H-9102 - Metric Handbook

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Acknowledgements

Chapter 1

A. Introduction. This Handbook introduces the basics of the metric system, including conversion factors from the Inch-Pound System to the System International (SI) Metric System.

1. The Bureau is committed to doing engineering design in the metric system, thereby meeting the requirements of the Metric Conversion Act and Executive Order 12770.

2. Bids to date have not shown detectable premiums for metric. No additional funds are being allocated for metric construction.

B. Metric Products. Some "hard" metric products have minimum order quantities that may limit them to a project involving renovation of an entire floor or more of a building. Most products, however, are identical to the English-dimensioned products and can be used on any project.

Most modular products are undergoing "hard conversion" -- their dimensions will change to new rounded metric numbers. Suspended ceiling grids will convert to 600 x 600 mm or 600 x 1200 mm. Drywall, plywood, and rigid insulation will change to 1200 mm widths, but their thicknesses will remain the same to eliminate the need for recalculating fire and acoustic rates and U-values. Raised access flooring will go to 600 x 600 mm. Brick will become 90 x 57 x 190 mm and block will become 190 x 190 x 390 mm; both will use 10-mm mortar joints and be laid in 600-mm modules. Before specifying hard metric products be sure they are available from the suppliers in the area where the project is located.

What happens to the traditional 2-by-4 wood stud? Two-by-four inches is a nominal size, not a finished size. Neither wood studs nor other framing lumber will change in cross-section, but they will be spaced at 400 mm instead of 16 inches -- about 1/4 inch closer together. Batt insulation installed between studs might not change in width; instead, there will be more of a "friction fit."

There are other products in the same category. A 2-inch pipe has neither an inside nor an outside diameter of 2 inches. A 24-inch I-beam contains no actual 24-inch dimension. These products won't change sizes either; they'll just be relabeled. Perhaps they will eventually get new nominal names, such as 50-mm pipe or 600-mm beams. However, with or without names, the metrication process won't be affected.

C. Metric Facts.

1. Length. The meter has been defined as the wavelength of a specified radiation equal to 3.2808398 ft. For conversion, one foot equals 0.3048 meters or 304.8 millimeters.

For shorter lengths, the meter is divided into 1000 parts or millimeters (mm); 25.4 mm = 1 inch.

2. Tertiary Powers of 10. Use tertiary powers of 10 (.001, 1, 1000 for units of measure, i.e., millimeters, meters, and kilometers. In most cases, intermediate powers (.01, .1, 100) should not be used in construction, i.e., centimeters, decimeters, and hectometers.

2. Power. In the inch-pound system, power is expressed in many different ways -- Btu per hour, horsepower, foot/pound force per second, etc. This multitude of terms results in the need for much converting. In the metric system, power consumption, as well as the power output of an electric motor, is expressed in watts, making the efficiency of the motor easily calculated.

For conversion purposes, there are 746 watts in one horsepower.

Problem: A gasoline engine is rated at 100 hp. What is its power output expressed in metric units?

Solution: 100 hp. x (746/hp)W x k/1000 = 74.6 kW

3. Pressure and Stress. In the inch-pound system, pressure and stress are expressed in many ways, including pounds per square inch (psi), inches of mercury, and inches of water. In the metric system, the unit for pressure and stress is the *pascal*. One pascal is defined as the force of one newton exerted over an area of one square meter. In symbolic language, this is shown as Pa = N/m2.

One psi equals 6894 pascals. Since the pascal is such a small unit, pressure and stress are often given in kilopascals (kPa) or megapascals (MPa),

Problem: The operating pressure in a boiler is 125 psi. Express this in pascals with a convenient prefix.

Solution: 125 lb/in2 x 6894 Pa/lb/in2 x k/1000 = 892 kPa

D. Applying the Metric System.

1. Becoming Familiar with the Size of Metric Units. When you hear the terms inch, foot, yard, mile, ounce, pound, pint, quart, and gallon, you have good idea of their size. That's because we use these terms almost every day.

Although we often hear metric terms such as millimeter, centimeter, meter, kilometer, gram, kilogram, and liter, we feel much less comfortable with them because we don't have a good picture of their size. In this section our goal is to provide visual reminders and *ball park* sizes for these metric units.

A few basic comparisons are worth remembering to help visualize or at least roughly convert between U.S. and metric:

a. One inch is just a fraction (1/64 inch) longer than 25 mm (1 inch = 25.4 mm; 25 mm = 63/64 inch).

b. Four inches are about 1/16 inch longer than 100 mm (4 inches = 101.6 mm; 100 mm = 3-15/16 inches).

c. One foot is about 3/16 inch longer than 300 mm

(12 inches = 304.8 mm; 300 mm = 11-13/16 inches).

d. Four feet are about 3/4 inch longer than 1200 mm

(4 feet = 1219.2 mm; 1200 mm = 3 feet, 11-1/4 inches).

e. Therefore, the metric equivalent of a 4 by 8 sheet of plywood or drywall would be 1200 x 2400 mm.

f. Rounding down from multiples of 4 inches to multiples of 100 mm makes dimensions exactly 1.6 percent smaller and areas about 3.2 percent smaller.

g. One meter equals about 39-1/2 inches, just under 3-1/2 inches longer than a yard.

2. Units of Length. The stem unit of length is the meter. A meter is a little longer than a yard, about a yard plus the length of a piece of chalk.

Illustration 1 - **Meter** (a little longer than a yard).

A millimeter, which is one-thousandth of a meter, is about the thickness of a dime.

Illustration 2 - **Millimeter** (about the thickness of a dime).

A kilometer, which is 1000 meters, is about 5/8ths of a mile. If a mile is about 10 city blocks, then a kilometer is about 6 blocks. A mile is 4 times around a typical nonmetric track. A kilometer is about 2.5 times around the track.

Illustration 3 - **Kilometer** (about 5/8 of a mile).

3. Units of Weight. The stem unit of weight is the gram. A gram is quite small. A package of *Sweet 'n Low*TM has a weight of one gram. A paper clip also has a weight of about one gram.

Illustration 4 - **Gram** (contents of a package of artificial sweetener).

A milligram, which is one-thousandth of a gram, is much smaller. Imagine dividing up the contents of a package of artificial sweetener into 1000 equal parts. One of those parts is a milligram.

A kilogram, which is 1000 grams, is a little over 2 pounds (2.2 pounds) - about the weight of a good-sized orange.

4. Units of Volume. The base unit for volume is the liter. A liter is somewhat larger than a quart. A quart is 32 fluid ounces, while a liter is 33.8 fluid ounces, or about a quart and a quarter of a cup.

Illustration 5 - **Liter** (about a quart and a quarter of a cup).

A milliliter, which is one-thousandth of a liter, is quite small. It takes about 5 milliliters to make one teaspoon.

E. Basic Metric.

1. Base Units. In the metric system, all quantities are derived using decimal units derived from the following base units of measurement, six of which are used in design and construction.

TABLE 1 BASIC UNITS

Quantity/Measurement	S.I. Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
luminous intensity	candela	cd

Celsius temperature (oC) is more commonly used than kelvin (K), but both have the same temperature gradients. Celsius temperature is simply 273.15 degrees warmer than kelvin, which begins at absolute zero.

2. Decimal Prefixes. Although prefixes mega (M) for one million (106), giga (G), for one billion (109), micro () for one millionth (10-6), and nano (n) for one billionth (10-9) are used in some engineering calculations, the two most commonly used specialized prefixes are below:

TABLE 2 DECIMAL PREFIXES

Prefix	Symbol	Order of Magnitude	Expression
kilo	k	103	1000 (one thousand)
milli	m	10-3	0.001 (one thousandth)

3. Plane and Solid Angles. The radian (rad) and steradian (sr) denote plane and solid angles. They are used in lighting work and in various engineering calculations. In surveying, the units degree (), minute ('), and second ('') continue in use.

4. Derived Units. Other derived units used in engineering calculations are shown below:

TABLE 3 DERIVED UNITS

Quantity	Name	Symbol	Expression
frequency	hertz	Hz	Hz=1/s
force	newton	N	N=kgm/s2
pressure, stress	pascal	Pa	Pa=N/m2
energy, work, quantity of heat	joule	J	J=Nm
power, radiant flux	watt	W	W=J/s
electric charge, quantity	coulomb	C	C=As
electric potential	volt	V	V=W/A or J/C
capacitance	farad	F	F=C/V
electric resistance	ohm		=V/A
electric conductance	siemens	S	S=A/V or 1/
magnetic flux	weber	Wb	Wb=Vs
magnetic flux density	tesla	T	T=Wb/m2
inductance	henry	H	H=Wb/A
luminous flux	lumen	lm	lm=cdsr
illuminance	lux	lx	lx=lm/m2

5. Liter, Hectare, and Metric Ton. The liter (L) measures liquid volume. The hectare (ha) measures surface area. The metric ton (t) is used to denote mass.

F. Metric Rules.

1. Rules For Writing Metric Symbols and Names.

a. Print unit symbols in lower case except for liter (L) or unless the unit name is derived from a proper name.

b. Print unit names in lower case, even those derived from a proper name.

c. Leave a space between a numeral and a symbol (write

45 kg or 37 oC, not 45kg or 37oC or 37o C).

d. Do not leave a space between a unit symbol and its decimal prefix (write kg, not k g).

e. Do not use the plural of unit symbols (write 45 kg, not 45 kgs), but do use the plural of written unit names (several kilograms).

f. Do not mix names and symbols (write Nm or newton meter, not Nmeter or newtonm).

g. Do not use a period after a symbol (write "12 g", not "12 g.") except when it occurs at the end of a sentence.

2. Rules For Writing Numbers.

a. Use a zero before the decimal marker for values less than one (write 0.45 g, not .45 g).

b. Use spaces instead of commas to separate blocks of three digits for any number over four digits (write 45 138 kg or 0.004 46 kg or 4371 kg).

3. Rules for Conversion and Rounding.

a. To convert numbers from inch-pound to metric, round the metric value to the same number of digits as there were in the inch-pound (11 miles at 1.609 km/mi equals 17.699 km, which rounds to 18 km).

b. To avoid mistakes, convert mixed inch-pound units (feet and inches, pounds and ounces) to the smaller inch-pound unit before converting to metric and rounding (10 feet, 3 inches = 123 inches; 123 inches x 25.4 mm = 3124.2 mm; round to 3120 mm).

c. In a "soft conversion", an inch-pound measurement is mathematically converted to its exact (or nearly exact) metric equivalent. With hard conversion, a new rounded, rationalized metric number is created that is convenient to work with and remember. A hard conversion is also an item or component that is made to metric size by a manufacturer.

4. Rules For Linear Measurement (Length).

a. Use only the meter and millimeter in building design and construction.

b. Use the kilometer for long distances and the micrometer for precision measurements.

c. Do not use the centimeter.

d. For survey measurement, use the meter and the kilometer.

5. Rules For Area.

a. The square meter is most commonly used.

b. Large areas may be expressed in square kilometers and small areas in square millimeters.

c. The hectare (10 000 square meters) is used for land and water measurement only.

d. Do not use the square centimeter.

e. Linear dimensions such as 40 x 90 mm may be used; if so, indicate width first and length second.

6. Rules For Volume and Fluid Capacity.

a. The cubic meter is most commonly used for volumes in construction and for storage tanks.

b. Use the liter (L) and millimeter (mL) for fluid capacity (liquid volume). One liter is 1/1000 of a cubic meter or 1000 cubic centimeters.

G. Conversion Factors for Length, Area, and Volume. See

Table 4 for guidance when converting from Inch-Pound Units to Metric Units. Appendix 2 contains complete tables of conversion factors.

TABLE 4

LENGTH, AREA, and VOLUME CONVERSION FACTORS

QUANTITY	FROM INCH-POUND UNITS	TO METRIC UNITS	MULTIPLY BY:
Length	mile	km	1.609 344
	yard	m	0.914 4
	foot	m	0.304 8
	foot	mm	304.8
	inch	mm	25.4
Area	square mile	km2	2.590 99
	acre	m2	4046.856
	acre	ha (10 000 m2)	0.404 685 6
	square yard	m2	0.836 127 36
	square foot	m2	0.092 903 04
	square inch	mm2	645.16
	acre foot	m3	1233.49
	cubic yard	m3	0.764 555
	cubic foot	m3	0.028 316 8

	cubic foot	cm3	28 316.85
	cubic foot	L (1000 cm3)	28.316 85
Volume	100 bd feet	m3	0.235 974
	gallon	L (1000 cm3)	3.785 41
	cubic inch	mm3	16 387.064

NOTE: Underline denotes exact number.

H. Estimating Basics.

1. Construction Time/Costs. Metric design and construction take the same number of months as English projects. No adjustments have been made to time expectations.

2. Cost. These estimates shall be done in metric units only.

3. Design Costs. There will be no change to the standard design fee charts used to calculate design costs, given that: a. specifications are metric,

b. metric estimating tools are offered,

c. criteria are metric,

d. most codes and standards are in metric, and

e. sample drawings exist for most items.

4. Estimating Tools. The R.S. Means Company, Inc. offers metric estimating handbooks. There are several construction metric databases available from private firms.

I. Preferred Metric Dimensions in Building Construction.

1. In design and construction, most measurement statements involve linear measurement. Frequently, such measurement statements are not independent; they are part of a set or sequence of values. A common set of preferred dimensions is used to establish the geometry of a building as well as the sizes of constituent components or assemblies. To select the most appropriate metric values during conversion of linear dimensions, it is helpful to appreciate the concept of dimensional coordination, which involves special dimensional preferences for buildings and building products. Because all preferred dimensions are related to a building module, the term modular coordination is sometimes substituted. In building construction, the fundamental unit of size is the basic module of 100 mm. It is slightly shorter than the 4" (101.6 mm) module that has been used in the United States, and should not be equated with this customary module because metric modular product dimensions will be 1.6% shorter.

2. The basic module of 100 mm has already been endorsed as the basic unit of size in metric dimensional coordination in the United States. Preferred dimensions of buildings and preferred sizes of building components should be whole multiples of 100 mm, wherever practicable.

3. Building products vary from small components placed by hand that range in size up to about 1000 mm, to larger elements placed by mechanical means that may range up to 12 000 mm.

Building dimensions vary from small thicknesses of structural elements and dimensions of small spaces to very large spaces with dimensions of 60 000 mm or more in special structures. To ensure efficient use of materials, preferred dimensions play an important part in design, production, and construction.

4. It is important to appreciate that preferred dimensions in the context of metric dimensional coordination are reference dimensions or ideal dimensions rather than actual dimensions. Allowances for joints, tolerances, and deviations are taken into account in the determination of actual dimensions. For example, when a component is described by a preferred size of 400 mm, this dimension includes an allowance for half a joint width on either side of the component, and the actual dimension is less to ensure fit in a coordinating space. If the design joint thickness is 10 mm, the dimension for use as a manufacturing target dimension will be 390 mm.

5. The construction process involves joining many individual and often repetitive components, assemblies, or elements into an organized whole. Therefore, building dimensions that are highly divisible multiples of the basic module are superior to prime number multiples.

J. Construction Trades. The metric units used in the construction trades are charted below. The term "length" includes all linear measurements (that is, length, width, height, thickness, diameter, and circumference).

TABLE 5

CONSTRUCTION UNITS and TERMINOLOGY

TRADE	QUANTITY	UNIT	SYMBOL
Carpentry	length	meter, millimeter	m, mm
	length	meter, millimeter	m, mm
	area	square meter	m2
	volume	cubic meter	m3
Concrete	temperature	degree Celsius	oC
	water capacity	liter (1000 cm3)	L
	mass (weight)	gram, kilogram	g, kg
	cross-sec. area	square millimeter	mm2
	length	meter, millimeter	m, mm
	area	square meter	m2
Drainage	volume	cubic meter	m3
	slope	millimeter/meter	mm/m
	length	meter, millimeter	m, mm
	frequency	hertz	Hz
	power	watt, kilowatt	W, kW
Electrical	elec. current	ampere	A
	elec. potential	volt, kilovolt	V, kV
	resistance	ohm	
	energy	kilojoule, megajoule	kJ, MJ

Excavating	length	meter, millimeter	m, mm
	volume	cubic meter	m3
Glazing	length	meter, millimeter	m, mm
	area	square meter	m2
HVAC	length	meter, millimeter	m, mm
	force	newton, kilonewton	N, kN
	volume	cubic meter	m3
	temperature	degree Celsius	oC
	capacity	liter (1000 cm3)	L
	velocity	meter/second	m/s
	rate of heat flow	watt, kilowatt	W, kW
	energy, work	kilojoule, megajoule	kJ, MJ
Masonry	length	meter, millimeter	m, mm
	area	square meter	m2
	mortar volume	cubic meter	m3
Painting	length	meter, millimeter	m, mm
	area	square meter	m2
	capacity	liter, milliliter(cm3)	L, mL
Paving	length	meter, millimeter	m, mm
	area	square meter	m2
Plastering	length	meter, millimeter	m, mm
	area	square meter	m2
	water capacity	liter (1000 cm3)	L
Plumbing	length	meter, millimeter	m, mm
	mass	gram, kilogram	g, kg
	capacity	liter (1000 cm3)	L
	pressure	kilopascal	kPa
Roofing	length	meter, millimeter	m, mm
	area	square meter	m2
	slope	millimeter/meter	mm/m
Steel	length	meter, millimeter	m, mm
	mass	gram, kilogram	m2

		metric ton (1000 kg)	t
	length	meter, kilometer	m, km
		square meter	m2
	area	square kilometer	km2
Surveying		hectare (10,000 m2)	ha
		degree (non-metric)	o
	plane angle	minute (non-metric)	'
		second (non-metric)	"
	distance	kilometer	km
Trucking	volume	cubic meter	m3
	mass	metric ton (1000 kg)	t

K. Drawing and Specifications Guidance.

1. Drawing Scales.

a. Metric drawing scales are expressed in nondimensional ratios.

b. Nine scales are preferred; 1:1 (full size), 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 1:500, and 1:1000. Three others have limited usage: 1:2, 1:25, and 1:250.

TABLE 6

COMPARISON BETWEEN INCH-FOOT and METRIC SCALES

Inch-Foot Scales	Ratios	Metric Scales		Remarks
		Preferred	Other	
Full Size	1:1	1:1		No Change
Half Size	1:2		1:2	No Change
4" = 1'-0"	1:3	1:5		Close to 3" scale
3" = 1'-0"	1:4			
2" = 1'-0"	1:6	1:10		Between 1" and 1-1/2" scales
1-1/2" = 1'-0"	1:8			
1" = 1'-0"	1:12			
3/4" = 1'-0"	1:16	1:20	1:25	Between 1/2" and 3/4" scales
1/2" = 1'-0"	1:24			Close to 1/2" scale
3/8" = 1'-0"	1:32			

1/4" = 1'-0"	1:48			
1" = 5'-0"	1:60	1:50		Close to 1/4" scale
3/16" = 1'-0"	1:64			
1/8" = 1'-0"	1:96			
1" = 10'-0"	1:120	1:100		Close to 1/8" scale
3/32" = 1'-0"	1:128			
1/16" = 1'-0"	1:192	1:200		Close to 1/16" scale
1" = 20'-0"	1:240		1:250	Close to 1" = 20'-0" scale
1" = 30'-0"	1:360			
1/32" = 1'-0"	1:384	1:500		Close to 1" = 40'-0"
1" = 40'-0"	1:480			
1" = 50'-0"	1:600			
1" = 60'-0"	1:720	1:1000		Close to 1" = 80'-0"
1" = 1 chain	1:792			
1" = 80'-0"	1:960			

2. Metric Units Used on Drawings.

a. Use only one unit of measure on a drawing. Except for large-scale site or cartographic drawings, the unit should be the millimeter (mm). Centimeters shall not be used. On large scale site or cartographic drawings, the unit should be the meter.

b. Metric drawings use millimeters (mm) exclusively. Each drawing should have the following note on it:

"All DIMENSIONS ARE MILLIMETERS (mm) UNLESS OTHERWISE NOTED."

c. Metric drawings should almost never show decimal millimeters (for example: 2034.5), unless a high precision part or product thickness is being detailed. Use whole millimeters (for example: 2035).

d. Dual dimensions should not be used; for example, 200 mm (7-7/8").

e. A space should separate groups of three digits on drawing dimensions. This allows faster and more accurate dimensional interpretation. For example: A 20-meter dimension would show as 20 000 (twenty thousand millimeters).

3. Drawing Sizes.

a. The ISO "A" series drawing sizes are preferred metric sizes for design drawings. A0 is the base drawing size with an area of one square meter. Smaller sizes are obtained by halving the long dimension of the previous size. All A0 sizes have a height-to-width ratio of one to the square root of 2 (1:1.414).

b. There are five "A" series sizes:

(1) A0 1189 x 841 mm (46.8 x 33.1 inches)

(2) A1 841 x 594 mm (33.1 x 23.4 inches)

(3) A2 594 x 420 mm (23.4 x 16.5 inches)

(4) A3 420 x 297 mm (16.5 x 11.7 inches)

(5) A4 297 x 210 mm (11.7 x 8.3 inches)

4. Codes and Standards. Codes and standards needed for design are available today in metric. Codes and standards have not hindered renovation or new construction designs in metric to date. For codes or standards not in metric, rounding techniques have proven sufficient.

5. Submittals. To assist manufacturers with metric conversion, the following submittal classes should be utilized. These classes should be supplemented for each project.

a. Class 1. Drawings That Must Be Metric Only. English units are not permitted on these submittals. Drawings must use metric scales. In general, any drawing that is job specific, and is custom generated for this project, must be in metric only. Here are some samples:

Floor Plans

Reflected Ceiling Drawings

Stairwell Erection Drawings

Foundation Wall Drawings

Concrete/Rebar Installation Drawings

Sitework Drawings

Sheeting and Shoring Plans

Steel Erection/Fabrication Drawings and Details

Precast Manhole Drawings

Door Schedules

Wall Paneling Drawings

Caisson Details

Millwork Drawings

Cabinet Work Details

Toilet Room Details

Ductwork Drawings

Pipe Installation Drawings

HVAC Schedules

Switchgear Drawings

Electrical Component Layout Drawings

Signage Drawings

b. Class 2. Data That Must Be Metric Only. The following types of items must be submitted in metric only. Data generated specifically for these projects must also be submitted in SI only.

Concrete Design Mixes

Concrete Test Data

Core Bore Depths Data

Aggregate Mixes (must show metric sieves)

Mechanical Air and Water Flow or Balancing Data

Environmental or Hazardous Material Data

Most Test Data

Other data generated for the project that is not in bound, preprinted catalogs or publications.

6. Specifications.

a. Millimeters (mm). Metric specifications should use mm for most measurements, even large ones. Use of mm is consistent with dimensions in major codes, such as the National Building Code (Building Officials and Code Administrators International, Inc.) and the National Electric Code (National Fire Protection Association).

Use of mm leads to integers for all building dimensions and nearly all building product dimensions, so use of the decimal point is almost completely eliminated.

b. Meters (m). Meters may be used where large, round metric sizes are involved.

Example: "Contractor will be provided an area of 5 by 20 meters for storage of materials."

c. Centimeters (cm). Centimeters should **never** be used in specifications. Centimeters are not used in major codes. Use of centimeters leads to extensive usage of decimal points. Whole millimeters should be used for specific measurements, unless extreme precision is being indicated. A credit card is about 1 mm thick.

(1) Example 1 - Mortar Joint Thickness. If a 3/8-inch mortar joint between brick is needed, this would convert to 9.525 mm. Whole mm should be used, so specify 10 mm joint thickness.

(2) Example 2 - Stainless Steel Thickness. Bath accessories are commonly made from 22-gauge (0.034-in) thick stainless steel. Exact conversion is 0.8636 mm. This is a precision measurement; an appropriate conversion is 0.86

mm.

(3) Example 3 - Concrete Thickness. Concrete shall be 200 mm thick.

(4) Example 4 - Clearance. Clearance shall be 1500 mm.

In specifications, the unit symbols (e.g., m or mm) are almost always present. Little room exists for confusion. On drawings, using mm eliminates the need to write m or mm and eliminates decimal usage for all but large-scale civil and road design drawings.

A small class of items reference standards using centimeters or square centimeters, such as fire ratings for some products. These items only, which account for less than 2 percent of specification references, should make reference to centimeters or square centimeters.

d. Nominal Technique. Many specification references can effectively use nominal mass, nominal volume, or nominal length technique. For example, if one gallon (3.785 L) of product X is required, the specification could be rewritten using nominal volume, requiring 4 L (0.25 L). Users can then say "4 liters" when referencing this item, while still allowing the current product to be submitted.

e. Professional Rounding. This technique takes the result of simple mathematical rounding and applies professional judgment. First, a small discussion of metric design is necessary. The basic module of metric design is 100 mm. The multimodules and submodules, in preferred order, are 6000, 3000, 1200, 600, 300, 100, 50, 25, 20, and 10.

(1) How to Use Professional Rounding.

(a) Convert the dimension mathematically. Let's say a pavement width in some codes becomes 914 mm minimum.

(b) Select a replacement dimension.

(i) 1000 would be the preferred re-placement.

(ii) 950 would be used only with justification.

(iii) 900 would offend the code and could not be used.

(2) How to Correctly Apply Professional Judgment to Design Criteria.

(a) Example: Conversion of an Existing Code Requirement

(i) Determine the non-offending direction. National Building Code Article 1011.3 requires 44 inches (1118 mm) of unobstructed pedestrian corridor width. However, 1118 mm is not a clean number. It should be rounded to facilitate the cleanest construction possible. Narrower offends the code. The non-offending direction is larger, so it is better to round up.

(ii) Every effort should be made to keep design dimensions in increments of 100 mm, which is the basic module, or in multimodules.

f. Measurements. All measurements in construction specifications should be stated in metric. Until existing specification systems are fully converted, the specifier may:

(1) Specify metric products. Check to see if the products to be specified are available in metric sizes.

(2) Refer to metric or dual unit codes and standards. The American Society of Heating, Refrigerating, and Air-

Conditioning Engineers, Inc. (ASHRAE), American Society of Mechanical Engineers (ASME), and American Concrete Institute (ACI), among others, publish metric editions of some standards. The Building Officials and Code Administrators (BOCA), as well as the American Society for Testing and Materials (ASTM) and the National Fire Protection Association (NFPA), publish their documents with dual units (both metric and inch-pound measurements). In addition, most handicapped accessibility standards and a number of product standards are published with dual units. The metric measurements are virtually exact, soft numerical conversions that, over time, will be changed through the consensus process into rounded hard metric dimensions. For now, use the soft metric equivalents.

(3) Convert existing unit measurements to metric. Follow the conversion rules below.

g. Standards, Criteria, and Product Information. For organizations that publish construction standards, criteria, or product information: Review all active documents and follow the conversion rules below. The standards referenced in e. and f. below may be consulted for additional guidance conversion.

(1) Whenever possible, convert measurements to rounded, hard metric numbers. For instance, if anchor bolts are to be imbedded to a depth of 10 inches, the exact converted length of 254 mm might be rounded to either 250 mm (9.84 inches) or 260 mm (10.24 inches). The less critical the number, the more rounded it can be, but **ensure that allowable tolerances or safety factors are not exceeded**. When in doubt, stick with the exact soft conversion.

(2) Round to "preferred" metric numbers.

(a) The preferred numbers for the "1 foot = 12 inches" system are, in order of preference, those divisible by 12, 6, 4, 3, and 2.

(b) Preferred metric numbers are, in order, those divisible by 10, 5, and 2, or decimal multiples thereof. National Bureau of Standards (NBS) Technical Note 990, *The Selection of Preferred Metric Values for Design and Construction*, explains the concept of preferred numbers in detail and states in its foreword:

It is widely recognized that a transfer to a metric technical environment based upon a soft conversion -- *that is, no change other than the description of the physical quantities and measurements in metric units* -- *would cause considerable longer term problems and disadvantages due to the encumbrance of the resulting awkward numbers. The overall costs of soft conversion could greatly outweigh any savings due to its short term expediency.*

*The Technical Note provides a rational basis for the evaluation and selection of preferred numerical values associated with metric quantities. Precedent has shown that the change to metric units can be accompanied by a change to preferred values at little or no extra cost, especially in specifications, codes, standards, and other technical data.*NBS Technical Note 990; *The Selection of Preferred Metric Values for Design and Construction*

(3) Use hand calculators or software conversion programs that convert inch-pounds to metric. They are readily available and are indispensable to the conversion process. Simply check with any store or catalog source that sells calculators or software.

(4) Be careful with the decimal marker when converting areas and volumes; metric numbers can be significantly larger than inch-pound numbers (a cubic meter, for instance, is one billion cubic millimeters).

(5) Use ASTM E621, *Standard Practice For the Use of Metric (SI) Units in Building Design and Construction*, as a basic reference.

(6) Follow the rules for usage, conversion, and rounding in ASTM E 380, *Standard Practice of Use of the International System of Units (SI)*, Sections 3 and 4; or *American National Standards Institute* (ANSI) 268, *Metric Practice*, Sections 3.5 and 4.

Chapter 2

A. Architectural.

1. Block.

a. Standard sizes are 90, 140, and 190 mm thick, with a 190 x 390 mm face. Normal metric modular block is 190 x 190 x 390 mm. This nearly equates to 7-1/2 x 7-1/2 x 15-3/8 inches. American modular block is 194 x 194 x 397 mm, quite similar to metric block. Stacking nonmortar joint block is usually 203 x 203 x 406 mm. Hard metric block has 12.5 blocks per m2.

b. Metric block has been installed on U.S. projects. Some metric blocks are being supplied using molds borrowed from sources that already owned them, eliminating mold purchase costs.

c. The standard mortar joint for block is 10 mm.

2. Brick.

a. The "metric modular brick" is the most common. Its size is 90 x 57 x 190 mm (3-9/16 x 2-1/4 x 7-1/2 inches). Jumbo brick is 90 x 90 x 190 mm.

b. American modular brick is:

(1) 3-5/8 x 2-1/4 x 7 5/8 inches (92 x 57 x 194 mm) when a 3/8-inch joint is used.

(2) 3-1/2 x 2-3/16 x 7-1/2 inches (89 x 56 x 190 mm) when a 1/2 inch joint is used.

c. Thus the standard American modular brick used with a 1/2-inch joint is so close to the metric modular brick that it can be used with only a slight variation in joint thickness during field installation.

d. Three vertical courses of metric modular brick with 10 mm joints equals 201 mm, which is rounded to 200. Two jumbo courses equals 200. Weepholes are mostly spaced in 100 mm sizes. (e.g., 600 mm). Seventy-five modular metric bricks per m2, 50 metric jumbo bricks per m2.

e. Metric brick has been used on U.S. projects. Standard mortar joint for brick and block is 10 mm. Brick should be specified in metric, regardless of whether ASTM C 216 or ASTM C 62/AASHTO M 114 is used.

3. Carpet.

a. Most firms have the dies and can or do make metric carpet tile. Most common sizes are 500 x 500 mm and 600 x 600 mm.

b. Minimum orders are available (several hundred square meters or less). As the industry goes metric, premiums for minimums will shrink or be eliminated.

4. Ceiling Systems.

a. Many domestic manufacturers regularly make hard metric tiles and grids for use in metric projects. Most common sizes are 600 x 600 mm and 600 x 1200 mm.

b. Many design and construction projects, both renovation and new construction, are using the 600 x 600 mm system.

c. Many facilities with 2 x 2 grids are not adversely affected by use of new 600 x 600 mm grids.

d. With hard metric ceilings, room dimensions can be multiples of 600 mm, giving clean, rounded dimensions to construction personnel for layout.

5. Drywall.

a. Only sheet length and width are classified in hard metric. The standard sheet width is 1200 mm. Lengths available are 2400 mm and several longer sizes.

b. Thicknesses remain the same to minimize code impact. Most architects show these as 13 x 16 mm on drawings, instead of the exact 12.7 and 15.9 mm. Standard stud spacing is 400 mm, as it is the closest to 16 inches and is an even multiple of the sheet size.

6. Doors.

a. A common metric door size is 900 x 2100 mm, although 1000 x 2000 mm is sometimes used. This may be used on metric projects where other project specific design criteria are satisfied.

b. Louvers and glass should be in hard metric dimensions, such as 300 x 300 mm, 450 x 450 mm, etc.

c. Door thicknesses will remain the same, being identified by the nominal mm equivalent. Most architects soft-convert door thickness and are using nominal 45 mm as standard.

d. Most door frame section dimensions are being rounded to the nearest 1 mm (e.g., 13, 25, 41, 50, or 80 mm). Lengths and widths match hard metric door sizes and should be hard metric. (e.g., 900 x 2100 mm)

7. Elevators.

a. Capacities should be specified to the next lowest 50 kg. (e.g., 40,000 lb = 18 144 kg). Signage in the elevator would show 18 100 kg only.

b. Most manufacturers can make hard metric platforms. Specifying 50 mm platform sizes is preferred, but allow standard English platform sizes to be submitted. (For example, 5'7" x 7' platform = 1702 x 2134 mm. Specify as 1700 x 2100 mm, but approve the standard English size) Note: Code and criteria requirements may restrict this approach and must be considered on each project.

c. Speeds should be in meters/second, shown to two digits (e.g., 0.64 m/s, 0.51 m/s).

d. Thus, manufacturers supply standard product, and rounded numbers appear in specifications and drawings as well as to the public.

8. Glass.

a. ASTM C 1036 gives metric sizes for flat glass, heat absorbing glass, and wired glass.

b. Glass shall be specified in mm only.

c. Thicknesses for Type 1, Transparent Flat Glass are 1, 1.5, 2, 2.5, 2.7, 3, 4, 5, 5.5, 6, 8, 10, 12, 16, 19, 22, 25, and 32.

9. Lumber.

a. Two by four-inch is a nominal size. Neither wood studs nor other framing lumber will change in cross-section. A 2 x 4-inch piece can be soft converted to 51 x 102 mm (nominal) or 38 x 89 mm actual. The actual dimensions in millimeters would most commonly be used.

b. Millimeter dimensions are frequently used in exact layout work only, such as layout of cabinetry, but 2 x 6 and

2 x 10 boards will still be used.

10. Plywood.

a. Projects using plywood should specify metric sheets.

b. Thickness is the same to minimize production impacts. The standards are 12.7 and 19.05 mm, commonly given nominal thicknesses on drawings (e.g., 19 mm).

11. Roofing.

a. Use millimeters squared for areas.

b. State membrane thickness in millimeters only.

c. Lap widths should be even millimeters. (e.g., 100 mm, 150 mm, etc.)

12. Sheet Metal.

a. Most specification references use gauge numbers followed by the decimal inch thickness.

Example: 22 gauge (0.034 inch).

b. Metric specifications use millimeter thickness. It is not the intent to change the thickness of currently used sheeting. The thickness under "Specify" is thinner than the actual gauge thickness, since specifications give minimum thickness.

The following chart may be used to specify sheet metal:

Gauge	Inch	Exact mm	Specify (< exact) mm	% Thinner
32	0.0134	0.3404	0.34	0.1
30	0.0157	0.3988	0.39	2.2
28	0.0187	0.4750	0.47	1.1
26	0.0217	0.5512	0.55	0.2
24	0.0276	0.7010	0.70	0.1
22	0.0336	0.8534	0.85	0.4
20	0.0396	1.0058	1.00	0.6
18	0.0516	1.3106	1.30	0.8
16	0.0635	1.6129	1.60	0.8
14	0.0785	1.9939	1.90	4.7

12	0.1084	2.7534	2.70	1.9
10	0.1382	3.5103	3.50	0.3
8	0.1681	4.2697	4.20	1.6

This schedule was developed since no existing material was found to clearly identify existing sheeting in metric units. Until a more efficient method is developed to address this issue, specifiers may wish to retain the gauge number in specifications, coupling this with a rounded mm size.

c. For example: *Provide grab bar with a minimum wall thickness of 18 gauge (0.051 inch)* should be replaced with: *Provide grab bar with minimum wall thickness of 1.3 mm*. Since 18 gauge is thicker than 1.3 mm, 18 gauge is acceptable.

d. Show minimum thickness in millimeters only. Specifying 1 or 0.1 mm thicknesses wherever possible. (e.g., 1 mm, 1.6 mm). Hard metric sheet metal is obtainable, even in smaller quantities.

13. Stone. Stone, such as granite and marble, should be specified in hard metric (e.g., 30 or 50 mm thick, or 100 x 300).

14. Metal Studs. Common metal studs are available in the following nominal mm sizes, which closely align with the dimensions in the standard English sizes: 42, 64, 92, 102, and 153 mm. A 22 mm hat channel for furring is also common. both wood and metal studs are soft converted and will not change in actual cross section.

15. Woodwork. Custom casework, such as cabinets, built-in benches, shelves, security desks, and judges benches, should be developed in hard metric to the fullest degree possible.

a. Cabinets. Many cabinet widths are shown as increments of 50 mm. (e.g., 450, 500 mm wide).

b. Lockers. Dimensions should be furnished in metric sizes.

B. Civil Engineering.

1. Units. The metric units used in civil and structural engineering are:

a. meter (m)

b. kilogram (kg)

c. second (s)

d. newton (N)

e. pascal (Pa)

2. Rules for Civil Engineering.

a. There are separate units for mass and force.

b. The kilogram (kg) is the base unit for mass, which is the unit quantity of matter independent of gravity.

c. The newton (N) is the derived unit for force (mass times acceleration, or kgm/s2). It replaces the unit "kilogram-force" (kgf), which should not be used.

d. The newton meter designates torque, not the joule.

e. The pascal (Pa) measures pressure and stress (Pa=N/m2).

f. Structural calculations should be shown in MPa or kPa (megapascals or kilopascals).

g. Plane angles in surveying (cartography) will continue to be measured in degrees (either decimal degrees or degrees, minutes, and seconds) rather than the metric radian.

h. Percentages should be used primarily for long, standing slopes, while ratios should generally be used for shorter or steeper distances. Since both are basically "dimensionless"--that is, they refer to each other instead of a specific standard of measurement--either could be used as required. Just remember to follow current, standard designating practices regarding each.

When using percentages, follow this rule: **Percent x 10 = mm/m (vertical distance in millimeters per horizontal meter)** For example: 2% x 10 = 20 mm/m, and 45% = 450 mm/m.

i. Road construction must be designed using metric units. For additional guidance, use the AASHTO Guide to Metric Conversion for geometric design values, lane and shoulder widths, curb heights, sight distances, curvatures, and other values.

TABLE 8

CIVIL AND STRUCT ENGINEERING CONVERSION FACTORS

Quantity	From Inch-Pound Units	To Metric Units	Multiply by
Mass	lb	kg	0.453 592
	kip	metric ton	0.453 592
Mass/unit length	plf	kg/m	1.488 16
Mass/unit area	pcf	kg/m2	1.482 43
Mass density	pcf	kg/m3	16.018 5
Force	lb	N	4.448 22
	kip	kN	4.448 22
Force/unit length	plf	N/m	14.593 9
	klf	kN/m	14.593 9
Pressure, stress, modulus of elasticity	psf	Pa	47.880 3
	ksf	kPa	47.880 3
	psi	kPa	6.894 76
	ksi	MPa	6.894 76

Bending moment, torque, moment of force	ft-lb	Nm	1.355 82
	ft-kip	kNm	1.355 82
Moment of mass	lbft	kgm	0.138 255
Moment of inertia	lbft2	kgm2	0.042 140 1
Second moment of area	in4	mm4	416 231
Section modulus	in3	mm3	16 387.064

NOTE: Underline denotes exact number.

kip = 1000 lb

metric ton = 1000 kg

C. Structural Engineering.

1. Units. The metric units used in structural engineering are:

a. meter (m)

b. kilogram (kg)

c. second (s)

d. newton (N)

e. pascal (Pa)

2. Rules for Structural Engineering.

a. There are separate units for mass and force.

b. The kilogram (kg) is the base unit for mass, which is the unit quantity of matter independent of gravity.

c. The newton (N) is the derived unit for force (mass times acceleration, or kgm/s2). It replaces the unit "kilogram-force" (kgf), which should not be used.

d. The newton meter designates torque, not the joule.

e. The pascal (Pa) measures pressure and stress (Pa=N/m2).

f. Structural calculations should be shown in MPa or kPa (megapascals or kilopascals).

g. Design dimensions must be rounded. Bar spacing, wall and slab thickness, and similar dimensions must be even mm

(e.g., 100, 250, or 400 mm), not exact conversions (e.g., 305 mm).

h. Structural steel shall be specified in metric only, such as 250 MPa. Shapes shall be specified according to the millimeter sizes and dimensions in ASTM A 6M.

i. Wind pressures are given in Pa, while wind speeds are most frequently given in m/s.

3. Structural Strategies.

a. Fasteners. Use ASTM A 325M and A 490M metric bolts. There are seven standard metric bolt sizes, which replace the nine bolts currently used. Standard sizes are 16, 20, 22, 24, 27, 30, and 36 mm.

b. Steel.

(1) ASTM A 6/A 6M lists both inch and mm dimensions of the shapes.

(2) Another reference is the International Standards Organization (ISO) standard for steel.

c. Floorload.

(1) Calculations are in kPa, but floorloading can be in kilograms (kg) per square meter because many dead and live loads are given in kg. Use the following rounded, slightly conservative, rule: *kPa x 100 = kg/m2 (e.g., 5 kPa x 100 = 500 kg/m2)*

(2) The chart below gives kPa strength ratings that can be used to replace the psf strength rating.

Previous (psf)	New (kPa)	Percent Stronger
50	2.5	4.4
80	4	1.8
100	5	4.4
120	6	4.4
150	7.5	4.4
200	10	4.4
250	12	0.2
300	15	4.4
350	17	1.4
400	20	4.4
450	22	2.1
500	24	0.2

(3) A typical office rating is 5 kPa, with 4 kPa and

1 kPa components. Drawings and calculations should reflect these numbers only.

(4) In existing facilities, the preferred method is to convert values to exact kPa and then round to the next lowest 0.1 kPa.

D. Surveying and Project Layout.

1. Databases of hundreds of thousands of horizontal and vertical survey control points on which U.S. surveys are based have been completely metric since 1983. USGS, which produces topographic maps of terrain elevations, has digitally mapped the U.S. surface. The ground distance between each pair of digitized points is 30 meters. Thus, survey and mapping data needed to do metric design and construction in the United States is available.

2. The following information can be used as guidance on how site plans and topographic maps are to be executed:

a. Contour intervals utilize either 1000, 500, or 250 mm as contour intervals, depending on site slope.

b. Elevation measurements are given in mm.

c. Benchmark elevations are converted from feet to mm.

3. Examples:

a. Benchmark is 314.15 feet. Convert to 95 753

b. Sample Finished Floor Elevation: 105 025

c. Sample Top of Curb: TC 305 224

d. Sample Bottom of Curb: BC 305 024

e. Sample Contour Lines:

------------------106 000--------------------

------------------105 500--------------------

4. Large mapping scales use metric symbols. 1:2000 is written as 1:2k, 1:5,000,000,, as 1:5M. Contour lines may also be given in meters.

5. Electronic surveying and mapping equipment provides data in metric squared units. Many states utilize electronic data measurement (EDM) equipment, which almost always can work in metric units.

6. Plane angles in surveying (cartography) will continue to be measured in degrees (either decimal degrees or degrees, minutes, and seconds) rather than the metric radian.

7. Percentages should be used primarily for long, standing slopes, while ratios should generally be used for shorter or steeper distances. Since both are basically dimensionless-- that is, they refer to each other instead of a specific standard of measurement--either could be used as required. Just remember to follow current, standard designating practices regarding each. When using percentages, follow this rule: **Percent x 10 = mm/m (vertical distance in millimeters per horizontal meter)** For example: 2% x 10 = 20 m/m, and 45% = 450 mm/m.

E. Materials Guidance (General).

1. Concrete.

a. Concrete strength is specified throughout the country in MPa. The following strengths should be used in metric construction. The general purpose concrete strengths are reduced from 6 strengths to 4 strengths. Strengths above 35 MPa should be specified in 5 MPa intervals (40, 45, 50, 55, etc.).

Previous psi	Exact Conversion MPa	Specify MPa

2 500	17.23	20
3 000	20.67	20 or 25*
3 500	24.12	25
4 000	27.56	30
4 500	31.01	35
5 000	34.45	35

*If code requires 3000 psi, then 25 MPa should be used; otherwise, it is a professional judgment on whether to use 20 or 25. Refer to the PSI versus MPa chart in the Graphic Standards Book.

b. ACI 318M, metric version, should now be used.

c. Slump Limits on metric projects always use 10 or 5 mm increments (e.g., 75, 80, or 90 mm).

2. Concrete Pipe.

a. ACPA 5.0 states that concrete pipe can now be specified using hard metric ASTM and AASHTO standards.

b. Reinforced concrete pipe (RCP) is specified as ASTM

C 76M/AASHTO M 170M.

c. ASTM C76 RCP meets the hard metric standard, since tolerances were set in the hard metric standard to accept current product.

d. For nonreinforced concrete pipe, sizes are as follows:

C 76M sizes (mm)	300	375	450	525	675	750	825	900	1050
	1200	1350	1500	1650	1800	1950	2100	2250	2400
C 14M	100	150	200	250	300	375	450	525	600
sizes	675	750	825	900					

3. Geotechnical. Geotechnical reports shall be metric units only and, equally important, shall be in rounded metric units. Bearing and side friction values shall be in MPa, rounded to 1 or 0.1 MPa increments wherever possible.

4. Reinforcement.

a. Metric projects will use ASTM A 615M reinforcing bars for general purpose applications. The A 615M reinforcing bar comes in Grades 300 and 400, indicating 300 and 400 MPa yield strength.

b.There are 8 bar sizes, which replace the 11 bar sizes currently used, as listed below:

	Diam	Area		Diam	Area

Size	(mm)	(mm2)	Size	(mm)	(mm2)
3	9.52	71	10M	11.3	100
4	12.70	129	15M	16.0	200
5	15.87	200	20M	19.5	300
6	19.05	284	25M	25.2	500
7	22.22	387	30M	29.9	700
8	25.40	510	35M	35.7	1000
9	28.65	645	45M	43.7	1500
10	32.25	819	55M	56.4	2500
11	35.81	1006			
14	43.00	1452			
18	57.32	2581			

c. Some applications may need A 616M, A 617M, A 706M, or

A 775M. Note that a nominal 15 mm bar is called a "Number 15 bar."

5. Pipe. Steel pipe and copper tube sizes will not now change, since American sizes are still used in many parts of the world. Designate tube sizes by nominal mm size. Hard metric pipe sizing may be used in the future. ASTM B 88M provides standard hard metric copper tube sizes. During the transition to metric units, the following paragraph and chart should be placed on the mechanical cover sheet:

"ALL SIZES ARE INDUSTRY-STANDARD ASTM A 53 PIPE AND ASME B 88 TUBE DESIGNATED BY THEIR NOMINAL MILLIMETER (mm) DIAMETER EQUIVALENT. SEE CHART BELOW."

Nominal Size	
Inch	mm
1/2	15
3/4	20
1	25
1-1/4	32
1-1/2	40
2	50
2-1/2	65
3	80
3-1/2	90

4	100
5	125
6	150

6. General Fasteners.

a. U.S. industry is now using metric fasteners extensively.

b. The Thomas Register lists hundreds of firms under Metric Fasteners, Metric Screws, and Metric Bolts. The Industrial Fasteners Institute (IFI) has guides for fastener types and producers.

c. Many pieces of mechanical and electrical equipment already use both metric and English fasteners. Metric fasteners use M numbers. (For example, M10 x 40 is a nominal 10 mm diameter and 40 mm length.)

d. Metric socket head cap screws, set screws, hex bolts, and similar items are available.

7. Anchor Bolts. Metric anchor bolts (e.g., L, J and U bolts) are available. ASTM F 568 gives metric chemical and mechanical data for carbon steel anchor bolts and studs, and also references ANSI dimensional standards.

a. ISO Metric Grades. As given in ISO 898 and ASTM F 568, ISO metric grades should be used. Many anchor bolts are made from low carbon steel grades, such as ISO classes 4.6, 4.8, and 5.8.

b. Preferred Diameters. Preferred nominal diameters for items such as anchor bolts and threaded rod are as shown below. Reference individual standards prior to specification. Sizes are given between M5 and M45, as these are commonly used in construction.

1: M5 6 8 10 12 16 20 24 30 36 42

2: M14 18 22 27 33 39 45

3: M45 7 9 11 15 17 25 26 28 32 35 38 40

8. Fastener Data. Tables 9 and 10 provide much of the data available for different metric fasteners.

TABLE 9

FASTENER DATA

Basic Product	Product Type and Head Style	Size Range	For Dimensions Refer to:	For Mechanical and/or Performance Properties Refer To:
	hex	M5-M100	ANSI/ASME B18.2.3.5M	
	heavy hex	M12-M36	ANSI/ASME B18.2.3.6M	
	round head short square neck (carriage)	M8-M20	ANSI/ASME B18.5.2.1M	ASTM F #568
				ASTM F#486M

Metric Bolts	round head square neck (carriage)	M5-M24	ANSI/ASME B18.5.2.2M	ASTM F #738
	bent	M5 and larger	IFI 528	
	heavy hex structural	M12-M36	ANSI/ASME B18.2.3.7M	ASTM A#325M ASTM A#490M
	hex transmission tower	M16-M24	IFI 541	IFI 541
Metric Screws	hex cap	M5-M100	ANSI/ASME B18.2.3.1M	
	formed hex	M5-M24	ANSI/ASME B18.2.3.2M	ASTM F#568
	heavy hex	M12-M36	ANSI/ASME B18.2.3.3M	ASTM F#468M
	hex flange	M5-M16	ANSI/ASME B18.2.3.4M	ASTM F#738
	heavy hex flange	M10-M20	ANSI/ASME B18.2.3.9M	
	hex lag	5-24mm	ANSI/ASME B18.2.3.8M	see note 3
Metric Studs	double end	M5-M100	IFI 528	ASTM F#568 ASTM F#468M ASTM F#736
	continuous thread	M5-M100		
Metric Locking Screws	prevailing torque, non-metallic insert	M1.6-M36	see note 3	IFI 524
	chemical coated	M6-M20	see note 3	IFI 525
Metric Socket Screws	socket head cap	M1.6-M48	ANSI/ASME B 18.3.1M	ASTM A#574M F#837M
	socket head shoulder	6.5-25mm	ANSI/ASME B 18.3.3M	ASTM F#835M
	socket button head cap	M3-M16	ANSI/ASME B18.3.4M	ASTM A#574M
	socket countersunk head cap	M3-M20	ANSI/ASME B18.3.5M	ASTM F#879M
	socket set	1.6-24mm	ANSI/ASME B18.3.6M	ANSI/ASME B.18.3.6M ASTM F#912M

				ASTM F#880M
Metric Nuts	hex, style 1	M1.6-M36	ANSI/ASME B18.2.4.1M	
	hex, style 2	M3-M36	ANSI/ASME B18.2.4.2M	ASTM A#563M
	slotted hex	M5-M36	ANSI/ASME B18.2.4.3M	ASTM F#467M
	hex flange	M5-M20	ANSI/ASME B18.2.4.4M	ASTM F#836M
	hex jam	M5-M36	ANSI/ASME B18.2.4.5M	ASTM A#194M
	heavy hex	M12-M100	ANSI/ASME B18.2.4.6M	
Metric Prevailing-Torque Nuts	hex, steel	M3-M36	ANSI/ASME B18.16.3M	ANSI/ASME B18.16.1M
	hex flange, steel	M6-M20		ANSI/ASME B18.16.2M

a. When only the property class number is shown, the class is standard in both ISO and ASTM documents. Properties specified in each are identical except for minor exceptions. Where differences exist, the F 568 values are given.

b. To compute the proof load, yield strength, or tensile strength in kilonewtons for a bolt, screw, or stud, divide the stress value, MPa as given in Table 10, for the property class by 1000 and multiply this answer by the tensile stress area of the product's screw thread as given in Table 9.

c. In general, identification markings are located on the top of the head and preferably are raised.

d. Class 5.8 products are available in lengths 150 mm and less.

e. Caution is advised when considering the use of Class 12.9 products. The capabilities of the fastener manufacturer, as well as the anticipated service environment, should be carefully considered. Some environments may cause stress corrosion cracking of nonplated as well as electroplated products.

TABLE 10

MECHANICAL REQUIREMENTS FOR CARBON STEEL

EXTERNALLY THREADED FASTENERS -- METRIC SERIES

Property Class Designation	Nominal Size of Product	Material and Treatment	Mechanical Requirements: Proof Load Stress, MPa	Yield Strength, MPa, Min	Tensile Strength, MPa, Min	Prod. Hardness, Rockwell: Surface Max	Core Min	Core Max	Property Class Ident. Marking
4.6	M5-M100	low or medium carbon steel	225	240	400	--	B67	B95	4.6

4.8	M1.6-M16	low or medium carbon steel, fully or partially annealed	310	340	420	--	B71	B95	4.8
5.8	M5-M24	low or medium carbon steel, cold worked	380	420	520	--	B82	B95	5.8
8.8 A325M Type 1	M16-M72 M16-M36	medium carbon steel; the product is quenched and tempered	600	660	830	30N56	C23	C34	8.8 A325M 8S
8.8 A325M Type 2	M16-M36	low carbon boron steel; the product is quenched and tempered	600	660	830	30N56	C23	C34	8.8 A325M 8S
A325M Type 3	M16-M36	atmospheric corrosion resistant steel; the product is quenched and tempered	600	660	830	30N56	C23	C34	A325M 8S3
9.8	M1.6-M16	medium carbon steel; the product is quenched and tempered	650	720	900	30N58	C27	C36	9.8
9.8	M1.6-M16	low carbon boron steel; the product is quenched and tempered	650	720	900	30N58	C27	C36	9.8
10.9	M5-M20	medium carbon boron steel; the product is quenched and tempered	830	940	1040	30N59	C33	C39	10.9
10.9 A490M Type 1	M5-M100 M12-M36	medium carbon alloy steel; the product is quenched and tempered	830	940	1040	30N59	C33	C39	10.9 A490M 10S
10.9	M5-M36	low carbon boron							10.9

A490M Type 2	M12-M36	steel; the product is quenched and tempered	830	940	1040	30N59	C33	C39	A490M 10S
A490M Type 3	M12-M36	atmospheric corrosion resistant steel; the product is quenched and tempered	830	940	1040	30N59	C33	C39	A490M 10S3
12.9	M1.6-M1000	alloy steel; the product is quenched and tempered	970	1100	1220	30N63	C38	C44	12.9

F. Electrical Engineering.

1. Units. The metric units used in electrical engineering and their symbols are shown below:

meter (m)

second (s)

candela (cd)

radian (rad)

steradian(sr)

ampere (A)

coulomb (C)

volt (V)

farad (F)

henry (H)

ohm ()

siemens (S)

watt (W)

hertz (Hz)

weber (Wb)

tesla (T)

lumen (lm)

lux (lx)

TABLE 11

METRIC UNITS USED IN CONSTRUCTION

(ELECTRICAL)

QUANTITY	UNIT	SYMBOL
length	meter, millimeter	m, mm
frequency	hertz	Hz
power	watt, kilowatt	W, kW
energy	megajoule, kilowatt hour	MJ, kWh
electric current	ampere	A
electric potential	volt, kilovolt	V, kV
resistance	ohm	

2. Rules for Electrical Engineering.

a. The only unit change for electrical engineering is the renaming of conductance from "mho" to siemens (S).

b. The lux (lx) is the unit for illuminance and replaces lumen per square foot and footcandle.

c. Luminance is expressed in candela per square meter (cd/m2) and replaces candela per square foot, footlambert, and lambert.

3. Conversion Factors. Table 12 identifies the conversion factors unique to electrical engineering.

TABLE 12

ELECTRICAL ENGINEERING CONVERSION FACTORS

QUANTITY	FROM INCH-POUND UNITS	TO METRIC UNITS	MULTIPLY BY
Power, radiant flux	W	W	1 (same unit)
Radiant intensity	W/sr	W/sr	1 (same unit)
Radiance	W/(srm2)	W/(srm2)	1 (same unit)
Irradiance	W/m2	W/m2	1 (same unit)
Frequency	Hz	Hz	1 (same value)
Electric current	A	A	1 (same unit)
Electric charge	Ahr	C	3600
Electric potential	V	V	1 (same unit)
Capacitance	F	F	1 (same unit)

Inductance	H	H	1 (same unit)
Resistance			1 (same unit)
Conductance	mho	S	100
Magnetic flux	maxwell	Wb	10-8
Mag. flux density	gamma	T	10-9
Luminous intensity	cd	cd	1 (same unit)
	lambert	kcd/m2	3.183 01
Luminance	cd/ft2	cd/m2	10.763 9
	footlambert	cd/m2	3.426 26
Luminous flux	lm	lm	1 (same unit)
Illuminance	foot-candle	lx	10.763 9

NOTE: Underline denotes exact number.

4. Conduit. Conduit will not change size in metric. It will be classified by a nominal mm size. The following paragraph and chart may be placed on the electrical drawing sheet.

"ALL CONDUIT SIZES ARE INDUSTRY-STANDARD ENGLISH-SIZE CONDUIT DESIGNATED BY THEIR ROUNDED NOMINAL MILLIMETER (mm) DIAMETER EQUIVALENT. SEE CHART BELOW."

Nominal Size	
Inch	mm
1/2	15
3/4	20
1	25
1-1/4	32
1-1/2	40
2	50
2-1/2	65
3	80
3-1/2	90
4	100
5	125
6	150

5. Cabling. Metric sizes are available.

a. Projects with medium and larger wire requirements may wish to start using international sizes, where permitted by governing codes and criteria.

b. ASTM B 682 gives metric sizes. Common sizes (in mm2) are, 0.5, 0.75, 1, 1.5, 2.5, 4, 6, 10, 16, 25, 35, 50, 70, 95, 120, 150, 185, 240, and 300.

c. Many projects have begun to refer to existing sizes by millimeter squared dimensions to become familiar with the millimeter squared scale. On the chart below are millimeter squared equivalents with detailed rounding. In some cases, rounding to the nearest 0.1, 1, or more square millimeters may be feasible. Use professional judgment.

AWG	mm2	kcm	mm2
22	0.506	250	126.68
20	0.517	300	152.01
18	0.82	350	177.35
16	1.31	400	202.68
14	2.08	450	228.0
12	3.31	500	253.4
10	5.26	550	278.7
9	6.6	600	304.0
8	8.37	650	329.4
7	10.6	700	354.7
6	13.30	750	380.0
5	16.8	800	405.4
4	21.15	900	456.0
3	26.66	1000	506.7
2	33.63	1100	557.4
1	42.41	1200	608.1
1/0	53.48	1250	633.4
2/0	67.44	1300	658.7
3/0	85.03	1400	709.4
4/0	107.2	1500	760.1
		1600	810.7
		1700	861.4
		1800	912.1
		1900	962.7
		2000	1013.4

6. Fiber Optics. Most cables are made to metric dimensions, so these will be specified in hard metric (e.g., 125 m fiber cable). Illumination levels are in lux (lx).

7. Lighting Fixtures. Use hard metric fixture sizes for lay-in type. Common sizes are 600 x 600 mm and 600 x 1 200 mm. Use the 600 x 600 mm size with sockets on one end wherever possible as it is easier to manufacture in hard metric. Use either a compact tube or a T-8 U-tube for higher efficiency.

G. Mechanical Engineering.

1. Units. The metric units used in mechanical engineering are listed below.

meter (m)

kilogram (kg)

second (s)

joule (J)

watt (W)

kelvin (K) or degree

Celsius (C)

pascal (Pa)

radian (rad)

newton (N)

TABLE 13

METRIC UNITS USED IN CONSTRUCTION

Quantity	Unit	Symbol
length	meter, millimeter	m, mm
volume	cubic meter	m3
capacity	liter (1000 cm3)	L
velocity	meter/second	m/s
volume flow	cubic meter/second	m3/s
	liter/second	L/s
temperature	degree Celsius	C
force	newton, kilonewton	N, kN
pressure	kilopascal	kPa
energy, work	kilojoule, megajoule	kJ, MJ

rate of heat flow	watt, kilowatt	W, kW

2. Rules For Mechanical Engineering.

a. The joule (J) is the unit for energy, work, and quantity of heat. It is equal to a newton meter (Nm) and a watt second (Ws), and it replaces inch-pound units, such as ftlbf.

b. The watt (W) is both the inch-pound and metric unit for power and heat flow. It replaces horsepower, foot pound-force per hour, Btu per hour, calorie per minute, and ton of refrigeration.

c. Moisture movement is expressed by the terms "vapor permeance" and "vapor permeability."

d. The inch-pound unit "perm" continues to represent the degree of retardation of moisture movement. The lower the value, the greater the retardation.

e. The newton (N) is the derived unit for force (mass times acceleration, or (kgm/s2). It replaces the unit "kilogram-force" (kgf), which should not be used.

3. General Guidelines.

a. Temperature. Use Celsius for temperature measurements in new or modernization building projects. Renovation projects where the entire HVAC system is not to be renovated may retain Fahrenheit.

b. Air Distribution. Use a hard metric ceiling grid accompanied by hard metric lay-in diffusers and registers or smaller ones that are cut in.

c. Ductwork. Rectangular metal ductwork is a custom-made product. Hard metric sizes are easier to measure (e.g., 300 x 600 mm). Prefabricated flexible round duct is specified in soft converted sizes.

4. Conversion. Table 14 below provides the conversion factors needed to adjust current plans to metric standards.

TABLE 14

MECHANICAL ENGINEERING CONVERSION FACTORS

Quantity	From Inch-Pound Units	To Metric Units	Multiply By
Mass/area (density)	lb/ft2	kg/m2	4.882 428
Temperature	F	oC	5/9 (F-32)
	kWh	MJ	3.6
Energy, work, quantity of heat	Btu	J	1 055.056
	ftlbf	J	1.355 82
	ton (refrig.)	kW	3.517
Power	Btu/s	kW	1.055 056
	hp (electric)	W	745.700

	Btu/h	W	0.293 071
Heat flux	Btu/(f2h)	W/m2	3.152 481
Rate of heat flow	Btu/s	kW	1.055 056
	Btu/h	W	0.293 071 1
Thermal conductivity (k value)	Btu/(fthF)	W/(mK)	1.730 73
Thermal conductance (U value)	Btu/(ft2hF)	W/(m2K)	5.678 263
Thermal resistance (R value)	(ft2hF)/Btu	(m2K)/W	0.176 110
Heat capacity, entropy	Btu/F	kJ/K	1.899 1
Specific heat capacity, specific entropy	Btu/(lbF)	kJ/(kgK)	4.186 8
Specific energy, latent heat	Btu/lb	kJ/kg	2.326
Vapor permeance	perm (23 C)	ng/(Pasm2)	57.452 5
Vapor permeability	perm/in	ng/(Pasm)	1.459 29
	ft3/s	m3/s	0.025 316 8
Volume rate of flow	cfm	m3/s	0.000 471 947 4
	cfm	L/s	0.471 947 4
Velocity, speed	ft/s	m/s	0.304 8
Acceleration	ft/s2	m/s2	0.304 8
Momentum	lbft/sec	kgm/s	0.138 255 0
Angular momentum	lbft2/s	kgm2/s	0.042 140 11
Plane angle	degree	rad	0.017 453 3
		mrad	17.453 3

NOTE: Underline denotes exact number.

5. Heating, Ventilating, & Air Conditioning (HVAC). Air flow out of registers and diffusers should be rounded to even increments of 5 or 10 L/s wherever possible.

a. Ductwork (Round, Rigid). Most designers are showing hard metric diameters (e.g., 250, 300 mm).

b. Ductwork (Round, Flexible). Many designers are showing flexible round duct in hard metric sizes but are accepting soft metric during construction (e.g., 200 or 250 mm).

c. Ductwork (Rectangular). Use 50 and 100 mm sizes (e.g., 500 x 1000, 250 x 350) unless not possible.

6. Pipes.

a. Steel pipe, ASTM A 53, will not physically change. Pipe is classified by nominal mm sizes.

b. ASTM B 88 M hard metric copper tube sizes are available.

c. Schedule designations remain the same (e.g., Schedule 40, and type K, L, and M).

d. 18 mm may be used for 5/8 inch. All other designations remain the same.

e. The paragraph and chart below may be placed on the mechanical drawing sheet.

"ALL SIZES ARE INDUSTRY-STANDARD ASTM A 53 PIPE AND ASTM B 88 TUBE DESIGNATED BY THEIR NOMINAL MILLIMETER (mm) DIAMETER EQUIVALENT. SEE CHART BELOW."

Nominal Size		Nominal Size		Nominal Size	
Inch	mm	Inch	mm	Inch	mm
1/2	15	2	50	5	125
3/4	20	2-1/2	65	6	150
1	25	3	80	8	200
1-1/4	32	3-1/2	90	10	250
1-1/2	40	4	100	12	300

7. Schedules.

1. Flow rates, pressures, thermal powers, and other metric criteria on schedules should be rounded wherever possible. The one percent analysis provides a useful technique.

a. Example 1: A fan flow rate converts to 8,022 L/s. 1% is +/- 80.22 L/s. This fan could possibly be shown as minimum 8000 L/s (8 m3/s) and is easier to utilize.

b. Example 2: A pump flow converts to 75.7 L/s. One percent of this is 0.757 L/s. Therefore, 75 L/s could possibly be used.

2. It is important to note that, in some cases, codes or design criteria may not allow this liberty. In other cases, however, 2 or 3% analyses may be feasible, using your professional judgement.

8. Temperature.

a. Mechanical schedule temperatures, design temperatures, leaving and entering temperatures, and others shall be stated in even Celsius (e.g., 5, 12, 25, and 40 degrees C) unless this is not feasible.

b. Construction projects shall use Celsius only. Renovation projects where new control systems are being installed should also use Celsius.

c. HVAC calculations shall be in metric.

d. Thermal ratings for boilers and chillers should be specified in even nominal MW or kW increments (e.g., 2100 kW, 2 MW).

APPENDIX 1

GLOSSARY OF TERMS

Glossary of Terms

-B-

basic module: The fundamental unit of size in the systems of coordination in metric building construction: 100 mm (similar to inches in the inch-pound system).

base units: In the metric system, the meter (length), kilogram (mass), second (time), kelvin (thermodynamic temperature), ampere (electric current), and candela (luminous intensity). The mole is also a base unit, but it a physics term and has no application in BLM work.

-D-

digit: One of the ten Arabic numerals (0-9).

degree Celsius: Related directly to thermodynamic temperature (kelvins). Unit of temperature. Zero degrees Celsius is equivalent to 32 degrees Fahrenheit (the freezing point of water) and 100 degrees Celsius is equivalent to 212 degrees Fahrenheit (the boiling point of water). A Celsius degree is 1.8 times larger than a Fahrenheit degree.

derived units: Units that are formed from base units, supplementary units, and other derived units, e.g., meters per second (m/s).

dimensional coordination: Special dimensional preferences for buildings and building products. In metric dimensional coordination, a common set of preferred dimensions is used to establish the geometry of a building as well as the sizes of constituent components or assemblies. Also called modular coordination.

dual dimensions: The expression of dimensions in both customary and metric units of measure.

-H-

hard conversion: Changing the actual size of a product so that its measurements are in rounded metric sizes.

-I-

inch-pound measurement system: The foot, pound, gallon, degree Fahrenheit system used in the U.S.

inframodular size: A selected dimension smaller than the basic module (100 mm).

intermodular size: A selected dimension larger than the basic module (100 mm) but not a whole multiple of the module.

-K-

kilogram: Base unit of mass (weight). Symbol: kg. The kilogram is equal to 1000 grams and is approximately 2.2 pounds.

-L-

liter: Unit of volume or capacity used mainly to measure quanti ties of liquid or gaseous materials. It is equal to a cubic decimeter. Symbol: L. The liter is 6 percent larger than a quart. A smaller unit is the milliliter (mL), which is 1/1000 of a liter.

-M-

meter: The base unit of length. Symbol: m. The meter is equiv- alent to 39.37 inches. Smaller units are the centimeter (cm), which is 1/100 of a meter (a little less than 1/2 inch), and the millimeter (mm) which is 1/1000 of a meter (a little more than 1/32 inch.) The kilometer (km) is a larger unit and is equal to 0.62 mile.

metrication: The process of converting to the metric system.

-N-

nominal value: A value assigned for the purpose of convenient designation; existing in name only.

-P-

preferred multimodular dimension: A selected multiple of the basic module of 100 mm.

-R-

rounded metric sizes: Sizes expressible in simple numbers based on non-decimal multiples of 1000, 100, 50, 20, 10, 5, 2, and 1 in order. Examples are 500 g, 1 kg, 2 kg, 500 ml, 1 L, 5 L, etc.

-S-

SI: Abbreviation for the modern metric system, the International System of Units (from the French, Systeme International

d'Unites). It evolved from the original French metric system and is currently being used virtually worldwide.

significant digit: Any digit that is necessary to define a value

or quantity.

soft conversion: The translation of customary unit measurements to their equivalent values in metric units.

supplementary units: The second class of metric units in the metric system. Units added to the system to enhance its capabilities. There are two units: radian (angles in one plane) and steradian (three-dimensional angles).

APPENDIX 2

CONVERSION TABLES

TO CONVERT	MULTIPLY BY	TO OBTAIN
acres	4.047 x 10-1	hectares
	4.047 x 103	sq. meters
	1.562 x 10-3	sq. miles
	4.840 x 103	sq. yards
	7.348 x 10-3	tons/sq. inch

	1.058	tons/sq. foot
atmospheres	1.033 x 104	kgs./sq. meter
	1.033	kgs./sq. cm
	7.6 x 102	mm of mercury (0 C)
	4.356 x 104	cubic feet
acre-feet	1.234 x 103	cubic meters
	3.259 x 105	gallons
	9.869 x 10-1	atmospheres
bars	1.0 x 106	dynes/sq. cm
	1.020 x 104	kgs./sq. meter
	1.041 x 101	liter-atmosphere
btu	1.055 x 103	joules
	2.928 x 10-4	kilowatt-hours
btu/min	2.356 x 10-2	horsepower
	1.757 x 10-2	kilowatts
candle/sq. cm	3.146	lamberts
candle/sq. in	4.870 x 10-1	lamberts
cubic feet	2.832 x 10-2	cubic meters
	2.832 x 101	liters
cubic ft/min	4.720 x 10-1	liters/sec
cubic inches	1.639 x 10-5	cubic meters
	1.639 x 10-2	liters
	6.102 x 104	cubic inches
cubic meters	3.531 x 101	cubic feet
	1.308	cubic yards
	1.000 x 103	liters
cubic yards	7.646 x 10-1	cubic meters
	7.646 x 102	liters
cubic yds/min	1.274 x 101	liters/sec

	9.869 x 10-7	atmospheres
dynes/sq. cm	2.953 x 10-5	in. of mercury (0C)
	1.020 x 10-6	kilograms
	7.376 x 10-8	foot-pounds
ergs	1.000 x 107	joules
	2.773 x 10-11	kilowatt-hours
fathoms	1.8288	meters
	3.048 x 102	millimeters
feet	3.048 x 10-1	meters
	3.048 x 10-4	kilometers
	1.829 x 10-2	kilometers/hour
feet/min	3.048 x 10-1	meters/min
	1.136 x 10-2	miles/hour
	3.048 x 101	centimeters/sec
feet/sec	1.097	kilometers/hour
	1.829 x 101	meters/min
foot candle	1.076 x 101	lumen/sq meter (lux)
	1.286 x 10-3	btu
foot-pounds	1.356	joules
	3.766 x 10-7	kilowatt-hours
foot-lbs/min	3.030 x 10-5	horsepower
	2.260 x 10-5	kilowatts
foot-lbs/sec	1.818 x 10-3	horsepower
	1.356 x 10-3	kilowatts
gallons	3.785 x 10-3	cubic meters
	3.785	liters
gallons/min	2.228 x 10-3	cubic feet/sec
	6.308 x 10-2	liters/sec
gausses	1.0 x 10-4	webers/sq meter

	9.807 x 10-5	joules/cm
grams	9.807 x 10-3	joules/meter (newton)
	2.205 x 10-3	pounds
hectares	2.471	acres
	1.076 x 105	square feet
horsepower	4.244 x 101	btu/min
	7.457 x 10-1	kilowatts
hp (boiler)	3.352 x 104	btu/hour
	9.803	kilowatts
	2.547 x 103	btu
hp-hours	2.684 x 106	joules
	7.457 x 10-1	kilowatt-hours
inches	2.540 x 101	millimeters
	2.540 x 10-2	meters
inches of mercury	3.342 x 10-2	atmospheres
	3.453 x 102	kilograms/sq. meter
joules	9.486 x 10-4	btu
	1.020 x 10-1	kilogram-meters
kilograms	9.807	joules/meter (newton)
	2.2046	pounds
	9.678 x 10-1	atmospheres
kilograms/sq cm	2.048 x 103	pounds/sq foot
	1.422 x 101	pounds/sq inch
	9.678 x 10-5	atmospheres
kilograms/sq meter	2.048 x 10-1	pounds/sq foot
	1.422 x 10-3	pounds/sq inch
kilogram-meters	9.296 x 10-3	btu
	7.233	foot-pounds

	9.807	joules
	2.723 x 10-6	kilowatt-hours
	3.281 x 103	feet
kilometers	1.094 x 103	yards
	6.214 x 10-1	miles (statute)
	5.692 x 101	btu/min
kilowatts	4.426 x 104	foot-lbs/min
	1.341	horsepower
	3.413 x 103	btu
kilowatt-hours	2.655 x 106	foot-pounds
	3.6 x 106	joules
lamberts	3.183 x 10-1	candles/sq cm
	2.054	candles/sq inch
	1.000 x 103	cubic centimeters
	3.531 x 10-2	cubic feet
	6.102 x 101	cubic inches
liters	1.308 x 10-3	cubic yards
	2.642 x 10-1	gallons (U.S.)
	2.113	pints (U.S.)
	1.057	quarts (U.S.)
liters/min	5.886 x 10-4	cubic ft/sec
	4.403 x 10-3	gallons/sec
lumen	7.958 x 10-2	spherical candle pwr
lumen/sq foot	1.076 x 101	lumen/sq meter
lux	9.29 x 10-2	foot-candles
meters	5.468 x 10-1	fathoms
	3.281	feet
	3.937 x 101	inches

	5.400 x 10-4	miles (nautical)
	6.214 x 10-4	miles (statute)
	1.094	yards
meters/min	1.667	centimeters/sec
	5.468 x 10-2	feet/sec
	6.0 x 10-2	kilometers/hour
	3.728 x 10-2	miles/hour
meters/sec	1.968 x 102	feet/minute
	3.6	kilometers/hour
	2.237	miles/hour
miles (nautical)	6.076 x 103	feet
	1.852	kilometers
	1.1516	miles (statute)
	2.0254 x 103	yards
miles (statute)	1.6093	kilometers
	8.684 x 10-1	miles (nautical)
miles/hour	8.8 x 101	feet/minute
	1.467	feet/second
	1.6093	kilometers/hour
	2.682 x 101	meters/minute
millimeters	3.281 x 10-3	feet
	3.937 x 10-2	inches
ounces (avdp)	2.835 x 101	grams
	6.25 x 10-2	pounds
	9.115 x 10-1	ounces (troy)
ounces (fluid)	1.805	cubic inches
	2.957 x 10-2	liters
	3.1103 x 101	grams

ounces (troy)	1.097	ounces (avdp)
	8.333 x 10-2	pounds (troy)
	3.36 x 101	cubic inches
pints (dry)	5.0 x 10-1	quarts
	5.506 x 10-1	liters
	1.671 x 10-2	cubic feet
	2.887 x 101	cubic inches
pints (liquid)	4.732 x 10-4	cubic meters
	4.732 x 10-1	liters
	4.536 x 102	grams
	4.448	joules/meter (newton)
pounds (avdp)	4.536 x 10-1	kilograms
	1.458 x 101	ounces (troy)
	1.215	pounds (troy)
	3.7324 x 102	grams
	1.3166 x 101	ounces (avdp)
pounds (troy)	1.2 x 101	ounces (troy)
	8.2286 x 10-1	pounds (avdp)
	3.7324 x 10-4	tons (metric)
	1.602 x 10-2	cubic feet
pounds of water	1.198 x 10-1	gallons
	1.602 x 10-2	grams/cubic cm
pounds/cubic foot	1.602 x 101	kilograms/cu meter
	5.787 x 10-4	pounds/cubic inch
	2.768 x 101	grams/cubic cm
pounds/cubic inch	2.768 x 104	kilograms/cu meter
	1.728 x 103	pounds/cubic foot
	4.725 x 10-4	atmospheres

	1.414 x 10-2	inches of mercury
pounds/sq. foot	4.882	kilograms/sq meter
	6.944 x 10-3	pounds/sq inch
	6.804 x 10-2	atmospheres
pounds/sq. inch	2.036	inches of mercury
	7.031 x 102	kilograms/sq meter
	1.44 x 102	pounds/sq inch
quarts (dry)	6.72 x 101	cubic inches
	5.775 x 101	cubic inches
quarts (liquid)	9.464 x 10-4	cubic meters
	1.238 x 10-3	cubic yards
	9.463 x 10-1	liters
	5.029	meters
rods (survey)	5.5	yards
	1.65 x 101	feet
	2.296 x 10-5	acres
square feet	1.44 x 102	square inches
	9.29 x 10-2	square meters
	1.111 x 10-1	square yards
	6.944 x 10-3	square feet
square inches	6.452 x 102	square millimeters
	7.716 x 10-4	square yards
	2.471 x 102	acres
	1.076 x 107	square feet
square kilometers	1.0 x 106	square meters
	3.861 x 10-1	square miles
	1.196 x 106	square yards
	2.471 x 10-4	acres

square meters	1.076 x 101	square feet
	1.55 x 103	square inches
	3.861 x 10-7	square miles
	1.196	square yards
square miles	6.40 x 102	acres
	2.788 x 107	square feet
	2.590	square kilometers
	2.590 x 106	square meters
	3.098 x 106	square yards
square millimeters	1.076 x 10-5	square feet
	1.55 x 10-3	square inches
square yards	2.066 x 10-4	acres
	8.361 x 10-1	square meters
	3.228 x 10-7	square miles
temperature C	1.8 (+ 32)	temperature F
temperature F (-32)	5.555 x 10-1	temperature C
tons (short)	9.072 x 102	kilograms
	2.0 x 103	pounds (avdp)
	2.43 x 103	pounds (troy)
	9.078 x 10-1	tons (metric)
tons/square foot	9.765 x 103	kilograms/sq meter
	1.389 x 101	pounds/sq inch
tons/square inch	1.406 x 106	kilograms/sq meter
watts	3.4129	btu/hour
	5.688 x 10-2	btu/minute
	1.341 x 10-3	horsepower
	1.0	joules/second
watt-hours	3.413	btu

	2.656 x 103	foot-pounds
webers/sq inch	1.55 x 103	webers/sq meter
	9.144 x 10-1	meters
yards	4.934 x 10-4	miles (nautical)
	5.682 x 10-4	miles (statute)

APPENDIX 3

PROJECT PLANS

(Illustrative Examples)

Project Plans - (Illustrative Examples)

A. Architectural

Acknowledgements

The metric units in this guide are those adopted by the U.S. government (see the *Federal Register* of December 20, 1990; Federal Standard 376A, *Preferred Metric Units for Use by the Federal Government*; and PB 89-226922, *Metric Handbook for Federal Officials)*. They are identical to the units in the following publications, which constitute the standard reference works on metric in the United States.

ANSI/IEEE 268, *American National Standard Metric Practice*, and

ASTM E 380, *Standard Practice for Use of the International System of Units (SI)*.

ASTM E 621, *Standard Practice for Use of Metric (SI) Units in Design and Construction*,

National Institute of Building Sciences, *Metric Guide for Federal Construction* and the *Metric Construction* newsletters

General Services Administration, M2: *Metric Design Guide*, Third Edition (October 1993).