TECHNICAL GUIDE

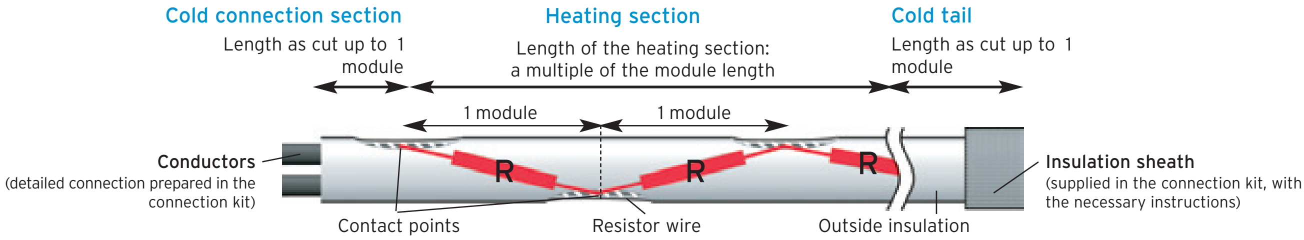
OPERATING PRINCIPLES

CONSTANT POWER CABLES

A constant power cable is a succession of identical resistors **R** connected in parallel, which makes it possible to have the same power dissipation on each of these sections.

These resistors are made up of a heating wire coiled around insulated conductor cables, with which it comes into contact at each contact point. These sections, between 2 consecutive contact points, are known as modules.

This is why the cable can only heat between 2 contact points, as shown in the following diagram:

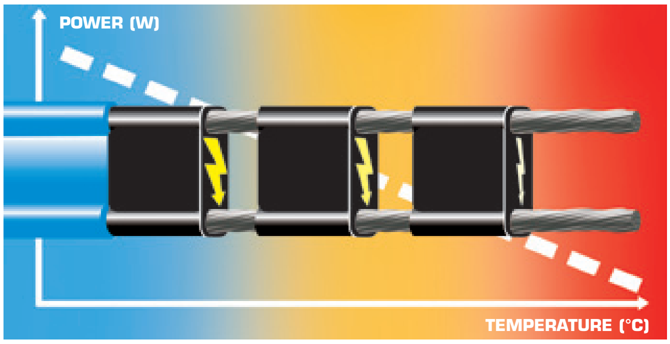


SELF-REGULATING CABLES

Between the conductors, the dark material which makes up the heating element is a polymer enriched with carbon as a conductor. The resistivity of this material varies with temperature because of the dilation of the internal structures which reduce the space available for the current to pass.

Consequently, when the temperature rises, the power dissipated by the cable decreases. This is the phenomenon referred to as **self-regulation**.
This prevents overheating which could damage the cable and allows the part of the cable placed in a colder environment to produce more energy in that zone.

When in operation, the cable will therefore always reach a balance between the power it dissipates and the losses due to the outside environment.
However, it is impossible to accurately determine at what temperature the surface of the cable will stabilise, because of the complexity and variability of its environment . Similarly, in order to keep control over the installation and to make significant energy savings, it is always recommended to adjust these cables by means of a thermostat.



NB: unlike the other heating elements, it is impossible to check that a self-regulating cable is operating correctly by measuring resistance with an ohmmeter. This can be done instead by measuring the voltage/current.

SERIES RESISTORS

A series resistor is an element with an electric current running between its two ends. It dissipates an amount of power governed by Ohm's law (cf. formula). As a result, any change in length, voltage or current is extremely tricky and means that we have to perform a new, in-depth study.

For series resistors sold by their Ohm/m rating (semi-finished products ordered by the metre or kilometre), a prior study is absolutely essential to at least be sure that the final cut length will produce a maximum power level that is in keeping with the recommendations of our technical documentation.

For finished products sold by their wattage (ordered individually), the power supply voltage must be strictly respected and the length never modified.

TECHHNICAL FORMULAE

OHM'S LAW:

The formulae linking the electrical variables of a purely resistive element are as follows:

$$U = R x I = P/I = \sqrt{(PxR)}$$
$$I = U/R = \sqrt{(P/R)} = P/U$$
$$R = U/I = P/I^2 = U^2/P$$
$$P = U x I = I^2 x R = U^2/R$$

where:
U: voltage in Volts (V)
I: current in Amps (A)
R: resistance in Ohms (Ω)
P: power en Watts (W)

WINDING PITCH:

The winding pitch is the distance between two successive turns of a cable wound round a cylindrical support. This winding should be used when the linear power obtained by straight tracing is insufficient or when very uniform heating is required.

$$P = \frac{\pi \times D \times L}{\sqrt{T^2 - L^2}} \qquad T = \frac{(\pi \times D \times L)^2}{P^2} + L^2$$

where:
P: winding pitch in mm
D: outside diameter of the support
L: total length of the piping
T: total length of the cable

USUAL METAL PIPE DIAMETERS

Nominal diameter DN (inches)	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12
Outside diameter D (mm)	13.71	17.14	21.34	26.67	33.4	42.16	48.26	60.32	73.02	88.9	101.6	114.3	141.3	168.27	219.07	273.05	323.85

LOSSES PER m OF PIPING: HEAT LOSSES TO BE COMPENSATED FOR IN ORDER TO MAINTAIN A TEMPERATURE

$$Q = \frac{\pi \times (Tm - Ta)}{\frac{1}{2 \times \lambda} \times Ln\left(\frac{D + 2 \times e}{D}\right)}$$

where:

Ambient temperature	Ta	°C
Maintenance temperature	Tm	°C
Outside dia. of piping	D	mm
Thickness of heat lagging	e	mm
Heat lagging lambda	λ	W/m.K
Theoretical losses	Q	W/m

IMPORTANT: this is a theoretical calculation and must be weighted using a safety coefficient which depends on how the installation will be used. Please consult us to evaluate this coefficient.

LOSSES in W/m FOR INSULATED PIPING

Thermal insulation thickness (mm)	dT in deg C	Dimension of the piping																		
		ND (mm)	8	15	20	25	32	40	50	65	80	100	150	200	250	300	350	400	450	500	600
		Ext. D (mm)	14	21	27	34	42	48	60	76	89	114	168	219	273	324	356	406	457	508	610
10	20		6.2	7.2	8.5	10	12	14	16	19	23	28.8	41.1	52.6	64.7	76.1	83.3	94.6	106	117	140
	30		9.4	11	13	15	19	21	25	29	35	43.8	62.5	80	98.5	116	127	144	161	178	213
	40		13	15	18	21	25	28	34	40	47.3	59.2	84.5	108	133	157	171	195	218	241	287
20	20		4	4.6	5.3	6.2	7.3	8	9.5	11	13	16	22.5	28.5	34.9	40.9	44.7	50.7	56.7	62.6	74.6
	30		6.2	7	8.1	9.4	11	12	15	17	19.8	24.4	34.2	43.4	53.2	62.3	68	77.1	86.2	95.3	113
	40		8.3	9.5	11	13	15	17	20	23	26.7	33	46.3	58.7	71.9	84.2	92	104	117	129	153
	60		13	15	17	20	23	26	30	35	41.2	50.9	71.4	90.5	111	130	142	161	180	199	237
25	20		3.6	4.1	4.6	5.3	6.2	6.9	8.1	9.3	10.9	13.4	18.6	23.5	28.7	33.5	36.5	41.4	46.2	51.1	60.7
	30		5.4	6.2	7.1	8.1	9.5	10	12	14	16.6	20.3	28.3	35.7	43.6	51	55.6	63	70.3	77.7	92.4
	40		7.4	8.4	9.5	11	13	14	17	19	22.4	27.5	38.2	48.3	59	69	75.2	85.2	95.1	105	125
	60		11	13	15	17	20	22	26	30	34.5	42.4	59	74.5	90.9	106	116	131	147	162	193
	80		16	18	20	23	27	30	35	41	47.4	58.2	81	102	125	146	159	180	201	222	265
	100		20	23	26	32	30	39	45	53	61.2	75.2	105	132	161	189	206	233	260	287	342
30	20		3.3	3.7	4.2	4.8	5.5	6.1	7.1	8.1	9.5	11.6	15.9	20.1	24.4	28.5	31	35.1	39.2	43.2	51.3
	30		5	5.6	6.3	7.3	8.4	9.2	11	12	14.4	17.6	24.3	30.5	37.1	43.3	47.2	53.4	59.6	65.8	78.1
	40		6.7	7.6	8.6	9.8	11	13	15	17	19.5	23.8	32.8	41.3	50.2	58.6	63.8	72.2	80.6	88.9	106
	60		10	12	13	15	18	19	23	26	30	36.6	50.6	63.6	77.4	90.4	98.4	111	124	137	163
	80		14	16	18	21	24	26	31	36	41.2	50.3	69.4	87.3	106	124	135	153	171	188	224
	100		18	21	23	27	31	34	40	46	53.2	65	89.7	113	137	160	175	197	220	243	289
	120		23	26	29	33	39	42	49	57	65.9	80.4	111	140	170	198	216	244	273	301	358
	140		27	31	35	40	46	51	59	68	79.3	96.8	134	168	204	239	260	294	328	362	430
	160		32	36	41	47	55	60	70	80	93.3	114	157	198	241	281	306	346	386	426	506
	180		37	42	48	55	63	69	81	93	108	132	182	229	279	325	354	401	447	494	586
40	20		2.8	3.2	3.6	4	4.6	5	5.8	6.6	7.6	9.2	12.6	15.7	19	22.1	24	27.1	30.2	33.3	39.4
	30		4.3	4.8	5.4	6.1	7	7.7	8.9	10	11.6	14.1	19.1	23.9	28.9	33.6	36.6	41.3	45.9	50.6	60
	40		5.8	6.5	7.3	8.3	9.5	10	12	14	15.7	19	25.9	32.3	39.1	45.5	49.4	55.8	62.1	68.5	81.1
	60		9	10	11	13	15	16	19	21	24.3	29.3	39.9	49.8	60.3	70.1	76.2	86	95.8	106	125
	80		12	14	16	18	20	22	25	29	33.3	40.2	54.8	68.4	82.7	96.2	105	118	132	145	172
	100		16	18	20	23	26	28	33	37	43	52	70.8	88.3	107	124	135	152	170	187	222
	120		20	22	25	28	32	35	41	46	53.3	64.4	87.6	109	132	154	167	189	210	232	275
	140		24	27	30	34	39	42	49	56	64.1	77.4	105	132	159	185	201	227	253	279	330
	160		28	31	35	40	46	50	57	66	75.4	91.1	124	155	187	218	237	267	298	328	339
	180		32	36	41	46	53	58	67	76	87.3	106	144	179	217	252	274	310	345	380	450
50	20		2.6	2.8	3.2	3.6	4.1	4.4	5	5.7	6.5	7.8	10.5	13.1	15.7	18.2	19.8	22.3	24.7	27.2	32.2
	30		3.9	4.3	4.8	5.4	6.2	6.7	7.7	8.7	9.9	11.9	16	19.9	23.9	27.7	30.1	33.9	37.6	41.4	48.9
	40		5.3	5.9	6.5	7.3	8.4	9.1	10	12	13.4	16.1	21.7	26.9	32.3	37.5	40.7	45.8	50.9	56	66.2
	60		8.1	9	10	11	13	14	16	18	20.7	24.8	33.4	41.4	49.9	57.8	62.7	70.6	78.5	86.3	102
	80		11	12	14	16	18	19	22	25	28.5	34.1	45.9	56.8	68.4	79.3	86.1	96.9	108	119	140
	100		14	16	18	20	23	25	28	32	36.7	44	59.2	73.4	88.3	102	111	125	139	153	181
	120		18	20	22	25	28	31	35	40	45.5	54.5	73.3	90.9	109	127	138	155	172	190	224
	140		22	24	27	30	34	37	42	48	54.7	65.6	88.2	109	132	153	166	186	207	228	269
	160		25	28	31	35	40	43	50	56	64.4	77.2	104	129	155	180	195	220	244	268	317
	180		29	33	36	41	46	50	58	65	74.6	89.4	120	149	179	208	226	254	282	311	367
80	20		2.1	2.3	2.6	2.8	3.2	3.4	3.8	4.3	4.8	5.7	7.4	9	10.7	12.3	13.3	14.9	16.4	18	21.1
	30		3.2	3.5	3.9	4.3	4.8	5.2	5.8	6.5	7.3	8.6	11.3	13.7	16.3	18.7	20.2	22.6	25	27.4	32.1
	40		4.4	4.8	5.2	5.8	6.5	7	7.9	8.8	9.9	11.6	15.2	18.5	22	25.3	27.3	30.6	33.8	37	43.5
	60		6.7	7.4	8.1	9	10	11	12	14	15.3	17.9	23.5	28.6	34	39	42.1	47.1	52.1	57.1	67
	80		9.2	10	11	12	14	15	17	19	20.9	24.6	32.2	39.2	46.6	53.5	57.8	64.7	71.5	78.3	92
	100		12	13	14	16	18	19	22	24	27	31.8	41.6	50.6	60.2	69.1	74.6	83.5	92.3	101	119
	120		15	16	18	20	22	24	27	30	33.5	39.3	51.5	62.7	74.5	85.5	92.4	103	114	125	147
	140		18	19	21	24	27	28	32	36	40.3	47.3	61.9	75.4	89.6	103	111	124	138	151	177
	160		21	23	25	28	31	33	38	42	47.4	55.7	72.9	88.8	106	121	131	146	162	177	208
	180		24	27	29	32	36	39	44	49	54.9	64.5	84.4	103	122	140	152	170	188	205	241

CONVERTING BETWEEN THE METRIC SYSTEM AND THE IMPERIAL SYSTEM

Multiply		by		to obtain	Multiply		by		to obtain
Unit	x	Coefficient	=	Unit	Unit	x	Coefficient	=	Unit
millimetres	x	0.03937	=	inches	Ω / km	x	0.3048	=	Ω / 1000 feet
millimetres	x	39.37	=	mils	Ω / 1000 feet	x	3.281	=	Ω / km
metres	x	39.37	=	inches	pounds / 1000 feet	x	1.488	=	kilograms/km
metres	x	3.28	=	feet	square inches	x	645.2	=	square millimetres
inches	x	25.4	=	millimetres	square millimetres	x	1.273	=	circular mms
feet	x	0.3048	=	metres	square millimetres	x	1973.5	=	circular mils
mils	x	0.0254	=	millimetres	square mils	x	1.273	=	circular mils
kilograms	x	2.205	=	pounds	circular mms	x	1550	=	circular mils
pounds	x	0.4536	=	kilograms	circular mils	x	0.7854	=	square millimetres

BEHAVIOUR WITH COMMMON CHEMICALS

A Excellent
B Good
C Average
D Not good
Unknown
1 At 20°C
2 Up to 50°C
3 For O-ring

Chemical	PTFE Fluoropolymer	PVC	Silicon elastomer
Acetaldehyde	A	D	A
Acetamide	A	D	B
Acetic acid	A	D	C
20%	A	D	B
80%	A	D	B
glacial	A	D	B
Acetic anhydride	A	D	C
Acetone	A	D	B
Acetylene	A	A1	B
Aluminium fluoride	A	A2	B
Aluminium hydroxide	A	A2	-
Aluminium sulphate	A	A2	A
Alums	A	-	A1
Ammonia 10%	A	B1	-
Ammonia ahydrous	A	A2	C
Ammonia liquid	A	A1	-
Ammonium carbonate	A	A2	C
Ammonium chloride	A	A2	C
Ammonium hydroxide	A	A	A
Ammonium nitrate	A	A2	C
Ammonium phosphate dibasic	A2	A2	A
Ammonium sulphate	A	A2	A
Ammonium thoisulphate	-	-	-
Amyl alcohol	A	A2	D
Amyl chloride	A	D	D
Aniline	A	C1	B
Aqua regal			
(80 % HCl + 20 % HNO3)	A	C1	D
Arsenic acid	A	A1	A
Arsenic salts	-	A	-
Asphalt	A1	A2	D
ASTM n°1oil	-	-	B
ASTM n°2 oil	-	-	B
ASTM n°3 oil	-	-	C
Barium carbonate	A	A2	-
Barium chloride	A	A1	A
Barium hydroxide	A	A2	A
Barium sulphate	A	B1	A
Barium sulfide	A	A2	A
Beer	A	A2	A
Beet sugar liquids	A1	A2	A
Benzaldehyde	A1	D	D
Benzen	A	C1	D
Benzyl chloride	-	-	D
Borax (Sodium borate)	A	A1	B
Boric acid	A	A2	A
Bromine	A	C1	D
Butane	A	C1	D
Butyl alcohol	A2	C1	B
Butyl eher	A1	A2	D
Butyric acid	A2	B1	D
Calcium bisulfate	A	B	A
Calcium chloride	A	C	A
Calcium hydroxide	A	B	A
Calcium hypochlorite	A	B1	B
< 20%	A	A	B
Carbolic acid	A	D	D
Carbon dioxyde	A	A1	B
Carbon monoxide	A	A2	A2
Carbon oxide	A	A2	A2
Carbon tetrachloride	A	-	D
Carbon tetrachloride dry	A	-	D
Caustic potash	A	A1	C
Caustic soda			
20%	A	A	A2
50%	A	A	A1
80%	A1	A	A1
Chloracetic acid	A	B1	D
Chlorine	A	A2	D
Chlorine anhydrous liquid	A	D	D
Chlorine dry	A	D	D
Chlorobenzene	B	D	D
Chlorobromomethane	A	D	D
Chloroform	A1	D	D
Chlorosulfonic acid	A	D	D
Chromic acid			
5%	A	A2	C
10%	A	A2	C
30%	A	A1	C
50%	A	D	C
Citric acid	A	B2	A
Coconut oil	A	A1	A
Cod liver oil	A	A1	B
Copper chloride	A	A1	A1
Copper cyanide	A	A2	A
Copper nitrate	A	A2	-
Copper sulphate			
5%	A	A2	A
> 5 %	A	A2	A
Corn oil	A	B	A
Cottonseed oil	A	B2	A

Chemical	PTFE Fluoropolymer	PVC	Silicon elastomer
Cresylic acid	A	D	D
Cyclohexane	A	D	D
Cyclohexanone	A	D	D
Diacetone alcohol	A	B1	D
Dichlorobenzene	A	D	D
Diethylamine	D	D	B
Diethyleneglycol	A2	C1	B1
Diethylether	A	D	D
Dimethylaniline	A	D	D
Dimethylformamide	D	D	C
Diphenyloxide	A1	D	C
Distilled water	A	A2	C
Ethane	A	A1	D
Ethanol	A	C	B
Ethanolamine	A1	D	B
Ether	A	D	D
Ethyl alcohol	A	C	B
Ethyl bromide	A	D	D
Ethyl chloride	A	D	D
Ethylene chlorhydrine	A	D	C
Ethylene diamine	A	D	A
Ethylene dichloride	A	D	D
Ethylene glycol	A	A	A
Ethylene oxide	A	D	D
Fatty acids	A	A	C
Ferric chloride	A	A	B
Ferric sulphate	A	A	B
Ferrous chloride	A	A	-
Ferrous sulphate	A	A	-
Formaldehyde			
40%	A	A	-
100%	A	A	B
Formic acid	A	A1	B
Freon 11	A	A2	D
Freon 113	A	B	D
Freon 12	A	A2	D
Freon 22	A	A	D
Freon TF	-	B	D
Fuel oil	B	A2	D
Furane (resin)	A	A	D
Furfural	A	D	D
Gasoline	B	A	D
Gelatine	A	B	A
Glucose	A	A2	A
Glycerine	A	A	A
Grease	A	A	D
Hexane	A	B1	D
Hexyl alcohol	A	A2	B
Hydraulic oil	A	A	B
Hydrobromic acid			
20%	-	B2	D
100%	A	A1	D
Hydrochloric acid			
20%	A	A2	D
37%	A	B	B
100%	A	D	D
Hydrocyanic acid	A	B	C
Hydrofluoric acid			
20%	A	B	D
50%	A	B1	D
75%	A	C	D
100%	A	C	D
Hydrogen	A	A2	C
Hydrogen (dry)	A	A2	C
Hydrogen gas	A	A2	C
Hydrogen peroxide			
10%	A	A1	A
30%	A	A1	B
50%	A	A1	B
100%	A	A	B
10%	A	A1	A
30%	A	A1	B
50%	A	A1	B
100%	A	A	B
Hydrogen sulphide	A	B1	C
Isobutyl alcohol	A2	A1	A
Isooctane	A	A1	D
Isopropyl ether	A1	B	D
Isopropyl alcohol	A2	A1	A
Jet fuel	A	C	D
Kerosene	A	A2	D
Lacquers	A	D	D
Lactic acid	A	B1	A
Lard	A	A1	B
Lead nitrate	A1	A2	B1
Lead sulfamate	B	B	B
Linseed oil	A	A2	A
Magnesium Carbonate	A1	B	-
Magnesium chloride	A	B	A
Magnesium hydroxide	A	A2	A
Magnesium nitrate	A	A2	-
Magnesium sulphate	A	A1	A
Malic acid	A	A2	B
Manganese sulphate	A	C	A1
Mercuric chloride	A	A	-
Mercuric cyanide	B	A	A
Mercury	A	A	-
Methane	A	B	D
Methyl alcohol	A	A1	A
Methyl chloride	A	D	D
Methyl ethyl ketone	A	D	D
Methyl methacrylate	-	A	C

Chemical	PTFE Fluoropolymer	PVC	Silicon elastomer
Methylène chloride	A	D	-
Methylisobutylketone	A	D	D
Milk	A	A2	A
Mineral oils	A	B	C
Monobasic	A	A	A
Monochlorobenzene	B	D	D
Monoethanolamine	A1	D	B
Mustard	A	B	-
Naphta	B	A1	D
Naphtalene	A	D	D
Natural gas	A	A	A
Nickel chloride	A	A	A
Nickel nitrate	A2	A	-
Nickel sulphate	A	A	A
Nitric Acid			
5 - 10 %	A	A1	C
20%	A	A1	D
50%	A	B1	D
concentrated	A	B1	D
Nitrobenzene	A	D	D
Oelic Acid	A	C2	D
Olive oil	A1	C	D
Oxalic acid	A1	B	B
Ozone	A	B	A
Palmitic acid	A2	B1	D
Paraffin	A	B	-
Peanut oil	A	A1	A
Pentane	A	A	D
Petrol	A	B	D
Petroleum	A2	-	D
Phenol	A	D	D
10%	A	C1	D
Phosphoric acid			
≤ 40 %	A	B	C
> 40 %	A	B	D
Phosphorus trichloride	A2	D	-
Phtalic anhydride	A	D	-
Pine oil	A	D	D
Pitric acid	A	D	D
Potassium bichromate	A	A	A
Potassium bromide	A	A	A1
Potassium carbonate	-	A	-
Potassium chloride	A	A	A
Potassium cyanide solutions	A	A	A
Potassium hydroxide	A	A1	C
Potassium nitrate	A	A	A
Potassium permanganate	A	A1	-
Potassium sulphate	A	A2	A
Propane liquid	A	A1	D
Propyl alcohol	A	A1	A
Propylene glycol	A	C1	A
Pyridine	A	D	D
Salted water	A	B	B
Salycilic acid	A2	B1	-
Sea water	A	A2	A1
Silicone oil	A	A	C
Silver nitrate	A	A1	A
Soap solutions	A	A	A
Soda (sodium carbonate)	A	A2	A
Sodium bicarbonate	A	A2	A
Sodium carbonate	A	A2	A
Sodium chloride	A	A2	A
Sodium cyanide	A	A2	A
Sodium fluoride	A1	A2	-
Sodium hydroxide			
20%	A	A	A2
50%	A	A	A1
80%	A1	A	A1
Sodium hypochlorite	A	B	B
Sodium nitrate	A	A2	D
Sodium peroxide	A	B2	D
Sodium phosphate	A	A1	D
Sodium silicate	A	A2	A
Sodium sulphate	A	A2	A
Sodium sulfide	A	A2	A
Sodium thoisulphate	A	A2	A
Soybean oil	A	A1	A
Stéaric acid	A	B2	B
Styrene	A	D	D
Sugar liquids	A	-	A
Sulphuric acid			
< 10 %	A	A1	C
10 - 75 %	A	A1	D
75 - 100 %	A	D	D
concentrated cold	A	D	D
concentrated hot	A	D	D
Sulfurous acid	A	A2	D
Sulphur chloride	A	C1	C
Sulphur trioxide	A	A	B
Synthetic hydraulic oil	A	A	B
Tannic acid	A	A1	B
Tartric acid	A	A1	A
Tetrachloroethylene	A	D	D
Toluene	A	D	D
Tribasic	A	A	A
Trichloroethylene	A	D	D
Tricresilphosphate	A	D	C
Triethylamine	A	B	-
Turpentine	A	D	D
Unleaded petrol	A	C2	D
Vinegar	A	B	A
Vinyl chloride	A2	D	-
Water <80°C	A	B	B

LEGAL UNITS IN THE INTERNATIONAL MEASUREMENT SYSTEM (SI)

Variables			Unit	Customary units	
	Names	Symbols	Names and symbols	Names and symbols	SI value
GEOMETRY	Length	ℓ	metre (m)		
	Wavelength	λ	metre (m)		
	Wavenumber	σ	metre to the power minus one (m^{-1})		
	Surface area	A	square metre (m^2)	are (a) hectare (ha)	10^2 10^4
	Cross section	σ	square metre (m^2)	barn (b)	10^{-28}
	Volume	V	cubic metre (m^3)	litre (L ou l)	10^{-3}
	Plane angle	α	radian (rad)		
	Solid angle	Ω	steradian (sr)		
MASS	Mass	m	kilogram (kg)	tonne (t)	10^3
	Atomic mass	m_a	kilogram (kg)		
	Mass per unit length	ρ_ℓ	kilograms per metre (kg/m)	tex (tex)	10^{-6}
	Suface density	ρ_A	kilograms per square metre (kg/m^2)		
	Density	ρ	kilograms per cubic metre (kg/m^3)		
	Volume per unit mass	v	cubic metres per kilogram (m^3/kg)		
	Concentration	ρ_B	kilograms per cubic metre (kg/m^3)		
TIME	Time	t	second (s)		
	Frequency	f	hertz (Hz)		
MECHANICS	Velocity	v	metres per second (m/s)		
	Angular velocity	ω	radians per second (rad/s)		
	Acceleration	a	metres per secondsquared (m/s^2)	gal (Gal)	10^{-2}
	Angular acceleration	α	radians per second squared (rad/s^2)		
	Force	F	newton (N)		
	Moment of force	M	newton-metre (N.m)		
	Surface voltage	γ	newtons per metre (N/m)		
	Work, energy, quantity of heat	W	joule (J)		
	Radiant intensity	I	watts per steradian (W/sr)		
	Power, radiant flux thermal flux	P Φ	watt (W)		
	Strain Pressure	σ ρ	pascal (Pa)	bar (bar)	10^5
	Dynamic viscosity	η	pascal-second (p.s) or poiseuille	poise (P)	10^{-1}
	Kinetic viscosity	υ	square metres per second (m^2/s)	stockes (St)	10^{-4}

Variables			Unit	Customary units	
	Names	Symbols	Names and symbols	Names and symbols	SI value
ELECTRICITY	Electric current	I	ampere (A)	biot(bi)	10
	Electromotive force	E	volt (V)		
	Potential difference voltage	U			
	Electrical resistance	R	*ohm* (Ω)		
	Electric field strength	E	volts per metre (V/m)		
	Electrical conductance	G	siemens (S)	mho	1
	Amount of electricity, electrical charge	Q	coulomb (C)		
	Electrical capacity	C	farad (F)		
	Self-induction	L	henry (H)		
	Magnetic flux induction	Φ	weber (Wb)	maxwell (Mx,M)	10^4
	Magnetic induction	B	tesla (T)	Gamma (γ) Gauss (Gs, G)	10^{-9} 10^4
	Magnetic field strength	H	amperes per metre (A/m)		
	Magnetomotive force	F	ampere (A)		
HEAT	Temperature	T	kelvin(K) degree Celsius (°C)		
	Heat capacity, entropy	C S	joules per kelvin (J/K)		
	Specific heat capacity, specific entropy	c s	joules per kilogram kelvin (J/(kg.K))		
	Thermal conductivity	λ	watts per metre-kelvin (W/(m.K))		
IONISING RADIATION	Activity	A	becquerel (Bq)		
	Exposure	X	coulomb par kilogram (C/kg)		
	Absorbed dose	D	gray (Gy)	rad(rd)	10^{-2}
	Dose equivalent	H	sievert (Sv)	rem (rem)	10^{-2}
PHYSICAL CHEMISTRY	Quantity of matter	n	mole (mol)		
OPTICS	Light intensity	I	candela (cd)		
	Luminous flux	Φ	lumen (lm)		
	Illuminance	E	lux (lx)		
	Luminance	L	candelas per square metre (cd/m^2)		
	Optical system vergence		metres to the power minus one (m^{-1})		

MAIN CONVERSION FACTORS

Unit	Conversion factor	Unit	Conversion factor
Length (conversion into metres)			
angström (Ä)	1x 10^{-10}	mile	1.609344 x 10^3
fermi (fm)	1 x 10^{-15}	mile (nautical mile)	1.852 x 10^3
foot (ft)	3.048 x 10^{-1}	pica	4.2175 x 10^{-3}
inch (in)	2.54 x 10^{-2}	point (US)	3.515 x 10^4
light year	9.46073 x 10^{15}	rod	5.029 2
micron (μ)	1 x 10^{-6}	sigma(σ)	1 x 10^{-12}
mil	2.54 x 10^{-5}	yard (yd)	9.144 x 10^{-1}
Area (conversions into square metres)			
acre	4.04686 x 10^3	circular mil	5.067075 x 10^{-10}
are (a)	1 x 10^2	rood	1.01171 x 10^3
Volume (conversion into cubic metres)			
barrel (US)	1.58987 x 10^{-1}	gill (UK)	1.42065 x 10^{-4}
board foot	2.36 x 10^{-3}	gill [US](gi)	1.18294 x 10^{-4}
bushel (UK)	3.63687 x 10^{-2}	liquid pint [US](liq pt)	4.73176 x 10^{-4}
bushel [US](bu)	3.52391 x 10^{-2}	liquid quart [US](liq qt)	9.46352 x 10^{-4}
dry barrel [US](bbl)	1.15627 x 10^{-1}	litre (L, l)	1 x 10^{-3}
dry pint [US](dry pt)	5.50610 x 10^{-4}	minim [UK](min)	5.91939 x 10^{-8}
dry quart [US](dry qt)	1.10122 x 10^{-3}	minim [US](min)	6.16115 x 10^{-8}
fluid ounce [UK](fl oz)	2.84130 x 10^{-5}	peck (UK)	9.0922 x 10^{-3}
fluid ounce [US](fl oz)	2.95735 x 10^{-5}	peck (US)	8.809768 x 10^{-3}
gallon [UK](gal)	4.54609 x 10^{-3}	quart [UK](qt)	1.13652 x 10^{-3}
gallon [US](gal)	3.78541 x 10^{-3}		
plane angle (conversion into radians)			
degree (°)	1.745329 x 10^{-2}	minute (')	2.908882 x 10^{-4}
grade (gr)	1.570796 x 10^{-2}	second ('')	4.848137 x 10^{-6}
Time (conversion into seconds)			
day	8.64 x 10^4	minute (min)	60
hour	3.6 x 10^3		
Mass (conversion into kilograms)			
atomic mass unit (u)	1.66054 x 10^{-27}	quintal (q)	1 x 10^2
		short ton (sh tn)	9.07185 x 10^2
cental	4.53592 x 10	ton (ton)	1.016047 x 10^3
long ton (US)	1.016047 x 10^3	tonne (t)	1 x 10^3
ounce (oz)	2.834952 x 10^{-2}	troy ounce	3.11035 x 10^{-2}
pound (lb)	4.535924 x 10^{-1}	troy pound	3. 73242 x 10^{-1}
Velocity (conversion into metres per second)			
international knot, knot	5.144 44 x 10^{-1}		

Unit	Conversion factor	Unit	Conversion factor
Force (conversion into newtons)			
dyne (dyn)	1 x 10^{-5}	pound-force (lbf)	4.44822
kilogram-force (kgf)	9.80665	poundal (pdl)	1.38255 x 10^{-1}
pound (p)	9.80665 x 10^{-3}		
Work, energy (conversion into joules)			
British thermal unit (Btu) (Intern Table)	1.055056 x 10^3	kilogramtre (kgm)	9.80665
		therm	1.055056 x 10^8
calorie I.T. (cal I.T)	4.186 8	thermie (th)	4.1855 x 10^6
calorie 15°C (cal15)	4.185 5	thermochemical calorie (calth)	4.184
electronvolt (eV)	1.60218 x 10^{-19}	watthour (Wh)	3.6 x 10^3
frigorie (fg)	- 4.1855 x 10^3		
Power (conversion into watts)			
mechanical horsepower [UK]	7.457 0 x 10^2	var (var)	
metric horsepower	7.354 99 x 10^2		
Strain and pressure (conversion into pascals)			
bar (bar)	1 x 10^5	millimetre of water (mmH^{2}0)	9.806 65
foot of water (ftH^{2}0)	2.989 07 x 10^3	normal atmosphere	1.013 25 x 10^5
inch of mercury (inHg)	3.386 39 x 10^3	pound-force per square inch (psi)	6.894 757 x 10^3
inch of water (inH^{2}0)	2.490 89 x 10^2		
millimetre of mercury (mmHg)	1.333224 x 10^2	technical atmosphere	9.806 65 x 10^4
		torr (Torr)	1.333 224 x 10^2
Magnetomotive force (conversion into amperes)			
gilbert (Gb)	7.957 7 x 10^{-1}		
Quantity of electricity, electrical charge (conversion into coulombs)			
ampere-hour (Ah)	3.6 x 10^3	franklin (Fr)	3.335 64 x 10^{-10}
faraday (F)	9.648 70 x 10^4		
Activity (conversion into becquerels)			
curie (Ci)	3.7 x 10^{10}		
Exposure (conversion into coulombs per kilogram)			
röntgen (R)	2.58 x 10^{-4}		

flexelec
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LIQUIDS HEATING (NOTES AND FORMULAE)

PHYSICAL CHARACTERISTICS OF THE MAIN LIQUIDS

LIQUIDS	DENSITY	Solidific. TEMP.	Boiling TEMP.	Cp	Heat of vaporis.
Acetone	0,814	- 95	57	0,53	124,5
Acetic acid	1,07	17	118	0,51	117
Ammonia	0,82	-78	-33,4	1,1	327
Beer	1	2		1	
Benzene	0,87	5	80	0,45	-94
Bromine	3	-7	58,8	0,11	43,7
Carbon disulphide	1,27	-108	46	0,23	90
Carbon tetrachloride	1,63	-23	76,8	0,21	45
Castor oil	0,96			0,43	68
Chloroform	1,48	-63	61	0,23	60
Ether	0,74	-117	35	0,54	90
Ethyl alcohol	0,80	-130	78	0,68	210
Formic acid	1,23	8,4	100,7	0,39	120
Freon 12	1,33		-30	0,20	40
Glycerine	1,27	17	290	0,58	
Hydrochloric acid	1,2	-114	83	0,60	97,5
Mercury	13,6	-39	358	0,033	73
Methacrylate	0,9			0,25	
Methyl alcohol	0,80	-97,8	65	0,60	269
Methyl chloride	1,33	-96	40	0,60	95
Mineral oil	0,84			0,50	
Milk	1,03			0,94	
Nitric acid	1,52	-42	86	0,66	115
Paraffin	0,8			0,45	
Paraffin oil	0,88			0,52	
Petroleum	0,89			0,50	
Phenol	1,08	41	182	0,56	
Sulphuric acid at 66° B	1,80	10	330	0,33	123
Tetrachlorethylene	1,6	-20	120	0,22	52
Toluene	0,87	-95	110,6	0,39	
Trichlorethylene	1,49	-73	87	0,23	57,3
Turpentine	0,86			0,42	
Vinegar	1,02			0,92	
Water	1	0	100	1	539
Wine	0,99			0,90	
Honey	1,395 to 1,445			0,6 to 0,65 (liquid) 0,65 to 0,70 (solid)	
UNITS	kg/dm^3	Degrees C	Degrees C	K.Cal/kg /°C	Kg.cal/kg

Notes

Aqueous solutions have a specific heat that varies between that of water for very weak concentrations and the specific heat of the substance for strong concentrations.

All oils have a specific heat of approximately 0.5.

Boiling temperature and solidification temperature vary with pressure.

Heat of vaporisation varies with temperature.

For water, Régnault's formula is applied:
L = 606,5 - 0,695 T, which gives for T= 100°: 537 Kcal/kg.

THERMAL CONDUCTIVITY AND SPECIFIC HEAT

Metals, liquids, air

	TEMP. °C	Thermal conductivity coeeficient λ		Average specific heat	
		Kcal.h / m°C	W / m°C	Kcal./Kg / °C	J/Kg°C
Metals					
Pure aluminium	20°	197	228	0,22	921
Steel(c ≃ 1,5)	20°	45	52	0,115	481
Pure copper	20°	332	385	0,094	393
Brass	20°	63	73	0,092	385
Zinc					
Various materials					
Asbestos	20°	0,13	0,15	0,20	837
Asphalt	20°	0,80	0,93	0,22	921
Concrete (2000 Kg/m^3)	20°	0,80	0,93	0,22	921
Bitumen	20°	0,14	0,16	0,15	628
Solid bricks	20°	0,42 at0,60	0,49 at0,70	0,215	900
Cement mortar	20°	0,44	0,51	0,22	921
Plaster rendering (1200 Kg/m^3)	20°	0,37	0,43	0,273	1143
Liquids					
Alcohol	20°	0,15 at0,20	0,17 at0,23	0,56	2344
Benzol	20°	0,12	0,14	0,42	1758
Heavy fuel oil	20°	0,116	0,135	0,48	2010
Petroleum	20°	0,13	0,15	0,50	2093
Water	0°	0,477	0,553	1,005	4207
	20°	0,505	0,586	0,999	4182
	60°	0,562	0,652	0,998	4177
Light fuel oil (domestic) d = 0,846	20°			0,48	
Steam					
Saturated water at constant pressure	100 to 270°	-	-	0,4639	1942
	100 to 440°	-	-	0,4713	1973
	110 to 620°	-	-	0,4717	1975
Superheated steam	150°	-	-	0,16	1925
1 bar	250°	-	-	0,468	1959
1 bar	350°	-	-	0,477	1997
1 bar	450°	-	-	0,486	2034
1 bar	550°	-	-	0,495	2072
4 bar	150°	-	-	0,524	2193
4 bar	350°	-	-	0,490	2051
4 bar	550°	-	-	0,518	2168
Air					
Air at	20°	0,0216	0,025	0,240	1005
	50°	0,0232	0,027	0,241	1008
	100°	0,0259	0,030	0,242	1013
	200°	0,0314	0,036	0,244	1021
	250°	0,0336	0,039	0,245	1026
Polyol d = 1,1				0,525	2200
Isocyanate d = 1,1				0,332	1390

SPECIFIC WEIGHTS AND DENSITIES OF GASES

in g/dm^3, AS COMPARED WITH AIR AT 0°C and 760 mm Hg

GAS	Specific weight	Density
Acetylene	1,173	0,906
Air*	1,2928	1
Allylene	1,786	1,381
Ammonia	0,7718	0,597
Argon	1,7828	1,38
Arsine	3,484	2,695
Bromine	7,5887	5,87
Carbon dioxide*	1,9779	1,53
Carbon disulphide	3,4	2,63
Carbon monoxide	1,2514	0,968
Carbon oxygen sulphide	2,71	2,1
Carbonyl chloride	4,47	3,46
Chlorine	3,219	2,49
Chlorine dioxide	3,01	2,33
Cyanogen	2,3348	1,806
Dimethylamine	0,6804	0,526
Ethane	1,3566	1,057

GAS	Specific weight	Density
Ethyl chloride	2,87	2,219
Ethylzne	1,264	0,975
Fluorine	1,635	1,264
Helium	0,1768	0,1368
Hydrobromic acid	3,5035	2,71
Hydrochloric acid	1,6393	1,268
Hydrofluoric acid	0,922	0,713
Hydrogen	0,08982	0,06948
Hydrogen phosphide	1,529	1,18
Hydride-silicon	1,44	1,11
Hydrogen sulphide	1,5378	1,1895
Hydriodic acid	5,688	4,4
Hydroselenic acid	3,67	2,84
Krypton	3,6431	2,818
Methane	0,7168	0,554
Methyl chloride	0,991	0,766
Natural gas (processed)	0,74	0,57

GAS	Specific weight	Density
n-Butane	2,5985	2,01
Neon	0,8713	0,674
Nitric oxide	1,34	1,036
Nitrogen	1,2515	0,968
Nitrogen dioxide	1,3402	1,0367
Nitrogen protoxide	1,9779	1,53
Nitrosyl chloride	2,9863	2,31
Nitrous oxide	1,9781	1,53
Oxygen	1,4289	1,1053
Ozone	2,1434	1,658
Phosgene	4,5313	3,505
Producer gas	1,141	0,893
Propane	1,966	1,52
Silicon tetrafluoride	4,684	3,62
Sulphur dioxide	2,9269	2,264
Xenon	5,8564	4,53