehyde	—

Phenol formaldehyde	
Styrene acrylonitrile	
Poly urethane	
Polyethylene or Polythene	
P B R rubber	
A B S rubber	
S B R rubber	
Urea formaldehyde	
Nylon − 6/66	Glacial acetic acid-Formic acid
Acetal (Poly formaldehyde)	
Nitrile rubber	
Cellulose nitrate	
Ethylene Glycol terephthalate	
(Polyester satd. resin)	
Shellack	Ethyl alcohol

Table 102 : Melting Point of Pure Ceramic Oxides

		M.P.°C
Al_2O_3	=	2050
MgO	=	2800
CaO	=	2600
SiO_2	=	1780
ZrO_2	=	2700
Cr_2O_3	=	2265
FeO	=	1360
Fe_3O_4	=	1600
$MgO\ Al_2O_3$	=	2135
$2MgO\ SiO_2$	=	1890
$3MgOSiO_2$	=	1810
ZrO_2SiO_2	=	1775

Table 103 : Electrical resistivity of ceramic materials

Insulators	*E. Resistivity, Ohm–cm*
L. V. Porcelain	10^{12}–10^{14}
Stealite Porcelain	10^{14}
Mullite Porcelain	10^{13}–10^{14}
Zircon Porcelain	10^{14}
Alumina Porcelain	10^{16}–10^{14}
Cordierite Porcelain	10^{13}–10^{4}
Silica	10^{19}
Semiconductors	

Selenium Carbide	10
Boron Carbide	0.5
Ferric Carbide	10^{-2}

Table 104 : ASTM codes for refractory bricks

1. Fireclay (ASTM C27) and high Alumina (50–99%) bricks

2. Basic bricks/refractories (ASTM C455) viz chrome bricks, chrome magnesite bricks (30% Mgo) and magnesite bricks.

3. Insulating bricks or fire bricks (ASTM C 155)

4. Mullite refractories (ASTM C467). It contains Al_2O_3 = 56–79%.

5. Silica bricks, type A or B (ASTM C416)

6. Castable refractories (ASTM C401). Among other uses it is used in molten steel pouring pits.

7. Dolomite refractories (ASTM C435)

8. Zircon refractories (ASTM C545)

ASTM specification gives US Federal spec and use. The list for refractories gives softening temperature and thermal strength and stability are as per ASTM C605 and C436.

Table 105 : Explosive limits and F. P of organic chemicals and Veg. oils.

	Explosive Lower	Limits, %vol. Higher	Flash Point, °C
Benzene	1.1	7.2	–11
Glycerine			160
Ethyl alcohol	3.5	19	13
Dibutyl Phthalate	–	–	157
Butyl acetate	1.4	7.6	22
Acetone	2.1	13	–17
Ethyl acetate	2.2	11	
Toluene	1.3	7.0	4.4
Xylene	1	6.0	17
Linseed oil	–		224
Castor oil			229.4
Petro naphtha			37
(B. R = 149 – 177°C)			

Table 105 A : Swedish limits of Coliform bacteria and pesticides and herbicides in drinking water sources

Classification	Limit	Remarks
1. Ground water wells	MPN = 0/100 ml pesticides = Nil and herbicides	
2. Surface water (city or county water works–Govt	MPN = 0/100 ml Pesticides and = nil herbicides	
3. Bottled drinking water (spring water or natural water)	MPN = 0/100ml	Sand filtration and quality tested. Often carbonated to make it sparkling.
4. Surface water (Private water works)	MPN = 10 or greater Pesticides = Nil and herbicides	Not allowed by Govt

N.B. Finished drinking water is also subjected to test for heterotropic bacteria after incubation 2 (test for health reasons) which shall be less than 10/1 and 7 days incubation for esthetic and tech. reasons i.e. smell and appearance.

Cryptospora is micro fungi and other microbal organisms.

Source: Stephen Gerth of a Swedish engg. firm

Table 106 : Thermal conductivity of Refractory bricks

Type of bricks	% Porosity	Thermal conductivity $Wm^{-1}{}^{\circ}K^{-1}$	
		371°C	1000°C
Alumina bricks			
28% Al_2O_3	22	0.84	1.72
42% Al_2O_3	19	1.21	1.42
72% Al_2O_3	22	1.55	1.42
Mullite bricks	23	0.92	1.26
Silica bricks	23	1.34	1.76
Magnesium bricks	20	6.86	2.76
Zircon bricks	17	2.76	2.38
Chrome magnesite bricks	22	1.72	1.80

Table 107 : Mechanical Properties of Refractory materials

Name of bricks	Compressive Strength MPa	Flexural Strength MPa	Modus of Elasticity GPd
Solid bricks	10–25	5–10	5–20
Silica refractories	15–40	30–80	8–14
Fire Clay bricks (10-44% Al_2O_3)	10–80	5–15	20–45
Silica refractories (96-97% SiO_2)	15–40	30–80	8–14
Corundum refractories (75–90% Al_2O_3)	40–200	10–150	30–124
Zircon refractories	30–60	80–200	35–40
Stonewares	40–100	20–40	30–70
Whitewares	30–40	20–25	10–20
Elec. Porcelein	350–850	90–145	55–100
Capacitor Ceramics	30–1000	90–160	

N.B. Sulphate lye instead of mollases is used in tempering water for mixing with grounded material for refractory bricks to get good green strength.

Table 108 : Angle of repose

	Degree
Coke	35°
Bitnminous coal	50°
Anthracite coal	27°
Lignite	$27\frac{1}{2}$ to 45°
Slack coal	30 − 45°
Coal Ash	40°
Iron ore (soft)	35°
Earth (loose)	30 − 45°
Sand (dry)	32°
Sand (moist)	27°
Clay (moist)	20 − 25°
Gravel	36°
Gravel (wet)	25°
Rock lumps	38°
Cement	40°
Wheat	28°
Maize	27 − 30°
Barley	27°
Oats	28°

(Contd.)

Clay soil (dry)	40 – 50°
B. F slag	35 – 40°
powder lime (dry)	50°
Limestone	30 – 45°
Pit coal	30 – 45°
Soft coal	35 – 50°
Top soft	27 – 40°
Ballast	35 – 40°
Ores	30 – 40°
Rock salt	35 – 50°

Table 109 : Flash point (F. P) of petroleum products

Petrol or gasoline	=	– 7°C
Diesel	=	54°C – 64°C
Naphtha	=	38° to 43°C (Naphtha for thinner use = 51°C)
Kerosine	=	46° – 64°C
Fuel oil (distillate)	=	66 – 74°C
Residual fuel oil	=	115°C
White oil	=	176°C
A T F	=	38°C – 60°C

Remarks : As per Petroleum Act 1934, class A Petroleum Products have F.P. below 23°C, class B Petroleum products, F.P. ranges between 23°C to below 65°C and class C petroleum products have F.P. ranging from 65°C to below 93°C.

2. Flash point is defined as the lowest temperature at which vapour arising from oil sample will ignite momentarily or flash on appln. of flame under test condition.

Table 110 : Dry cleaning oil (Stoddard solvent) specification

F. P	=	38°C
Colour	=	Water white
90% distillation pt	=	190.5°C
Cu strip test	=	Slight decolouration
Doctor test	=	– ve

Table 111 : Properties of Gasoline (Petrol), Methanol and Ethanol

Item	Gasoline	Methanol	Ethanol
Sp. Gravity	0.70 – 0.78	0.796	0.794
Liq. density, Kg/m^3	698	781	789
Vapour pressure			
PSI, 100°F (Reid)	7 – 15	4.6	2.5
PSI, 77°F	0.3	2.31	0.85
Boiling point, °F	80 – 44	149	173

(Contd.)

Freezing point °F	–70	–144	–173
Water solubility			
H_2O in Fuel	88 ppm	–	–
Fuel in water	240 ppm	–	–
Dielectric Constant	1.8 – 2.6	32.6	24.3
Viscosity, 100°F, cSt	0.37	0.47	0.85
Specific resistivity	2×10^{16}	0.14×10^6	0.3×10^6
Molecular wt	varies	32	46.1
$\dfrac{C}{H}$ ratio	5.6 – 7.4	3.0	4.0
Fuel, vol.% of vaporised			
Stoichiometric mixture	2.1	12.3	6.5
Air/Fuel stoichiometric ratio	14.2–15.1	6.4	9.0
Lower heating value kcal/kg	10508	4782	6394
Heat of vaporisation kcal/kg	83	281	220
Flammability limit % vol. in air	1.4–7.6	6.7 – 36.0	43.19
Specific heat kcal/kg°C	0.48	0.60	0.60
Auto ignition temp, °C	232–482	470	362
Flash point, °C	– 7	11	21
Temperature °C, at which vaporisation is similar to flammable mixture	– 30	10	15
Octane rating	87 – 98	99 –101	98 – 101

N.B. All industrial grade ethanol is denatured with 5% methanol to avoid drinking.

Table 112 : Blended gasoline fuels for automobiles

1. Blends of gasoline with 10–20% methanol or ethanol are used in automobiles in some countries. In U.S.A it is called Gasohol or Arconol.

2. Volumetric fuel consumption for blended gasoline in automobiles will be higher (60% more for methanol) requiring higher capacity fuel tanks.

3. Modified carburator for fuel injection and Air/fuel ratio controller on signal from an exhaust gas analyser is reqd.

4. Alkonol is blended gasoline with 25% C_2–C4 alcohols and is having better technical advantages viz increased volatility, improved hydrocarbon solubility, more water tolerance and higher heats of combustion.

5. Emission of NOX is reduced by 30% for methanol/ethanol based gasoline.

6. Fuel grade ethanol must be 190° proof.

7. Blended gasoline with methanol can contain maximum 0.2% water.

8. Gasoline is also blended with 5% benzene and is available in Europe.

9. In India, a 5% ethanol blending with gasoline is being considered.

Table 113 : Naphtha composition Refinery

Flash point	=	38 – 43°C
Boiling range	=	149 – 177°C
Density, gm/cc	=	0.718
Sulphur	=	0.30
Hydrocarbons :		
Aliphatic vol%	=	43
Naphthenes vol%	=	46
Benzine	=	1.4
Aromatics	=	11
Toluene	=	9.3
Xylenes	=	0.5

N.B. Sulphur content varies according to sulphur in crude oil.

Table 114 : Petroleum Coke Analysis

F. C	=	79 – 92% wt
V. m	=	3.5 – 18
Ash	=	0.05 – 1.5
Sulphur	=	0.2 – 4
Moistre	=	0.1 – 5
Calorific value	=	8450 – 9000 kcal/kg

Table 115 : Mosquito spray oil

A P I gravity	=	27 – 35
F. P	=	130°F (min)
Viscosity	=	35 – 40 SSU at 100°F
10% distillation pt	=	430° – 450°F
50% distillation pt	=	510° – 558°F
90% distillation pt	=	630°F

Table 116 : Aviation Turbine Fuel (superior Kerosene) Specification

Boiling range	=	150 – 280°C
Flash point	=	38°C
Freezing point	=	– 40°C
V. Pat 38°C	=	21 KPa
Density 38°C	=	773 – 840 Kg/m^3
Paraffins	=	63% (Vol)
Cyclo Paraffins	=	18.6
Aromatics	=	18 – 25
Single C ring	=	14 – 16
Double C ring	=	1.4

More than 2 C ring	=	0.11
Sulphur	=	0.3
Lower cal. Value	=	4.8 Mj/Kg

N.B. Sulphur content depends on crude.

Table 117 : White oil Specification

Specification:

Flash point	=	176°C
Kinematic Viscosity at 21°C, cSt	=	Min. 10 Max. 35
Freezing Point (C. Cup)	=	−150°C
Pour point	=	12°C
Saponification value	=	1.0
Iodine Value	=	1.5 (max.)

White oil is manufactured from lube oils, refined with Sulphuric acid; Sulphuric acid reacts with unsaturated and aromatic hydrocarbons and refined to a high purity.

Uses : Food, cosmetics and medicinal preparations and dry cleaning of garments. Tech. grades are often used as lubricants and synthetic textile fibres lubrication during spinning. Batching oil hydraulic and recoil oils insecticide spray oils, ointment, food packaging and baking

Table 118 : Kerosene oil Specification

Flash Point	=	51.8°C
Charcoal value or smoke point per kg of oil consumed	=	20 mg
Distillation 10% point	=	420°F.
Distillation end point at	=	625°F.
Calorific Value	=	11120 − 11676 kcal/kg.
$\dfrac{C}{H}$	=	5.25
Sulphur	=	0.125
Kinamatic Viscosity	=	2.2 (min)
Ignition temperature	=	255°C
A P I degree gravity	=	35 (min)

Low% of aromatic unsaturated hydrocarbons are desirable to maintain lowest possible level of smoke during burning.

Table 119 : Smoke point of Kerosene oil

From Paraffin hydrocarbon crude	=	73 mm
From naphthaline hydrocarbon crude	=	24 mm
From aromatic hydrocarbon crude	=	7.5 mm
Formula for smoke pt.	=	0.48P + 0.32N + 0.20A where P, N and A are % of paraffins, naphthalene and aromatics in crudes processed in a refinery.

N.B. Smoke point is defined as the maxm. flame height in mm at which K, oil will burn without smoking.

Mollier (i, s)—Diagram for Steam
Graph G-9
Vapour pressure P(ata)
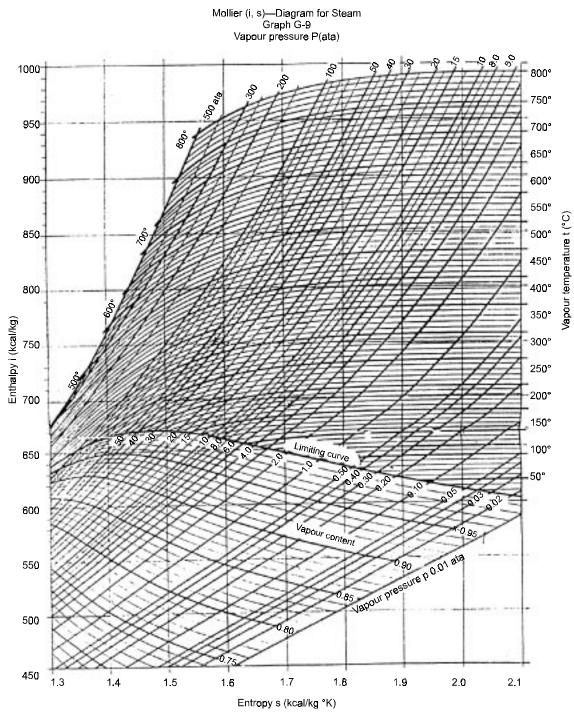
Fig. 1

Table 120 : Pyrolysis gasoline

Typical specification

API gravity/Sp. gravity	0.868
RVP (ASTM D–86 distillation) psi	
Antioxidant (amine type)	10 ppmw (max)
RONC	100
(Resarch Octane no)	
MONC	88
Induction Period	500 mins (with 10 ppm amine type oxidant)
(ASTM D525)	
Existing gums	3.5 mg/100 ml (max)
(ASTM D381)	(after heptane wash)
Sulphur	1000 ppmw (max)
(ASTM D1320)	
Dien value	1 (max)
(UOP – 326)	

Other properties : It is an excellent source of BTX.

The Pyrolysis gasoline contains 60% BTX. It also contains other unsaturates and diolifines (5%). Total aromaties C_6–C_9 is 73%. The pyrolysis gasoline is usually treated to remove dien content (by shell process or Francair de Petrole (France) process. Toluene content varies from 42–46% and ethyl benzene 25–27%. Separation process : pure Benzene, Toluene and Xylene fractions from P. G is done using Udex process (UOP. Dovv) using tetra ethylene glycol.

Table 121 : Detail Naptha Composition (Refinery)

Component	$\%\dfrac{W}{W}$
C_3 hydrocarbons	2.0
C_4 hydrocarbons	7.0
C_5 hydrocarbons	11.0
cyclo pentadiene and isoprene	4.5
branched C_6 hydrocarbons and	1.5
cyclic C_5 hydrocarbons	
methyl cyclopentane	
methyl cyclo pentadiene etc.	3.0
Benzene	32.0
Component	$\%\dfrac{W}{W}$
Cyclic C_6 hydrocarbons	1.0
1–1 dimethyl cyclopentane	.5
n–Heptane	1.5

methyl cyclohexane	1.0
Toluene	17.0
n. C_8 dimethyl cyclohexene	0.5
other C_7, C_8 and C_9 non–aromatics	1.0
ethyl benzene	1.0
m – p xylene	2.5
o – xylene	1.5
Styrene	2.5
$C_9 H_{12}$	1.5
Dicyclopentadiene	2.0
Indene	1.0
Napthalene	1.0
Other high boiling components	4.0
	100
Ref. B. C. E March'65 P 159	

Table 122 : Diesel oil Specification
(ASTM D396)
No. 2

Parameters	
Flash Point, °C	38
90% recoverable,	282°C (min)
	338°C (max)
Kinematic Viscosity, cSt at 40°C	1.9 (min)
	3.4 (max)
Reboiler bottom carbon	
residue on 10% distillation	0.35% (max)
Carbon residue (Conradson)	≤ 3.0 (max)
Sulphur, %wt	0.5 (max)
Cu strip corrosion (3hr at 50°C)	No. 3
Max. density, kg/m^3	876
Pour point °C	≤ 6
Ash % wt	≤ 0.05
Water –Do–	≤ 0.3

N.B. In addition it contains metals, Al, Na, V and Silicon.

Table 123 : Hydrogen Zeolite or Hydrogen Cation Exchanger resin specification

Capacity	=	26 kg/cft (based on 0.204 kg of salt per kg of hardness
Colour	=	light yellow or tan
Mech. eff.	=	20 – 50 %
size	=	0.4 – 0.6 mm dia
Maxm pH	=	11
Min pH	=	none
Min SiO_2, ppm	=	none
Maxm. temperature	=	120°C

This type of cation exchanger resin will also remove dissolved ferrous ion and manganous ion by ion exchange. No contact with air before or during exchanger operation. The ion exchange resin is usually styrene based.

Table 124 : Heavy and Light oil specification

		HFO	*LFO*
Density at 15°C	Kg/m^3	≤ 940	≤ 920
Kinematic Viscosity	mm^2/s		
30°C	(SI unit)	180	
50°C		125 – 180	
Kinematic viscosity			
at 40°C	cSt		2.8 – 14
Net calorific value	Mj/kg	41304	
Pour point	°C	≤ 30	≤ 6
Flashpoint (closed pensky–martens)	°C	≥ 66	≥ 60
Sulphur	w/°%	≤ 4.0	≤ 2.0
Ash	w/°%	≤ 0.1	≤ 0.05
Water	w/°%	1.0	0.3
Water before engine	w/°%	≤ 0.3	≤ 0.2
Aluminium and Silicon	ppm	≤ 5 and 10	≤ 25
Sodium	ppm	≤ 10	Nil
Vanadium	ppm	≤ 200	≤ 100
Asphaltenes	w/w%	≤ 0.38	NA
Carbon residue (Conradson)	w/w%	≤ 9.0	≤ 3.0
Total sediment potential	w/w%	≤ 0.1	≤ 0.1
CCAI number	–	≤ 870	NA

Note – HFO is also suitable for heavy D. G set. LFO falls under diesel oil category.

Table 124 A : Fuel Oil analysis

Sp. Gravity	=	0.92
Kin. Viscosity	=	1.70 centistokes (max)
Ash	=	1.0% vol (max)
Sulphur	=	4.5% wt (max)
F.P.	=	60°C
G.C.V.	=	10, 000 kcal/kg

Table 125 : Residual Fuel oil analysis

			Distillation range
F. P	=	115°C	5% at 264°C
Pour Pt.	=	− 31.6°C	90% at 490°C
Sulphur	=	0.58%	95% at 529°C
Water	=	0.1% − 0.7%	Explosive limit = 5%
Carbon residue	=	5.58%	Gross Calorific Value = 11000 kcal/kg
Ash	=	0.016	

In addition, it contains various metals in small quantities ranging from 0.05 − 0.09% (A1, Ca, Cu, Lead, Magnesium, Manganese, Nickel, Potassium, Silicon etc).

Table 126 : Types and Application of refrigerants

Refrigerant No.	Name of Refrigerant	Temp. range °C	Application
R – 717	Ammonia	–60 to +10	Med. and Large installations with reciprocating, screw and turbine compressors.
R – 11	Trichloro–monofluoro Methane	–10 to +20	Suitable both for water chillers and refrigeration with turbine compressors.
R – 13	Chloro trifluoro methane	–100 to –60	Low temp, cascade system with reciprocating compressors.
R – 12	Dichlorodifluoro methane	–40 to +20	Refrigeration systems and heat pumps with reciprocating, rotary, screw and turbine compressors.
R – 13 B_1	Bromotriflouro methane	–90 to –30	Low temp system with reciprocating compressors.
R – 22	Difluoro Monochloro methane	–70 to +20	All systems with compressors.
R – 114	Dichlorotetra fluoro-methane	–20 to +20	Heat pumps with all types of compressors.
R – 170	Ethane	–110 to –70	Low temp cascade system with turbine compressors, Vol. refrigerent effect = 1811 Kj/m^3
R – 290	Propane	–60 to –20	Large capacity refrigeration with turbine compressors. Vol. refri gerent effect = 2238 Kj/m^3
R – 1270	Propylene	–60 to –20	Large capacity refrigeration with turbine compressors. Vol. refri gerent effect = 2238 Kj/m^3
R – 1150	Ethylene	–90 to –25	Refrigeration effect = 481.3 Kj/kg
R – 744	Carbondioxide	–15 to +25	Vol. refrigeration effect = 434 $kcal/m^3$
R – 40	Methyl Chloride	–15 to +25	Vol. refrigeration effect = 307 $kcal/m^3$
R –134 a	1, 1, 1, 2 Tetrafluorine	–15 +30	Small and med. installations.

Table 127 : Secondary cooling liquids (refrigerants as per evaporation temp)

Cooling Media	Evaporating Temperature °C
Brine soln	– 15
Brine soln with $CaCl_2$	– 40
$MgCl_2$ in Brine soln	– 25
K_2CO_3 in Brine soln	– 25
Ethanol Water mix	– 20
Ethylene Glycol Water Mix	– 25
Use depends on toxicity on materials	

Table 127 A : Gelatine (Type A) specification

Gel strength	–	50 – 300
Viscosity, mpoise	–	20 – 70
Isoelectric pt.	–	7 – 9
Ash	–	0.3 – 2%
pH	–	3.8 – 5.5

N.B. Gelatine is formed by hydrolysis of collagen protein from green cattle bones into single chains and is a mixture of proteins of varying molecular wt. Pigskin gelatine gives edible gelatine.

Table 128 : Cooling Conditions required in Industry and Trade

Most suitable temperatures and ralative humidity values for cooling and airconditioning of trade and industrial premises.

Trade of Industry	Temperature °C	Relative Humidity %	Remarks*
1. Food industry and Brewing			
Bakeries			
Fresh bread storage	+ 8 to + 10	–	–
Bread (to prevent staling)	– 25 to – 30	–	–
Flour	+ 2 to + 4	–	–
Macaroni, spaghetti, etc.	+ 8 to + 10	–	–
Ready-to-sell goods	+ 6 to + 8	–	–
Breweries			
Beer storage cellars	+ 1 to + 1.5	90	ML
Beer fermenting cellars	+ 3.5 to + 6	–	St L
Beer, top-fermented, in cellar	+ 5 to + 8	–	ML
Beer in barrels for transport	+ 6 to + 8	–	ML
Draught beer in public houses, etc. (Pilsner)	10 + 6	–	–
Draught Beer in public houses, etc. (Munich)	to + 7	–	–
Yeast rooms	+ 12 to +16	–	StL
Hops stores	± 0 to – 2	75	ML
Malting floors	+ 9 to + 10	85	ML
Wort cooling, cool to	+ 5	–	–
Ice, Ice-cream			
Ice-cream hardening room	– 25 to – 30	–	–
Ice-cream storage room	– 18 to – 22	–	–

Ice-cream container	− 8 to − 12	−	−
Artificial ice-cream storage room	− 4 to − 6	−	−
Butcher's Shops See under meat-packing Plants			
Margarine Factories Stores for finished margarine	− 10	75 to 80	D

Source : Rules for Refrigeration Machines 5th edn. 1958

Cooling Conditions required in Industry and Trade (contd.)

Most suitable temperatures and relative humidity values for cooling and airconditioning in trade and industrial premises.

Trade or Industry	Temperature °C	Relative Humidity %	Remarks
Dairies			
Milk	± 0 to + 2	−	ML
Cooling room for evening milk	+ 10	−	ML
Cream ripening room	+ 14 to + 18	−	−
Butter-making room	+ 12 to + 15	−	−
Butter, short-term storage	+ 1 to + 4	75 to 80	StL
Butter, long-term storage	− 10 to − 20	80 to 85	D
Dried milk	+ 10	70 to 75	ML
Curds	+ 1	75 to 80	ML
Cheese, soft	± 0 to + 2	80 to 85	ML
Tilsit cheese	+ 2	90	ML
Emmentaler cheese	+ 10 to + 12	80 to 85	ML
Cheese-ripening room (Swiss)	+ 15	80 to 85	ML
Cheese store-room (Swiss)	+1.5 to + 4	70	ML
Bottled milk-room	+ 10 to + 12	−	−
Meat–packing Plants and Butcher's Shops			
Precooling room	+ 6 to + 8	85 to 90	StL
Rapid-cooling room	± 0 to + 1	90 to 95	vary St L
Cold-room	± 0 to + 1	85 to 90	St L
Rapid-freezing room	− 25 to − 35	90 to 95	vary St L
Frozen-meat store	−18 to − 20	90	D
Salting room	+ 6 to + 8	−	−
Cold-room for offal	± 0 to + 1	75 to 80	ML

Thawing room	+ 5 to + 8	90	ST L
Cold-room for sausages, smoked	+ 1 to + 5	80 to 85	ML
Cold-room for preserved meat, smoked ham and bacon	+ 10 to + 12	70	ML
Cold-room for salted bacon	± 0	70 to 80	ML
Cold-room for fats	+ 2 to + 4	75 to 80	M or St L
Cold-room for tinned meats	± 0 to +2	75 to 80	–
Work-room	+ 10	–	M or St L
Fish–Industry			
Cold-room, fish packing in ice	= 0 to + 1	90 to 100	–
Rapid-freezing room	– 25 to – 40	90 to 95	–
Salted fish	– 2 to + 1	85 to 95	ML
Pickled herrings	– 2 to – 4	90 to 95	–
Tinned fish	= 0 to + 1	75 to 80	–
Smoked fish	– 6 to – 8	–	D

Table 128 : Cooling Conditions required in Industry and Trade

Most suitable temperatures and relative humidity values for cooling and airconditioning in trade and industrial premises.

Trade or Industry	Temperature °C	Relative Humidity %	Remarks
Eggs			
Cold-room	– 0.5 to + 0.5	75 to 85 according to packing	StL
Cool-room	+ 6 to + 8	–	StL
Egg mixture, frozen in tins	– 18	–	–
Egg powder	± 0 to + 1	below 75	ML
Game and Poultry			
Game, frozen	– 8 to – 10	85 to 90	ML
Poultry, fresh	– 1 to + 0.5	85 to 90	ML
Freezing room	– 30 to – 35	85 to 90	–
Store-room	– 25	85 to 90	D
Chocolate, Biscuit and Sweet Factories			
Store-room for chocolate	+ 4 to + 6	–	–

Sundry			
Artificial ice-rinks, atmosphere	+ 15		
Artificial ice-rinks, ice	− 5	–	–
Mortuaries, freezing rooms	− 10 to − 15	–	–
Mortuaries, cold-room	± 0 to − 5	–	–
2.Chemical and Other Industries Pharmacies (Chemists' Shops)			
Store-rooms	+ 20 to + 27	30 to 35	–
Serum and vaccine storage	− 6 to + 8	85	in glass tubes
Dye-works and large soap laundries	+ 20 to + 24	65 to 75	–
Precision-engineering workshops and measuring apparatus	+ 20	50	–
StL =	Rapid air-change		
M L =	Moderate air-change		
D =	Dark		

Cooling Conditions required in Industry and Trade (Contd.)

Trade or Industry	Temperature °C	Relative Humidity %	Remarks
Film-Developing and Copying Businesses			
Exposure	+ 22 to + 23	30	–
Developing and fixing	+ 22 to + 23	60 to 65	–
Copying rooms	+ 20 to + 22	50 to 55	–
Drying rooms	+ 24 to + 25	50	–
Rubber Factories			
Fresh-water temperature for cooling of mills, calenders, kneading machines and sprayers	+ 2 to + 10	–	–
Refrigeration of rubber blocks, brine-bath temperature	− 15 to − 20	–	–
Air-conditioning of work-rooms	+ 22 to + 24	50 to 70	–
Processing of rubber thread to produce elastic textile articles	+ 20	55	–
Rubber-goods stores	+ 10 to + 14	65	–
Synthetic Fibre Works			
(artificial wool and rayon factories) (Viscose process)			
Preageing	+ 18 to + 25	–	StK
Ageing	+ 12 to + 18	–	ML

Sulphiding rooms	+ 20 to + 22	70	–
Rayon spinning	+ 20	80 to 90	–
Rayon twisting	+ 20	70 to 80	–
Cooling of Processing Machinery and Equipment			
Agitators and Mixers	+ 10 to + 16	–	–
Stuff grinders	+ 20 to + 25	–	–
Sulphiding drums	+ 20 to + 25	–	–
Xanthate kneaders	+ 25 to + 30	–	–
Paper Mills, Printing Works			
Binding, sizing, cutting and drying of paper	– 15 to + 23	60	–
Printing shop	– 15 to + 23	60 to 70	–
Lithographic shop	– 15 to + 24	60	–
Store-rooms	– 15 to + 20	35 to 40	–
*StL =	Rapid air-change		
StK =	No-draught cooling		
M L =	Moderate air-change		
D =	Dark		

Table 128 : Cooling Conditions required in Industry and Trade (Contd.)

Trade of Industry	Temperature °C	Relative Humidity %	Remarks
Scent and Perfume Works			
Processing rooms	Up to + 20	55 to 60	–
Raw-material stores	Approx. + 10	–	–
Bottling	Approx. + 10	–	–
Pharmaceutical and Cosmetic Works			
Work-rooms	+ 20 to + 22	65	–
Store-rooms	+ 16 to + 28	50	–
Soap Works			
Work-rooms	+ 21 to + 23	65 to 70	–
Stores and basements	+ 15 to + 19	60	–
Despatch rooms	+ 20 to + 22	60	–

Tobacco Factories			
Moistening rooms	+ 22 to + 24	92 to 93	–
Store-rooms	+ 18 to + 20	60 to 65	–
Unbaling rooms	+ 22 to + 24	80	–
Packing rooms	+ 20 to + 22	60	–
Textile Industry			
Cotton, preparation	+ 20 to + 25	50 to 60	–
Cotton, spinning	+ 20 to + 25	60 to 70	–
Cotton, weaving	+ 20 to + 25	70 to 80	–
Wool, preparation	+ 20 to + 25	65 to 70	–
Wool, spinning	+ 20 to + 25	60 to 80	–
Wool, weaving	+ 20 to + 25	60 to 80	–
Silk, spinning	+ 22 to + 25	65 to 70	–
Silk, weaving	+ 22 to + 25	60 to 80	–
Matches			
Work-rooms	+ 22 to + 23	50	–
Store-rooms	–15	50	–

Table 129 : Storage Temperature and Relative Humidity for cold storage Goods

	Temperature °C	Relative Humidity %	Air-flow*)
Fruit			
Apples, depending on variety	− 1 to + 3	90 to 95	M
Oranges	± 0 to + 2	85	M
Pineapples	+ 4	85	–
Apricots	− 1 to + 1	85	M
Bananas	+ 11.5	85	M
Pears	− 1 to + 2	90 to 95	M
Dates, Figs, fresh	− 2 to + 0	75	–
Strawberries, Raspberries	− 1 to + 1	90	M
Red currants	± 0 to + 1	90	M
Chestnuts	+ 1	85 to 90	–
Cherries	± 0 to + 1	85 to 90	M
Melons	+ 2 to + 7	80 to 85	–
Mirabelle plums	± 0	85	M
Nuts	± 0 to + 2	75 to 80	M
Grapefruit	± 0 to + 10	85	M

	Temperature °C	Relative Humidity %	Air-flow*)
Peaches	± 0	85 to 90	M
Plums	± 0 to + 2	85	M
Cranberries	+ 2 to 4	90	M
Gooseberries	± 0 to + 1	85 to 90	M
Grapes	− 0.5 to + 2	80 to 85	M
Lemons	+ 2 to + 5	80 to 85	M
Frozen fruit and fruit-juice	− 18 to − 23	−	−
Dried fruit	− 1 to + 4	70 to 75	−
Vegetables			
Artichokes	± 0	85 to 90	M
Cauliflowers	± 0 to + 2	85 to 90	M
Beans, green	+ 1 to + 7.5	85 to 90	M
Beans, dried	+ 0.7	70	−
Peas, green	± 0	80 to 90	−
Peas, dried	+ 0.5	75	−
Vegetables (contd.)	*Temperature °C*	*Relative Humidity %*	*Air-flow*)*
Mushrooms, fresh	± 0 to + 2	80 to 85	MD
Cucumbers	+ 2 to + 7	75 to 85	−
Carrots	+ 0 to + 1	80 to 95	−
Potatoes	± 3 to + 6	85 to 90	M
Cabbage	± 0 to + 1	85 to 90	M
Olives, fresh	+ 7 to + 10	85 to 90	M
Radishes	± 0 to + 1	85 to 90	−
Rhubarb	± 0 to + 1	85 to 90	M
Salad (lettuce)	± 0 to + 1	85 to 90	−
Pickled cabbage	+ 3	−	−
Celery	± 0 to −0.5	95 to 98	−
Asparagus	± 0 to + 2	85 to 90	−
Spinach	± 0 to + 1	90	−
Tomatoes, green	+ 10 to + 20	85 to 90	M
Tomatoes, ripe	+ 1 to + 5	80 to 90	M
Onions	+1.5	80	St
Tinned vegetables	+ 2 to + 4	70 to 75	−
Frozen vegetables	− 18 to − 24	−	−
Sundry Goods			
Cereals	+ 7	−	−

Honey	+ 1	75	–
Rice	+1.5	65	–
Wine	+ 10	85	–
Spirits	+ 3	–	–
Tobacco (bales)	+ 1	75	–
Tabacco Plants	+ 1	85	–
Cut flowers	+ 2	–	–
Seeds	– 2 to – 10	70	–
Furs	+ 2 to – 2	90	–
Woollen goods	+ 2 to + 5	80	–
Hides	+ 1 to + 2	95	–
Blood	– 3.9	75	–
*St = Strong air–flow			
M = Moderate air–flow			
D = Dark			

Source : Rules for Refrigeration machines 5th edn. 1958.

Table 130 : Cooling Media
Calcium Chloride Solution ($CaCl_2$)

Baume °Bé	Density kg/l 15 °C	$CaCl_2$ content, kg/100 kg solution	$CaCl_2$ content, kg/100 l water	Begins to freeze °C	Spec.Heat ± 0 °C kcal/kg deg C	Dynamic Viscosity at 0°C $\eta \cdot 10^4$ kg·s/m^2
0.1	1.00	0.1	0.1	0.0	1.003	1.81
3.0	1.02	2.5	2.6	– 1.2	0.968	1.87
7.0	1.05	5.9	6.3	– 3.0	0.915	2.02
12.0	1.09	10.5	11.7	– 6.1	0.851	2.27
13.2	1.10	11.5	13.0	– 7.1	0.836	2.34
14.4	1.11	12.6	14.4	– 8.1	0.822	2.43
16.7	1.13	14.7	15.9	– 10.2	0.795	2.61
20.0	1.16	17.8	21.7	– 14.2	0.758	2.93
22.1	1.18	19.9	24.9	– 17.4	0.737	3.18
24.1	1.20	21.9	28.0	– 21.2	0.717	3.51
26.1	1.22	23.8	31.2	– 25.7	0.700	3.89
28.0	1.24	25.7	34.6	– 31.2	0.685	4.34
29.8	1.26	27.5	37.9	– 38.6	0.671	4.90
32.3*	1.286	29.9	42.7	– 55.0	0.654	5.80

33.4	1.30	31.2	45.4	− 41.6	0.645	6.46
35.1	1.32	33.0	49.3	− 27.1	0.633	7.53
36.7	1.34	34.7	53.2	− 15.6	0.621	8.82
39.1	1.37	37.3	59.5	0.0	0.604	11.13

Table 131 : Sodium Chloride Solution (NaCl)

Bé	Density kg/l 15 °C	NaCl content, kg/100 kg solution	NaCl content, kg/100 l water	Begins to freeze °C	Spec.Heat at ± 0 °C kcal/kg deg C	Dynamic Viscosity at 0 °C $\eta \cdot 10^4$ kg·s/m²
0.1	1.00	0.1	0.1	0.0	1.001	1.80
3.0	1.02	2.9	3.0	− 1.8	0.956	1.84
7.0	1.05	7.0	7.5	− 4.4	0.914	1.91
12.0	1.09	12.3	14.0	− 8.6	0.867	2.12
13.2	1.10	13.6	15.7	− 9.8	0.857	2.19
14.4	1.11	13.9	17.5	− 11.0	0.848	2.28
15.6	1.12	16.2	19.3	− 12.2	0.839	2.37
16.7	1.13	17.5	21.2	− 13.6	0.830	2.48
17.8	1.14	18.8	23.1	− 15.1	0.822	2.61
18.9	1.15	20.0	25.0	− 16.6	0.814	2.74
20.0	1.16	21.2	26.9	− 18.2	0.806	2.88
21.6*)	1.175	23.1	30.3	− 21.2	0.794	3.10
22.1	1.18	23.7	31.3	− 17.2	0.791	3.20
23.1	1.19	24.9	33.1	− 9.5	0.784	3.36
24.4	1.203	26.3	35.7	0.0	0.776	3.57

*Eutectic

From: Rules for Refrigeration Machines, 5th Edition, 1958.

Table 132
Cooling Media
Ethylene Glykol Solutions

Density kg/l at 15°C	Glykol content kg glykol/ 100 kg solution	Begins to freeze °C	Specific Heat at		Dynamic Viscosity $\eta \cdot 10^4$ kg·s/m² at	
			± 0 °C kcal/kg	− 10 °C deg C	0°C	− 10°C
1.005	4.6	− 2	0.98	–	2.0	–
1.010	8.4	− 4	0.97	–	2.3	–
1.015	12.2	− 5	0.95	–	2.6	–

1.020	16.0	– 7	0.93	–	2.9	–
1.025	19.8	– 10	0.92	–	3.2	–
1.030	23.6	– 13	0.90	0.90	3.6	5.2
1.035	27.4	– 15	0.89	0.88	4.0	5.8
1.040	31.2	– 17	0.87	0.87	4.5	6.8
1.045	35.0	– 21	0.85	0.85	5.0	7.8
1.050	38.8	– 26	0.84	0.83	5.7	8.8
1.055	42.6	– 29	0.82	0.81	6.3	9.8
1.060	46.4	– 33	0.80	0.79	7.0	11.0

Table 133 : Methylene Chloride (CH_2Cl_2)*

Density kg/l	Temperature t °C	Specific Heat kcal/kg deg C	Dynamic Viscosity $\eta \cdot 10^4$ kg·s/m²
1.340	10	0.276	0.49
1.360	0	0.275	0.54
1.395	– 20	0.273	0.66
1.430	– 40	0.272	0.88
1.470	– 60	0.270	1.24
1.525	– 90	0.268	2.25

From: Rules for Refrigeration Machines, 5th Edition, 1958.

*Source : DKV Work Sheet 1–48, Refrigeration 15 (1963) No. 5.

Table 134 : Typical parameters of a 15MW Gas turbine (NG fired) generating set with waste heat boiler (As per ISO condition)

Rated output of generator	:	19.2 MW	15 MW	10 MW
Heat rate, kcal/KWH	:	3350	3570	4140
Thermal efficiency, %	:	25.7	24.0	20.8
Fuel consumption (NG) NM³/hr:		7200	5950	4600
(Ncv = 9001 kcal/NM³)				
Steam Prodn :				
(*a*) Without auxiliary fixing in boiler, MT/hr		42.6	34	20
(*b*) with auxiliary firing, MT/hr:		48	48	48
Steam Press :				
Steam Press at condition, a kg/cm² a		48	48	48
– do – at condition, b kg/cm²a		48	48	48
(*a*) Steam temperature at condition a, °C		380 ± 5	380 ± 5	380 ± 5

(*b*) Steam temperature at condition

b, °C   380 ± 5   380 ± 5   380 ± 5

N.G. Consumption rate

with auxiliary firing

in boiler, NM^3/hr.   400   950   1920

Utilities requirement for G T G :

Cooling water = 80 M^3/hr

Cooling water temp = 33°C

Instrument air 7 kg/cm^{2}g, amb = 150 NM^3/hr.

Table 135 : Critical humidity of fertilisers at 20°C.

		% R.H
Urea	=	80
C A N	=	–
Ammon. Sulphate	=	81
M A P	=	91.7
Ca. nitrate	=	55.4
Pot. nitrate	=	92.1
Ammon. Nitrate	=	66.9
D A P	=	
S S P	=	usually < 75%
T S P	=	
Ammon. chloride	=	79.3
N P K	=	< 75%
Nitrophosphate	=	< 75%

N.B. Critical humidity or hygroscopic point of fertilisers is defined as relative atmospheric humidity below which it will remain dry at a given temp and above which it will absorb moistre from atmosphere at the same temp.

Table 136 : Spec. of Grade B liq. ammonia

Anhydrous ammonia	=	99.5 % wt min.
Moisture	=	0.5 % wt max.
Nitrogen	=	81.9% wt min.
Oil	=	10 ppm max.

Table 137 : Urea Prills (uncoated) spec. as per Fertiliser control order 1969–70. (G O I notification May 71)

Moisture	=	1.0% (max) – wt.
Biuret	=	1.5% (max)
Total nitrogen	=	46% (min)
IS Sieve analysis	=	– 200 + 100 mesh = 80% (min)

N.B. IS std : IS 5406 – 1969

Table 138 : Tech. grade urea specification IS 1781–1971

Moisture	=	0.5% (max) – wt
Total nitrogen	=	46% (min)
Biuret	=	0.8% (max)
Free ammonia	=	100 ppm
Residue on ignition (ash)	=	0.002%
Iron as Fe	=	0.0002%
pH of 10% soln	=	7 – 9.5
Alkalinity value	=	2.0
*Buffer value	=	4.0
M. P	=	130 – 132°C

*No firm value and is subject to agreement between purchaser and seller.

Table 139 : Usual specification of Fertiliser Grade urea prills (uncoated) and Tech grade urea

	F. Grade	Tech, Grade
Total nitrogen	46.3% (min.) wt	46.4% wt
Moisture	0.3%	0.3%
Biuret	0.3%	0.2%
Free ammonia	100 ppm (max)	20
Iron	1 ppm (max)	1
Ash	20 ppm	10
Prill size	90% between 1 – 2.4mm	–

Table 140 : Temp limits of nonmetal parts in phosphoric acid manufacture

		Temp°F
Teflon	=	500
PVC	=	140
Polyethlene	=	120
Saron	=	150
Karbate	=	Boiling H_3PO_4
Soft rubber	=	150
Hard rubber and	=	160
Butyl rubber	=	160
Hary 41	=	250
Pentan	=	250
C/graphite	=	500
Duncon	=	200

Table 141 :   Conversion factors for Fertilisers

Nutrient	Multiply by	Type of fertilisers
1 kg Nitrogen	4.854	Ammon. Sulphate
	2.222	Urea
	4.0	Ammon. Chloride
	3.03	Ammon. Nitrate
1 kg P_2O_5	6.25	S S P
	–	T S P
	2.857	Di–Calcium Phosphate
	5 – O	Bone meal (raw)
1 kg K_2O	1.666	Muriate of Potash
	2.0	Potassium Sulphate

Table 142 :   Typical analysis of single super phosphate

Water   =   5.3% water of constitution,

                               2.61% water of crystallisation,

                               11% Hygroscopic water.

P_2O_5, water soluble = 18% of which 6% is present as free acid corresponding to 8.30% H_3PO_4.

P_2O_5, ammon. citrate soluble	=	0.40%
P_2O_5, insoluble	=	0.46%
CaO	=	26.6%
SO_3	=	31.30%
Al_2O_3	=	0.25%
Fe_2O_3	=	0.48%
F	=	1.10%
SiO_2	=	1.25%
MgO	=	0.14

N.B.   A high rate of water solubility to total P_2O_5 of the fertiliser is associated with high proportion of free acid in the product.

Table – 143 : Analysis of rock phosphate

Phosphorous	32.24% wt.
Iron	0.11
Alumina	0.28
CO_2	4.35
Chloride (as Cl^-)	0.07
Flouride (as F^-)	3.85
Silica	4.15
Calcium (as CaO)	50.97

SO_3	1.35
Sodium (as Na_2O)	0.48
Potassium (as K_2O)	0.40%
Colour	off white.

N.B.   1. Rock Phosphate composition varies according to country or origin (Israel, Morocco, Jordon, Egypt, U. S. A. and Rajasthan (India)

2. The analysis given above is for Israel R. P.

Table 144 : Nitrogen soln appln for Fertiliser use

Ammonia slon.	=	30% wt NH_3.
Water	=	70%
Total nitrogen	=	24.6%
Sp. Gravity	=	0.895
V.P at 40°C	=	11 PSIG.

N.B. Anhydrous liquid ammonia purity   =   99.9% wt

and oil   =   5 – 10 ppm.

Table 145 : N G consumptions in 600te/day Ammonia and 1167 te/day Urea plant complex, India.

Ammonia Plant	NG feed	NG fuel	other
Reformer	516 NM^3/te	515 NM^3/te	–
Import Steam	–	–	0.58/te
40 ata 385°C)			
Power (incl. C. T)			192 Kwh/te
Auxiliary boiler			66 NM^3/te
(105 ata, 505°C)			
Urea Plant			
NG Ammonia @ for ammonia, 0.6 te/te			633 NM^3/te
Steam, 1.66 te/te			46 NM^3/te (steam)
Power = 98 kwh/te (excl.C.T)			87 NM^3/te
			766 NM^3/te
Steam @ 1.66 te/te			
40 ata, 385°C urea steam			
Captive Power			
NG			469 NM^3/Mwh

N.B. NCV for NG feed = 10624 Kcal/ NM^3 and Fuel = 9600 NM^3/te

Table 146 : ENERGY PROFILE IN AMMONIA PLANT
Plant, size 48.6849 MMSCFD (H$_2$+CO)

ENERGY REQUIREMENT		MKCAL/MT
Feed stock NG		5.47
(N. C. V. = 10303.66 Kcal/Nm^3)		
Fuel NG		4.77
(N. C. V. = 9440.32 Kcal/Nm^3)		
P. G. As Fuel		0.162
(Credit).		
TOTAL		10.24
ENERGY BALANCE		
Product Ammonia	=	4.568*
Stack Losses	=	0.578
Colling water	=	4.853
Export steam	=	NIL
Wall Losses	=	0.241
TOTAL	=	10.24
*Theoritical requirement	=	4.46 MKcal/MT

Table 147 : Other Flocculating agents

Silica soln, 0.5% SiO$_2$

Bentonite

Kieselghur

Certain clay

Precipitated CaCO$_3$

Activated Carbon Powder

Alginates

Acrylic Polymer – solid or liq. – 1%

Table 148 : Viscosity and film thickness of inks

Printing Process	Printing ink viscosity (Poise)	Printing film thickness in micron
Lithography	50 – 500	1 – 2
Letter Process	20 – 2000	3 – 5
Flexography	0.1 – 1	6 – 8
Rotogravure	0.1 – 0.5	8 – 12
Letter set	30 – 3000	1.5 – 3
Screen	1 – 100	26 – 100

N.B. Higher viscosity inks are solid paste types.

Table 149 : Mud chemicals for oil exploration

1. Chrome lignite
2. Lignosulphonate
3. Resinated Lignite
4. Causticised Lignite
5. Sulphonated ashphalt
6. Carboxymethyl Cellulose
7. Diasclal M
8. Extreme Press. Lubricant.
9. Pregelatinised starch
10. Spooling fluid.

Table 150 : Auto ignition Temp of fuels and gases (°C)

Petrol (regular)	=	257	H_2	=	557.22
Petrol (92 octane)	=	390	H_2S	=	260
Kerosine	=	229	Co	=	664.44
Diesel Oil	=	256	NH_3	=	651
Coal gas	=	598	Methanol	=	463.88
Naptha	=	260	Acetylene	=	299.44
Lube oil	=	377	Sulphur	=	232.22
Heavy Fuel Oil	=	407	Acetone	=	537.77
Benzene	=	581	Ethylene	=	490

Table 151 : Plant air safety standards
T L V or Maxm. permissible conc.
of gases and vapours in air.

Gas	T L V (ppm)
CO	50
H_2S	10
NH_3	50
CO_2	5000
SO_2	5
NO_2	50
Cl_2	1
Chloroform	50
Pyridine	10
Toluene	200
Benzene and other Aromatic hydrocarbons	25
CS_2	20
HCL	5

HNO_3	10
N_2	3
HF	0.1
H_3PO_4	200
Methanol	2
Xylene	435 mg/NM^3
CCL_4	10
Trimethylene benzene	120 mg/NM^3

Note: 1. T L V in wt. ratio and for 8 hrs exposure limit.

2. Silica dust T L V = 5 million particles/cft.

3. TLV–abbreviated form, stand for threshhold limit value.

4. Methanol ingestion as low as 28–57 gm can cause death. Blindness is incurred from smaller Quantity. It is absorbed through skin also.

Table 152

Preservatives concentration in processed foods

Preservative	Conc in ppm
Benzoic acid and its salt (benzoate)	500 – 1000
Sulphur dioxide and sulphites	200 – 2000
Sorbic acid and sorbates	500 – 2000
Lactic acid	5000 – 30,000
4 hydroxy benzoic acid esters	500 – 1000
Thio bendazole	10 – 12
Acetic acid and acetates	200 – 600
CO_2	2000 – 3000
Nitrites	
Nitrates	50 – 100
Formic acid and formatas	3 – 6

N.B. 1. Concentration varies depending on type of processed foods.

2. Flavouring agent, MSG (mono sodium gluconate) in ppm range also used for processed foods.

Table 153 : Composition of molasses

Sugar	=	85.50%
Moistre	=	13.37
Ash	=	0.66 (Sulphated ash = 14 – 15%)
Total reducing sugar as invert sugar	=	45.5%

Table 153 A : Analysis of Lime

CaO	=	81.60% wt
MgO	=	2.7
SiO_2	=	4.36
L O I	=	10.67
Available $Ca(OH)_2$	=	85 − 86.5%
Acid insolubles	=	2.4%
MgO	=	1 − 2%

Table 154 : Smoke, flash and fire points of refined vegetable oils.

	FFA %	Smoke Point °C	Flash Point °C	Fire Point °C
Coconut oil	0.20	194	288	329
Soyabin oil	0.039	214	316	343
Rape seed oil	0.08	217	317	344

Table 155 : Empirical physical data for vegetable oils

(*i*) d^{25} = density of oil = 0.8475 + 0.0003 × Sap. value + 0.00014 × Iodine value

(*ii*) Thermal conductivity of oil, $W\ m^{-1}\ k^{-1}$ = 0.181 − 0.00025 t (where t = °C)

(*iii*) Refractive index $N_D{}^{40}$ = 1.4643 − 0.00066 × Sap. Value

$$- \frac{0.00066 \times \text{acid value}}{\text{Sap. value}}$$

(*iv*) Dielectric constant of all veg. oils = 3 − 3.2 at 25 − 30°C These oils have poor conductance of electricity.

(*v*) Heat of combustion (J/gm) = 47645 − 4.1868 × Iodine value

$$- 38.31 \times \text{Sap. value.}$$

Table 156 : Fatty acid conc. in oils, fats and milk

Buffalo milk	% saturated 63.56 (wt)	% unsaturated 36.4(wt)
Cow milk	59.5	40.5
Coconut oil	90	10
Rape seed oil	11.4	88.6
Groundnut oil	10.9	79.1
Cottonseed oil	29.3	70.7
Sunflower oil	6	94
Soyabin oil	13.9	86.1
Hydrogenated oil	95	5
Rice Bran oil	11	89
Tisi oil	10	90
Kusum oil	7.8	92

Table 157

2. Types of milk

(*i*) Toned milk – combination of animal milk, soya or ground nut protein and homogenised. Double toned milk contains more water.

(*ii*) Filled milk – It is a combination of skim milk, butter oil and whey and homogenised.

(*iii*) Synthetic milk – Made from Soyabean products, homogenised.

(*iv*) Whole milk –

Carbohydrate	=	38.9
Fats	=	27.8
Protein	=	27.8	Expressed in gm/100gm dry matter
Ash	=	5.6
Calcium	=	936
Phosphorous	=	738	Expressed in mg/100gm dry matter
Sodium	=	396
Potassium	=	1360 µgm.
Total solids	=	12.6 gm/100gm dry matter

Table 158 : Vegetable oil specification

	Sap. Value	Iodine Value	NSM %	Solidifying Temp °C	Refractive index ND^{40}
Sun flower oil	188–194	125–144	0.4 – 1.4	–16	1.466–1.468
Sesame oil	187–193	136–138	0.9 – 2.3	–6– (–3)	–
Linseed oil	188–196	170–204	1.5	10 – 21	1.475 – 1.48
Safflower oil	180–194	136–152	0.3 – 2	–13– (–)25	1.467–1.469
Soyabin oil	188–195	120–136	0.5–1.5	(–) 15 – 8	1.465–1.469
Ground nut oil	184–191	89–105		0	
Rice bran oil	183–194	92–109	3.5 – 5.0	–10	1.466–1.469

Note. NSM – Non-saponifiable matter.

Table 159 : Physical Data of common Plastics

	PVC	LDPE	HDPE	PP (with 20% talcum reinforced)	PP
Density, gm/cc M.P. °C	0.56	0.92	0.954	1.04	0.908
Thermal conductivity, w/m°K	0.16	0.35	0.50	0.44	0.22
Vicat soft. temperature °C, B/50	70–90	<40	75–70	105	105–100
Melt flow rate gm/10 min, 190/2	–	0.1–22	0.4–8	2.3	3.2
Thermal expansion (20–80°C), co-eff. K	7.8×10^{-5}	2.5×10^{-4}	2×10^{-4}	1.10×10^{-4}	1.6×10^{-4}

Tensile strength at 23°C, N/mm^2	70–110	8–10	20–30	38–42	40–60
Elongation, %	–	20	12	–	12
Flexural strength					
Hardness, Ball indexation (30 secs) N/mm^2	–	15	50	80–85	75–85

Table 160 : Density of Plastics (gm/cc) Pelletised/amorphous

Polypropylene	=	0.90 − 0.91
LDPE	=	0.92
HDPE	=	0.95 − 0.96
Polystyrene	=	1.05 − 1.06
P V C	=	1.31 − 1.38
P E T	=	1.37 − 1.38
Urea Formaldehyde	=	1.5 − 1.6
Methyl Methacrylate (MMA)	=	1.18
Poly acrylonitnile (PAN)	=	1.17 − 1.20
Styrene acrylonitrile (SAN)	=	
Acetyl Polycarbonate (APC)	=	
A B S rubber	=	1.05
S B R rubber	=	–
Polybutadiene	=	–
P V A	=	1.10 − 1.14
Polyamide (Nylon–6)	=	1.13
Polyamide (Nylon–66)	=	1.14
Melamine formaldehyde	=	1.45 − 1.55
Phenol formaldehyde	=	1.32 − 1.36
Polyesters (Terene, Dacron)	=	1.54 − 1.60
P U R	=	1.11 − 1.25
Poly Acetals	=	1.41
Celluloid (Cellulose nitrate)	=	1.38
Epoxy resin	=	1.11 − 1.4
Silicones (asbestos filled)	=	1.6 − 1.9
P T F E	=	2.2.
Phenol Formaldehyde with wood flour filler	=	1.4
Phenol Formaldehyde with mineral filler	=	1.9
Poly Carbonate	=	1.2
Poly Styrene copol with butadiene	=	1.04
PMM copol with acrylonitrile	=	1.4
PP with 20% talcum powder	=	1.04

Table 161 : Specific heat and Thermal conductivity of Plastics (Polymers)

Plastics	Specific heat at 20°C KJ/Kg°K	Thermal conductivity W/m°K
Polypropylene (PP)	1.7	0.22
Polypropylene (20% talcum)	1.04	0.44
L D P E	2.1	0.32
H D P E	1.8	0.40
Polystyrene	1.3	0.16
P V C	–	0.16
P E T	–	–
Melamine formaldehyde (MF)	1.2	–
Urea formaldehyde (UF)	–	–
Methyl methacrylate (MMA)	1.5	0.18
Styrene acrylonitrile (SAN)	–	–
Poly acrylonitrile (PAN)	–	–
Acetyl Polycarbonate (APC)	–	–
A B S rubber	1.5	0.18
S B R rubber	–	–
Polybutadiene	–	–
P V A	–	–
P T F E	1.0	0.23
Nylon – 6 (Polyamide)	1.7	0.29
Nylon – 66 (Polyamide)	1.7	0.23
Polyesters	1.2	0.6
P U R	–	–
Poly acetates	1.4	0.3
Celluloid	–	–
Epoxy resin	–	–
Silicone resin	–	–
Phenol formaldehyde	–	–
Phenol formaldehyde with wood flour	1.3	0.35
Phenol formaldehyde with mineral filter	1.0	0.70
Poly carbonate	1.2	0.21
PS with copoly butadiene	1.3	0.18
PMM copoly with acrylontrile	–	–
Urea formaldehyde with cellulose filler	1.3	0.36
Polyninyl alcohol	–	–

Table 162 : Burning Characteristics of Thermo Plastics

Plastics	Mode of burning	Burning rate cm/min
Polyethylene	melts, drips	0.8 – 3.0
Polypropylene	melts, drips	1.8 – 4
P V C	Difficult to ignite White smoke	Self extinguishing
A B S	Burns	2.5 – 5.0
S A N	Melts and chars	1 – 4.0
P S	Softens, bubbles with black smoke	1.3 – 6.3
Acrylic Plastic	Burns and drips	1.4 – 4.0
Nylons	Burns and drips and frothing	Self extinguishing
Cellulose acetate butyrate	Burns and drips	0.8 – 4.3
Cellulose acetate	Burns with yellow flame.	1.3 – 7.6
Acetal	burns with bluish flame	1.3 – 2.8
Poly butylene	burns	2.5

N.B. 1. Test methods as per ASTM D – 635 – 77

2. Flame retardant thermoplastics, during moulding stage, flame retardant chemicals are added to the charge. For LDPE, the charge is made up of 90.5% LDPE, 6% chlorinated (70% Cl_2) Paraffin and 3.5% antiomony trioxide, For Polypropylene charge formulation is 94.5% pp, 3.5% Bis –dibromo Propylether of tetra bromobisphenol A and 2% antimony trioxide. Different thermo–plastics have different charge formulation.

Table 163 : Glass transition and melting temps of thermoplastics

Thermoplastics	$T_g °C$	$T_m °C$
H D P E	−115°C	137
Polystyrene (PS)	100	240
PVC	81	212
Nylon 6	53	265
Polyester	69	265
Natural rubber (Polyisoprene)	– 73	28
P T F E	45	220
Poly propylene	65	170

N.B. 1. T_g (glass transition temp) – Lower temp limit for rubber

T_m (melting transition temp – upper temp limit for amorphors plastics viz PMMA or PS)

2. Between T_g and T_m semicrystalline Polymers tend to behave as a strong leathery materials.

3. Glass transition temp. of a material is the ability of the material to crystalize and if so it is the crystalite m.p. In case of an amorphous polymer, GTT will define whether the material is glasslike or rubber at a given temp A regular molecular structure means the material is likely to crystalize.

Table 164 : Process for Ethylene manufacture

Ethylene is usually made from petro Naphtha by steam cracking : Naphtha + steam $\dfrac{\text{Heat}}{500 - 600°C}$ steam cracking at 750–875 °C in cracking furnace having radiant type coils.

$\dfrac{\text{Formation}}{\text{of cracked gases}}$ ethylene, Benzene, Toluene, cyclohexane, cyclo pentane etc $\dfrac{\text{Cooling}}{\text{of cracked gases exit cracking furnace}}$ separation of individual products.

Process parameters – The cracking reactions are highly endothermic and naphtha/steam ratio in cracking furnace is 0.40–0.75.

$\dfrac{C}{H}$ ratio for Ethane   =   0.25 − 0.6

$\dfrac{C}{H}$ ratio for Propane   =   0.30 − 0.6

$\dfrac{C}{H}$ ratio for gas oils   =   0.60 − 1.10

Heats of formation in cracking reactions

H_2	=	0
CH_4	=	−5646.3 Kj/Kg
C_2H_6	=	−348.1
C_2H_4	=	1345.3
C_2H_2	=	8540.7

Table 165 : Physical Propertices of some plastics

	Phenol Formaldehyde	Melamine Formaldehyde	Epoxy glass film filled
Sp. gravity, gm/cc	1.37 − 1.46	1.47 − 1.52	1.6 − 2.00
Sp. heat	0.35 − 0.4	0.4	0.19
Tensile strength PSI $\times 10^{-3}$	5 − 9	5 − 13	5 − 26
Compressive strength PSI $\times 10^{-3}$	25 − 31	33 − 40	18 − 40
Flexural yield strength PSI $\times 10^{-3}$	7 − 14	9 − 16	8 − 30
Dielectric strength KV/in	200 − 400	270 − 300	300 − 400
Solvent at room temp	none	none	none

Table 166 : Data on combustible gases, fuels and organic chemicals

Item	Approx. Ignition temp °C	Flash point °C	Limits of inflammability by Volume %	
			lower	upper
1	2	3	4	5
Paraffin hydrocarbons				
Methane	632	Gas	5	15
Ethane	42	Gas	3.22	12.45
Propane	481	Gas	2.37	10.10
n-Butane	543	Gas	1.86	8.41
Isobutane		Gas	1.80	8.44
n-Pentane	275	−40	1.40	7.80
n-Hexane	284		1.25	6.90
n-Heptane	233	−4	1.0	6.0
Octane	230	13	0.84	3.20
Olefines				
Ethylene	490	Gas	2.75	28.60
Propylene	458	Gas	2.0	11.10
Butadiene	429	−	2.0	11.5
Butylene			1.98	9.65
Acetylene	305	Gas	2.50	80.0
Gases				
Carbon monoxide	−	Gas	12.5	74.2
Hydrogen	−	Gas	4.0	74.2
BF gas	−	Gas	35	73.5
Coal gas	−	Gas	5.3	33
Natural gas	−	Gas	4.3	13.5 − 15
Oil gas	−	Gas	4.75	32.5
Producer gas	−	Gas	20.70	73.7
Water gas	−	Gas	6.0	70.0
Ammonia	651	Gas	15.5	26.60
H_2S	292	−11	4.3	45.5
Petroleum Products				
Kerosine	255	46 − 64	1.40	7.5
Gasoline regular	280	−7	1.50	7.6
White oil		40		
Diesel oil	390	54 − 64	1.10	6.0

Source : Perry's Hand book 3rd edn.

1	2	3	4	5
Naphtha	232 − 277	38 − 43		
Fuel oil		66 − 74		
Residual fuel oil		115		
Organic Chemicals				
Benzene	580	−11	1.35	6.75
Toluene	552	4	1.27	6.75
O-xylene	496	17	1.0	6.0
Stryene	490	30	1.10	6.10
m-xylene	−			
p-xylene				
Naphthalene	55.9	80	0.90	−
Anthracene	422	−18	63	−
Acetone	561	−	2.55	12.80
Methanol	−	11	6.72	36.5
Ethanol	−	13–21	3.28	18.35

Example : Calculate the lower limit of inflammability of natural gas of composition.

$$CH_4 \qquad = \qquad 92\% \text{ (vol)}$$
$$C_2H_6 \qquad = \qquad 5.5\%$$
$$C_3H_8 \qquad = \qquad 2.5\%$$

Formula : $\qquad\qquad n_1/N_1 + n_2/N_2 + n_3/N_3 +... = 1 \qquad ...(1)$

Where, n = percentage volume (or mole) of each constituent in gas. N = Lower/higher limites of inflammability for each constituent as pure constituent vol% or mole%. 1, 2, 3 .... Subscript is for each constituent.

Let x = Lower limit of inflammability of the mixture

$$\text{Now, } x92/5 + x5.5/3.22 + x2.50/2.37 \text{ .... } = 1.$$
$$\text{or, } 18.4x + 1.71x + 1.05x = 1$$

$$x = \frac{1}{21.16} \times 100 = 4.72\% \text{ (vol)}.$$

Note : Higher pressure of mixture of gases increases the higher limit of imflammability. At lower limit gases burn with explosive violence and at higher limit gases burn in long flame.

Table 167 : Colour-Change Temperatures of Heat-Sensitive Dyes (Thermocolours) and Heat–Sensitive Pencils (Thermochromes)

Dye No.	Thermocolours Colour-change		At °C	Pencil No.	Thermochromes Colour-change		At °C
	From	*To*			*From*	*To*	
1	Pink	Blue	40	2815/65	Light pink	Blue	65
2	Light geen	Blue	60	2815/75	Light pink	Light blue	75

3	Yellow	Violet	110	2815/100	Pink	Ultramarine	100
4	Purple	Blue	140	2815/120	Light grey green	Light blue	120
5	White	Brown	175				
6	Green	Brown	220	2815/150	Light green	Violet	150
7	Yellow	Red–brown	290	2815/200	Blue	Black	200
8	White	Brown	340	2815/260	Dark green	Black	260
9	Violet	White	440	2815/300	Green	Olive	300
10	Pink	White	500	2815/350	Brown	Orange	350
		(via brown)		2815/450	Pink	Black	450
11	Blue	Violet	580	2815/510	Light yellow	Yellow orange	510
12	Olive green	Light green	650	2815/600	Dark blue	White	600

Manufacturers : Thermocolours – BASF Germany

Thermochromes – A. W. Faber, Germany

Source : Borsig pocket book 3rd edn 1970

Table 168 : Average Melting Temperatures of Seger Cones and temper colours of Steel

Cone No.	Melting Temp. °C	Temper Colour	Cone No.	Melting Temp. °C	Temper Colour	Cone No.	Melting Temp. °C	Temper Colour
022	600	Red	02 a	1060		19	1520	
021	650	heat	01 a	1080		20	1530	
020	670	commen-	1 a	1100		26	1580	
019	690	ces	2 a	1120	Light	27	1610	
			3 a	1140	yellow	28	1630	
			4 a	1160		29	1650	
			5 a	1180		30	1670	
018	710					31	1690	
017	730	Dark red				32	1710	Full
016	750					33	1730	white
			6 a	1200		34	1750	heat
015 a	790	Dark	7	1230		35	1770	
014 a	815	cherry–	8	1250	Yellow/	36	1790	
013 a	835	red	9	1280	White	37	1825	
			10	1300		38	1850	
						39	1880	
						40	1920	
012 a	855	Cherry-red				41	1960	

011 a	880	Cherry red				42	2000	
			11	1320				
			12	1350				
010 a	900	Light	13	1380				
09 a	920	cherry-	14	1410	White-			
08 a	940	red	15	1435	hot			
			16	1460				
			17	1480				
07 a	960							
06 a	980							
05 a	1000	Yellow						
04 a	1020		18	1500				
03 a	1040							

Source : Borsig pocket book 3rd edn 1970

Table 169 : Typical specification of domestic L P G burner

	Big burner	Small burner
Heat out put	1740 kcal/hr	1340 kcal/hr
Gas flow	151 gm/hr	117 gm/hr
Cylinder Pressure	10 kg/cm^{2}g	

Pressure at burner after regulator 0.03 kg/cm^{2}g.

Burner to conform ISI standard 4246

LPG heating value = 11523 kcal/ kg.

Table 170 : Some pigments used in paint industry

White pigment	–	TiO_2, ZnO
Black pigment	–	Carbon black, lamp black
Red pigment	–	Red iron oxide, azo red, oxy naphthonic acid, naphthol red etc.
Violet pigment	–	Carbazole, molybdate violet
Blue pigment	–	Prussion blue, chinese blue
Yellow pigment	–	Yellow iron oxide, chrome yellow, cadmium yellow, hansa yellow and benzedine yellow.
Orange pigment	–	Chrome orange, benzedine orange, dinitro aniline orange.
Green pigment	–	Chrome green, thalocyanine green, pigment green B.
Brown pigment	–	brown oxide, Van duke brown.
Metallic pigment	–	Aluminium powder (leafing and non leafing type)

N.B. Pigments can be opaque, transparent and special purpose.

Table 171 : Ingradients in synthetic detergents

It is a mixture of several ingredients as stated below:

1. Surfactants Syn. soap (anionic) viz Linear alkyl benzene sulphonate

2. Builders – Sodium silicate/Sod. carbonate.

3. Bleaching agents – Sod. perborate/organic peroxyacid salts with bleaching activator and catalysts stabilisers. Photo bleachers (zinc or Al pthalocyanine tetra sulphonate) is often used in expensive detergents.

4. Auxiliary agents –

(*a*) Enzymes – proteolytic enzymes for stain removal.

(*b*) Foam boosters – fatty acids amides (Calcium binding agent)

(*c*) Filters – Sod. sulphate.

(*d*) Whitening agents

(*e*) Fragrances.

Total Composition–
Syn. detergent = 20%, Sod. tripolyphosphate = 30%, Sod. perborate = 10%, Silicates = 10% (corrosion inhibitor), Sod. carboxymethyl cellulose = 2%, auxiliary agents = 1%, Sod. sulphate = 15% (inert filler) and water = 12%.

Table 172 : Liq. soap for hand wash (IS – 4199)

Sod dodecylbenzene sulphonate =		15%
Water	=	84
Water soluble blue colouring	=	1% or as reqd.
agent (food grade)		
Perfume (Rose or Lavender)	= as reqd.	

Table 173 : Specification of Hard Al sheets for Raschig Rings (BS – 1470 – 318)

Aluminium	=	99.5% wt (min.)
Cu	=	0.05 (max)
Si + Fe	=	0.5 (max)

Tensile strength is 13 kg/mm^2 (min)

Table 174 : Porcelain Raschig Rings specification

Compressive strength	=	2500 kg/cm^2 (min)
Tensile strength	=	300 kg/cm^2 (min)
Bending strength	=	300 kg/cm^2 (min)
Torsional strength	=	300 kg/cm^2 (min)
Modulus of elasticity	=	65 10^4 kg/cm^2 (min)
Hardness	=	7 – 8 (Moh's scale)
Sp. gravity	=	2.3
Sp. heat	=	0.23
absorption	=	0.4% (maxm)

Table 175 : Porcelain R/R composition

SiO_2	=	76.3% wt
Al_2O_3	=	16.98
Fe_2O_3	=	0.88
CaO	=	0.18
MgO	=	0.22
Na_2O_3	=	1.4
Pot. oxide	=	3.04
TiO_2	=	0.32
Ignition loss	=	0.2

Table 176 : Specification of H. P. Steam turbine condensate

Conductivity, µs/cm at 20°C for boiler circulating water	–	0.3
Conductivity, µs/cm at 20°C for boiler circulating water for once through boiler	–	0.2
Silica, mg/kg	–	0.02
Total Fe, mg/kg	–	0.02
Copper, mg/kg	–	0.003
Sodium + Potassium, mg/kg	–	0.01

Source : VGP (1962)

Table 177 : Latent heats of substances at B. P at atmospheric pressure

	B. P, °C	*Latent heat, kcal/kg*
H_2O	100	538
HCl	−84.3	99
SO_2	−10.1	95
NH_3	−33.4	327
HNO_3	86	115
CO_2	−56.6	81
CS_2	46.3	84
CH_3OH	64.7	263
Acetic acid	11.3	96.6
C_2H_5OH	78.3	204
Acetone	56.1	125
Aniline	183	104
Naphthalene	218	75.5

Table 178 : Analysis of Vermiculite

MgO	=	24 – 28 %
Al_2O_3	=	11 – 19
SiO_2	=	36 – 44
Fe_2O_3	=	4 – 8
Alkalies	=	5

N.B. Asbestos for steam pipe insulation is hydrated magnesium silicate.

Table 179 : Composition of solid, liquid and gaseous Fuels

Solid Fuels	Net Calorific Value kcal/kg	Ash %	Water %	Volatile Matter %	CO_2 max. %
Coffee husks	3300	2	15	70	
Cocoa shells	2600–3900	7–24	7–9	60–65	
Coconut shells	3500–4500	2–3	10–15	60–70	
Tannin bark (pressed)	1200–1550	1.5–4	55–60	28–36	
Fruit refuse					
Olive refuse	4300	4.4	11.4		
Oil-cake	3900–4200	5–10	7–10		
Oil-shale	2550	45–50	1–15	30–40	
Petroleum coke	8100	1.5	2.0	7.1	
Coal-tar pitch (as binder)	8500	0.2–0.5	0	55–65	
Peat, fresh	≈170	0–5	85–90	60–72	19.9
air-dry	2600–3000	1–2	37–45	38–40	19.15
compressed	3600–4300	3–12	14–17	50–60	19.8

N.B. Peat refers to decomposed vegetable.

Liquid and Gaseous Fuels

Liquid Fuels	ρ at 15°C kg/dm³	Composition %				Net cal. value kcal/kg	CO_2 max. %	Viscosity °Engler at/°C
		C	H_2	O_2	S			
Gas oil	0.85	86.64	12.88	0.22	0.26	9994	15.5	2.6/20
(Diesel oil)	0.89							
Fuel oil	0.92	86.5	12.2	1.0	0.3	9950	17.3	5/80
Pacura	0.95	87.0	11.4	1.1	0.5	9850	16.1	6/80
Mexican crude oil	0.96	83.3	10.9	2.2	3.6	9650	15.5	11/80

Lignite-tar oil	0.93	84.0	11.0	4.3	0.7	9600	16.16	2.8/20
Coal-tar oil	1.08	89.5	6.5	3.4	0.6	9000	18.06	3/20
Fuel tar	1.12	90.4	6.0	3.2	0.4	8980	18.25	

Gaseous Fuels	ρ kg/dm^3	Composition %							Net cal. value kcal/ m^3	CO_2 max. %
		CO	H_2	CH_4	$C_n H_m$	CO_2	N_2	O_2		
Coke-oven gas (Ruhr gas)	0.49	5.4	56.8	23.9	1.6	2.2	9.3	0.4	4029	10.03
Town gas (mixed gas)	0.59	21.5	51.5	17.0	2.0	4.0	4.0	–	3713	13.78
L T retort brown coal gas	1.60	13.6	5.5	11.9	11.3	4.8	2.9	0.8	3582	15.45
L T retort coal gas	0.86	3.2	23.8	46.1	14.4	4.5	5.0	0.5	7415	12.36
Water gas	0.71	40	50	0.3	–	5.0	4.7	–	2519	20.48
Producer gas	1.16	29	11	0.3	–	5.0	54.7	–	1184	20.60
Blast-furnace gas	1.29	31	2.3	2.3	–	9.0	57.4	–	1021	24.78
Natural Gas (Holland)	0.83	–	–	81.3	3.3	0.8	14.0	–	7475	11.80

Source : Borsig pocket book 3rd edn. 1970

Table 180 : Material for latent heat storage

	M.P°C	Density kg/m^3	Heat of fusion kcal/kg.
Lithium hydride	682	817	1000
Lithium nitrate	249	2402	88
NaOH	322	2130	50
FeCl$_3$	304	2899	63
CaCl$_2$	39	1650	42
Sodium metal	97	945	23

Table 181 : Material for sensible heat storage

	Spec. heat Kcal/kg°C	Density kg/m^3	Heat capacity Kcal/m^3°C
Bricks	0.2	2242	448
Magnetite (Fe$_3$O$_4$)	0.18	5125	913
Concrete	0.27	2242	609
Scrap iron	0.12	7848	946
Scrap Aluminium	0.23	2723	625
Water	1.0	993	994

Table 182 : Products from saturated Hydrocarbons

1. $C_1HC + 1100°C \rightarrow$ acetylene
2. $C_1HC + O_2 \rightarrow$ Synthesis gas
3. $C_2HC + 700 - 900°C \rightarrow$ Olefines, diolefines and aromatics.
4. C_3 and C_4HCs + catalyst $\rightarrow$ BTX aromatics.
5. C_4HC, catalyst $\rightarrow$ Olefines and diolefins dehydrogenation
6. *n*-paraffins + O_2 + $SO_2 \rightarrow$ alkane sulphonic acid
7. Cyclo paraffins + $O_2 \rightarrow$ secondary alcohols
8. $C_1HC + Cl_2 \rightarrow$ Chlorinated hydrocarbons
9. $C_1HC + O_2 + NH_3 \rightarrow$ HCN
10. $C_1HC + S \rightarrow CS_2$
11. Cyclohexane + NOCL $\rightarrow$ Caprolactum
12. *n*-paraffins + Cl_2 + $SO_2 \rightarrow$ alkane sulphonyl chlorides
13. *n*-paraffins + O_2, $\rightarrow$ Proteins nutrients and microorganism.

Table 183 : Carbon atoms in petro products and vegetable oil

St. run gasoline	=	$C_5 - C_{11}$
Kerosine	=	$C_{11} - C_{16}$
Diesel oil	=	$C_{16} - C_{18}$
Residual oil	=	$C_{17} - C_{30}$
Lube oil	=	$C_{17} - C_{20}$
Paraffin wax	=	$C_{20} - C_{30}$
Vegetable oils	=	$C_8 - C_{20}$

Table 184 : Passivation of stainless steels

A. 200/300 series S. S. containing 17% Cr or more

HNO_3 (70%)	….	6 – 15 % (Vol)
Water	….	Remainder
operating temp	….	room
Contact time	….	10 – 30 minutes.

B. S.S. containing Cr less than 17%

(free machining grade, polished surfaces)

HNO_3 (70%)	….	18% (vol)
Sod. dichromate, $2H_2O$	….	2% wt
Water	….	Remainder
Operating temp	….	room
Contact time	….	10 – 30 minutes.

C. Iron and Steel Chemical Cleaning .... 5% NaOH (wt)

Table 185 : Flushing oil specification

Specific Gravity at 15°C	….	0.9007
Colour (Union)	….	1 – ½
F.P.	….	144°C
Viscosity cSt	….	at 37.8°C = 8.982
		at 98.9°C = 2.171
Viscosity index	….	31
Pour point	….	– 40°C.

N.B. Lube oil circuit needs to be circulated with warm (60–70°C) flushing oil using 140 mesh wire mesh. Check strainer for rust.

Table 186 : Desulphurisation Iron Oxide Catalyst

Bulk density –	=	0.70 ton/m^3
(with wood shavings)		
Fe_2O_3 –	=	61.08 % (wt)
SiO_2 –	=	8.6
Al_2O_3 –	=	1.35
CaO –	=	0.9
Na_2O –	=	2.08
K_2O –	=	2.05
Ignition loss	=	23.86

Table 186 A : Nomenclature of Pressures

1. Absolute press, is the total press. exerted by a fluid.
2. Differential press, is the algebraic difference in two press.
3. Gage press. is the algebraic difference between total press and the press exerted by atmosphere. It is a special case of differential press.

$$P_g = p_a – p_s, \text{ where } p_s \text{ is atmospheric press}$$

4. Vacuum is another special case of differential press.

$$V = p_s – p_a$$

5. A negative vacuum and positive gage pressures are identical.
6. U tube manometer is used for measurement of differential press ($p_2 – p_1$); for measurement of gage press p_1 equals atmospheric press and for measurement of absolute press p_2 equals zero. In case of measurement of vacuum p_2 equals atmospheric press.

Table 187 : Particulate matter diameter ranges

Dust	=	10 microns
Dust Cloud	=	0.1 – 10 microns
Smoke	=	0.001 – 0.1 micron
Mist	=	40 – 500 microns
Oil smoke	=	0.03 – 1 micron
Fly ash	=	3 – 70 microns

Carbon black	=	0.04 − 0.2 micron
Pulverised Coal	=	10 − 400 microns
Metallurgical fumes	=	0.1 − 100 microns

N.B. 1 micron = $\dfrac{1}{1000}$ mm, Dust particles less than

10 micron in size may cause lung silicosis.

Table 188 : Pore size of filtering media

Active carbon	–	< 0.2 nm
Active coke	–	0.5 − 0.7 nm
Carbon molecular sieve	–	0.2 − 0.3 nm
Furnace black	–	10 − 25 nm
Carbon black	–	1.0 nm
Molecular sieve (Al silicate)	–	0.2 − 0.3 nm

Table 189 : Specification of exfoliated perlite

Rock perlite is solidified and ground volcanic lava

1. Chemical composition of exfolialed perlite:

SiO_2	=	62 − 73 %
Al_2O_3	=	13 − 14
MgO	=	0.3 − 0.9
CaO	=	0.9 − 2.3
FeO	=	Traces
Fe_2O_3	=	0.8 − 2.7
Na_2O	=	1.7 − 3.6
K_2O	=	2.7 − 4
TiO_2	=	0.1 − 0.5
MnO_2	=	0.1 − 0.2

2. Physical properties:
   (*i*) Compacted density = 48 − 80 kg/m^3.
   (*ii*) Freshly prepared bulk density = 35 − 45 kg/m^3.
   (*iii*) Moistre content = 0.5%
   (*iv*) Combustibility = Non-combustible.
   (*v*) Thermal conductivity = 0.0256 − 0.0258 kcal/hr/cm/°C
   (*vi*) Angle of repose = 28° − 29°
   (*vii*) Apparent mean thermal conductivity, (µw/cm/°k) = 270 − 300 µw/cm/°k
   (Based on packing density = 44 − 60 kg/m^3)
   (*viii*) Temp. range = 77 − 295°k

3. Filler gas over = air or N_2
   exfolialed perlite.
   (*i*) Filler gas press. over perlite. = 744 − 754 mm Hg

4. Sieve analysis:

B.S. mesh	% wt
+ 30	10.96
−30 + 60	29.60
−60 + 100	21.72
−100 + 200	24.57
−200 + 300	14.15

Uses: As insulating material for low temp liquid storages *e.g.,* liq. NH_3 storage tank at low pressure.

PART II
Other Information

THIS PAGE IS BLANK

CIVIL ENGINEERING INFORMATION

CODES OF CEMENT

Table 1

1.	R.H. Cement	–	Rapid hardening
2.	O P C	–	Ordinary Portland
3.	W C	–	White cement
4.	P P C	–	Portland Puzzolona
5.	P B F C	–	Portland Blast furnace
6.	O W C	–	Oil Well Treatment
7.	H P C	–	Hydrophobic
8.	B S S	–	Cement as per BS standard
9.	I S S	–	Cement as per IS standard
10.	53 Grade	–	Cement having compressive strength of 53 MPa

Table 2 : Building materials density

	kg/m^3
Portland cement	1400
Bricks – cl. I	1600
Sand	1440 – 1700
Earth (loose) dry	1200
Clay (dry)	1600
Clay (Plastic)	1760

Table 3 : Safe bearing stresses for the more commonly soils
DIN 1054 (June 1953)

Safe Bearing Stresses	kp/cm^2
Backfilled earth, not artificially compacted, depending on time since backfilling and provided that the unmade foundation layer is of greater solidity..............	0 to 1
Natural and obviously unmade earth :—	
Mud, peat, marshy soil—in general.....	0
Non-cohesive reasonably firm soils :—	

Depth of Foundations below surface	Fine to Medium Sand with a minimum foundation width of				Coarse Sand to Gravel			
	0.4 m	1 m	5 m	10 m	0.4 m	1 m	5 m	10 m
Upto 0.5 m	1.5	2.0	2.5	3.0	2.0	3.0	4	5
1 m	2.0	3.0	4	5	2.5	3.5	5	6
2 m	2.5	3.5	5	6	3.0	4.5	6	8

Intermediate values may be obtained using a straight-line ratio. In the case of strip foundations used for normal overground structures, the values shown for a 1 m foundation depth may be adopted even though the bottom of such foundations lies less than 1 m below the basement floor, provided that they are prevented from moving inwards by the normal partition walls of the cellar or by a solid cellar floor.

Cohesive soils : pasty 0   Soft .... 0.4   Semi-solid 2.0

Consistent........ 1.0   Hard 4.0

Rock containing few fissures, in a firm unweathered condition and with the strata suitably disposed (if there is major fissuring or the strata lie unsuitably, the values shown should be halved) :

Strata in a continuous sequence 15

Solid or columnar-formation rock 30

Table 4 : Combustible Building materials class
(DIN 4102)

Class of materials	Type
B	Combustible
B_1	Low inflammable
B_2	Moderately inflammable
B_3	Highly inflammable

French Equivalent std. for building materials combustibility is NF P92–505. Styrene foam surface treated with fire retardants is used in aircrafts. Such foam is called styrofoam.

Table 4A : Building construction as per earthquake resistant design – IS 13920 – 1993

1. Normal routine building design codes are for design against non earthquake effects even if RCC beams, columns and floors are used.

2. Conventional design does not ensure ductility of the structure. The ductility factor depends on proper elongation of steel rods used in the face of maxm. force exerted during an earthquake.

3. The seismic inertia forces are generated at floor levels and are transmitted through beams and columns to the ground level at foundation. The failure of columns affects the stability of the building but beam failure is a localised affair.

4. The relevant seismic design code is as per IS 13920–1993 and earthquake zone division and stipulations are as per IS–1893.

Chapter 2

MECHANICAL ENGINEERING INFORMATION

1. MATERIALS DESIGNATION SYSTEM (GERMANY) DIN 76006

1. Plain Steels (Engineering Steels)

Those steels are regarded as plain steels in which the Si content does not exceed 0.5%, the Mn content 0.8%, the Al or Ti content 0.1% and the Cu content 0.25%. Plain steels may be designated on the basis of their Tensile strength or on that of their carbon content, *e.g.,*

<center>St 37,</center>

where the figure 37 denotes the minmum TS in kp/mm2, or

<center>C 35</center>

where the letter C denotes carbon and the figure 35 the average carbon content multiplied by 100, *i.e.,* 0.35% C × 100.

If a K is added to these designations, this indicates "cold-worked", corresponding to the z ("bright drawn") formerly used. For example, C 35 K = 0.35% C, bright drawn.

2. Low-Alloy Steels

These steels are regarded as low-alloy steel in which the upper limit of the total alloy content does not exceed 5%.

The designation of a low-alloy steel consists essentially of:—

The carbon indicator,

The chemical symbols for the alloying elements in order of the quantity present.

The figure representing the percentage content of the individual alloying elements.

These figures are obtained by multiplying the individual percentage content values by 4, 10 or 100.

e.g. 24 CrMo 54

The factor 4 is used for : Cr, Co, Mn, Ni, Si, W

The factor 10 is used for : Al, Cu, Mo, Nb, Ti, V

The factor 100 is used for : C, N, P, S.

<center>140</center>

In 24 CrMo 54, for example, the meaning would be :

24 = Carbon content = 0.24% × 100,

CrMo = Chemical symbols for alloying elements, namely chromium-molybdenum,

5 = Figure relating to alloying element Cr = 1.25% Cr × 4,

4 = Figure relating to alloying element Mo = 0.4% Mo × 10.

3. High Alloy Steels

High-alloy steels are designated in the same manner as low-alloy steels, but are given as X as prefix to distinguish them from the latter. Since the alloy content values are fairly high, the multiplication factor 1 is always used. For example :—

× 10 CrNi 188 = Stainless steel containing 0.10% C, 18% Cr and 8% Ni.

4. Cast Materials

The designation of a cast material always commences with the letter G (German guss = cast).

A further letter is used, depending on the cast material, namely S for cast steel (Stahlguss), G for grey cast iron (Grauguss) and T for malleable cast iron (Temperguss).

Thus : GS = cast steel, GG = grey cast iron, GT = malleable cast iron. The figures which follow these letters denote the tensile strength in kg/mm^2 for grey cast and malleable cast iron while, for plain cast steel, they denote, in combination with the latter C, the C content (%) multiplied by 100 and, for low-alloy cast steel, they indicate the alloying elements as under Para 2.

Table 5A : Weight of Square and Round Steel Bars
Per Running Foot

Dia or Side in inch	Square lb	Round lb
1/8	.053	.042
3/16	.120	.894
1/4	.213	.167
5/16	.332	.261
3/8	.479	.376
7/16	.651	.511
1/2	.851	.658
9/16	1.08	.845
5/8	1.37	1.04
11/16	1.61	1.19
3/4	1.91	1.50
13/16	2.25	1.77
7/8	2.61	2.05
15/16	2.99	2.35
1	3.40	2.63
2	13.6	10.7

3	30.6	24.1
4	54.4	43.8
5	28.1	66.9
6	122.5	96.3

Materials Designation System – DIN 76006 (contd.)

Additional symbols indicating the type of melting, treatment state, etc. are used only where design requirements make a particular type of melting, etc., desirable.

The carbon steels contained in the present selection are in general melted as killed open-hearth steel whilst the alloy steels are melted in an electric furnace. No additional symbols are required in these cases.

M	A	St 45	.6	N
		Heart to Designation according to strength : Symbol St min. tensile strength according to composition: Symbol for carbon Carbon indicator or Carbon indicator Symbols for Alloying elements Alloy content figures or Prefix X Carbon indicator Symbols for Alloying elements Alloy content figures		

	Type of melting (Code letters)		Special Properties (Code letters)		Guaranteed Values (Code figures)		Treatment State (Code letters)
B.	Bessemer steel	A.	Resistant to ageing	.1.	Yield point	A.	Annealed
				.2.	Folding or up-setting test	B.	Treated for best machinability
E.	Electric steel	H.	Semi-killed cast	.3.	Impact value		
M.	Open-hearth steel	L.	Resistant to caustic embritt-element	.4.	.1 and .2 required	E.	Case-hardened
PP.	Puddled steel	P.	Suitable for pressure welding	.5.	.2 and .3 required	G.	Spheroidised
				.6.	.1 and .3 required		

SS. Welding steel	Q. Suitable for cold-upsetting	.7. .1, .2 and .3 required	H. Hardened
T. Thomas Steel	R. Killed cast	.8. High-temperature strength or creep limit	K. Cold-drawn
Ti. Crucible steel	S. Suitable for fusion welding	.9. Electric or magnetic properties	N. Normalised
W. Air-refined substitute steel	U. Unkilled cast		NT. Nitrided
	Z. Drawable		S. Stress relieved
			U. Untreated
			V. Hardened and tempered

Table 5B : Tylor sieve and U.S. sieve data

Sieve opening mm.	Tylor mesh No.	Dia. of Wire inch.	Equivalent U.S. Sieve No. (Approx.)
26.67	–	0.148	
22.43	–	0.135	
18.85	–	0.120	
15.85	–	0.105	
13.33	–	0.105	
11.20	–	0.092	
9.423	–		
7.925	2½	0.088	
6.68	3	0.070	
5.613	3½	0.065	–
4.699	4	0.065	4
3.962	5	0.044	5
3.327	6	0.036	6
2.794	7	0.328	7
2.362	8	0.032	8
1.981	9	0.033	10
1.651	10	0.035	12
1.397	12	0.028	14
1.168	14	0.025	16
0.991	16	0.0235	18
0.833	20	0.0172	20
0.701	24	0.0141	25
0.589	28	0.0125	30
0.425	32	0.0118	35
0.417	35	0.0122	40
0.351	42	0.0100	45
0.295	48	0.0092	50

0.246	60	0.0070	60
0.208	65	0.0072	70
0.175	80	0.0056	80
0.147	100	0.0042	100
0.124	115	0.0038	120
0.104	150	0.0026	140
0.089	170	0.0024	170
0.074	200	0.0021	200
0.061	250	0.0016	230
0.053	270	0.0016	270
0.093	325	0.0014	325
0.038	400	0.0010	–

Table 6 : Vibrating screens capacity

Material	Wire cloth	Capacity-US Tons feed/hr/ sq. ft. screening area
Coal	1/4"	5.0
Coal	1/8"	2.0
Coke	1"	1.5
Coke	1/8"	0.5
Crushed stone	3 mesh	2.5
Sand	7.16" mesh	2.0
Sugar	12 mesh	0.5
T S P	20 mesh	0.065

Note : Mesh no. is no. of openings per inch in both horizontal and vertical direction.

Table 7 : Analysis of Steel Balls material for Ball mills

Type	=	Forged and annealed
Size	=	35 mm
C	=	0.6 – 1% wt
Cr	=	0.1 – 0.6
Mn	=	0.4 – 0.9
Mo	=	0.05 – 0.2
Silicon	=	0.12 – 0.6
Phosphorus and sulphur	=	0.035 (max)
Hardness	=	731 Brinnel No.

Table 8 : Ultimate Strength of Materials in 1bs. per square inch

	Tension	Compression	Shear	Youngs Modulus	Modulus of Rigidity
Cast iron	20,000	90,000	15,000	18,000,000	6,500,000
Wrought iron	48,000	40,000	35,000	28,000,000	9,500,000
Steel casting	50,000	....	....	29,000,000	....
Mild steel	60,000	65,000	54,000	29,000,000	13,500,000
Steel	80,000	90,000	70,000	30,000,000	14,000,000
Copper, rolled	32,000	....	26,000	15,000,000	6,000,000
Brass, cast	24,000	11,000	10,000	9,500,000	4,400,000
Bronze	36,000	....	36,000	10,000,000	4,400,000
Phosphor Bronze	56,000	....	42,000	14,000,000	5,000,000
Gun metal	36,000	....	36,000	9,900,000	4,400,000
Aluminium, cast	14,000	11,500	....	9,000,000	....
Monel metal, cast	80,000	....	60,000	....	....
Hemp rope	5,380	....	....	....	....
Leather belting	4,200	....	....	....	....
Timber (along grain)	8,000	7,000	500	1,800,000	300,000
Timber (across grain)	....	....	2,150	....	....
Brick (l)	....	3,000	....	2,000,000	....
Concrete (1 : 2 : 4)	400	4,000	....	3,000,000	....
Granite	....	12,000	....	6,000,000	....

Safety factors :

(*i*)	Low tensile steels	=	50% of UTS
(*ii*)	High tensile steels	=	40–35% of UTS
(*iii*)	Non ferrous materials	=	25–39% of UTS
(*iv*)	Plastics	=	20–50% of UTS

Table 9 : Copper wire diameter

S WG	Dia (mils)	S W G	Dia (mils)
1	300	27	16.4
2	276	28	14.8
3	252	29	13.6
4	232	30	12.6
5	212	31	11.6
6	192	32	10.8
7	176	33	10
8	160	34	9.2
9	144	35	8.4

10	128	36	7.6
11	116	37	6.8
12	104	38	6.0
13	92	39	5.2
14	80	40	4.8
15	72	41	4.4
16	64	42	4.0
17	56	43	3.6
18	48	44	3.2
19	40	45	2.8
20	36	46	2.4
21	32	47	2.0
22	28	48	1.6
23	24	49	1.2
24	22	50	1.0
25	20		
26	18		

Note : 1 mil = 1/1000 of an inch.

Table 10 : Wires and Plates thickness data (in inches)

Gage No.	Brown and Sharpe (U.S.)	B.W.G.	B.G.	S.W.G.
0	0.325	0.34	0.3964	0.324
1	0.287	0.30	0.3532	0.30
2	0.258	0.284	0.3147	0.276
3	0.229	0.259	0.2804	0.252
4	0.2094	0.238	0.2500	0.232
5	0.182	0.220	0.2225	0.212
6	0.162	0.203	0.1981	0.192
7	0.144	0.180	0.1764	0.176
8	0.128	0.165	0.1570	0.16
9	0.114	0.148	0.1398	0.144
10	0.102	0.134	0.1250	0.128
11	0.091	0.120	0.1113	0.116
12	0.081	0.109	0.0091	0.104
13	0.072	0.095	0.0882	0.092
14	0.064	0.083	0.0785	0.08
15	0.057	0.072	0.0699	0.072
16	0.051	0.065	0.0625	0.064
17	0.045	0.058	0.0556	0.056

18	0.040	0.049	0.0495	0.048
19	0.036	0.042	0.0440	0.04
20	0.034	0.035	0.0392	0.036
21	0.0285	0.032	0.0349	0.032
22	0.0253	0.028	0.0313	0.028
23	0.0226	0.025	0.0278	0.024
24	0.0201	0.022	0.0248	0.022
25	0.0179	0.020	0.0220	0.020
26	0.0159	0.018	0.0196	0.018
27	0.0142	0.016	0.0175	0.0164
28	0.0126	0.014	0.0156	0.0148
29	0.0113	0.013	0.0139	0.0136
30	0.011	0.012	0.0123	0.0124
31	0.0089	0.010	0.0110	0.0116
32	0.0080	0.009	0.0098	0.0108
	upto		upto	upto
	40 gage		52 gage	50 gage
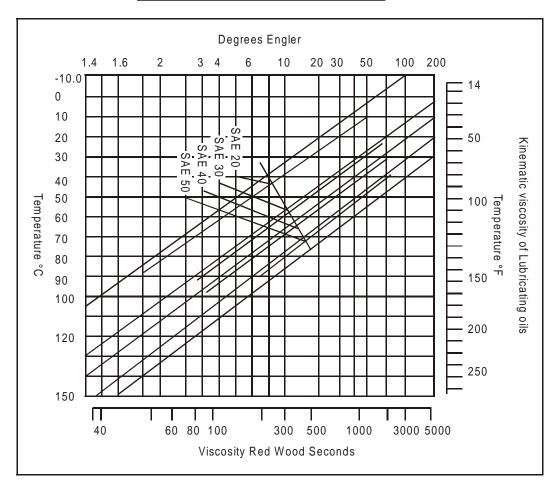
Note : 1. Brown and Sharpe is for non-ferrous wires and sheets.

2. Birmingham Wire gage (B.W.G.) is for Steel sheets and rods.

3. British gage (B.G.) is for Iron and Steel Sheets/hoops.

4. Standard Wire gage (S.W.G.) – British.

Table 11 : Weight of rolled Steel Sheets (in Lb./Ft^2)

B.W.G. No.	Weight (Lb/Ft^2)
0	13.872
1	12.24
2	11.5872
3	10.5672
4	9.7104
5	8.976
6	8.2824
7	7.344
8	6.732
9	6.0384
10	5.4672
11	4.896
12	4.4972
13	3.876
14	3.3864

15	2.9376
16	2.651
17	2.364
18	1.9992
19	1.7126
20	1.428
21	1.3056
22	1.1424
23	1.020
24	0.8976
25	0.816

Fig. 1

Source : Borsig pocket book 3rd edn. 1970

Table 12 : Lube oil specification (SAE)

Characteristics	Engine and cooling oil, all engines	Cylinder oil bore 520 mm and above
Density at 15°C	0.87 to 0.93	0.87 to 0.93
Flash pt. not below	200°C	240°C
Engler viscosity, 50°C	6–10	17–25
Pour pt. below	–14°C	–12°C
Max ash content	0.05	0.05
Max conradson residue	0.25	0.7
Water and impurities	nil	nil
Acid and alkali content	nil	nil
Neutralisation no.	0.20	0.20
Hard ashphalt-max	nil	nil
Asphalt and pitch, max	0.05%	0.05%
Viscosity index not below	80	80
Saponification no, max	0.2	0.3

Table 13 : Carbon content limit of thin walled chem. vessels

Materials		Carbon content
Carbon steel	–	0.28% (maxm.)
Low alloy steel	–	0.2% (min.)
High alloy steel	–	0.15% (maxm.)

Table 14 : Extruded brass rod composition

Cu	=	56–60% (wt)
Pb	=	1 – 1.5%
Fe	=	0.3%
Mn	=	0.75 – 1
Zinc	=	rest
Impurities	=	0.25%
(Al and Sn)		

Table 15 : Wall Thicknes Calculation of Cylindrical Shells and Domed Head subjected to Internal Pressure

Precise calculation as per AD Pamphlets B 1 and B3 (Pressure Vessels Study Group)

Applicable where D_a/D_i is <1.2 if D_a/D_i > 1.2, sec AD Pamphlet B 10.

Cylindrical shell for wall temperatures > 120°C

$$s = \frac{D_i \cdot p}{200 \frac{K}{S} \cdot v - p^*} + c_2 \qquad\qquad s = \frac{D_a \cdot p}{200 \frac{K}{S} \cdot v + p^*} + c_2$$

Domed head

$$s = \frac{D_a \cdot p \cdot \beta}{400 \cdot \dfrac{K}{S} \cdot v} + c_1 + c_2$$

D_i, D_a internal and external diameter, respectively, mm

s   wall thickness, mm

p   maximum permitted working pressure allowing for static head, atü

K   strength characteristic, kp/mm^2

S   safety coefficient in relation to yield point

v   joint efficiency of walded seam (welding factor)

> $v = 1$ for seamless sections and welded joints where a higher joint efficiency has been approved for the weld
>
> $v = 0.8$ for welded joints
>
> $v = 0.7$ for brazed lap joint seams
>
> (Maximum permitted wall thickness 5 mm)

c_1 design allowance 1 mm

c_2 wall thickness wear allowance :

> for $s \leq 30$ mm, $c_2 = 1$ mm, for $s > 30$ mm, $c_2 = 0$ mm
>
> Calculation factor for domed heads (without cutouts)

Head	H/Da	β
Dished head : $R = D_a$ $r = 0.1$ D_a	0.2	2.9
Semi-ellipsoidal head : $R = 0.8$ D_a $r = 0.15$ D_a	0.25	2.0
Hemispherical head :	0.5	1.1

H   Depth of convexity of whole head,

         including wall thickness, mm

Safety Coefficients

	Material	Cylinder with without Acceptance Cert.		Head with without Acceptance Cert.	
1.	Steel, alloy and plain	1.5	1.8	1.5	1.8
2.	Cast steel	2.0	2.5	2.0	2.5
3.	Grey cast iron, unannealed	9.0	11.0	7.0	9.0
	Grey cast iron, annealed	7.0	8.0	6.0	7.0
	Grey cast iron, enamelled	7.0	8.0	6.0	7.0
4.	Aluminium and aluminium alloys	3.5	4.0	3.5	4.0
5.	Copper and copper alloys	3.5	4.0	3.5	4.0

* With wall temperatures below 120°C, −p or + p disapears.

ELECTRICAL ENGINEERING INFORMATION

1. SAFETY CODES IN ELECTRICAL HAZARDS NEPA 70-1981

NEPA – 70–1981

American national electrical code specifies hazardous locations by class, group and division. The class defines the physical form of combustible materials mixed with air :—

Class – I	=	Combustible material in the form of gas or vapour
Class – II	=	Combustible material in the form of dust
Calls – III	=	Combustible material in the form of fibre including textile flying materials.

The class is then subdivided into the following groups :

Group A	=	Atmosphere containing acetylene.
Group B	=	Atmosphere containing H_2, gases and Vapours of equivalent hazard such as manufactured gases.
Group C	=	Atmosphere containing ethyl ether vapours, ethylene or cyclopropene.
Group D	=	Atmosphere containing gasoline, haxane, naphtha, benzene, solvent vapour or natural gas.
Group E	=	Atmosphere containing metal dust including Al, Mg and their common alloys or other metals having similarly hazardous characteristics.
Group F	=	Atmosphere containing Carbon black.
Group G	=	Atmosphere containing flour starch or grain dusts.

The divisions of above groups specifies the probability that an explosive mix is present, examines a hazardous mix is normally present in divisions area but will only accidentally be present in Division 2 areas.

Division I	Hazardous mixtures normally present
Division II	Hazardous mixtures can accidentally be present.

2. NEMA STANDARD FOR EQUIPMENT ENCLOSURES

National Electrical manufactures Association had specified the following standard for classifying electrical equipment, cables, MCC, etc. and enclosures.

NEMA – 1   :   General purpose
NEMA – 2   :   Drip tight
NEMA – 3   :   Weather Proof
NEMA – 4   :   Water tight
NEMA – 6   :   Submersible
NEMA – 7   :   Hazardous (Class I, Group A B C or D)
NEMA – 8   :   Hazardous (Class I, Group A B C or D)
NEMA – 9   :   Hazardous (Class II, Group E, F or G)
NEMA – 10 :   Explosion Proof (as per US Bureau of Mines regulation)
NEMA – 12 :   Other Industrial areas.

3. POWER SYSTEM AND SPECIAL ELECTRICAL EQUIPMENT REQUIRED FOR CHEMICAL INDUSTRY

3.1 Introduction

The source of power for industrial establishment is mainly the utilities power grid. The utilities are not guaranting quality or continuity of supply as the power distribution system is subject to various abnormal conditions like lightning, damage to the transmission lines, line faults etc., which are beyond the reasonable control of the utilities.

3.2 A.C. Power Disturbances

The disturbances in a.c. power can be classified as follows:

1. Voltage

2. Wave shape

3. Frequency

The most frequently encountered deviations occur in respect of voltage. In case of voltage, disturbances are of the following nature:

3.3 Steady state values

The minimum grid voltage often encountered is much less than the limit specified in the Indian Standad. The industrial consumer drawing power at extra high voltage often encounters the voltage as low as 85%. The consumer often faces difficulty in maintaining the steady load end voltage even after operating on-load tap changer provided on the step down transformer and switching on shunt capacitor. The condition in case of low or medium voltage consumer is much worse where there is little or no control available with consumer to improve upon the voltage. The unequal loading on polyphase lines is often the cause of the voltage unbalance in the low voltage system.

3.4 Outages and Interruptions

The outages and interruptions of overhead distribution system due to lightning and various faults are common. Though these can be reduced by proper preventive maintenance regime however cannot be altogether avoided. Besides due to demand exceeding very much of the generation, the

planned outages of power have almost become accepted condition of the power supply in India. The utilities are quite often resorting to load shedding to the industry. Power outages faced by the industry can be classified on basis of deviation as

(*i*)   Long duration (hours)

(*ii*)   Medium duration (minutes) and

(*iii*)   Short duration (secs).

Irrespective of duration, outages cause disruption of production and actual loss of outages depends on type of industry. Besides, such outages may cause safety hazards also.

3.5 Surges and Impulses

Surges are caused by

(*a*)   Fault clearances

(*b*)   Switching surges

(*c*)   Inrush current transient caused by energising electrical devices like capacitors.

Impulses are associated with lightning, electrostatic discharges etc. and duration of such surges is less than 0.001 cycles.

The frequency of a.c. supply is often less than specified –3% and in many parts of the country, it remain –4 to –5%. The frequency variation is encountered most depending upon peak load demand vis-a-vis generation available.

As it is impossible to get the ideal power quality and continuity from power supplying utility, the consumer is left with no option but to design his power system utilisation equipment in such a way that the effect on the production due to erratic power supply is contained to the minimum and safety of the plant and personnel is not jeopardized.

3.6 Types of Industrial electrical load

The industrial load can broadly be classified as under :

Motive power. The major industrial electrical load is constituted of various types of drive motors, low as well as high tension for driving pumps, compressors, conveyors, elevators etc., which constitute around 85% of the industrial load. Some of these loads are classified as critical load. Every industry, depending its process requirements, identifies certain drives as critical. The critical load constitute 5 to 10% of the total requirement in case of continuous process industry. Such critical loads can be further subdivided as follows.

(*a*)   **No Break Load.** The quality and continuity of power is required to be maintained through out the operation. Any failure will adversely affect the production as well as process equipment. These types of drives are mainly used in chemical industry.

(*b*)   **Momentary Break.** The drives which are required to be restarted immediately on restoration of alternate power supply within few seconds of total power failure for safe shutdown of the plant.

(*c*)   **Emergency Operation.** Drives like the fire fighting pumps falls under this category which are required to be put in service under emergency conditions.

Electrical Furnaces and Heaters. Depending upon the industry's requirement this type of load also can be grouped under critical and non critical load.

3.7 Process control instrumentation and data processing Equipment

The electronic equipment are very susceptible to the transients encountered in the power system like surges, impulses and noises etc. Further, wave shape may also cause malfunctioning of such electronic components. Excessively large impulses or noise burst and inadequate filtering may result in component voltage overstress or in the pre-matured triggering of control circuit elements such as SCRs and TRIACs. Besides the need to maintain quality supply, failure of power for a duration of few milliseconds may cause failure of process instrumentation and also corrupt the performance of hardwares and softwares of data processing systems. This will ultimately result interruption of process and loss of data which may cause financial loss and safety to personnel. No break power supply is essential for proper and safe functioning of the equipment.

3.8 Control System for Power Distribution and Utilisation Equipments

Continuous and assured power supply for the control system is essential for the safe operation of electrical equipment. Further, various types of contactors, relays etc. used in the system drops in the event of heavy voltage dip.

3.9 Illumination System

This also can be subdivided as critical and noncritical depending upon the location. Areas such as staircase, exits, critical process plant sections, electrical substation etc., fall under critical plant sections where illumination is required to be restored at the earliest for safety of plant and personal.

3.10 Communication and Safety alarm System

The communication in modern industrial establishment plays a vital role in safe operation by maintaining flow of information between various section of staff on site and offsite who are involved in the operation of plant. Safety alarm systems like fire alarms, toxic gas alarms etc., if works properly can save an industrial establishment from disaster. The successful operation of this system depends on the assured power supply.

4. CLASSIFICATION OF POWER SUPPLY FOR CRITICAL INDUSTRIAL LOAD

It is evident from above that an industrial establishment cannot depend only on primary source of power supply for safe operation. Besides primary source, standby power sources are required to be established to meet the requirement of critical loads. The critical load as identified above can be further classified and power supply for such load shall be provided as detailed below.

4.1 No break or Uninterrupted Power Supply

This also can be further grouped as

(*a*) D.C. Supply

(*b*) A.C. Supply

The electrical control system, part of the process instrumentation, communication, safety alarm systems and critical lighting etc., are provided with d.c. supply which is most reliable and stable power supply. The data processing systems etc., and certain critical electrical drives are provided with a.c. uninterrupted power supply or U.P.S. This is comparatively less reliable vis-a-vis d.c. systems. Though in modern U.P.S. failure is remote but cannot be altogether ruled out.

4.2 The other Emergency Load like Certain critical drives/loads as mentioned in 3.2 to 3.5 are provided supply from the emergency power generation system immediately after normal supply failures for such duration as required for safe shutdown and safety of personnel. The emergency power is also used as standby power to d.c. and u.p.s power systems.

4.3 In view of severe constraints in getting reliable power from the utilities, many industrial establishment particularly the large chemical industry have started setting up captive power plant. The captive plant can be gainfully setup as co-generation plant. Besides supplying reliable power, this arrangement will make the process energy efficient. Not with standing comparative reliability of captive plant, the emergency standby power supply and uninterrupted power supply requirement cannot be dispensed with.

4.4 Standby power system shall be independent of site source. System shall be designed to take care of load transfer from prime energy source to standby and also meet the following requirement.

(*a*) Close voltage and frequency regulation.

(*b*) Freedom from transient voltage/frequency disturbance and harmonics.

(*c*) Increased short time overload capability.

(*d*) Increased reliability and availability.

(*e*) Close voltage and frequency regulation with wide range rapid load changes.

5. SOURCE OF POWER SUPPLY

As stated earlier, the power required for the industry is normally provided by the utility undertaking like State Electricity Board or any other licensee.

Captive power generation plant based on cogeneration principle is also being set up by the industry. This improves the reliability of power supply in addition to making the plant energy efficient.

Normally cogeneration plant meets the power requirement of essential and critical equipment as far as possible. Balance power is drawn from the utility grid which also remains as standby for full/critical load requirement in case of failure of cogeneration plant.

Standby power supply is provided by DG sets. Standby supply is required for safety of the plant and personnel providing power to all critical equipment, illumination, fire fighting pumps etc., as stated at 3.2, 3.4. This becomes the ultimate source of power when normal supply from utility or captive and or both together fails.

Main supply, Captive power plant and standby DG sets are integrated in such a way that power is made available during normal and emergency condition of outage of mainand or Capative power or both together.
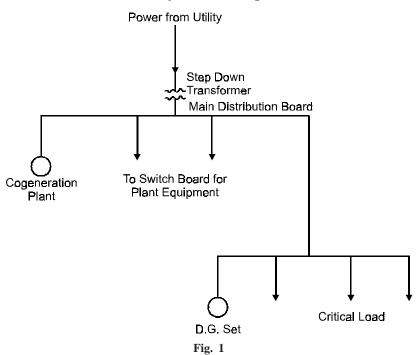
5.1 Power System Configuration

Depending on load requirement, the utility undertaking provides 3 phase AC power to the industrial consumers at various voltages like 11KV, 22KV, 33KV, 66KV and 132KV. For industry requiring high load, power may be supplied even at 220KV.

Supply can be provided either by single feeder or duplicate feeder. Depending on power requirement and also criticallity of power in the process of manufacturing duplicate feeder arrangement is a desirable option from the stand point of reliability. Alternatively, single utility source, supplemented by congeneration or standby DG set will ensure reliability of power supply. Reliability of power should be given high priority in designing power supply for chemical plant. The utility power supply is stepped down through power transformer to the level of main distribution voltage within the plant premises.

The captive generator can be connected to the Main Distribution switch board. If the capacity of this generator is small with respect to the total power requirement, this can be connected to the switch board which supplies power to critical load and other priority loads; such switch board in the distribution network shall have alternative supply from the Main Power Supply System with provision of automatic/manual change over system.

Power System Configuration

Power from Utility

Step Down
Transformer
Main Distribution Board

Cogeneration
Plant

To Switch Board for
Plant Equipment

D.G. Set

Critical Load

Fig. 1

Power System Configuration

Power from Utility

Step Down
Transformer
Main Distribution Board

To Switch Board for Plant Equipment

Essential Load

Cogeneration
Plant

Critical Load

D.G. Set
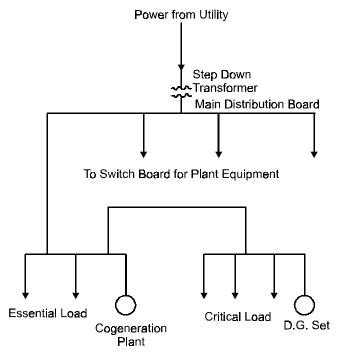
Fig. 2

DG set is connected to the switch board which supplies all such critical load like UPS, DC system. Fire pumps illumination etc., which are required for safe shutdown of the plant and safety of personnel. This switch board shall have alternative power supply from either Main Supply or Captive Power. Normally these critical load will get supply from Main supply/Captive power and in the event of failure, DG set will start up and feed these loads. Appropriate startup and change over scheme shall be incorporated for smooth change over of power during emergency condition.

Schematic arrangements of power system configuration are as below :

For purpose of simplicity, for the stopping down of supply voltages is not shown in the schematic diagrams in Fig. 1 and 2. Depending of voltage rating of cogenerator and DG set, these are connected to the appropriately rated switch board.

Distribution network is developed depending on the load requirement of the process equipment. The same may have, besides main distribution voltage, one or two level of voltages suiting to the voltage rating of the process equipment drives. The detailed network shall incorporate all isolating and protective devices including further stepdown transformers etc., as per the best electrical engineering practices.

5.2 DISTRIBUTION SYSTEM

Power received at Main Receiving station is stepped down to the Main Distribution Voltage. Where load requirement is small like few hundred KVA, the distribution voltage and utilisation voltage may be same as 415 voltage.

For large power consuming plant, the main distribution voltage may be either of the following.

1. 11000 volts   3 phase 50 Hz.

2. 6600 volts   3 phase 50 Hz.

The entire industrial plant shall be divided into several load centres. These load centres may be provided power by any of the alternative systems.

(*a*) Single radial feeder.

(*b*) Duplicate radial feeder.

(*c*) Ring main feeder.

Where high reliability is required, duplicate radial feeder system may be adopted though this system is costliest. Cheapest is single radial feeder system but least reliable. While designing distribution network, coast reliability analysis may be made so that the system meets the requirement of process optimally.

The Load Centres shall have substantions where in various types of switchgears, distribution board, stepdown transformers shall be installed to cater the requirement of power for various electrical drives and equipment.

5.3 Utilisation Voltages

(*a*) For any special installation, 240 gvolt single phase AC motor is used.

(*b*) For auxiliary equipment like heaters, exahust fans, power sockets etc. (*i*) 415 Volts 3 phase or (*ii*) 240 Volts 1 phase are used.

(*c*) Illumination system
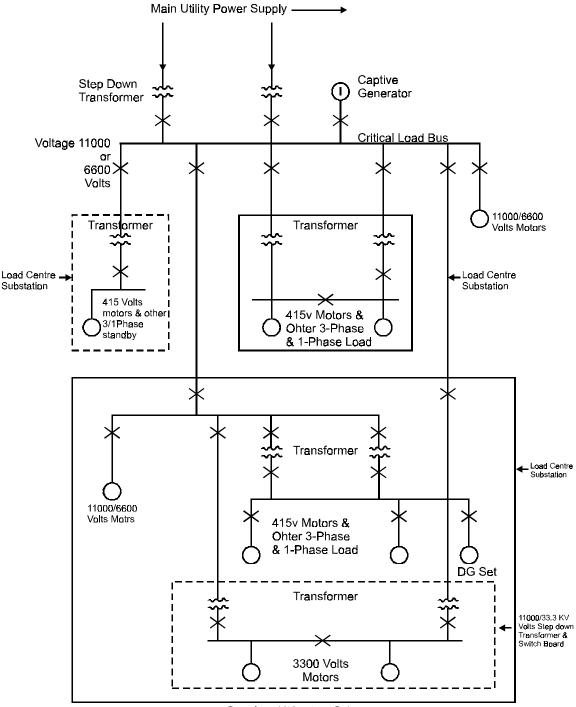
240 Volts single phase AC whereas main distribution may be 415 Volt 3 phase 4 wire. 110V DC for panel light.

(*d*) Electrical Control System

   (*i*) DC 220/110V 2 wire (*ii*) AC 115 Volt 2 wire uninterrupted power supply

   (*iii*) 240Volts 2 wire.

(*e*) Instrumentation and process control

   (*i*) 26 Volt 2 wire DC.

   (*ii*) 115 Volt/220 Volt AC phase 2 wire system from uninterrupted.

Possible Network of power supply distribution and utilisation voltage options are given below:

(*i*)   1100 Volts, 3300 Volts and 415 Volts 3 phase AC.

(*ii*) 6600 Volts, 415 Volts 3 phase AC.

(*iii*) 415 Volts 3 phase A.C.

A typical Power Distribution and Utilisation Network is given at Fig. 3.

Power Supply & Utilisation Scheme

Fig. 3

In case main distribution is at 6600 Volts, 3300 Volts Transformer and Switch Gears will not be required.

Chapter

4

SPECIFIC REQUIREMENTS OF ELECTRICAL EQUIPMENT

SPECIFIC REQUIRMENTS

4.1 PROTECTION AGAINST INGRESS OF DUST, SOLID FOREIGN OBJECTS AND INGRESS OF MOISTURE

The electrical equipment installed in Industrial plant and elsewhere need to be protected against ingress of dust, moisture. The insulation of electrical system will fail if not properly protected and cause flash over, spark etc. Considering the intensity of dust and moisture present in the atmosphere, the degree of protection can be suitably provided to the equipment enclosures. Accordingly the enclosures are classified in the relevant Indian Standard. This covers both rotating machinery and static equipment like switchgear and controlgear.

4.2 The enclosures are designated as IPXY. X and Y are numerals. X denotes type of protection against solid particles, dust etc., while Y denotes degree of protection against water. The classifications of enclosures are given in IS: 4691–1985. These standard also specifies the test procedures for verifying the protection provided by the enclosure.

4.3 COMMON ENCLOSURES OF ELECTRICAL EQUIPMENT SPECIALLY ELECTRICAL MOTOR

IP 12 – Enclosure partly enclosed to avoid accidental contact of moving parts by personnel and also against dripping water when tilted to 15°.

IP 23 – As above but protected against spraying water.

IP 44 – Protected against ingress of small size particles and splashing water.

IP 54 – Dust protected and protected against splashing water.

IP 55 – Dust protected and protected against waterget.

Switchgears and control gears are normally installed indoor. The common enclosures for indoor installation are as follows :

IP 40 – Protected against ingress of solids exceeding 1mm dia.

IP 50 – Dust protected.

Table

	Numeral	*Numeral X* Description	Numeral	*Numeral Y* Description
	0	Non protected	0	Non protected
	1	Protected against solid size greater than 50 mm and also protected against accidental contact of moving/live parts by personnel.	1	Protected against dripping water.
IP	2	Protected against ingress of solid object exceeding 12mm and finger contact of live and moving part.	2	Protected against dripping water when tilted upto 15°.
	3	Protected against ingress of solid objects exceeding 2.5 mm dia.	3	Protected against spraying water.
	4	Protected against ingress of solid objects exceeding 1mm dia.	4	Protected against splashing of water from any direction.
	5	Dust protected. Ingress of dust is not totally prevented but quantity of dust not sufficient to interfere operation.	5	Protected against water jet.
			6	Protected against heavy seas or water projected by jets from all direction.
			7	Protected against immersion.
			8	Protected against continuous submersion under water.
			Note :	Ingress of water in all above cases will not have harmful effect.

4.4 ELECTRICAL EQUIPMENT FOR EXPLOSIVE ATMOSPHERE AS PER IS CODES

4.4.1 The atmosphere in an industrial plant handling petroleum products and explosive gases or vapours as raw material or manufacturing such explosive intermediate or end product is likely to be explosive. The electrical equipment installed in such atmosphere should be appropriately designed to avoid ignition of such explosive gases or vapours during the operation of plant machinery. The electrical equipment are classified in two groups.

Group I – Electrical equipment for mines susceptible to fire damp methane.

Group II – Electrical equipment for explosive atmosphere other than mines.

Group II is further subdivided as IIA, IIB, IIC. The classification is done on the basis of following.

a. Maximum experimental safe gap. (MESG)

(between joint surfaces)

Group IIA   –   MESG > 0.9 mm.

Group IIB   –   MESG > 0.5 < 0.9 mm

Group II C   –   MESG ≤ 0.5 mm

Minimum igniting current (MIC) for intrinsically safe apparatus.

Group IIA   –   MIC ratio above 0.8

Group IIB   –   MIC ratio between 0.45 and 0.8.

Group IIC   –   MIC ratio below 0.45.

MIC ratio is determined as ratio of minimum igniting current of the explosive gases or vapours to that of Laboratory methane. For most of the gases or vapours, it is sufficient to make only one determination of either MESG or MIC to classify the gas or vapour.

4.4.2 Broad classification of Gases or vapours based on MIC and MESG

Group II-A

(*a*) Hydrocarbons

 (*i*) Methane, ethane, Propane, Butane etc.

(*ii*) Mixed hydrocarbons like petroleum naphtha, coal tar naphtha, petroleum, diesel, kerosene etc.

(*iii*) Benzoids.

(*b*) Compounds containing oxygen oxides, like methanol ethanol, carbon monoxide, acetone, butanone, acetic acid etc.

(*c*) Compounds containing halogens like chloromethane etc.

(*d*) Compound containing nitrogen like Ammonia, Ethylnitrite etc.

(*e*) Compound containing sulphur like Ethanethiol.

Group-IIB

(*a*) Hydrocarbons like propane, ethylene etc.

(*b*) Compound containing nitrogen like Acrylonitrile hydrogen cyanide etc.

(*c*) Compound containing Oxygen like Dimethyle either, Ethylmethyl ether etc.

(*d*) Mixtures : Coke oven gas.

(*e*) Compound containing Halogens like Tetrafluoro-ethylene.

Group-IIC

Hydrogen, Acetylene, Carbon disulphide etc.

Detailed list of gases and vapours under all three gas groups are available in IS : 9570-1980. (Chapter 3 Table 22).

4.4.3 Classification based on Maximum Surface Temperature

The maximum surface temperature shall be below the lowest ignition temperature of explosive gas or vapour for which the electrical equipment is designed.

Group I   –   90°C

Group II   –   Temperature Class

Maximum surface temperature °C.

$$T_1 \quad T_2 \quad T_3 \quad T_4 \quad T_5 \quad T_6$$
$$\leq 450 \quad \leq 300 \quad \leq 200 \quad \leq 135 \quad \leq 100 \quad \leq 85$$

4.4.4 Classification or Hazardous Area

Classification of areas having flammable gases or vapours.

Area where explosive atmosphere is present or likely to be present is called hazardous area. Explosive atmosphee is defined as mixture of air with flammable gases or vapour under normal atmospheric condition if ignited cause combustion throughout unconsummated mixtures.

The hazardous areas are classified as per IS : 5572-1994 as 3 zones.

Zone 0 – Vapour space above closed process vessels, storage tanks etc., and areas containing open tanks of flammable volatile liquid.

Zone 1 – Area where flammable gas or vapour concentration is likely to exist in air under normal operating condition or occur frequently due to leakage or break down of process or storage equipment. Examples include:

(*i*) In adequately ventilated room for pump, piping system for volatile flammable liquid.

(*ii*) Top of floating roof tank of explosive gases, liquid due to imperfect peripherial seal.

(*iii*) Loading or unloading gantries of hazardous product.

(*iv*) Oily waste water sewer/basins.

Zone 2 – The area where any of the following conditions exists:

(*i*) Well ventilated areas where explosive liquid or vapour and gas, remain confined in closed container and system and can escape only due to break down like failure of gasket or packing etc.

(*ii*) Where ventilation is provided by mechanical ventilator, the failure of which can cause build up of vapour or gas air mixture upto explosive limit.

(*iii*) Area connected by trenches, pips or ducts through which flammable vapour or gas can flow.

(*iv*) Locations adjacent to zone 1 area.

Flammable substances considered for area classification include non liquified gases, liquefied petroleum gases and vapour of flammable liquid.

4.4.5 Extent of Hazardous Area

In open calm, atmosphere, heavier than air vapour disposes, mainly downward and outward; while lighter than air, upward and outward. Thus from point of source, the horizontal area covered by dispersed vapour or gas will be circle. Presence of air current will accelerate dispersion of vapour or gas. Areas covered will be different for heavier and lighter gases or vapours as detailed in figure, 4, 5.

4.4.6 Classification of Electrical Equipment suitable for Explosive Atmosphere

The electrical equipment are classified as under :

	Type of equipment	Area for use
1.	Flame proof enclosure Ex d	Zone 1
2.	Pressurised construction Ex p	Zone 1

3.	Oil immersed Ex O	Zone 1
4.	Sand filled Ex q	Zone 1
5.	Intrinsically safe equipment Ex ia/Ex ib	Zone 0
6.	Increased safety Ex e	Zone 2
7.	Equipment for type of protection 'n' incapable of causing sparks Ex n	Zone 2

Keeping is view the categories of equipment, gas groups and temperature classes, these equipment are marked and designated in the following manner:

(*a*) Flame proof enclosure for mining Exd I.

(*b*) Flame proof enclosure suitable for Exd IIB T_3 gas group IIB and temperature class T_3.

(*c*) Increased safety equipment for gas Ex eII B T_2 group IIB temperature Class T_2.

(*d*) Pressurised construction for gas areas Exp IIA T_3 group IIA, Temperature T_3.

(All dimensions are in Meter)
(a) Gas or Vapour heavier than air.
Fig. 4

(b) Gas Vapour lighter than air.

If source of hazard is above ground but height is less that 4.5 meters, the entire area upto ground level will fall under zone 2.

(All dimensions are in Meter)
(b) Gas Vapour lighter than air.
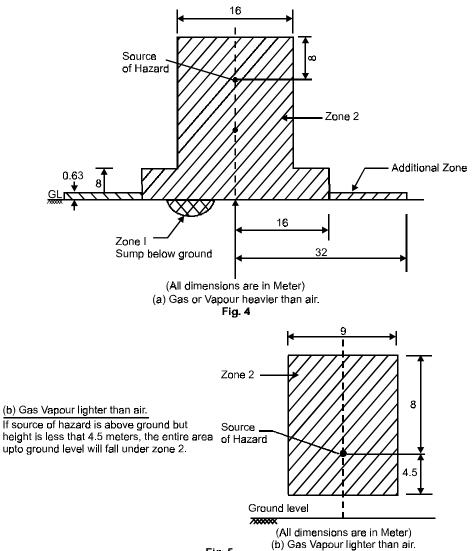
Fig. 5

4.4.7 Brief Technical Features of Electrical Equipment Suitable for Explosive Atmosphere

4.4.7.1 Flame proof enclosure

The equipment is installed where surrounding atmosphere is explosive and entry of explosive gases or vapours inside the enclosure is possible. The enclosure with fully secured covers shall withstand an internal explosion of flammable gas or vapour without suffering damage and without communicating the internal flammation to the external explosive atmosphere through any joint or other structural opening.

The construction shall be suitable for the gas group I, IIA, IIB and IIC and temperature class T_1, T_2, T_3 etc. The surface temperature of enclosure during normal operation shall not ignite the surrounding gas or vapour. The construction shall conform to IS-2148-1981.

4.4.7.2 Pressurised enclosure

The equipment has no internal source of flammable gas or vapour. The enclosure is pressurised by non flammable safe gas at a pressure above the external atmosphere. Nitrogen is commonly used for this purpose. The over pressure is maintained with or without continuous purge of safe gas. The equipment is energised after purging and the same continues after de-energisation for such time that the surface temperature of any internal part of the equipment is adequately cooled. The equipment shall conform to IS : 7389 Part I-1976. The common example of this type of enclosure is slipring enclosure of wound Rotor AC motor or synchronous motor.

4.4.7.3 Oil immersed equipment

The electrical equipment like switch gears, control gears and transformers which has to be installed in explosive atmosphere, shall be made safe by oil immersion so that flammable gases or vapours above the insulating oil or outside the enclosure shall not be ignited. The equipment shall conform to IS 7693-1975.

4.4.7.4 Sand filled equipment

The electrical apparatuses inside the enclosure shall be fully embedded in a mass of non combustible material like sand of appropriate particle size so that if arc occurs inside the enclosure, the same shall not cause ignition of the outer explosive atmosphere. The equipment shall conform to IS : 7724-1975.

4.4.7.5 Intrinsically safe equipment

The intrinsically safe circuit is defined as a circuit in which spark or heat produced during normal operation or during fault shall not cause ignition of explosive gas or vapour. Intrinsically safe equipment is one in which all circuits are intrinsically safe. The equipment shall conform to IS : 5780-1980.

4.4.7.6 Increased safety construction

The equipment incorporates special measures to provide increased safety against excessive temperatures and also to prevent occurrences of sparks or areas under normal condition of operation. The equipment shall conform to IS : 6381-1972.

4.4.7.7 Electrical equipment with 'n' type protection

The equipment under this category is standard electrical equipment with special features so that possibility of ignition of surrounding explosive atmosphere is avoided. The equipment shall not in

normal operation produce an arc or spark and develop surface temperature or hotspot capable of causing, ignition of ambient explosive atmosphere with the following exception:

(*a*) Make-break contact hermatically sealed enclosure.

(*b*) Spark energy is insufficient to cause ignition.

(*c*) Enclosed break device meeting the requirement of applicable standard.

The equipment shall conform to IS : 8289-1976.

4.5 BASICS OF EXPLOSION PROTECTION

Electrical systems-IEC and EN standards

Flammable gases, mists and dusts, together with oxygen, form explosive atmospheres. If such an atmosphere is ignited, an explosion results which may cause serious damage to personae and equipment.

An explosion can only take place if the following factors are jointly active:

1. flammable substance (gas, vapour, mist or dust) in a suitable distribution and concentration.

2. oxygen (from the air) and

3. ignition source.

An explosive atmosphere only occurs if the substance-air mixture lies within a certain concentration range, the explosion limits. The explosion limits depend on the ambient pressure and the oxygen concentration of the air.

100 Vol %	concentration of air	0 Vol %
mixture too clean	ignition range	mixture too rich
no combustion	$\longleftarrow$ lower — ignition limit — upper $\longrightarrow$	deflagration, no explosion
0 Vol %	concentration of combustible material in air	100 Vol %

Explosion Protection

In order to avoid explosions and associated dangers, an operator must incorporate effective explosion protection precautions into his plant.

The principle integrated explosion requires that explosion protection measures be taken in the following order

1. Measures to prevent formation of a dangerous explosive atmosphere.

2. Measures which prevent dangerous explosive atmospheres from igniting.

3. Measures which restrict the effects of an explosion to a safe level.

Also are distinguishes:

Primary explosion protection:

– all measures which prevent the formation of an explosive atmosphere.

Secondary explosion protection:

– all measures which restrict the effects of an explosion to an insignificant level.

Classification of Zones

Hazardous areas are classified into Zones, depending on the composition and presence of an explosive atmosphere. This enables both selection of suitable equipment and appropriate electrical installation.

Gases, vapours, mists	Dust	Definition (94/9/EG) explosive explosive atmosphere is present
Zone 0 — category 1G	Zone 20 — category 1 D	permanent, long-term
Zone 1 — category 2G	Zone 21 — category 2 D	occasional
Zone 2 — category 3G	Zone 22 — category 3 D	seldom or short-period

G = gases, D = dusts

Classification of zones and use of equipment

Zone 0 – Equipment with certificate of conformity or type test certificate especially approved for zone 0

Zone 1 – Equipment with certificate of conformity or type test certificate.

Zone 2 – Equipment complying with the basic requirements of Directive 94/9/EC (Equipment certified for Zone 0 and Zone 1 can also be used).

Types of Protection

In areas where explosive atmospheres can occur despite the explosion protection measures employed, only explosion-protected electrical equipment may be used. Explosion protected electrical equipment can be manufactured to IEC protection type levels.

Protection type to IEC or EN standard	Basic principle	Schematic representation	Principal application
Flame-proof enclosure d IEC 60079-1 EN 50 018	Parts which can ignite an explosive atmosphere are placed in an enclosure which, if there is an ignition of an explosive mixture internally, will withstand the pressure and prevent the explosion being transmitted to the atmosphere around the enclosure.		Switch gear and switching installations, control and display units, control boards, motors, transformers, heating devices, light fittings.
Increased safety e IEC 60 079-7 EN 50 019	Additional measures are taken to achieve a higher level of safety and avoid the risk of impermissibly high temperatures and the occurrence of sparks and arcs internally or on external parts of electrical equipment, which in normal use produce neither sparks, arcs nor dangerous temperatures.		Terminal and connection boxes, control boxes for the installation of Ex-components (which are protected in another protection class), squirrel cage motors, light fittings.

Pressurised apparatus p IEC 60 079-3 EN 50 016	The formation of an explosive atmosphere inside an enclosure prevented by using a protective gas to maintain an internal overpressure relative to the surrounding atmosphere, and if necessary, the interior of the enclosure is permanently supplied with protective gas so that here is dilution of flammable mixtures.		Switching an control cabinet, analysis devices large motors.
Intrinsic safety i IEC 60 079-11 EN 50 020	The equipment placed in the hazardous area contains only intrinsically safe circuits. A circuit is intrinsically safe if no sparks or thermal effects occur under established test conditions (including) the normal operating and certain fault conditions), which could lead to the ignition of a given explosive atmosphere.		Measurement and control equipment, communications equipment, sensors, actuators.
Oil immersion o IEC 60 079-6 EN 50 015	Electrical equipment or parts of electrical equipment are immersed in a protective liquid in such a way that an explosive atmosphere above the surface or outside the enclosure cannot be ignited.		Transformers, starting resistors.
Powder fitting q IEC 60 079-5 EN 50 017	Type of protection by which the equipment parts that could become an ignition source are fixed in position and completely surrounded by finely ground solids. So as to prevent ignition of an external explosive atmosphere.		Electronic devices
Moulding m IEC 60 079-18 EN 50 028	Parts which can ignite an explosive atmosphere are embedded in a casting compound so that the explosive atmosphere cannot be ignited.		Switch gear for low powers, control gear and indicating equipment, display equipment, sensors.
Protection method n IEC 60 079-15 EN 50 021	Electrical equipment is not capable of igniting a surrounding explosive atmosphere (in normal operation and under defined abnormal operating conditions).	Zone 2 Several protection methods are subsumed under the protection type.	All electrical equipment for zone 2, less suitable for switch gear and switching installations.

Temperature Classes

Ignition temperature is the lowest temperature of a surface at which an explosive atmosphere ignites on it. Flammable vapours and gases can be classified into temperature classes according to their ignition temperature.

The maximum surface temperature of a piece of equipment must always be lower than that of the ignition temperature of the gas-air mixture or vapour-air mixture in which it is placed.

Temperature Classes to IEC

Temperature class IEC/EN NEC 505-10	Maximum permissible surface temperature of the equipment (°C)	Ignition temperatures of flammable substances (°C)	Temperature class NEC 500-3 CEC 18-052
T1	450	>450	T1
T2	300	> 300 ≤ 450	T2
	280	> 280 ≤ 300	T2A
	260	> 260 ≤ 280	T2B
	230	> 230 ≤ 260	T2C
	215	> 215 ≤ 230	T2D
T3	200	> 200 ≤ 300	T3
	180	> 180 ≤ 200	T3A
	165	> 165 ≤ 180	T3B
	160	> 160 ≤ 165	T3C
T4	135	> 135 ≤ 200	T4
	120	> 120 ≤ 135	T4A
T5	100	> 100 ≤ 135	T5
T6	85	> 85 ≤ 100	T6

Explosion Groups

Explosion protected electrical equipment is divided into 2 groups:

Group I: Electrical equipment for mining.

Group II: Electrical equipment for all other hazardous areas.

Electrical equipment of group II is further subdivided in group IIA, IIB and IIC, depending on the danger level of the gas or vapour atmosphere in which they are operated. Equipment of group IIC is suitable for use in the most dangerous atmospheres.

Example of the Classification of Gases and Vapours into Explosion Groups and Temperature Classes

	T1	T2	T3	T4	T5	T6
I	Methane					
IIA	Acetone	Ethyl alcohol	Gasoline	Acetaldehyde		
	Ethane	i-amyl acetate	Diesel fuel	Ethyl ether		
	Ethyl acetate	n-butane	Aviation fuel			
	Ammonia	n-butyl alcohol	Heating oils			

		n-hexane			
	Benzene (pure)				
	Acetic acid				
	Carbon monoxide				
	Methane				
	Methanol				
	Propane				
	Toluene				
II B	Town gas (coal gas)	Ethylene			
II C	Hydrogen	Acetylene			

Certification and Marking

Only appropriately certified and marked units may be used in hazardous areas. Two directives are valid up to year 2003 for placing on market explosion protected equipment.

EC Directive 79/196/EEC (until 30.06.2003)

EC Directive 94/9/EC (ATEX 100a)

EC Directive	79/196/EEC	94/9/EC
Validity	until 30.06.2003	from 01.03.1996
Range of validity for	- electrical equipment	- all equipment and protection system
equipment in hazardous areas	- gases and vapours - not for mining	- gases, vapours and dusts - including mining
QM system of manufacturer	no requirements	"QM certificate" of notified body
Certificate of conformity	conformity or inspection certificate of a notified body	manufactures declaration of conformity on the basis of the type examination.

Marking laid down by the Directive and the standards

Name or marking of manufacturer, e.g.,	STHAL	STHAL
Type marking (e.g.)	6000/562...	6000/562-...
Address	–	D-Künzelsau
CE mark, no. of testing authority (e.g. PTB)	–	CE 0102
Test station, no. of certificate (e.g.)	PTB No. Ex-91.C.1045 1)	PTB 97 ATEX 2031[1]
Mark according to EC Directive (free movement of goods)	$\langle \xi_x \rangle$[2]	$\langle \xi_x \rangle$[2]
Group and category of equipment:		Group I: M1 or M 2
mining (I)	I or II 3 GD	Group II: 1 g/D, 2G/D,
Other hazardous areas (II)		

EN marking	EEx/Ex	EEx/Ex
Protection types (e.g.)	d, e, q,...	d, e, q,...
	ib or (ib)[3]	ib or (ib)[3]
Subclassification for Group II (only for d and i)	A or B or C	A or B or C
Temperature class for II	T1-T6	T1-T6
Electrical data	V, A, W, Hz	V, A, W, Hz
Ambient temperature,		
if other than –20°C... + 40°C, (e.g.)	$Ta \leq 50°C$	$Ta \leq 50°C$

(1) With... X special conditions are indicated for use etc.

  With... U for Ex components.

(2) New: always present, old: not on Ex components.

(3) Intrinsically safe apparatus: ib/associated apparatus (ib).

Duties of the Manufacturer, Installer and Operator

Safety can only be guaranteed in hazardous areas through close collaboration between operators, installers and manufacturers of explosion protected plant and components, as well as test stations, authorities and standardising associations.

The manufacturers of explosion protected equipment must be responsible for part testing, certification and documentation, and ensure that each finished device corresponds to the tested type model.

The installer must comply with the installation requirements and select and install the electrical equipment in accordance with it use.

The operator is responsible for the safety of his plant. He must assess the explosion hazard and undertake zone classification. He must ensure that the plant is properly installed and tested before first use. He must ensure the correct condition by regular testing and maintenance.

Table 16 : Maximum Temperature (°C) and Maximum Temperature Rise (deg C) in Electrical Machines[1]

Insulating Material	Cotton, Silk, Paper and Similar Fibrous Materials						Varnished Wire				Mica and Asbestos Preparations and Similar Mineral Materials		Mica	Porcelain, Glass, Quartz and Similar Refractory Materials	Not insulated
Treatment	Non-impregnated and not immersed		Impregnated		In filling Compound or oil immersed				In filling Compound or oil immersed		With binder		Without binder		
	Max. temp. Rise² deg C	Max. temp. °C	Max. temp. Rise² deg C	Max. temp. °C	Max. temp. Rise² deg C	Max. temp. °C	Max. temp. Rise² deg C	Max. temp. °C	Max. temp. Rise² deg C	Max. temp. °C	Max. temp. Rise² deg C	Max. temp. °C			
A.C. stator windings embedded in slots	40	75	50	85	60	95	50	85	60	95	80	115			
Single-layer field windings, also double-layer field-windings in one-piece drum rotor	60	95	70	105	70	105	70	105	70	105	90	125	Limited only by effect on adjacent insulation		
Permanently short-circuited windings	55	90	65	100	65	100	65	100	65	100	85	120			
All other windings	50	85	60	95	60	95	60	95	60	95	80	115			

(1) If possible, use also with other frequencis. (2) Only for voltage transfomers.
Source: Borsig Pocket Book 3rd Edn. 1970.

Table 16 A : For machine components not insulated

Items	Maximum permitted temperature rise °C	Maximum temperature °C
Commutators and slip rings	60	95
Bearings	45	80
Iron cores with embedded windings	As for the winding	As for the winding
Iron cores without embedded windings	Limited only by adjacent insulation.	Limited only by effection adjacent insulation.
All other components	Limited only by adjacent insulation.	Limited only by effection adjacent insulation.

1. *Source* : Mathematical and Technical Tables 1944-After E. Schultz.

2. Maximum temperature rise permitted is above the temperature oil surrounding air/cooling media.

Table 17 : Standards speeds and Synchronous speeds, rev/min in AC machines, 50 hz

No. of poles	2	4	6	8	10	12	16	20	24
Rev/min	3000	1500	1000	750	600	500	375	300	250
	(28)	32	(36)	40	48	(56)	64	(72)	80
Rev/min	214	188	167	150	125	107	94	83	75

Source : VDE spec. 0530

1. Where possible same speeds apply for DC machines.

2. Values in brackets should be avoided.

Table 18 : Percentage Efficiency of DC Motors at 110, 220 and 440 Volts

Rev/min	Output, kW							
	0.2	0.7	1.0	5	10	50	80	100
2800	68	73	75	82	–	–	–	–
2000	67	74	75	82	84	–	–	–
1400	66	72	74	82	84	88.5	–	–
750	–	–	–	79	82	88.5	89.5	90
500	–	–	–	76	80	87	–	–

Machines of output above 1000 kW, running at high speeds, show a percentage efficiency of up to 94%.

Source : Borsig pocket book 3rd edn. 1970.

Table 18 A : Three-Phase Motors, Percentage Efficiency

Rev/min	Output, kW						
	7.5	15	30	50	100	200	250
3000	83	85	88.5	89.5	90.5	92	92.5
1500	85	87.5	89	90	91	92.5	93
750	83.5	86	88	89.5	91	92	92.5
500	–	85	87	88.5	90.5	92	92.5

Rev/min	Output, kW				
	400	500	800	1000	200
1500	93.5	94	94	94.5	–
1000	94	94	94.5	95	95.5
750	94	94	94.5	94.5	95.5
500	93	93	–	–	–

Source : Borsig pocket book 3rd Ed. 1970.

Table 19 : Load Capacity in amps of Copper Conductors

Load-Capacity of Three Separately Laid Non-armoured Single-Core Cables in Three-Phase Current System.

1	2	3	4	5	6	7	8	9	10
Nominal cross-section of copper conductor mm^2	$U_0 = 0.6$ $U = 1$	1.75 3	3.5 3	6 10	10 5	12 20	17.5 30	25 45	35 kV 60 kV
	Load-Capacity in Amps								
16	140	135	130	110	105	–	–	–	–
25	180	175	170	145	140	135	–	–	–
35	220	215	210	175	170	165	155	–	–
50	270	265	260	220	215	205	190	185	–
70	325	320	310	265	260	250	235	220	–
95	390	385	375	315	305	295	280	265	250
120	445	440	430	360	350	340	320	300	285
150	500	495	485	410	400	390	365	340	325
185	550	545	535	460	445	430	405	385	365
240	625	620	615	520	505	490	465	440	420
300	695	690	680	570	555	540	515	490	465
400	785	780	770	645	630	615	590	565	535
500	855	850	845	705	690	575	650	–	–

625	915	–	–	–	–	–	–	–	–
800	980	–	–	–	–	–	–	–	–
1000	1030	–	–	–	–	–	–	–	–

The above values apply to non-armoured cables laid at a centre-distance of approx. 13 mm, allowance being made for lead-sheath losses with resistanceless short-circuiting of the sheath at both ends of the cable.

It is recommended that only approx. 75% of the load shown in Table 1 and 2 be applied to overhead cables.

Where a number of cables run through the same conduit or cable tube section, or where a number of cables are laid in superimposed layers in a single trench, the safe load-capacity should be determined according to circumstances. This applies also to intermittent operation.

Source: Borsig Pocket Book 3rd Edn. 1970.

Table 20 :

I. Synchronous speed in r.p.m. I in AC machines

$$\text{r.p.m. Formula} = \frac{120\,f}{p}$$

where f = frequency of supply

p = no. of poles

Actual r.p.m is synchronous r.p.m. less % slip.

N.B. In winter, motor speed improves due to frequency improvement as it remain nearest to rated 50 cycles frequency.

II. Motor H.P.–Voltage

Fractional	110/220V single phase AC and DC
1-150	400 V, 3 phase AC
150-1000	3 KV or 6 KV 3 phase AC
1000 and above	11 KV 3 phase AC

III. Features

1. Online starting of motors is done for medium voltage.

2. Wound rotor motor is used for high starting current.

3. Starting torque in squirrel cage motor is 100-250% of F.L.T. and for slip ring and synchronous induction motor it is 200-250% of FLT. It is 30-80% of FLT in synchronous salient pole type motors.

4. Starting current in maximum (6 times F.L.C) in squirrel cage motors, 2-3 times in slip ring and syn. induction motors and 4 times in syn. salient pole.

Table 21 : Modern substation equipment list

Power transformer, Reactor, Capacitor bank, lightning arrester, Earth pit connectors, Incoming bus, battery bank, switch breakers, current and potential transformers, voltmeter and ammeter, energy meters, software for substation monitoring, PLCC equipment, AC/DC Panel boards, Power and control cables, exhaust fan, Transformer oil filters, cable racks etc.

Table 22 : IS : 9570 – 1980

Table 1 : Classification of Flammable Gases or Vapours for Which Group IIA Apparatus is Required

(*Clause 5*)

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
(*i*) **Hydrocarbons**		
Alkanes		
*Methane	CH_4	c
Ethane	C_2H_6	c
Propane	C_3H_8	c
Butane	C_4H_{10}	c
Peptane	C_5H_{12}	c
Hexane	C_6H_{14}	c
Heptane	C_7H_{16}	c
Octane	C_8H_{18}	a
Nonane	C_9H_{20}	d
Decane	$C_{10}H_{22}$	a
Cyclobutane	$CH_2(CH_2)_2CH_2$	d
Cyclopentane	$CH_3(CH_2)_3CH_2$	c
Cyclohexane	$CH_2(CH_2)_4CH_2$	d
Cycloheptane	$CH_2(CH_2)_5CH_2$	d
Methylcyclobutane	$CH_3CH(CH_2)_2CH_2$	d
Methyleyclopentane	$CH_3CH(CH_3)_3CH_2$	d
Methyleyclohexane	$CH_3CH(CH_2)_2CH_2$	d
Ethyleclobutane	$C_2H_5CH(CH_2)_2CH_2$	
Ethylcyclopentane	$C_2H_5CH(CH_2)_3CH_2$	d
Ethycyclohexane	$C_2H_5CH(CH_2)_4CH_2$	d
Decahydronaphthalene (dekalin)	$CH_2(CH_2)_3CHCHCH_2CH_2$	d
Alkenes		
Propene (propylene)	$C_2H_4 = CH_2$	a

*Methane (CH_4) refers to a gas with negligible impurities.

Table 1 : Classification of Flammable Gases or Vapours for Which Group IIA Apparatus is Required—*Contd.*

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
Arematic Hydrocarbons		
Styrene	$C_6H_5CH—CH_2$	b
Isopropenylbenzene	$C_6H_5C(CH_3) = CH_2$	a
(methylstyrene)		
Benzoids		
Benzene	C_6H_6	c
Toluene	$C_6H_5CH_3$	d
Xylene	$C_6C_4(CH_3)_2$	a
Ethylebenzene	$C_6H_5C_2H_5$	d
Trimethylbenzene	$C_6H_3(CH_3)_3$	d
Naphthalene	$C_{10}H_6$	d
Cumene	$C_6H_5CH(CH_3)_2$	d
Cymene	$(CH_3)_2CHC_6H_4CH_3$	d
Mixed Hydrocarbons		
Methane (industrial)*		a
		(calculated)
Turpentine		d
Petropleum naphtha		d
Coal tar naphtha		d
Petroleum (including motor spirit)		d
Solvent or cleaning petroleum		d
Heating oil		d
Kerosene		d
Diesel oil		d
Motor benzole		a
(*ii*) **Compounds Containing Oxygen Oxides (Including Ethers)**		
**Carbon monoxide	CO	c
Dipropyl ether	$(C_3H_7)_2O$	a
Alcohols and Phenols		
Methanol	CH_3OH	c
Ethanol	C_2H_5OH	c

*'Methane' (CH_4) refers to the gas with negligible impurities. 'Methane (industrial)' includes methane mixtures containing up to 15 percent by volume of hydrogen.

**'Carbon monoxide' may include a moisture content sufficient to saturate a carbon monoxide-air mixture at normal ambient temperature.

Table 1 : Classification of Flammable Gases or Vapours for Which Group IIA Apparatus is Required—*Contd.*

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
Propanol	C_3H_7OH	c
Butanol	C_1H_9OH	a
Pentanol	$C_3H_{11}OH$	a
Hexanol	$C_6H_{13}OH$	a
Heptanol	$C_7H_{15}OH$	d
Octanol	$C_8H_{17}OH$	d
Nonanol	$C_9H_{19}OH$	d
Cyclohexanol	$CH_2(CH_2)_4\ CH\ OH$	d
Ethylyclohexanols	$CH_3CH(CH_2)_4CH\ OH$	d
Phenol	C_6H_5OH	d
Cresol	$CH_3C_6H_4OH$	d
4-hydroxy-4-mehtylpentan-2-one (diacetone alcohol)	$(CH_3)_2C(OH)CH_2COCH_3$	d
Aldehydes		
Acetaldehyde	CH_3CHO	a
Metaldehyde	$(CH_3CHO)n$	d
Ketones		
Acetone	$(CH_3)_2CO$	c
Butanoae (ethyl methyl ketone)	$C_2H_5COCH_3$	c
Pentane-2-one (propyl methyl ketone	$C_3H_7COCH_3$	a
Hexane-2-one (butyl methyl Ketone)	$C_1H_9(CO\ CH_2)$	a
Amyl methyl ketone	$C_5H_{11}CO\ CH_3$	d
Pentane-2, 4-dione (acetylacetone)	$CH_3COCH_2COCH_3$	a
Cyclohexanone	$CH_2(CH_2)_4CO$	a
Esters		
Methyl formate	$H\ COO\ CH_3$	a
Ethyl formate	$H\ COO\ C_2H_5$	a
Methyl acetate	$CH_3\ COO\ CH_3$	c
Ethyl acetate	$CH_3\ COO\ C_2H_5$	a
Propyl acetate	$CH_3\ COO\ C_3H_7$	a
Brityl acetate	$CH_3\ COO\ C_4H_9$	c
Amyl acetate	$CH_3\ COO\ C_5H_{11}$	d

Table 1 : Classification of Flammable Gases or Vapours for Which Group IIA Apparatus is Required—*Contd.*

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
Methyl methacrylate	$CH_2 = C(CH)_3\ COO\ CH_3$	a
Ethyl methacrylate	$CH_2 = C(CH)_3\ COOC_2H_5$	d
Vinyl acetate	$CH_3COOCH = CH_2$	a
Ethyl acetoactate	$CH_3COCH_2COOC_2H_5$	a
Acid		
Acetic acid	CH_3COOH	b
(*iii*) **Compounds Containing Halogens**		
Compounds without Oxygen		
Chloromethane	CH_3Cl	a
Chloroethane	C_2H_5Cl	b
Bromoethane	C_2H_5Br	d
Chloropropane	C_3H_7Cl	a
Chlorobutane	C_4H_9Cl	a
Bromobutane	C_4H_9Br	d
Dichloroethane	$C_2H_4Cl_2$	a
Dichloropropane	$C_3H_6Cl_2$	d
Chlorobenzene	C_6H_5Cl	d
Benzyl chloride	$C_6H_5CH_2Cl$	d
Dichlorobenzene	$C_6H_4Cl_2$	d
Allyl chloride	$CH_2 = CHCH_2Cl$	b
Dichloroethylene	$CHCl = CH\ Cl$	a
Chloroethylene	$CH_2 = CH\ Cl$	e
d, d, d, — Trifluorotoluene (benzotrifluoride)	$C_6H_5CF_3$	a
Dichloromethane (methylene chloride)	CH_2Cl_2	d
Compounds with Oxygen		
Acetyl chloride	CH_3COCl	d
Chloroethanol	$CH_2Cl\ CH_2OH$	d
(*iv*) **Compounds Containing Sulphur**		
Ethanethiol (ethyl mercaptan)	C_2H_5SH	c
Propane-I-thiol (propyl-mercaptan)	C_3H_7SH	a (calculated)
Thiophene	$CH = CH = CH\ S$	a
Tetrahydrothiophene	$CH_2(CH_2)_2CH_2S$	a

Table 1 : Classification of Flammable Gases or Vapours for Which Group IIA Apparatus is Required—*Contd.*

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
(v) **Compounds Containing Nitrogen**		
Ammonia	NH_3	a
Acetonitrile	CH_3CN	a
Ethyl nitrite	CH_3CH_2ONO	a
Nitromethane	CH_3NO_2	d
Nitroethane	$C_2H_5NO_2$	d
Amines		
Methylamine	CH_3NH_2	a
Dimethylamine	$(CH_3)_2NH$	a
Trimethylamine	$(CH_3)_3N$	a
Diethylamine	$(C_2H_5)_2NH$	d
Triethylamine	$(C_2H_5)_3N$	d
Propylamine	$C_3H_7NH_2$	d
Butylamine	$C_4H_9NH_2$	c
Cyclohexylamine	$CH_2(CH_2)_4CH\ NH_3$	d
2-Aminoethanol (ethanolamine) (mono-ethanolamine)	$NH_2CH_4CH_2OH$	d
2-Diethylaminoethanol	$(C_2H_5)_2NCH_2CH_2OH$	d
Diaminoethane	$NH_2CH_2CH_2NH_2$	a
Aniline	$C_6H_5NH_2$	d
NN-dimethylaniline	$C_6H_5N(CH_3)_2$	d
Amphetamine	$C_6H_5CH_2CH(NH_2)CH_3$	d
Toluidine	$CH_3C_6H_4NH_2$	d
Pyridine	C_5H_5N	d

Table 2 : Classification of Gases or Vapours for Which Group IIB Apparatus is Required

(*Clause 5*)

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
(*i*) **Hydrocarbons**		
Propyne CH_3C CH	b	
Ethylene C_2H_4	c	
Cyclopropane	$CH_2CH_2CH_2$	b
1, 3-Butadiene	$CH_2 = CH$ $CH = CH_2$	c
(*ii*) **Compounds Containing Nitrogen**		
Acrylonitrile	$CH_2 = CHCN$	c
Isopropyl nitrate	$(CH_3)_2$ $CHONO_2$	b
Hydrogen cyanide	HCN	a
(*iii*) **Compounds Containing Oxygen**		
Dimethyl ether	$(CH_3)_2O$	c
Ethyl methyl ether	$CH_3OC_2H_5$	d
Diethyl ether	$(C_2H_5)_2O$	c
Dibutyl ether	$(C_4H_9)_2O$	c
Oxione (ethylene oxide)	CH_2CH_2O	c
1, 2-Epoxypropane	CH_3CHCH_2O	c
1,3-Dioxolane	$CH_2CH_2OCH_2O$	d
1, 4-Dioxane	$CH_2CH_2OCH_2CH_2O$	a
1, 3, 5-Trioxane	$CH_2OCH_2OCH_2O$	b
Butyl glycolate (hydroxyacetic acid, butyl ester)	$HOCH_2COOC_4H_3$	a
Tetrahydrofurfuryl alcohol	$CH_2CH_2CH_2OCHCH_2OH$	d
Methyl acrylate	$CH_2 = CHCOOCH_3$	a
Ethyl acrylate	$CH_2 = CHCOOC_2H_5$	a
Furan	$CH = CHCH — CHO$	a

Crotonaldehyde	$CH_3CH = CHCHO$	a
Acrylaldehyde (acrolein)	$CH_2 = CH$ CHO (calculated)	a
Tetrahydrofuran	$CH_2(CH_2)_2CH_2O$	a
(*iv*) **Mixtures**		
Coke oven gas		d
(*v*) **Compounds Containing Halogens**		
Tetrafluoroethylene	C_2F_4	a
1-Chloro-2, 3-epoxypropane (epichlorohydrin)	OCH_4CHCH_2Cl	a

Table 3 : Classification of Flammable Gases or Vapours for Which Group IIC Apparatus is Required

(*Clause 5*)

Gas or Vapour (1)	Chemical Formula (2)	Method of Classification (3)
Hydrogen	H_2	c
Acetylene	C_2H_2	c
Carbon disulphide	CS_2	c
Ethyl nitrate	$C_2H_5ONO_2$	

Chapter

5

PROCESS INSTRUMENTATION

5.1. DCS CONTROL SYSTEM IN PROCESS PLANTS

(*i*)   Upto 90s chemical process plants used mainly pneumatic and electrical control systems.

(*ii*) Due to advances in subsequent yrs. in process controls, Analog electronics based controls and distributed control systems (DCS) came up although based on cost with reference to old pneumatic control system cost, the cost of analog electronics control system is about 27% more and that for DCS is about 32%. The draw backs of analogue electronics control system are more as regards flexibility, plant data processing and presentation which could not be improved significantly.
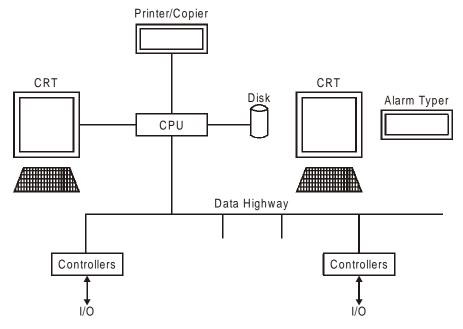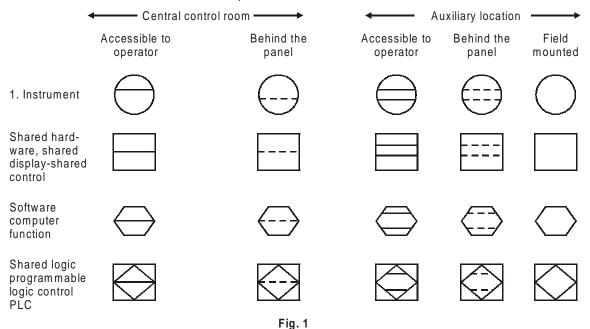
Fig. 3 DCS Example (Distributed Control System)

The development in the field of digital control method is a quite interesting concept that is named, as the distributed control system (DCS). This concept is based on distributing the hardware, intelligence and risk as shown in Fig. 3.

In DCS the Computer talks directly to intelligent digital controllers which in turn perform powerful functions and communicate with the actual process. The system can be termed as some of the Computer functions or intelligence are distributed to a no. of intelligent units. Functions such as simulation, optimisation and histroical trending mainly are Computer functions.

183

(*iii*) A distributed control system is based on modern technology and main advantages of this computerised control technology are :-

   (*a*)   Very good flexibility with regard to control configuration, plant data processing and data presentation.

   (*b*)   Different sections of a continuous process plants is segregated into various loops and signals from these section and out put signals from DCS is sent to these loops making effective control. Failure of any loop functions is taken over by a another control system. In Fig. 3 a DCS system located in control room is shown.

   (*c*)   Improved control accuracy, reliability and availability.

   (*d*)   Possibility to introduce advance control schemes and plant optimisation packages.

   (*e*)   Labour cost for operation and maintenance cost of DCS are reduced considerably as computerised control takes over.

(*iv*) Briefly a DCS system contains different controllers for various loops with input signals coming from a loop is sent by data highway to CPU which process the input data from controllers and appropriate output signal is routed via data highway to controllers which sends the output signals to the particular loop. The computer monitor displays both input/ output signals etc. and alarm typer is also provided. A data logger is also part of the system. DCS is digital.

(*v*) Major international instrumentation companies can carry out and implement DCS in a process industry, chemical or otherwise. These cos. are Honeywell, Foxboro, Taylor etc.
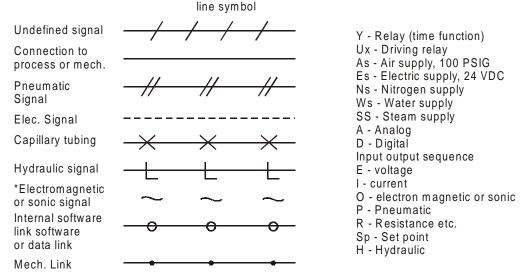
Instrument Symbols in process and instrument (P and I) flow diagrams and abbreviations in computerised instrumentation

Fig. 1

    Process plants of early 90's design were usuallly provided with pneumatic and electrical instruments (both field and control room) without any shared distributed control system (DCS) with basic logic diagram for specific control system using pneumatic-electronic transducers for controllers and pressure/flow etc. were transmitted to controller electronically by an electronic transmiters. The working of DCS using basic logic diagrms and computers is given in Fig. 2/2a.
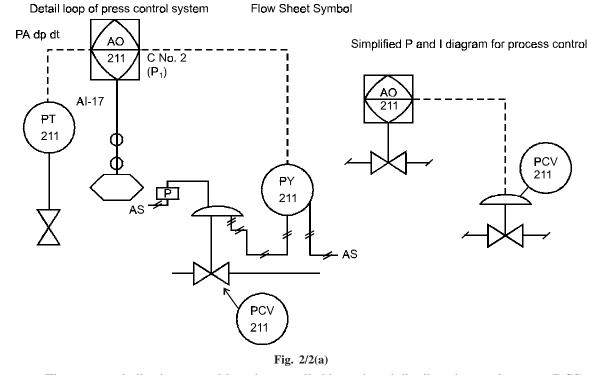
2. Line symbol-all lines should be firm in relation to process:
line symbol

Undefined signal		Y - Relay (time function)
Connection to process or mech.		Ux - Driving relay As - Air supply, 100 PSIG
		Es - Electric supply, 24 VDC
Pneumatic Signal		Ns - Nitrogen supply Ws - Water supply
Elec. Signal		SS - Steam supply
		A - Analog
Capillary tubing		D - Digital
		Input output sequence
Hydraulic signal		E - voltage
		I - current
*Electromagnetic or sonic signal		O - electron magnetic or sonic P - Pneumatic
Internal software link software or data link		R - Resistance etc. Sp - Set point
Mech. Link		H - Hydraulic

* Include heat, light, neuclear radiation of radio waves
Detalied loop: ------ It is a simplified in P and I diagram.

The Figs. 2/2a give the idea about how a loop can be combined with symbols. Left side look as it would appear in detail P and I diagram while on right side as it would be appearing in process flow diagram.

Fig. 2/2(a)

The pressure indicating control loop is controlled by a shared distributed control system (DCS). The set point of this controller is received from a supervisor computer over a shared data high way

that provides soft ware link between the computer and (DCS) system. The control loop tag no. is 211 which indicates this is 11th instrument on flow sheet no. 2.

On the measurement side of loop is an electronic (4–20 mA dc out put) pressure transmitter which is connected to the process pipe by a ½ inch valve and has a range of 0–300 psig. The output from transmitter is received and identified at the multiplexer of DCS system as analoging input no. 17 (A1–17). The controller PIC 211 is found on control no. 2 (C–2) of the DCS system and is provided with proportional and integral PI Algorithm. DCS system also provides a high pressure alarm function PA and a high rate of pr. rise alarm functions on this measurement.

The analog signal leaving the multiplexer in the out put side is identified as AO–211. The signal is 4–20 mA DC signal which is received by a current to air coverter (PY–211) mounte on the control value. The peneumatic out put signal from I/P converter goes to the diaphragm motor of the control value. Air supply is provided for both valve positioner (P) and I/P converter. Therefore, (a) process function diagram which gives a site specific logic diagram Fig. 2. (a) P and I diagram Fig. 2(b) and (c) a hardware diagram giving detail wiring diagram, will constitue the basic drawings for a process plant. Such set of drawings should be provided by the plant designer.

5.3 PRESSURE MEASUREMENT IN FLOWING FLUID

The formula is :—

$$P_{total} = P_{stat} + P_{dyn} \ in \ kg/m^2 \ (mm \ water\text{-}column).$$

The total pressure at the mouth and the static pressure in the annular slot are measured using a Prandtl tube. The difference between these two pressures represents the dynamic pressure. If no Prandtl tube is available, the total pressure may be measured with the aid of a simple Pitot tube and the static pressure by drilling the tube wall. The interior of the bore thus drilled must be satisfactorily deburred.

The velocity is obtained from :

$$w = \sqrt{\frac{2g}{\gamma}} \ P_{dyn} \ in \ m/s.$$

For cold air, the following is sufficiently accurate :

$$w = 4\sqrt{P_{dyn}} \ in \ m/s.$$

The driver power required by a blower is :—

$$N = \frac{Q \cdot \Delta P_{total}}{102. \eta} \ in \ kW$$

Where Q is the delivery in m^3/s, ΔP_{total} the difference in total pressure up-stream and down-stream of the blower. For planning purposes it is generally sufficient to use, for ΔP_{total}, the static delivery pressure ΔP_{stat} + approx. 20 mm water-column for the dynamic pressure at the blower outlet. The efficiency η lies approximately between 60 and 80%.
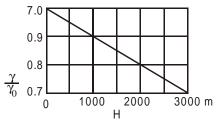
Fig. 3. Relation between density of air at H*t* and sea level.
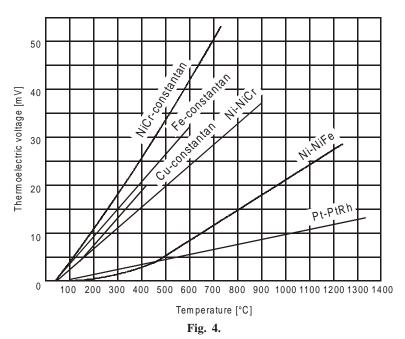
The relationship beween the density γ of the air at ground-level and its density γ_0 at sea-level at the same temperature can be seen from the above curve*) :

When planning a boiler blower or induced-draught plant at a ground-level H_2 it should be remembered that the delivery Q in m^3/s is greater than would be obtained with an identical boiler at sea-level in the proportion $\dfrac{\gamma_0}{\gamma}$, and the same applies to the delivery pressure; in these conditions the power consumption increases in a square-law relationship.

Source : Borsig pocket book 3rd edn. 1970.

5.4 THERMOELECTRIC MEASUREMENTS

The thermoelectric voltage (EMF) in a thermocouple depends on the temerpature difference between the two junctions and may be used for the purpose of temperature measurement when one of the temperatures is known.

Fig. 4.

The graph shows the value of the thermoelectric voltage in millivolts and its variation with tempearture for the thermocouples most frequently encountered in industry (reference temperature of cold junction +20°C).

The curve provide only approximate values, since the relationship between temperature and thermoelectric voltage is influenced by the alloy used in the wire.

If the temperature at the cold junction (t_m) at the time of measurement is different from the reference temperature obtaining during calibration (t_b), the true temperature at the point of measurement (t_w) will be :—

$$t_w = t_r + C (t_m - t_b) \text{ in °C. } (t_r = \text{temperature read})$$

If the voltage curve rises in direct proportion to the temperature, the factor C is equal to 1 (e.g., for Ni-NiCr).

Where the curve does not run straight, C depends on the value of the temperature under measurement. For Ni-NiFe thermocouples C = 0 and the temperature read (t_r) is unaffected by temperature changes at the reference junction, being identical to the ture temperature (t_w).

5.5 KEY POINTS IN SETTING INSTRUMENT CONTROLLERS (PNEUMATIC)

Proportional band (P.B.)

Decreasing P.B. (thereby increasing gain) increases the decay ratio thus making the system less stable. However, frequency of response is increased which is desirable. Increasing the P.B. has an opposite effect.

Reset mode (R.M.)

When the reset time is increased the decay ratio is decreased, thus making the system more stable. Simultaneously, frequency of response increases. Decreasing R.M., has an opposite effect. When the reset time is made maxm., the R.M. is tuned out of controller.

Derivative mode (D.M.)

The effect of this mode is most difficult to predict. Starting at Ø and increasing derivative time is beneficial upto a certain point beyond which increasing D.M. will be detrimental. To check the effect of increasing the derevative time and set accordingly.

N.B. Critical controllers viz temp. controllers are usually have 3 mode controls.

Table 23 : Moisture content of compressed instrument air

Dew Point	Moisture content
°C	W/V
0	3800 ppm
−5	2500 ppm
−10	1600 ppm
−20	685 ppm
−30	234 ppm
−40	80 ppm
−60	6.5 ppm
−80	0.3 ppm

Note : For IA, dry air at −40°C dew point is preferable.

Table 24 : Thermocouple element temp. ranges
Ref. cold junction temp. 0°C

Thermocouple	Temperature range (°C)
Iron-constantan	0-815
Chromel-constantan	(−) 150-980
Chromel-Alumel	(−) 150-1250
Copper–constantan	(−) 93-980
Platinum 87-RH 13	0-1645
Platinum 90–Rh10	0-1645

Platinum 70-Rh30/Platinum 94-RH6	0-1800
Tungsten 74–Re 26	(–) 18-2300
Copper–Gold-Cobalt	(–) 230 - (–) 18
Ir. 40 - Rh 60	(–) 18 - 2090

Table 25 : Recommended Temperature Range for Thermocouple Extension Wires

Thermocouple		Extension wire		Range °F
+	–	–	+	
Platinum-rhodium	Platinum	Copper	Copper-nickel	75 to 400
Chromel R	Alumel R	Chromel R	Alumel R	0 to 400
	Copper	Constantan R	75 to 200	
	Iron	Copper-nickel	75 to 400	
Iron	Constantan R	Iron	Constantan R	0 to 400
Copper	Constantan R	Copper	Constantan R	–75 to +200

Table 26 : Advantages of Electronic and Pneumatic Controlling

		Electronic	Pneumatic
1.	Accuracy, %	0.25 – 0.5	0.5 – 1
2.	Control loop	Fast action	Fast action not possible
3.	Remote transmission	Possible	only upto a distance of about 250 ft.
4.	Computer control and (PLC) Control data processing	Possible	Not available now.
5.	Final element control (control value)	Electrically operated or by Electro-pneumatic transducer	pneumatic control
6.	Ease of maintenance	Requires less maintenance but fault detection may be time consuming.	Maintenance is simpler.
7.	Nature of instrument systems	Costlier	Less constlier.

N.B. Instrument air (dry) is usually supplied at 7 kg/cm^{2}g at preferably –40°C dew point.

INSTRUMENTATION-PRACTICAL GUIDE

1.0. CONTROL VALVES FOR

		Type of control modes
(*i*)	Temperature controllers	Percentage proportional-reset-rate (3 mode controllers) Auto reset type
(*ii*)	Flow controllers	Percentage proportional-reset type (2 mode controllers)
(*iii*)	Ratio controllers	Percentage-reset type (2 mode controller)
(iv)	Level controllers	Proportional-reset type (2 mode controller)
(v)	Proportional controller	Proportional-reset type (2 mode controller)

N.B. For pneumatic control

2.0 THERMOMETER

(*i*) Locally mounted thermometer upto 8m indistance from impulse pt. shall be dial type bimetallic. Liq. filled/mercury type may be used for low temperature services.

3.0 THERMOCOUPLES

1. Resistance type upto 350°C or less.
2. Iron-constantan upto (350°C–450°C)
3. Chromel-Alumel upto (450°C–850°C)
4. See temp. range of thermocouples in table-24 (instrumentation).

4.0 RECORDERS

Multipoint recorder shall be Electric type with maxm. 12 points.

5.0 CONTROLLERS

1. Auto-manual change over switches to be provided.

   2. Control point of controllers may be 75–80% of full scale range.

   3. Reset rate mode to be added for precision control with added sensivity.

6.0 PRESSURE MEASURING ELEMENTS

   1. Bellow, diaphragm or manometer upto 5 kg/cm^2.

   2. Spiral or helical type upto above 5 kg/cm^2.

   3. Diff. pressure measurement shall be made with bellow or diaphragm type instrument for pressure below 2 kg/cm^2g.

   4. Dial range of pr. gauges shall be twice the operating pressure.

   5. Phosphor bronze or A1 brass tubes to be used for air, water, or steam services.

7.0 TRANSMITTERS

   1. Elec/pneumatic type transmitters for press. and temp. controllers.

   2. Flow transmitters will be pneumatic type.

8.0 VALVE POSITIONERS

They are intended to eliminate incorrect positioning of control valve due to hysteresis and friction between valve stem and packing material. The positioner in effect, a closed loop controller that has the instrument signal as input, diaphragm pressure as output and feed back from valve stem.

They are installed for :

   1. Butterfly valve sized 4 inch or above.

   2. Temp. control valve above 200°C.

   3. Distance from controller to control valve exceeds 50 m.

   4. Control valve with extra deep gland packing.

   5. Double seated control valve 1 inch and above.

   6. Single seated valve 2 inch and above.

   7. For services where close control is reqd. or hunting is to be avoided.

   8. Where control valve requires valve positioners these shall be force balance type.

   9. Vol. Booster and spl. purpose relay may be incorporated into the control loop to overcome lag time or accomplish spl. control function.

10. CONTROL VALVES TYPES

It comprises single or double seated glove valve, and actuator (spring loaded) which operates on signals from controllers. Control valve can also be available in the diaphragm or butterfly design. The actuator can be pneumatic, electric or hydraulic in action. Controlled air pressure to diaphram determines the valve opening either air to open or air to close.

   1. All control valves of port sizes 1/2" or smaller shall be single seated. Above ½ inch double seated valves are used which however do not give tight sealing.

   2. Butterfly control valves to be used in large sized lines and where low press. drop in desireable.

3. 3-way control valves are either combining types of divergent types also.Hand wheels are usually provided.

4. By pass valve for control value of size 1/2" or more.

5. Emergency control valves shall not be provided with by-pass valve.

6. Hand wheels are not provided in emergency control valve.

11. SOLENOID VALVE

Usually solenoids are applied to sliding stem of valve; the stem is provided with an armature, drawn into field of solenoid wiring and current passes through it. It is normally used for emergencey shut off service. Solenoid force must be sufficient to move the valve plug held by a spring in opposite direction.

12. CORRECTION FRACTORS FOR ORIFICES

1. Steam orifices

$$K_S = \sqrt{\frac{\rho sm}{\rho sd}}$$

Where K_s = Correction factor.

ρ_{sm} = Steam density at operating conditon.

ρ_{sd} = do-at design condition

For Rupture disc, the discharge co-efficients are as follows :

Vapour = 0.80 ; Liquid = 0.60.

2. Gas orifices

$$K_g = \sqrt{\frac{\rho_m}{\rho_d}} \times \sqrt{\frac{T_d}{T_m}} \times \sqrt{\frac{\rho_d}{\rho_m}}$$

Where K_g = Correction factor.

$\rho_d \, \rho_m$ = Press, at design and operating conditions.

τ_d, T_m = Temperature at design and operating condition.

ρ_d, ρ_m = Gas densities at design and operating condition.

3. Oval flow meter

$$E_2 = E_1 - K \frac{\mu_1 - \mu_2}{\mu_1 \times \mu_2}$$

where K = 0.12

μ_1, μ_2 = viscosities at design and operating condition.

E_1 = design

E_2 = correction factor.

13. PR. RELIEF VALVES DISCHARGE

1. For inflamable gases, the discharge shall be made to a flare stack header with a separator at bottom with LPG stage ignition system.

2. When it is dangerous to discharge a gas near the relief valves or discharge is poisonous, it should be discharged into atmosphere at least 3m above any service platform within a radius of 15m.

3. Liq. ammonia or hazardous liquids should be discharged in a separator and vapour from the separator led to top of the structure with liquid draining to a closed drain.

N.B. The calculated value of relief discharge shall be multiplied by discharge co-efficient as follows :

$$\text{Vapour} = 0.95; \text{Liquid} = 0.40$$

For Rupture disc, the discharge co-efficents are as follows:

$$\text{Vapour} = 0.80; \text{Liquid} = 0.60$$

1. For relief valves in Liquid Ammonia service

NH_3 service, use API Fire service formula for capacity determination.

Calculation for adequacy of discharge capacity of Safety Valves.

600 MT/day liq. ammonia Horton sphere

2. API Fire sizing formula :

$$O = 21000 \, F \, A^{0.82} \, \text{B.T.U/hr.}$$

where, A = Total wetted surface area (ft^2)

F = Environmental factor

Q = Total heat absorption into the wetted surface B.T.U./hr.

Example

Here, Total surface area for 8.5 m radius sphere

$$= 4\pi, \, 8.5^2 = 908 \, \text{m}^2 = 908 \times 10.76$$

$$= 9770 \, \text{ft}^2.$$

taking wetted perimeter factor of 0.80

$$A = 9770 \times 0.80 = 7816 \, \text{ft}^2$$

$$A^{0.82} = 7816^{0.82} = 1569$$

$$F = 0.75$$

∴ $$Q = 21000 \times 0.75 \times 1569$$

$$= 24.71 \times 10^6 \, \text{B.T.U./hr}$$

$$\text{Now, relief capacity} = \frac{Q}{\text{latent heat of vaporisation}}$$

Latent heat of ammonia at –2.2°C from chart in Chemical Engg. handbook (Perry)

$$= 305 \, \text{Kcal/kg.}$$

$$= 549 \, \text{B.T.U./lb.}$$

∴   Relief valve cap. $W = \dfrac{24.71 \times 10^6}{549}$ lbs/hr. $= 4.50 \times 10^4$ lbs/hr.

$$= 20460 \, \text{kg/hr.}$$

Safety valve rated capacity provided = 21500 kg/hr therefore, relief valve blow down rate is O.K.

3. Formula for S.V. sizing for sphere

$$A = \frac{W}{P} \times \frac{1}{C \times k \sqrt{\dfrac{m}{T_z}}}$$

Where   A = Orifice area, in^2

W = Rated capacity in lbs/hr = 21,500 kg/hr = 47300 lbs/hr.

P = Flow pressure PSIA = 3.85 × 14.22 + 14.7 = 69.44 PSIA

M = Mol. wt. = 17 (NH_3)

T = Temp°R = –2.2°C = 488°R

Z = Compressibility factor = 1

C × K = 337 (as per crossby data of valve manufacturer)

$$\therefore \qquad A = \frac{47300}{69.44} \times \frac{1}{337 \sqrt{\dfrac{17}{488}}}$$

$$= \frac{681.16}{337 \times 0.186}$$

$$= 10.866 \ in^2.$$

Orifice area provided = 11.05 in^2; therefore, valve size is adequate.

Note: Usuallly double safety valves are reqd. for maintenance.

Table 27 : Wave lengths of ionising rays

Gamma rays	....	10^{-9} μm
X-rays	....	5×10^{-2} to 5×10^{-6} μm
Visible light	....	0.35-0.75 μm
Ultra violet rays	....	0.005 to 0.35 μm
Infrared rays	....	0.75 to 500 μm
Microwave	....	above : 500 μm
Radio waves-short wave	....	1×10^2 μm
Long wave	....	1×10^8 μm

Table 28 : Wave length of visible spectrum of light wave

		Wave length
Red	=	7000 Angstrom (Å) unit
Orange	=	6500 Å
Yellow	=	6000 Å
Cyan	=	5750 Å
Green	=	5500 Å

Blue	=	4500 Å
Violet	=	4000 Å

N.B. 1. One Angstrom (Å) unit is 1/10,000 of a micron.

2. Red light having longest wave length is of lowest frequency.

3. Violet rays having shortest wave length, makes it rays of highest frequency.

4. Ultra violet radiation wave length-360-380 nm.

Table 29 : Sound decibel levels

Normal level for continuous 8 hrs. = 65 decibel.

Maxm. permissible level for short period = 90 decibel

Note : Sound level or sound press. is measured at 2 m distance from machine emitting sound. Sound level in decibel is 20 times the log to the base 10 of the ratio of effecive value of measurement and a reference sound press. generally. 20 μp_a (2×10^{-4} μ bar).

Chapter 7

GENERAL

Table 30 : Division of Botanical plant kingdom

Thalophytes   -   Algae, fungi, bacteria etc.

Bryophytes   -   Tiver worts or mosses etc.

Pteridophytes   -   Ferns, sounding rushes, club mosses and qurill worts etc.

Super mytophytes   -   All seed plants including coniferous and deciduous trees.

Table 31 : International Paper sizes

Sizes	mm	inches
A0	841 × 1189	33.1 × 46.8
A1	594 + 841	23.4 × 33.1
A2	420 × 594	16.5 × 23.4
A3	297 × 420	11.7 × 16.5
A4	210 × 297	8.3 × 11.7
A5	148 × 210	5.8 × 8.3
A6	105 × 148	4.1 × 5.8
A7	74 × 105	2.9 × 4.1

Table 32 : Sections in patent classifications

Section 1   =   Human requirements

Section 2   =   Chemistry and metallurgy.

Section 3   =   Physics

Section 4   =   Fixed constructions

Section 5   =   Electricity.

Section 6   =   General

Table 33 : Earth Quake record in India

Location	Year	Reichter Magnitude
Cachar (Assam)	10.1.1869	7.5
Assam	12.6.1897	8.7

Srimangal	8.7.1918	7.6
Jainthia Hills (Meghalaya)	9.9.1923	7.8
Assam	15.8.1950	8.5
Manipur-Burma (Border)	6.5.1994	6.6
Gujrat Kutch area and Ahmedabad	26.1.2001	7.9

Table 34 : Fire Classification

A-class : Involves wood, paper, grass and can be cooled down with water. Soda acid extinguisher and sand buckets reqd.

B-class : Involves oils, combustible liquids, paints; can be handled by cutting off O_2 supply and using water-foam. CO_2 extinguisher, sand buckets are reqd.

C-class : Involves electrical equipment and wiring. Proper earthing need to be maintened. CO_2 and CTC extinguisher reqd.

D-class : Involves metal fire, can be tackled by using special dry powder extinguisher, sand buckets.

E-class : Involves combustible gas fires which can be controlled by stopping gas supply and sorrounding air cooled by water jets.

Chapter

8

GLOSSERY OF TERMS IN CHEMISTRY AND OHTERS

1. Normal solution–A soln. containing one gm. equivalent wt. of the solute dissolved per lit.

2. Sub normal solution–A soln. contg. a fraction of gm. equivalent wt of the solute dissolved per lit.

3. Normality factor–It is the ratio between strength in gms/lit and eq. wt. of solute dissolved.

4. Molar soln.–A soln. contg. one gm-mol. wt. of solute dissolved per lit of solution.

5. Molal soln.–A soln. contg. one gm-mol. wt of the solute dissolved in 1000 gms of solvent.

6. Equivalent wt. of acid, base or a salt $= \dfrac{\text{Molecular wt.}}{\text{Total + ve valencies}}$.

7. Gram molecular volume–It is the volume occupied by 1 gm. mol. wt. of any gas and is found to be 22.4 litres at N T P (G. M. V.) or 1 lb mole of any gas will occupy 359 cft at NTP or 1 kg-mole of any gas will occupy 22.4 m^3 at N.T.P.

8. Volatility–The volatility of a component in a mixture of liquid is defined as its partial pressure in the vapour in equilibrium with that liquid divided by its mole fraction in liquid *i.e.,* $R_a = P_{a/x_1}$.

9. N.T.P. or S.T. P.–It is reckoned as 0°C or 273° Kelvin and 760 mm pressure and is called normal or standard temp and pressure.

10. Atomic wt.–It is the average relative wt. of an atom of an element compared with that of oxygen atom taken as 16. It is only a number.

$$\text{Atomic wt. = Equivalent wt.} \times \text{valency.}$$

11. Molecular wt.–Mol. wt. of a substance is the no. of times its molecule is as heavy as one-sixteenth of oxygen of atom. It is also the sum of wts of all atomic weights in the molecule.

12. Basicity–For acids, it is the no. of replaceable hydrogen in one molecule of acid.

$$\text{Eq. wt of a acid } = \frac{\text{Mol. wt.}}{\text{Basicity}}$$

13. Acidity–For caustics, it is the no. of replaceable OH groups in one molecule of base.

14. $$\text{Eq. wt. of a base} = \frac{\text{Mol. wt.}}{\text{acidity}}$$

15. Valency–As per electronic theory of valency it is the no. of electronics in the outer most orbit of an atom, which can be lent, borrowed or shared.

16. Specific heat–Heat reqd. to increase the temp. of unit mass by 1°C.

17. Latent heat of vaporisation–Heat given off when unit mass of the vapour of a substance condenses to form liquid without change in temp.

18. Heat of fusion–Amount of heat needed to be added to a unit mass of solid to change it to its liquid phase. It is the change in enthalpy between the liquid phase and vapour phase at the same temp. and press.

19. Solidification temp.–The temperature at which a liquid changes to a solid (equal to its m.p.)

20. Heat of vaporisation–Amount of heat needed to be added to unit mass of liquid to change it to its gaseous phase without change in temp.

21. Heat of solidification–Amount heat to be removed from unit mass of liquid to change it to solid phase (Equal to heat of fusion).

22. Heat of crystallisation–It is the amount of heat to be removed from a supersaturated soln. of a salt so as to facilitate crystallisation of the salt. Often seeding is reqd. for start of crystallisation.

23. Peptides–A class of chemicals that forms Proteins.

24. N.M.R.–Nuclear magnetic resonance system used in spectrophotometer.

25. Glass transition temp (GTT), plastics–It is the ability of a material to crystallise and where relevant, it is the crystalline m.p. In case of amorphous polymer G.T.T. will define whether or not a material is glass like or rubbery at a given temp. Ability of a material to crystallise is determined by regularity of its molecular structure. Many polymers (excl. co-polymers) have G.T.T. less than M.P.

26. Surface tension–It is the attractive forces between atoms or molecules.

27. Battery rating–Based on 8 hr. rate of discharge, A 320 amp. hr. battery has a normal rating of 40 amp. hr.

28. Cetene no–For diesel only; indicates smooth burning and easy ignition (usually 40–60°C).

29. Calorie–Amount of heat reqd. to increase the temp of 1 gm of water by 1°C.

30. Heat radiation–It is measured in units of power, W/m^2 or W/cm^2.

31. Nitrite nitrogen–At concetration of 10–20 ppm in water it may cause meglobinemia in inants.

32. Solubility Product–The product of the concentration of ions of a salt in a solution at a definite temp. is called solubility product. A reaction becomes possible due to shift of ionic equilibria as per theory of ionisation. If conc. of each ion of Ca^{++} and $SO_4 =$ is 1.5×10^{-2} gm ions per litre than solubility product becomes (Ca^{++}). $(SO_4)^F = 1.5 \times 10^{-2} \times 1.5 \times 10^{-2}$ $= 2.25 \times 10^{-4}$. The effect of electrostatic forces acting between the ions on the solubility of an electrolyte is very small. In case of slightly soluble electrolytes the influence of these forces may be neglected. If an ionic equilibrium is shifted towards right or left due to presence of other ions in the soln, then it will be precipitated when the solubility product of the ions exceed, resulting in decrease of ionic conc. of the ions of the salt in soln.

33. Heating value of a fuel (Dry basis) = Gross heating value $\times \dfrac{30}{29.92} \times \dfrac{30 - 0.522}{30}$

34. Geotropic distillation–Normal distillation of binary and terniary systems having normal equilibrium curves for liq. and vapour phases.

35. Periodic table–Mendeleeff's period table was discovered in 1869 and consists of 0–8 group of elements arranged in a way which states that properties of elements are a periodic function of their atomic weight. There are about 204 elements in the periodic table now. New elements are being added in Actinide series.

36. Refractive index, nD_{25}–1.5432 of a compound or material denote R.I. determined at 25°C and value measured is 1.5432 by sodium light of wave length 549 nm. and means optical rotation. (where ever indicated).

37. B.M.C. index–Bureau of mines (US) co-relation index for carbon black properties viz viscosity, temp. of solidification, alkaline content, sulphur and medium boiling point.

38. Fusel oil–Contains propanol, butyl alcohol, isobutyl alcohol, amyl alcohol etc.

39. Pyrolysis gasoline–It is an excellent source of BTX and obtained in petrochemical processing.

40. General trends in physical properties :

     (*a*) Latent heat of substances decrease with increase of press. and temp.

     (*b*) Heat capacity of a liq increase with increase of temp.

     (*c*) Heat capacity of gases do not greatly affected by small variation in press. at lower press. However, at low temp. near normal B.P. the effect is more.

     (*d*) At critical point, heat capacity increases rapidly.

     (*e*) Kopp's rule : Heat capacity of a solid compound is equal to the sum of heat capacities of the constituents materials.

41. Phase Rule–It is applicable when a system is in equilibrium.

     For non reactive components/for reactive components

     F = C + 2 – P   F = N – R + 2 – P

     Where   P = no. of phases,

              C = no. of chemical species which do not enter into reactions.

              F = degree of freedom or variance.

              R = min. no. of independent reaction.

              N = no. of chemical species in the system which enter into reaction.

42. Ossein–Cattle green bones from slaughter houses are cleaned, degreased, dried, sorted and crushed to 1–1.25 cm size. It is then treated with HCI to remove mineral salts, mainly Cal. phosphates. The residue is ossien.

43. Gelatine–It is formed by hydrolysis of collagen protein into single chains. It is a mixture of protein fragments of varying molecular mass. Pigskin gelatine is edible grade.

44. Gum Karaya–Gummy exudation of Stereytia Companulata tree used for varnish, lacquers, ink, polish and paper coating and engraving.

45. Gum rosin–Pine resin. also obtained from distillation of crude turpentine; used in soap,

    varnish, paint driers, wax composition, high speed machine lubricant, printing ink and medicine.

46. Guar gum–Mucilage formed from seeds of guar plant. Used as thinkening agent in paper, foods, pharma and cosmetics.

47. Selexol–Dimethyl ether of polyethylene glycol.

48. Gama acid-2-amino-8-naphthol-6 Sulphonic acid.

49. Pour point–It indicates the temp at which an oil ceases to flow and is important for low temp. operation.

50. Deemulsification value of an oil–It is associated with the operation of steam turbines.

51. Acidity of an oil–In mineral oil it is a almost negligible, oxidation of fatty oils gives rise to free fatty acids. (Inhibitor for oxidation of mineral oils are β naphthol and phenyl ∞ naphthalamine. Acidity is indicated in mg KOH/100ml.

52. Aniline point of an oil–It is the lowest temp. at which the oil is completely soluble in an equal volume of aniline. It indicates action on rubber.

53. Fire point of an oil–It is the temp. at which an oil just commences to burn continuously when ignited. It is approx. 60°F more than open flash point.

54. Iodine value–Iodine value of a vegetable oil indicates extent of unsaturation.

55. Saponification value–For a vegetable oil it indicates hydrolysis and expressed in mg. KOH/100 ml.

56. Flash point of an oil–It is the temp at which it flashes into vapour or condenses when cooled.

57. Oleochemicals–These chemicals include fatty acids, glycerine fatty alcohols, fatty amines and derivatives, fatty acid methyl esters, castor oil derivatives and soaps. The chemicals are manufactured from vegetable oils and fats. Some fatty alcohols are listed below which are used to make salts viz F.A. Carboxylates, ether sulphates/sulfides etc.

    (*i*) Fatty alcohol ethers

   (*ii*) Cetyl alcohol

  (*iii*) Lauryl alcohol and

  (*iv*) Stearyl alcohol.

    Fatty amines are used in road construction, effluent treatment and textile processing.

58. Polyurethane–New raw materials are adiprene and vibrothane.

59. RON. Research Octane No.–It gives the degree of severerity in reforming process in a refinery.

60. Epoxy ring molecule–

61. Curing agents–For epoxy adhesives, it is organic acid anhydrides and aliphatic amines (MDA, DPS and DETA). Common epoxy resin is DGEBA (diglycidyl ether of bisphenol).

62. Latex–Aqueous suspension of minute natural rubber particles which are kept in suspension by an adsorbed layer of protein. Natural rubber latex contains 30% to 60% solids.

63. Urethane–Common name for ethyl carbamate.

64.   Cold Vulcanising–By silicone rubber.

65.   Azadirachtin Indica–Active agent in "neem" seeds, leaves and bark.

66.   Equivalent wt.–It is the no. of parts by wt. of a substance which combine with or displace directly or indirectly 1.008 parts by wt. of hydrogen or 8 parts by wt. of oxygen or 35.5 parts by wt. of chlorine.

67.   Seasoning of wood by steam heating removes moistre upto 15%. Unseasoned wood contain about 50% moistre.

68.   Peat coal–It is the product of the 1st stage of formation of coals. Its carbon content is below 65% where as for anthracite, it is 95%. For brown coal or lignites carbon content is about 70%. Charcoal is having 100% carbon.

69.   Heat of solution–The quantity of heat absorbed or liberated when one mole of a substance is dissolved is called its heat of solution. The value is –ve if heat is abosrbed and +ve if heat is evolved.

70.   Oligomers–An oligomer is composed of molecules containing a few or more species of atoms or groups of atoms (constitutional units) repeatedly linked to each other. This, of course, does not indicate the absolute degree of polymerisation or molecular wt. which differentiates between an oligomer and a polymer. Physical properties of an oligomer vary with addition or removal of one or more of constitutional units from its molecule.

71.   Polymerization–The term polymerization is given to those reactions in which many small molecules combine together to produce very large molecules.

       The simple compounds from which polymers are made are known as monomers.

       Polymers have molecular wt. varying from 10,000 to over 1 million. There are two types of polymer (*i*) addition polymer and (*ii*) condensation polymer.

       Addition polymerization is by addition of monomers to form a single huge molecule. Example-Polyethylene. Polymers made from only one type of monomar are called Homopolymers.Condensation polymerization involves combination of monomers with the elimination of simple molecules such as H_2O or CH_3OH.

       Example : Polyethelene Terephthalate.

72.   Monomers–Simple organic molecule containing a double bond or a min. of two active functional groups. The process of transformation of a monomer molecule into a polymer molecule is called polymerization.

73.   Steroids–They are compounds mainly of plant or animal origin and composed of a series of 4 carbon rings joined together to form a structural unit called cyclopentenoperhydro phenanthrene. There are 64 compounds called stereoisomers with this structure can be possible. Important members are Sterol, male and female hormones.

74.   Radical–An atom or a group of atoms forming part of a compound and behaving like a single atom in a chemical change. In inorganic chemistry, there are acid and basic radicals and in organic chemistry there is hydrocarbon radical.

75.   Salt Eutectics–For reducing refrigeration plant loads, energy storage tanks, containing euitctic salt (Temp. range –33°C to +23°C) is used. Energy is stored by freezing an eutectic salt when latent heat of cyrstallization is released. When load demand increases the eutectic salt melts absorbing latent heat of fusion of eutectic salt.

76. Optical Glass Polish–It is processed Alumina powder size ranges from 0.05 – 3μ.

77. Synthetic rubbers–These are Styrene butadiene rubber (SBR), Acrylonitrile butadiene rubber (NBR), Polybutadiene rubber (PBR), EVA (Ethylene Vinyl Copolymer), EPDM rubber, Silicon rubber, Vinyl Pyridene Latex (V P Latex).

78. Mercerising–By treatment of cotton clothes/yarn with NaOH soln. at 50°–55°C gives cotton increased strength (10–40%) but results in shrinking (10–15%). By stretching cotton during caustic wash followed by water wash cotton shrinking can be reduced greatly and its lusture also increases.

79. M.P. of synthetic fibres :

Nylon - 6	=	215°C
Nylon - 66	=	250
Polyester	=	256
P.U. fibres	=	250
PAN	=	Decomposes
PVA	=	230–238
PP	=	163–175

CHEMICAL LAWS

80. Avogadro's Law–Equal volumes of gases under similar conditions of temperature and pressure contain equal no. of molecules.

81. Raoult's Law–The partial pressure of any component P_a in a soln. is equal to its V.P. in pure state times the conc. in liquid $P_a = X_a \times P_o$. Raoult's Law is applicatble for solvent and also stipulates that :

   (*i*) The lowering of freezing point of a soln. on cooling is proportional to the quantity of the substance dissolved in a given wt. of the solvent.

   (*ii*) Equimolecular quantities of various substances dissolved in the same wt. of a given solvent lower its freezing point by equal no. of degrees.

82. Boyle's Law–Temp. remaining constant, the volume of a gas is inversely proportional to its pressure.

83. Charle's Law–Pressure remaining constant, the volume of a gas is directly proportional to the absolute temperature.

84. Gas equation from Boyle's and Charle's Law :

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

85. Dalton's Law of Partial Pressure–If two or more gases which do not interact chemically are enclosed in a closed space, the total pressure exerted by the gaseous mixture is the sum of partial pressure, P_1, P_2, P_3 etc., which each gas will exert if present alone in that space or $P = P_1 + P_2 + P_3$.

86. Graham's Law of gaseous diffusion–At a specified temp. and pressure the relative rates of diffusion of gases through a permeable membrane are inversely proportional to the square roots of their densities.

Eqns : $\dfrac{r_1}{r_2} = \sqrt{\dfrac{M_2}{M_1}}$ or $\dfrac{t_1}{t_2} = \dfrac{r_2}{r_1}$

Where r is the rate of diffusion and

t time of diffusion process.

M is Mol wt. (Mol wt = 2 × v.d.)

87.   Law of mass action–The rate of reaction is proportional to the molecular conc. of each reacting substances.

$$K = \dfrac{K_1}{K_2} = \dfrac{C \times D}{A \times B}$$

Where C, D, A and B are products and reactants.

k_1, k_2 = velocity constants

K = Equilibrium constants.

87A.   Gay Lussac Law–Gases react in volumes which bear a simple relation-

(*i*) to one another and

(*ii*) to the vols. of products if gaseous.

88.   Le Chatelier Principle–If a system is in equlibrium and is subjected to a change of pressure, temp. or concentration, the equilibrium will then shift in a direction which tends to nullyfy the effect of change imposed.

89.   Henry's Law–The wt. of a gas dissolved in a given volume of a liquid is directly proportional to the pressure of the gas. The law holds good only for gases of comparatively low solubility and which do not react chemically with the solvent. It is primarily applicable to solute in soln.

90.   Hess's Law–The thermal effect of a chemical reaction depends only on the initial and final conditions of the reacting susbtance but not on the intermediate stage or stages of the process. The law can also be stated as the thermal effects of a chemical reaction equals the sum of heats of formation of the resulting substances minus the sum of heats of formation of the reactants. This is an important law of thermochemistry.

91.   Perfect gas law is PV = NRT.

THERMODYNAMICS

93.   Ist law of thermodynamics–The difference between heat and work done in a system is equal to the work transferred to the surrounding outside of the system.

$$Q_1 - Q_2 = W.$$

94.   2nd law of thermodynamics–It states that if the working fluid is to be reduced to its original state so that heat-work process could begin all over again, then some heat must be rejected to the surroundings.

95.   Internal energy change–It is equal to the amount of adiabatic work done on the system.

96.   Zeroeth law of thermodynamics–The law states that for any isothermal process involving only phases in internal equilbm. or alternately if any phase is in frozen metastable equilbm., then the change in entropy is 0 when T(abs) $\rightarrow$ 0.

97.   Equation of state–It is the relationship between average variables which give complete information about state of the systems.

98.   Adiabatic process–Where there is no transfer of heat from the system and no heat flow from external sources.

99.   Isothermal process–A process which is carried out at constant temp. Gas Constant, R–A constant in ideal gas equation of state having a value of 8.31 kj/kg mole°K.

100.   Reversible Process–A process is reversible when the thermodynamic potential differences between the system and surrounding are only differential in amount.

101.   Steady state process–It is a state in which there is no change in property at a given point with respect to time.

102.   For a throttling process change in enthalpy is 0 *i.e.,* $\Delta H = 0$ or $H_1 = H_2$.

103.   Extensive properties of a system depend on quantity of matter with the system e.g., total volume.

104.   Intensive properties of a system do not depend on quantity of matter e.g., press, temp. sp. volume and density. (macroscopic properties).

OTHERS

105.   Avogadro no. N–It is the no. of molecules present in one gm molecular wt. of any gas which is same for all gases and is determined to be 6.023×10^{23}.

106.   Atomic no.–It is the number of protons or no. of electrons in the nucleus of an atom of an element. Electrons carry a unit –ve charge.

107.   Atomic wt.–It is the sum of weights of Protons and Neutrons. Each proton carries a unit +ve charge and neutrons do not carry any charge.

108.   Electrons–Weight $\dfrac{1}{1846}$ of the of the weight of a hydrogen atom. No. of electrons distributed in extra nuclear part of an atom is given by $2n^2$ where n is the orbit no. However, the outermost orbit can not carry more than 8 electrons and the next inner orbit cannot carry more than 18 electrons.

109.   Isotopes–Forms of the same element having the same atomic no. but different atomic weights due to different nuclear structure.

110.   Nano technology–It is the science of creating molecular sized machines that manipulate matter, one atom at a time. The name comes from namometer– one by one billionth of a meter. This started in 1959 when physicist Richard Feyman proposed manipulating matter, atom by atom.

111.   Wobble no.–Gives the combustion characteristic of a gas. It is given by eqn. $W = C_g/\sqrt{d}$ where C_g is the gross calorific value of the gas and d is the specific gravity.

112.   Planck's Constant $= 6.624 \times 10^{-27}$ erg-sec.

113.   Mach no.–It is the ratio of flow velocity to the acoustic velocity.

114.   Coffer dam–A wall serving to exclude water from any side normally under water, so as to fascilitate laying of foundations or other similar work usually formed by driving sheet piles.

115.   Refrigeration–Thermoelectric (Peltier effect) is reverse of Seebeck principle.

116.   Electrostatic separation is effected by which charge is transferred to and from a particle through conductivity or electric differences in particles comprising the mixture. This is called electrophoresis.

117.   Dielectrophoresis is called to a phenomenon in electrostatic separation when there is no external transfer of charge but where polarisation is induced and separation occurs due to difference in polarisation levels.

118.   Earthquake factor–The percentage of combined dead and live loads that the tower must be braced to withstand as a horizontal load is called the earthquake factor. The factor varies from place to place. In USA the common value is 0.2 or 20%. In India, the common value is 0.1 or 10%; However, earthquake requirements is as per IS Code 1893.

119.   Ultrasonic sound frequency = 20 KH_2.

120.   Seasoned wood–contains 15% moistre and only top 2" is dried.

120.(a) Lethal dose, L_{D50} dose, specify lethal done to 50% of test animals usually rats (oral dose-Pesticidal effect).

121.   Decibel–It is the unit of sound press. level. It is 20 times the logarithim to the base 10 of the ratio of effective value of the measuring and a reference sound press. level, usually 20μ Pa (2×10^{-4}μ bar).

        Another unit in the accoustic engg. is the accoustic ohm which is the ratio of accoustic press. to the flow rate of sound in NS/m^2.

122.   ELC stainless steels–AISI 304L and AISI 316L contain 0.02% carbon. Such steel during welding or heat treatment near 1200°F do not sensitise and chromium carbide do not precipitate at grain boundaries and all the carbon is retained in solid soln. ELC S.S. has high corrosion resistance; likewise all austenitic S.S. including AISI 317. Minor carbide precipitation do not affect the tensile strength but may lead to premature metal failure. Immediate cooling by water after welding reduce carbide precipitation.

123.   Cladding of S.S.–Because of its own hardenability, the backing S.S. metal usually cannot be cooled rapidly enough to keep all carbon in S.S. in solid soln. Consequently, carbide precipitation in S.S. is inevitable during subsequent cooling. Also rapid cooling might damage the bond between the cladding material (S.S.) and the backing steel material because of difference in thermal expansion.

        By cladding about 1/4th of the cost of solid vessels can be saved provided the wall thickness is above 5/8".

124.   Flammable dust–Each flammable dust has a maximum explosive pressure when explosion can occur; plastic particle dust of size < 100 mesh has maximum explosive pressure of 80-120 lb/inch^{2}g. Presence of inerts (8-14%) maximum will not initiate combustion of plastic or flammable dust.

125. Welder/cutter capacity–Electrodes consumption per welder per day = 120 ft (M.S. rods) and oxygen consumption is 280 cft and acetylene consumption rate is 70 cft per gas cutter.

125.(*a*) Hardy Cross Method–It is used for cooling water network analysis. At steady state, the algebraic sum of all pressure losses (due to friction) is zero. For analysis, select flow rate and equal velocity or pressure drop criteria and flow pattern-clock wise (+ve) or anticlockwise (–ve). Usually pressure drop criteria is considered. This method can be used in steam network analysis.

126. Urea silo capacity–It is 1.8 te/m^2 when pile height is 3.0 meter. When the pile height is 5.0 meter, the storage capacity is 4.70 te/m^2.

127. Urea Prilling Tower Capacity–It is 0.17–0.19 te/m^2 for I.D. Prilling tower and air rate through the tower is 1000 NM^3/te and air velocity of 0.46–0.48 m/sec. Spinning bucket (hole dia 1–1.3 mm) speed in prilling tower is 370–380 r.p.m. for uniform size of urea prills.

128. Urea Prills Coating Mixture–The composition for avoiding caking in storage silo is Natural Paraffin 25% (maxm.), synthetic Paraffin 85% and soyabin oil 5%. Application is done by a spray.

129. Plexiglass–It is poly methyl methacrylate resin.

130. Magnetic drive–It is a German technology in which there is no drive shaft and gland for the pump as impeller is magnetically connected to magnetic drive motor. The advantage is 40% cost saving and less mechanical parts for the pump driven by magnetic drive.

131. Computer basics–1byte = 8 bits (combination of 8 bits) Each byte is a binary digit (0 or 1) and each byte represent an alpha numeric character or two decimal digits usually shorter than a word.

132. Heat Pump–A vapour compression heat pump, pumps 35 Kw of heat (501.06 Kcal/min) from say 7°C to 55°C will consume 15 Kw of electrical energy and gives out 50 Kw (715.8 Kcal/min) using R-12, 22 and R-134 refrigerants.

   A thermo electric heat pump using Seebeck effect does cooling of air or water or heat up air or water has low (10%) combined co-efficient of performance.

133. Ultra Violet light irradiation–L.P. quartz tube mercury vapour lamp is used which emit 95% ultraviolet radiation at 2537A^0. Often min. 3-4 shots are required for irradiation of drinking water. For food items min. 3-4 irradiation treatment is necessary.

134. Magnetic filtration–Electrostatic separation when there is no external transfer of charge to and form a particle.

134.(*a*) NOISH–Registry of National Institute of occupational safety and health in Washington DC, USA.

135. Wood measure:

   (*a*) Length in ft × width in inch × thickness in inch divided by 144 which gives volume in cft.

   (*b*) Running or board foot in 1 ft. square and 1 inch thick.

   (*c*) 50 cft of Burmateak approx. weights 1 Br. ton (2240 lb).

136. Transportation: FOR – Free on rail

   FAS – Free along side

   C and F – Cost and freight

CIF   –   Cost insurance and freight

FIO   –   Free in and out

Teu   –   Carrying capacity of containers in ships expressed in 20 ft equivalent length.

137.   Frozen foods–Refrigeration temperature level = –35 to –45°C.

138.   Aluminium–1 te of aluminium ingot requires 4 te of bauxite.

139.   Pig iron–1 te of Pig iron requires 1.44 te of iron ore (Fe_2O_3)–purity = 86.6%.

140.   Wind turbine–Min. wind speed required 6-7 miles/hr.

At wind speed 12m/hr, power generated = 12KW

At wind speed 15m/hr, power generated = 24KW

At wind speed of 22m/hr, power generated = 56KW.

Average output of a wind turbine through out the year is only 20% due to variation of wind speeds.

141.   Geothermal energy–Geothermal energy is tapped by drilling wells around hot springs. Hot water contg. NaCl gushes out from under the earth which do not boil as it is under high press and steam is released from collecting separators and flashed steam is used to drive power turbine. The exhaust steam from turbine is condensed and sent back to earth core well by a pump. Cooling water is cooled and recycled with make up water addition. Average temperature rise of water is 30°C/KM from surface temperature. Helium extraction from hot water is possible. Temp. of hot water reservoir below ground level is 150/250°C. Cost of power is about 1/4th of thermal power. A 30 MW plant cost is Rs. 60 Crores.

142.   Microwave radiation (oven)–Allowable limit 1000 µW/cm². Different countries have different limits ranging from 25-1000 µW/cm²; for Poland it is 200 and for USA and India it is 1000 µW/cm². Microwave radiation can cause damage to human immune system.

143.   Electrical field around–765 KV line, of the electric H.T. Power transmission line, field voltage generation is 10,000 volts/meter.

144.   Use of dry type of transformer–As per ammendment of central electricity rules in 2001 use of dry type of transformer is mandatory for residential and commercial buildings.

145.   ASME code for vessels–The relevant code specifies that if a mechanical equipment is under hot/cold cycles within 60000 cycles, then the equipment is permitted through out its life span.

146.   Osmotic pressure–It is the pressure applied to a salt solution separated by a semipermable membrane which allows solute to pass through but retains the solvent. The pressure applied is called osmotic pressure and depends on various factors viz. conc. of solute in soln. differential press. across membrane, and membrane properties. A small qty. of solvent also passes.

147.   Cryogenic gas–It is defined as the gas whose boiling pt. is less than 116°K. at one atomosphere.

148.   Wave power from sea water–The machine (tank and agitator) is placed in sea bed 300 m off coast by filled ballast tanks (usually 9) in 14.5 meters of water and operates by trapping swell of the ocean inside its partly submersed collector vessels. As the swell rises and falls

inside collector, air is pushed and sucked in through the top of structure turning two air turbines connected to 4 AC generators in two pedestals that rise 6 meters above surface; power is transferred through under sea cables. This facility exists; at a U.K. Coast and produces 2MW power and was commissioned by 1996.

149. Photographic camera–Normal lens can see within 45-60°. A 35 mm camera have about 50 mm focal length (distance between optical centre of lens to a pt. when image appears sharp when aimed at infinity. A camera lens having less than 40 mm focal length is called wide angle or short lens.

If it is over 80 mm, it is called telephoto long lens having 180° angle of view. Focal length of such lens varies between 80-200 mm.

150. Wrought iron–A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

151. Electron flow in a battery–Electric current is the result of flow of electrons and +ve ions. The electrons flow from –ve plate to +ve plate while the +ve ions flow from +ve plate to –ve plate in soln. The direction of conventional current in the external circuit is from +ve plate to –ve plate, thus the direction of flow of current is opposite to the direction of flow of electrons in soln.

152. Parkinson's law–In any organisation, the no. of subordinate staff multiplies at a predeterminable annual rate, irrespective of the quantity of work, the organisation turns out. Major reason being the bureaucratic attitude of the administrator which prevents him from exercising his initiative and creativity. The law was discovered in 1957.

153. Third law of thermodynamics–For any isothermal process involving only phases in internal equilibrium or alternately if any phase is in frozen metastable equilibrium, provided the process does not disturb the frozen equilibrium, then, $\lim T \to 0$, $\Delta S = 0$. Internal equilibrium of phase is fixed by its temperature, phase and composition. This is also called Zeroeth Law.

154. Laser–A laser is a device by which a beam of coherent light wave is obtained by pumping the atoms of dope (say chromium in ruby crystal) to an excited state by powerful source of light. The excited dope atoms cause the vibration of the neighbouring atoms to such an extent that they emit light wave of well defined frequency with two reflecting mirrors placed on both sides of ruby crystals, coherent light wave emission builds up along the axial direction. All the laser light radiate in phase with each other. In gas lasers two gases are used-one can be put to excited state and in other gas in which laser action is produced.

155. Special Theory of relativity (1905) of Einstein:

(*i*) There is no way to tell whether an object is at rest or in motion relative to a fixed ether. There is no ether wind.

(*ii*) Regardless of the motion of its source, light always moves through empty space with the same constant speed of 300,000 km/sec.

(*iii*) No object could move along with the speed of light. The velocity of light is the ultimate "light barrier".

Fitzgerald's contraction formula:

$$\sqrt{1 - \frac{V^2}{C^2}}$$

where   C = Vel. of light

V = Vel. of object.

The length of a moving object (spaceship) should be multiplied by the value of the above formula to ascertain the extent of contraction. As the spaceship goes faster and faster, its realistic mass keeps increasing in the same proportion as its lengths and time is decreasing.

When the moving spaceship has contracted to 1/10th of its length, its realistic mass has become ten times as greater and offering 10 times resistance to rocket motors.

156.   Electron speed–It can be speeded to 0.999999 times the velocity of light, consequently the mass of electrons has increased to 40,000 times than at rest.

157.   Loss of mass–Amount of mass lost in a chemical change in nuclear reaction is transformed to energy by the Einstein's equation $E = mc^2$ where m = mass lost, c = velocity of light and E = energy produced from lost mass.

158.   Mercerising–Cotton fabric treatment with NaOH at 50-55°C when 10-15% shrinkage occurs as well as strength is increased by 10-40%. Usually during caustic wash the cloth is kept stretched. Lustre also increases.

159.   OTEC–Ocean thermal energy conversion.

Here sea water's differential temperature at deep sea (–800 m) which is about 5°C and the surface water temperature being 25-28°C is used to evaporate liquid NH_3 in cooling coils which is placed in a closed chamber and sensible heat of deep sea water (5-25°C) or Δt 20°C is used to evaporate liquid NH_3 to vapour NH_3 and heating fluid temperature drops to 10°C which is sent back to suction. The vapour NH_3 from cooling coil is used to drive a turbo generator followed by condensation of NH_3 in a condenser with cooling water. India has high potential of OTEC power.

160.   Capacitance–It is the ratio of charge to the potential difference between conductors.

161.   Induction–It is the property of an electric circuit or of two neighbouring circuits where-by an emf is generated (by electromagnetic induction) in one circuit by change of current in itself or in the other circuit. It is the ratio of emf to rate of change of current.

162.   CNC–Computerised neumerical control (For mechanical workshop machines).

163.   DCS–Distributed control system-a system of computerised process control system. A Modern process control sequence in place of analogue, pneumatic and electric controls in, say, chemical process plants.

164.   Joule's Law–The quantity of heat produced in an electrical circuit is (*i*) proportionate the square of current (*ii*) proportional to the resistance and (*iii*) also proportional to the time for which the current flow.

$$H = \frac{C^2 R t}{4.186 \times 10^3}$$

where   H = Heat, Kcal

C = Current, amps

R = Resistance, ohms

t = Time in secs.

165. Infra red imaging system–An infra red camera measures the heat transmitted from facial blood vessels of a person. The picture thus obtained is called thermogram which is compared with the person's photograph and data stored in a computer. The computers recognition software concentrates on emission from 5 areas of face around eyes and forehead (Other areas are prone to change by change of air temperature). This method is used for proper identification.

Other use is detection of enemy at dark in night when the camera is put on the weapon or monitoring by a concealed camera in a space.

166. Reverse osmosis–It is the reverse of osmosis in which the solvent passes through the semipermiable membrane but retains the solute. Such feature is used in desalineisation of sea water, microfiltration of water cotaining pollutants present in minute quantities viz. pesticide, arsenic etc. This process depends on differential press, across the membrane, solvent, membrane properties etc.

167. DIN stand for German standard and the name symbolyses the cooperative work of German standards institutions.

168. CAS–Chemical abstract system for registration of all articles published on chemicals and is put a registry no. to facilitate quick detection in chemcial abstracts.

169. Kharif season (India)–June to November and Ravi season–March to November.

INDEX

FOR PART I

INDEX

FOR PART II

217