Fan Engineering Wealth Guide

PART I

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Abbreviations, Fan Terminology and Definitions

ARR. Arrangement of fan.

BHP Brake horsepower, the fan's power consumption.

CCW Counterclockwise. Used to describe the rotation of an impeller. Rotation is determined by viewing the impeller from the drive side on centrifugal fans. Determining the rotation is not a factor on axial and inline centrifugal fans.

CFM Cubic feet per minute, the volume of air moved per minute.

CL Class of fan. The class identifies the limit of the fan's performance range.

CW Clockwise. Used to describe the rotation of an impeller. Rotation is determined by viewing the impeller from the drive side on centrifugal fans.

dBA Estimated sound pressure level in the space using "A" weighting.

DWDI Double width double inlet.

EFFICIENCY A Ratio of the useful energy (work) provided by a system to the energy supplied to it. Used to provide a relative performance comparison of fans.

FPM Feet per minute, the velocity of the airstream.

HP Horsepower, the fan's motor size.

I.D. Inside diameter of fan, duct or transition.

Lp Sound Pressure Level. Describes the loudness level of the sound, like the brightness level of a light bulb. This value varies with the distance from the sound source and the environment surrounding the sound source. Sound pressure is usually expressed in decibels with a reference level to 0.0002 microbars.

Lw Sound Power Level. Describes the total amount of acoustical energy the fan emits, like the watt rating of a light bulb describes the total amount of energy the light emits. This value is independent of location, distance, and environment. Sound power is usually expressed in decibels with a reference level to 10^{-12} watts.

LwA Sound Power Level 'A' weighted. This is a single value representing the fan's overall sound power level. 'A' weighting adjusts the sound power level for the response of the human ear. This value is often used in the calculation of sound pressure levels.

ME Mechanical efficiency (or Total efficiency). Mechanical efficiency is a ratio of the total fan power output to the power supplied to the fan. Mechanical efficiency uses total pressure, which includes the kinetic energy, to calculate the efficiency.

O.D. Outside diameter of fan, duct or transition.

OV Outlet velocity, the average air velocity at the outlet of the fan. Outlet velocity is calculated by dividing the CFM by outlet area.

RPM Revolutions per minute, the number of rotations the fan shaft makes per minute.

SE Static efficiency. Static efficiency is a ratio of the fan power output to the power supplied to the fan. Static efficiency uses static pressure, which does not include the kinetic energy, to calculate the efficiency. It can be found by multiplying the Mechanical efficiency by the ratio of the fan static pressure to the fan total pressure.

SP Static pressure is the measure of the potential energy of the airstream. SP acts equally in all directions. It is this pressure in the duct that tends to burst or collapse the duct.

SWSI Single width single inlet.

TP Total pressure, the measure of the energy content of the airstream. It is the sum of static pressure (SP) and velocity pressure (VP).

TS Tip speed, the speed of the fan blade tip.

VP Velocity pressure, the measure of the energy content of the airstream. Velocity pressure acts in the direction of the airflow. It is the pressure necessary to accelerate the air.

Formulas For Fan Applications

Mechanical Efficiency, ME $= \frac{CFM \times TP \times K_p}{6343.3 \times BHP} \times 100$

Static Efficiency, SE $= \frac{CFM \times SP \times K_p}{6343.3 \times BHP} \times 100$ (where SP is in inches H_2O)

Total Pressure, TP $= SP + VP$

Velocity, V $= \frac{CFM}{\text{Area in Sq. Ft.}}$

Velocity Pressure, VP $= \left(\frac{V}{1097.8}\right)^2 \times$ density in pounds per cubic foot

If the density is 0.075 lbs/ft^3, the equation for VP reduces to $= (V/4008.6)^2$

Kp $= \left(\frac{\ln(1+x)}{x}\right) \times \left(\frac{z}{\ln(1+z)}\right)$

x $= Pe1 + 13.595 \times P_b$

z $= \left(\frac{y+1}{y}\right) \times \left(\frac{\frac{6343.3 \times BHP}{CFM}}{P_{t1} + 13.595 \times P_b}\right)$

P_{t1} = Total Pressure @ fan's inlet in in-wg

P_b = Barometric Pressure in in-Hgz

SYSTEM CURVE EQUATION

The following formula is used to find other points on the system line when SP_1 and CFM_1 are known. Most, but not all, systems follow this relationship.

$$SP_2 = SP_1 \left(\frac{CFM_2}{CFM_1}\right)^2$$

How to Use the Fan Laws for Performance Changes

There are two reasons why a fan's performance may need to be changed:

- The system or area requires additional airflow (CFM).
- The actual system static pressure (SP) is different from the design value.

When these situations occur, it is important to understand how they can affect the fan's performance.

The effect on the fan's performance can be shown by using the Fan Laws, shown below.

FAN LAW EQUATIONS

$$CFM_2 = \frac{RPM_2}{RPM_1} \times CFM_1$$

$$SP_2 = \left(\frac{RPM_2}{RPM_1}\right)^2 \times SP_1$$

$$BHP_2 = \left(\frac{RPM_2}{RPM_1}\right)^3 \times BHP_1$$

Subscript 1 = existing conditions
Subscript 2 = new conditions

3. After installing the fan, the Plant Manager wants to increase the airflow into the plant to 41,500 CFM. The fan laws are used to determine how this fan will be affected by the new system requirements.
4. The known values are

   CFM_1 = 33,120 CFM; SP_1 = 2.5" SP
   CFM_2 = 41,500 CFM; RPM_1 = 620 RPM
   BHP_1 = 20.01 BHP

5. The unknown values are RPM_2 = ??, SP_2 = ??, BHP_2 = ??
6. Using the fan law equations, the unknown values are calculated as follows

$$RPM_2 = \frac{41{,}500}{33{,}120} \times 620 = 777\ RPM_2$$

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620

EXAMPLE

1. Assume a customer requires a fan to operate at 33,120

$$SP_2 = \left(\underline{777}\right)^2 \times 2.5'' = 3.93''$$

SP_2

$$BHP_2 = \left(\underline{777}\right)^3 \times 20.01 =$$

2. CFM at 2.5" SP, at standard air density. Per the specifications, a BC backward inclined fan is required.
3. Based on the above information, VSPL engineer selects a suitable fan, which will operate at 620 RPM and 20.01 BHP to meet the required performance.

7. What does this information tell us?

   In order to use the same fan for an airflow of 41,500 CFM, the RPM needs to be increased to 777 RPM.

   The new performance increases the fan's horsepower requirement from 25 HP to 50 HP. If the fan is sped up to 777 RPM the motor must be resized.

IMPORTANT NOTE: The new RPM should be checked to make sure it does not exceed the maximum allowable RPM for the fan that is installed. If this information is not provided in the catalog or you would like **VENTECH SYSTEMS PVT. LTD.** to review the application, please contact us.

39.39 BHP_2

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Performance Correction for Temperature & Altitude

In each fan catalog the performance tables are based on standard air density, which is defined as dry air at 70°F at sea level (29.92 Hg barometric pressure). This is equal to 0.075 lb./ft^3 density. The fan performance tables provide the fan RPM and brake horsepower requirements for the given CFM and static pressure, at standard air density.

When the fan performance is not at standard conditions, the performance must be converted to standard conditions before entering the fan performance tables. The fan performance is converted to standard conditions by using the correction factor in the Temperature and Altitude Correction Chart shown below.

The following are examples explaining how to convert the fan's performance to standard conditions.

Temperature and Altitude Correction Factors

AIR TEMP °F	ALTITUDE IN FEET ABOVE SEA LEVEL											
	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	15000
	BAROMETRIC PRESSURE IN INCHES OF MERCURY											
	29.92	28.86	27.82	26.82	25.84	24.90	23.98	23.09	22.22	21.39	20.58	16.89
–50	1.293	1.247	1.201	1.159	1.116	1.076	1.036	.997	.960	.924	.889	.729
0	1.152	1.111	1.071	1.032	.995	.959	.923	.889	.856	.824	.792	.650
50	1.039	1.003	.967	.932	.897	.864	.833	.801	.772	.743	.715	.586
70	1.000	.964	.930	.896	.864	.832	.801	.772	.743	.714	.688	.564
100	.946	.912	.880	.848	.818	.787	.758	.730	.703	.676	.651	.534
150	.869	.838	.808	.770	.751	.723	.696	.671	.646	.620	.598	.490
200	.803	.774	.747	.720	.694	.668	.643	.620	.596	.573	.552	.453
250	.747	.720	.694	.669	.645	.622	.598	.576	.555	.533	.514	.421
300	.697	.672	.648	.624	.604	.580	.558	.538	.518	.498	.480	.393
350	.654	.631	.608	.586	.565	.544	.524	.505	.486	.467	.450	.369
400	.616	.594	.573	.552	.532	.513	.493	.476	.458	.440	.424	.347
450	.582	.561	.542	.522	.503	.484	.466	.449	.433	.416	.401	.328
500	.552	.532	.513	.495	.477	.459	.442	.426	.410	.394	.380	.311
550	.525	.506	.488	.470	.454	.437	.421	.405	.390	.375	.361	.296
600	.500	.482	.465	.448	.432	.416	.400	.386	.372	.352	.344	.282
650	.477	.460	.444	.427	.412	.397	.382	.368	.354	.341	.328	.269
700	.457	.441	.425	.410	.395	.380	.366	.353	.340	.326	.315	.258
750	.439	.423	.407	.393	.379	.365	.351	.338	.326	.313	.303	.248
800	.420	.404	.389	.375	.362	.350	.336	.323	.311	.300	.290	.237
850	.404	.391	.376	.363	.349	.336	.324	.312	.300	.289	.279	.228
900	.389	.376	.363	.349	.336	.324	.312	.300	.289	.279	.268	.220
950	.376	.363	.350	.337	.325	.313	.301	.290	.279	.269	.259	.212
1000	.363	.350	.338	.325	.314	.302	.291	.280	.270	.259	.250	.205

How to Convert the Fan's Performance to Standard Conditions

When Operating Conditions Are Known:

Assume, SWSI fan is to handle 17,000 CFM, 2.5" SP, at 300°F and 3000 ft. altitude. This fan is not operating at standard conditions; therefore, the performance needs to be converted to standard conditions to find the fan's speed and brake horsepower. The fan's performance is converted to standard conditions as follows:

1. From the table above, the correction factor for 300°F and 3000 ft. altitude is 0.624.
2. The static pressure, at standard air density, is calculated by dividing the operating SP by the correction factor; i.e., 2.5" ÷ .624 = 4" SP. The static pressure is 4" at standard air density.
3. Knowing the CFM and the static pressure, at standard air density, the fan RPM and BHP can be found. SWSI fan performance table with 17,000 CFM and 4" SP.
4. In this example, the RPM and BHP are between the values listed in the performance table; therefore, the RPM and BHP are determined by interpolation. The RPM is determined by the following equation

17,000 – 16,850 = **RPM** – 915

17,620 – 16,850   929 – 915

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5. Subtracting the top and bottom values reduces the equation to

$$\frac{150}{770} = \frac{RPM - 915}{14}$$

6. Dividing the values on the left side and multiplying each side by 14 reduces the equation to

0.19 x 14 = **RPM** – 915

7. Multiplying the values on the left side and adding 915 to each side reduces the equation to

2.66 + 915 = **RPM**

8. Solving the left side of the equation results in a fan RPM equal to

RPM = 918 RPM

9. Next, the BHP is determined by the following equation

$$\frac{17{,}000 - 16{,}850}{17{,}620 - 16{,}850} = \frac{BHP - 14.20}{15.03 - 14.20}$$

10. Subtracting the top and bottom values reduces the equation to

$$\frac{150}{770} = \frac{BHP - 14.20}{0.83}$$

11. Dividing the values on the left side and multiplying each side by 0.83 reduces the equation to

0.19 x 0.83 = **BHP** – 14.20

12. Multiplying the values on the left side and adding 14.20 to each side reduces the equation to

$$0.16 + 14.20 = \mathbf{BHP}$$

13. Solving the left side of the equation results in a fan BHP equal to

BHP = 14.36 BHP

Conclusions — For this example, the required fan RPM is 918 RPM and the brake horsepower at standard conditions is 14.36 BHP. The brake horsepower, 14.36 BHP at standard conditions (70°F at sea level), is also referred to as the cold or starting brake horsepower.

If the fan is installed at a higher altitude than sea level, such as described in this example, the cold or starting brake horsepower at that altitude is determined by the following equation:

Cold BHP at altitude =
BHP_{std} x Correction Factor
at Required Elevation and 70°F

For this example, the cold or starting brake horsepower at 3000 ft. altitude and 70°F is

14.36 x 0.896 = 12.87 BHP,
cold BHP @ 3000 ft. altitude

To determine the BHP at operating conditions, 300°F and 3000 ft. altitude, multiply the BHP at standard conditions by the factor for these conditions:

14.36 x 0.624 = 8.96 BHP
at operating conditions,
300°F and 3000 ft. altitude

The fan performance information for 17000 CFM, 2.5" SP, at 300°F and 3000 ft. altitude is

- 918 RPM
- 8.96 BHP at operating conditions (300°F and 3000 ft. altitude)
- 12.87 BHP (cold BHP, 70°F and 3000 ft. altitude)
- 14.36 BHP at standard conditions or cold BHP at 70°F and sea level
- 4" SP at standard conditions

When Operating Density Is Known:

Assume a SWSI fan suitable for handling 23,500 CFM, 3.0" SP, at 0.06364 lb./ft^3. This fan is not operating at standard conditions; therefore, the performance needs to be converted to standard conditions to find the fan's speed and brake horsepower. The fan's performance is converted to standard conditions as follows:

1. Using the operating density of 0.06364 lb./ft^3, the correction factor is determined by dividing the operating density by the standard density, 0.075 lb./ft^3.

$$\text{Correction Factor} = \frac{\text{Operating Density}}{\text{Standard Density}} = .848$$

2. The static pressure at standard air density is calculated by dividing the operating SP by the conversion factor, i.e., 3.0" ÷ .848 = 3.5" SP. The static pressure is 3.5" at standard air density.
3. Knowing the CFM and the static pressure at standard air density, the fan RPM and BHP can be found. Enter the 365 BC, SWSI fan performance table (Bulletin 300) with 23,500 CFM and 3.5" SP.
4. This example also finds the RPM and BHP between the values listed in the performance table; therefore, the RPM and BHP are determined by interpolation.
5. The RPM is determined by the following equation

$$\frac{23{,}500 - 22{,}980}{24{,}510 - 22{,}980} = \frac{\mathbf{RPM} - 1015}{1054 - 1015}$$

6. Subtracting the top and bottom values reduces the equation to

$$\frac{520}{1530} = \frac{\mathbf{RPM} - 1015}{39}$$

7. Dividing the values on the left side and multiplying each side by 39 reduces the equation to

$$0.3 \times 39 = \mathbf{RPM} - 1015$$

8. Multiplying the values on the left side and adding 1015 to each side reduces the equation to

$$13 + 1015 = \mathbf{RPM}$$

9. Solving the left side of the equation results in a fan RPM equal to

RPM = 1028 RPM

10. Next, the BHP is determined by the following equation

$$\frac{23{,}500 - 22{,}980}{24{,}510 - 22{,}980} = \frac{\mathbf{BHP} - 20.15}{22.48 - 20.15}$$

11. Subtracting the top and bottom values reduces the equation to

$$\frac{520}{1530} = \frac{\mathbf{BHP} - 20.15}{2.33}$$

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12. Dividing the values on the left side and multiplying each side by 2.33 reduces the equation to

$$0.34 \times 2.33 = \textbf{BHP} - 20.15$$

13. Multiplying the values on the left side and adding 20.15 to each side reduces the equation to

$$0.79 + 20.15 = \textbf{BHP}$$

14. Solving the left side of the equation results in a fan BHP equal to

$$\textbf{BHP = 20.94 BHP}$$

Conclusions — For this example, the required fan RPM is 1028 RPM and the brake horsepower is 20.94 BHP at standard conditions. The brake horsepower, 20.94 BHP at standard conditions (70°F at sea level), is also referred to as the cold or starting brake horsepower.

To determine the BHP at operating conditions, multiply the BHP at standard conditions by the conversion factor for these conditions:

20.94 x 0.848 = 17.76 BHP
at operating conditions

The fan performance information for 23,500 CFM, 3.0" SP, at 0.06364 lb./ft^3 is

- 1028 RPM
- 17.76 BHP at operating conditions of 0.06364 lb./ft^3
- 20.94 BHP at standard conditions (70°F at sea level)
- 3.5" SP at standard conditions.

Capture velocities (or Airflow) For Exhaust Hoods

Exhaust hoods are critical devices used to protect workers from process fumes or dust. Exhaust hoods induce airflow from the work station to the hood to remove contaminants or particles from the work area. The "capture velocity" is the air velocity required to move the contaminants from the work station to the hood. Capture velocities and hood designs depend on the type of fume or dust being removed. Hood designs include canopy hoods, downdraft hoods, booth-type hoods, slot hoods, etc. The chart at right shows the capture velocity and hood design for a given process.

PROCESS	TYPE OF HOOD	AIRFLOW OR CAPTURE VELOCITY
Abrasive Blasting	Down draft Hood Cross draft Hood	60-100 CFM/ft^2 of Floor 100 CFM/ft^2 of Wall
Auto Parking Garage	2 Level	500 CFM/Parking Space
Bag Loading for Grain Elevators, Feed Mills, Flour Mills	Canopy Hood	100 CFM/ft^2 Open Face Area 500 FPM Maximum
Ceramic: Dry Pan Dry Press Spraying (Lead Glaze)	Enclosure Hood Local at Die Local at Die At Supply Bin Booth Hood	200 FPM Thru All Openings 500 CFM 500 CFM 500 CFM 400 FPM (Face)
Cooling Tunnels (Foundry)	Enclosure Hood	75-100 CFM Per Running Foot of Enclosure
Core Sanding (on Lathe)	Downdraft Hood Under Work	100 FPM at Source
Crushers & Grinders	Enclosure Hood	200 FPM Thru Openings
Degreasing; Evaporation From Tanks	Canopy Hood	50-100 FPM
Forge (Hand)	Booth Hood	200 FPM at Face
Furniture Stripping Tank	Slot Hood	45 CFM/ft^2 of Tank Area
Metal Cutting Bandsaw	Booth Hood	225 CFM/ft^2 of Open Area
Metal Spraying	Booth Hood	a) 150 CFM/ft^2 of Face Area, Non-toxic b) 200 CFM/ft^2 of Face Area, Toxic
Outboard Motor Test Tank	Side Draft Hood	200 CFM/ft^2 of tank openings
Packaging Machines	Booth Hood Downdraft Hood Complete Enclosure	50-100 FPM at Face 95-150 FPM Down 100-400 FPM Opening
Paper Machine	Canopy Hood	200-300 FPM at Face
Pickling Metals	Canopy Hood	200-250 FPM
Plating Metals	Canopy Hood	225-250 FPM
Restaurant Range	Hood Against Wall Island Type Hood	80 CFM/ft^2 of Hood Area 125 CFM/ft^2 of Hood Area
Spray Booth	Booth Hood	a) 200 CFM/ft^2 for Face Area Up To 4 ft^2 b) 150 CFM/ft^2 for Face Area Over 4 ft^2
Steam Kettles	Canopy Hood	150 FPM at Face
Varnish Kettles	Canopy Hood	200-250 FPM at Face
Wire Impregnating	Covered Tanks	200 CFM/ft^2 of Opening

Note: The flow rates and velocities shown in the charts on this page are based on standard air density. For conditions not at standard density such as high temperature, moisture or elevation, convert the operating conditions to standard air conditions using the correction factors found in the Temperature and Altitude Correction Chart on page 4.

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Minimum Duct velocities For Conveying Materials

After the exhaust hood removes the fumes or dust from the work station, the velocity downstream of the hood must be high enough to prevent the material from clogging the ductwork. The velocity downstream of the hood is defined as the *minimum duct velocity* and is determined by the type of material being conveyed through the duct. The table at right shows typical duct velocities for various materials.

MATERIAL	AVG. VELOCITY TO CONVEY MATERIAL (FPM)
VERY FINE LIGHT DUST: Cotton Lint, Wood Flour, Litho Powder	2500–3000
DRY DUSTS & POWDERS: Fine Rubber Dust, Jute Lint, Cotton Dust, Light Shavings, Soap Dust	3000–4000
AVERAGE INDUSTRIAL DUST: Grinding Dust, Buffing Lint-Dry, Wool Jute Dust-Shaker Waste, Shoe Dust, Granite Dust, Silica Flour, General Material Handling, Brick Cutting, Clay Dust, Foundry-General, Limestone Dust, Packaging & Weighing Asbestos Dust in Textile Industries	3500–4000
HEAVY DUSTS Sawdust-Heavy & Wet, Metal Turnings, Foundry Tumbling Barrels & Shake-Out, Sandblast Dust, Wood Blocks, Brass Turnings, Cast Iron Boring Dust, Lead Dust	4000–4500
HEAVY OR MOIST: Lead Dusts with Small Chips, Moist Cement Dust, Asbestos Chunks From Transite Pipe Cutting Machines, Buffing Lint-Sticky, Quick-Lime Dust	4500 & Up

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Air Change Rates for ventilation

The volume of fresh air (CFM) required to a given area can be easily estimated by the "air change method." This method is recommended for standard commercial type applications where environmental control of hazards, heat and/or odors is not necessary.

Other items to consider when determining the number of air changes required are:

- Local code requirements on air changes.
- How the space is used.
- The type of climate in the area, e.g., hot, moderate or cold.

The air volume (CFM) can be estimated by using the following equation and the chart at right that defines the number of air changes for given area.

$$\text{Volume of Air} = \frac{\text{Room Volume (ft}^3\text{)}}{\text{No. of Air Changes (min./change)}}$$

AREA TYPE	MINUTES PER CHANGE
ASSEMBLY HALL	3-10
BAKERY	1- 3
BAR	2- 4
BOWLING ALLEY	3- 7
BOILER ROOM	1- 3
CAFETERIA	3- 5
CHURCH	4-10
CLASSROOM	4- 6
ENGINE ROOM	1- 3
FACTORY	2- 7
FORGE SHOP	1- 2
FOUNDRY	1- 5
GENERATOR ROOM	2- 5
HOSPITAL	4- 6
KITCHEN	2- 3
LABORATORY	2- 5
LAUNDRY	2- 4
LOCKER ROOM	4-15
MACHINE SHOP	3- 6
MILL	3- 8
OFFICE	2- 8
RESTAURANT	5-10
RETAIL STORE	5-10
RESTROOM/TOILET	2- 5
TRANSFORMER ROOM	1- 5
WAREHOUSE	4-10

velocity-to-velocity Pressure Conversion Chart

Values based at Standard Density, 0.075lbs/ft^3.

Calculated by the formula:

$$VP = \left(\frac{V}{4008.6}\right)^2$$

For other densities use the formula:

$$VP = \left(\frac{V}{1097.8}\right)^2 x \text{ Density}$$

Where:

V is velocity in ft./min.
Density is in lb/ft^3.

V-VELOCITY FPM	VP-VELOCITY PRESSURE IN. WATER	V-VELOCITY FPM	VP-VELOCITY PRESSURE IN. WATER	V -VELOCITY FPM	VP-VELOCITY PRESSURE IN. WATER
100	0.0006	**2500**	0.389	**4900**	1.49
200	0.0025	**2600**	0.421	**5000**	1.56
300	0.0056	**2700**	0.454	**5100**	1.62
400	0.010	**2800**	0.488	**5200**	1.68
500	0.016	**2900**	0.523	**5300**	1.75
600	0.022	**3000**	0.560	**5400**	1.81
700	0.030	**3100**	0.598	**5500**	1.88
800	0.040	**3200**	0.637	**5600**	1.95
900	0.050	**3300**	0.678	**5700**	2.02
1000	0.062	**3400**	0.719	**5800**	2.09
1100	0.075	**3500**	0.762	**5900**	2.17
1200	0.090	**3600**	0.807	**6000**	2.24
1300	0.105	**3700**	0.852	**6100**	2.32
1400	0.122	**3800**	0.899	**6200**	2.39
1500	0.140	**3900**	0.947	**6300**	2.47
1600	0.159	**4000**	1.00	**6400**	2.55
1700	0.180	**4100**	1.05	**6500**	2.63
1800	0.202	**4200**	1.10	**6600**	2.71
1900	0.225	**4300**	1.15	**6700**	2.79
2000	0.249	**4400**	1.20	**6800**	2.88
2100	0.274	**4500**	1.26	**6900**	2.96
2200	0.301	**4600**	1.32	**7000**	3.05
2300	0.329	**4700**	1.37	**7100**	3.14
2400	0.358	**4800**	1.43	**7200**	3.23

Definitions of English & Metric Units

°C = degrees Celsius
cfm = cubic feet per minute
cm = centimeter
°F = degrees Fahrenheit
ft = foot
fpm = feet per minute
g = gram
Hg = mercury
hp = horsepower
hpm = metric horsepower
hr. = hour

in. = inch
kg = kilogram
km = kilometer
kPa = kilopascal
l = liter
lb. = pound
lb_f = pound force
lb_m = pound mass
m = meter
min. = minute
mm = millimeter

N = Newton
Nm = Newton-meter
oz. = ounce
psi = pounds per square inch
rpm = revolutions per minute
rps = revolutions per second
sec. = second
W = Watts
wg = water gauge

Pressure Equivalent Chart

This chart shows pressure values in inches water gauge and the equivalent pressure in other commonly used unit.

INCHES WATER (IN. WG)	INCHES MERCURY (IN. Hg)	OUNCES PER SQ. IN. $(oz./in)^2$	POUNDS PER SQ. IN. $(lb./in)^2$	PASCALS (Pa)	KILOPASCALS (kPa)	MILLIMETERS WATER (mm WG)
1	0.0736	0.577	0.0361	249	0.25	25.4
2	0.1471	1.154	0.0721	498	0.50	50.8
3	0.2207	1.731	0.1082	747	0.75	76.2
4	0.2942	2.308	0.1443	996	1.00	101.6
5	0.3678	2.886	0.1804	1245	1.25	127.0
6	0.4414	3.463	0.2164	1495	1.49	152.4
7	0.5149	4.040	0.2525	1744	1.74	177.8
8	0.5885	4.617	0.2886	1993	1.99	203.2
9	0.6620	5.194	0.3246	2242	2.24	228.6
10	0.7356	5.771	0.3607	2491	2.49	254.0
11	0.8092	6.348	0.3968	2740	2.74	279.4
12	0.8827	6.925	0.4328	2989	2.99	304.8
13	0.9563	7.503	0.4689	3238	3.24	330.2
14	1.0298	8.080	0.5050	3487	3.49	355.6
15	1.1034	8.657	0.5411	3736	3.74	381.0
16	1.1770	9.234	0.5771	3985	3.99	406.4
17	1.2505	9.811	0.6132	4235	4.23	431.8
18	1.3241	10.388	0.6493	4484	4.48	457.2
19	1.3976	10.965	0.6853	4733	4.73	482.6
20	1.4712	11.542	0.7214	4982	4.98	508.0
21	1.5448	12.120	0.7575	5231	5.23	533.4
22	1.6183	12.697	0.7935	5480	5.48	558.8
23	1.6919	13.274	0.8296	5729	5.73	584.2
24	1.7654	13.851	0.8657	5978	5.98	609.6
25	1.8390	14.428	0.9018	6227	6.23	635.0
26	1.9126	15.005	0.9378	6476	6.48	660.4
27	1.9861	15.582	0.9739	6725	6.73	685.8
28	2.0597	16.159	1.0100	6974	6.97	711.2
29	2.1332	16.736	1.0460	7224	7.22	736.6
30	2.2068	17.314	1.0821	7473	7.47	762.0
31	2.2804	17.891	1.1182	7722	7.72	787.4
32	2.3539	18.468	1.1542	7971	7.97	812.8
33	2.4275	19.045	1.1903	8220	8.22	838.2
34	2.5010	19.622	1.2264	8469	8.47	863.6
35	2.5746	20.199	1.2625	8718	8.72	889.0
36	2.6482	20.776	1.2985	8967	8.97	914.4
37	2.7217	21.353	1.3346	9216	9.22	939.8
38	2.7953	21.931	1.3707	9465	9.47	965.2
39	2.8688	22.508	1.4067	9714	9.71	990.6
40	2.9424	23.085	1.4428	9964	9.96	1016.0
41	3.0160	23.662	1.4789	10213	10.21	1041.4
42	3.0895	24.239	1.5149	10462	10.46	1066.8
43	3.1631	24.816	1.5510	10711	10.71	1092.2
44	3.2366	25.393	1.5871	10960	10.96	1117.6
45	3.3102	25.970	1.6232	11209	11.21	1143.0

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English & Metric Conversions

See page 12 for expanded Temperature Conversion table.

AREA

MULTIPLY	By	TO OBTAIN
in^2	0.006944	ft^2
	0.0006452	m^2
	645.16	mm^2
ft^2	144	in^2
	0.09290	m^2
	92903	mm^2
m^2	10.76	ft^2
	1550	in^2
	10^6	mm^2

DENSITY

MULTIPLY	By	TO OBTAIN
lb/ft^3	16.02	kg/m^3
kg/m^3	0.06243	lb/ft^3

LENGTH

MULTIPLY	By	TO OBTAIN
ft	12	in
	0.3048	m
	304.80	mm
in	0.0833	ft
	0.02540	m
	25.4	mm
m	3.2808	ft
	39.37	in
	1000	mm
mm	0.003281	ft
	0.03937	in
	0.001	m

MASS

MULTIPLY	By	TO OBTAIN
lb$_m$	16	oz
	453.59	grams
	0.45359	kg
oz	0.0625	lb$_m$
	28.35	grams
	0.0283	kg
grams	0.002205	lbm
	0.03527	oz
	0.001	kg
kg	2.2046	lbm
	35.274	oz
	1000	grams

MOMENT OF INERTIA

MULTIPLY	By	TO OBTAIN
lb-in^2	0.0069	lb-ft^2
	0.0002926	kg-m^2
lb-ft^2	144	lb-in^2
	0.04214	kg-m^2
kg-m^2	23.73	lb-ft^2
	3417.2	lb-in^2

POWER

MULTIPLY	By	TO OBTAIN
HP	33000	ft-lb/min
	550	ft-lb/s
	745.7	W
	0.7457	kW
	76.04	kg-m/sec
ft-lb/min	0.0000303	HP
	0.0167	ft-lb/s
	0.0226	W
	0.0023	kg-m/sec
ft-lb/s	0.0018	HP
	60	ft-lb/min
	1.3558	W
	0.1388	kg-m/sec
W	0.00134	HP
	44.254	ft-lb/min
	0.73756	ft-lb/s
	0.1019	kg-m/sec
KW	1.34	HP
	44,254	ft-lb/min
	737.56	ft-lb/s
	101.90	kg-m/sec

POWER

MULTIPLY	By	TO OBTAIN
kg-m/sec	0.01	hp
	434.78	ft-lb/min
	7.20	ft-lb/s
	9.81	W

PRESSURE

MULTIPLY	By	TO OBTAIN
psi	27.68	in-wg
	2.036	in-Hg
	6894.8	Pa
	703.07	mm-wg
	51.715	mm-Hg
	0.06805	atm
	68.948	mbar
in-wg	0.03613	psi
	0.07356	in-Hg
	249.089	Pa
	25.4	mm-wg
	1.8683	mm-Hg
	0.002458	atm
	2.49089	mbar
in-Hg	0.49115	psi
	13.595	in-wg
	3386.4	pa
	345.31	mm-wg
	25.4	mm-Hg
	0.03342	atm
	33.864	mbar
Pa	0.000145	psi
	0.004015	in-wg
	0.0002953	in-Hg
	0.10197	mm-wg
	0.007501	mm-Hg
	0.0000098692	atm
	0.01	mbar
mm-wg	0.001422	psi
	0.03937	in-wg
	0.002896	in-Hg
	9.8067	Pa
	0.07356	mm-Hg
	0.000096784	atm
	0.098067	mbar
mm-Hg	0.01934	psi
	0.53524	in-wg
	0.002896	in-Hg
	133.32	Pa
	13.595	mm-wg
	0.001316	atm
	1.3332	mbar
atm	14.696	psi
	406.78	in-wg
	29.921	in-Hg
	101325	Pa
	10332	mm-wg
	760	mm-Hg
	1013.25	mbar
mbar	0.0145	psi
	0.40146	in-wg
	0.02953	in-Hg
	100	Pa
	10.1972	mm-wg
	0.75006	mm-Hg
	0.000987	atm

ROTATING SPEED

MULTIPLY	By	TO OBTAIN
RPM	0.0167	rps
	0.0167	Hertz
RPS	60	rpm
	1	Hertz
Hertz	60	rpm
	1	rps

TEMPERATURE

$$°F = 9/5\ C + 32$$

$$°C = 5/9\ (F - 32)$$

TORQUE

MULTIPLY	By	TO OBTAIN
lb-in	0.083	lb-ft
	0.11298	N-m
lb-ft	12	lb-in
	1.3558	N-m
N-m	0.73756	lb-ft
	8.8507	lb-in

VELOCITY

MULTIPLY	By	TO OBTAIN
fpm	0.0167	fps
	.2	in/sec
	0.005080	m/s
	0.30480	m/min
fps	60	fpm
	12	in/sec
	0.30480	m/s
	18.288	m/min
in/sec	5	fpm
	0.0833	fps
	0.02540	m/s
	1.524	m/min
m/s	196.85	fpm
	3.2808	fps
	39.37	in/sec
	60	m/min
m/min	3.2808	fpm
	0.05468	fps
	0.65617	in/sec
	0.0167	m/s

VOLUME

MULTIPLY	By	TO OBTAIN
ft^3	1728	in^3
	28.317	l
	0.02832	m^3
in^3	0.000579	ft^3
	0.01639	l
	0.0000164	m^3
l	0.03531	ft^3
	61.024	in^3
	0.001	m^3
m^3	35.315	ft3
	61024	in3
	1000	l

VOLUME FLOW

MULTIPLY	By	TO OBTAIN
CFM	0.0004719	m^3/sec
	0.02832	m^3/min
	1.6990	m^3/hr
	0.47195	l/s
	28.317	l/min
m^3/sec	2118.9	CFM
	60	m^3/min
	3600	m^3/hr
	1000	l/s
	60000	l/min
m^3/min	35.315	CFM
	0.0167	m^3/sec
	60	m^3/hr
	16.667	l/s
	1000	l/min
m^3/hr	0.58858	CFM
	0.0167	m^3/min
	0.0003	m^3/sec
	0.2778	l/s
	16.667	l/min
l/s	2.1189	CFM
	0.001	m^3/sec
	0.06	m^3/min
	3.6	m^3/hr
	60	l/min
l/min	0.03531	CFM
	0.000016	m^3/sec
	0.001	m^3/min
	0.06	m^3/hr
	0.0167	l/s

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Friction Loss Per 100 Feet of Round Duct

Data is for duct roughness of 0.0005 feet. If a special duct material is being used, please contact the duct material manufacturer for the friction losses. Friction loss in inches H_2O.

vEL.	DUCT DIAMETER													
	4"		5"		6"		7"		8"		10"		12"	
	CFM	FL	CFM	FL	CFM	FL	CFM	FL	CFM	FL	CFM	FL	CFM	FL
2000	175	1.85	273	1.39	393	1.11	535	0.92	698	0.77	1091	0.59	1571	0.47
2200	192	2.21	300	1.67	432	1.33	588	1.10	768	0.93	1200	0.71	1728	0.56
2400	209	2.59	327	1.97	471	1.57	642	1.30	838	1.10	1309	0.83	1885	0.67
2600	227	3.04	355	2.30	511	1.83	695	1.51	908	1.28	1418	0.97	2042	0.78
2800	244	3.49	382	2.65	550	2.11	748	1.74	977	1.47	1527	1.12	2199	0.90
3000	262	4.00	409	3.02	589	2.41	802	1.99	1047	1.68	1636	1.28	2356	1.02
3200	279	4.52	437	3.43	628	2.72	855	2.25	1117	1.91	1745	1.45	2513	1.16
3400	297	5.10	464	3.85	668	3.07	909	2.53	1187	2.15	1854	1.63	2670	1.30
3600	314	5.68	491	4.30	707	3.43	962	2.83	1257	2.40	1963	1.82	2827	1.45
3800	332	6.33	518	4.77	746	3.80	1016	3.14	1327	2.66	2073	2.02	2985	1.62
4000	349	6.97	546	5.28	786	4.21	1069	3.47	1396	2.94	2182	2.23	3142	1.79
4200	367	7.69	573	5.80	825	4.62	1123	3.82	1466	3.23	2291	2.46	3299	1.96
4400	384	8.39	600	6.35	864	5.05	1176	4.17	1536	3.54	2400	2.69	3456	2.15
4600	402	9.18	627	6.91	903	5.51	1230	4.56	1606	3.86	2509	2.93	3613	2.34
4800	419	9.95	655	7.53	943	5.99	1283	4.95	1676	4.19	2618	3.18	3770	2.54
5000	437	10.80	682	8.14	982	6.49	1337	5.36	1746	4.54	2727	3.45	3927	2.76
5200	454	11.63	709	8.78	1021	7.00	1390	5.78	1815	4.90	2836	3.72	4084	2.97
5400	471	12.50	737	9.47	1061	7.54	1443	6.22	1885	5.27	2945	4.00	4241	3.20
5600	489	13.45	764	10.16	1100	8.10	1497	6.68	1955	5.66	3054	4.30	4398	3.44
5800	506	14.37	791	10.88	1139	8.67	1550	7.15	2025	6.07	3163	4.61	4555	3.68
6000	524	15.39	818	11.62	1178	9.26	1604	7.65	2095	6.48	3272	4.92	4712	3.93
6200	541	16.38	846	12.41	1218	9.88	1657	8.15	2164	6.91	3381	5.25	4869	4.20
6400	559	17.47	873	13.19	1257	10.51	1711	8.68	2234	7.35	3491	5.59	5027	4.47
6600	576	18.52	900	14.00	1296	11.16	1764	9.22	2304	7.81	3600	5.93	5184	4.74
6800	594	19.68	928	14.87	1336	11.84	1818	9.78	2374	8.28	3709	6.29	5341	5.03
7000	611	20.80	955	15.73	1375	12.53	1871	10.34	2444	8.77	3818	6.66	5498	5.32

VEL.	DUCT DIAMETER													
	14"		16"		18"		20"		22"		24"		30"	
	CFM	FL	CFM	FL	CFM	FL	CFM	FL	CFM	FL	CFM	FL	CFM	FL
2000	2138	0.39	2793	0.33	3534	0.29	4363	0.25	5280	0.22	6283	0.20	9817	0.15
2200	2352	0.47	3072	0.40	3888	0.34	4800	0.30	5808	0.27	6912	0.24	10799	0.19
2400	2566	0.55	3351	0.47	4241	0.41	5236	0.36	6336	0.32	7540	0.29	11781	0.22
2600	2779	0.64	3630	0.55	4595	0.47	5672	0.42	6863	0.37	8168	0.33	12763	0.26
2800	2993	0.74	3910	0.63	4948	0.55	6109	0.48	7391	0.43	8796	0.39	13744	0.29
3000	3207	0.85	4189	0.72	5302	0.62	6545	0.55	7919	0.49	9425	0.44	14726	0.34
3200	3421	0.96	4468	0.82	5655	0.71	6981	0.62	8447	0.55	10053	0.50	15708	0.38
3400	3635	1.08	4747	0.92	6008	0.79	7418	0.70	8975	0.62	10681	0.56	16690	0.43
3600	3848	1.20	5027	1.02	6362	0.89	7854	0.78	9503	0.70	11310	0.63	17671	0.48
3800	4062	1.34	5306	1.14	6715	0.99	8290	0.87	10031	0.77	11938	0.70	18653	0.53
4000	4276	1.48	5585	1.26	7069	1.09	8727	0.96	10559	0.85	12566	0.77	19635	0.59
4200	4490	1.63	5864	1.38	7422	1.20	9163	1.05	11087	0.94	13195	0.84	20617	0.65
4400	4704	1.78	6144	1.51	7776	1.31	9599	1.15	11615	1.03	13823	0.92	21598	0.71
4600	4917	1.94	6423	1.65	8129	1.43	10036	1.26	12143	1.12	14451	1.01	22580	0.77
4800	5131	2.11	6702	1.79	8483	1.55	10472	1.37	12671	1.22	15080	1.10	23562	0.84
5000	5345	2.28	6982	1.94	8836	1.68	10909	1.48	13199	1.32	15708	1.19	24544	0.91
5200	5559	2.46	7261	2.09	9189	1.81	11345	1.60	13727	1.42	16336	1.28	25525	0.98
5400	5773	2.65	7540	2.25	9543	1.95	11781	1.72	14255	1.53	16965	1.38	26507	1.05
5600	5986	2.85	7819	2.42	9896	2.10	12218	1.85	14783	1.64	17593	1.48	27489	1.13
5800	6200	3.05	8099	2.59	10250	2.25	12654	1.98	15311	1.76	18221	1.58	28470	1.21
6000	6414	3.26	8378	2.77	10603	2.40	13090	2.11	15839	1.88	18850	1.69	29452	1.29
6200	6628	3.48	8657	2.95	10957	2.56	13527	2.25	16367	2.01	19478	1.81	30434	1.38
6400	6842	3.70	8936	3.14	11310	2.72	13963	2.40	16895	2.14	20106	1.92	31416	1.47
6600	7055	3.93	9216	3.34	11664	2.89	14399	2.55	17423	2.27	20735	2.04	32397	1.56
6800	7269	4.16	9495	3.54	12017	3.07	14836	2.70	17951	2.40	21363	2.16	33379	1.65
7000	7483	4.41	9774	3.75	12370	3.25	15272	2.86	18479	2.55	21991	2.29	34361	1.75

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Area and Circumference of Circles

DIA. (IN.)	AREA IN^2	AREA FT^2	CIRCUMFERENCE IN	CIRCUMFERENCE FT
1	0.785	0.005	3.14	0.262
2	3.14	0.022	6.28	0.523
3	7.07	0.049	9.42	0.785
4	12.57	0.087	12.57	1.054
5	19.63	0.136	15.71	1.31
6	28.27	0.196	18.85	1.57
7	38.48	0.267	21.99	1.83
8	50.27	0.349	25.13	2.09
9	63.62	0.441	28.27	2.36
10	78.54	0.545	31.42	2.62
11	95.03	0.659	34.56	2.88
12	113.00	0.785	37.70	3.14
13	133.00	0.921	40.84	3.40
14	154.00	1.07	43.98	3.66
15	177.00	1.23	47.12	3.93
16	201.00	1.40	50.27	4.19
17	227.00	1.57	53.41	4.45
18	254.00	1.77	56.55	4.71
19	284.00	1.97	59.69	4.97
20	314.00	2.18	62.83	5.23
21	346.00	2.40	65.97	5.50
22	380.00	2.64	69.12	5.76
23	415.00	2.88	72.26	6.02
24	452.00	3.14	75.40	6.28
25	491.00	3.41	78.54	6.54
26	531.00	3.68	81.68	6.80
27	573.00	3.97	84.82	7.07
28	616.00	4.27	87.96	7.33
29	661.00	4.58	91.11	7.59
30	707.00	4.90	94.25	7.85
31	755.00	5.24	97.39	8.11
32	804.00	5.58	100.53	8.37
33	855.00	5.93	103.67	8.64
34	908.00	6.30	106.81	8.90

DIA. (IN.)	AREA IN^2	AREA FT^2	CIRCUMFERENCE IN	CIRCUMFERENCE FT
35	962	6.68	109.96	9.16
36	1018	7.06	113.10	9.42
37	1075	7.46	116.24	9.68
38	1134	7.87	119.38	9.94
39	1195	8.29	122.52	10.21
40	1257	8.72	125.66	10.47
41	1320	9.16	128.81	10.73
42	1385	9.61	131.95	10.99
43	1452	10.08	135.09	11.25
44	1521	10.55	138.23	11.51
45	1590	11.04	141.37	11.78
46	1662	11.53	144.51	12.04
47	1735	12.04	147.65	12.30
48	1810	12.56	150.80	12.56
49	1886	13.08	153.94	12.82
50	1963	13.62	157.08	13.08
51	2043	14.17	160.22	13.35
52	2124	14.74	163.36	13.61
53	2206	15.31	166.50	13.87
54	2290	15.89	169.65	14.13
55	2376	16.49	172.79	14.39
56	2463	17.09	175.93	14.65
57	2552	17.71	179.07	14.92
58	2642	18.33	182.21	15.18
59	2734	18.97	185.35	15.44
60	2827	19.62	188.50	15.70
61	2922	20.28	191.64	15.96
62	3019	20.95	194.78	16.23
63	3117	21.63	197.92	16.49
64	3217	22.32	201.06	16.75
65	3318	23.03	204.20	17.01
66	3421	23.74	207.35	17.27
67	3526	24.46	210.49	17.53
68	3632	25.20	213.63	17.80

DIA. (IN.)	AREA IN^2	AREA FT^2	CIRCUMFERENCE IN	CIRCUMFERENCE FT
69	3739	25.95	216.77	18.06
70	3848	26.70	219.91	18.32
71	3959	27.47	223.05	18.58
72	4072	28.25	226.19	18.84
73	4185	29.04	229.34	19.10
74	4301	29.84	232.48	19.37
75	4418	30.66	235.62	19.63
76	4536	31.48	238.76	19.89
77	4657	32.31	241.90	20.15
78	4778	33.16	245.04	20.41
79	4902	34.01	248.19	20.67
80	5027	34.88	251.33	20.94
81	5153	35.76	254.47	21.20
82	5281	36.64	257.61	21.46
83	5411	37.54	260.75	21.72
84	5542	38.45	263.89	21.98
85	5675	39.37	267.04	22.24
86	5809	40.31	270.18	22.51
87	5945	41.25	273.32	22.77
88	6082	42.20	276.46	23.03
89	6221	43.17	279.60	23.29
90	6362	44.14	282.74	23.55
91	6504	45.13	285.88	23.81
92	6648	46.13	289.03	24.08
93	6793	47.14	292.17	24.34
94	6940	48.15	295.31	24.60
95	7088	49.18	298.45	24.86
96	7238	50.23	301.59	25.12
97	7390	51.28	304.73	25.38
98	7543	52.34	307.88	25.65
99	7698	53.41	311.02	25.91
100	7854	54.50	314.16	26.17

Equations: Area = πr^2 (r = radius of circle)
Circumference = $2\pi r$ or πd (r = radius of circle; d = diameter of circle)

Gauges & Equivalent Metal Thickness

Steel Sheet Gauges & Weights

GAUGE				
1"	1	25.4000	41.829	204.379
3/4"	3/4	19.0500	31.372	153.280
5/8"	5/8	15.8750	26.143	127.73
1/2"	1/2	12.7000	20.915	102.187
3/8"	3/8	9.5250	15.686	76.640
5/16"	5/16	7.9375	13.072	63.867
1/4"	1/4	6.3500	10.457	51.093
3/16"	3/16	4.7625	7.843	38.320
7	.1793	4.5542	7.500	36.644
8	.1644	4.1758	6.875	33.591
9	.1495	3.7973	6.250	30.537
10	.1345	3.4163	5.625	27.483
11	.1196	3.0378	5.000	24.429
12	.1046	2.6568	4.375	21.376
13	.0897	2.2784	3.750	18.322
14	.0747	1.8974	3.125	15.268
15	.0673	1.7094	2.813	13.744
16	.0598	1.5189	2.500	12.215
17	.0538	1.3665	2.250	10.993
18	.0478	1.2141	2.000	9.772
19	.0418	1.0617	1.750	8.550
20	.0359	0.9119	1.500	7.329
21	.0329	0.8357	1.375	6.718
22	.0299	0.7595	1.250	6.107
23	.0269	0.6833	1.125	5.497
24	.0239	0.6071	1.000	4.886
25	.0209	0.5309	0.875	4.275
26	.0179	0.4547	0.750	3.664
27	.0164	0.4166	0.688	3.361

Fractions to Equivalent Decimal values

FRACTION	DECIMAL	FRACTION	DECIMAL	FRACTION	DECIMAL
1/64	.016	23/64	.359	45/64	.703
1/32	.031	3/8	.375	23/32	.719
3/64	.047	25/64	.391	47/64	.734
1/16	.063	13/32	.406	3/4	.750
5/64	.078	27/64	.422	49/64	.766
3/32	.094	7/16	.438	25/32	.781
7/64	.109	29/64	.453	51/64	.797
1/8	.125	15/32	.469	13/16	.813
9/64	.141	31/64	.484	53/64	.828
5/32	.156	1/2	.500	27/32	.844
11/64	.172	33/64	.516	55/64	.859
3/16	.188	17/32	.531	7/8	.875
13/64	.203	35/64	.547	57/64	.861
7/32	.219	9/16	.563	29/32	.906
15/64	.234	37/64	.578	59/64	.922
1/4	.250	19/32	.594	15/16	.938
17/64	.266	39/64	.609	61/64	.953
9/32	.281	5/8	.625	31/32	.969
19/64	.397	41/64	.641	63/64	.984
5/16	.313	21/32	.656	1	1.00
21/64	.328	43/64	.672		
11/32	.344	11/16	.688		

Temperature Conversions

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
–40	–40.0	–2	28.4	36	96.8	74	165.2	160	320	350	662
–39	–38.2	–1	30.2	37	98.6	75	167.0	165	329	355	671
–38	–36.4	0	32.0	38	100.4	76	168.8	170	338	360	680
–37	–34.6	1	33.8	39	102.2	77	170.6	175	347	365	689
–36	–32.8	2	35.6	40	104.0	78	172.4	180	356	370	698
–35	–31.0	3	37.4	41	105.8	79	174.2	185	365	375	707
–34	–29.2	4	39.2	42	107.6	80	176.0	190	374	380	716
–33	–27.4	5	41.0	43	109.4	81	177.8	195	383	385	725
–32	–25.6	6	42.8	44	111.2	82	179.6	200	392	390	734
–31	–23.8	7	44.6	45	113.0	83	181.4	205	401	395	743
–30	–22.0	8	46.4	46	114.8	84	183.2	210	410	400	752
–29	–20.2	9	48.2	47	116.6	85	185.0	215	419	410	770
–28	–18.4	10	50.0	48	118.4	86	186.8	220	428	420	788
–27	–16.6	11	51.8	49	120.2	87	188.6	225	437	430	806
–26	–14.8	12	53.6	50	122.0	88	190.4	230	446	440	824
–25	–13.0	13	55.4	51	123.8	89	192.2	235	455	450	842
–24	–11.2	14	57.2	52	125.6	90	194.0	240	464	460	860
–23	–9.4	15	59.0	53	127.4	91	195.8	245	473	470	878
–22	–7.6	16	60.8	54	129.2	92	197.6	250	482	480	896
–21	–5.8	17	62.6	55	131.0	93	199.4	255	491	490	914
–20	–4.0	18	64.4	56	132.8	94	201.2	260	500	500	932
–19	–72.2	19	66.2	57	134.6	95	203.0	265	509	510	950
–18	–0.4	20	68.0	58	136.4	96	204.8	270	518	520	968
–17	1.4	21	69.8	59	138.2	97	206.6	275	527	530	986
–16	3.2	22	71.6	60	140.0	98	208.4	280	536	540	1004
–15	5.0	23	73.4	61	141.8	99	210.2	285	545	550	1022
–14	6.8	24	75.2	62	143.6	100	212.0	290	554	560	1040
–13	8.6	25	77.0	63	145.4	105	221.0	295	563	570	1058
–12	10.4	26	78.8	64	147.2	110	230.0	300	572	580	1076
–11	12.2	27	80.6	65	149.0	115	239.0	305	581	590	1094
–10	14.4	28	82.4	66	150.8	120	248.0	310	590	600	1112
–9	15.8	29	84.2	67	152.6	125	257.0	315	599	650	1202
–8	17.6	30	86.0	68	154.4	130	266.0	320	608	700	1292
–7	19.4	31	87.8	69	156.2	135	275.0	325	617	750	1382
–6	21.2	32	89.6	70	158.0	140	284.0	330	626	800	1472
–5	23.0	33	91.4	71	159.8	145	293.0	335	635		
–4	24.8	34	93.2	72	161.6	150	302.0	340	644		
–3	26.6	35	95.0	73	163.4	155	311.0	345	653		