Scanivalve Corp.

Pressure and Temperature Handbook

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Pressure Basics

Pressure is defined as the force exerted perpendicularly by a fluid at rest on any bounding surface of any unit area. It is expressed by the formula:

$P = F/A$ Where: p is equal to a force applied to a unit area A

For example a pressure of 35 pounds per square inch results from a total force of 35 pounds exerted over one square inch or 140 pounds exerted over 4 square inches.

Three observations are the basis of all pressure measurement

1. Pressure is influenced by position in a static fluid, but is independent of direction. So, the pressure will vary with elevation

2. Pressure is unaffected by the shape of the confining boundaries.

3. Pressure applied to a confined fluid is transferred undiminished throughout the fluid to all bounding surfaces.

Pressure Terms

Absolute Pressure	-	Pressure referenced to zero pressure(perfect vacuum)
Gauge Pressure	-	Pressure referenced to ambient barometric pressure
Differential Pressure	-	The pressure difference between two pressure points
Pressure Head	-	Pressure of the height of a column of liquid, measured at the base.
Vacuum	-	Pressure below barometric pressure
Standard Pressure	-	Absolute pressure at sea level in a standard atmosphere. 14.696 psi, 1.013 Pascals, 760 Torr, or 1 Bar.

Pressure Units

PSI	-	Pounds per square inch
in H_2O	-	Inches of Water Column
in Hg	-	Inches of Mercury Column
Atm	-	Atmospheres
Bar	-	Bar
Pa	-	Pascals, formerly Newtons per square meter
kPa	-	KiloPascals
Torr	-	Millimeters of Mercury Column, used mainly to express low vacuum pressures

Pressure Transducers

A pressure transducer is any device that transfers energy from one system to another system. A pressure transducer will have some type of an elastic element to convert the energy to an indicator. The elastic element may be a flexible tube, a diaphragm, or a fluid. Some transducers have an electrical element which will convert the energy to an electrical signal.

There are two types of transducers, Mechanical and Electrical. Mechanical transducers include bourdon tube gauges, bellows gauges, manometers, and dead weight piston gauges. Electrical transducers are any type of transducer that requires an excitation current or voltage, such as, piezoresistive, LVDT's, variable reluctance, capacitive, and strain gauge transducers.

Selecting a Pressure Transducer

Accuracy

This is the first consideration. Accuracy is generally expressed as a percentage of full scale. Accuracy consists of several errors: Hysterisis, Non-linearity and repeatbility must be known and considered.

Pressure Media

This is the fluid that will be measured. Gas or liquid. Corrosive or non-corrosive. The transducer selected must have elastomers and a diaphragm compatible with the pressure media.

Frequency Response

This is the rate at which a transducer can respond to a change in pressure. Steady state pressure measurements are much simpler than transient pressure measurements. The frequency to be measured will have a large effect on the type of transducer selected.

Output

The data system and signal conditioning equipment will determine the output requirements. Outputs are low level or high level. Low level outputs are expressed in millivolts output full scale per excitation volt (mv/v). A transducer with an output of 3 mv/v will have a full scale output of 30 mv when the excitation voltage is 10 v. High level outputs are generally 1 to 10 Vdc. In this case, the transducer has built in signal conditioning with a DC amplifier to amplify the output to the high level.

Environment

What are the temperature, humidity, shock and vibration requirements for the test? All of these can have a large effect on the function of the transducer.

Transducer Performance

Accuracy	-	A percentage of full scale. Includes nn-linearity, hysteresis, and non-repeatability.
Linearity	-	The deviation of the output from a best fit straight line.
Hysteresis	-	The difference in output at any point when the point is approached first with increasing pressure and then decreasing pressure.
Repeatability	-	The difference in output at any point when the measurement is repeated. Not to be confused with hysteresis.
Output	-	Expressed in mv/V for strain gauge transducers unless the transducer has built in signal conditioning. In that case, the output will be expressed in volts.

Thermocouple Basics

When two dissimilar metals are joined together to form a closed loop, and if one junction is held at a different temperature from the other, an Electromotive Force(EMF) is generated. The amount of EMF generated is predictable based on the materials used and the temperature of the junction.

The EMF is generated by the wires, not the junction. A temperature gradient must exist before the EMF can be generated.

Three laws have been established that govern thermoelectric circuits.

Law of Homogeneous Materials

A thermoelectric current cannot be sustained in a circuit of a single homogeneous material, however it varies in cross section, by the application of heat alone.

Simply stated, two different materials are required for any thermocouple circuit. If current can be detected in a homogeneous wire when it is heated, this is evidence that the wire is inhomogeneous.

Law of Intermediate Materials

The algebraic sum of the thermoelectromotive forces in a circuit composed of any number of dissimilar materials is zero if all of the circuit is at a uniform temperature.

This law states that a third homogeneous material can be added to a circuit with no effect on the net EMF of the circuit as long as temperature of the junctions remain the same.

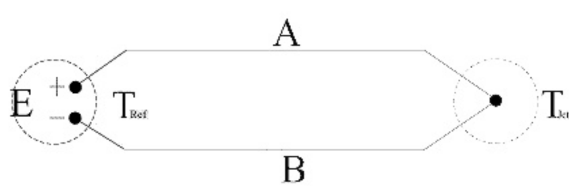
Law of Successive or Intermediate Temperature

If two dissimilar homogeneous materials produce a thermal EMF of E_1 when the junctions are at temperature T_1 and T_2 , and a thermal EMF of E_2 when the junctions are at T_2 and T_3, the EMF generated when the junctions are at T_1 and T_3 will be $E_1 + E_2$.

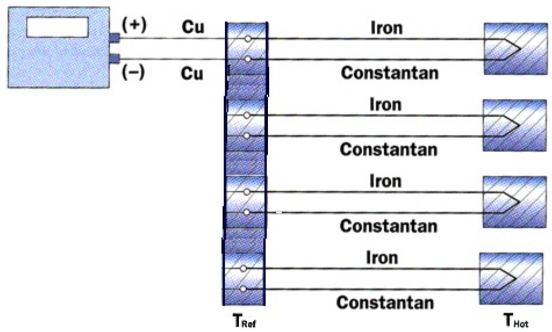
This law states that a thermocouple calibrated for one reference temperature can be used with any other reference temperature with a correction. Also, extension wires having the same characteristics as those of the thermocouple wires can be introduced to the circuit without affecting the circuit.

Thermocouple Circuits

A basic thermocouple circuit consists of two dissimilar homogenous materials extending from the measuring junction to the reference junction.



When more than one thermocouple is to be measured, each thermocouple should be two continuous wires between the measuring and reference junctions. This is the most common circuit for thermoelectric testing.



Thermocouple Accuracy

Thermocouple accuracy can be defined as relative and absolute accuracy.

Relative Accuracy

This is the ability of the system to repeat a given measurement. This depends upon the quality of the sensors, the measuring system used and how the system is installed.

Absolute Accuracy

This is the ability of the system to determine a standard accepted value. This can be achieved by calibration relative accepted and recognized standards.

Thermocouple Calibration

Calibration will not change the characteristics of a thermocouple. It does validate the system and ensure proper readings by allowing corrections to be entered for each thermocouple in the system. Calibrations should conform to ISO 10012-1:1992.

Sources of Error in Thermocouple Measurements

Measuring Junction

The thermocouple junction at the temperature measuring point is the measuring junction. Errors at this point depend upon the age of the junction, the method of joining and materials used to form the junction. Generally, errors from the measuring junction are small.

Extension Wires

Extension wires are any elements inserted between the measuring junction and the reference junction. Extension wires should have the same characteristics as the thermocouple wire. Extension wires introduce four junctions to each circuit. This can cause errors as large as ±2 °C. The errors can be minimized by calibrating the system with the extension wires in place. If possible, extension wires should not be used.

Reference Junctions

The thermocouple junction maintained at a known temperature is the reference junction. Reference junctions can introduce errors as large as ±0.6 °C.

Copper Connecting Wires

These wires are used to connect the reference junction to the measuring device. The errors caused by these wires are very small.

Thermocouple Switches

When used, these devices can induce errors as large as ±1 °C. Switching should occur in the copper wires between the reference junction and the measuring device.

Noise in Thermocouple Circuits

The external effects that can cause errors in thermocouple circuits include: electrical and magnetic fields, cross-talk, and common mode voltage.

Electric fields radiated from voltage sources are capacitively coupled to thermocouple extension wires. This imposes an AC voltage on the thermoelectric EMF. This can be minimized by shielding the thermocouple extension wire and grounding the shield.

Magnetic fields produce noise current in the thermocouple extension wire. This can be minimized by twisting the thermocouple extension wire pairs.

In a multipair thermocouple extension wire, adjacent pairs can pick up noise from a pulsating signal. This can be minimized by shielding the individual pairs.

Common mode noise will be generated if a grounded thermocouple is connected to a grounded instrument. This can be minimized by grounding the thermocouple and shield as close as possible to the measuring point.

Thermocouple Design

The thermocouple used in an application should be selected specifically for the application.

Size
: The temperature sensed will be the average temperature across the length of the sensor.

Shape
: The shape must conform to the shape of the surface if the thermocouple is measuring surface temperatures.

Response
: The response time of a thermocouple is mass dependent. Therefore the size of the thermocouple must be small in relation to the object being measured. The response time should be approximately 5 times shorter than the fastest rate of temperature change to be monitored.

Heat Conduction
: Thermocouple extension wires can conduct heat into or out of the thermocouple. The wire must be insulated from the environment if this can occur.

Sensor Position
: The thermocouple measures the temperature of the object it is touching or the environment in which it is installed. Therefore the thermocouple must be positioned very carefully to insure that the temperature is being sensed at the correct point.

Thermocouple Types and Descriptions

The DTS family of Temperature Scanners will accept inputs from Type E, J, K, N, R, S, and T Thermocouples. The accuracy of the measurement will depend upon the type of thermocouple and the quality of the extension wire used for the measurement.

Type E - Chromel Constantan

Positive leg	90% nickel, 10% chromium
Negative leg	43% nickel, 57% copper
Range	-270 to 1000 °C
Usable range	0 to 900 °C
Notes	Highest EMF output per degree of all recognized thermocouples. Recommended for continuously oxidizing or inert atmospheres. Has similar drift between 316 and 593 °C as a Type K thermocouple

Type J - Iron Constantan

Positive leg	100% iron
Negative leg	43% nickel, 57% copper
Range	-210 to 1200 °C
Usable range	0 to 816 °C
Notes	Not susceptible to aging from 371 to 538 °C. Very stable, should be used with a 96% pure MgO insulation and stainless steel sheath to prevent corrosion of the iron lead. Most commonly used thermocouple.

Type K - Chromel Alumel

Positive leg	90% nickel, 10% chromium
Negative leg	95% nickel, 2% aluminum, 2% manganese, 1% silicon
Range	-270 to 1372 °C
Usable range	-36 to 1260 °C
Notes	Not recommended from 316 to 593 °C because of aging that can cause drift rates of 2 °C in a few hours. Best used when corrosion may be a problem.

Type N

Positive leg	14% chromium, 1.4% silicon, 84.6% nickel
Negative leg	95.6% nickel, 4.4% silicon
Range	-270 to 1372 °C
Usable range	0 to 1260 °C
Notes	Less aging from 316 to 593 °C than a Type K thermocouple. Recommended for use where Type K thermocouples might have stability problems.

Type R

Positive leg	87% platinum, 13% rhodium
Negative leg	100% platinum
Range	-50 to 1767 °C
Usable range	0 to 1482 °C
Notes	Has a higher output than Type S thermocouples. Easily contaminated. This thermocouple should be protected by compacted mineral insulation and a metal outer sheath. Type R is used mainly in Industrial Applications

Type S

Positive leg	90% platinum, 10% rhodium
Negative leg	100% platinum
Range	-50 to 1767 °C
Usable range	0 to 1482 °C
Notes	Easily contaminated. This thermocouple should be protected with a gas tight ceramic tube, a secondary tube of porcelain and a silicon carbide or metal outer tube. Type S is mainly used in Laboratory Applications.

Type T - Copper Constantan

Positive leg	Pure copper
Negative leg	43% nickel, 57% copper
Range	-270 to 400 °C
Usable range	-262 to 350 °C
Notes	Good for low temperature and cryogenic applications. Not likely to corrode in moist atmospheres. Copper conductor deteriorates quickly above 400°C.

International Thermocouple and Extension Wire Color Codes

Country	USA	USA	United Kingdom	United Kingdom	Germany	Japan	France
Standard	ANSI MC96.1 T/C	ANSI MC96.1 Extension	BS 1843	BS 4937	DIN 43714	JIS C1610-1981	NFE C42-323
E Overall E Positive E Negative	Brown Purple Red	Purple Purple Red	Brown Brown Blue	Brown Brown Blue	Black Red Black	Purple Red White	---------
J Overall J Positive J Negative	Brown White Red	Black White Red	Black Yellow Blue	Black Black White	Blue Red Blue	Yellow Red White	Black Yellow Black
K Overall K Positive K Negative	Brown Yellow Red	Yellow Yellow Red	Red Brown Blue	Green Green White	Green Red Green	Blue Red White	Yellow Yellow Purple
N Overall N Positive N Negative	Brown Orange Red	Orange Orange Red	-------	-------	-------	-------	-------
R Overall R Positive R Negative	-------	Green Black Red	Green White Blue	Orange Orange White	White Red White	Black Red White	Green Yellow Green
S Overall S Positive S Negative	-------	Green Black Red	Green White Blue	Orange Orange White	White Red White	Black Red White	Green Yellow Green
T Overall T Positive T Negative	Brown Blue Red	Blue Blue Red	Blue White Blue	Brown Brown White	Brown Red Brown	Brown Red White	Blue Yellow Blue

Conversion Factors

Prefixes

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

International (SI) System of Units

Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electrical current	ampere	A
temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol
plane angle	radian	rad
electric charge	coulomb	C
capacitance	farad	F
inductance	henry	H
electric potential	volt	V
resistance	ohm	Ω
energy	joule	J
force	newton	N
frequency	hertz	Hz
illuminance	lux	lx
luminous flux	lumen	lm
magnetic flux	weber	Wb
magnetic flux density	tesla	T
power	watt	W
pressure	pascal	Pa

Length

Multiply	by	to obtain
angstrom	10^{-10}	meters
feet	0.30480	meters
	12.0	inches
inches	1000	mil
	25.40	millimeters
	0.02540	meters
	0.08333	feet
kilometers	3280.8	feet
	0.6214	miles
	1094	yards
meters	39.370	inches
	1.094	yards
miles	5280	feet
	1.6093	kilometers
	0.8694	miles(nautical)
millimeters	0.03937	inches
yards	0.9144	meters
	3.0	feet
	36.0	inches

Area

Multiply	by	to obtain
acres	43560	square feet
	4047	square meters
square centimeters	0.1550	square inches
square feet	144.0	square inches
	0.09290	square meters
	0.1111	square yards
square inches	645.16	square millimeters
square kilometers	0.3861	square miles
square meters	10.764	square feet
	1.196	square yards
square miles	640	acres
	2.590	square kilometers

Volume

Multiply	by	to obtain
cubic centimeters	0.06102	cubic inches
cubic feet	1728	cubic inches
	7.480	gallons(US)
	0.02832	cubic meters
	0.03704	cubic yards
cubic inches	16.387	cubic centimeters
	0.01732	quarts(liquid)
cubic meters	35.315	cubic feet
	264.2	gallons(US)
	1.308	cubic yards
	1000	liters
cubic yards	27.0	cubic feet
	0.7646	cubic meters
gallons(Imperial)	277.4	cubic inches
	1.201	gallons(US)
	4.546	liters
gallons(US)	231	cubic inches
	3.7854	liters
	4.0	quarts
quart(US)	0.9463	liters

Mass

Multiply	by	to obtain
carat	0.200	grams
grams	0.03527	ounces
kilograms	2.2046	pounds
ounces	28.3350	grams
pound	16	ounces
	453.6	grams
stone	6.350	kilograms
	14	pounds
ton	2000	pounds
	907.2	kilograms

Force

Multiply	by	to obtain
dynes	10^{-5}	newton
grams	980.7	dynes
kilogram	9.80665	newtons
newton	10^{5}	dynes
	0.1020	kilogram
	3.597	ounce
	0.2248	pound
ounce	0.2780	newton
	0.0625	pound
pound	16.0	ounce
	0.45359	kilogram
	4.448	newton
ton	2000	pounds
	8896	newtons

Torque

Multiply	by	to obtain
ounce inch	0.007061	newton meters
pound inch	1.152	kilogram centimeters
	0.1130	newton meters
pound foot	1.356	newton meters
newton meters	0.7376	pound foot

Velocity

multiply	by	to obtain
feet/second	0.3048	meters/second
inches/second	0.0254	meters/second
km/hour	0.6214	miles/hour
knot	0.5144	meters/second
	1.151	miles/hour
meters/second	3.2808	feet/second
	2.237	miles/hour
miles/hour	1.4667	Feet/second
	0.44704	meters/second
	1.6093	km/hour
	0.8684	knots

Pressure

Multiply	by	to obtain
atmospheres	1.01325	bars
	33.90	Feet H_2O
	29.92	Inches Hg
	760.0	Millimeters Hg (Torr)
	101.325	KiloPascals (kN/m^2)
	14.696	PSI
bar	75.01	Centimeters Hg
	10^5	Pascals (N/m$^{2)}$
	14.5	PSI
inches H_2O	248.84	Pascals (N/m$^{2)}$
	0.07355	Inches Hg
millimeters Hg	133.32	Pascals
	0.1933	PSI
Pascals	0.0001450	PSI
PSF	0.19242	inches H_2O
	47.880	Pascals
PSI	0.06805	atmospheres
	2.036	inches Hg
	27.708	inches H_2O
	68.948	millibar
	51.72	Millimeters Hg
	6894.8	Pascals

Acceleration

multiply	by	to obtain
gravity (g)	9.80665	meters/second^2
	32.174	feet/second^2
feet/second^2	0.3048	meters/second^2
inches/second^2	0.02540	meters/second^2

Power

multiply	by	to obtain
ergs/second	10^{-7}	watts
foot pounds/second	1.3566	watts
horsepower (electric)	746.0	Watts
horsepower (UK)	745.7	Watts
	550.0	Foot pounds/second
BTU/second	1055.9	Watts

Electrical

multiply	by	to obtain
oersted	79.58	Ampere/meter
faraday	96490	coulombs
gauss	10^{-4}	tesla
gilbert	0.7958	ampere turn
maxwell	10^{-8}	weber

Temperature

Celsius to Kelvin	K = °C + 273.15
Celsius to Fahrenheit	°F = 9/5 °C + 32
	°F = 1.8 (°C + 40) -40
Fahrenheit to Celsius	°C = 5/9 (°F - 32)
	°C =[(°F + 40) /1.8] - 40
Fahrenheit to Kelvin	K = 5/9 (°F + 459.67)
Fahrenheit to Rankin	°R = °F + 459.67
Rankin to Kelvin	K = 5/9 °R

Charts

Temperature Reference Points (ITS-90)

Temperature Point	°C	°F
Absolute Zero	-273.15	-459.67
Helium, Boiling Point	-268.6	-451.5
Hydrogen, Boiling Point	-252.87	-423.2
Nitrogen, Boiling Point	-195.8	-320.4
Oxygen, Boiling Point	-183.0	-297.4
Mercury, Triple Point	-38.8344	-37.902
Water, Ice Point	0.0	32
Water, Triple Point	0.01	32.018
Gallium, Melting Point	29.765	85.576
Water, Boiling Point	100	212
Indium, Freezing Point	156.6	313.88
Tin, Freezing Point	231.93	449.47
Zinc, Freezing Point	419.53	787.15
Aluminum, Freezing Point	660.32	1220.58
Silver, Freezing Point	961.78	1763.20
Copper, Melting Point	1084	1983
Platinum. Melting Point	1773	3221

Temperature Conversion

To °C	Temperatur e	to °F
-40	-40	-40
-34.44	-30	-22
-28.89	-20	-4
-23.33	-10	14
-20.56	-5	23
-17.78	0	32
-15	5	41
-12.2	10	50
-9.44	15	59
-6.67	20	68
-3.89	25	77
-1.11	30	86
1.67	35	95
4.44	40	104
7.22	45	113
10	50	122
15.56	60	140
21.11	70	158
26.67	80	176
37.78	100	212
93.33	200	392
148.89	300	572
204.44	400	752
260	500	932
398.89	750	1382
537.78	1000	1832
648.89	1200	2192
815.56	1500	2732

Standard Atmosphere

Altitude, Feet	°F	°C	Pressure, psia	Pressure, mB	Density, lb/ft^3	Sonic Velocity, ft/sec
-1000	62.6	17.0	15.23	1050	.0787	1120.2
-500	60.8	16.0	14.96813	1032	.0776	1118.3
0	59.0	15.0	14.69603	1013.24	.0765	1116.4
500	57.2	14.0	14.43148	995	.0754	1114.5
1000	55.4	13.0	14.17041	977	.0743	1112.6
2000	51.9	11.0	13.66277	942	.0721	1108.7
3000	48.3	9.1	13.16963	908	.0700	1104.9
4000	44.7	7.1	12.691	875	.0679	1101.0
5000	41.2	5.1	12.22687	843	.0659	1097.1
6000	37.6	3.1	11.77725	812	.0639	1093.2
7000	34.0	1.1	11.34213	782	.0620	1089.2
8000	30.5	-0.8	10.92151	753	.0601	1085.3
9000	26.9	-2.8	10.5009	724	.0583	1081.3
10000	23.4	-4.8	10.10929	697	.0565	1077.4
12000	16.2	-8.8	9.35508	645	.0530	1069.4
14000	9.1	-12.7	8.62988	595	.0497	1061.3
16000	2.0	-16.7	7.962696	549	.0466	1053.2
18000	-5.1	-20.6	7.339024	506	.0436	1045.1
20000	-12.3	-24.6	6.758864	466	.0408	1036.8
22000	-19.4	-28.5	6.207712	428	.0381	1028.5
24000	-26.5	-32.5	5.700072	393	.0355	1020.2
26000	-33.6	-36.4	5.22144	360	.0331	1011.7
28000	-40.7	-40.4	4.78632	330	.0308	1003.2
30000	-47.8	-44.4	4.365704	301	.0287	994.6
32000	-54.9	-48.3	3.9886	275	.0266	986.0
34000	-62.1	-52.3	3.640504	251	.0247	977.3
36000	-69.2	-56.2	3.306912	228	.0229	968.5
38000	-69.7	-56.5	3.002328	207	.0208	968.1
40000	-69.7	-56.5	2.729653	188.2	.01890	968.1
42000	-69.7	-56.5	2.480184	171.0	.01717	968.1
44000	-69.7	-56.5	2.253922	155.4	.01560	968.1
46000	-69.7	-56.5	2.047965	141.2	.01418	968.1
48000	-69.7	-56.5	1.862314	128.4	.01288	968.1
50000	-69.7	-56.5	1.691166	116.6	.01271	968.1
60000	-69.7	-56.5	1.048639	72.3	.00726	968.1
70000	-67.4	-55.2	0.65123	44.9	.00448	971.0
80000	-62.0	-52.2	0.406112	28.0	2.76	977.8
90000	-56.5	-49.2	0.255415	17.61	1.710	984.5
100000	-51.1	-46.2	0.161575	11.14	.001068	991.2

Wire Gauge

Gage, AWG	Diameter, inch	Area, mils	Weight, lbs/1000 Ft	Ohms/ 1000 Ft	Max Current
0000	.4600	211600	640.5	.04901	225
000	.4096	167800	507.9	.06180	175
00	.3648	133100	402.8	.07793	150
0	.3249	105500	319.5	.09827	125
1	.2893	83690	253.3	.1239	100
2	.2576	66370	200.9	.1563	90
3	.2294	52640	159.3	.1970	80
4	.2043	41740	126.4	.2485	70
5	.1819	33100	100.2	.3133	55
6	.1620	26250	79.46	.3951	50
8	.1285	16510	49.98	.6282	35
10	.1019	10380	31.43	.9989	25
12	.08081	6530	19.77	1.588	20
14	.06408	4107	12.43	2.525	15
16	.05082	2583	7.818	4.016	6
18	.04030	1624	4.917	6.385	3
20	.03196	1022	3.092	10.15	2
22	.02535	642.4	1.945	16.14	
24	.02010	404.0	1.223	25.67	1
26	.01594	254.1	.7692	40.81	0.5
28	.01264	159.8	.4837	64.90	
30	.01003	100.5	.3042	103.2	0.2
32	.007950	50.13	.1517	206.9	0.1
36	.00500	25.0	.07568	414.8	0.05
40	.003145	9.888	.02993	1049	0.02

Inches - Decimal - Millimeters

Inches	Decimal	Millimeter		Inches	Decimal	Millimeter
1/64	0.0156	0.397		33/64	0.5156	13.097
1/32	0.0313	0.794		17/32	0.5313	13.494
3/64	0.0469	1.191		35/64	0.5469	13.891
1/16	0.0625	1.588		9/16	0.5625	14.228
5/64	0.0781	1.984		37/64	0.5781	14.684
3/32	0.0938	2.381		19/32	0.2935	15.081
7/64	0.1094	2.778		39/64	0.6094	15.478
1/8	0.1250	3.175		5/8	0.6250	15.875
9/64	0.1406	3.572		41/64	0.6406	16.272
5/32	0.1563	3.969		21/32	0.6563	16.669
11/64	0.1719	4.366		43/64	0.6719	17.066
3/16	0.1875	4.762		11/16	0.6875	17.463
13/64	0.2031	5.159		45/64	0.7031	17.859
7/32	0.2133	5.556		23/32	0.7188	18.256
15/64	0.2344	5.953		47/64	0.7344	18.653
1/4	0.2500	6.350		3/4	0.7500	19.050
17/64	0.2656	6.747		49/64	0.7656	19.447
9/32	0.2813	7.144		25/32	0.7813	19.844
19/64	0.2969	7.541		51/64	0.7969	20.241
5/16	0.3125	7.938		13/16	0.8125	20.638
21/64	0.3281	8.334		53/64	0.8281	21.034
11/32	0.3438	8.731		27/32	0.8438	21.431
23/64	0.3594	9.128		55/64	0.8594	21.838
3/8	0.3750	9.525		7/8	0.8750	22.225
25/64	0.3906	9.922		57/64	0.8906	22.622
13/32	0.4063	10.319		29/32	0.9063	23.019
27/64	0.4219	10.716		59/64	0.9219	23.416
7/16	0.4375	11.112		15/16	0.9375	23.812
29/64	0.4531	11.509		61/64	0.9531	24.209
15/32	0.4688	11.906		31/32	0.9688	24.606
31/64	0.4844	12.303		63/64	.98441	25.003
1/2	0.500	12.700		1.0	1.0000	25.400

Pressure Conversion

Engineering Unit	PSI to EU 1 psi =	EU to PSI 1 EU =
Atmospheres	0.068046 A	14.6960 psi
Bars	0.068947 b	14.5039 psi
Centimeter of Mercury	5.17149 cmHg	0.193368 psi
Centimeter of Water	70.308 cmH_2O	0.014223 psi
Decibar	0.68947 db	1.4504 psi
Foot of Water	2.3067 ftH_2O	0.43352 psi
Gram per square Centimeter	70.306 g/cm^2	0.014224 psi
Inch of Mercury @ 0°C	2.0360 inHg	0.491159 psi
Inch of Water @ 4°C	27.680 inH_2O	0.036127 psi
Kilogram per square Centimeter	0.0703070 kg/cm^2	14.2235 psi
Kilogram per square Meter	703.069 kg/m^2	0.0014223 psi
kips per square inch(ksi)	0.001 kip/in^2	1000.0 psi
Kilonewton per square Meter	6.89476 kN/m^2	0.145038 psi
Kilopascal	6.89476 kPa	0.145038 psi
Millibar	68.947 mb	0.014504 psi
Meter of Water	0.70309 mH_2O	1.42229 psi
Millimeter of Mercury	51.7149 mmHg	0.0193368 psi
Megapascal	0.00689476 Mpa	145.038 psi
Newton per square Centimeter	0.689476 N/cm^2	1.45038 psi
Newton per square Meter	6894.76 N/m^2	0.000145038 psi
Ounce per square Foot	2304.00 oz/ft^2	0.000434028 psi
Ounce per square Inch	16.00 in/ft^2	0.062500 psi
Pascal	6894.76 Pa	0.000145038 psi
Pound per square Foot	144.00 lb/ft^2	0.00694444 psi
Torr	51.7149 T	0.0193368 psi

	Pa (N/m^2)	kPa (kN/m$^{2)}$	Atm (kg/cm^2)	Bar (Mdyne/cm^2)	psi (lb/in^2)	cm H_2O @4°C	in H_2O @4°C	mm Hg @0°C	in Hg @0°C
1 Pa	1	0.001	0.0000099	0.00001	0.000145	0.010197	0.0040147	0.0075006	0.0002953
1 kPa	1000	1	0.009869	0.01000	0.14504	10.1973	4.0147	7.5006	0.2953
1 Atm	101325	101.325	1	1.01325	14.696	1033.2	406.78	760	29.921
1 Bar	100000	100	0.98692	1	14.504	1019.73	401.47	750.06	29.53
1 psi	6894.7	6.8947	0.068045	0.068947	1	70.308	27.680	51.715	2.036
1 cm H_2O	98.06	0.09806	0.0009679	0.0009806	0.014223	1	0.3937	0.7355	0.028958
1 in H_2O	249.1	0.2491	0.0024585	0.002491	0.036127	2.54	1	1.8683	0.07356
1 mm Hg	133.3228	0.13323	0.0013158	0.0013332	0.019337	1.3595	0.53525	1	0.03937
1 in Hg	3386.4	3.3864	0.033421	0.033864	0.49116	34.532	13.596	25.4	1

Airspeed vs. Pressure

Airspeed (Knots)	in Hg	in H_2O	psi	Pa
0	0.000	0.000	0.000	0.000
10	0.005	0.01798	0.0025	16.932
20	0.019	0.258324	0.01	64.3416
30	0.043	0.584628	0.021	145.615
40	0.077	1.046892	0.038	260.753
50	0.120	1.63152	0.059	406.368
60	0.173	2.352108	0.085	585.847
70	0.235	3.19506	0.1154	795.804
80	0.307	4.173972	0.1508	1039.62
90	0.390	5.30244	0.1916	1320.7
100	0.481	6.539676	0.2362	1628.86
110	0.583	7.926468	0.2863	1974.27
120	0.695	9.44922	0.3414	2353.55
130	0.817	11.10793	0.4013	2766.69
140	0.949	12.9026	0.4661	3213.69
150	1.091	14.83324	0.5359	3694.56
160	1.243	16.89983	0.6105	4209.3
170	1.406	19.11598	0.6906	4761.28
180	1.580	21.48168	0.776	5350.51
190	1.764	23.98334	0.8664	5973.61
200	1.959	26.63456	0.9622	6633.96
210	2.165	29.43534	1.0634	7331.56
220	2.382	32.38567	1.1699	8066.4
230	2.610	35.48556	1.2819	8838.5
240	2.849	38.735	1.3993	9647.85
250	3.100	42.1476	1.5226	10497.8
260	3.363	45.72335	1.6518	11388.5
270	3.637	49.44865	1.7863	12316.3
280	3.924	53.3507	1.9273	13288.2
290	4.223	57.41591	2.0742	14300.8
300	4.534	61.64426	2.2269	15353.9
310	4.858	66.04937	2.3861	16451.1
320	5.195	70.63122	2.5516	17592.3
330	5.545	75.38982	2.7235	18777.6
340	5.909	80.33876	2.9023	20010.2
350	6.286	85.46446	3.0874	21286.9
360	6.677	90.78049	3.2795	22611
370	7.082	96.28687	3.4784	23982.5
380	7.502	101.9972	3.6847	25404.8
390	7.936	107.8979	3.8978	26874.5
400	8.385	114.0025	4.1184	28395
410	8.850	120.3246	4.3468	29969.6
420	9.330	126.8507	4.5825	31595.1
430	9.826	133.5943	4.8261	33274.8
440	10.338	140.5554	5.0776	35008.6
450	10.868	147.7613	5.3379	36803.4

$Q = .5\delta V^2/144$
Where: Q = pressure in PSI
$\delta = .002378$
V = ft/sec

$Q = .00256V^2/144$
Where: Q = pressure in PSI
V = mph

Formulas and Other Information

Ohm's Law (DC Circuits)

$I = E/R = P/E$
$R = E/I = P/I^2 = E^2/P$
$E = IR = P/I$
$P = I^2R = EI = E^2/R$

Where: I = Amperes
E = Volts
P = Watts
R = Ohms

Ohm's Law (AC Circuits)

$I = E/Z = P/E \cos\theta$
$E = IZ = P/I \cos\theta$
$Z = E/I = P/I^2 \cos\theta = E^2 \cos\theta/P$
$P = I2Z \cos\theta = EI \cos\theta = E2 \cos\theta/Z$

Where: $\cos\theta I = R/Z = P/EI$ = Power Factor
E = Volts
P = Watts
θ = Lead or Lag angle between Current and Voltage
Z = Ohms (Impedance)

Series Resistors or Capacitors

$R_T = R_1 + R_2 + R_3 + R_n$

$1/C_T = 1/C_1 + !/C_2 + !/C_3 + 1/C_n$

Parallel Resistors or Capacitors

$1/R_T = 1/R_1 + !/R_2 + !/R_3 + 1/R_n$

$C_T = C_1 + C_2 + C_3 + C_n$

Reactance

$X_C = -1/2\pi fC$

$X_L = 2\pi fL$

Impedance

Series Circuit: $Z = \sqrt{R^2 + (X_l + X_C)2}$

Environment Constants

Term	Constant	Value
Speed of Light	C	2.997925×10^{10} cm/sec
	C	983.6×10^{6} ft/sec
	C	186284 miles/sec
Velocity of Sound (Dry Air @ 15 °C)	V_s	340.3 m/sec
	V_s	1116 ft/sec
Gravity	g	9.80665 meters/sec
	g	32.174 ft/sec
	g	386.089 inches./sec
1 atmosphere	atm	14.70 psi
	atm	101.33 kPa
	atm	2116 lb/ft^2

Undersea Pressure

$$P = A + 0.445D$$

Where: P = Absolute pressure in psi
A = Atmosphere pressure in psi
D = depth, in feet

$$P = A + 10.0D$$

Where: P = Absolute pressure in kPa
A = Atmosphere pressure in kPa
D = depth, in meters