INDEX AND REFERENCE

Need to find a quick conversion table for flow measurements or pressure units? Want to look up the dielectric constant for a liquid or solid? Confused about how IEC and NEMA ratings relate? Here's where we store it all. We've expanded our reference tables to include dielectrics, viscosities, and refractive indices, tubing compatibility with chemicals, and other tables you've requested over the last two years.

We'll be adding more of these tables to our website, so check there if you don't see what you need in this section.

Converting Fractions to Their Decimal Equivalents

1/64.....0.015625	3/16.....0.1875	23/64.....0.359375	17/32.....0.53125	45/64.....0.703125	7/8.....0.875
1/32.....0.03125	13/64.....0.203125	3/8.....0.375	35/64.....0.546875	23/32.....0.71875	57/64.....0.890625
3/64.....0.046875	7/32.....0.21875	25/64.....0.390625	9/16.....0.5625	47/64.....0.734375	29/32.....0.90625
1/16.....0.0625	15/64.....0.234375	13/32.....0.40625	37/64.....0.578125	3/4.....0.75	59/64.....0.921875
5/64.....0.078125	1/4.....0.25	27/64.....0.421875	19/32.....0.59375	49/64.....0.765625	15/16.....0.9375
3/32.....0.09375	17/64.....0.265625	7/16.....0.4375	39/64.....0.609375	25/32.....0.78125	61/64.....0.953125
7/64.....0.109375	9/32.....0.28125	29/64.....0.453125	5/8.....0.625	51/64.....0.796875	31/32.....0.96875
1/8.....0.125	19/64.....0.296875	15/32.....0.46875	41/64.....0.640625	13/16.....0.8125	63/64.....0.984375
9/64.....0.140625	5/16.....0.3125	31/64.....0.484375	21/32.....0.65625	53/64.....0.828125	1.....1.0
5/32.....0.15625	21/64.....0.328125	1/2.....0.5	43/64.....0.671875	27/32.....0.84375	
11/64.....0.171875	11/32.....0.34375	33/64.....0.515625	11/16.....0.6875	55/64.....0.859375	

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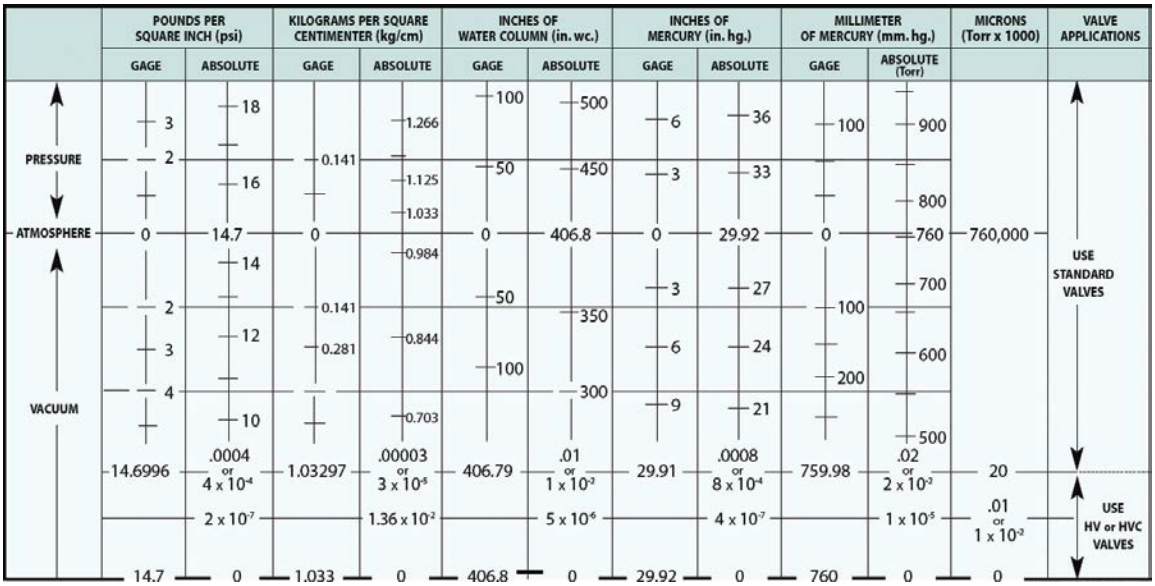
Conversion Factors

To Convert	To	Multiply By
Atmospheres	Pounds per Square Inch	14.697
	Kilograms per Square Inch	1.033
	Inches of Mercury	29.92
	Millimeters of Mercury	760
	Inches of Water	407
	Feet of Water	33.90
Barrels (Petroleum)	Gallons	42
	Cubic Meters	0.15876
Barrels per day	Gallons per Minute	0.0292
°Celsuis	°Fahrenheit	(°C x 1.8) +32
Centimeters	Inches	0.3937
	Feet	0.03281
	Meters	0.01
	Yards	0.01094
Cubic Centimeters	Cubic Inches	0.06102
	Cubic Feet	0.000035314
Cubic Feet	Cubic Inches	1728
	Liters	28.3168
	Gallons	7.48055
	Barrels	0.17812
	Cubic Meters	0.028317
Cubic Feet per Second	Gallons per Minute	448.833
Cubic Inches	Cubic Centimeters	16.39
	Cubic Feet	0.00058
	Gallons	0.004329
Cubic Meters	Cubic Inches	61025
	Pints	1816
	Gallons	264.17
	Cubic Feet	35.3165
	Barrels (Petroleum)	6.2989
	Cubic Yards	1.308
	Register Tons	0.3532
Cubic Meters per Hour	Gallons per Minute	4.4
Cubic Yards	Cubic Meters	0.764557
°Fahrenheit	°Celsius	(°F-32) x 0.5555
Feet	Meters	0.3048
	Yards	0.3333
	Centimeters	30.48
Feet of Water	Inches of Mercury	0.882
	Pounds per Square Inch	0.433
	Inches of W.C.	11.987
Foot-Pounds	BTU (British Thermal Units)	0.001266
	Horsepower Hours	0.000000505
Gallons (US)	Cubic Centimeters	3785
	Cubic Feet	0.13368
	Cubic Inches	231
	Liters	3.785
	Gallons (Imperial)	0.833
Gallons (Imperial)	Cubic Inches	277.4
	Gallons (US)	1.2009
Gallons of Water	Pounds (at 70°F)	8.328
Gallons per Minute (Liquid)	Pounds per Hour Liquid (70°F)	500 x Sp. Gr.
Gallons per Minute	Cubic Feet per Second	0.002228
Horsepower	BTU per Minute	42.44
	Foot-Pounds per Minute	33000
	Foot-Pounds per Second	550
	Kilowatts	0.74565
Horsepower (Boiler)	Pounds of Water per Hour Evaporation	34.5
	BTU per Hour	33479
	Kilowatts	9.804
Horsepower Hours	BTU per Minute	2547

To Convert	To	Multiply By
Inches	Millimeters	25.4
	Centimeters	2.54
	Feet	0.0833
	Meters	0.0254
	Yards	0.02778
Inches of Mercury	Feet of Water	1.133
	Pounds per Square Inch	0.4912
	Atmospheres	0.0334
	Kilograms per Square Centimeter	0.0345
Inches of Water	Pounds per Square Inch	0.03613
	Inches of Mercury	0.07355
Kilograms	Pounds	2.205
	Short Tons (2,000 lbs.)	0.001102
	Long Tons	0.0009842
	Ounces	35.27
Kilograms per Minute	Pounds per Hour	132.3
Kilograms/Sq. Centimeter	Pounds per Square Inch	14.22
	Atmospheres	0.9678
	Inches of Mercury	28.96
Kilogram Calories	BTU	3.96832
Kilometers	Miles Nautical	0.53961
	Miles Statute	0.62137
Kilowatts	Horsepower	1.341
Kilowatt Hours	BTU	3415
Liters	Cubic Centimeters	1000
	Cubic Inches	61.0240
	Pints	1.816
	Quarts	1.0567
	Gallons	0.2642
	Cubic Feet	0.035315
Liters per Hour	Gallons per Minute	0.0044
Meters	Feet	3.281
	Yards	1.0936
	Inches	39.37
Pounds	Grams	453.6
	Short Tons (2,000 lbs.)	0.0005
	Kilograms	0.4536
	Metric Tons	0.000454
	Ounces	16
Pounds per Hour	Cubic Feet per Minute	6.32/M.W.
Pounds per Hour Liquid	Gallons per Minute Liquid	0.002/Sp. Gr.
Pounds per Hour Steam	BTU (Sea Level)	1000
Pounds per Square Inch	Inches of Water	27.684
	Feet of Water	2.307
	Inches of Mercury	2.036
	Kilograms per Square Centimeter	0.0703
	Atmospheres	0.0680
	Millimeters of Mercury	51.71
	Meters of Water	0.7037
Specific Gravity (Gas/Vapor)	Molecular Weight (Gas/Vapor)	28.97
Square Centimeters	Square Inches	0.1550
	Square Feet	0.001076
Square Inches	Square Feet	0.00695
	Square Centimeters	6.452
Tons (Short)	Kilograms	907.2
Tons (Register)	Cubic Meters	2.8316
Tons (Metric)	Short Tons	1.102
Tons (Metric) per Day	Pounds per Hour	91.8
Water (Cubic Feet)	Pounds (70°F)	62.3
Yards	Meters	0.9144
	Centimeters	91.44

Converting Vacuum Range Values



Conversion Table for Pressure Units (USA — Europe)

Example 1 bar = 14.504 psi	Physical Atmosphere atm	Technical Atmosphere at	lb/inch2 psi	bar	Newton/m² Pascals	cm H_2O (+4°C)	Inch H_2O (+4°C)	Torr	cm Hg (0°C)	Inch Hg (0°C)
Phys Atmosphere atm	1	1.0332	14.696	1.0133	$101.33x10^3$	1033.2	406.79	760	76.0	29.92
Tech Atmosphere at	0.9678	1	14.223	0.9807	98067	1000.03	393.71	735.56	73.556	28.96
lb/inch2 psi	0.068	0.0703	1	0.0689	6894.8	70.309	27.68	51.715	5.172	2.036
bar	0.9869	1.0197	14.504	1	10^5	1019.7	401.47	750.06	75.0	29.53
Newton/m² Pascals	$9.869x10^{-6}$	$10.197x10^{-6}$	$145.0x10^{-6}$	10^{-5}	1	$10.197x10^{-3}$	$4.015x10^{-3}$	$7.50x10^{-3}$	$0.75x10^{-3}$	$0.2953x10^{-3}$
cm H_2O (+4°C)	$0.9678c10^{-3}$	$1x10^{-3}$	$14.223x10^{-3}$	$0.9806x10^{-3}$	98.064	1	0.3937	0.7355	$73.55x10^{-3}$	$28.96x10^{-3}$
inch H20 (+4°C)	$2.458x10^{-3}$	$2.540x10^{-3}$	$36.13x10^{-3}$	$2.490x10^{-3}$	249.08	2.54	1	1.868	0.1868	$73.55x10^{-3}$
Torr	$1.3158x10^{-3}$	$1.3594x10^{-3}$	$19.34x10^{-3}$	$1.333x10^{-3}$	133.32	1.3595	0.5353	1	0.1	$39.37x10^{-3}$
cm Hg (0°C)	$13.158x10^{-3}$	$13.594x10^{-3}$	0.1934	$13.33x10^3$	1333.2	13.595	5.353	10	1	0.3937
Inch Hg (0°C)	$33.421x10^{-3}$	$34.531x10^{-3}$	0.4912	$33.86x10^{-3}$	3386.4	34.532	13.595	25.4	2.54	1

Conversion Table for Flow Units (Europe — USA)

Europe → USA ↓	cm³/sec	cm³/min	cm³/h	l/sec	l/min	l/h	m³/sec	m³/min	m³/h
1 GPSec	3.788×10^3	2.27×10^5	13.64×10^6	3.788	227	13.64×10^3	3.788×10^{-3}	0.227	13.64
1 GPM	63.09	3.788×10^3	2.27×10^5	0.0631	3.788	227	6.31×10^{-5}	3.788×10^{-3}	0.227
1 GPH	1.0515	63.09	3.788×10^3	1.05×10^{-3}	0.063	3.788	1.05×10^{-6}	6.31×10^{-5}	3.788×10^{-3}
1 SCFSec	28.33×10^3	1.6989×10^6	102.04×10^6	28.33	1.6989	102.04×10^3	0.02833	1.6989	102.04
1 SCFM	472.14	28.329×10^3	1.6989×10^6	0.472	28.329	1.6989×10^3	4.72×10^{-4}	0.02833	1.6989
1 SCFH	7.874	472.14	28.329×10^3	7.874×10^{-3}	0.472	28.329	7.874×10^{-6}	4.72×10^{-4}	0.02833

Conversion Table for Flow Units (USA — Europe)

USA → Europe ↓	(USGPSec) GPSec	(USGPMin) GPM	(USGPH) GPH	(SCFSec) SCFSec	(SCFMin) SCFM	(SCFH) SCFH
1 cm3/sec	0.264×10^{-3}	1.585×10^{-2}	0.951	3.53×10^{-5}	2.118×10^{-3}	0.127
1 cm3/min	4.403×10^{-6}	2.6417×10^{-4}	1.585×10^{-2}	5.886×10^{-7}	3.53×10^{-5}	2.118×10^{-3}
1 cm3/h	7.338×10^{-8}	4.403×10^{-6}	2.6417×10^{-4}	9.8×10^{-9}	5.886×10^{-7}	3.53×10^{-5}
1l/sec	0.26417	15.850	915.014	0.035	2.118	127
1l/min	4.403×10^{-3}	0.26417	15.850	5.886×10^{-4}	0.0353	2.118
1l/h	7.338×10^{-5}	4.403×10^{-3}	0.26417	9.8×10^{-6}	5.886×10^{-4}	0.0353
1 m3/sec	264.17	15850.23	9.51×10^5	35.31	2118.88	1.27×10^5
1 m3/min	4.403	264.17	1.585×10^4	0.588	35.315	2118.88
1 m3/h	0.0733	4.403	264.17	9.8×10^{-3}	0.58858	35.315

Conversion Table for Water

1 Lb	0.016 Ft³	0.120 Gal
1 Ft³	7.48 Gal	62.4 Lb.
1 Gal	8.33 Lb	0.134 Ft³
1 Lb/Hr	0.000004 Ft³/Sec	0.002 GPM
1 Ft³/Sec	449 GPM	250,000 Lb/Hr
1 GPM	500 Lb/Hr	0.00223 Ft³/Sec

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Conversion Factors

Flanges for Use with Steel Pipe

Nominal Pipe Size	Flange Outside Diameter	Bolt Circle Diameter	Number of Bolts	Bolt Hole Diameter
Dimensions for 150 Lb. Flange				
1″	4 1/4″	3 1/8″	4	5/8″
1 1/4″	4 5/8″	3 1/2″	4	5/8″
1 1/2″	5″	3 7/8″	4	5/8″
2″	6″	4 3/4″	4	3/4″
2 1/2″	7″	5 1/2″	4	3/4″
3″	7 1/2″	6″	4	3/4″
4″	9″	7 1/2″	8	3/4″
6″	11″	9 1/2″	8	7/8″
8″	13 1/2″	11 3/4″	8	7/8″
10″	16″	14 1/4″	12	1″
12″	19″	17″	12	1″
Dimensions for 300 Lb. Flange				
1″	4 7/8″	3 1/2″	4	3/4″
1 1/4″	5 1/4″	3 7/8″	4	3/4″
1 1/2″	6 1/8″	4 1/2″	4	7/8″
2″	6 1/2″	5″	8	3/4″
2 1/2″	7 1/2″	5 7/8″	8	7/8″
3″	8 1/4″	6 5/8″	8	7/8″
4″	10″	7 7/8″	8	7/8″
6″	12 1/2″	1 5/8″	12	7/8″
8″	15″	13″	12	1″
10″	17 1/2″	15 1/4″	16	1 1/8″
12″	20 1/2″	17 3/4″	16	1 1/4″

Pipe Size to Wall Thickness (Inches)

Pipe Size	DN	OD	Wall Thickness	
			SCH 40	SCH 80
1/8	6	0.405	0.068	0.095
1/4	8	0.54	0.088	0.119
3/8	10	0.675	0.091	0.126
1/2	15	0.84	0.109	0.147
3/4	20	1.05	0.113	0.154
1	25	1.315	0.133	0.179
1-1/4	32	1.66	0.14	0.191
1-1/2	40	1.9	0.145	0.2
2	50	2.375	0.154	0.218
2-1/2	65	2.875	0.203	0.276
3	80	3.5	0.216	0.3
3-1/2	90	4	0.226	0.318
4	100	4.5	0.237	0.337
4-1/2	115	5	0.247	0.355
5	125	5.563	0.258	0.375
6	150	6.625	0.28	0.432
7	—	7.625	0.301	0.5
8	200	8.625	0.322	0.5
9	—	9.625	0.342	0.5
10	250	10.75	0.365	0.593
12	300	12.75	0.406	0.687
14	350	14	0.437	0.75
16	400	16	0.5	0.843
18	450	18	0.562	0.937
20	500	20	0.593	1.031
22	550	22	—	1.125
24	600	24	0.687	1.218

Electrical Wire Attributes

AWG Gauge	Conductor Diameter		Ohms		Max. Amps		Max Frequency*
	Inches	mm	per 1000 Ft	per km	for Chassis Wiring	for Power	
0000	0.46	11.684	0.049	0.16072	380	302	125 Hz
000	0.4096	10.40384	0.0618	0.202704	328	239	160 Hz
00	0.3648	9.26592	0.0779	0.255512	283	190	200 Hz
0	0.3249	8.25246	0.0983	0.322424	245	150	250 Hz
1	0.2893	7.34822	0.1239	0.406392	211	119	325 Hz
2	0.2576	6.54304	0.1563	0.512664	181	94	410 Hz
3	0.2294	5.82676	0.197	0.64616	158	75	500 Hz
4	0.2043	5.18922	0.2485	0.81508	135	60	650 Hz
5	0.1819	4.62026	0.3133	1.027624	118	47	810 Hz
6	0.162	4.1148	0.3951	1.295928	101	37	1100 Hz
7	0.1443	3.66522	0.4982	1.634096	89	30	1300 Hz
8	0.1285	3.2639	0.6282	2.060496	73	24	1650 Hz
9	0.1144	2.90576	0.7921	2.598088	64	19	2050 Hz
10	0.1019	2.58826	0.9989	3.276392	55	15	2600 Hz
11	0.0907	2.30378	1.26	4.1328	47	12	3200 Hz
12	0.0808	2.05232	1.588	5.20864	41	9.3	4150 Hz
13	0.072	1.8288	2.003	6.56984	35	7.4	5300 Hz
14	0.0641	1.62814	2.525	8.282	32	5.9	6700 Hz
15	0.0571	1.45034	3.184	10.44352	28	4.7	8250 Hz
16	0.0508	1.29032	4.016	13.17248	22	3.7	11 kHz
17	0.0453	1.15062	5.064	16.60992	19	2.9	13-k Hz
18	0.0403	1.02362	6.385	20.9428	16	2.3	17 kHz
19	0.0359	0.91186	8.051	26.40728	14	1.8	21 kHz
20	0.032	0.8128	10.15	33.292	11	1.5	27 kHz
21	0.0285	0.7239	12.8	41.984	9	1.2	33 kHz
22	0.0254	0.64516	16.14	52.9392	7	0.92	42 kHz
23	0.0226	0.57404	20.36	66.7808	4.7	0.729	53 kHz
24	0.0201	0.51054	25.67	84.1976	3.5	0.577	68 kHz
25	0.0179	0.45466	32.37	106.1736	2.7	0.457	85 kHz
26	0.0159	0.40386	40.81	133.8568	2.2	0.361	107 kHz
27	0.0142	0.36068	51.47	168.8216	1.7	0.288	130 kHz
28	0.0126	0.32004	64.9	212.872	1.4	0.226	170 kHz
29	0.0113	0.28702	81.83	268.4024	1.2	0.182	210 kHz
30	0.01	0.254	103.2	338.496	0.86	0.142	270 kHz
31	0.0089	0.22606	130.1	426.728	0.7	0.113	340 kHz
32	0.008	0.2032	164.1	538.248	0.53	0.091	430 kHz
Metric 2.0	0.00787	0.200	169.39	555.61	0.51	0.088	440 kHz
33	0.0071	0.18034	206.9	678.632	0.43	0.072	540 kHz
Metric 1.8	0.00709	0.180	207.5	680.55	0.43	0.072	540 kHz
34	0.0063	0.16002	260.9	855.752	0.33	0.056	690 kHz
Metric 1.6	0.0063	0.16002	260.9	855.752	0.33	0.056	690 kHz
35	0.0056	0.14224	329	1079.12	0.27	0.044	870 kHz
Metric 1.4	.00551	.140	339	1114	0.26	0.043	900 kHz
36	0.005	0.127	414.8	1360	0.21	0.035	1100 kHz
Metric 1.25	.00492	0.125	428.2	1404	0.20	0.034	1150 kHz
37	0.0045	0.1143	523.1	1715	0.17	0.0289	1350 kHz
Metric 1.12	.00441	0.112	533.8	1750	0.163	0.0277	1400 kHz
38	0.004	0.1016	659.6	2163	0.13	0.0228	1750 kHz
Metric 1	.00394	0.1000	670.2	2198	0.126	0.0225	1750 kHz
39	0.0035	0.0889	831.8	2728	0.11	0.0175	2250 kHz
40	0.0031	0.07874	1049	3440	0.09	0.0137	2900 kHz

**** For 100% Skin Depth for Solid Conductor Copper***

Converting % Range to Current

Range 0 to 100%	Current in mA	Range 100 to 0%
0	4.0	100
5	4.8	95
10	5.6	90
15	6.4	85
20	7.2	80
25	8.0	75
30	8.8	70

Range 0 to 100%	Current in mA	Range 100 to 0%
35	9.6	65
40	10.4	60
45	11.2	55
50	12.0	50
55	12.8	45
60	13.6	40
65	14.4	35

Range 0 to 100%	Current in mA	Range 100 to 0%
70	15.2	30
75	16.0	25
80	16.8	20
85	17.6	15
90	18.4	10
95	19.2	5
100	20.0	0

Power Supply Capacities

Watts	Milliamps @ 24 VDC	Watts	Milliamps @ 24 VDC
2.5	100 mA	25	1000 (1A)
5	200 mA	30	1300 (1.3A)
7.5	300 mA	50	2000 (2A)
15	600 mA	120	5000 (5A)
		240	10000 (10A)

Dewpoint Temperature Calculation

The table shows the dewpoint temperature of the air in °F as a function of relative humidity. Example: At an air temperature of 86°F and a relative humidity of 70%, the dewpoint temperature is 75.2°F.

Air Temp	10% RH	20% RH	30% RH	40% RH	50% RH	60% RH	70% RH	80% RH	90% RH	100% RH
122°F	46.4	66.2	78.8	89.6	96.8	104.0	109.4	113.0	118.4	122.0
113°F	39.2	59.0	71.6	80.6	89.6	96.8	100.4	105.8	109.4	113.0
104°F	33.8	51.8	64.4	73.4	80.6	86.0	91.4	96.8	100.4	104.0
95°F	28.4	46.4	57.2	64.4	69.8	77.0	82.4	87.8	91.4	95.0
86°F	21.2	37.4	50.0	57.2	64.4	69.8	75.2	78.8	82.4	86.0
77°F	17.6	32.0	41.0	50.0	55.4	60.8	66.2	69.8	73.4	77.0
68°F	10.4	24.8	33.8	41.0	48.2	53.6	57.2	60.8	64.4	68.0
59°F	3.2	19.4	26.6	33.8	39.2	44.6	48.2	51.8	55.4	59.0
50°F	-2.2	12.2	19.4	26.6	32.0	33.8	39.2	42.8	46.4	50.0
41°F	-9.4	5.0	12.2	19.4	23.0	28.4	32.0	35.6	37.4	41.0
32°F	-14.8	-2.2	6.8	12.2	17.6	21.2	24.8	26.6	28.4	32.0
23°F	-20.2	-7.6	-0.4	5.0	8.6	12.2	17.6	19.4	21.2	23.0
14°F	-29.2	-14.8	-7.6	-2.2	1.4	5.0	8.6	12.2	12.2	14.0
5°F	-34.6	-22.0	-14.8	-9.4	-5.8	-2.2	1.4	3.2	5.0	5.0
-4°F	-43.6	-31.0	-25.6	-20.2	-16.6	-13.0	-11.2	-7.6	-5.8	-4.0
-13°F	-49.0	-40.0	-32.8	-29.2	-25.6	-22.0	-20.2	-16.6	-14.8	-13.0

Properties of Saturated Steam

	Gauge Pressure	Absolute Pressure (psia)	Steam Temp. (°F)	Heat of Sat. Liquid (BTU/Lb)	Latent Heat (BTU/Lb)	Total Heat of Steam (BTU/Lb)	Specific Volume of Sat. Liquid (Ft^3/lb)	Specific Volume Sat. Steam (Ft^3/lb)
Inches of Vacuum	29.743	0.08854	32.00	0.00	1075.8	1075.8	0.096022	3306.00
	29.515	0.2	53.14	21.21	1063.8	1085.0	0.016027	1526.00
	27.886	1.0	101.74	69.70	1036.3	1106.0	0.016136	333.60
	19.742	5.0	162.24	130.13	1001.0	1131.0	0.016407	73.52
	9.562	10.0	193.21	161.17	982.1	1143.3	0.016590	38.42
	7.536	11.0	197.75	165.73	979.3	1145.0	0.016620	35.14
	5.490	12.0	201.96	169.96	976.6	1146.6	0.016647	32.40
	3.454	13.0	205.88	173.91	974.2	1148.1	0.016674	30.06
	1.418	14.0	209.56	177.61	971.9	1149.5	0.016699	28.04
PSIG	0.0	14.696	212.00	180.07	970.3	1150.4	0.016715	26.80
	1.3	16.0	216.32	184.42	967.6	1152.0	0.016746	24.75
	2.3	17.0	219.44	187.56	965.5	1153.1	0.016768	23.39
	5.3	20.0	227.96	196.16	960.1	1156.3	0.016830	20.09
	10.3	25.0	240.07	208.42	952.1	1160.6	0.016922	16.30
	15.3	30.0	250.33	218.82	945.3	1164.1	0.017004	13.75
	20.3	35.0	259.28	227.91	939.2	1167.1	0.017078	11.90
	25.3	40.0	267.25	236.03	933.7	1169.7	0.017146	10.50
	30.3	45.0	274.44	243.36	928.6	1172.0	0.017209	9.40
	40.3	55.0	287.07	256.30	919.6	1175.9	0.017325	7.79
	50.3	65.0	297.97	267.50	911.6	1179.1	0.017429	6.66
	60.3	75.0	307.60	277.43	904.5	1181.9	0.017524	5.82
	70.3	85.0	316.25	286.39	897.8	1184.2	0.017613	5.17
	80.3	95.0	324.12	294.56	891.7	1186.2	0.017696	4.65
	90.3	105.0	331.36	302.10	886.0	1188.1	0.017775	4.23
	100.0	114.7	337.90	308.80	880.0	1188.8	0.017850	3.88
	110.3	125.0	344.33	315.68	875.4	1191.1	0.017922	3.59
	120.3	135.0	350.21	321.85	870.6	1192.4	0.017991	3.33
	125.3	140.0	353.02	324.82	868.2	1193.0	0.018024	3.22
	130.3	145.0	355.76	327.70	865.8	1193.5	0.018057	3.11
	140.3	155.0	360.50	333.24	861.3	1194.6	0.018121	2.92
	150.3	165.0	365.99	338.53	857.1	1195.6	0.018183	2.75
	160.3	175.0	370.75	343.57	852.8	1196.5	0.018244	2.60
	180.3	195.0	379.67	353.10	844.9	1198.0	0.018360	2.34
	200.3	215.0	387.89	361.91	837.4	1199.3	0.018470	2.13
	225.3	240.0	397.37	372.12	828.5	1200.6	0.018602	1.92
	250.3	265.0	406.11	381.60	820.1	1201.7	0.018728	1.74
		300.0	417.33	393.84	809.0	1202.8	0.018896	1.54
		400.0	444.59	424.00	780.5	1204.5	0.019340	1.16
		450.0	456.28	437.20	767.4	1204.6	0.019547	1.03
		500.0	467.01	449.40	755.0	1204.4	0.019748	0.93
		600.0	486.21	471.60	731.6	1203.2	0.02013	0.77
		900.0	531.98	526.60	668.8	1195.4	0.02123	0.50
		1200.0	567.22	571.70	611.7	1183.4	0.02232	0.36
		1500.0	596.23	611.60	556.3	1167.9	0.02346	0.28
		1700.0	613.15	636.30	519.6	1155.9	0.02428	0.24
		2000.0	635.82	671.70	463.4	1135.1	0.02565	0.19
		2500.0	668.13	730.60	360.5	1091.1	0.02860	0.13
		2700.0	679.55	756.20	312.1	1068.3	0.03027	0.11
		3206.2	705.40	902.70	0.0	902.7	0.05053	0.05

Capacity and Volume Conversions

Dry Measurements	
2 pints	1 quart
8 quarts	1 peck
4 pecks	1 bushel
Liquid Measurement	
4 gills	1 pint
2 pints	1 quart
4 quarts	1 gallon
31.5 gallons	1 barrel

Volume Measurements	
1 cm^3	0.061 in^3
1 in^3	16.39 cm^3
1 ft^3	0.0283 m^3
1 m^3	1.308 $yard^3$
1 $yard^3$	0.7646 m^3
1 liter	1.0567 qt liquid
1 quart dry	1.101 liters
1 quart liquid	0.9463 liters
1 liter	1.0567 quarts
1 gallon	3.78541 liters
1 peck	8.810 liters
1 hectoliter	2.8375 bushels
1.728 in^3	1 ft^3
27 ft^3	1 $yard^3$
128 ft^3	1 cord (wood)
2,150.42 in^3	1 standard bu.
231 in^3	1 U.S. std gallon

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Explaining Rating Standards

Comparing Specific Applications of NEMA-Rated Enclosures in Nonhazardous Locations

Descriptions		1	2	3	3R	3S	4	4X	5	6	6P	11	12	12K	13
Indoor Non-hazardous locations	Incidental contact with enclosed equipment	•	•				•	•	•	•	•	•	•	•	•
	Falling dirt	•	•				•	•	•	•	•	•	•	•	•
	Falling liquids and light splashing		•				•	•		•	•	•	•	•	•
	Dust, lint, fibers, and flyings*						•	•	•	•	•		•	•	•
	Hosedown and splashing water						•	•		•	•				
	Oil and coolant seepage												•	•	•
	Oil or coolant spraying and splashing														•
	Corrosive agents							•			•	•			
	Occasional temporary submersion									•	•				
	Occasional prolonged submersion										•				
Outdoor Non-hazardous locations	Incidental contact with enclosed equipment			•	•	•	•	•		•	•				
	Rain, snow, and sleet**			•	•	•	•	•		•	•				
	Sleet***					•									
	Windblown dust			•		•	•	•		•	•				
	Hosedown						•	•		•	•				
	Corrosive agents							•			•				
	Occasional temporary submersion									•	•				
	Occasional prolonged submersion										•				

** Nonhazardous materials, not considered the Class III type ignitable fibers or combustible flyings.*
*** External operating mechanisms are not required to be operable when enclosure is ice-covered.*
**** External operating mechanisms are operable when enclosure is ice-covered.*

Comparing NEMA and IEC Enclosure Ratings

Though the two systems seem to parallel each other, there is no direct conversion between them. The following shows the highest IEC rating equivalent to the corresponding NEMA type. It *should not be used* to convert IEC to NEMA types.

NEMA Type	NEMA Definition	IEC Class
1	***General Purpose:*** Protects against dust, light, and indirect splashing but is not dust-tight; primarily prevents contact with live parts; used indoors and under normal atmospheric conditions.	IP10
2	***Drip-tight:*** Similar to Type 1, adding drip shields; used where condensation may be severe (e.g., cooling rooms and laundries)	IP11
3, 3S	***Weather-resistant:*** Protects against weather hazards such as rain and sleet; used outdoors on docks, in construction work, and in tunnels and subways.	IP54
3R	***Intended for outdoor use:*** Provides a degree of protection against falling rain and ice formation. Meets rod entry, rain, external icing, and rust-resistance design tests.	IP14
4, 4X	***Watertight/weatherproof:*** Must exclude at least 65 GPM water from 1″ nozzle, delivered from a distance no less than 10 feet for five minutes. Used outdoors on docks, in dairies, and in breweries.	IP56
5	***Dust-tight:*** Provided with gaskets or equivalent to exclude dust; used in high-dust atmospheres (steel mills and cement plants).	IP52
6, 6P	***Submersible in water:*** For submerged operation under specified pressures and time; used in quarries, mines, and manholes.	IP67
7	***Hazardous:*** For indoor use in Class I, Groups A–D environments, as defined in the NEC.	—
8	***Hazardous:*** For indoor and outdoor use in locations classified as Class I, Groups A–D environments, as defined in the NEC.	—
9	***Hazardous:*** For indoor and outdoor use in locations classified as Class II, Div 1, Groups E–G environments (combustible dust), as defined in the NEC.	—
10	***MSHA Explosion-Proof:*** Meets the requirements of the Mine Safety and Health Administration, 30 CFR Part 18 (1978). Units designed to contain gas or vapor explosions within the enclosure and prevent ignition of the surrounding atmosphere.	—
11	***General Purpose:*** Protects against corrosive effects of liquids and gases. Meets drip- and corrosion-resistance tests. Acid- or fume-resistant. Provides for immersion of enclosed equipment in oil.	—
12, 12K	***General Purpose:*** Intended for indoor industrial use, provides some protection against dust, falling dirt, and dripping non-corrosive liquids. Meets drip-, dust-, and rust-resistance tests.	IP52
13	***General Purpose:*** Primarily used to provide protection against dust, spraying of water, oil, and non-corrosive coolants. Meets oil exclusion and dust-resistance design tests.	IP54

IEC/IP Enclosures and Classification Designations

IEC 529 outlines a classification system for the sealing effectiveness of electrical equipment enclosures. It uses a designation of ***IP(ab)***, where (a) denotes the degree of protection against contact and ingress of solid bodies and (b) denotes the degree of protection against ingress of water.

(a) Solids Protection

0 No special protection.
1 Protection against ingress of solid objects, diameter >50mm.
2 Protection against penetration by solid objects, diam. >12mm.
3 Protection against ingress of solid objects, diameter >2.5mm.
4 Protection against ingress of solid objects, diameter >1 mm.
5 Dust-protected.
6 Dust-tight.

(b) Water Protection

0 No special protection.
1 Protection against dripping water falling vertically.
2 Protection against dripping water falling at 75° to 90° angles.
3 Protection against water being sprayed.
4 Protection against water being splashed.
5 Protection against water jets.
6 Protection against heavy seas.
7 Protection against the effects of immersion.
8 Protection against indefinite immersion.

Enclosure	IP10	IP30	IP32	IP55	IP64	IP65	IP66	IP67
NEMA 1	•							
NEMA 2		•						
NEMA 3					•			
NEMA 3R			•					
NEMA 3S					•			
NEMA 4							•	
NEMA 4X							•	
NEMA 6								•
NEMA 12						•		
NEMA 13						•		

Note: *NEMA standards meet or exceed IEC standards; therefore, the conversion does not work in the opposite direction.*

Agency Approvals and Safety Ratings

As a way of standardizing enclosure performance, worldwide organizations use rating systems to identify an enclosure's ability to resist external environmental influences.

NEMA, UL, and CSA are standard-writing organizations commonly recognized in North America. UL and CSA both require enclosure testing by qualified evaluators. NEMA does not require independent testing and leaves compliance completely up to the manufacturer.

NEMA Type	Underwriters Laboratories Inc. (UL 50 and UL508)	Canadian Standards Association (Standard C22.2 No. 94)
1	Indoor use, primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt.	General purpose enclosure. Protects against accidental contact with live parts.
2	Indoor use to provide a degree of protection against limited amounts of falling water and dirt.	Indoor use to provide a degree of protection against dripping and light splashing of non-corrosive liquids and falling dirt.
3	Outdoor use to provide a degree of protection against windblown dust and rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use, provides a degree of protection against rain, snow, and windblown dust; undamaged by the external formation of ice on the enclosure.
3R	Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use, provides a degree of protection against rain and snow; undamaged by the external formation of ice on the enclosure.
4	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water, undamaged by the formation of ice on the enclosure.	Indoor or outdoor use, provides a degree of protection against rain, snow, windblown, dust, splashing, and hose-directed water; undamaged by the external formation of ice on the enclosure.
4X*	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure; resists corrosion.	Indoor or outdoor use, provides a degree of protection against rain, snow, windblown, dust, splashing, and hose-directed water; undamaged by the external formation of ice on the enclosure, resists corrosion.
6	Indoor or outdoor use to provide a degree of protection against entry of water during temporary submersion at a limited depth; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against the entry of water during temporary submersion.
12	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water, and external condensation of non-corrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers, and flyings; dripping and light splashing of non-corrosive liquids; not provided with knockouts.
13	Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil, and non-corrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings, seepage and spraying of non-corrosive liquids, including oils and coolants.

** 4X rating only indicates that an enclosure can resist corrosion. It does not provide information on how a specific corrosive agent will affect a given enclosure material.*

What Is a Safety Integrity Level?

A measure of the amount of risk reduction provided by hardware or systems, based on a probability analysis of the failure of a device. SIL requirements prevent systematic failures (bugs) from being designed into a device. They can be met by establishing a rigorous development process, or by establishing that the device has sufficient operating history to argue that it has been proven in use.

Safety Integrity Level	Safety	Probability of Failure on Demand	Risk Reduction Factor
SIL4	> 99.99%	0.001% to 0.01%	100,000 to 10,000
SIL3	99.9% to 99.99%	0.01% to 0.1%	10,000 to 1,000
SIL 2	99% to 99.9%	0.1% to 1.0%	1,000 to 100
SIL 1	90% to 99%	1.0% to 10%	100 to 10

Understanding Class/Division/Zone Hazardous Location Classification Methodology

In the last several years, the standards and language for classifying hazardous locations has changed. The following charts will help explain how to move from older Class/Division/Group ratings to their equivalent Class/Zone/Group ratings.

Area Classification Table

Continuous Hazard	Intermittent Hazard	Hazard Under Abnormal Conditions
Zone 0	Zone 1	Zone 2
Division 1		Division 2

Division Atmospheric Groups

Typical Hazard	Division Groups	Zone Groups
Acetylene	A	IIC
Hydrogen	B	
Ethylene	C	IIB
Propane	D	IIA

Classes (Defining the material risk)

Class I — Area made hazardous due to the presence of flammable or combustible gas.

Class II — Area made hazardous due to the presence of flammable or combustible dusts.

Class III — Area made hazardous due to the presence of flammable or combustible fibers or flyings.

Divisions/Zones (Addresses the risk, probability, and frequency the material is present in hazardous concentrations)

Div 1 — Explosive atmosphere is normally present, either continuously or intermittently.

Div 2 — Explosive atmosphere is present abnormally only.

Zone 0 — Gaseous hazard is normally present, continuously.

Zone 1 — Gaseous hazard is normally present, intermittently.

Zone 2 — Gaseous hazard is present only in abnormal circumstances.

Zone 20 — Dust hazard is normally present, continuously.

Zone 21 — Dust hazard is normally present, intermittently.

Zone 22 — Dust hazard is present only in abnormal circumstances.

Groups (Identifies the possible gas hazards)

Group A (IIC) — Acetylene

Group B (IIC) — Hydrogen

Group C (IIB) — Ethylene

Group D (IIA) — Propane

Group E — Metal (conductive) dusts

Group F — Carbon-rich dusts

Group G — Grain dusts

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Media Properties

Dielectric Constants for Common Materials

Unless stated otherwise, values are measured at 68°F

Material	Temp. °F/°C	Dielectric Constant
Acetal		3.6
Acetoaldehyde		22.2
Acetoanilide, granules		2.8
Acetone		21.4
Acetyl methyl hexyl ketone		28
Acrylic resin		2.7 to 6
Alcohol		16 to 31
Aluminium carbonate		5.6
Aluminium chlorate		5.1
Aluminium ether		3.1
Aluminium powder		1.6 to 1.8
Ammonia	-27/-332	2.4
Ash (flyash)		1.9 to 2.6
Bakelite		4.5 to 5.5
Barley, powder		3.4 to 4.0
Benzene		2.3
Benzil	202/94	13
Bleaching powder		1.8 to 2.0
Bromine		3.1
Butane	30/-1	1.4
Calcium carbonate		1.8 to 2.0
Carbon dioxide		1.6
Carbon tetrachloride		2.2
Castor oil	60/16	4.7
Cellophane		7 to 7.7
Celluloid		4.1
Cellulose		6.7
Chlorine	32/0	2
Chlorine		2.1
Chloroform	32/0	5.5
Coal		1.2 to 1.8
Coke, powder		1.1 to 2.2
Colophonium		2.5 to 2.6
Corn		2.3 to 2.6
Cyclohexane		2
Dimethylheptane		1.9
Dimethylpentane		1
Dolomite		8.8
Dowtherm	70/21	3.3
Ethanol	77/25	24.3
Ethyl acetate		6.4
Ethyl alcohol		23
Ethyl benzene		2.5
Ethyl ether		4.3
Ethyl toluene		2.2
Ethylene chloride		10.5
Ethylene glycol		37
Ferric oxide		1.4 to 1.8
Fluorine resin		2 to 8
Formic acid	60/16	58.5
Freon		2.2
Freon 12	70/21	2.4
Glass raw material		2.0 to 2.5
Glass-silicon plate		3.5 to 4.2
Glycerine		47
Glycol		36
Heptane		1.9
Hexane		1.9
Hydrogen chloride	82/28	4.6
Iodine	224/107	118
Kerosene	70/21	1.8
Manganese dioxide		5.0 to 5.2
Margarine, liquid		2.8 to 3.2
Melamine resin		4.7 to 10.2
Methanol	77/25	33.6
Methyl acetate		7.3
Methyl alcohol		33.1
Methyl ether	78/26	5
Methyl salycilate		9
Mica		4.5 to 7.5
Napthalene		2.5
Nylon		4 to 5
Octane		2
Oil, mineral		2.2 to 2.4
Oils, petroleum		1.8 to 2.2
Oils, vegetable		2.5 to 3.5
Olefin		3.2
Oleic acid		2.5
Paraffin		1.9 to 2.5
Pentane		1.8
Phenol	118/47	9.9
Phenolic resin		4 to 12
Phosgene	32/0	4.7
Polyacetal resin		2.6 to 3.7
Polyamide resin		2.5 to 2.6
Polycarbonate resin		2.9 to 3
Polyester resin		2.8 to 4.5
Polyethylene resin		2.2 to 2.6
Polystrene resin		2.2 to 2.6
Propane	32/0	1.6
Pyridine		12.5
Rubber, raw		2.1 to 2.7
Rubber, vulcanized		2.0 to 3.5
Sand		3 to 5
Sesame, powder		1.8 to 2.0
Silica sand		2.5 to 3.5
Silicon		2.4
Silicon resin		3.5 to 5
Silicon tetrachloride		2.4
Soap, powder		1.2 to 1.5
Sodium carbonate		5.3 to 8.4
Sodium nitrate		5.2
Soybean		1.8 to 2.0
Steatite		5.3 to 6.8
Styrene (styrol resin)	77/25	2.4
Sugar		3
Sulfur monoxide		4.8
Sulfur, powder		1.5 to 1.8
Teflon		2
Toluene		2.4
Trichloethylene		3.4
Urea		3.5
Urethane		6.5 to 7.1
Vinyl ether		3.9
Water		80
Wheat, powder		2.5 to 3
Xylene		2.4

Emissivities of Common Materials

Emissivities of most materials are measured at 32°F (0°C) but do not differ significantly at room temperature.

Material	Emissivity
Aluminum, polished	0.05
Aluminum, rough surface	0.07
Aluminum, strongly oxidized	0.25
Asbestos board	0.96
Asbestos fabric	0.78
Asbestos paper	0.94
Asbestos slate	0.96
Brass, dull, tarnished	0.22
Brass, polished	0.03
Brick, common	0.85
Brick, glazed, rough	0.85
Brick, refractory, rough	0.94
Bronze, porous, rough	0.55
Bronze, polished	0.10
Carbon, purified	0.80
Cast iron, rough casting	0.81
Cast iron, polished	0.21
Charcoal, powdered	0.96
Chromium, polished	0.10
Clay, fired	0.91
Concrete	0.54
Copper, polished,	0.01
Copper, commercial burnished	0.07
Copper, oxidized	0.65
Copper, oxidized to black	0.88
Electrical tape, black plastic	0.95
Enamel (80.6°F)	0.90
Formica	0.93
Frozen soil	0.93
Glass	0.92
Glass, frosted	0.96
Gold, polished	0.02
Ice	0.97
Iron, hot rolled	0.77
Iron, oxidized	0.74
Iron, sheet galvanized, burnished	0.23
Iron, sheet, galvanized, oxidized	0.28
Iron, shiny, etched	0.16
Iron, wrought, polished	0.28
Lacquer, Bakelite	0.93
Lacquer, black, dull	0.97
Lacquer, black, shiny	0.87
Lacquer, white	0.87
Lampblack	0.96
Lead, gray	0.28
Lead, oxidized	0.63
Lead, red, powdered	0.93
Lead, shiny	0.08
Mercury, pure	0.10
Nickel, on cast iron	0.05
Nickel, pure polished	0.05
Paint, silver finish (77°F)	0.31
Paint, oil, average	0.94
Paper, black, shiny	0.90
Paper, black, dull	0.94
Paper, white	0.90
Platinum, pure, polished	0.08
Porcelain, glazed	0.92
Quartz	0.93
Rubber	0.93
Shellac, black, dull	0.91
Shellac, black, shiny	0.82
Snow	0.80
Steel, galvanized	0.28
Steel, oxidized strongly	0.88
Steel, rolled freshly	0.24
Steel, rough surface	0.96
Steel, rusty red	0.69
Steel, sheet, nickel plated	0.11
Steel, sheet, rolled	0.56
Tar paper	0.92
Tin, burnished	0.05
Tungsten	0.05
Water	0.98
Zinc, sheet	0.20

Refractive Indices of Common Materials

Material	Refractive Index	Material	Refractive Index	Material	Refractive Index	Material	Refractive Index
Acetaldehyde	1.3316	Di-Ethyl Benzene	1.4955	Isopropyl Myristate	1.4332	Sulfuric Acid	1.834
Acetic Acid	1.3717	Di-Ethyl Ether	1.3497	Lead Tetraethyl	1.5198	Tetrahydrofuran	1.4072
Acetic Anhydride	1.3904	Dimethyl Acetamide	1.4384	Menthol	1.458	Titanium	2.16
Acetone	1.3588	Dimethyl Benzene	1.4972	Methyl Alcohol	1.3288	Toluene	1.4969
Acetonitrile	1.3441	Dimethyl Sulfoxide	1.4793	Methyl Ethyl Ketone	1.3788	Toluidine(o)	1.5728
Acrylic Acid	1.4224	Dimethylaniline	1.5582	Methyl Iodide	1.5293	Trichlorofluoroethane (Freon 113)	1.36
Aluminum	1.39	Dodecane	1.41	Methyl Isoamyl Ketone	1.407	Tricholoroethane	1.4377
Amyl Acetate	1.4012	Ethanol	1.36	Methyl Isobutyl Ketone	1.3957	Triethylamine	1.401
Aniline	1.5863	Ethyl Acetate	1.3722	Methyl n-Propyl Ketone	1.3901	Trifluoroacetic Acid	1.285
Beer	1.345	Ethyl Alcohol	1.3624	Methyl t-Butyl Ether	1.3689	Turpentine	1.472
Benzaldehyde	1.5463	Ethyl Benzene	1.4952	Methylacetate	1.3594	Turpentine (wood)	1.47
Benzene	1.5011	Ethyl Bromide	1.4239	Nickel	1.08	Water	1.333
Benzyl Alcohol	1.5396	Ethyl Ether	1.3524	Nitric Acid	1.397	Water (0° C)	1.33346
Benzylamine	1.5401	Ethylene Dichloride	1.4448	Nitrobenzene	1.5529	Water (100° C)	1.31766
Bromoaniline (m)	1.626	Ethylene Glycol	1.4627	Nitromethane	1.3818	Xylene(o)	1.5055
Butyl Acetate	1.3951	Formamide	1.4453	Nitrotoluene(o)	1.5474		
Butyl Alcohol	1.3993	Formic Acid	1.3714	N-Methylpyrolidone	1.47	***Brix Scale (% Sugar Content)***	
Butyl Chloride (n)	1.4021	Freon R-11	1.37	Nonane	1.4055	0% Brix	1.3330
Butylene	1.3962	Freon R-12	1.29	Octane	1.3975	5% Brix	1.3403
Carbon Disulfide	1.6295	Freon R-22	1.26	Oil, vegetable (50° C)	1.47	10% Brix	1.3479
Carbon Tetrachloride	1.4631	Furan	1.47	Pentane	1.3575	15% Brix	1.3557
Carbonated Beverages	1.34 - 1.356	Glycerol (Glycerin)	1.4729	Perchloroethylene	1.5053	20% Brix	1.3639
Chlorine, Liquid	1.385	Glycol	1.4318	Petroleum Ether	1.365	25% Brix	1.3723
Chlorobenzene	1.5248	Gold	0.47	Phenol	1.5425	30% Brix	1.3811
Chloroform	1.4464	Heptane	1.3876	Platinum	2.33	35% Brix	1.3902
Copper	2.43	Hexane	1.3749	Pronanol(iso)	1.3776	40% Brix	1.3997
Cranberry Juice (25%)	1.351	Hexanol	1.4135	Propane	1.34	45% Brix	1.4096
Cycloheptane	1.444	Hydrazine	1.47	Propyl Alcohol (n)	1.3856	50% Brix	1.4200
Cyclohexane	1.4262	Hydrogen Chloride	1.256	Propyl Bromide	1.4341	55% Brix	1.4307
Cyclohexanone	1.4503	Ice	1.309	Propylene	1.36	60% Brix	1.4418
Cyclopentane	1.4065	Isobutyl Alcohol	1.3959	Propylene Carbonate	1.421	65% Brix	1.4532
Decane	1.41203	Iso-Octane	1.3914	Propylene Glycol (100%)	1.433	70% Brix	1.4651
Decane	1.41	Isopentane	1.355	Pyridine	1.5102	75% Brix	1.4774
Dichlorobenzene (o)	1.5514	Isopropyl Acetate	1.377	Silver	1.35	80% Brix	1.4901
Dichloromethane	1.4241	Isopropyl Alcohol	1.3772	Styrene	1.5434	85% Brix	1.5003

Viscosities of Common Substances

Medium @68°F	Approx. Viscosity	Medium @68°F	Approx. Viscosity
Ammonia	0.009 82 cP	Ketchup	50,000 cP
Argon	0.022 17 cP	Light machine oil	102 cP
Benzene	0.652 cP	Mercury	1.554 cP
Benzyl Ether	5.33 cP	Methyl Alcohol	0.597 cP
Caster Oil	986 cP	Molasses	100,000.0 cP
Chloroform	0.58 cP	Neon	0.031 11 cP
Chocolate Syrup	25,000 cP	Olive Oil	84.0 cP
Confectioners' Glucose	1,000,000.0 cP	Pancake Syrup	2,500 cP
Corn Syrup	10,000.0 cP	Peanut Butter	250,000 cP
Ether	0.233 cP	SAE 10 Motor Oil	100.0 cP
Ethyl Alcohol	1.2 cP	Soybean Oil	69.3 cP
Glycerin	1,490 cP	Tar or Pitch	30,000,000,000 cP
Glycol	19.9 cP	Air @ 18°C	0.018 2 cP
Heavy Machine Oil	233 cP	Air @ 229°C	0.026 38 cP
Honey	10,000 cP	Liquid Air @ -192.3°C	0.173 cP
Hydrogen	0.008 6 cP	Water	1.002 cP
Kerosene	10.0 cP	Water @ 99°C	0.2848 cP
		Water Vapor @100°C	0.125 5

Viscosity Conversion: *Centistokes= Centipoise/Specific Gravity (SG)*
Centipoise= 0.22 x SG x SSU - (180 x SG/SSU)
SSU= Viscosity in Saybolt Seconds Universal

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Media Properties

Specific Gravities for Common Materials

Unless stated otherwise, values are measured at 68°F

Fluid	Temp °F	SG
Acetaldehyde CH3CHO	61	0.790
Acetaldehyde CH3CHO	68	0.760
Acetic acid, 10%	59	1.014
Acetic acid, 50%	59	1.061
Acetic acid, 80%	59	1.075
Acetic acid, concentrated	59	1.055
Acetic acid 5%, vinegar	59	1.006
Acetic acid anhydride (CH3COO)2O	59	1.087
Acetone	77	0.787
Acetone CH3COCH3	68	0.792
Acetylene, liquid	-121	0.620
Acetylene, liquid	70	0.380
Adipic acid		0.720
Alcohol, allyl	68	0.855
Alcohol, butyl-n	68	0.810
Alcohol, ethyl (grain)	68	0.789
Alcohol, ethyl (grain)	104	0.772
Alcohol, methyl (wood)	68	0.790
Alcohol, methyl (methanol)	77	0.791
Alcohol, propyl	68	0.804
Aluminum sulfate 36% solution	60	1.055
Ammonia	0	0.662
Ammonia (aqua)	77	0.826
Aniline	68	1.022
Auto crankcase oil SAE-5W-50W	60	0.88-0.94
Auto gear oil SAE-75W-150W	60	0.88-0.94
Beer	60	1.010
Benzene (benzol) C6H6	32	0.899
Benzene (benzol) C6H6	60	0.885
Benzil	77	1.084
Bone oil	60	0.918
Boric acid H3BO3	46.4	1.014
Bromine	32	2.900
Bromine	77	3.120
Butane, liquid	77	0.601
Butane-n	60	0.584
Butyric acid	68	0.959
Calcium chloride 25%	60	1.230
Calcium chloride 5%	65	1.040
Caproic acid	77	0.924
Carbolic acid (phenol)	65	1.080
Carbon disulfide CS2	32	1.293
Carbon disulfide CS2	68	1.263
Carbon tetrachloride CCl4	68	1.594
Carene	77	0.860
Castor Oil	68	0.960
Castor Oil	104	0.950
China wood oil	60	0.943
Chloride	77	1.560
Chlororm	77	1.469
Citric acid	77	1.665
Coconut Oil	59	0.927
Cod liver oil	59	0.920-0.925
Corn oil	60	0.924
Cotton Seed Oil	59	0.929
Creosote	59	1.070
Cresol	77	1.027
Crude oil 32.6° API	60	0.832
Crude oil 32.6° API	130	0.840
Crude oil 35.6° API	60	0.847
Crude oil 35.6° API	130	0.824
Crude oil 40° API	60	0.825
Crude oil 40° API	130	0.805
Crude oil 48° API	60	0.790
Crude oil 48° API	130	0.760
Crude oil Salt creek	60	0.843
Crude oil Salt creek	130	0.820
Crude oil, California	60	0.918
Crude oil, Mexican	60	0.976
Crude oil, Texas	60	0.876
Cumene	77	0.862
Decane-n	68	0.730
Diesel Fuel Oil 2D/3D/4D/5D	60	0.81, 0.96
Diethyl ether	68	0.714
Diethylene glycol	60	1.120
Diphenylamine		1.160
Dodecane	77	0.757
Dowtherm	77	1.056
Ethane	-128.2	0.572
Ether	77	0.716
Ether, sulfuric		0.720
Ethyl acetate CH3COOC2H3	68	0.900
Ethyl bromide C2H3Br	59	1.450
Ethylamine	0.8	0.683
Ethylene bromide	68	2.180
Ethylene chloride	68	1.246
Ethylene glycol	60	1.125
Ethylene glycol	77	1.100
Fluoric acid		1.500
Fluorine (freon) refrigerant R-11	77	1.480
Fluorine refrigerant R-12	77	1.315
Fluorine refrigerant R-22	77	1.197
Formaldehyde	113	0.815
Formic acid, 10%	68	1.025
Formic acid, 50%	68	1.121
Formic acid, 80%	68	1.186
Formic acid, concentrated	68	1.221
Freon, 11	70	1.490
Freon, 12	70	1.330
Freon, 21	70	1.370
Fuel oil	60	0.893
Fuel oils 1/2/3/5A/5B/6	60	0.82-0.95
Furan	77	1.421
Furfurol	68	1.159
Gas oils	60	0.890
Gasoline, natural	60	0.713
Gasoline, Vehicle	60	0.739
Glucose	60	1.35-1.44
Glycerine 100%	68	1.260
Glycerine 50% water	68	1.130
Glycerol	77	1.129
Heptane-n	60	0.688
Hexane-n	60	0.664
Hexanol	77	0.813
Hexene	77	0.673
Hydrazine	77	0.797
Ink printers	60	1.0-1.4
Jet fuel	60	0.820
Kerosene	60	0.820
Lard	60	0.960
Lard oil	60	0.91-0.93
Linolenic Acid	77	0.902
Linseed Oil	77	0.932
Mercury	60	13.600
Methane	-263.2	0.466
Methyl acetate	68	0.930
Methyl iodide	68	2.280
Milk	60	1.035
Mineral oil		0.920
Molasses A first	60	1.40-1.46
Molasses B second	60	1.43-1.48
Molasses C blackstrap	60	1.46-1.49
Muriatic acid		1.200
Naphtha, Petroleum Naphtha	59	0.667
Naphthalene	68	1.145
Napthalene	77	0.963
Neatsfoot oil	60	0.917
Nitric acid		1.500
Nitrobentzene	68	1.203
Nonane-n	60	0.722
Nonane-n	68	0.718
Nonanol	77	0.823
Octane-n	60	0.707
Oil, Castor	77	0.959
Olive Oil	59	0.703
Oxygen	-297.4	1.140
Palm oil	60	0.924
Palmitic Acid	77	0.853
Parole	77	0.969
Peanut oil	60	0.920
Pentane	77	0.755
Pentane-n	32	0.650
Pentane-n	60	0.631
Petroleum oil		0.820
Phenol	77	1.075
Phosgene	32	1.381
Phosphoric acid		1.780
Phytadiene	77	0.826
Pinene	77	0.858
Potassium hydrate		1.240
Propane	-40	0.585
Propane	77	0.495
Propylene	77	0.516
Propylene glycol	77	1.036
Pyridine	77	0.968
Rape oil		0.920
Resorcinol	77	1.272
Sabiname	77	0.814
Sea water	77	1.028
Silane	77	0.719
Sodium chloride		1.190
Sodium hydrate		1.270
Sorbaldehyde	77	0.898
Stearic Acid	77	0.941
Styrene	77	0.906
Sulphuric acid		1.840
Tar		1.000
Terpinene	77	0.850
Toluene	77	0.865
Tuluol		0.870
Turpentine	77	0.871
Turpentine oil		0.870
Vinegar		1.080
Water, pure	39.2	1.000
Water, sea	77	1.025
Whale oil		0.920
Wood	77	0.701
Xylene		0.870

Common Flammable Gases

Flash point is the lowest temperature at which the surface of a liquid emits sufficient vapor to be ignited by a small flame.

Ignition temperature is the point at which a gas will ignite, even without an external spark or flame ignition source.

Lower explosive limit/lower flammable limit (LEL/LFL) is the lowest concentration at which a mixture is able to produce an explosion. Below this point, the mixture is too lean (insufficient oxygen).

Upper explosive limit/Upper flammable limit (UEL/UFL) is the highest concentration at which a mixture would be flammable. Above this point, the mixture is too rich, and lacks the sufficient oxygen to burn.

Common Name	CAS Number	Mol. Weight	Vapor Density	Boiling Point °C	Flash Point °C	Ignition Temp °C	Flammable Limits			
							LFL %v/v	UFL %v/v	LFL mg/L	UFL mg/L
Acetone	67-64-1	58.08	2.00	56	<–20	535	2.50	13.00	80	316
Acetylene	74-86-2	26	0.90	-84		305	2.30	100.00	24	1,092
Benzene	71-43-2	78.1	2.70	80	-11	560	1.20	8.60	39	280
Butane	106-97-8	58.1	2.05	-1		372	1.40	9.30	33	225
Cyclobutane	287-23-0	56.1	1.93	13			1.80		42	
Cyclohexane	110-82-7	84.2	2.90	81	-18	259	1.20	8.30	40	290
Dimethyl Ether	115-10-6	46.1	1.59	-25	-42 gas	240	2.70	32.00	51	610
Ethane	74-84-0	30.1	1.04	-87		515	2.50	15.50	31	194
Ethanol	64-17-5	46.1	1.59	78	12	363	3.10	19.00	59	359
Ethyl Acetate	141-78-6	88.1	3.04	77	-4	460	2.20	11.00	81	406
Ethylene	74-85-1	28.1	0.97	-104		425	2.30	36.00	26	423
Ethylene Oxide	75-21-8	44	1.52	11	<-18	435	2.60	100.00	47	1,848
Hexane (Mixed Isomers)	110-54-3	86.2	2.97	69	-21	233	1.00	8.40	35	290
Hydrogen	1333-74-0	2	0.07	-253		560	4.00	77.00	3,4	63
Isobutane	75-28-5	58.12	2.00	-12	gas	460	1.30	9.80	31	236
Kerosene	8008-20-6			150	38	210	0.70	5.00		
Methane (Firedamp)	74-82-8	16	0.55	-161		537	4.40	17.00	29	113
Methanol	67-56-1	32	1.11	65	11	386	5.50	38.00	73	484
Methyl Acrylate	96-33-3	86.1	3.00	80	-3	415	2.40	25.00	85	903
Methylamine	74-89-5	31.1	1.00	-6	-18 gas	430	4.20	20.70	55	270
Methyl Formate	107-31-3	60.05	2.07	32	-20	450	5.00	23.00	125	580
Pentanes (Mixed Isomers)	109-66-0	72.2	2.48	36	-40	258	1.40	7.80	42	236
Pentane-2,4-Dione	123-54-6	100.1	3.50	140	34	340	1.70		71	
Petroleum			2.80		<-20	560	1.20	8.00		
Propene	115-07-1	42.1	1.50	-48		455	2.00	11.00	35	194
Styrene	100-42-5	104.2	3.60	145	30	490	1.10	8.00	48	350
Toluene	108-88-3	92.1	3.20	111	4	535	1.10	7.60	42	300
Vinyl Acetate	108-05-4	86.09	3.00	72	-8	425	2.60	13.40	93	478
Xylenes	1330-20-7	106.2	3.66	144	30	464	1.00	7.60	44	335

Common Toxic Gases

8-Hour TWA is a long-term exposure limit based on a time-weighted average exposure to the toxic substance.

STEL is based on a short-term, typically 15-minute, exposure to the toxin.

Threshold limit value is defined by the American Conference of Governmental Industrial Hygienists (ACGIH) as an exposure limit to which it is believed nearly all workers can be exposed day after day for a working lifetime without ill effect.

Ceiling is the concentration that should not be exceeded during any part of the workday exposure.

Common Name	CAS Number	EH40 Workplace Exposure Limits 8-Hour TWA		EH40 Workplace Exposure Limits 15-Minute STEL		OSHA Permissible Exposure Limits 8-Hour TWA		ACGIH Threshold Limit Value
		ppm	mg.m-3	ppm	mg.m-3	ppm	mg.m-3	ppm
Ammonia	7664-41-7	25	18	35	25	50	35	25
Carbon Monoxide	630-08-0	30	35	200	232	50	55	25
Chlorine	7782-50-5	0.5	1.5	1	2.9	1 (ceiling)	3 (ceiling)	0.5
Ethylene Oxide	75-21-8	5	9.2			1		1
Hydrazine	302-01-2	0.02	0.03	0.1	0.13	1	1.3	0.01
Hydrogen	1333-74-0							Asphyxiant
Hydrogen Chloride	7647-01-0	1	2	5	8	5 (ceiling)	7 (ceiling)	2 (ceiling)
Hydrogen Cyanide	74-90-8			10	11	10	11	4.7 (ceiling)
Hydrogen Peroxide	7722-84-1	1	1.4	2	2.8	1	1.4	1
Hydrogen Sulfide	7783-06-4	5	7	10	14	20 (ceiling)		10
Nitric Acid	7697-37-2	2	5.2	4	10	2	5	2
Nitric Oxide	10102-43-9					25	30	25
Nitrogen Dioxide	10102-44-0					5 (ceiling)	9 (ceiling)	3
Ozone	10028-15-6			0.2	0.4	0.1	0.2	100 ppb
Phosgene	75-44-5	0.02	0.08	0.06	0.25	0.1	0.4	100 ppb
Phosphine	7803-51-2			0.3	0.42	0.3	0.4	300 ppb
Sulfur Dioxide	7446-09-5					5	13	2
Toluene Diisocyanate	584-84-9			0.02 (ceiling)	0.14 (ceiling)			0.005

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Chemical Resistance of Common Compounds

Corrosion and degradation depend on many parameters: Temperature, pressure, concentration, impurities, pH value, materials and surface characteristics, joinings (welding or soldering), and mechanical stress of materials. This table should be used as a guide only. The final responsibility of material selection resides with the end user, who knows the specific process conditions.

▲ High resistance
◆ Moderate resistance
▼ No resistance

Table is valid for pure solutions (unless other percentage stated) at 68°F (20°C.).

	PTFE	PFA	EPDM	NBR	Neoprene	Ebonite	Linatex	FKM/FPM	PVDF (Kynar)	Zirconium Oxide	Aluminum Oxide	AISI316	Titanium	Tantalum	Hastelloy C4	Hastelloy C22	Hastelloy C276	Platinum	Monel	Graphite
Acetic Acid 30%	▲	▲	▲	◆	▲	▲	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▼
Acetic Acid 100%	▲	▲	▲	▼	▼	▲	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	
Aluminum Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	▲	▼
Aluminum Nitrate	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Aluminum Sulphate	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Ammonium Bromide	▲	▲				▲				▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Ammonium Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Ammonium Fluoride	▲	▲	▲	▲	◆	▲	▲	▲	▲	◆	◆	◆	▼	▼	▲	▲	▲	▲	▲	▼
Ammonium Hydroxide	▲		▲	▼	▲	▲	◆	◆	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▼	
Ammonium Nitrate	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▼	▼
Ammonium Sulphate	▲	▲	▲	▲	◆	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Arsenic Acid	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Barium Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Barium Hydroxide	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	
Beer	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Benzoic Acid	▲	▲	▼	▼	▼	▼	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▲
Boric Acid	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	◆
Bromine	▲	▲	▼	▼	▼	◆	▼	▲	▲	▲	▲	▼	◆	▲	◆	◆	◆	▲	◆	▼
Butyl Alcohol	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Butyric Acid	▲	▲	◆	▼	▼	◆		◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆
Calcium Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▼
Calcium Fluoride	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	◆	▲	▼	▼	▲	▲	▲	▲	▲	▼
Calcium Hydroxide	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	
Calcium Hypochlorite	▲	▲	▲	◆	◆	◆	◆	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	◆	▼
Calcium Nitrate	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Calcium Phosphate	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Calcium Sulphate (Gypsum)	▲	▲	▲		▲	▲			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Camphoric Acid	▲	▲				◆			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Carbonic Acid	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	◆
Chlorine	▲	▲	◆	▼	▼	◆	▼	▲	▲	▲	▲	▼	◆	▲	▲	▲	▲	▲	◆	▼
Chlorine Dioxide	▲	▲	▼	▼	▼	◆	▼	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	▼	
Chromic Acid	▲	▲	◆	▼	▼	▲	▼	▲	▲	▲	▲	◆	▲	▲	◆	◆	◆	▲	◆	▼
Citric Acid	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Copper (II) Chloride	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	◆	▲	▲	◆	◆	◆	▲	◆	▼
Copper Sulphate	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▼
Diesel Oil	▲	▲	▼	▲	▼	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Ethanol/Ethyl Alcohol	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Ferric Chloride	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▼	▲	▲	◆	◆	◆	▲	▼	▼
Ferric Nitrate	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▼
Formaldehyde	▲	▲	◆	◆	◆	▲	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Formic Acid	▲	▲	▲	▼	◆	▲	◆	▼	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▼
Fruit Juice	▲	▲	▲	◆	◆	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲[1]	
Hydrobromic Acid	▲	▲	▲	▼	◆	▲	▲	▲	▲	▲	▲	▼	▲	▲	◆	◆	◆	▲	◆	▼
Hydrochloric Acid	▲	▲	▲	◆	◆	◆	◆	▲	▲	▲	▲	◆	▼	▲	◆	◆	◆	▲	◆[1]	▼
Hydrochloric Acid, 0.1%	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	◆	▲[2]	▲	▲[2]	▲[2]	▲[2]	▲	◆[1]	▼
Hydrochloric Acid, 1.0%	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▼	▲[11]	▲	▲[2]	▲[2]	▲[2]	▲	◆[1]	▼
Hydrochloric Acid, 10%	▲	▲	▲			▲		▲	▲	▲	▲	▼	▼	▲	▲[4]	▲[5]	▲[5]	▲	◆[1]	▼
Hydrochloric Acid, 20%	▲	▲	▲		▲	▲	▲	▲	▲	▲	▲	▼	▼	▲	▼	▼	▼	▲	◆[1]	▼
Hydrochloric Acid, 37%	▲	▲	▲	▼	▼	◆	◆	▲	▲	▲	▲	▼	▼	▲	▲[6]	▲[7]	▲[7]	▲	◆[1]	▼
Hydrocyanic Acid	▲	▲	▲	◆	◆	▲	◆	▲	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	▲
Hydrofluoric Acid	▲	▲	◆	▼	◆	▼	▼	◆	▲	▼	◆	▼	▼	▼	◆	◆	◆	▲	▲	▼
Hydrogen Peroxide	▲	▲	▼	▼	▼	◆	▼	▲	▲	?	▲	▲	◆	▲	◆	◆	◆	◆	▼	▼

▲ High resistance
◆ Moderate resistance
▼ No resistance

Table is valid for pure solutions (unless other percentage stated) at 68°F (20°C.).

	PTFE	PFA	EPDM	NBR	Neoprene	Ebonite	Linatex	FKM/FPM	PVDF (Kynar)	Zirconium Oxide	Aluminum Oxide	AISI316	Titanium	Tantalum	Hastelloy C4	Hastelloy C22	Hastelloy C276	Platinum	Monel	Graphite
Hydroiodine Acid	▲	▲			▼	◆			▲	▲	▲	◆	▲	▲	▲	▲	▲	▼	◆	
Iodine	▲	▲	◆	◆	▼	◆	▼	▲	▲	▲	▲	◆	◆	▲	◆	◆	◆	▲	◆	
Kerosene	▲	▲	▼	▲	▼	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Lactic Acid	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	
Magnesium Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▼
Magnesium Hydroxide	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	
Magnesium Nitrate	▲	▲	▲	▲	▲	▲	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Magnesium Sulphate	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Manganese Chloride	▲	▲				▲			▲	▲	▲	◆	▲	▲	▲	▲	▲	◆	◆	
Methanol/Methyl Alcohol	▲	▲	▲	▲	▲	▲	▲	▼	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲
Methylene Chloride	▲	▲	◆	▼	▼	◆	▼	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲
Nitric Acid	▲	▲	◆	◆	◆	◆	▼	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▼
Nitric Acid, 1.0%	▲	▲	▲	◆	◆	▲	▼	◆	▲	▲	▲	▲2	▲2	▲	▲2	▲2	▲2	▲	▼	▼
Nitric Acid, 10%	▲	▲	▲	◆	◆	▲	▼	◆	▲	▲	▲	▲2	▲2	▲	▲2	▲2	▲2	▲	▼	▼
Nitric Acid, 50%	▲	▲	▼	▼	▼	◆	▼	◆	▲	▲	▲	▲2	▲12	▲	▲2	▲2	▲2	▲	▼	▼
Nitric Acid, 70%	▲	▲	◆	▼	▼	▼	▼	▼	▲	▲	▲	▲11	▲2	▲	▲8	▲12	▲5	▲	▼	▼
Nitric + Hydrofluoric Acids (1:1)	▲	▲				▼			▲	▼	◆	▼	▼	▼	◆	◆	◆	◆	▼	
Oxalic Acid	▲	▲	▲	◆	◆	▲	◆	▲	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	▼
Petrol/Gasoline	▲	▲	▼	▲	◆	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Phosphoric Acid	▲	▲	◆	◆	◆	◆	◆	▲	▲	◆	◆	▲	◆	▲	▲	▲	▲	▲	▲1	▼
Phosphoric Acid, 1.0%	▲	▲	▲	◆	◆	▲	◆	▲	▲	▲	▲	▲2	▲2	▲	▲2	▲2	▲2	▲	▲1	▼
Phosphoric Acid, 10%	▲	▲	▲	◆	◆	▲	◆	▲	▲	▲	▲	▲2	▲7	▲	▲2	▲2	▲2	▲	▲1	▼
Phosphoric Acid, 50%	▲	▲				◆				▲	▲	▲13	▼	▲	▲2	▲2	▲2	▲	▲1	▼
Phosphoric Acid, 80%	▲	▲	◆	▼	▼	◆	▼	▲	▲	◆	◆	▲11	▼	▲	▲14	▲14	▲14	▲	▲1	▼
Phosphoric/Hydrofluoric/Nitric Acids (1:1:1)	▲	▲				▼			▲	▼	▼	▼	▼	▼	◆	◆	◆	◆	▼	
Phosphoric/Sulfuric/Nitric Acids (1:1:1)	▲	▲				▼			▲	◆	◆	▼	▼	▲	▲	▲	▲	▲	▼	
Phosphoric + Sulfuric Acids (1:1)	▲	▲				▼			▲	◆	◆	▼	▼	▲	▲	▲	▲	▲	◆1	
Phosphoric + Hydrofluoric Acids (1:1)	▲	▲				▼			▲	▼	▼	▼	▼	▼	◆	◆	◆	▲	◆1	
Potassium Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	◆	▲	▲	▲	▲	▲	▲	
Potassium Cyanide	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	◆	◆	◆	▲	
Potassium Hydroxide	▲	▲	▲	◆	◆	▲	◆	▼	▲	▲	▲	◆	▲	◆	▲	▲	▲	▲	▲	▼
Potassium Nitrate	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▼
Potassium Sulphate	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Sea Water/Salt Water	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲3	
Sodium Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▼
Sodium Hydroxide	▲	▲	▲	◆	▲	▲	▲	▼	▲	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	
Sodium Hypochlorite	▲	▲	◆	▼	◆	◆	▼	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	◆	▼
Sodium Nitrate	▲	▲	▲	◆	◆	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Sodium Sulphate	▲	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼
Sulfuric Acid	▲	▲	◆	▼	▼	◆	◆	◆	▲	◆	◆	◆	◆	▲	▲	▲	▲	▲	◆1	▼
Sulfuric Acid, 1.0%	▲	▲	◆	▼	▼	▲	◆	▲	▲	▲	▲	▲13	▲9	▲	▲10	▲13	▲10	▲	◆1	▼
Sulfuric Acid, 10%	▲	▲	◆	▼	▼	▲	◆	▲	▲	▲	▲	▲6	▼	▲	▲10	▲13	▲10	▲	◆1	▼
Sulfuric Acid, 20% (Oleum)	▲	▲	▼	▼	▼	◆	▼	▲	▲	▲	▲	◆	▼	▲	▲	▲	▲	▲	◆	▼
Sulfuric Acid, 50%	▲	▲	▼	▼	▼	◆	▼	◆	▲	◆	◆	▼	▼	▲	▲4	▲8	▲5	▲	◆1	▼
Sulfuric Acid, 100%	▲	▲	▼	▼	▼	▼	▼	◆	▲	◆	◆	▲6	▼	▲	▲4	▲7	▲6	▲	▼	▼
Sulfuric + Nitric Acids (1:1)	▲	▲				◆			▲	◆	◆	▼	▼	▲	▲	▲	▲	▲	▼	
Tin Chloride (Stannous Chloride)	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▲	▲	◆	◆	◆	▲	◆	▼
Toluene	▲	▲	▼	▼	▼	◆	▼	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Water, Deionized	▲	▲	▲	◆	◆	▲		▲	▲	▲	▲	◆	◆	▲	◆	▲	▲	▲	◆	
Water, Potable	▲	▲	▲	▲	◆	▲	◆	◆	▲	▲	▲	◆	▲	▲	▲	▲	▲	▲	▲	▼
Zinc Chloride	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◆	◆	▲	◆	◆	◆	▲	▲	▼

Exception Codes

1 No Air
2 Max Boiling Point
3 No Stagnation
4 Max 40°C (104°F)
5 Max 45°C (113°F)
6 Max 50°C (122°F)
7 Max 55°C (131°F)
8 Max 60°C (140°F)
9 Max 65°C (149°F)
10 Max 75°C (167°F)
11 Max 80°C (176°F)
12 Max 85°C (185°F)
13 Max 95°C (203°F)
14 Max 110°C (230°F)

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Chemical Compatibility of Parker Tubing

- Results below are simplified ratings based on immersion tests at 75°F. Higher temperatures tend to reduce ratings. True ratings depend on pressure, fluid and ambient temperature, and other factors.
- Ratings do not imply compliance with codes such as FDA, NSF, AGA, or UL, and do not cover possible fluid discoloration, taste, or odor effects. Ratings do not imply low permeation rates. Call Lesman for a recommendation for your specific application requirement.
- While Teflon (TFE) tubing is compatible with some chemicals, extreme caution must always be used in dealing with chemicals that can cause severe injury.

▲ Good to excellent. Little or no swelling, tensile or surface changes.
◆ Marginal or conditional. Noticeable effects, but not necessarily indicating lack of serviceability. Further testing may be required for specific applications. Long-term effects such as stiffening should be evaluated.
▼ Poor or unsatisfactory. Not recommended without extensive testing realistic to specific application.
Blank field indicates that chemical was not tested with this tubing.

No performance guarantee is expressed or implied through this table.

Chemical	Tubing See Page	E 400	PP 403	N 402	PV 403	U 401	FRPE Call	PFA 404	TFE 404
Acetone		▼	▲	▲	▼	▼	◆	▲	▲
Acetal Bromide		◆	◆	▼	▼				
Acetal Chloride		◆	◆	▼	▼			▲	▲
Air		▲	▲	▲	▲	▲	▲	▲	▲
Alcohols		▲	▲	▲	◆	◆	▼	▲	▲
Aluminum Salts		▲	▲	▲	▲	▲	▲		
Ammonia		▲	▲	▲	▲	▲	◆		
Amyl Acetate		▲	▲	▲	▼	◆		▲	▲
Aniline		◆	◆	▼	▼	▼		▲	▲
Animal Oils		▼	◆	▲	▲	▲			▲
Aromatic Hydrocarbons		▼	◆	▲	▼	◆	▼		▲
Arsenic Salts		▲	▲	▲	▲	▲	▲		
Barium Salts		▲	▲	▲	▲	▲	▲		
Benzaldehyde		▼	◆	◆	▼	◆	▼	▲	▲
Benzene		▼	◆	▲	▼	◆	▼	▲	▲
Benzyl Alcohol		▼	◆	◆	▲	◆	▼	▲	▲
Bleaching Liquors		▲	▲	◆	◆	◆			
Boric Acid Solutions		▲	▲	▲	▲	▲	▲	▲	▲
Bromine		◆	▼	▼	◆	▼		◆	▲
Butane		◆	▲	▲	◆	▼			
Butanol		▲	▲	▲	▲	▲	▲		
Butyl Acetate		▲	◆	▲	▼	◆	▲	▲	▲
Calcium Hypochlorite		◆	▼	▼	◆	▼	◆	▲	▲
Calcium Salts		▲	▲	▲	▲	▲	▲		
Carbon Dioxide		▲	▲	▲	▲	▲	▲		
Carbon Disulfide		◆	◆	◆	▼	◆			
Carbon Tetrachloride		▼	◆	◆	◆	▼	▼	▲	▲
Caustic Potash		▲	▲	▲	◆	▲		▲	▲
Caustic Soda		▲	▲	▲	◆	▲		◆	▲
Chloracetic Acid		◆	◆	◆	▼	▼		◆	▲
Chlorine (Dry)		◆	◆	▼	▲	▼			
Chlorine (Wet)		◆	◆	▼	▲	◆		▲	▲
Chlorobenzene		▼	◆	◆	▼	◆	▼	▲	▲
Chloroform		▼	▼	▼	▼	▼	▼	▲	▲
Chromic Acid		◆	◆	▼	▲	▼		▲	▲
Copper Salts		▲	▲	▲	▲	▲	▲		
Cresol P		▼	◆	▼	◆	▼	▼	▲	▲
Cyclohexanone		◆	◆	◆	▼	▼		▲	▲
Ethers		◆	▼	▲	◆	▼		▲	▲
Ethyl Chloride		▼	▼	◆	▼		▼	▲	▲
Ethyl Acetate		▲	▲	▲	▼	◆		▲	▲
Ethyl Alcohol		▲	▲	◆	◆	▲	▲		
Ethyl Bromide		▼	◆	◆	▼		▼		
Ethylamine		◆	◆	◆	▼	◆			
Fatty Acids		◆	◆	▲	◆	◆	▼	▲	▲
Ferric Salts		▲	▲	▲	▲	▲			
Formaldehyde		▲	▲	◆	◆	▼		▲	▲
Formic Acid		▲	▲	▼	▲	▼	▲	▲	▲
Freon		◆	◆	▲	▼	◆			
Gasoline		▼	◆	▲	▼	◆	▼	▲	▲
Glucose		▲	▲	▲	▲	▲	▲	▲	▲

Chemical	Tubing See Page	E 400	PP 403	N 402	PV 403	U 401	FRPE Call	PFA 404	TFE 404
Glycerin		▲	▲	▲	▲	◆	▲	▲	▲
Hydriodic Acid		◆	▲	▼	▲				
Hydrochloric Acid (Conc.)		◆	▲	◆	◆	▼		◆	▲
Hydrochloric Acid (Med Conc.)		◆	▲	◆	◆	▼		◆	▲
Hydrofluoric Acid		◆	▲	▼	◆	▼			▲
Hydrogen Peroxide (Conc.)		◆	◆	◆	◆	▲			
Hydrogen Peroxide (Dil.)		◆	◆	▲	▲	▲			
Hydrogen Sulfide		▲	▲	▲	▲	▼		▲	▲
Iodine		◆	▲	▲	◆	◆		▲	▲
Kerosene		◆	◆	▲	◆	◆		▲	▲
Ketones		▲	▲	▲	▼	▼		▲	▲
Lacquer Solvents		◆	◆	▲	▼			▲	▲
Lactic Acid		▲	▲	▲	▲	▲		▲	▲
Lead Acetate		▲	▲	▲	▲	▲		▲	▲
Linseed Oil		◆	▲	▲	◆	▲		▲	▲
Magnesium Salts		▲	▲	▲	▲	▲			▲
Naphtha		◆	◆	▲	▼	◆	▲	▲	▲
Natural Gas		◆	◆	▲	▲	▲			
Nickel Salts		▲	▲	▲	▲	▲			
Nitric Acid (Conc.)		▼	▼	▼	◆	▼	▲	◆	▲
Nitric Acid (Dil.)		▼	◆	◆	▲	▼	▼	◆	▲
Nitrobenzene		▼	▲	◆	▼	▼	▼	▲	▲
Nitrogen Oxides		◆	▲	◆	▲				
Nitrous Acid		◆	▲	◆	▲	◆		▲	▲
Oils (Animal and Mineral)		◆	◆	▲	◆	▲		▲	▲
Oils (Vegetable)		◆	◆	▲	◆	▲		▲	▲
Oxygen		▲	▲	▲	▲	▲	▲	▲	▲
Perchloric Acid		▼	◆	▼	◆	▼	▼	▲	▲
Phenols		▼	▲	▼	◆	▼	▼		▲
Potassium Salts		▲	▲	▲	▲	▲	▲		
Pyridine		◆	◆	◆	▼	▼		▲	▲
Silver Nitrate		▲	▲	▲	▲	▲	▲	▲	▲
Soap Solutions		▲	▲	▲	▲	▲	▲	▲	▲
Sodium Salts		▲	▲	▲	▲	▲	▲		
Stearic Acid		◆	◆	▲	▼	◆		▲	▲
Sulfur Chloride		◆	▼	◆	◆			▲	▲
Sulfuris Acid (Conc.)		▼	▲	▼	◆	▼	▼		
Sulfuris Acid (Dil.)		▼	▲	◆	▲	◆	▼		
Sulfurous Acid		▼	◆	◆	▲	◆	▼	▲	▲
Tannic Acid		▲	▲	▲	▲	▼		▲	▲
Tanning Extracts		▲	▲	▲	▲	▼			
Titanium Salts		▲	▲	▲	▲	▲	▲		
Toluene		▼	▼	▲	▼	◆	▼	▲	▲
Trichloracetic Acid		◆	◆	▼	▼	▼			
Trichloroethylene		▼	▼	◆	▼	▼	▼	▲	▲
Turpentine		▼	◆	▲	◆	◆		▲	▲
Urea		▲	▲	▲	▲	▲		◆	▲
Uric Acid		▲	▲	▲	▲	▲		▲	▲
Water		▲	▲	▲	▲	▲	▲	▲	▲
Xylene		▼	▼	▲	▼	▼	▼	▲	▲
Zinc Chloride		▲	▲	▲	▲	▲		◆	▲

Standard Wiring Diagrams for T/Cs and Transmitters

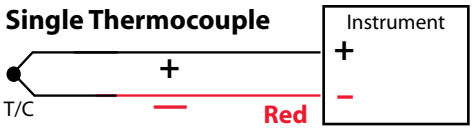
Thermocouple Symbol: T/C

Diagram Color: Red wire is always negative.

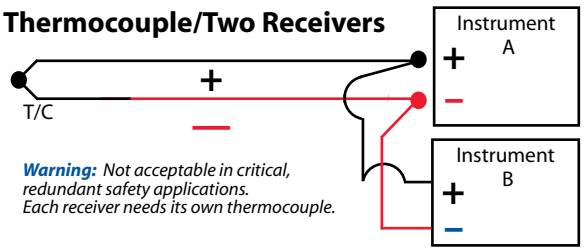
Notes: Thermocouple wire or thermocouple extension wire required. Do NOT use copper wire.

Switch contacts need not be T/C material. But, any difference in temperature between + and – switch contacts becomes an error in the signal.

Single Thermocouple

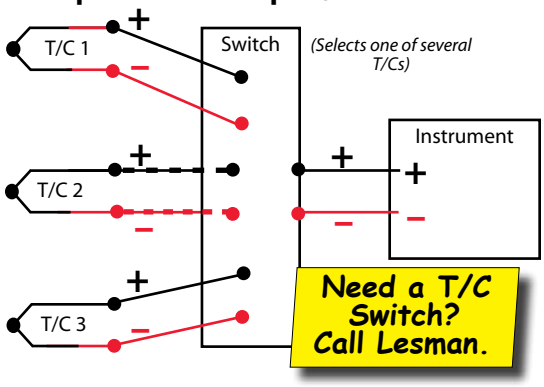


Thermocouple/Two Receivers

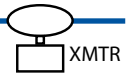


Warning: *Not acceptable in critical, redundant safety applications. Each receiver needs its own thermocouple.*

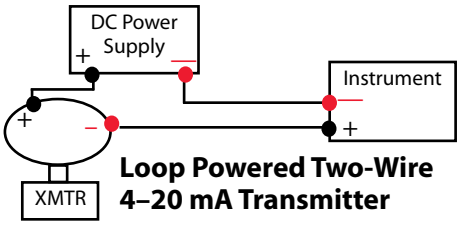
Multiple Thermocouples/One Receiver



Transmitter Symbol

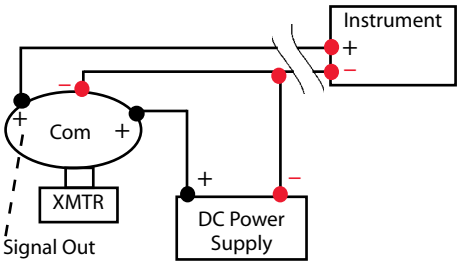


Notes: *Transmitters typically transmit a current signal of 4–20 mA. Each transmitter needs a power supply to operate. A thermocouple is NOT considered a transmitter. See above for more information.*

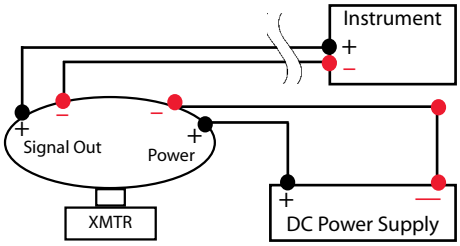


Loop Powered Two-Wire 4–20 mA Transmitter

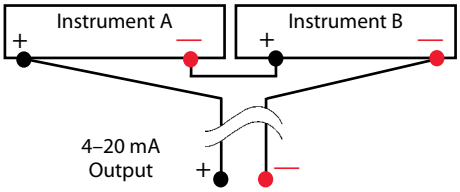
Three-Wire 4–20 mA Transmitter



Four-Wire 4–20 mA Transmitter



4–20 mA Output/Two Receivers



Thermocouple Initial Material Tolerances

** Thermocouples and thermocouple materials are supplied to meet the limits of error specified for temperatures above 0°C (32°F). May not conform to the published sub-zero limits unless specified at time of purchase.*

Type	Standard Limits of Error				Special Limits of Error			
	°F Range	Error	°C Range	Error	°F Range	Error	°C Range	Error
J	32° to 559° 559° to 1400°	±4° ±0.75%	0° to 293° 293° to 760°	±2.2° ±0.75%	32° to 527° 527° to 1400°	±2° ±0.4%	0° to 275° 275° to 760°	±1.1° ±0.4%
K	-328° to -166° -166° to 32° 32° to 559° 559° to 2282°	±2%* ±4°* ±4° ±0.75%	-200° to -110° -110° to 0° 0° to 293° 293° to 1259°	±2%* ±2.2° ±2.2° ±0.75%	32° to 527° 527° to 2282°	±2° ±0.4%	0° to 275° 275° to 1250°	±1.1° ±0.4%
T	-328° to -89° -89° to 32° 32° to 271° 271° to 662°	±1.5%* ±1.8°* ±1.8° ±0.75%	-200° to -67° -67° to 0° 0° to 133° 133° to 350°	±1.5%* ±1° ±1° ±0.75%	32° to 257° 257° to 662°	±0.9° ±0.4%	0° to 125° 125° to 350°	±0.5° ±0.4%
E	-328° to -274° -274° to 32° 32° to 644° 644° to 1652°	±1%* ±3.1°* ±3.1° ±0.5%	-200° to -170° -170° to 0° 0° to 340° 340° to 900°	±1%* ±1.7° ±21.7° ±0.5%	32° to 482° 482° to 1652°	±1.8° ±0.4%	0° to 250° 250° to 900°	±1° ±0.4%
R	32° to 1112° 1112° to 2642°	±2.7° ±0.25%	0° to 600° 600° to 1450°	±1.5° ±0.25%	32° to 1112° 1112° to 2642°	±1.1° ±0.1%	0° to 600° 600° to 1450°	±0.6° ±0.1%
S	32° to 1112° 1112° to 2642°	±2.7° ±0.25%	0° to 600° 600° to 1450°	±1.5° ±0.25%	32° to 1112° 1112° to 2642°	±1.1° ±0.1%	0° to 600° 600° to 1450°	±0.6° ±0.1%
B	1472° to 3092°	±0.5%	800° to 1700°	±0.5%	1472° to 3092°	—	800° to 1700°	—

Thermocouple Type Color Codes

T/C	Alloy Combinations	Magnetic: Yes	Magnetic: No	Thermocouple-Grade Wire			Extension-Grade Wire			Plug and Jack
T	Copper Constantan		• •	Brown Blue Red	+	Blue Red	Blue Blue Red	+	Blue Red	Blue
J	Iron Constantan	•	•	Brown White Red	+	White Red	White Black Red	+	White Red	Black
E	Chromel Constantan		• •	Brown Purple Red	+	Purple Red	Purple Purple Red	+	Purple Red	Purple
K	Chromel Alumel	•	•	Brown Yellow Red	+	Yellow Red	Yellow Yellow Red	+	Yellow Red	Yellow
S	Platinum 10% Rhodium Pure Platinum		• •		+	Black Red	Black Green Red	+	Black Red	Green
R	Platinum 13% Rhodium Pure Platinum		• •		+	Black Red	Black Green Red	+	Black Red	Green
B	Platinum 30% Rhodium Platinum 6% Rhodium		• •		+	Gray Red	Gray Gray Red *Compensated Cable*	+	Gray Red	White *Uncompensated*

When wiring thermocouples, the red wire is always negative.

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Wireless Terminology

0123

10Base-T: Common Ethernet wiring standard. Uses twisted pair wiring, runs at 10 Mbps, uses a star network topology, and is limited to a segment length of 100 meters max.

802.11: Family of wireless networking standards developed by the IEEE. 802.11a provides up to 54 Mbps on the 5GHz band. 802.11b hits 11 Mbps in the 2.4GHz band. 802.11g provides over 20 Mbps on the 2.4GHz band. Both 802.11b and g have effective ranges of about 300 feet; 802.11a's higher frequency limits its range to about 60 feet. Other standards in this family include 802.11e, h, and n.

A

Access point (AP): The hub of a wireless network. Also called wireless router, wireless gateway, or base station. Wireless clients connect to it, and traffic between clients must travel through it.

Amplifier: A device connected to an antenna to increase the signal strength and amplify weak incoming signals.

Antenna: A device connected to a wireless transceiver that concentrates transmitted and received radio waves to increase signal strength, and increase the effective range of a wireless network.

B

Band: Another term for spectrum, used to indicate a particular set of frequencies. Wireless networking protocols work in either the 2.4 GHz or the 5 GHz bands.

Bandwidth: The capacity of a network, or how much data a network can transfer. Bandwidth is often measured in bits per second.

Bridge: Allows the connection of devices on a wired Ethernet network to a wireless network, and acts as the connection point to the Wireless LAN. Wireless bridge devices work in pairs (point-to-point), one on each side of the bridge. There can be many simultaneous bridges using one central device (point-to-multipoint).

C

Channel: A specific portion of the radio spectrum. E.g., the channels allotted to one of the wireless networking protocols. 802.11b/g use 14 channels in the 2.4 GHz band. In the 5 GHz band, 802.11a uses eight channels for indoor use and four others for outdoor use.

Collision: The interference that results when two devices on a network start transmitting at the same time.

D

Data rate: Speed at which data can pass through a wireless network when transferred at its maximum pace. Different than the throughput rate and is almost always higher.

Decibels (dB): Unit of measure for antenna gain. Also noted as dBm (relative to a reference level of 1 milliwatt) and dBi (relative to an isotropic radiator, or a single point antenna).

Dipole Antenna: An antenna type that offers omnidirectional coverage, but low gain.

Direct sequence spread spectrum (DSSS): One of two approaches (with frequency hopping spread spectrum) for sorting out overlapping data signals transmitted via radio waves. DSSS generates a redundant pattern for each bit to be transmitted, called a chipping code. Using this, the signal is split over several frequencies, and the different parts are sent concurrently. DSSS is faster than FHSS, but is more sensitive to environmental factors. WiFi and 802.11b use DSSS.

E

Encryption: The process of transforming information using an algorithm to make it unreadable to anyone except those possessing the encryption key. Used to protect data in transit, for example data being transferred via networks.

Ethernet: The most common networking standard in the world, formally known as IEEE 802.3.

Ethernet backbone: Wired 802.3 network that connects access points in a roaming network.

F

File transfer protocol (FTP): A common way of transferring files on the Internet, primarily used for uploading and downloading large files in secure areas.

Firmware: The internal software that runs dedicated hardware devices.

Frame: A packet encapsulated to travel on a physical medium, like Ethernet or WiFi. A packet is like a shipping container; a frame is the boat on which the shipping container is loaded.

Frequency hopping spread spectrum (FHSS): One of two approaches (with DSSS) for sorting out overlapping data signals transmitted via radio waves. FHSS changes, or hops, frequencies in a pattern known to both sender and receiver. FHSS is little influenced by radio stations, reflections, or other environmental factors, but it is much slower than DSSS.

Fresnel zone: An elliptical area on either side of the straight line of sight that must also be clear for a long-range wireless network to work.

G

Gain: The amount by which an antenna concentrates signal strength in a wireless network.

Gateway: Device that joins two networks together. Most commonly implemented as a software set residing on a wireless access point or router.

Gigahertz (GHz): A measure of electromagnetic wave frequency, in complete cycles per second, equal to one billion hertz. Used to specify the radio frequency used by wireless devices.

H

Header: Address information on packets that says where the data should go.

High-gain antenna: An antenna that significantly increases signal strength. Necessary for long-range wireless networks.

Hub: The central device in a star network, whether wired or wireless. Wireless access points act as hubs in wireless networks.

I

IEEE: Institute of Electrical and Electronics Engineers. (Pronounced I-triple-E). The organization develops standards for the computer and electronics industry, such as WiFi.

Internet protocol (IP): Method by which data is sent from one device to another on the Internet.

IP address: The numeric address (like 192.168.1.1) that identifies the unique location of each device in a TCP/IP network.

K

Kbps: A measure of bandwidth. Kilobits (thousands of bits) per second.

L

Latency: Length of time between a packet being sent and the response to it being returned.

Line of sight: A clear, unobstructed line of vision from one antenna to another in a wireless network. Necessary for a long-range network to connect.

Local area network (LAN) : The computers at one physical site, connected via Ethernet or WiFi.

M

Mbps: A measure of bandwidth. Megabits (millions of bits) per second.

Megahertz (MHz): A measure of electromagnetic wave frequency equal to one million hertz. Used to specify the radio frequency used by wireless devices.

Mesh networking: A type of network where each node may act as a router, regardless of whether it is connected to another network or not. It allows for continuous connections and reconfiguration around broken or blocked paths by "hopping" from node to node until the destination is reached.

Modem: Short for modulator/demodulator. Converts outgoing digital data into analog signals so they can be sent over copper phone lines, and converts incoming analog signals into digital.

Multiplex: Transmitting multiple signals over a single channel. A WiFi connection uses Orthogonal Frequency Division Multiplexing (OFDM), which spreads the signal power over a large band. It breaks the signal into parts, enabling a fast transmission that is sent as several slower transmissions simultaneously, using different frequencies.

N

Network: A collection of interconnected computers and associated devices. Networks can be characterized by the protocols they use (TCP/IP) or by the geographic area they cover (LAN and WAN).

Network adapter: The removable card or built-in hardware used in a computer or handheld device to connect to a network, whether wired or wireless.

Network diagram: A rough picture of the structure of a network. Network diagrams are useful for planning new networks and for troubleshooting problems with existing networks.

Network segments: Physically and logically separate sections of a network. Breaking a network into segments increases bandwidth by reducing the amount of traffic that each device must listen to.

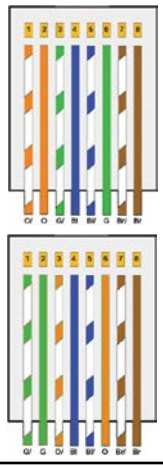
How to wire Ethernet cables

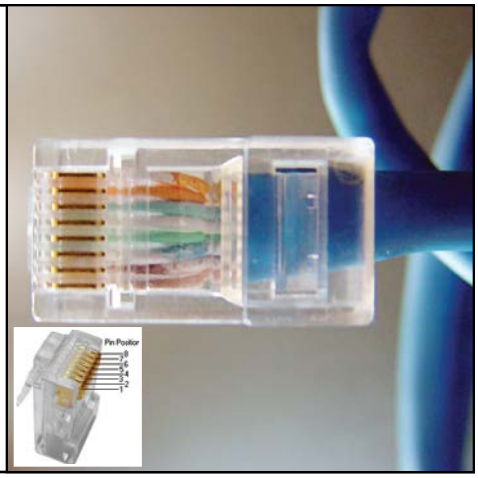
Strip the end of a Category 5 cable and separate the four twisted pairs (left) into individual wires.

A straight-through (standard network) cable has matching ends. Set the wires in pin order from 1 to 8, so that both RJ-45 connector ends follow the top diagram.

A crossover cable has dissimilar ends, where the green and orange pairs are swapped. Set the wires in pin order so that one end follows the top diagram, and the other end follows the bottom.

Crimp each end to be sure the cable is secure, and test your cable to make sure it can transmit properly.





P

Packet: A discrete chunk of data, being transferred on a TCP/IP or other addressable network.

Panel antenna: An antenna type that radiates in only a specific direction. Panel antennas are commonly used for point-to-point applications. Also called patch antennae.

Parabolic antenna: Antenna type that radiates a very narrow beam in a specific direction. Parabolic antennae offer the highest gain for long-range point-to-point situations.

Pigtail: A thin cable that connects an antenna to a wireless network adapter, usually converting between plug types in the process.

Point-to-multipoint: A wireless network in which the access point serves multiple other points around it. Indoor wireless networks are all point-to-multipoint. Long-range wireless networks that serve multiple clients usually employ either a single omni directional antenna or multiple sector antennas.

Point-to-point: A long-range wireless network between two points. Point-to-point wireless networks use directional antennas.

Port: Either a physical jack on a network device or a way of identifying the type of data being sent in an Internet connection. Every Internet service has its own port number.

R

Radio Frequency Identification (RFID): A technology used to uniquely identify objects. A transceiver sends out a signal that activates a transponder, which sends data back to the transceiver.

Received signal strength indication (RSSI): The power present in a received radio signal. RSSI can be used in a wireless networking card to determine when the amount of radio energy in the channel is below a certain threshold at which point the network card is clear to send (CTS). Once the card is clear to send, a packet of information can be sent.

Remote access point: One of a number of secondary access points in a wireless network that uses WDS to extend its range. Remote access points, also called relay access points, connect to a master access point.

RJ-11: A plug type for four- or six-wire connections, used for phone cables.

RJ-45: A plug type for eight-wire twisted pair connections, used in Ethernet networks.

Router: An intelligent network device that converts address-based protocols to describe how packets move from one place to another. In practice, this generally comes down to translating between IP addresses and MAC addresses for data flowing between your local network and the Internet.

S

Service set identifier (SSID): Identifying name of a wireless network. Extended SSID (ESSID) is the unique name for a wireless network with an access point.

Signal loss: The amount of signal strength that's lost in antenna cable, connectors, and free space, measured in decibels.

Signal strength: The strength of the radio waves in a wireless network.

Specification: A formal language used by different devices to communicate. Term is generally interchangeable with "protocol."

Spectrum: A range of electromagnetic frequencies.

Spread spectrum: A form of wireless communication in which a signal's frequency is deliberately varied. This increases bandwidth and lessens the chances of interruption or interception of the transmitted signal.

Star network: A network topology in which all traffic goes through a central hub. Most wireless networks are star networks.

Switch: A specific type of network routing device that isolates the communications between any two computers from the rest of the network, thus increasing throughput.

T

Throughput: Amount of data that can be transmitted in a given amount of time. Commonly measured in bits per second.

Topology: The specific layout of a network.

Transmit power: Amount of power used by a radio transceiver to send the signal out. Generally measured in milliwatts, which you can convert to dBm.

Twisted pair: A wiring type in which each pair of wires twists in a certain way to reduce electromagnetic interference. 10Base-T, 100Base-T, and Gigabit (1000Base-T) Ethernet all use twisted pair wires.

U

Unshielded twisted pair: The most common type of twisted pair wiring. Unshielded twisted pair lacks a shield to act as a ground. Unshielded twisted pair is often abbreviated to UTP.

W

Wide area network (WAN): A collection of local area networks connected by a variety of physical means. The Internet is the largest and most well known wide area network.

Wi-Fi (Wireless fidelity): Wireless Internet delivered to Web-enabled devices using the IEEE 802.11 group of wireless standards. Access to a Wi-Fi connection is generally limited to small geographical spaces, such as your home or a coffee shop, and can often be expanded to the size of plant campuses.

Wi-Fi protected access (WPA): Wireless security technology builds off WEP (Wired equivalent privacy), to deliver stronger authentication and encryption features. WPA 2 is the next level of wireless security above WPA, and it comes as either enterprise- or personal-grade protection.

Wireless local area network (WLAN): Links devices via a wireless distribution method (typically spread-spectrum or OFDM radio), and usually provides a connection through an access point to the wider internet. This gives users the mobility to move around within a local coverage area and still be connected to the network.

Wired equivalent privacy (WEP): A type of encryption used to secure wireless networks.

Y

Yagi antenna: An antenna type that radiates in only a specific direction. Yagi antennas are used only in point-to-point situations.

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Wireless Antenna Terminology

Antenna: That part of a transmitting or receiving system which is designed to radiate or to receive electromagnetic waves. An antenna can also be viewed as a transitional structure (transducer) between free-space and a transmission line. An important property of an antenna is the ability to focus and shape the radiated power in space e.g.: it enhances the power in some wanted directions and suppresses the power in other directions.

Antenna Pattern: A three-dimensional graphical representation of antenna radiation as a function of angular direction. Radiation performance is measured and recorded in two orthogonal planes, plotted in polar or rectangular coordinates.

Directional Antenna: An antenna having the property of radiating or receiving electromagnetic waves more effectively in some directions than others.

Directivity: Directivity of a wireless antenna is given by the ratio of the maximum radiation intensity to the average radiation intensity.

Effective radiated power (ERP): The relative gain of a transmitting antenna with respect to the maximum directivity of a half-wave dipole multiplied by the net power accepted by the antenna from the connected transmitter.

Efficiency: The total antenna efficiency accounts for the following losses: (1) reflection because of mismatch between the feeding transmission line and the antenna and (2) antenna conductor and dielectric losses.

Frequency Bandwidth: The range of frequencies within which the performance of the antenna, with respect to some characteristics, conforms to a specified standard.

Front-to-Back (F/B) Ratio: The ratio of the maximum directivity of a wireless antenna to its directivity in a specified rearward direction. Sometimes, the directivity in the rearward direction is taken as the average over an angular region.

Gain: Maximum gain of a wireless antenna is defined as the product of the directivity by efficiency. If the efficiency is not 100%, the antenna gain is less than the directivity. Gain is expressed in dBi. The gain of any antenna is proportional to its size.

Half-Wave Dipole: A wire antenna consisting of two straight collinear conductors of equal length, separated by a small feeding gap, with each conductor approximately a quarter-wave length.

Isolation: A measure of power transfer from one antenna to another. The ratio of the power input to one antenna to the power received by the other antenna, expressed in decibels (dB).

Linear Array: A set of radiating elements (e.g. dipole or patch) arranged along a line. Radiating elements have dimensions comparable to a wavelength. A linear array has a higher gain than a single radiator, and its radiation pattern can be synthesized to meet various antenna performance requirements such as upper side lobe suppression and null fill.

Parabolic Reflector Antenna: Consists of a parabolic metal surface (dish) with a feed antenna in front. The feed antenna consists of a directive antenna such as a dipole and reflector, log-periodic dipole array or horn antenna. Capable of producing extremely high gains, usually in the 20 - 30 dBi range.

Power Handling: The ability of a wireless antenna to handle high power without failure. High power can cause voltage breakdown and excessive heat which would result in an antenna failure.

Radiation Efficiency: Ratio of the total power radiated by a Wireless LAN antenna to the net power accepted by the antenna from the connected transmitter.

Antenna properties

At its most basic, an antenna is a length of conductive metal that radiates radio signals into the air. Most common antennae are designed to be one-quarter or one-half the wavelength of the radio signals they are transmit or receive.

An antenna has three fundamental properties: gain, direction, and polarization.

Every antenna is designed to raise the power in the wanted direction and reduce it in unwanted directions. **Gain**, measured in decibels (db), is the term used to describe an increase in an antenna's ability to focus its signal in the desired direction. The antenna with a higher gain is more effective in its radiation pattern.

Direction is the shape of the wireless signal after leaving the antenna. Omnidirectional antenna radiate power equally in 360°. Directional antenna, like the Yagi or parabolic dish, focus the radiant power to increase performance and reduce interference.

Polarization is the orientation of wireless signal relative to the earth. It can be vertical, horizontal, circular or combinations of these. In WiFi networks most signals are vertically polarized. For best performance, you'll need to match up the polarization of your transmitting and receiving antennae.

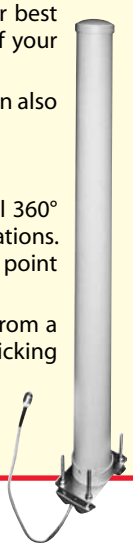
Objects (metallic, water and glass) that reflect signals can also affect polarization.

Omnidirectional antenna

The omnidirectional antenna provides a signal in a full 360° radius, and can be used in either indoor or outdoor applications. This antenna type usually has the lowest gain and is used in point to multipoint links.

It's ideal for applications where you want to transmit from a central node to users scattered all around the area, or for picking up wireless signals within a 360° radius of your position.

Fiberglass construction provides great protection to the antenna from outdoor weather conditions.



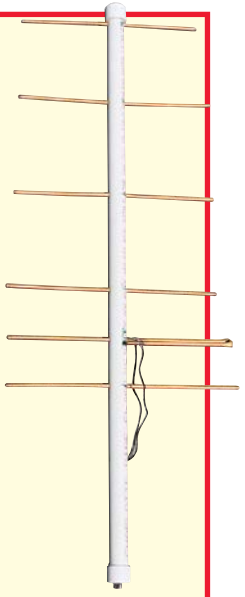
Yagi-Uda array antenna

Known as the Yagi, this is a semi-directional antenna used for point-to-point network topology. It's sometimes used for point-to-multipoint, if long distance must be achieved.

A Yagi antenna is made of an array of elements running parallel to each other. The longest element in this array is the reflector. Next is the driven element, the one that actually transmits electromagnetic waves. The other elements are called directors.

The antenna propagates signal in the direction from the reflector to the directors.

The director elements are set at a precise distance apart, and precise lengths (about half wavelength) to cause the antenna to operate most efficiently for a given radio frequency. A Yagi with more directors has a greater gain and antenna becomes longer.



Parabolic dish antenna

This highly directional antenna type transmit/receives signals in a very narrow angle, so it is ideal for long distance and point to point network connections.

The parabolic dish has a solid main reflector surface that is shaped like a paraboloid or sphere with an active element at its focus. That way, the surface can reflect parallel signals to a single focal point.

The narrow beam width of a parabolic dish antenna provides minimum interference with other wireless networks, longest signal distance, and fastest links.

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