APPENDIX I

GLOSSARY

BLOCK— One or more sheaves fitted in a wood or metal frame supported by a hook or shackle inserted in the strap of the block.

BREECH— The part of the block opposite the swallow.

BURR— The sharp edge remaining on metal after cutting.

CHOKER— A chain or wire rope so fastened that it tightens on its load as it is pulled.

COMPRESSION STRESSES— The stresses developed within a material when forces tend to compress or crush the material.

COPE—The notch or shape to fit or conform to the shape of another member.

DUCTILITY— The property that enables a material to withstand extensive permanent deformation due to tension.

ELASTICITY— The ability of a material to return to its original form after deformation.

FALL— A line reeved through a pair of blocks to form a tackle.

FATIGUE— The tendency of a material to fail after repeated stressing at the same point.

FATIGUE STRENGTH— The ability of a material to resist various kinds of rapidly alternating stresses.

GUY LINE—The fiber line or wire rope used for holding a structure in position.

IMPACT STRENGTH— The ability of a metal to resist suddenly applied loads; measured in foot-pounds of force.

LAY— Refers to the direction in which wires are twisted into strands or strands into rope.

LAYOUT— The process of measuring and marking materials for cutting, bending, drilling, or welding.

MALLEABILITY— The property that enables a material to withstand permanent deformation caused by compression.

MOUSING— technique often used to close the open section of a hook to keep slings, straps, and so on, from slipping off the hook.

OVERHAUL— To Lenghten a tackle by pulling the two blocks apart.

PLASTICITY— The ability of a material to permanently deform without breaking or rupturing.

ROUND IN— To bring the blocks of a tackle toward each other.

SCAFFOLD— A temporary elevated platform used to support personnel and materials in the course of any type of construction work.

SEIZE— To bind securely the end of a wire rope or strand with seizing wire.

SHEARING STRESSES— The stresses developed within a material when external forces are applied along parallel lines in opposite directions.

SNATCH BLOCK— A single sheave block made so the shell on one side opens to permit the line to be placed over the sheave.

SHELTERING— TO attach a socket to wire rope by pouring hot zinc around it.

STRESS— External or internal force applied to an object.

SWALLOW— The opening in the block through which the line passes.

TACKLE— An assembly of blocks and lines used to gain a mechanical advantage in lifting or pulling.

TENSILE STRENGTH— The resistance to being pulled apart.

TENSION STRESSES— The stresses developed when a material is subjected to a pulling load.

TWO-BLOCKED— Both blocks of a tackle are as close together as they wilI go.

ULTIMATE STRENGTH— The maximum strain that a material is capable of withstanding.

WHIPPING— The process of securing the ends of a line to prevent the strands from unlaying or separating.

APPENDIX II

MATHEMATICS

The purpose of this mathematics section is twofold: first, it is a refresher for the Steelworker who has encountered a time lapse between his or her schooling in mathematics and the use of this subject in sheet metal work; second, and more important, this section applies mathematics to steelworking tasks that can not be accomplished without the correct use of mathematical equations.

The mathematics problems described in this section are examples only and are not converted into the metric system. However, if you so desire, you can convert all of the problems by using the metric conversion tables in appendix 111 of this manual. If you need more information on metrics, order *The Metric System,* NAVEDTRA 475-01-00-79, through your Educational Services Officer (ESO)..

LINEAR MEASUREMENT

Measurements in sheet metal are most often made in feet (ft) and inches (in.). It is necessary that a sheet metal worker know how to make computations involving feet and inches. In addition, it is necessary to become familiar with the symbols and abbreviations used to designate feet and inches, such as the following:

12 inches = 1 foot; 12 in. = 1 ft; 12" = 1'

CHANGING INCHES TO FEET AND INCHES

To change inches to feet and inches, divide inches by 12. The quotient will be the number of feet, and the remainder will be inches.

Example:

Change 30 1/2 inches to feet and inches.

```
   2    ft.     (quotient)
12|30 1/2
   24
    6 1/2 in.   (remainder)
```

CHANGING FEET AND INCHES TO INCHES

To change feet and inches to inches, multiply the number of feet by 12 and add the number of inches. The result will be inches.

Example:

Change 3 feet 6 inches to inches.

3 ft × 12 = 36 inches + 6 inches = 42 inches

CHANGING INCHES TO FEET IN DECIMAL FORM

To change inches to feet in decimal form, divide the number of inches by 12 and carry the result to the required number of places.

Example:

Express 116 inches as feet to 2 places.

```
     9.666
12|116.000
   108
     80
     72
      80
      72
```

Answer: 9.67

CHANGING FEET TO INCHES IN DECIMAL FORM

To change feet in decimal form to inches, multiply the number of feet in decimal form by 12.

Example;

Change 26.5 feet to inches.

```
 26.5
   12
  530
 265
 318.0  inches
```

ADDITION OF FEET AND INCHES

A sheet metal worker often finds it necessary to combine or subtract certain dimensions which are given in feet and inches.

Arrange in columns of feet and inches and add separately. If the answer in the inches column is more than 12, change to feet and inches and combine feet.

Example:

```
 12 ft  4 1/2 in.
  5 ft  9 1/4 in.
 ----------------
 17 ft 13 3/4 in.
```

In the changing inches column, we have

```
  1′ 1 3/4″
 17′ 0
 ---------
 18′ 1 3/4″
```

SUBTRACTION OF FEET AND INCHES

Arrange in columns with the number to be subtracted below the other number. If the inches in the lower number is greater, borrow 1 foot (12 in.) from the feet column in the upper number.

Subtract as in any other problem.

Example:

Subtract 2′ 8 1/4″ from 4′ 1″.

```
 4′  1″
 2′  8 1/4″

 3′ 13″
 2′  8 1/4″
 ----------
 1′  4 3/4″
```

MULTIPLICATION OF FEET AND INCHES

A sheet metal worker maybe required to determine the total length of metal required to make eight pieces of duct 1' 8“ long. To do this, you should be able to multiply feet and inches by the number of pieces.

Arrange in columns. Multiply each column by the required number. If the inches column is greater than 12, change to feet and inches then add to the number of feet.

Example:

Multiply 1′ 8″ by 8.

```
 1′  8″
     8
 ------
 8′ 64″
```

Change 64″ to feet and inches

```
     5 = 5′ 4″
 12)64
    60
    --
     4
```

Combine: 8′ and 5′ 4″ = 13′ 4″

NOTE: On occasion it might be necessary to multiply feet and inches by feet and inches. To do this, either change to inches or change to feet using decimals.

DIVISION OF FEET AND INCHES

Two problems may require the sheet metal worker to know how to divide feet and inches. An example of one problem is the division of a piece of metal into an equal number of parts. The other problem is to determine the number of pieces of a certain size which can be made from a piece of metal of a given length.

In dividing feet and inches by a given number, the problem should be reduced to inches unless the number of feet will divide by the number evenly.

Example:

Divide 36 ft 9 in. by 4.

Since 36 is divisible by 4 evenly, you may proceed.

```
   9′  2 1/4″
 4)36′ 9″
```

Example:

Divide 34 ft 9 in. by 4.

Since 34 is not divisible evenly by 4, change the problem to inches.

```
  34
  12
  --
  68
 34
 ---
 408 in.

 408
  +9
 ---
 417 in.
```

The answer should then be changed to feet and inches (104 1/4″ = 8′ 8 1/4″).

$$4\overline{)417}\quad = 104\ 1/4''$$

To divide feet and inches by feet and inches, change to inches or feet (decimals).

Example:

Divide 10 ft 4 in. by 2 ft 6 in.

Example:

Same problem as above by use of ft (decimals).

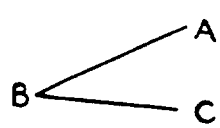
$$30\overline{)124} = 4$$
$$120$$
4 inches remainder

$$2.5\overline{)10.33} = 4$$
$$10.3$$
.33 ft remainder

It will divide 4 times with .33 ft remainder.

ANGLES

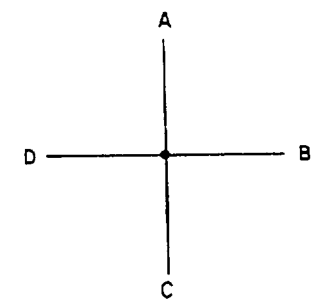
When two lines are drawn in different directions from the same point, as shown below, an angle is formed. /is the symbol for angle, and this angle is described as ∠ABC or simply ∠B. B is the vertex of the angle. AB and CB are the sides of the angle.



Angles are of four types:

1. Right angle-a 90° angle.
2. Acute angle-an angle less than 90°.
3. Obtuse angle-an angle greater than 90°, but less than 180°.
4. Reflex angle—an angle greater than 180°.

MEASUREMENT OF ANGLES

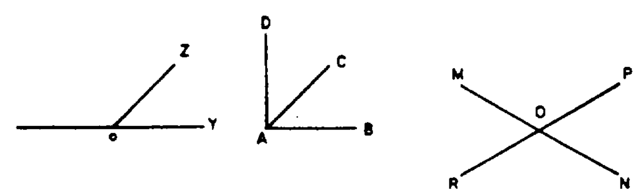


Observe that two straight lines have been drawn to form four right angles.

In order to have a way to measure angles, a system of angle-degrees has been established. Assume that each of the four right angles is divided into 90 equal angles. The measure of each is 1 angle degree; therefore, in the four right angles, there are 4 x 90°, or 360 angle-degrees. For accurate measurement, degrees have been subdivided into minutes and minutes into seconds.

1 degree= 60 minutes ('). 1 minute= 60 seconds (“).

RELATIONSHIP OF ANGLES



1. ∠ZOY and ∠ZOX are *supplementary angles* and their total measure in degrees is equal to 180°. When one straight line meets another, two supplementary angles are formed. One is the supplement of the other.
2. ∠DAC and ∠CAB are *complementary* angles and their total is a right angle or 90°.

Two angles whose sum is 90° are said to be complementary, and one is the complement of the other.

3. ∠ MOP and ∠ RON are a pair of *vertical* angles and are equal.

∠ MOP and ∠ PON are a pair of vertical angles and are equal.

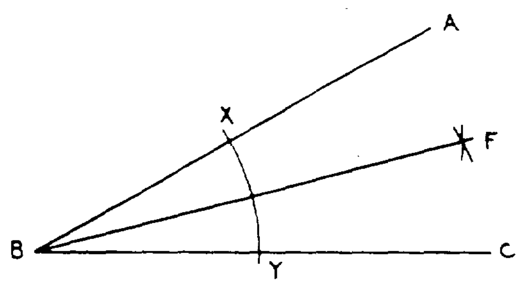
When two straight lines cross, two pairs of vertical angles are formed. Pairs of vertical angles are equal.

BISECTING ANGLES

To bisect an angle merely means to divide the angle into two equal angles. his may be done by use of a compass.

Problem:

Bisect ∠ ABC.



Solution:

Step 1. Draw an arc with the radius less than the shorter of AB or BC intersecting AB and BC at points X and Y.

Step 2. From X and Y using the same radius, draw arcs intersecting at point F.

Step 3. Draw BF which will bisect ∠ ABC.

Conclusion:

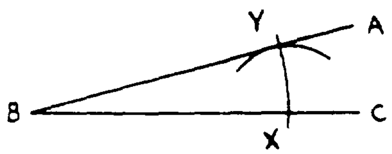
∠ ABF = ∠ CBF

TRANSFERRING ANGLES

It is often necessary in sheet metal layout to construct an angle that equals a given angle.

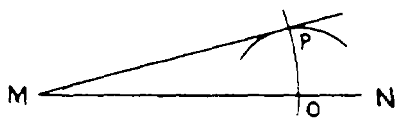
Given:

∠ ABC



Problem:

Construct an angle ∠ PMN equal to ∠ ABC.



Solution:

Step 1. From B, draw an arc with a convenient radius which intersects AB and CB at points X and Y.

Step 2. Using the same radius, draw an arc from M intersecting MN at point O.

Step 3. With X as center, set the compass to a radius which will pass an arc through Y.

Step **4.** Using this radius (Step 3) and O as center, draw an arc that will intersect the arc drawn from M in Step 2 at point P.

Step 5. Draw PM completing PMO.

Conclusion:

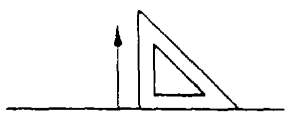
∠ PMO = ∠ ABC

PERPENDICULARS LINES

Lines are said to be perpendicular when they form a right angle (90°).

A perpendicular may be drawn to a line in several ways.

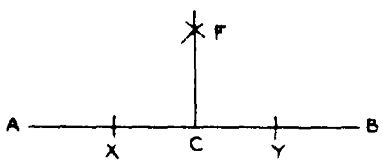
1. Using an object which has a right angle, such as a drawing triangle.



2. Using a compass from a point on a line.

Example:

Construct a perpendicular to AB at point C.



Solution:

Step 1. Draw an arc from C as a center, using any convenient radius cutting AC and CB at X and Y.

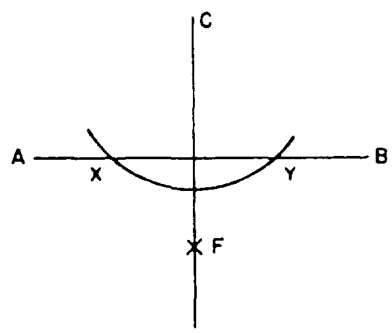
Step 2. Increase the size of the radius and from X and Y, draw arcs which intersect at point F.

Step 3. Draw CF which is perpendicular to AB at point C.

3. Using a compass, from a point outside the line.

Example:

Draw a perpendicular to AB from C.



Step 1. From C, draw an arc using any convenient radius, intersecting AB at X and Y.

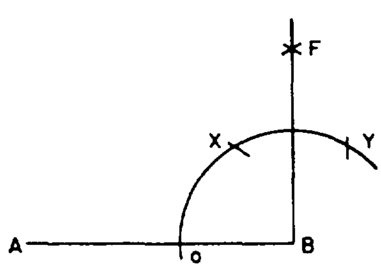
Step 2. Using the same radius, draw arcs from X and Y intersecting at F.

Step 3. Draw CF, which is perpendicular to AB.

4. Using a compass from a point at the end of a line.

Example:

Draw a perpendicular to AB from B.



Solution:

Step 1. From B, swing an arc with any convenient radius intersecting AB at O and continuing in a clockwise direction at least 120°.

Step 2. From O, using the same radius, draw an arc intersecting the arc drawn in Step 1 and X.

Step 3. From point X, draw an arc with the same radius intersecting the arc drawn in Step 1 at Y.

Step 4. From X and Y, draw arcs using the same radius intersecting at F,

Step 5. Draw FB perpendicular to AB at B.

PARALLEL LINES

Two lines are said to be parallel if they are equidistant (equally distant) at all points.

Facts about parallel lines:

Two straight lines lying in the same plane either intersect or are parallel.

Through a point there can be only one parallel drawn to a given line.

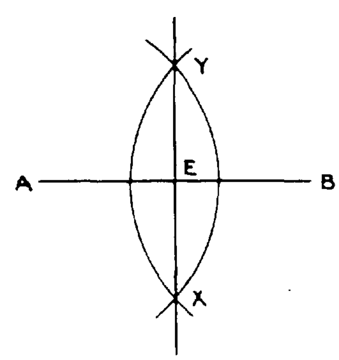
If two lines are perpendicular to the third, and in the same plane, they are parallel.

BISECTING LINES

It is often necessary to find the midpoint of a line. This may be found by measuring, or by using dividers and finding it by trial and error. A much simpler way is by the use of a compass.

Example:

To bisect a line AB by using a compass:



Solution:

Step 1. Using A as a center and a radius more than 1/2 of AB, but less than AB, draw an arc.

Step 2. Using B as a center and the same radius as Step 1, draw an arc intersecting the arc drawn in Step 1. Mark intersecting points X and Y. Draw XY.

Conclusion:

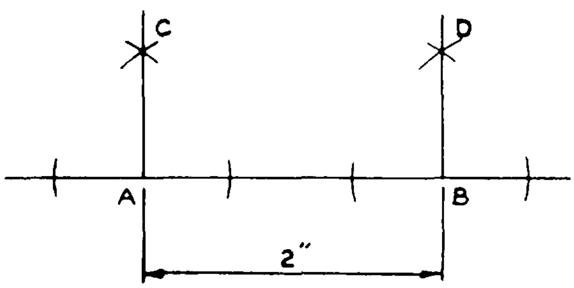
AE = EB

NOTE: That E also represents the midpoint of XY and that XY is perpendicular to AB. XY is termed the perpendicular bisector of AB,

CONSTRUCTION OF PARALLEL LINES USING PERPENDICULARS

Example;

Construct parallel lines 2“ apart.



Solution:

Step 1. Draw a base line and lay out two points A and B 2" apart.

Step 2. Construct perpendiculars AC and BD to AB at A and B.

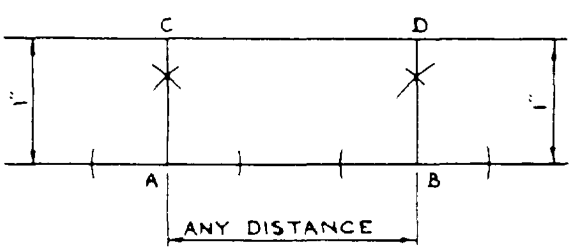
Conclusion;

AC is parallel to BD.

Principle:

Perpendiculars to the same line are parallel.

NOTE: Horizontal parallel lines can be drawn by the same procedures.



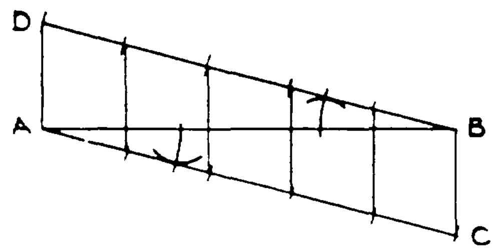
DIVIDING LINES

Lines can be divided into equal parts by a number of methods. Four of these methods are (1) by using parallel lines, (2) by transferring angles, (3) by using equal segments on the side of an angle, and (4) by using a scale.

1. Using parallel lines

Example;

Divide AB into 5 equal parts.



Solution:

Step 1. Assume any angle ABD and draw BD.

Step 2. At A construct ∠ BAC equal to ∠ ABD. Now BD and AC are parallel.

Step 3. Assume a radius so that 5 times the radius will fall within the BD, Swing arcs using this radius on BD and AC.

Step 4. Connect B with the last arc swung from A and connect corresponding points.

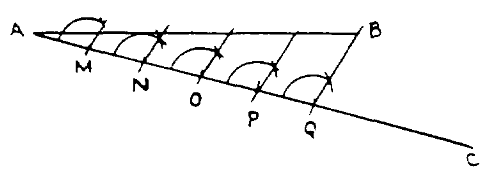
Conclusion:

Lines drawn in Step 3 divide AB into 5 equal parts.

2. Transferring angles

Example:

Divide AB into 5 equal parts.



Solution:

Step 1. Draw a line AC at any assumed angle to AB.

Step 2. Step off with compass 5 equal parts on AC.

Step 3. At Q (the end of 5 parts), draw line BQ.

Step 4. At points M, N, O, and P, construct angles equal to $\angle$ BQA.

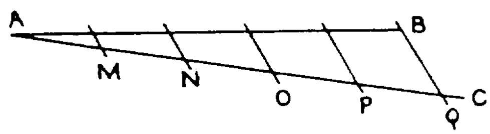
Conclusion:

Where sides of angles constructed in Step 4 meet AB, they will divide AB into equal parts.

3. Equal segments on the side of an angle

Example:

Divide AB into 5 equal parts.



Solution:

Step 1. At any assumed angle draw AC.

Step 2. Step off 5 equal parts on AC.

Step 3. At Q (the end of 5 parts), draw line BQ.

Step 4. Draw lines through P, O, N, and M parallel to BQ.

Conclusion:

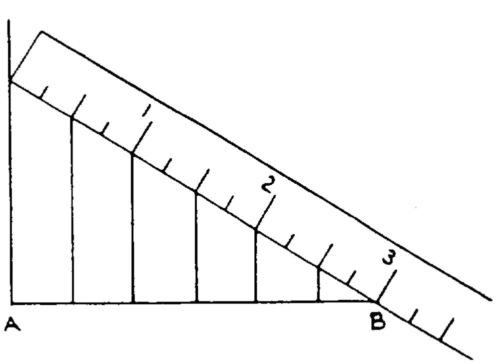
Where parallel lines intersect AB, AB will be divided into 5 equal parts.

Note the similarity of methods 3 and 2.

4. Use of a scale

Example:

Divide line AB, which is 29/16” long, into 6 equal parts.



Solution:

Step 1. At A draw a line perpendicular to AB.

Step 2. Place the scale at an angle so that the distance on the scale will divide easily into 6 parts. In the above, we have selected 3“ which will divide into 6 equal parts of 1/2” each.

Step 3. Draw lines from 1/2"; each division is perpendicular to AB.

Conclusion:

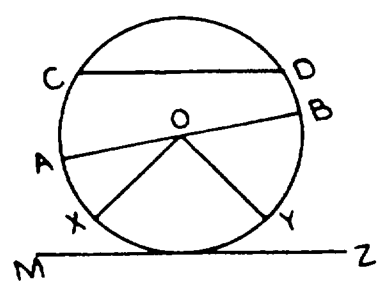
The perpendiculars drawn will divide AB into 6 equal parts.

PLANE SHAPES

A plane shape is a portion of a plane bounded by straight or curved lines or a combination of the two.

The number of different types of plane shapes is infinite, but we are concerned with those which are of importance to you as a sheet metal craftsman. We will cover the circle, triangle, quadrilateral, other polygons, and ellipses.

CIRCLES



Definitions:

A CIRCLE is a closed curved line in which any point on the curved line is equidistant from a point called the center. (Circle O).

A RADIUS is a line drawn from the center of a circle to a point on a circle. (As OA, OB, OX, and OY.)

A DIAMETER is a line drawn through the center of a circle with its ends lying on the circle.

A DIAMETER is twice the length of a radius. (AB is a diameter of circle O.)

A CHORD is a line joining any two points lying on a circle. (CD is a chord of circle O.)

An ARC is a portion of the closed curved lines which forms the circle. It is designated by CD. An arc is said to be subtended by a chord. Chord CD subtends arc CD.

A TANGENT is a straight line which touches the circle at one and only one point. (Line MZ is a tangent to circle O.)

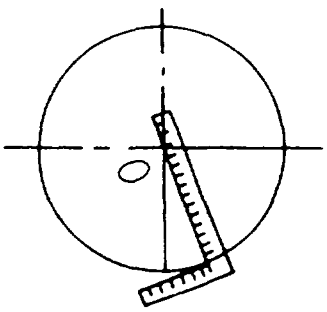
A CENTRAL ANGLE is an angle whose vertex is the center of a circle and whose side are radii of the circle. (As XOY, YOA, and XOB.)

CONCENTRIC CIRCLES are circles having the same center and having different radii.

The CIRCUMFERENCE of a circle is the distance around the circle. It is the distance on the curve from C to A to X to Y to B to D and back to C.

Some examples of problems involving circles applicable to sheet metal work are as follows:

1. Construct a tangent to circle O by use of a square.



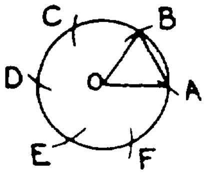
Solution:

Step 1. Place the square in a position so that one side touches the center and the other side touches the circle.

Conclusion:

A line drawn along the second side will be tangent to the circle.

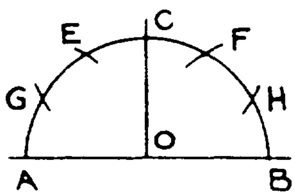
2. Divide a circle into 6 equal parts.



Solution:

Step 1. Using a radius of the circle, begin at any point, and step off chords equal to the radius. If done accurately, this will make 6 divisions of the circle.

3. Divide a semicircle into 6 equal parts.



Solution:

Step 1. At O erect a perpendicular to AB.

Step 2. With point A as the center and radius equal to AO, swing an arc cutting the circle at E.

Step 3. With point B as the center and the same radius as in step 2, swing an arc cutting the circle at F.

Step 4. With the same radius, and point C as the center, swing arcs cutting the circle at points G and H,

Conclusion:

AG = GE = EC = etc.

4. Divide a circle into 8 equal parts.

Problem:

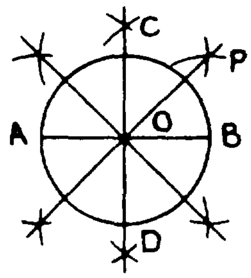
To divide circle O into 8 equal parts.

Solution:

Step 1. Draw diameter AB. Draw CD perpendicular to AB, thus dividing the circle into 4 equal parts.

Step 2. Bisect the central angle COB. Mark the point of the intersection of the bisector and circle O.

Step 3. From B swing an arc equal to BP and from this intersection with the circle, draw the diameter, thus dividing circle O into 8 equal



TRIANGLES

A triangle is a plane shape having 3 sides. Its name is derived from its three (tri) angles.

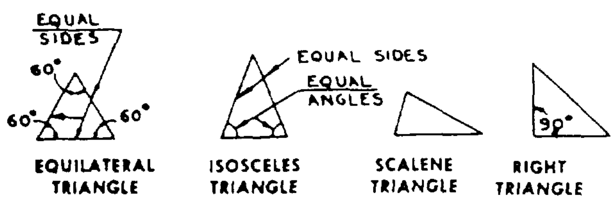
Other facts help define a triangle.

1. The sum of the angles in any triangle equals 180°.
2. A triangle is the only plane shape which maybe defined in terms of its sides only; in all others one or more angles must be stated.

Types of Triangles

There are four kinds of triangles. They are classified according to the size of their sides and angles as follows:

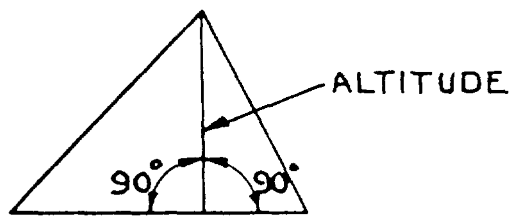
1. Equilateral-all sides are equal-all angles are equal-all angles are 60°
2. Isosceles—two sides equal-two angles equal
3. Scalene—all sides unequal-all angles unequal
4. Right—one right angle



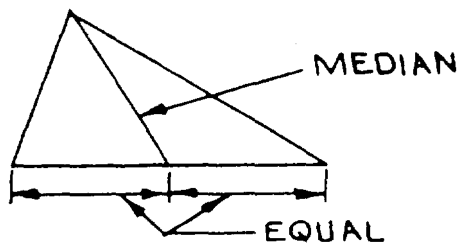
Altitudes and Medians

The altitude and median of a triangle are not the same; the difference is pointed out in the following definitions:

1. The altitude of a triangle is a line drawn from the vertex, perpendicular to the base.



2. The median of a triangle is a line drawn from the vertex to the midpoint of the base.



Construction of Triangles

There are many ways to construct a triangle, depending upon what measurements are known to you. The following examples will assist you. Select the appropriate method according to the information given about the triangle.

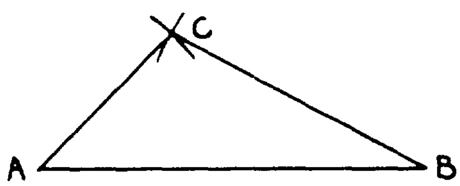
1. A triangle may be constructed if the lengths of three sides are known.

Problem:

Construct a triangle.

Given:

Three sides of a triangle: 2“, 1“, 1 1/2”.



Solution:

Step 1. Draw a base line equal to one of the sides. Mark the ends of lines A and B.

Step 2. Set the compass equal to the second side (l" in the above) and swing an arc from A.

Step 3. Set the compass equal to the third side (1 1/2" in this case) and swing an arc.

Conclusion:

The intersection of these two arcs will be the vertex C and will complete triangle ABC.

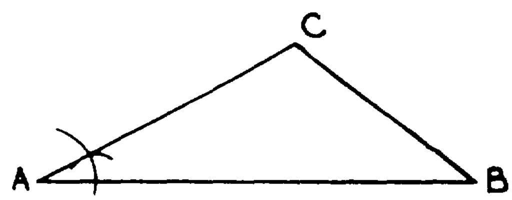
2. A triangle maybe constructed if two sides and the included angle (angle between the sides) are known.

Problem:

To construct a triangle with two sides and the included angle known.

Given:

Two sides 1 1/2" and 2 1/4" and the included angle.



Solution:

Step 1. Draw the base equal to one side.

Step *2.* Construct an angle equal to the given angle.

Step 3. Measure the second side on the side of the angle and connect the ends of the given sides BC.

Conclusion:

Triangle ABC has been constructed with two sides and the included angle given.

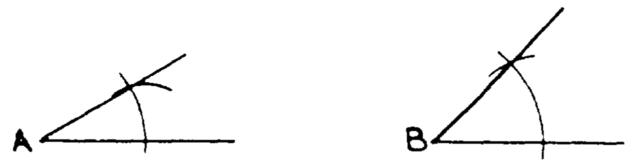
3. A triangle maybe constructed if two angles and the included side are given.

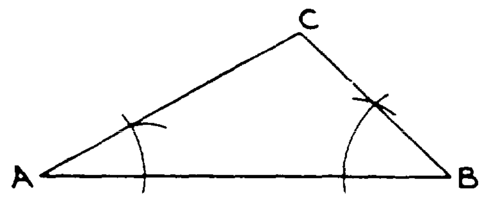
Problem:

Construct a triangle.

Given:

∠A, ∠B and line AB 2 1/8" long.





Solution:

Step 1. Draw line AB.

Step 2. At point A, transfer angle A.

Step 3. At point B, transfer angle B.

Step 4. Where sides of ∠A and ∠B intersect, mark point C.

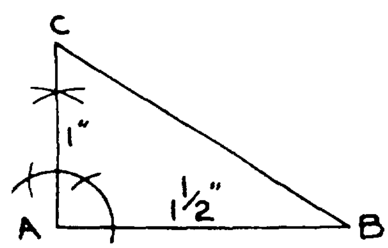
Conclusion:

Triangle ABC has been constructed with two angles and the included side given.

4. A right triangle may be constructed if the two sides adjacent to the right angle are known.

Problem:

Construct a right mangle whose sides adjacent to the right angle are 1 1/2" and l".



Solution:

Step 1. Draw AB 1 1/2" long.

Step *2.* At A, erect a perpendicular to AB.

Step 3. Locate point C 1" from AB and complete the triangle.

Conclusion:

Triangle ABC is a right triangle,

5. A right triangle maybe constructed by making the sides 3", 4", and 5" or multiples or fractions thereof.

Problem:

Construct a right triangle with sides of 1 1/2", 2", and 2 1/2" (1/2 of 3,4, and 5).

Solution:

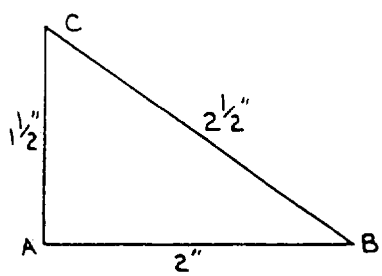
Step 1. Draw line AB = 2".

Step 2. From A, draw an arc equal to 1 1/2".

Step 3. From B, draw an arc equal to 2 1/2".

Conclusion:

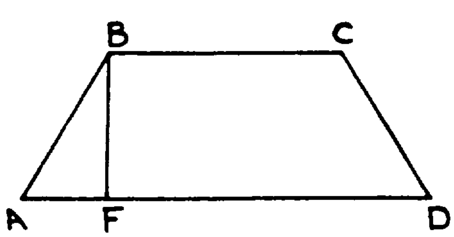
Triangle ABC is a right triangle,



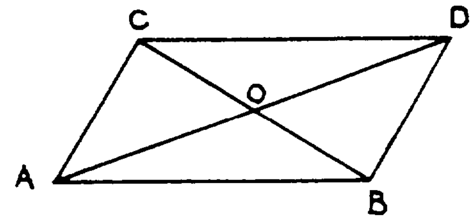
QUADRILATERALS

A quadrilateral is a four-sided plane shape. There are many types, but only the trapezoid, parallelogram, rectangle, and square are described here.

1. A **TRAPEZOID** is a quadrilateral having only two sides parallel. If the other two sides are equal, it is an isosceles trapezoid. BF is the altitude of the trapezoid.



2. A **PARALLELOGRAM** is a quadrilateral having opposite sides parallel.



a. AB is parallel to CD.

b. AC is parallel to BD.

c. AD and CB are diagonals.

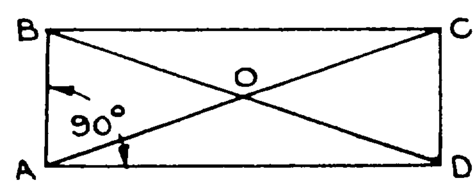
d. Diagonals bisect each other so CO = OB and AO = OD.

e. Opposite angles are equal ACD = DBA and CAB = BDC.

f. If two sides of a quadrilateral are equal and parallel, the figure is a parallelogram.

g. A parallelogram may be constructed if two adjoining sides and one angle are known.

3. A **RECTANGLE** is a parallelogram having one right angle.



a. ABCD is a parallelogram having one right angle. This, of course, makes all angles right angles.

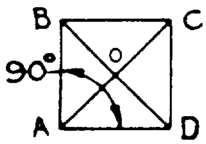
b. AC and BD are diagonals.

c. O is the midpoint of AC and BD and OB = OC = OD = OA.

d. O is equidistant from BC and AD and is also equidistant from AB and CD.

e. A rectangle may be constructed if two adjoining sides are known.

4. A **SQUARE** is a rectangle having its adjoining sides equal.



a. ABCD is a square.

b. AC and BD are diagonals.

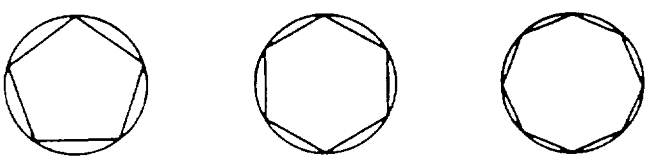
c. O is the geometric center of the square. AO = OC = OB = OD.

d. O is equidistant from all sides.

e. A square may be constructed if one side is known.

POLYGONS

A polygon is a many-sided plane shape. It is said to be regular if all sides are equal and irregular when they are not. Only regular polygons are described here.



Regular Polygons

Triangles and quadrilaterals fit the description of a polygon and have been covered previously. Three other types of regular polygons are shown in the illustration. Each one is inscribed in a circle. This means that all vertices of the polygon lie on the circumference of the circle.

Note that the sides of each of the inscribed polygons are actually equal chords of the circumscribed circle. Since equal chords subtend equal arcs, by dividing the circumference into an equal number of arcs, a regular polygon may be inscribed in a circle. Also note that the central angles are equal because they intercept equal arcs. This gives a basic rule for the construction of regular polygons inscribed in a circle as follows:

To inscribe a regular polygon in a circle, create equal chords of the circle by dividing the circumference into equal arcs or by dividing the circle into equal central angles.

Dividing a circle into a given number of parts has been discussed, so construction should be no problem. Since there are 360 degrees around the center of the circle, you should have no problem in determining the number of degrees to make each equal central angle.

Problem:

What is the central angle used to inscribe a pentagon in a circle?

Solution:

$$\frac{360°}{5\ slides} = 72°\ in\ each\ circle$$

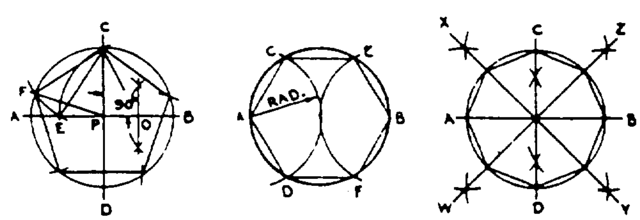
Methods for Constructing Polygons

The three methods for constructing polygons described here are the pentagon, the hexagon, and the octagon.

The **PENTAGON** is a method to develop the length of a side and departs from the rule given. Radius PB has been bisected to locate point O. Radius OC has been used to swing an arc CE from the center O. E is the intersection of arc CE with diameter AB. Chord CE is the length of the side and is transferred to the circle by arc EF using chord CE as radius and C as center.

The **HEXAGON** has been developed by dividing the circumference into 6 equal parts.

The **OCTAGON** method has been developed by creating central angles of 90° to divide a circle into 4 parts and bisecting each arc to divide the circumference into 8 equal parts,

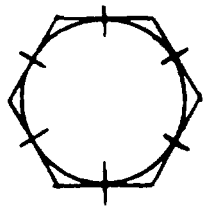


PENTAGON HEXAGON OCTAGON

Circumscribing a Regular Polygon about a Circle

Problem:

Circumscribe a hexagon about a given circle.



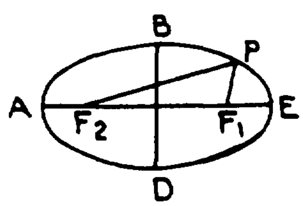
Solution:

Step 1. Divide the circumference into a given number of parts.

Step 2. At each division point draw a tangent to the circle. The intersection of the tangents forms vertices of the circumscribed polygon.

ELLIPSES

An ellipse is a plane shape generated by point P, moving in such a manner that the sum of its distances from two points, F_1 and F_2, is constant.



$BF_1 + PF_2 = C =$ (a constant)

AE is the major axis.

BD is the minor axis.

MATHEMATICAL SYMBOLS

Formulas, which are in effect statements of equality (equations), require the use of symbols to state the relationship between constants in any given set of conditions. To illustrate:

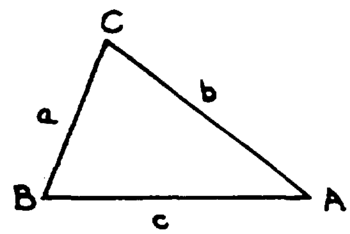
Consider triangle ABC.

Distance (D) around triangle ABC is equal to the sum of a, b, and c.

Expressed as a formula,

$$D = a + b + c$$

This formula would express the distance around a triangle regardless of conditions.



ADDITION AND SUBTRACTION OF MATHEMATICAL SYMBOLS

1. The sum of any two symbols, a and b, is written a + b.
2. The difference of any two symbols, a being the greater and b being the smaller, is written a -b.

MULTIPLICATION OF MATHEMATICAL SYMBOLS

1. The product of any two symbols, a and b, is written as a x b or ab.
2. The sum of any number of like symbols, such as a+ a + a + a, may be combined and written once, preceded by a numeral designating the number of times the symbol occurs, as 4a.

DIVISION OF MATHEMATICAL SYMBOLS

The quotient of any two symbols a and b where a is the dividend and b is the divisor maybe written a/b.

Summary

1. Addition

   a + b = sum

2. Subtraction

   a – b = difference

3. Multiplication

   a x b = ab = product

   a + a + a + a = 4a

4. Division

   a ÷ b = a/b = quotient

GROUPING—USE OF PARENTHESES

Occasionally a combination of symbols must be treated as a single symbol. When this occurs, the group is set apart by use of parentheses.

In order to symbolize 5 times the sum of a + b, you should write 5(a + b).

The quotient of a + b divided by 2 is written

$$\frac{(a + b)}{2}$$

REMOVAL OF COMMON FACTORS FROM AN EXPRESSION BY USE OF PARENTHESES

In the expression 2a + 2b + 2c: the common factor may be removed and the remainder combined in parentheses: 2(a + b + c) or in the following: 4ab + 2ac + 6ax.

All the terms contain the factor 2a. The expression may be changed to read 2a(2b + c + 3x).

Since the parentheses indicate that each term within is to be multiplied by the factor outside the parentheses, the parentheses may be removed by multiplying each term by the common factor.

Expression: 2x(2y + 3z + m)

Multiply: 4 x y + 6 x z + 2 x m

SUBSTITUTION OF NUMERICAL VALUES FOR GROUPED SYMBOLS

Consider the expression:

$$\frac{5(a + b)}{2}$$

This means to first: add a and b. Second: multiply the sum by 5. Third: divide the product by 2.

Assign numerical values to a and b.

Let a = 4 and b = 2.

Substitute:

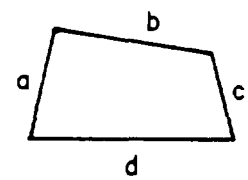
$$\frac{5(4 + 2)}{2} = \frac{5(6)}{2} = \frac{5 \times 6}{2} = \frac{30}{2} = 15$$

PERIMETERS AND CIRCUMFERENCES

Perimeter and circumference have the same meaning; that is, the distance around. Generally, circumference is applied to a circular object and perimeter to an object bounded by straight lines.

PERIMETER OF A POLYGON

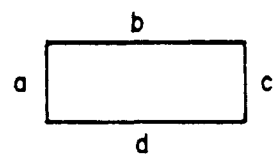
The perimeter of a triangle, quadrilateral, or any other polygon is actually the sum of the sides.



Write an equation for the perimeter(P) of the quadrilateral above.

P = a + b + c + d

If this figure were a rectangle,



the formula P= a + b + c + d would still apply, but since opposite sides are equal, we could substitute a for c and b ford and write

P = 2a + 2b

If the figure were a square, the formula would become:

P = 4 a

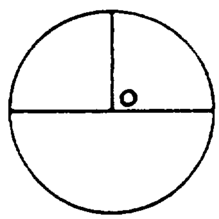
We may, by the same reasoning, establish that the formula for the perimeter of any regular polygon of n sides having a sides is:

P = n(s)

CIRCUMFERENCE OF A CIRCLE

Definition of Pi: Mathematicians have established that the relationship of the circumference to the diameter of a circle is a constant called Pi and written π. The numerical value of this constant is approximately 3.141592653. For our purpose 3.1416 or simply 3.14 will suffice.

The formula for the circumference of a circle is $C = \pi D$ where C is the circumference and D is the diameter since D = 2R where R is the radius, the formula may be written $C = 2\pi R$.



Given:

Diameter of circle O is 4".

Problem:

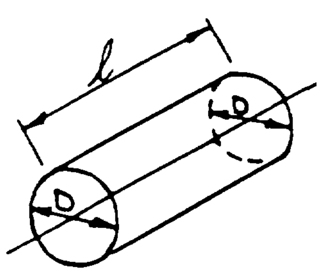
Compute the circumference.

Formula $C = \pi D$

$C = 3.1416 \times 4"$

$C = 12.5664'$

STRETCHOUT OF ROUND OBJECTS



Given:

Diameter of the round pipe= D

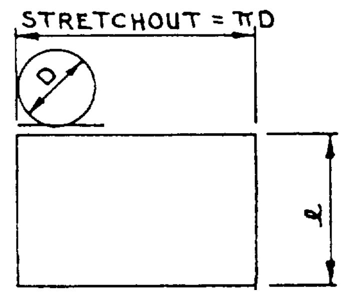
Length of the round pipe= 1

Problem:

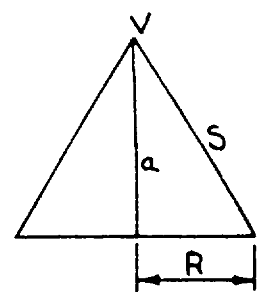
The size of flat sheet necessary to form pipe.

Solution:

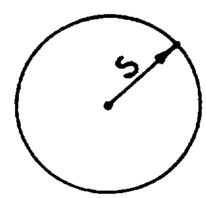
By formula the circumference of the end is πD. If this were rolled out, the stretchout would be πD.



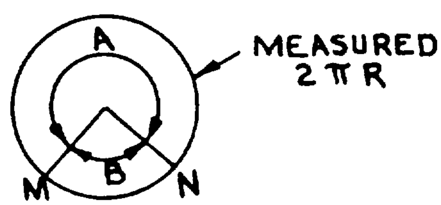
STRETCHOUT OF A RIGHT CIRCULAR CONE



The stretchout of a right circular cone will be a portion of a circle whose radius (S) is equal to the slant height of the cone.



To determine how much of the circle will be required for the cone, you measure on the circumference of this circle the circumference of a circle of radius R.

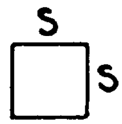


AREAS

All areas are measured in squares.

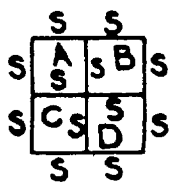
Illustration:

Let one side of a square be s.



This is a square s or s^2.

Ifs equals 1 inch then this would be 1 square inch. Ifs equals 1 foot then this would be 1 square foot, etc.

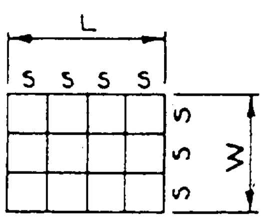


Consider the area of the above. The area of A is one square s or s^2; of B is s^2, etc. The area of the whole is A+ B+ C+ D = $s^2 + s^2 + s^2 + s^2 = 4s^2$. What is the length of one side? It is obviously 2s, so in the above the area is 2s x 2s = $4s^2$.

The area of a square is the product of two of its sides and since both sides are equal, it may be said to be the square of its side.

NOTE: The area of any plane surface is the measure of the number of squares contained in the object. The unit of measurement is the square of the unit which measures the sides of the square.

AREA OF A RECTANGLE



Establish a side of the small square as s and write the formula 3s x 4s = Area. But L = 4s and W = 3s, so our formula becomes

A = L x W

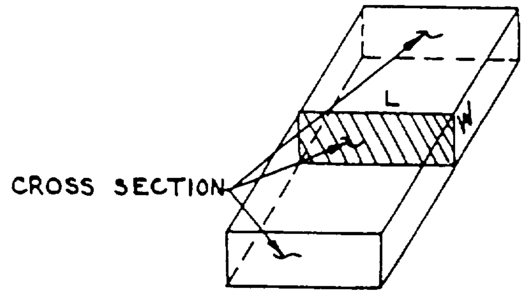
where

A = area of a rectangle

L = length of a rectangle

w = width of a rectangle

AREA OF A CROSS SECTION



The cross section of an object is a plane figure established by a plane cutting the object at right angles to its axis. The area of this cross section will be the area of the plane figure produced by this cut.

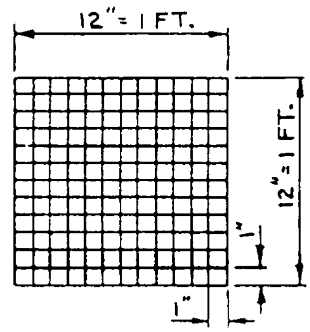
The area of the cross section is L x W.

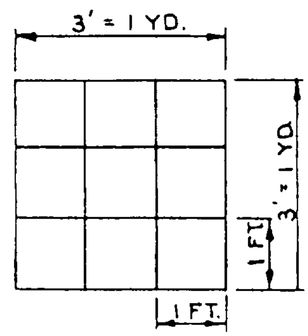
The most common units are square inches, square feet, square yards and in roofing, "squares."

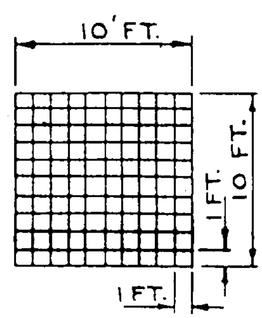
1 square foot = 144 square inches

1 square yard = 9 square feet

1 square of roofing = 100 square feet







COMMON CONVERSIONS

1. To convert square inches to square feet, divide square inches by 144.
2. To convert square feet to square inches, multiply by 144.
3. To convert square feet to square yards, divide by 9.
4. To convert square yards to square feet, multiply by 9.
5. To convert square feet to squares, divide by 100.

Example:

1. Convert 1,550 square inches into square feet.

$$144 \text{ sq in.} \overline{)1550 \text{ sq in.}} \quad = 10.76 \text{ sq ft}$$

2. Convert 15 square feet to square inches.

$$15 \text{ sq ft} \times 144 \text{ sq in.} = 2160 \text{ sq in.}$$

3. Convert 100 square feet to square yards.

$$9 \text{ sq ft} \overline{)100 \text{ sq ft}} \quad = 11.11 \text{ sq yd}$$

4. Convert 10.3 square yards to square feet.

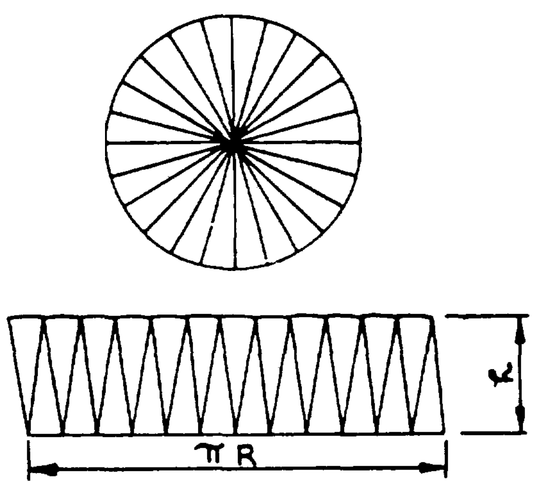
10.3 square yards **x** 9 square feet= 92.7 square feet

5. Convert 17,250 square feet to squares.

$$100 \text{ sq ft} \overline{)17250 \text{ sq ft}} \quad = 172.5 \text{ squares}$$

AREA OF A CIRCLE

Development of Formula:



The above demonstrates that a circle divided into a number of parts maybe laid out as a parallelogram. As the number of parts is increased, the longer side approaches 1/2 of the circumference; if divided into an indefinite number of parts, it would be equal to 1/2 the circumference. As the number increases, h approaches r and would be equal if the circle was divided into an infinite number of parts.

The areas of the parallelogram is

$$A = bh, \text{ but } b = \pi r$$
$$\text{so } A = \pi rh$$
$$\text{or } A = \pi r \times r$$

The formula for the area of a circle

$$A = \pi r^2$$

where

A = area of circle
r = radius of circle
π = 3.1416

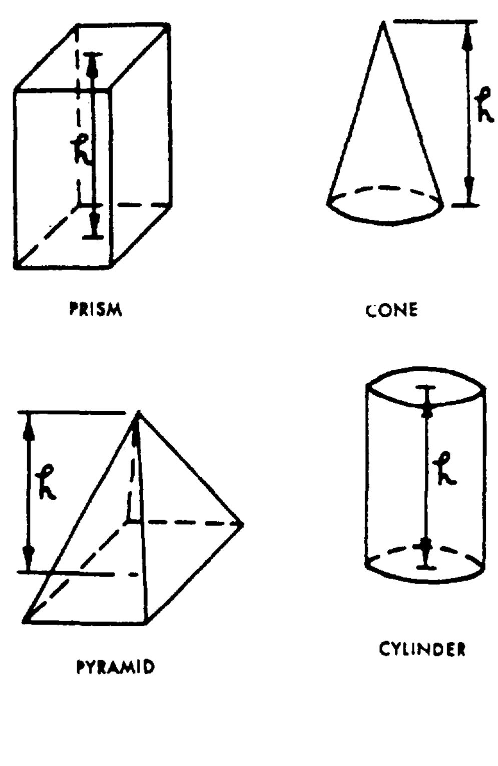
Since r = $d/2$ where d is the diameter of a circle, the formula for the area of a circle in terms of its diameter is

$$A = \pi\left(\frac{D}{2}\right)^2 = \frac{\pi d^2}{4}$$

GEOMETRIC SOLIDS

In describing plane shapes, you use only two dimensions: width and length; there is no thickness. By adding the third dimension, you describe a solid object.

Consider the solids shown below.



1. A **PRISM** is a figure whose two bases are polygons, alike in size and shape, lying in parallel planes and whose lateral edges connect corresponding vertices and are parallel and equal in length. A prism is a right prism if the lateral edge is perpendicular the base. The altitude of a prism is the perpendicular distance between the bases.

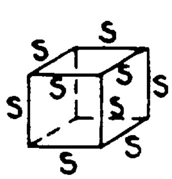
2. A **CONE** is a figure generated by a line moving in such a manner that one end stays fixed at a point called the "vertex." The line constantly touches a plane curve which is the base of the cone. A cone is a circular cone if its base is a circle. A circular cone is a right circular cone if the line generating it is constant in length. The altitude of a cone is the length of a perpendicular to the plane of the base drawn from the vertex.

3. A **PYRAMID** is a figure whose base is a plane shape bounded by straight lines and whose sides are triangular plane shapes connecting the vertex and a line of the base. A regular pyramid is one whose base is a regular polygon and whose vertex lies on a perpendicular to the base at its center. The altitude of a pyramid is the length of a perpendicular to the plane of the base drawn from the vertex.

4. A **CIRCULAR CYLINDER** is a figure whose bases are circles lying in parallel planes connected by a curved lateral surface. A right circular cylinder is one whose lateral surface is perpendicular to the base. (Note: Any reference in this text to a cylinder will mean a circular cylinder.) The altitude of a circular cylinder is the perpendicular distance between the planes of the two bases.

MEASUREMENT OF VOLUME

Volume is measured in terms of cubes,



This represents a cube of sides. The volume of this may be represented by S^3. Ifs equals l", then the volume would be 1 cubic inch, and ifs equals 1', then the volume would be 1 cubic foot, etc.

It can be said that the volume of an object is measured by the number of cubes contained in the object when one side of the cube is equal in length to some unit of linear measure.

COMMON VOLUME FORMULAS

All factors in the formulas must be in the same linear units. As an example, one term could not be expressed in feet while other terms are in inches.

Volume of a Rectangular Prism

$$v = 1 \times w \times h$$

where

v = Volume in cubic inches

w = width of the base in linear units

l = length of base in linear units

h = altitude of the prism in linear units

Example:

Find the number of cubic inches of water which can be contained by a rectangular can 5" x 6" x 10" high.

$$V = 1 \times w \times h$$

$$V = 5'' \times 6'' \times 10'' = 300 \text{ cubic inches}$$

Volume of a Cone

$$V = \frac{A \times h}{3}$$

$$\text{or } V = \frac{\pi r^2 h}{3}$$

$$\text{or } V = \frac{\pi d^2 h}{12}$$

where

V = Volume of a cone in cubic units

A = Area of the base in square units

h = Altitude of a cone in linear units

r = Radius of the base

d = Diameter of the base

Example:

Find the volume of a cone whose altitude is 2'6" and whose base has a radius of 10".

$$V = \frac{\pi r^2 h}{3} = \frac{\pi(10)^2\,(30)}{3} = \pi(1000)$$

= 3141.6 cubic inches

Volume of a Pyramid

$$V = \frac{Ah}{3}$$

where

V = Volume in cubic units

A = Area of a base in square units

h = Altitude in linear units

Example:

Find the volume of a rectangular pyramid whose base is 3" x 4" and whose altitude is 6".

Area of the base= 3 x 4 = 12 square inches

$$V = \frac{12 \times 6}{3} = 24 \textit{ cubic inches}$$

Volume of a Cylinder

$$V = Ah$$

$$\text{or } V = \pi r^2 h$$

$$\text{or } V = \frac{\pi d^2 h}{4}$$

where

V = Volume in cubic units

A = Area of the base in square units

h = Altitude in linear units

r = Radius of the base

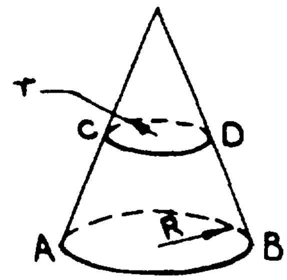
d = Diameter of the base

Example:

Find the volume of a cylindrical tank whose diameter is 9'6" and whose height is 11' 6".

$$V = \frac{3.1416(9.5)^2 \times 11.5}{4} = 815.15 \textit{ cubic feet}$$

Volume of the Frustum of a Right Circular Cone



The frustum of a cone is formed when a plane is passed parallel to the base of the cone. The frustum is the portion below base CD. The altitude of the frustum is the perpendicular distance between the bases.

$$V = 1/3\pi h(r^2 + R^2 + Rr)$$

where

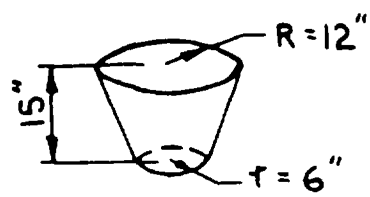
h = Altitude in linear units

r = Radius of the upper base in linear units

R = Radius of the lower base in linear units

Example:

Find the volume of a conical shaped container whose dimensions are indicated in the drawing.



$V = 1/3\pi h(r^2 + R^2 + Rr)$

$V = 1/3\pi 15(6^2 + 12^2 + 6 \times 12)$

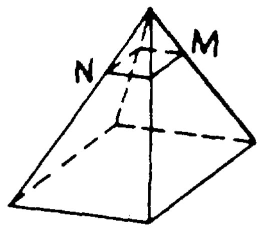
$V = 5\pi(36 + 144 + 72)$

V = 5x(252)

V = 3956.4 *cubic inches*

Volume of a Frustum of a Regular Pyramid

A frustum of a pyramid is formed when a plane is passed parallel to the base of the pyramid. The frustum is the portion below plane MN. The altitude is the perpendicular distance between the bases.



$$V = 1/3h(B + b + \sqrt{Bb})$$

where

V = Volume of the frustum in cubic units

h = Altitude in linear units

B = Area of the lower base in square units

b = Area of the upper base in square units

Example:

Find the volume of a frustum of a square pyramid if one side of its upper base is 2" and one side of the lower base is 8". The distance between the bases is 10".

The area of the bases will be

$B = (8)^2$

$b = (2)^2$

$V = 1/3 \times 10\,(8^2 + 2^2 + \sqrt{8^2 + 2^2})$

$V = 1/3x10[64+4+(8+2)]$

$V = 1/3x10(64+4+16)$

$V = 1/3x10x84$

$V = 280$ *cu in.*

Conversion of Units of Cubic Measure

It is often necessary to convert from one cubic measure to another. The conversion factors used are as follows:

1 cubic foot = 1,728 cubic inches

1 cubic yard= 27 cubic feet

1 cubic foot = 7.48 U.S. gallons (liquid measure)

1 U.S. gallon (liquid measure) = 231 cubic inches

1 bushel (dry measure) = 2,150.42 cubic inches

Example:

1. How many cubic feet are there in 4,320 cubic inches?

```
      2.5 cubic feet
1728|4320
     3456
      8640
      8640
```

To convert cubic inches to cubic feet, divide by 1,728.

2. How many cubic inches are there in 3.5 cubic feet?

```
1728
 3.5
8640
5184
6048.0 cubic inches
```

To convert cubic feet to cubic inches, multiply by 1,728.

3. How many cubic yards are there in 35 cubic feet?

```
     1.29
27|35.00
   27
    80
    54
    260
    243
     17
```

To convert cubic feet to cubic yards, divide by 27.

To convert cubic yards to cubic feet, multiply by 27.

4. How many gallons are contained in a tank having a volume of 25 cubic feet?

```
 7.48
   25
 3740
1496
187.00 gallons
```

To change cubic feet to,gallons, multiply by 7.48.

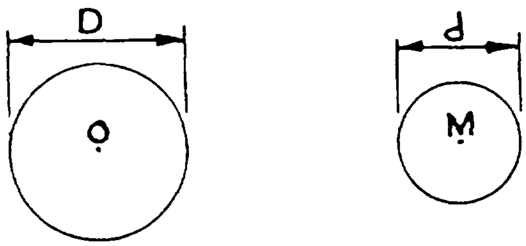
To change gallons to cubic feet, divide by 7.48.

RATIO

The ratio of one number to another is the quotient of the first, divided by the second. This is often expressed as a:b, which is read the ratio of a to b. More commonly, this is expressed as the fraction a/b.

Ratio has no meaning unless both terms are expressed in the same unit by measurement.

Example:



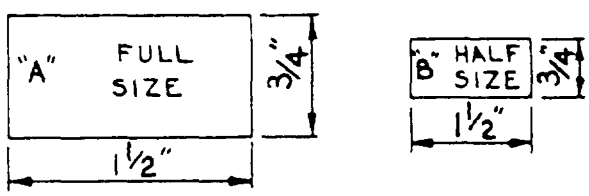
What is the ratio of the diameter of circle O to circle M? This ratio is D:d or D/d. If the diameter of O is 3 inches and the diameter of M is 1.5 inches, then the ratio of the diameters of circle O and circle M would be 3/1.5 or 2/1 (read “ratio of two 1 to one”).

What is the ratio of the diameter of circle M to the diameter of circle O?

RATIO APPLIED TO SCALE DRAWINGS

Since it is not always possible to make a drawing full size, the size of the drawing maybe made in a given ratio to the full size of the object.

Example:



In the above example, A represents the object in its full size and B represents a drawing one-half size. The ratio of the drawing B to object A is one to two. (1/2) (1:2)

Drawings may be commonly “scaled down” by the use of the following ratios:

Let:

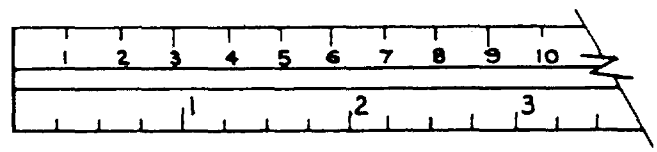
1/4 = 1'0" or a ratio of (1/48) or (1 to 48)

1/8” = 1'0" or a ratio of (1/96) or (1 to 96)

3 = 1'0" or a ratio of (1/4) or (1 to 4)

3/8 = 1'0" or a ratio of (1/32) or (1 to 32)

CIRCUMFERENCE RULE



The above illustration shows a portion of a circumference rule. This is an example of the application of a ratio. The upper edge of the rule is graduated in such a manner that one inch on the upper scale is in the ratio of 3.1416 to 1 on the lower scale. This is in the ratio of the circumference of a circle to its diameter, so that any diameter can be converted to a circumference or vice versa by reading directly across the rule.

In sheet metal pattern development, effective use can be made of the circumference rule. By using the circumference side, you can lay out the development of large objects. After making the layout, you can make the development of the pattern full size.

PERCENTAGE

Percentage (%) is a way of expressing the relationship of one number to another. In reality, percentage is a ratio expressed as a fraction in which the denominator is always one hundred.

Example:

The ratio of 6 to 12, expressed as %:

$$.2\overline{)6.0}\quad = .5$$

The ratio of 6 to 12 may be expressed as .5 or 1. To change to %, move the decimal two places to the right.

$$\frac{.5}{1} = \frac{50}{100} = 50\%$$

This means there are 50 parts to 100.

From a galvanized iron sheet weighing 46 1/4 pounds, an "ell" and one section of pipe were produced which weighed 30 pounds. Find the percentage of the scrap.

40 1/4	total weight
−30	amount used
16 1/4	weight of scrap

$$\frac{16\ 1/4}{46\ 1/4} = .351 = 35.1\%$$

PROPORTION

Proportion is a statement of two ratios which are equal.

Example:

1/3=5/15 or 1:3=5:15

$$\frac{r}{3} = \frac{3r}{9} = r{:}3 = 3r{:}9$$

SOLVING PROPORTIONS

Given the proportion:

$$\frac{a}{b} = \frac{c}{d}$$

by cross multiplying: a x d = b x c

Example:

If 50 sheets of galvanized iron weigh 2,313 pounds, how much will 39 sheets weigh?

Let W = weight of 39 sheets

$$\frac{39}{50} = \frac{W}{2313}$$

CROSS MULTIPLY

$$50 \times W = 39 \times 2313$$

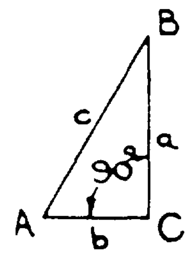
$$W = \frac{39 \times 2313}{50} = 1804.14$$

THE LAW OF PYTHAGORAS

The Law of Pythagoras is the square of the hypotenuse of a right triangle equals the sum of the squares of the two legs. It is expressed by the formula $a^2 + b^2 = c^2$.

1. **RIGHT TRIANGLE—** triangle having one right angle.
2. **HYPOTENUSE—** The hypotenuse of a right triangle is the side opposite the right angle.
3. **LEG—** The leg of a right triangle is a side opposite an acute angle of a right triangle.

Δ ABC is a right triangle.



$\angle$ C is a right angle.

c is side opposite $\angle$ C and is the hypotenuse.

a is side opposite $\angle$ A and is a leg.

b is side opposite $\angle$ B and is a leg.

According to the Law of Pythagoras:

$$a^2 + b^2 = c^2$$

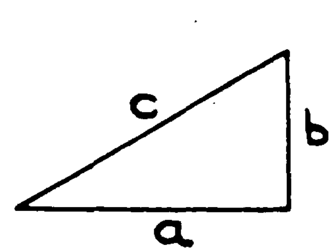
or by subtracting b^2 from both sides

$$a^2 = c^2 - b^2$$

or by subtracting a^2 from both sides

$$b^2 = c^2 - a^2$$

Example:



1. Given: a = 10; b= 7

Problem: find c.

$$a^2 + b^2 = c^2$$

$$10^2 + 7^2 = c^2$$

$$c^2 = 100 + 49$$

$$c = \sqrt{149} = 12.2$$

2. Given: C = 50; b = 40

Problem: find a

$$a^2 = c^2 - b^2$$

$$a^2 = 2500 - 1600$$

$$a^2 = 900$$

$$a = 30$$

3. Proof of a 3,4,5 triangle.

A right triangle can be constructed by making the sides 3, 4, and 5. We can prove it by the Law of Pythagoras.

$$a^2 + b^2 = c^2$$

$$3^2 + 4^2 = 5^2$$

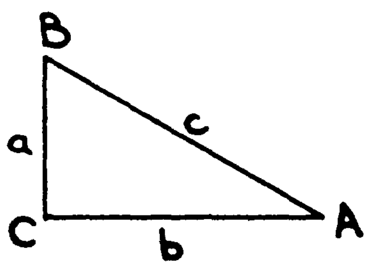
$$9 + 16 = 25$$

$$25 = 25$$

Since values of 3,4, and 5 satisfy the equation, we may conclude that the statement above is correct.

4. Application of the Law of Pythagoras

Given a right triangle ABC:



Prove that the area of a circle of a diameter of side c is equal to the sum of the areas of circles whose diameters are sides a and b.

area circle diameter c = area circle diameter a + area circle diameter b.

$$\text{area circle } c = \frac{\pi c^2}{4}$$

$$\text{area circle } a = \frac{\pi a^2}{4}$$

$$\text{area circle } b = \frac{\pi b^2}{4}$$

Then:

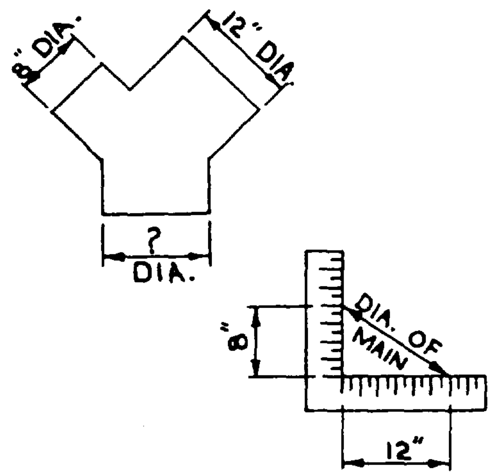
$$\frac{\pi c^2}{4} = \frac{\pi a^2}{4} = \frac{\pi b^2}{4}$$

$$c^2 = a^2 + b^2 \left[\text{multiply both sides by} \left(\frac{4}{\pi}\right)\right]$$

Since this is the rule of the right triangle, the above statement is true.

Example:

In the Y branch shown, the areas of the two branches must equal the area of the main. By the above proof, if the two known diameters are considered to be legs of a right triangle, the hypotenuse will be the diameter of the main.



APPENDIX III

METRIC CONVERSION TABLE

ENGLISH AND METRIC SYSTEM UNITS OF MEASUREMENT
COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number × Factor	
1 inch	= 25 millimeters	in × 25.4*	= mm
1 foot	= 0.3 meter	ft × 0.3048*	= m
1 yard	= 0.9 meter	yd × 0.9144*	= m
1 mile†	= 1.6 kilometers	mi × 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 × 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 × 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 × 0.836127	= m^2
1 acre	= 0.4 hectare	acres × 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 × 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 × 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 × 0.764555	= m^3
1 quart (1q.)	= 1 liter	qt (1q.) × 0.946353	= *l*
1 gallon	= 0.004 cubic meter	gal × 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) × 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) × 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp × 0.745700	= kW
1 pound per square inch	= 0.97 kilogram per square centimeter	psi × 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm × 0.0393701	= in
1 meter	= 3.3 feet	m × 3.28084	= ft
1 meter	= 1.1 yards	m × 1.09361	= yd
1 kilometer	= 0.6 mile	km × 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 × 0.155000	= in^2
1 square meter	= 11 square feet	m^2 × 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 × 1.19599	= yd^2
1 hectare	= 2.5 acres	ha × 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 × 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 × 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 × 1.30795	= yd^3
1 liter	= 1 quart (1q.)	*l* × 1.05669	= qt (1q.)
1 cubic meter	= 250 gallons	m^3 × 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g × 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg × 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW × 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 × 14.223226	= psi

†nautical mile = 1.852 kilometers

* exact

APPENDIX IV

HAND SIGNALS

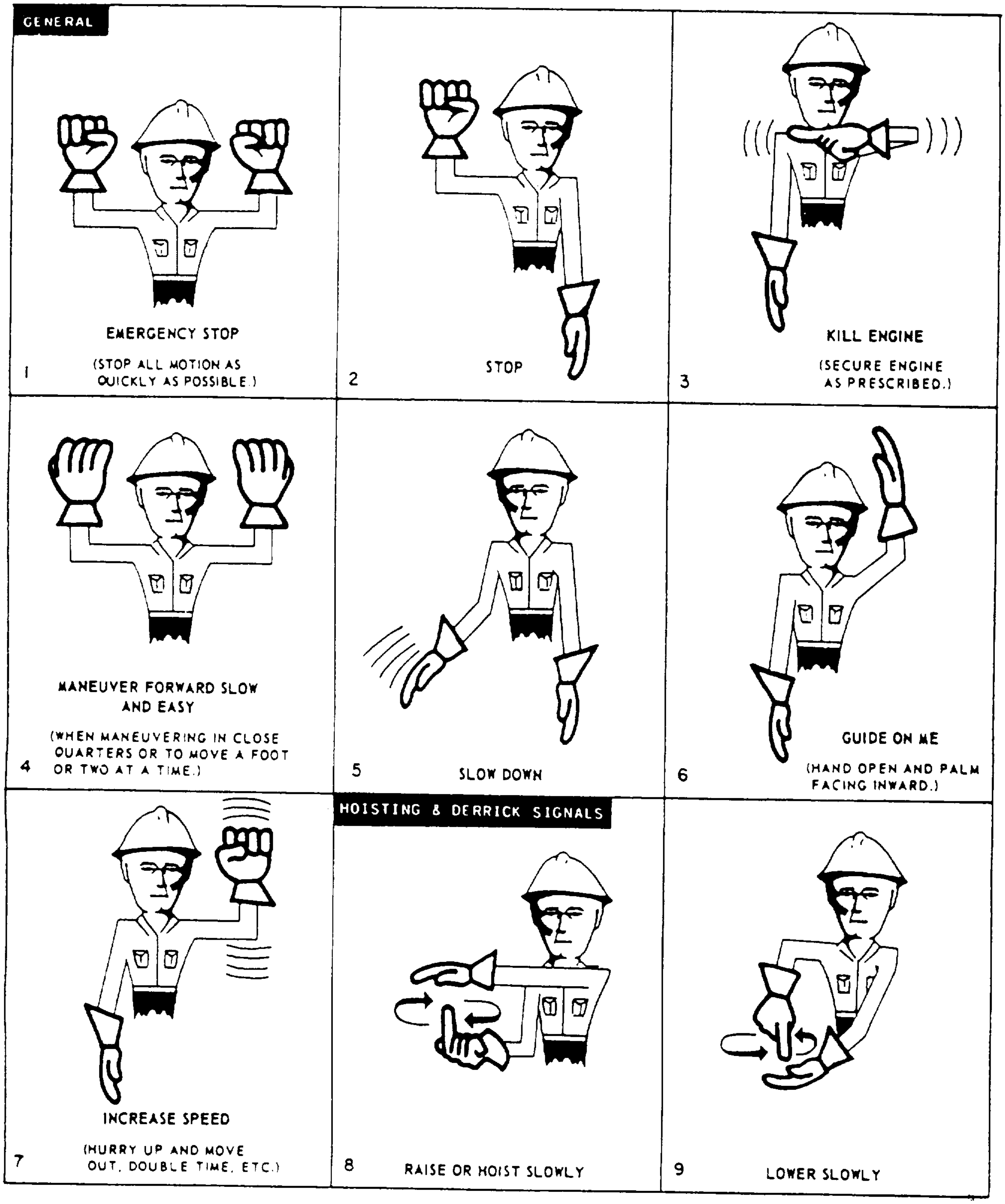


Figure AIV-1.—Hand signals.

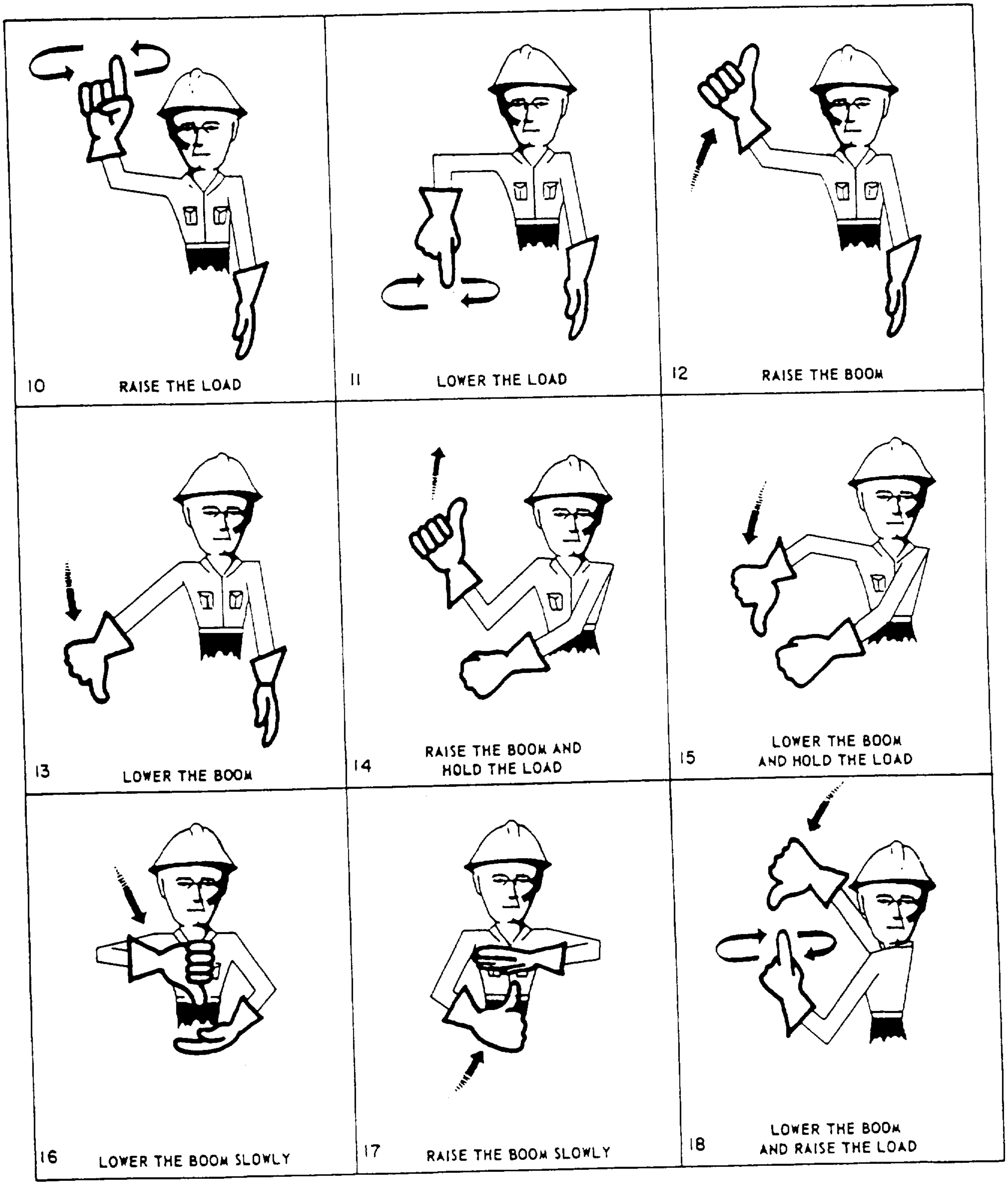
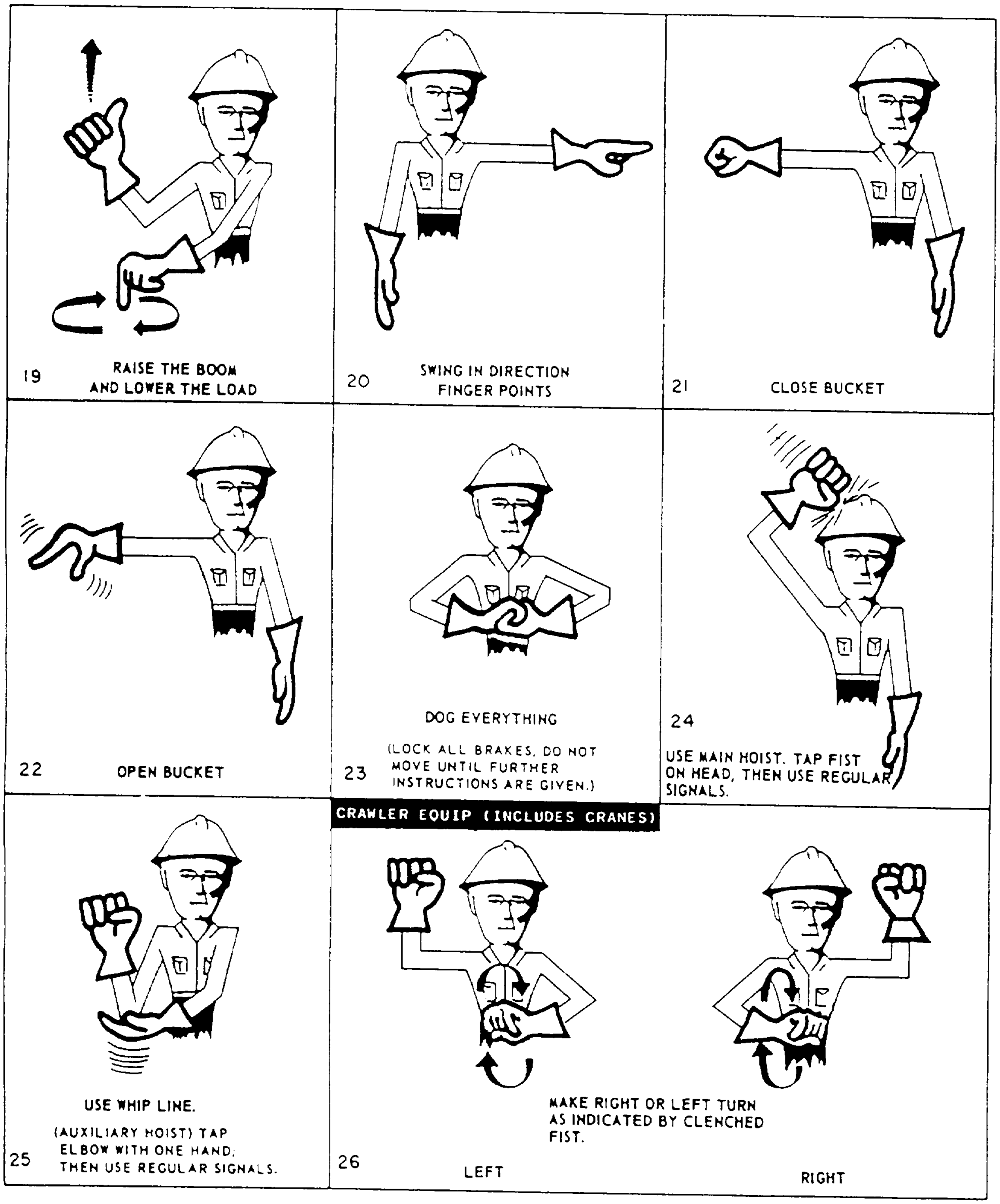


Figure AIV-1.—Hand signals—Continued.



F]gure AIV-1.—Hand signals.—Continued.

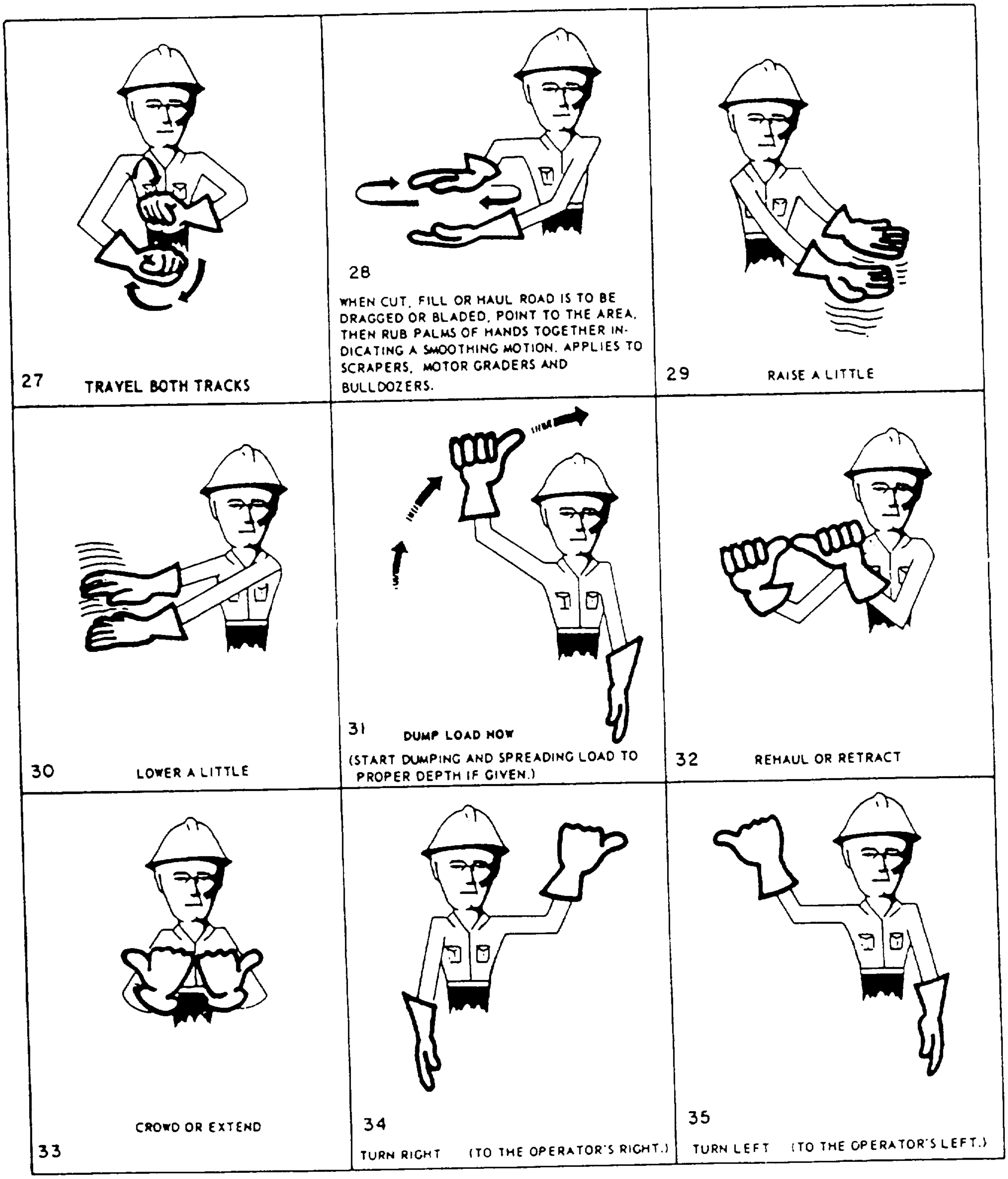


Figure AIV-1.—Hand signals—Continued.

APPENDIX V

REFERENCES USED TO DEVELOP THIS TRAMAN

Chapter 1

Crew Leader's Handbook, 5200X, Commander, Naval Construction Battalions, U.S. Pacific Fleet, Pearl Harbor, HI, 1992.

General Safety Requirements Manual, EM 385, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

Naval Construction Force Manual, NAVFAC P-315, Naval Facilities Engineering Command, Alexandria, VA, 1985.

Naval Construction Force Safety Manual 5100.23 series, Commander, Naval Construction Battalions, U.S. Atlantic Fleet, Norfolk VA, 1992.

Occupational Safety and Health for the Construction Industry (29 CFR, 1926/1910), 1985.

Operations Officer's Handbook, COMCBPAC/COMCBLANTINST 5200.2A, Commander, Naval Construction Battalions, U.S. Pacific Fleet, Pearl Harbor, HI, and Commander, Naval Construction Battalions, U.S. Atlantic Fleet, Norfolk, VA, 1988.

Personnel Readiness Capability Program Standards and Guides, Naval Facilities Engineering Command, Alexandria, VA, 1983.

Seabee Planner's and Estimator's Handbook, NAVFAC P-405, Change 3, Naval Facilities Engineering Command, Alexandria, VA, 1983.

Seabee *Supply Manual,* COMCBPAC/COMCBLANTINST 4400.3A Ccmmander, Naval Construction Battalions, U.S. Pacific Fleet, Pearl Harbor, HI, and Commander, Naval Construction Battalions, U.S. Atlantic Fleet, Norfolk, VA 1987.

Chapter 2

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education Training Program Management Support Activity, Pensacola FL, 1988.

Budzik Richard, S., 'Fittings Used Today that Require Triangulation Including the 'Theory of Triangulation" *Practical Sheetmetal Layout, Practical* Publications, Chicago, IL, 1971.

Budzik, Richard, S., "Round Fittings Used Today including Methods and Techniques of Fabricating Round Work" *Practical Sheetmetal Layout,* Practical Publications, Chicago, IL, 1971.

Budzik, Richard, S., "Today's 40 Most Frequently-Used Fittings, " *Practical Sheetmetal Layout,* Practical Publications, Chicago, IL, 1971.

Heating, Ventilation, Air Conditioning and Sheetmetal Work, TM-745, Headquarters Department of the Army, Washington, DC, 1968.

Johnston, Philip, M., *Sheet Metal,* Volumes 1-4, Delmar Publishers Inc., Albany, NY, 1966.

Tools and Their Uses, NAVEDTRA 10085-B2, Naval Education and Training Program Management Support Activity, Pensacola, FL, 1988.

Walker, John, R., Modern Metalworking, Goodheart-Wilcox Company Inc., South Holland, IL, 1973.

Chapter 3

Frankland, Thomas, W., The *Pipefitter's and Pipe Welder's Handbook,* Glenco Publishing Company, Encino, CA, 1969.

Nelson, Carl, A., *Millwright's and Mechanic's Guide, 2d* ed., Theodore Audel and Company, Indianapolis, IN, 1972.

The *Oxy-Acetylene Handbook,* 2d ed., Linde Company, New York NY, 1960.

Walker, John, R., *Modern Metalworking,* Goodheart-Wilcox Company Inc., South Holland, IL, 1973.

Chapter 4

Rigging, TM 5-725, Headquarters Department of the Army, Washington, DC, 1968.

Rigging Manual, 1lth ed., Construction Safety Association of Ontario, Toronto, Canada, 1990.

Chapter 5

Rigging, TM 5-725, Headquarters Department of the Army, Washington, DC, 1968.

Rigging Manual, 1lth ed., Construction Safety Association of Ontario, Toronto, Canada, 1990.

Chapter 6

Rigging, TM 5-725, Headquarters Department of the Army, Washington, DC, 1968.

Rigging Manual, 1lth ed., Construction Safety Association of Ontario, Toronto, Canada, 1990.

Chapter 7

Builder 3 and 2, NAVEDTRA 10646, Volume 1, Naval Education and Training Program Management Support Activity, Pensacola FL, 1985.

Consolidated *Cross-Reference, TA13,* Department of the Navy, Navy Facilities Engineering Command, Alexandria, VA, 1989.

Concrete and Masonry, FM-742, Headquarters Department of the Army, Washington, DC, 1989.

Construction Print Reading in the Field, TM 5-704, Headquarters Department of the Army, Washington, DC, 1969.

Placing Reinforcing Bars, 5th ed., Concrete Reinforcing Steel Institute, Schaumburg, IL, 1986.

Reinforcing Bar Detailing, 3d ed., Concrete Reinforcing Steel Institute, Schaumburg, IL, 1988.

Safety and Health Requirements Manual, EM 385-1-1, Department of the Army, Washington, DC, 1987.

Chapter 8

Facilities Planning Guide, NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, VA, 1990.

Naval Construction Battalion Table of Allowance, TA-01, Department of the Navy, Naval Facilities Engineering Command, Alexandria, VA, 1987.

MIC-120 ABM (K-Span), Training and Operator Manuals, MIC Industries, Reston, VA, 1993.

Chapter 9

Facilities Planning Guide, NAVFAC P-437, Volume 2, Naval Facilities Engineering Command, Alexandria, VA, October 1982.

Naval Construction Battalion Table of Allowance, TA-01, Department of the Navy, Naval Facilities Engineering Command, Alexandria, VA, 1987.

Tank, Steel Vertical Bolted Knockdown Sealed Openings Standard Bottom and Roof TM 5-9788-1, Headquarters Department of the Army, Washington, DC, 1956.

Chapter 10

Pontoon System Manual, NAVFAC P-401, Department of the Navy, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Chapter 11

AM-2 Airfield Landing Mat and Accessories, NAVAIR 51-60A-1, Change 5, Commander, Naval Air Systems Command, Washington, DC, 1993.

Chapter 12

Steelworker 3 &2, NAVEDTRA 10652-F, Naval Education and Training Program Management Support Activity, Pensacola FL, 1977.

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