Figure 9-33 – Steps in K-SPAN construction.

2.1.7 ABM 240

There is another type of K-SPAN building, actually referred to as a Super Span by the manufacturer, the ABM 240. Even though it can use heavier coil stock and is a larger version, the construction of the ABM 240 is the same as that for the ABM 120 (K-SPAN). *Figure 9-34* shows the differences between the two.

Figure 9-34 – ABM System 120 and 240 comparison chart.

Figure 9-35 shows the differences in crew size due in large part to the heavier gauge steel required by the ABM 240. Keep in mind that the information provided in this section on the K-SPAN building is basic. During the actual construction of this building, you must consult the manufacturer's complete set of manuals.

Figure 9-35 – Determining crew size for ABM 240.

Table 9-6 – Chart for determining crew size for ABM 240.

Loads		Steel Required		Maximum Forces in Arch		Maximum Arch Reactions per Foot at Foundation					
Live	Wind	Thickness & Grade		Axial	Moment	Horizontal (Lb)		Vertical (Lb)		Moment (In-Lb)	
		Top	End	(Lb)	(In-Lb)	+	-	+	-	+	-
0	50	.023D	.023C	133	-7462	135	-47	94	-70	805	-7462
0	60	.029D	.023C	199	-10854	201	-74	145	-88	1015	-10854
0	70	.035D	.023C	280	-14868	280	-108	207	-106	1224	-14868
0	80	.045C	.023C	367	-19459	367	-143	273	-137	1576	-19459
10	50	.023D	.023C	-341	7800	252	-252	94	-250	7800	-7794
10	60	.029D	.023C	-360	-10854	265	-265	145	-268	8006	-10854
10	70	.035D	.023C	-380	-14868	280	-277	207	-287	8209	-14868
10	80	.045C	.023C	-414	-19459	367	-298	273	-317	8570	-19459
20	50	.023D	.023C	-649	15212	482	-482	94	-467	15195	-15212
20	60	.029D	.023C	-649	15212	482	-482	145	-467	15195	-15212
20	70	.035D	.023C	-649	15212	482	-482	207	-467	15195	-15212
20	80	.045C	.023C	-680	-19459	503	-503	273	-597	15565	-19459
30	50	.045D	.023C	-950	22559	708	-708	43	-678	22559	-22537
30	60	.045D	.023C	-950	22559	708	-708	108	-678	22559	-22537
30	70	.045D	.023C	-950	22559	708	-708	184	-678	22559	-22537
30	80	.045D	.023C	-950	22559	708	-708	273	-678	22559	-22537
40	50	–	–	–	–	–	–	–	–	–	–
40	60	–	–	–	–	–	–	–	–	–	–
40	70	–	–	–	–	–	–	–	–	–	–
40	80	–	–	–	–	–	–	–	–	–	–

Steel Weights (Lb)						
Thickness (inch)	.023	.026	.029	.035	.041	.045
Arch weight* (lb)	140	158	176	213	249	274
End wall weight	1590	1798	2005	2420	2835	3112

NOTE

The arch weight shown above can be divided by 50 pounds (22.7 kg) carrying load per person to determine the number of workers required to transport each arch from the curved runout tables to the pre-staging area.

2.2.0 Towers and Bunkers

Towers are framework structures designed to provide vertical support. They may be used to support another structure, such as a bridge, or a piece of equipment, such as a communication antenna, or to serve as a lookout post or weapons mount. Since the prime purpose of a tower is to provide vertical support for a load applied at the top, the compression members providing this support are the only ones that require high-structural strength. The rest of the structure is designed to stiffen the vertical members and to prevent bending under load. Primarily, the bracing members are designed to take loads in tension and are based on a series of diagonals. Typical trestle towers used for observation are shown in *Figure 9-36*.

Bunkers are fortified shelters built partly or entirely below ground, with framework designed to provide protection against certain incoming munitions. *Figure 9-37* shows an example of a standard bunker constructed under contingency operations.

Training for tower and bunker construction is provided by each regiment during their CCCT.

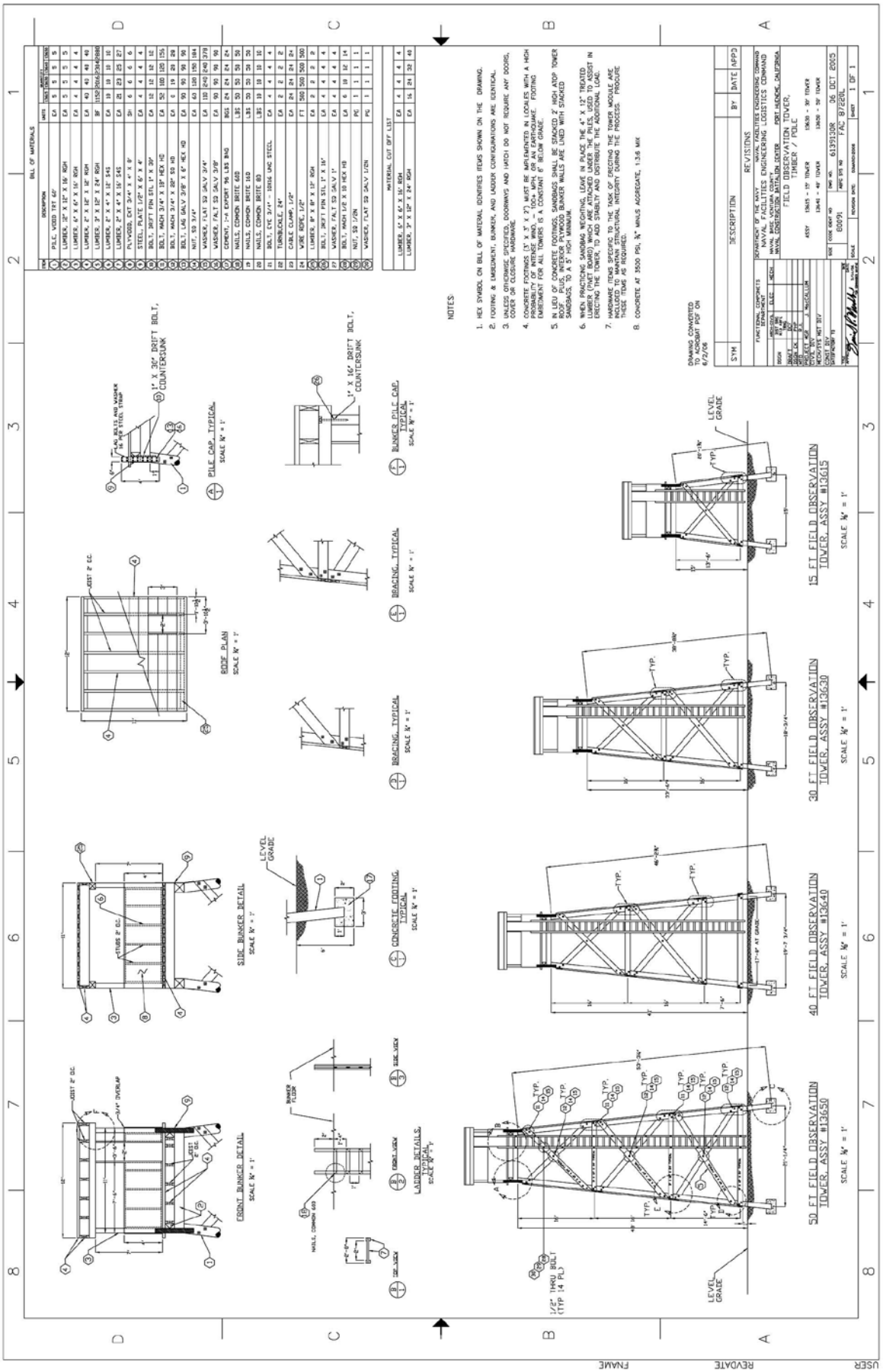

Figure 9-36 – Tower.

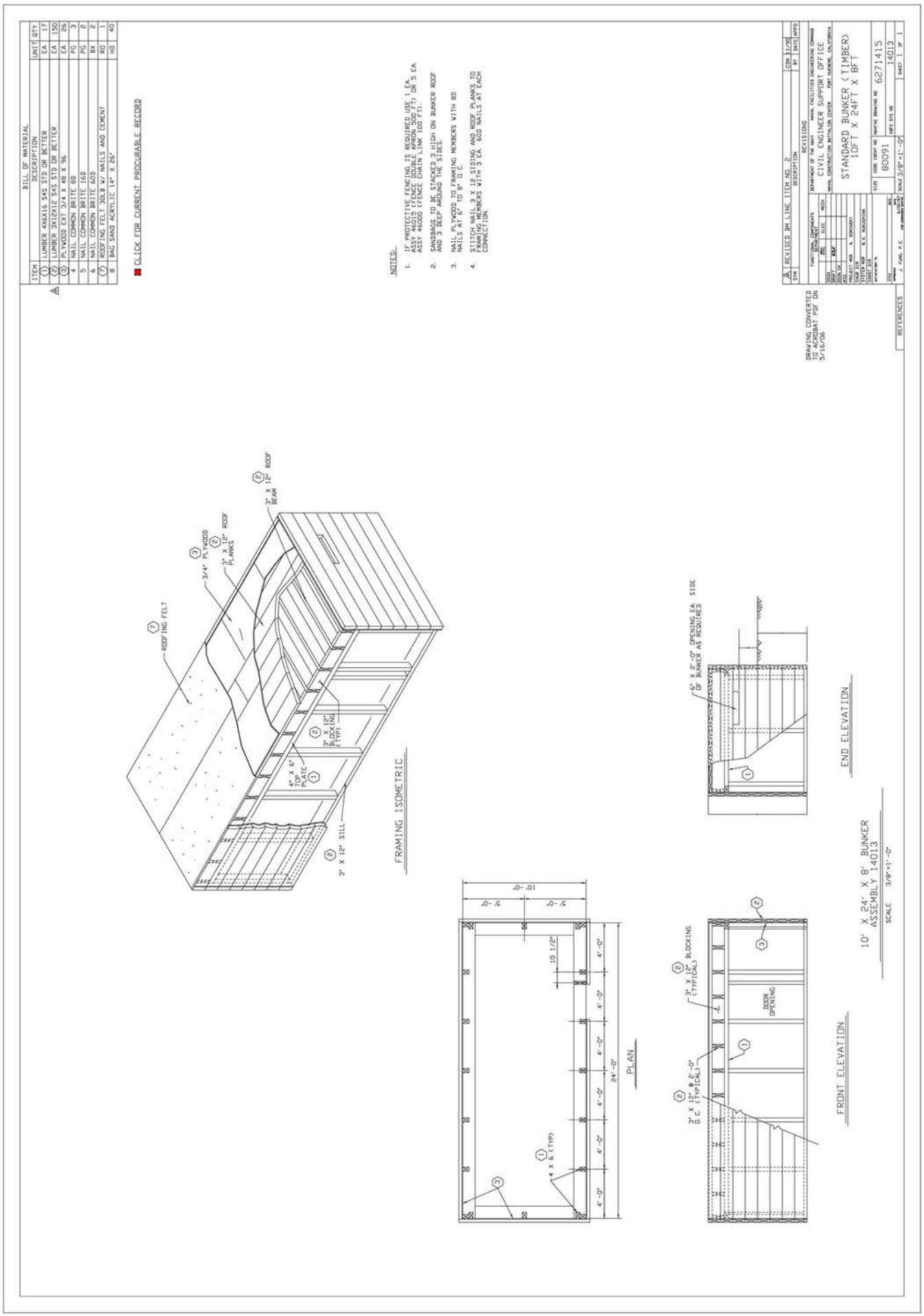

Figure 9-37 – Bunker.

3.1.1 NATURAL DISASTER RECOVERY OPERATIONS

In addition to their construction responsibilities, the Seabees are also tasked to help in humanitarian operations, providing disaster control and recovery measures in the event of natural disasters, such as the following:

- Hurricane (Atlantic Region) /Typhoon (Pacific Region)
- Flood/Tsunami
- Earthquake
- Tornado
- Major fires (such as forest fires that imminently endanger populated areas)
- Other disasters which may be decreed as a national emergency by the President of the United States or other officials authorized to declare emergencies and activate a military response

All actions taken by the NCF in response to a natural disaster are dedicated to reduce, prevent, and repair damage. Certain measures can be taken by the NCF to prepare for these types of potential disasters:

- Maintain emergency communication equipment in a state of readiness.
- Identify shelter areas designed to withstand specific types of disasters within those geographical areas that are prone to them.
- Advance stockpiling of critical materials, such as food, water, medicinal supplies, and basic creature comfort items (blankets, soap, emergency clothing, etc.).
- Maintain copies of the local Disaster Preparedness Plan within each department of a unit.
- Maintain an active disaster recovery organization and make sure all personnel are fully aware of what is expected of them. When they are assigned to recovery teams, ensure that training has been accomplished.
- Identify and maintain a listing of CESE and of operators required for each type of disaster response.

Each NCF unit is responsible for disaster control measures to protect its own personnel, equipment, campsites, and jobsites.

The standard organization of an NCF unit makes it a highly effective disaster control and recovery unit. These units must be prepared to give direct assistance to any military installation or civilian community to assist in returning conditions to as near normal as possible after a natural disaster occurs.

4.1.1 WAR DAMAGE REPAIR

When naval facilities are damaged by military action, they must be repaired to operational use in the shortest time possible. The United States has a policy of maintaining a forward defense strategy which contributes significantly to allied solidarity. Advanced basing is provided to support any deployed force. The NCF is tasked to establish and man the forward logistics support facilities to ensure sustainability of the operational forces according to the naval maritime strategy. This strategy identifies war damage repair as a critical NCF capability. The list of critical war damage repair capabilities shown below is not all-inclusive. It is only an example of some of the tasks

that may be assigned to the NCF in the event of conflict or attack upon the facilities of the United States or its allies.

- Airfields and operational facilities
- POL pipelines
- Fuel storage areas
- Fleet hospital facilities
- Piers and wharf facilities
- Railroad facilities that support fleet operations
- Communication facilities

OPNAVINST 3501.115C is the required operational capabilities and the projected operational environment (ROC/POE) which describes the major identifiable tasks that the NCF is expected to accomplish. The above listing is only a few of the many items identified by the ROC and POE.

Materials, procedures, and techniques for rapid repair of bomb-damaged airfield runways and taxiways have been under development for several years. The need for such developments has grown because of the substantial increase in the diversity and lethality of both air-launched and surface-launched weapons, capable of inflicting damage on airfield runways and taxiways.

As part of the mobilization planning process of the Navy, the NCF has developed standard units of material, personnel, and equipment to perform specific combat-related functions at advanced naval bases. Advanced base functional component (ABFC) P-36 is the functional component for use in performing rapid runway repair tasks. The ABFC P-36 rapid runway repair component contains the material and equipment required for the repair of bomb craters using specified types of earthmoving and earthworking equipment for crater cleanout, backfilling, grading, and compaction. Traffic surface panels, emplaced over the repaired craters, are fabricated from the following:

- Prefabricated panels of AM-2 matting
- On-site assembled traffic surface panels prepared from prefabricated bolt-together panels
- On-site preparation of fiberglass mats

Typically, ABFC P-36 is provided to an advanced naval airbase located in friendly territory for rapid runway repair. ABFC P-36 is also included with the ABFCs to be deployed with the NCF participating in the seizure, construction, and occupation of an advanced naval airbase in enemy territory.

All U.S. military services have evaluated rapid runway repair extensively. Presently, the U.S. Navy incorporates the methods and standards set forth in *U.S. Air Force Regulation 93-12* (AFR-93-12), which furnishes detailed guidance for rapid runway repair. This regulation lists and defines the use of specific equipment, materials, and manpower requirements necessary to repair a war-damaged runway. Air Force regulations of this type are similar in format and purpose to a U.S. Navy Instruction.

Other than the ABFC Component P-36, other facilities within the ABFC system for rapid repair of airfield support are as follows:

- Facility 121 OOWD – War damage repair kit for aircraft fuel station

- Facility 124 OOWD – War damage repair kit for ready-fuel storage
- Facility 125 OOWD – War damage repair kit for POL pipeline
- Facility 136 OOWD – War damage repair kit for airfield

When the previous facilities are incorporated with the P-36 and P-25 components, it greatly enhances the capability of the NCF to respond to a hostile action scenario directed against the United States or allied air facilities.

Summary

You have learned the principles involved in the use of the Advanced Base Functional Component system as well as the procedures used in the construction of field structures. In addition, you were provided information about the NCF's role in natural disaster recovery operations and war damage repair. This knowledge will help you provide the leadership necessary for effective Seabees' construction support in these contingency operations.

Review Questions (Select the Correct Response)

1. An ABFC system does NOT include which group?

   A. Component
   B. Facility
   C. Assembly
   D. Supply

2. Component Site Plans are contained in what part of the ABFC/TOA system?

   A. ABFC/TOA Component View
   B. ABFC/TOA General Data
   C. Facility/Group Component View
   D. Facility/Group General Data

3. You have the NSN for an assembly that you want to design and need the line item requirements. In this situation, you should refer to what part of the ABFC/TOA system?

   A. Assembly View
   B. ABFC/TOA Component View
   C. Facility/Group Component View
   D. All of the above

4. In NAVFAC P-72, what is the category code for Hospital and Medical?

   A. 100
   B. 300
   C. 500
   D. 700

5. **(True or False)** An ABFC building can be tailored to meet your specific needs.

   A. True
   B. False

6. ABFC assemblies required only in the North Temperate Zone are coded with what letter?

   A. A
   B. C
   C. N
   D. T

7. For which use is a K-Span building NOT designed?

   A. Office space
   B. Hangar
   C. Supply building
   D. Sports arena

8. What nomenclature is used to identify the two types of K-Span building machines?

   A. MIC 120 and MIC 240
   B. MIC 250 and MIC 260
   C. MIC 360 and MIC 380
   D. MIC 400 and MIC 410

9. The P-240 panel-forming machine produces what type of units for a K-span building?

   A. L spans
   B. Straight panels
   C. I spans
   D. Doorframes

10. The design of the foundation for a K-Span building does NOT depend on the _.

    A. size of the building
    B. existing soil conditions
    C. wind load
    D. local construction rules

11. **(True or False)** Towers are designed to provide horizontal support.

    A. True
    B. False

12. Seabees are tasked to help in humanitarian operations, providing disaster control and recovery measures in the event of natural disasters such as _.

    A. hurricanes, floods, and earthquakes
    B. floods, tornadoes, and fires
    C. earthquakes, typhoons, and monsoons
    D. plagues and volcanic eruptions

13. What publication describes the major identifiable tasks that the NCF is expected to accomplish?

    A. NAVFAC P-72
    B. NAVFAC P-405
    C. OPNAVINST 3501.115
    D. OPNAVINST 3501.118

14. Traffic surface panels are fabricated from which material?

    A. Prefabricated panels of AM-2 matting
    B. On-site assembled traffic panels
    C. On-site preparation of fiber glass mats
    D. All of the above

15. The U.S. Navy incorporates the methods and standards contained in *U.S. Air Force Regulation 93-12* (AFR 93-12) for detailed guidance for what type of operations?

A. Rapid runway repair
B. Bunker installation
C. K-span buildings
D. Evacuations

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Department of the Navy Facility Category Codes, NAVFAC P-72, Naval Facilities Engineering Command, Alexandria, VA, 1981.

Engineering Aid Intermediate/Advanced, NAVEDTRA 12540, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Facilities Planning Guide, NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, VA, 1991.

NCF/Seabee 1 & C, NAVEDTRA 12543, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Naval Construction Force Manual, NAVFAC P-315, Naval Facilities Engineering Command, Alexandria, VA, 1988.

Projected Operational Environment and Required Operational Capabilities for the Naval Construction Force, POE/ROC, OPNAVINST 3501.115, Department of the Navy, Washington, DC, 1974.

Steelworker, NAVEDTRA 12530, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1996.

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APPENDIX I
MATHEMATICS

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

Linear Measurement

Measurements are most often made in feet (ft) and inches (in). It is necessary that a Seabee know how to make computations involving feet and inches.

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.

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 results will be 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.

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.

Addition of Feet and Inches

A Seabee 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.

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 are greater, borrow 1 foot (12 Inches) from the feet column in the upper number. Subtract as in any other problem.

Multiplication of Feet and Inches

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.

Division of Feet and Inches

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.

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

Angles

When two lines are drawn in different directions from the same point, an angle is formed.

Angles are of four types:

- Right angle is a 90° angle.
- Acute angles are angles less than 90°.
- Obtuse angles are angles greater than 90°, but less than 180°.
- Reflex angle is an angle greater than 180°.

Measurement of Angles

Observe that two straight lines have been drawn to form four right angles. Refer to *Figure A-1*.

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 (“).

Figure A-1 — Right angles.

Relationship of Angles

Figure A-2 — 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. Refer to *Figure A-2, View 1*.

2. ∠DAC and ∠CAB are complementary angles and their total is a right angle or 90°. Refer to *Figure A-2, View 2*.

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. Refer to *Figure A-2, View 3*.

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. This may be done by use of a compass.

Perpendicular Lines

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

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.

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 Seabee. 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). Refer to *Figure A-3*.

A RADIUS is a line drawn from the center of a circle to a point on a circle. (As OA, OB, OX, and OY). Refer to *Figure A-3.*

A DIAMETER is a line drawn through the center of a circle with its ends lying on the circle. Refer to *Figure A-3*.

A DIAMETER is twice the length of a radius. (AB is a diameter of circle O) Refer to *Figure A-3*.

A CHORD is a line joining any two points lying on a circle. (CD is a chord of circle O.) Refer to *Figure A-3*.

Figure A-3 — Circle.

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. Refer to *Figure A-3*.

A TANGENT is a straight line which touches the circle at one and only one point. (Line MZ is a tangent to circle O.) Refer to *Figure A-3*.

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.) Refer to *Figure A-3*.

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. Refer to *Figure A-3*.

Triangles

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

1. Equilateral - all sides are equal, all angles are equal, and all angles are 60°. Refer to *Figure A-4*.
2. Isosceles - two sides are equal and two angles are equal. Refer to *Figure A-4.*
3. Scalene - all sides are unequal and all angles are unequal. Refer to *Figure A-4.*
4. Right - one right angle is present. Refer to *Figure A-4*.

Figure A-4 — Types of triangles.

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. Refer to *Figure A-5, View 1*.
2. The median of a triangle is a line drawn from the vertex to the midpoint of the base. Refer to *Figure A-5, View 2*.

Figure A-5 — Altitude and median of a triangle.

Construction of Triangles

There are many ways to construct a triangle, depending upon what measurements are known to you. The following definitions will assist you.

1. A triangle may be constructed if the lengths of three sides are known.
2. A triangle may be constructed if two sides and the included angle (angle between the sides) are known.
3. A triangle may be constructed if two angles and the included side are given.
4. A right triangle may be constructed if the two sides adjacent to the right angle are known.
5. A right triangle may be constructed by making the sides 3, 4, and 5 inches or multiples or fractions thereof.

Quadrilaterals

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

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. See *Figure A-6*.

Parallelogram is a quadrilateral having opposite sides parallel. Refer to *Figure A-7*.

1. AB is parallel to CD.
2. AC is parallel to BD.
3. AD and CB are diagonals.
4. Diagonals bisect each other so CO = OB and AO = OD.
5. Opposite angles are equal. ACD = DBA and CAB = BDC.
6. If two sides of a quadrilateral are equal and parallel, the figure is a parallelogram.
7. A parallelogram may be constructed if two adjoining sides and one angle are known.

Figure A-6 — Trapezoid.

Rectangle is a parallelogram having one right angle. Refer to *Figure A-8*.

1. ABCD is a parallelogram having one right angle. This, of course, makes all angles right angles.
2. AC and BD are diagonals.
3. O is the midpoint of AC and BD and OB = OC = OD = OA.
4. O is equidistant from BC and AD and is also equidistant from AB and CD.
5. A rectangle may be constructed if two adjoining sides are known.

Figure A-7 — Parallelogram.

Square is a rectangle having its adjoining sides equal. Refer to *Figure A-9*.

Figure A-8 — Rectangle.

1. ABCD is a square.
2. AC and BD are diagonals.
3. O is the geometric center of the square. AO = OC = OB = OD.
4. O is equidistant from all sides.
5. A square may be constructed if one side is known.

Figure A-9 — Square.

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.

Triangles and quadrilaterals fit the description of a polygon and have been covered previously. Three other types of regular polygons are shown in *Figure A-10*. 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.

Figure A-10 — Types of polygons.

Methods for Constructing Polygons

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

The Pentagon is a developed by dividing the circumference into 5 equal parts.

The Hexagon is 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.

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. Refer to *Figure A-11.*

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

AE is the major axis.

BD is the minor axis.

Figure A-11 — Ellipses.

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.

Circumference of a Circle

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

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

Areas

All areas are measured in squares.

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 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 Rectangle

$$A = L \times W$$

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.

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. 1 cubic foot = 1,728 cubic inches
2. 1 cubic yard = 27 cubic feet
3. 1 cubic foot = 7.48 US gallons (liquid measure)
4. 1 us gallon (liquid measure) = 231 cubic inches
5. 1 bushel (dry measure) = 2,150.42 cubic inches

Area of a Circle

The formula for the area of a circle is:

$$A = \pi r^2$$

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:

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

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 described below.

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.

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.

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 lays 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.

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. 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.

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

$$V = L \times W \times H$$

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

Volume of a Cone

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

Or

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

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

Volume of a Pyramid

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

Where:

V = Volume in cubic units

A = Area of base in square units

h = Altitude in linear units

Volume of a Cylinder

$$V = Ah$$

Or

$$V = \pi r^2 h$$

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

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 the plane. The altitude of the frustum is the perpendicular distance between the bases.

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

Where:

h = Altitude in linear units

r = Radius of the upper base in linear units

R = Radius of the lower base in linear units

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 the plane. 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

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 as the ratio of a to b. More commonly, this expressed as the fraction a/b.

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

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.

Proportion

Proportion is a statement of two ratios which are equal.

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

Solving proportions is done by cross multiplying.

Example: $\frac{a}{b} = \frac{c}{d}$ = a x d = b x c

Law of Pythagoras

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

Right Triangle: a triangle having one right angle

Hypotenuse: The hypotenuse of a right triangle is the side opposite the right angle

Leg: The leg of a right triangle is a side opposite and acute angle of a right triangle.

METRIC CONVERSION TABLES

Length Conversion

When You Know:	You Can Find:	If You Multiply By:
inches	millimeters	25.4
inches	centimeters	2.54
feet	centimeters	30
feet	meters	0.3
yards	centimeters	90
yards	meters	0.9
miles	kilometers	1.6
miles	meters	1609
millimeters	inches	0.04
centimeters	inches	0.4
centimeters	feet	0.0328
meters	feet	3.3
centimeters	yards	0.0109
meters	yards	1.1
meters	miles	0.000621
kilometers	miles	0.6
meters	nautical miles	0.00054
nautical miles	meters	1852

Weight Conversion

When You Know:	You Can Find:	If You Multiply By:
ounces	grams	28.3
pounds	kilograms	0.45
short tons (2000 lbs)	megagrams (metric tons)	0.9
grams	ounces	0.0353
kilograms	pounds	2.2
megagrams (metric tons)	short tons (2000 lbs)	1.1

Temperature Conversion

When You Know:	You Can Find:	If You Multiply By:
Degrees Fahrenheit	Degree Celsius	Subtract 32 then multiply by 5/9
Degrees Celsius	Degree Fahrenheit	Multiply by 9/5 then add 32
Degrees Celsius	Kelvins	Add 273.15°

Volume Conversion

When You Know:	You Can Find:	If You Multiply By:
teaspoons	milliliters	5
tablespoons	milliliters	1 5
fluid ounces	milliliters	3 0
cups	liters	0.24
pints	liters	0.47
quarts	liters	0.95
gallons	liters	3.8
milliliters	teaspoons	0.2
milliliters	tablespoons	0.067
milliliters	fluid ounces	0.034
liters	cups	4.2
liters	pints	2.1
liters	quarts	1.06
liters	gallons	0.26
cubic feet	cubic meters	0.028
cubic yards	cubic meters	0.765
cubic meters	cubic feet	35.3
cubic meters	cubic yards	1.31

Area Conversions

When You Know:	You Can Find:	If You Multiply By:
Square inches	Square centimeters	6.45
Square inches	Square meters	0.000 6
Square feet	Square centimeters	929
Square feet	Square meters	0.0929
Square yards	Square centimeters	8.360
Square yards	Square meters	0.836
Square miles	Square kilometers	2.6
Square centimeters	Square inches	0.155
Square meters	Square inches	1550
Square centimeters	Square feet	0.001
Square meters	Square feet	10.8
Square centimeters	Square yards	0.00012
Square meters	Square yards	1.2
Square kilometers	Square miles	0.4

Table A-1 — Decimal Equivalents.

Fraction	16th	32nd	64th	Decimal	Fraction	16th	32nd	64th	Decimal
			1	.015625				33	.515625
		1	2	.03125			17	34	.53125
			3	.046875				35	.54875
	1	2	4	.0625		9	18	36	.5625
			5	.078125				37	.578125
		3	6	.09375			19	38	.59375
			7	.109375				39	.609375
1/8	2	4	8	.125	5/8	10	20	40	.625
			9	.140625				41	.640625
		5	10	.15625			21	42	.65625
			11	.171875				43	.671875
	3	6	12	.1875		11	22	44	.6875
			13	.203125				45	.703125
		7	14	.21875			23	46	.71875
			15	.234375				47	.734375
1/4	4	8	16	.25	3/4	12	24	48	.75
			17	.265625				49	.765625
		9	18	.28125			25	50	.78125
			19	.296875				51	.796875
	5	10	20	.3125		13	26	52	.8125
			21	.328125				53	.818225
		11	22	.34375			27	54	.84375
			23	.359375				55	.859375
3/8	6	12	24	.375	7/8	14	28	56	.875
			25	.390623				57	.890625
		13	26	.40625			29	58	.90625
			27	.421875				59	.921875
	7	14	28	.4375		15	30	60	.9375
			29	.453125				61	.953125
		15	30	.46875			31	62	.96875
			31	.484375				63	.984375
1/2	8	16	32	.5	1	16	32	64	1.0

Table A-2 — Metric measures of length.

10 millimeters	=	1 centimeter (cm)
10 centimeters	=	1 decimeter (dm)
10 decimeters	=	1 meter (m)
10 meters	=	1 decameter (dkm)
10 decameters	=	1 hectometer (hm)
10 hectometers	=	1 kilometer (km)

Table A-3 — Conversion of inches to millimeters.

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
1	25.4	26	660.4	51	1295.4	76	1930.4
2	50.8	27	685.8	52	1320.8	77	1955.8
3	76.2	28	711.2	53	1346.2	78	1981.2
4	101.6	29	736.6	54	1371.6	79	2006.6
5	127	30	762	55	1397	80	2032
6	152.4	31	787.4	56	1422.4	81	2057.4
7	177.8	32	812.8	57	1447.8	82	2082.8
8	203.2	33	838.2	58	1473.2	83	2108.2
9	228.6	34	863.6	59	1498.6	84	2133.6
10	254	35	889	60	1524	85	2159
11	279.4	36	914.4	61	1549.4	86	2184.4
12	304.8	37	939.8	62	1574.8	87	2209.8
13	330.2	38	965.2	63	1600.2	88	2235.2
14	355.6	39	990.6	64	1625.6	89	2260.6
15	381	40	1016	65	1651	90	2286
16	406.4	41	1041.4	66	1676.4	91	2311.4
17	431.8	42	1066.8	67	1701.8	92	2336.8
18	457.2	43	1092.2	68	1727.2	93	2362.2
19	482.6	44	1117.6	69	1752.6	94	2387.6
20	508	45	1143	70	1778	95	2413
21	533.4	46	1168.4	71	1803.4	96	2438.4
22	558.8	47	1193.8	72	1828.8	97	2463.8
23	584.2	48	1219.2	73	1854.2	98	2489.2
24	609.6	49	1244.6	74	1879.6	99	2514.6
25	635	50	1270	75	1905	100	2540

Table A-4 — Conversions of fractions and decimals to millimeters.

Fraction of inch (64ths)	Decimal of Inch	Millimeters	Fraction of inch (64ths)	Decimal of Inch	Millimeters
1	.015625	.3968	33	.515625	13.0966
2	.03125	.7937	34	.53125	13.4934
3	.046875	1.1906	35	.546875	13.8903
4 (1/16”)	.0625	1.5875	36	.5625	14.2872
5	.078125	1.9843	37	.578125	14.6841
6	.09375	2.3812	38	.59375	15.0809
7	.109375	2.7780	39	.609375	15.4778
8 (1/8”)	.125	3.1749	40 (5/8”)	.625	15.8747
9	.140625	3.5817	41	.640625	16.2715
10	.15625	3.9686	42	.65625	16.6684
11	.171875	4.3655	43	.671875	17.0653
12	.1875	4.7624	44	.6875	17.4621
13	.203125	5.1592	45	.703125	17.8590
14	.21875	5.5561	46	.71875	18.2559
15	.234375	5.9530	47	.734375	18.6527
16 (1/4”)	.25	6.3498	48 (3/4”)	.75	19.0496
17	.265625	6.7467	49	.765625	19.4465
18	.28125	7.1436	50	.78125	19.8433
19	.296875	7.5404	51	.796875	20.2402
20	.3125	7.9373	52	.8125	20.6371
21	.328125	8.3342	53	.818225	21.0339
22	.34375	8.7310	54	.84375	21.4308
23	.359375	9.1279	55	.859375	21.8277
24 (3/8”)	.375	9.5248	56 (7/8”)	.875	22.2245
25	.390623	9.9216	57	.890625	22.6214
26	.40625	10.3185	58	.90625	23.0183
27	.421875	10.7154	59	.921875	23.4151
28	.4375	11.1122	60	.9375	23.8120
29	.453125	11.5091	61	.953125	24.2089
30	.46875	11.9060	62	.96875	24.6057
31	.484375	12.3029	63	.984375	25.0026
32 (1/2”)	.5	12.6997	64 (1”)	1.0	25.3995

Table A-5 Conversions of measurements.

Conversion Chart for Measurement								
inches								centimeters
Cm							inches	
Feet						meters		
Meters					feet			
Yards				meters				
Meters			yards					
Miles		kilometers						
km	miles							
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.21	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.81	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.70
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.4	22.97	2.13	2.76	17.78
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
12	7.46	19.31	13.12	10.97	39.37	3.66	4.72	30.48
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
24	14.91	38.62	26.25	21.95	78.74	7.32	9.45	60.96
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
36	22.37	57.94	39.37	32.92	118.11	10.97	14.17	91.44
40	24.37	64.37	43.74	36.58	131.23	12.19	15.75	101.60
48	29.83	77.25	52.49	43.89	157.48	14.63	18.90	121.92
50	31.07	80.47	54.68	45.72	164.04	15.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64	229.66	21.34	27.56	177.80
72	44.74	115.87	78.74	65.84	236.22	21.95	28.35	182.88

Table A-6 — Cubic conversion chart.

Cubic Conversion Chart					
Cubic Meters				Cubic Feet	Cubic Yard
Cubic Yard			Cubic Meters		
Cubic Feet		Cubic Meters			
Cubic Inches	Cubic Centimeters				
1	16.39	0.028	0.76	35.3	1.31
2	32.77	0.057	1.53	70.6	2.62
3	49.16	0.085	2.29	105.9	3.92
4	65.55	0.113	3.06	141.3	5.23
5	81.94	0.142	3.82	176.6	6.54
6	98.32	0.170	4.59	211.9	7.85
7	114.71	0.198	5.35	247.2	9.16
8	131.10	0.227	6.12	282.5	10.46
9	147.48	0.255	6.88	317.8	11.77
10	163.87	0.283	7.65	353.1	13.07
20	327.74	0.566	15.29	706.3	26.16
30	491.61	0.850	29.94	1059.4	39.24
40	655.48	1.133	30.58	1412.6	52.32
50	819.35	1.416	38.23	1765.7	65.40
60	983.22	1.700	45.87	2118.9	78.48
70	1174.09	1.982	53.52	2472.0	91.56
80	1310.96	2.265	61.16	2825.2	104.63
90	1474.84	2.548	68.81	3178.3	117.71
100	1638.71	2.832	76.46	3531.4	130.79
Example: 3 cu. Yd = 2.29 cu. M Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system.					

Table A-7 — Gallon and liter conversion chart.

Gallon	Liter	Gallon	Liter	Gallon	Liter
.1	.38	1	3.79	10	37.85
.2	.76	2	7.57	20	57.71
.3	1.14	3	11.36	30	113.56
.4	1.51	4	15.14	40	151.42
.5	1.89	5	18.93	50	189.27
.6	2.27	6	22.71	60	227.12
.7	2.65	7	26.50	70	264.98
.8	3.03	8	30.28	80	302.83
.9	3.41	9	34.07	90	340.69
NOTE: 1 us Gallon = 3.785412 Liters 100 us Gallons = 378.5412 Liters					

Table A-8 — Weight conversion chart.

Weight Conversion Chart						
Ounces						Grams
Grams					Ounces	
Pounds				Kilograms		
Kilograms			Pounds			
Short Ton		Metric Ton				
Metric Ton	Short Ton					
1	1.10	0.91	2.20	0.45	0.04	28.1
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.81	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.14	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.17	1981.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0
NOTE: 1 pound = 0.4535925 KG; 1 US Short Ton = 2,000 pounds; and 1 Metric Ton = 1,000 KG						

FORMULAS

Conversion Factors and Constants

$\pi = 3.14$	$2\pi = 6.28$
$\pi^2 = 9.87$	$(2\pi)^2 = 39.5$
$\varepsilon = 2.718$	$\sqrt{2} = 1.414$
$\sqrt{3} = 1.732$	LOG = 0.497

Sinusoidal Voltages and Currents

Effective Value	=	0.707 x Peak Value
Average Value	=	0.637 x Peak Value
Peak Value	=	1.414 x Effective Value
Effective Value	=	1.11 x Average Value
Peak Value	=	1.57 x Average Value
Average Value	=	0.9 x Effective Value

Temperature

(F to C) C = 5/9 (F – 32)

(C to F) F = 9/5 C = 32

(C to K) K = C + 73

Power

1 kilowatt = 1.341 horsepower

1 horsepower = 746 watts

Trigonometric Formulas

sin A = $\frac{a}{c} = \frac{Opposite\ Side}{Hypotenuse}$

cos A = $\frac{b}{c} = \frac{Adjacent\ Side}{Hypotenuse}$

tan A = $\frac{a}{b} = \frac{Opposite\ Side}{Adjacent\ Side}$

cot A = $\frac{b}{a} = \frac{Adjacent\ Side}{Opposite\ Side}$

Figure A-12 — Trapezoid.

Ohm’s Law- Direct Current

Figure A-13 — Direct Current.

Ohm’s Law- Alternating Current

Figure A-14 — Alternating Current.

Speed vs. Poles Formulas

$F = \frac{NP}{120}$ $N = \frac{F\ 120}{P}$ $P = \frac{F\ 120}{N}$

F = frequency

N= speed of rotation

P = number of poles

120 = time constant

Power Factor

$PF = \frac{\text{actual power}}{\text{apparent power}} = \frac{\text{watts}}{\text{amperes}}$ volts x $= \frac{kW}{kVA} = \frac{R}{Z}$

$PF = \frac{P}{E \times I}$

$= kVA \times PF$

lanced

$\sqrt{\ }$ $\sqrt{\ }$

$\sqrt{\ }$ $\sqrt{\ }$

Power: Three-Phase Balanced Wye or Delta Circuits

P = 1.732 x E x I x PF VA = 1.732 x E x I

$E = \frac{P}{PF \times 1.73 \times I} = \frac{0.577 \times P}{PF \times I}$

$I = \frac{P}{PF \times 1.73 \times E} = \frac{0.577 \times P}{PF \times E}$

$PF = \frac{P}{PF \times 1.73 \times E} = \frac{0.577 \times P}{I \times E}$

VA = apparent power (volt-amperes)

P = actual power (watts)

E = line voltage (volts)

I = line current (amperes)

WEIGHTS AND MEASURES

Dry Measure

2 cups = 1 quart (pt)

2 pints = 1 quart (pt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Liquid Measure

3 teaspoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (oz) = 1 pint

2 pints = 1 quart

4 quarts = 1 gallon

31.5 gallons = 1 barrel (bbl)

231 cubic inches = 1 gallon

7.48 gallons = 1 cubic foot (cu ft)

Weight

16 ounces = 1 pound (lb)

2,000 pounds = 1 short ton

2,240 pounds = 1 long ton

Distance

12 inches = 1 foot (ft)

3 feet = 1 yard (yd)

5-1/2 yards = 1 rod (rd) 16-

1/2 feet = 1 rod

1,760 yards = 1 statute mile (mi)

5,280 feet = 1 statute mile

Area

144 square inches = 1 square foot (sq ft)

9 square feet = 1 square yd (sq yd)

30- ¼ square yards = 1 square rod

160 square rods = 1 acre (A)

640 acres = 1 square mile (sq mi)

Volume

1,728 cubic inches = 1 cubic foot

27 cubic feet = 1 cubic yard (CU yd)

Counting Units

12 units = 1 dozen (doz)

12 dozen = 1 gross

144 units = 1 gross

24 sheets = 1 quire

480 sheets = 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Feet	x.00019	= miles
Feet	x 1.5	= links
Yards	x .9144	= meters
Yards	x .0006	= miles
Links	x .22	= yards
Links	x .66	= feet
Rods	x 25	= links
Rods	x 16.5	= feet
Square inches	x .007	= square feet
Square inches	x 6.451	= square centimeters
Square centimeters	x 0.1550	= square inches
Square feet	x .111	= square yards
Square feet	x .0929	= centares (square meters)
Square feet	x 929	= square centimeters
Square feet	x 144	= square inches
Square yards	x .0002067	= acres
Acres	x 4840.0	= square yards
Square yards	x 1,296	= square inches
Square yards	x 9	= square feet
Square yards	x 0.8362	= centares
Square miles, statute	x 640	= acres
Square miles, statute	x 25,900	=ares
Square miles, statute	x 259	= hectares
Square miles, statute	x 2,590	= square kilometers
Cubic inches	x .00058	= cubic feet
Cubic feet	x .03704	= cubic yards
Tons (metric)	x 2,204.6	= pounds (avoirdupois)
Tons (metric)	x 1,000	= kilograms
Tons (short)	x 2,000	= pounds (avoirdupois)

Tons (short)	x 0.9072	= metric tons
Tons (long)	x 2,240	= pounds (avoirdupois)
Tons (long)	x 1.016	= metric tons
π	= 3.14592654	
1 radian	= 180°/π = 57.2957790°	= approx. 57° 17’ 44.8”
1 radian	= 1018.6 miles	
1 degree	= 0.0174533 radian	
1 minute	= 0.0002909 radian	
1 mil	= 0.0009817	
π radians	= 180°	
π /2 radians	= 90°	
Radius	= arc of 57.2957790°	
Arc of 1° (radius = 1)	= .017453292	
Arc of $1'$(radius = 1)	= .000290888	
Arc of $1'$ (radius = 1)	= .000004848	
Area of sector of circle	= ½ Lr	(L= length of arc; r = radius)
Area of segment of parabola	= 2/3 cm	(c = chord; m = mid. ord.)
Area of segment of circle	= approx 2/3	
Arc – chord length	= 0.02 foot per 11 ½ miles	
Curvature of earth’s surface	= approx. 0.667 foot per mile	

APPENDIX II

Hand Signals

Emergency Stop
Stop all motion as quickly as possible.

Stop

Kill Engine
Secure engine as prescribed

Manuever Forward Slowly
When manuevering in close quarters or to move a foot or two at a time.

Slow Down

Guide On Me
Hand open and palm facing inward.

Increase Speed

Raise Hoist Slowly
Hurry up and move out, double time, etc.

Lower Hoist Slowly

Raise Load

Lower Load

Raise Boom

Lower Boom

Raise Boom and Hold Load

Lower Boom and Hold Load

Lower Boom Slowly

Raise Boom Slowly

Lower Boom and Raise Load

Raise Boom and Lower Load

Swing In Direction Finger Points

Close Bucket

Open Bucket

Use Whip Line For Preceding Signals
(Auxilliary Hoist)
Tap elbow then use regular signals

Make Left Turn

Make Right Turn

Travel Both Tracks

Cut, Fill, or Drag Road
Point to road to be dragged or bladed, then rub palms together.
Applies to scrapers, motor graders, and bulldozers.

Raise a Little

Lower a Little

Dump Load Now
Start dumping and spreading load to proper depth if given.

Rehaul or Retract

Crowd or Extend

Turn Right (Operator's Right)

Turn Left (Operator's Left)

APPENDIX III

COMMON CONSTRUCTION SYMBOLOGY

Lighting Outlets

Ceiling Wall

Surface or Pendant Incandescent, Mercury Vapor, or Similar Lamp Fixture

Surface or Pendant Individual Fluorescent Fixture

Surface or Pendant Continuous-Flow Individual Fluorescent Fixture

Bare Lamp Fluorescent Strip

Surface or Pendant Exit Light

Junction Box

Receptacle Outlets

Grounded Ungrounded

Single Receptacle Outlet

Duplex Receptacle Outlet

Duplex Receptacle Outlet - Split Wired

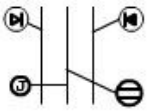
Single Special Purpose Receptacle Outlet

Range Outlet (typical)

Floor Duplex Receptacle Outlet

Floor Telephone Outlet

Application: example of the use of various symbols to identify location of different types of outlets or connections for underfloor duct or cellular floor systems



Switch Outlets

Single-Pole Switch

S

Double-Pole Switch

S_2

Three-Way Switch

S_3

Four-Way Switch

S_4

Key-Operated Switch

S_K

Switch and Pilot Lamp

S_P

Switch for Low-Voltage Switching System

S_L

Switch and Single Receptacle

S

Switch and Double Receptacle

S

Door Switch

S_D

Time Switch

S_T

Residential Occupancies

Signaling system symbols for use in identifying standardized residential type signal system items on residential drawings where a descriptive symbol list is not included in the drawing

Push Button

Buzzer

Bell

Annunciator

Interconnection Box

Bell-Ringing Tranformer

BT

Interconnecting Telephone

Radio Outlet

R

Television Outlet

TV

Panelboards, Switchboards, and Related Equipment

Flush-Mounted Panelboard and Cabinet
NOTE: Identify by notation or schedule

Surface-Mounted Panelboard and Cabinet

Switchboard, Power Control Center, Unit Substations (should be drawn to scale)

Flush-Mounted Terminal Cabinet
NOTE: In small-scale drawings the TC may be indicated alongside the symbol

TC

Surface-Mounted Terminal Cabinet

TC

Motor or Other Power Controller

MC

Externally Operated Disconnection Switch

Combination Controller and Disconnection Means

Remote Control Stations for Motors or Other Equipment

Push-button Stations in General

Float Switch - Mechanical

Limit Switch - Mechanical

Pneumatic Switch - Mechanical

Electric Eye - Beam Source

Electric Eye - Relay

Thermostat

Circuiting

Wiring method identification by notation on drawing or in specifications.

Wiring Concealed in Ceiling or Wall

Note: Use heavy weight line to identify service and feed runs

Wiring Concealed in Floor

Wiring Exposed

Branch Circuit Home Run to Panelboard

Number of arrows indicates number of circuits. (A numeral at each arrow may be used to identify circuit number.)

NOTE: Any circuit without further identification indicates a 2-wire circuit. For a greater number of wires, indicate with cross lines.

Application:

Unless indicated otherwise, the wire size of the circuit is the minimum size required by the specification.
Indicate size in inches and identify different functions of wiring system, such as signaling, by notation or other means.

Wiring Turned Up

Wiring Turned Down

Manhole

Handhole

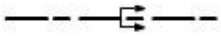
Transformer Pad

Underground Direct Burial Cable

Indicate type, size, and number of conductors by notation or schedule.

Underground Duct Line

Indicate type, size, and number of ducts by cross section identification of each run by notation or schedule. Indicate type, size, and number of conductors by notation or schedule.



Streetlight Standard Fed from Underground Circuit

Electrical Distribution or Lighting Systems, Aerial

Pole

Pole, with Streetlight

Pole, with Down Guy and Anchor

Transformer

Transformer, Constant-Current

Switch, Manual

Circuit Recloser, Automatic

Circuit, Primary

Circuit, Secondary

Circuit, Series Street Lighting

Down Guy

Head Guy

Sidewalk Guy

Service Weather Head

Qualifying Symbols

Connection Symbol

For use adjacent to other symbols

3-phase, 3-wire, delta

3-phase, 3-wire, delta, grounded

3-phase, 4-wire, delta, grounded

3-phase, open delta

3-phase, wye or star, ungrounded

3-phase, wye, grounded neutral

Graphic Symbols for Fundamental Items

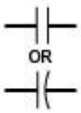
Resistor

General

Application: adjustable or continuously adjustable (variable) resistor rheostat

NOTE: Always add identification within , or adjacent to, the rectangle.

Capacitor



Antenna

General
Types or functions may be indicated by words or abbreviations adjacent to the symbol.

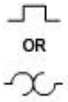
Battery

The long line is always positive, but polarity may be indicated in addition.
Example:

Multicell

Thermal Element

Actuating device, self-heating or with external heater. (Not operated primarily by ambient temperature.)



Graphic Symbols for Transmission Path

Transmission Path
Conductor
Cable
Wiring

Guided path, general

A single line represents the entire group of conditions or the transmission path needed to guide the power or signal.

When required, details of structure, type, impedance, ratings, etc., may be added adjacent to or within any symbol or in a note.

Busbar (with connections shown)
Use only if essential to distinguish bus from other circuit paths.

Conductive path or conductor; wire

Two conductors or conductive paths

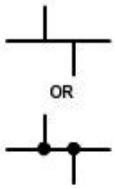
Crossing of paths or conductors not connected

The crossing is not necessarily at a 90° angle.

Junction of paths or conductors
Junction (if desired)

Junction of paths, conductors, or cable.
If desired, indicate path type, or size.

Junction of paths, conductors, or wires



2-conductor cable

Cable underground; underground line

These are long dashes

Overhead line

Circuit Return

Ground general symbol

NOTE: Supplementary information may be added to define the status or purpose of the earth if this is not readily apparent.

(1) A direct conducting connection to the earth or body of water that is a part therof.

(2) A conducting connect to a structure that serves a function similar to that of an earth ground (that is, a structure such as a frame of an air, space, or land vehicle that is not conductively connected to earth).

Chassis or frame connection, equivalent chassis connection (of printed-wiring boards)

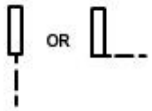
A conducting connection to a chassis of frame (or equivalent chassis connection of a printed-wiring board) may be at substantial potential with respect to the earth or structure in which this chassis or frame (or printed-wiring board) is mounted.

Graphic Symbols for Contacts, Switches, Contacts, and Relays

Electrical Contact

Fixed contact for jack, key, relay, switch, etc.

‡ Sleeve



‡ The broken line - - - indicates where line connection to a symbol is made and is not part of the symbol.

Moving Contact

Adjustable or sliding contact for resistor, inductor, etc.

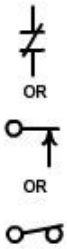
Locking

Nonlocking

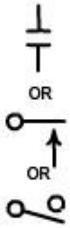
Basic Contact Assemblies

The standard method of showing a contact is by a symbol indicating the circuit condition it produces when the actuating device is in the de-energized or nonoperated position. The actuating device may be of a mechanical, electrical, or other nature, and a clarifying note may be necessary with the symbol to explain the proper point at which the contact functions; for example, the point where a contact closes or opens as a function of changing pressure, level, flow, voltage, current, etc. In cases where it is desirable to show contacts in the energized or operated condition and where confusion may result, a clarifying note shall be added to the drawing.

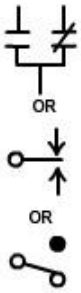
Closed contact (break)



Open contact (make)

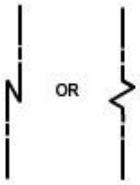


Transfer



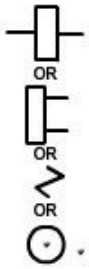
Make-before-break

Magnetic Blowout Coil



Operating Coil

Relay Coil



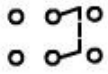
Switch

Fundamental symbols for contacts, mechanical connections, etc, may be used for switch symbols.

Single-throw, general

Double-throw, general

2-pole double-throw switch with terminals shown



NOTE: The asterisk is not part of the symbol. Always replace the asterisk by a device designation.

Push button, Momentary or Spring-Return

Circuit closing (make)

Circuit opening (break)

Two-circuit

Selector or Multiposition Switch

The position in which the switch is shown may be indicated by a note or designation of switch position.

General (for power and control diagrams)

Any number of transmission paths may be shown.

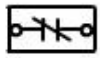
OR

Limit Switch
Sensitive Switch

NOTE: Identity by LS or other suitable note.

Track-type, circuit-closing contact

Track-type, circuit-opening contact



Flow-Actuated Switch

Closes on increase in flow

Opens on increase in flow

Liquid-Level-Actuated Switch

Closes on rising level

Opens on rising level

Pressure-or Vacuum-Actuated Switch

Closes on rising pressure

Opens on rising pressure

Temperature-Actuated Switch

Closes on rising temperature

Opens on rising temperature

Thermostat

Closes on rising temperature

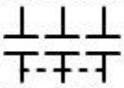
* See Note

Contactor

See also CIRCUIT BREAKER

Fundamental symbols for contacts, coils, mechanical connections, etc, are the basis of contactor symbols and should be used to represent contactors on complete diagrams. Complete diagrams of contactors consist of combinations of fundamental symbols for control coils, mechanical connections, etc, in such configurations as to represent the actual device. Mechanical interlocking should be indicated by notes.

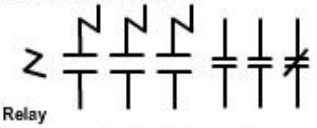
Manually operated 3-pole contactor



NOTE: The t° symbol shall be shown or be replaced by data giving the nominal or specific operating temperature of the device.

Electrically operated 1-pole contactor with series blowout coil

Electrically operated 3-pole contactor with series blowout coils; 2 open and 1 closed auxiliary contacts (shown smaller than the main contacts)



Relay

Fundamental symbols for contacts, mechanical connections, coils, etc, are the basis of relays on complete diagrams.

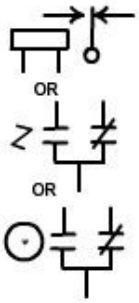
The following letter combinations or symbol elements may be used with relay symbols. The requisite number of these letters or symbol elements may be used to show what special features a relay possesses.

AC	Alternating-current or ringing relay
D	Differential
DB	Double-biased (biased in both directions)
DP	Dashpot
EP	Electrically polarized
FO	Fast-operate
FR	Fast-release
L	Latching
MG	Marginal
ML	Magnetic-latching (re-manent)
NB	No bias
NR	Nonreactive
P	Magnetically polarized using biasing spring, or having magnet bias
SA	Slow-operate and slow-release
SO	Slow-operate
SR	Slow-release
SW	Sandwich-wound to improve balance to longitudinal currents

The proper poling for a polarized relay shall be shown by the use of + and - designations applied to the winding leads. The interpretation of this shall be that a voltage applied with the polarity as indicated shall cause the armature to move toward the contact shown nearer the coil on the diagram. If the relay is equipped with numbered terminals, the proper terminal numbers shall alson be shown.

Basic

Relay with transfer contacts



Graphic Symbols for
Terminals and Connectors

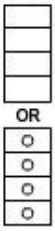
Terminals

Circuit terminal

Terminal board or terminal strip, with 4 terminals shown; group of 4 terminals

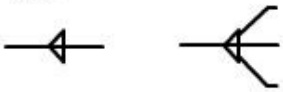
Number and arrangement as convenient.

NOTE: Internal lines and terminals may be omitted if terminal identifications are shown within the symbol.



Cable Termination

Line shown on left of symbol indicates cable.



Connector
Disconnecting Device
Jack
Plug

The contact symbol is not an arrowhead. It is larger and the lines are drawn at a 90-degree angle.

Female contact 

Male contact 

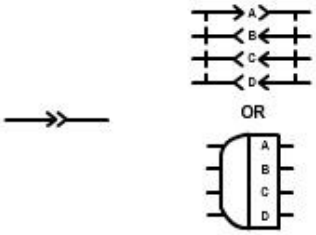
Receptacle or jack (usually stationary)

NOTE: The asterick is not part of the symbol. If desired, indicate the type of contacts: male (⟶) or female (⟵).

Plug (usually movable)

Separable connectors (engaged)

Engaged 4-conductor connectors; the plug has 1 male and 3 female contacts with individual contact designations shown in the complete-symbol column



Communication switchboard-type connector

2-conductor (jack) 

2-conductor (plug) 

Graphic Symbols for
Transformers, Inductors,
and Windings

Core

General or air core

If it is necessary to identify an air core, a note should appear adjacent to the symbol of the inductor or transformer

NO SYMBOL

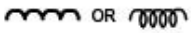
Magnetic core of inductor or transformer

Not to be used unless it is necessary to identify a magnetic core.

Inductor
Winding (machine or transformer)
Reactor
Radio-Frequency Coil
Telephone Retardation Coil

See also OPERATING COIL

General



Magnetic-core inductor
Telephone loading coil

If necessary to show a magnetic core.

Tapped 

Adjustable inductor

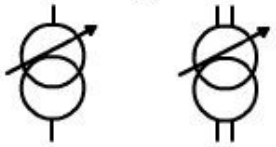
Transformer

General

Shielded transformer with magnetic core shown

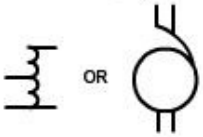
One winding with adjustable inductance

OR

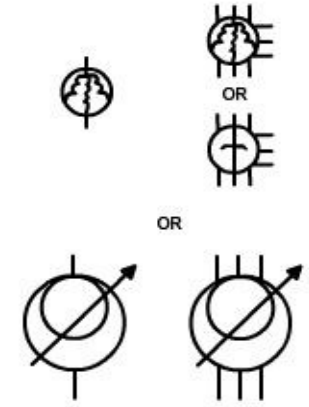


Adjustable mutual inductor; constant-current transformer

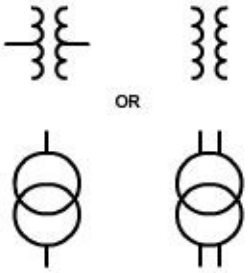
Autotransformer, 1-phase



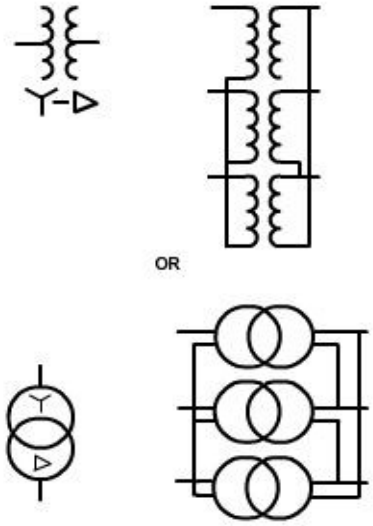
3-phase induction voltage regulator



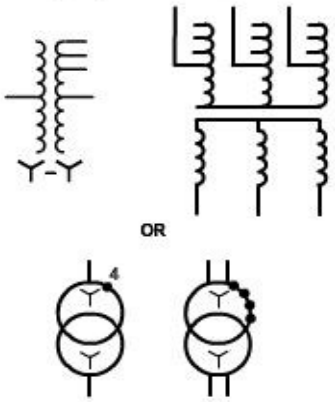
1-phase, 2-winding transformer



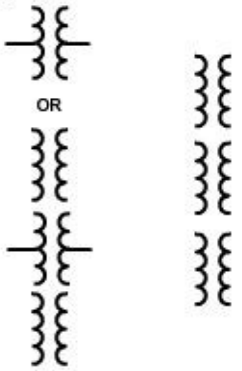
3-phase bank of 1-phase, 2-winding transformers with wye-delta connections



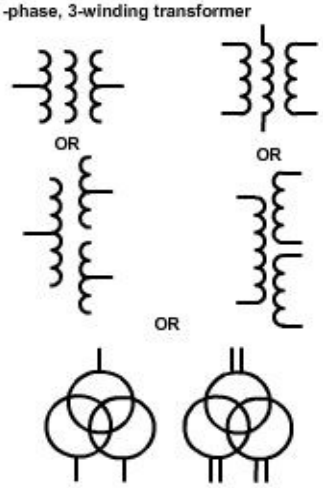
These phases transformer with 4 taps with wye-wye connections



Polyphase transformer

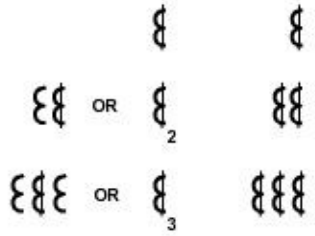


1-phase, 3-winding transformer

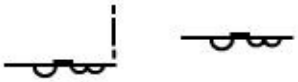


Current transformer(s)

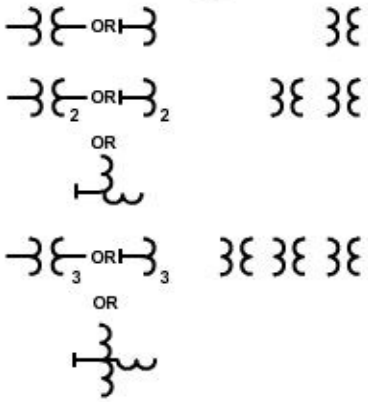
Avoid conflict with symbol for loaded line if used on the same diagram.



Bushing-type current transformer



Potential transformer(s)



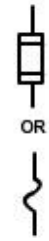
Outdoor metering device

SHOW ACTUAL CONNECTION INSIDE BORDER

Graphic Symbols for Circuit Protectors

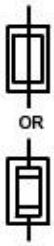
Fuse (one-time thermal current-over-load device)

General



Isolating fuse-switch: high-voltage primary fuse cutout, dry

High-voltage primary fuse cutout, oil



Current Limiter (for power cable)

The arrowheads in this case are filled.

Lightning Arrester
Arrester (electric surge, etc)
Gap

General

Carbon block; telephone protector block

Horn gap

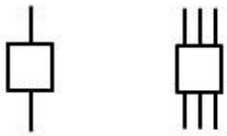
Circuit Breaker

Air circuit breaker, if distinction is needed; for alternating-current circuit breakers rated at 1,500 bolts or less and for all direct-current circuit breakers

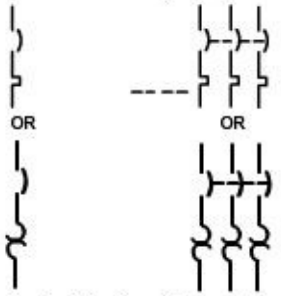
Network protector

Circuit breaker, other than covered by the above symbol

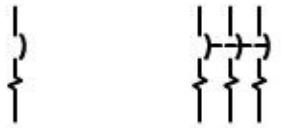
The symbol in the right column is for a 3-pole breaker.



3-pole circuit breaker with thermal-overload device in all 3 poles



3-pole circuit breaker with magnetic-overload device in all 3 poles



3-pole circuit breaker, drawout type

Protective Relay

Fundamental symbols for contacts, coils, mechanical connections, etc, are the basis or relay symbols and should be used to represent relays on complete diagrams.

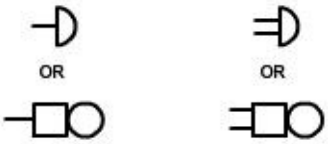
See RELAY COIL; OPERATING COIL and RELAY

Graphic Symbols for Acoustic Devices

Audible-Signaling Device

Bell, electrical; telephone ringer

NOTE: If specific identification is required, the abbreviation AC or DC may be added within or adjacent to the symbol.



Single-stroke

Buzzer

Loudspeaker
Horn, Electrical
Sirem

General

Microphone
Telephone Transmitter

General

Handset
Operator's Set

General

Telephone Receiver
Earphone

General

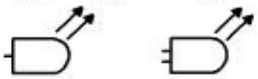
Headset, double

Headset, single

Graphic Symbols for Lamps and Visual-Signaling Devices

Lamp

Lamp, general; light source, general



NOTE: This symbol may be used to represent one or more lamps with or without operating auxiliaries.

NOTE: If it is essential to indicate the following characteristics, the specified letter or letters may be inserted within or placed adjacent to the symbol.

A	Amber
B	Blue
C	Clear
G	Green
O	Orange
OP	Opelescent
P	Purple
R	Red
W	White
Y	Yellow
ARC	Arc
EL	Electroluminescent
FL	Fluorescent
HG	Mercury vapor
IN	Incandescent
IR	Infrared
NA	Sodium vapor
NE	Neon
UV	Ultraviolet
XE	Xenon
LED	Light-emitting diode

Fluorescent lamp

2-terminal

4-terminal

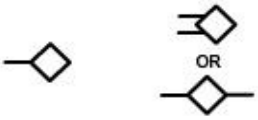
Incandescent lamp (incandescent-filament illuminating lamp

Ballest lamp; ballast tube

The primary characteristic of the element within the circle is designed to vary non-linearity with the temperature of the element.

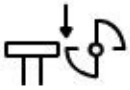
Visual-Signaling Device

Annunciator (general)



Annunciator drop or signal, shutter or grid type

Annunciator drop or signal, ball type



Manually restored drop

Electrically restored drop

Communication switchgoard-type lamp; indicating lamp

Indicating, pilot, signaling, or switch-board light; indicator light signal light

If confusion with other circular symbols may occur, the D-shape symbol should be used.

OR

OR

Jeweled signal light

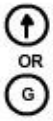
Graphic Symbols for Readout Devices

Meter Instrument

NOTE: The asterisk is not part of the symbol. Always replace the asterisk by one of the following letter combinations, depending on the function of the meter or instrument, unless some other identification is provided in the circle and explained on the diagram.

A	Ammeter
AH	Ampere-hour meter
C	Coulombmeter
CMA	Contact-making (or breaking) ammeter
CMC	Contact-making (orbreaking) clock
CMV	Contact-making (or breaking) voltmeter
CRO	Oscilloscope Cathode-ray oscillograph
DB	DB (decibel) meter Audio level/meter
DBM	DBM (decibels referred to 1 milliwatt) meter
DM	Demand meter
DTR	Demand-totalizing relay
F	Frequency meter
GD	Ground detector
I	Indicating meter
μ A or UA	Microammeter
MA	Milliammeter
NM	Noise Meter
OHM	Ohmmeter
OP	Oil pressure meter
OSCG	Oscillograph
PF	Power factor meter
PH	Phasemeter
PI	Position indicator
RD	Recording demand meter
REC	Recording meter
RF	Reactive factor meter
SY	Synchroscope
t°	Temperature meter
THC	Thermal converter
TLM	Telemeter
TT	Total time meter Elapsed time meter
V	Voltmeter
VA	Volt-ammeter
VAR	Varmeter
VARH	Varhour meter
VI	Volume indicator Audio-level meter
VU	Standard volume indicator Audio-level meter
W	Wattmeter
WH	Watthour meterv

Galvanometer



Graphic Symbols for
Rotating Machinery

Rotating Machine

Basic

Generator (general)

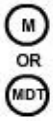
Avoid conflict with symbols for galvano-
meter if used on the same diagram.

OR

Generator, direct-current

Generator, alternating-current

Motor (general)



Motor, direct-current

Motor, alternating-current

Winding Connection Symbols

Motor and generator winding connection
symbols may be shown in the basic circle
using the following representations.

1-phase

2-phase

3-phase wye (ungrounded)

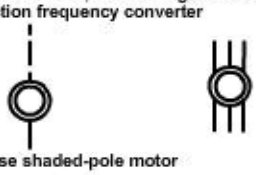
3-phase wye (grounded)

3-phase delta

Alternating-Current Machines

Squirrel-cage induction motor or
generator, split-phase induction motor or
generator, rotary phase converter, or
repulsion motor

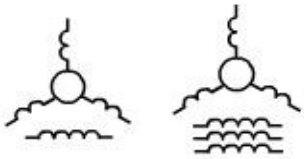
Wound-rotor induction motor, synchronous
induction motor, induction generator, or
induction frequency converter



1-phase shaded-pole motor

1-phase repulsion-start induction motor

3-phase regulating machine



Alternating-Current Machines with
Direct-Current Field Excitation

Synchronous motor, generator, or
condenserv

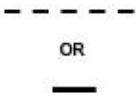
Graphic Symbols for
Mechanical Functions

Mechanical Connection
Mechanical Interlock

Mechanical connection

The top symbol consists of shor dashees.

NOTE: The short parallel lines should be
used only where there is insufficient space
for the short dashes in series



Mechanical Motion

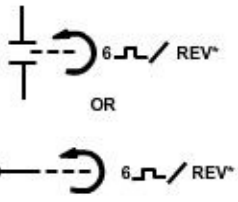
Translation, one direction

Translation, both directions

Rotation, one direction

Application: angular motion, applied
to open contact (make), symbol

NOTE: The asterisk is not part of the symbol.
Explanatory information (similar to type
shown) may be added if neccessary to
explain circuit operation.



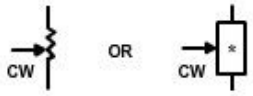
Rotation, both directions

Alternating or reciprocating

Rotation designation (applied to a resistor)

CW indicates position of adjustable contact
at the limit of clockwise travel viewed from
knob or actuator end unless otherwise
indicated.

NOTE: The asterisk is not part of the symbol. Always add identification within or adjacent to the rectangle.



Manual Control

General

Operated by pushing

Operated by pushing and pulling (pudh-pull)

Graphic Symbols for Composite Assemblies

Circuit Assembly
Circuit Subassembly
Circuit Element

NOTE: The asterisk is not part of the symbol. Always indicate the type of apparatus by appropriate words or letters.

NOTE: The use of a general circuit-element symbol is restricted to the following:

a. Diagrams drawn in block form.
b. A substitute for complex circuit elements when the internal operation of the circuit element is not important of the purpose of the diagram.

General

Accepted abbreviations from ANSI Z32.13-1950 may be used in the rectangle.

The following letter combinations may be used in the rectangle:

CLK	Clock
EQ	Equalizer
FAX	Facsimile set
FL	Filter
IND	Indicator
PS	Power supply
RG	Recording unit
RU	Reproducing unit
DIAL	Telephone dial
TEL	Telephone station
TPR	Teleprinter
TTY	Teletypewriter

Amplifier

General

The triangle is pointed in the direction of transmission.

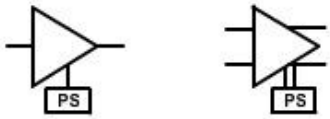
The symbol represents any method of amplification (electron tube, solid-state device, magnetic device, etc).

NOTE: If identification, electrical values, location data, and similar information must be noted within symbol, the size or aspect ratio of the original symbol may be altered providing its distinctive shape is retained.

Amplifier use may be indicated in the triangle by words, standard abbreviations, or a letter combination from the following list:

BOG	Bridging
BST	Booster
CMP	Compression
EXP	Direct-current
LIM	Limiting
MON	Monitoring
PGM	Program
PRE	Preliminary
PWR	Power
TRQ	Torque

Application: amplifier with associated power supply



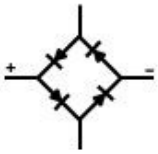
General

NOTE: Triangle points in direction of forward (easy) current as indicated by a direct-current ammeter, unless otherwise noted adjacent to the symbol. Electron flow is in the opposite direction.

NOTE: This symbol represents any method of rectification (electron tube, solid-state device, electrochemical device, etc).

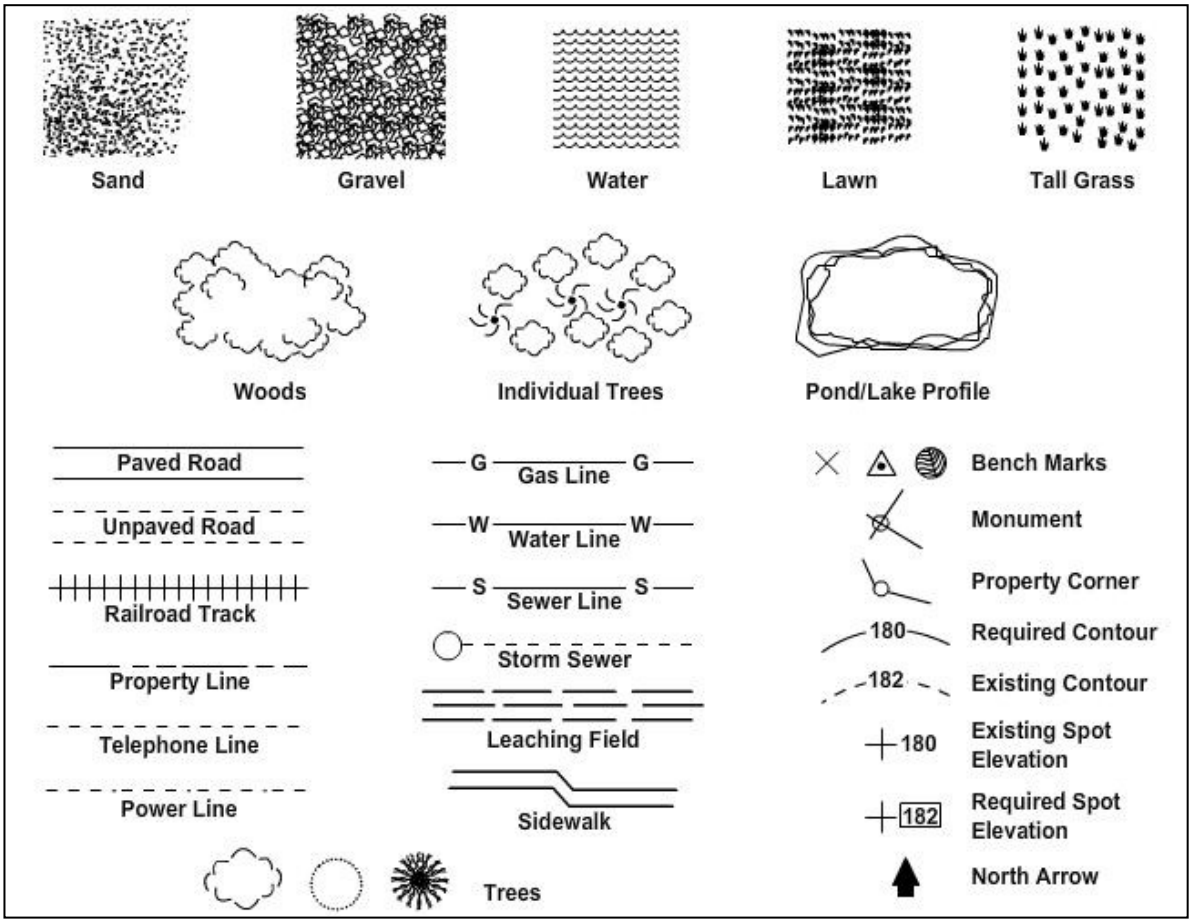
Controlled

Bridge-type rectifier



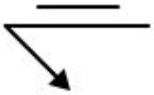
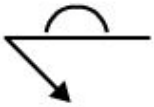
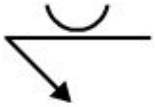
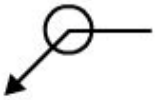
On connection or wiring diagrams, rectifier may be shown with terminals and plarity marking. Heavy line may be used to indicate nameplate or positive-polarity end.

For connection or wiring diagram

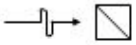


Description	Example	Symbol	Illustrated Use
W- Shape (Wide Flange)		W	W24 x 78
Bearing Pile		BP	BP14 x 73
S-Shape (American STD I-Beam)		S	S15 x 42.9
C-Shape (American STD Channel)		C	C9 x 13.4
M-Shape (Misc Shapes Other Than W, BP, S, & C)		M	M5 x 34.3 M5 x 17 M7 x 5.5
MC-Shape (Channels Other Than American STD)		MC	MC12 x 45 MC 12 x 12.8
Angles: Equal Leg Un-equal Leg		 L L	3x 3x L 3x 3x 1/4 L 7x 4x 1/2
Tees, Structural: Cut From W-Shape Cut From S-Shape Cut From M-Shape		 WT ST MT	 WT 12x38 ST 12x38 MT 12x38
Plate		PL	PL 1/2x18"x30"
Flat Bar		BAR	BAR 2 1/2 x 1/4
Pipe, Structural			Pipe 4 STD Pipe 4x-STRG Pipe XX-STRG

BASIC WELD SYMBOLS									
BEAD	FILLET	PLUG OR SLOT	GROOVE OR BUTT						
			SQUARE	V	BEVEL	U	J	FLARE V	FLARE BEVEL
									

CONTOUR			WELD-ALL-AROUND	FIELD WELD
FLUSH	CONVEX	CONCAVE		
				


Ceiling Diffuser (Arrows Indicate Direction of Air Flow)


Return Air Grille


Supply Duct Up

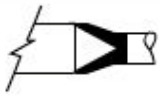

Supply Duct Down

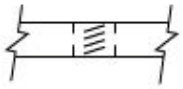

Return Duct Up


Return Duct Down

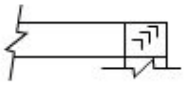
6"ϕ CD
200 ¢
Neck Size/ Air Device CFM

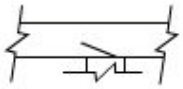

Thermostat


Square to Round Transition


Parallel Blade Damper


Fire Damper (Wall) (Floor)


Airfoil Blade Turning Vanes


Air Extractor

ϕ Diameter

¢ CFM (Cubic Feet Per Minute)

RA Return Air

OSA Outside Air

CD Condensate Drain

General Outlets

Junction Box, Ceiling	J
Fan, Ceiling	F
Recessed Incandescent, Wall	R
Surface Incandescent, Ceiling	
Surface or Pendant Single Fluorescent Fixture	

Switch Outlets

Single-Pole Switch	S
Double-Pole Switch	S_2
Three-Way Switch	S_3
Four-Way Switch	S_4
Key-Operated Switch	S_K
Switch w/ Pilot	S_P
Low-Voltage Switch	S_L
Door Switch	S_D
Momentary Contact Switch	S_{MC}
Weatherproof Switch	S_{WP}
Fused Switch	S_F
Circuit Breaker Switch	S_{CB}

Receptacle Outlets

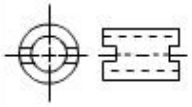
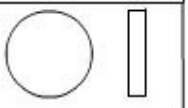
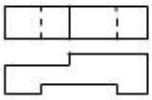
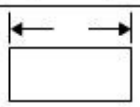
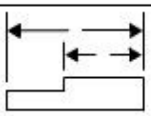
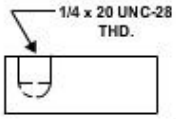
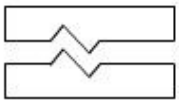
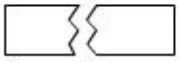
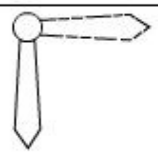
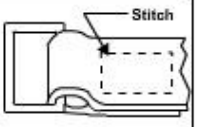
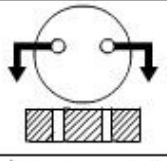
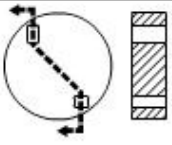
Single Receptacle	
Duplex Receptacle	
Triplex Receptacle	
Split-Wired Duplex Recep.	
Single Special Purpose Recep.	
Duplex Special Purpose Recep.	
Range Receptacle	R
Switch & Single Receptacle	s
Grounded Duplex Receptacle	G
Duplex Weatherproof Receptacle	WP
GFCI	GFCI

Auxiliary Systems

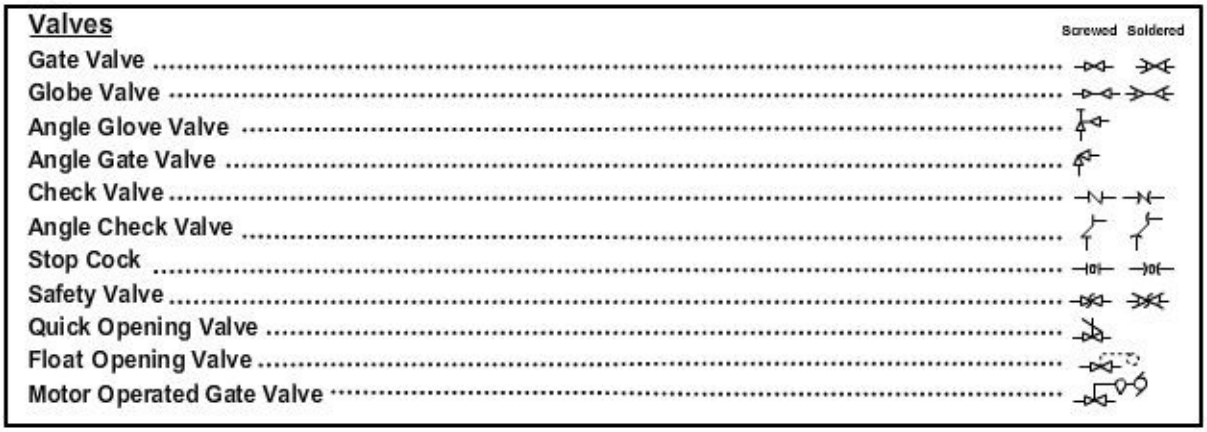
Telephone Jack	
Meter	M
Vacuum Outlet	
Electric Door Opener	D
Chime	CH
Pushbutton (Doorbell)	
Bell and Buzzer Combination	
Kitchen Ventilating Fan	
Lighting Panel	
Power Panel	
Television Outlet	TV

Plumbing

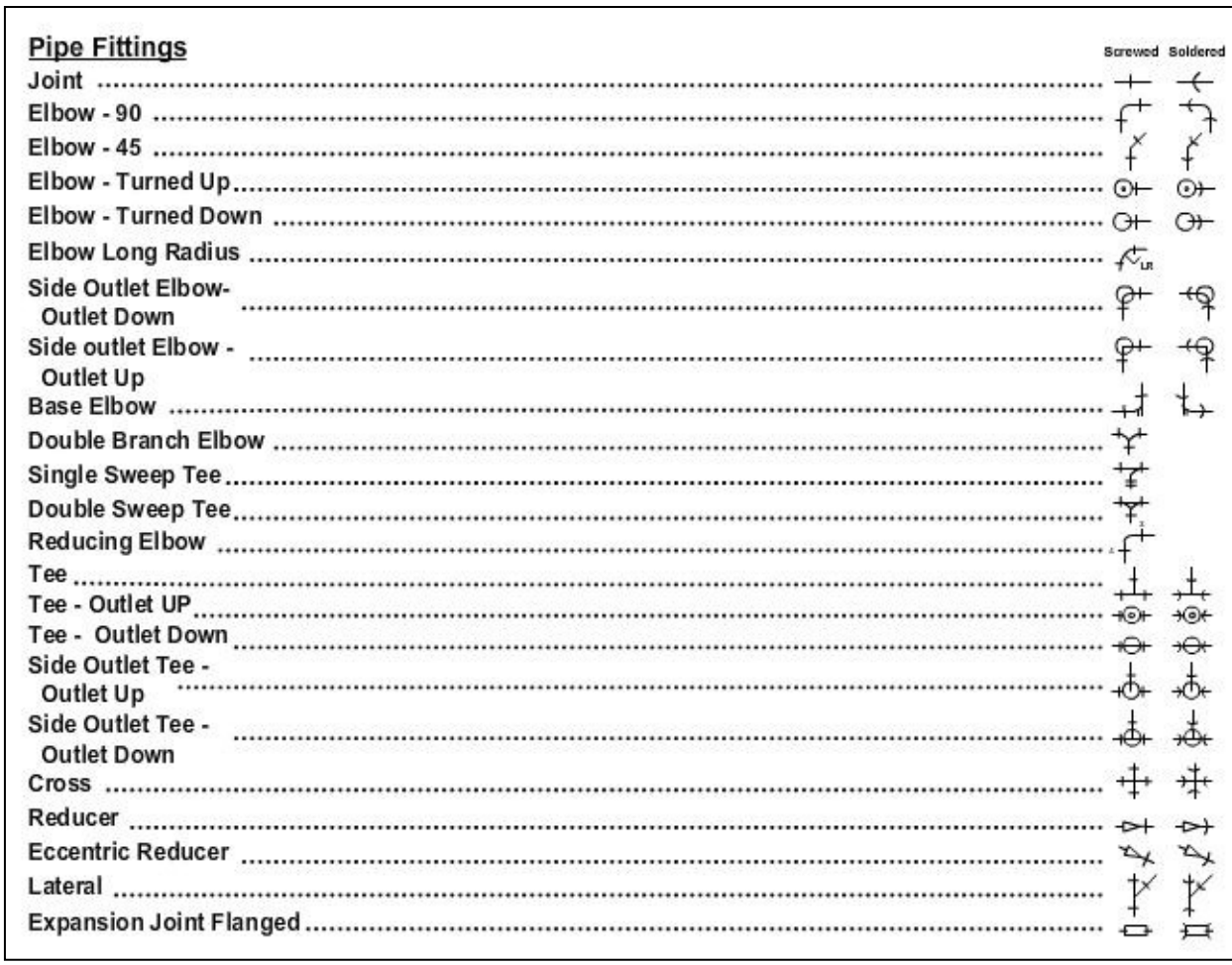
Corner Bath
Recessed Bath
Roll Rim Bath
Sitz Bath
Floor Bath
Bidet
Shower Stall
Shower Head
Overhead Gang Shower
Pedestal Lavatory
Wall Lavatory
Corner Lavatory
Manicure Lavatory
Medical Lavatory
Dental Lavatory
Plain Kitchen Sink
Kitchen Sink, R & L Drain Board
Kitchen Sink, L H Drain Board
Combination Sink and Dishwasher
Combination Sink & Laundry Tray
Service Sink
Wash Sink (Wall Type)
Wash Sink
Laundry Tray
Water Closet (Low Tank)
Water Closet (No Tank)
Urinal (Pedestal Type)
Urinal (Wall Type)
Urinal (Corner Type)
Urinal (Stall Type)
Urinal (Trough Type)
Drinking Fountain (Pedestal Type)
Drinking Fountain (Wall Type)
Drinking Fountain (Trough Type)
Hot Water Tank
Water Heater
Meter
Hose Rack
Hose Bibb
Gas Outlet
Vacuum Outlet
Drain
Grease Separator
Oil Separator
Cleanout
Garage Drain
Floor Drain With Backwater Valve
Roof Sump

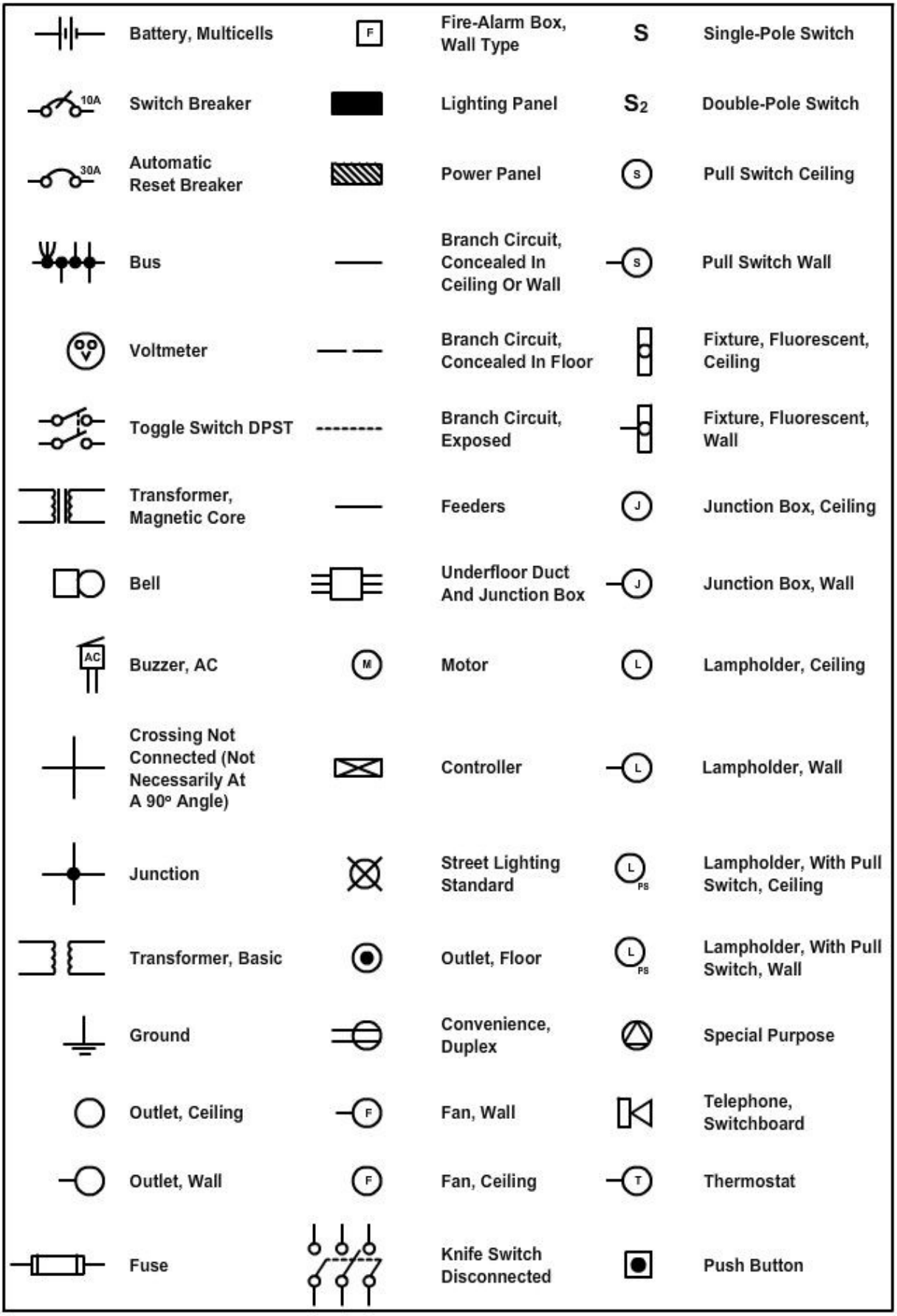
LINE STANDARDS			
Name	**Convention**	**Description and Application**	**Example**
Center Lines		Thin lines made up of long and short dashes alternately spaced and consistent in length. Used to indicate symmetry about an axis and location of centers.	
Visible Lines		Heavy unbroken lines Used to indicate visible edges of an object	
Hidden Lines		Medium lines with short evenly spaced dashes Used to indicate concealed edges	
Extension Lines		Thin unbroken lines Used to indicate extent of dimensions	
Dimension Lines		Thin lines terminated with arrow heads at each end Used to indicate distance measured	
Leader		Thin line terminated with arrowhead or dot at one end Used to indicate a part, dimension or other reference	
Break (Long)		Thin, solid ruled lines with freehand zigzags Used to reduce size of drawing required to delineate object and reduce detail	
Break (Short)		Thick, solid free hand lines Used to indicate a short break	
Phantom or Datum Line		Medium series of one long dash and two short dases evenly spaced ending with long dash Used to indicate alternate position of parts, repeated detail or to indicate a datum plane	
Stitch Line		Medium line of short dases evenly spaced and labeled Used to indicate stitching or sewing	
Cutting or Viewing Plane Viewing Plane Optional		Thick solid lines with arrowhead to indicate direction in which section or plane is viewed or taken	
Cutting Plane for Complex or Offset Views		Thick short dashes Used to show offset with arrowheads to show direction viewed	

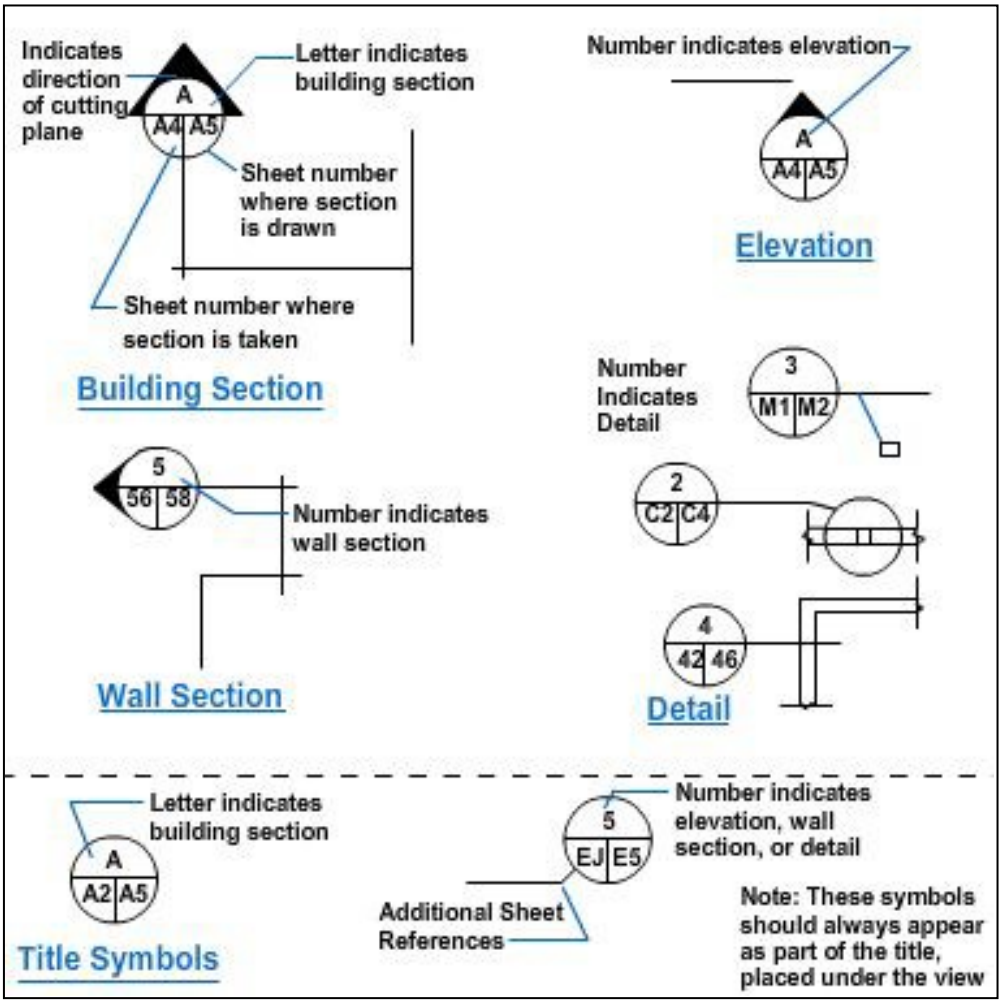
Valves

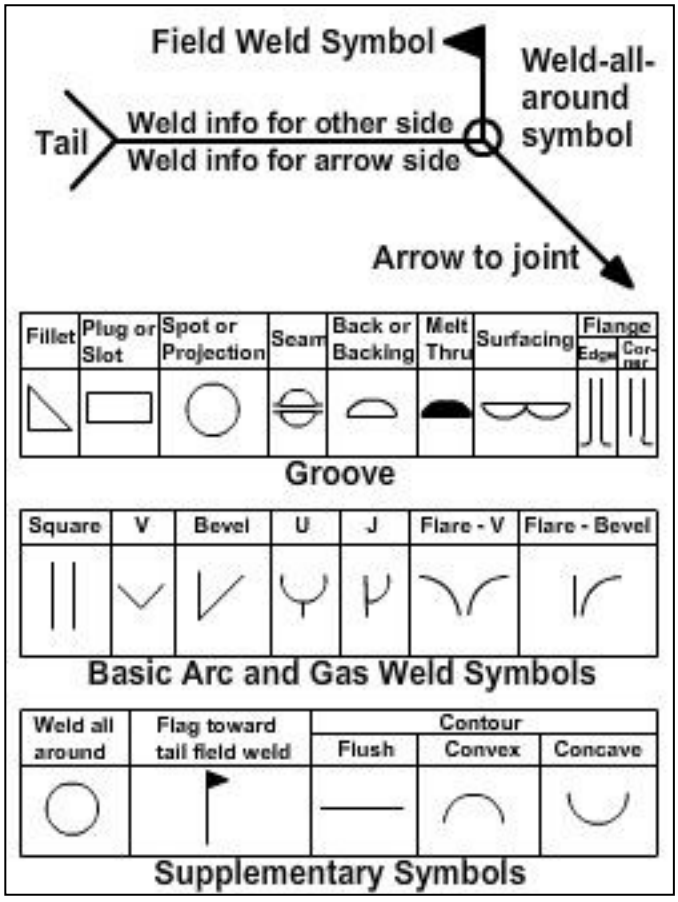


Pipe Fittings




Battery, Multicells
Switch Breaker
10A
Automatic Reset Breaker
30A
Bus
Voltmeter
V
Toggle Switch DPST
Transformer, Magnetic Core
Bell
Buzzer, AC
AC
Crossing Not Connected (Not Necessarily At A 90° Angle)
Junction
Transformer, Basic
Ground
Outlet, Ceiling
Outlet, Wall
Fuse
F
Fire-Alarm Box, Wall Type
Lighting Panel
Power Panel
Branch Circuit, Concealed In Ceiling Or Wall
Branch Circuit, Concealed In Floor
Branch Circuit, Exposed
Feeders
Underfloor Duct And Junction Box
M
Motor
Controller
Street Lighting Standard
Outlet, Floor
Convenience, Duplex
F
Fan, Wall
F
Fan, Ceiling
Knife Switch Disconnected
S
Single-Pole Switch
S2
Double-Pole Switch
S
Pull Switch Ceiling
S
Pull Switch Wall
Fixture, Fluorescent, Ceiling
Fixture, Fluorescent, Wall
J
Junction Box, Ceiling
J
Junction Box, Wall
L
Lampholder, Ceiling
L
Lampholder, Wall
L PS
Lampholder, With Pull Switch, Ceiling
L PS
Lampholder, With Pull Switch, Wall
Special Purpose
Telephone, Switchboard
T
Thermostat
Push Button


Indicates direction of cutting plane
A
A4 A5
Letter indicates building section
Sheet number where section is drawn
Sheet number where section is taken
Building Section
Number indicates elevation
A
A4 A5
Elevation
Number Indicates Detail
3
M1 M2
5
56 58
Number indicates wall section
Wall Section
2
C2 C4
4
42 46
Detail
Letter indicates building section
A
A2 A5
Title Symbols
5
EJ E5
Number indicates elevation, wall section, or detail
Additional Sheet References
Note: These symbols should always appear as part of the title, placed under the view


Field Weld Symbol
Weld-all-around symbol
Tail
Weld info for other side
Weld info for arrow side
Arrow to joint
Fillet
Plug or Slot
Spot or Projection
Seam
Back or Backing
Melt Thru
Surfacing
Flange
Edge
Corner
Groove
Square
V
Bevel
U
J
Flare - V
Flare - Bevel
Basic Arc and Gas Weld Symbols
Weld all around
Flag toward tail field weld
Contour
Flush
Convex
Concave
Supplementary Symbols

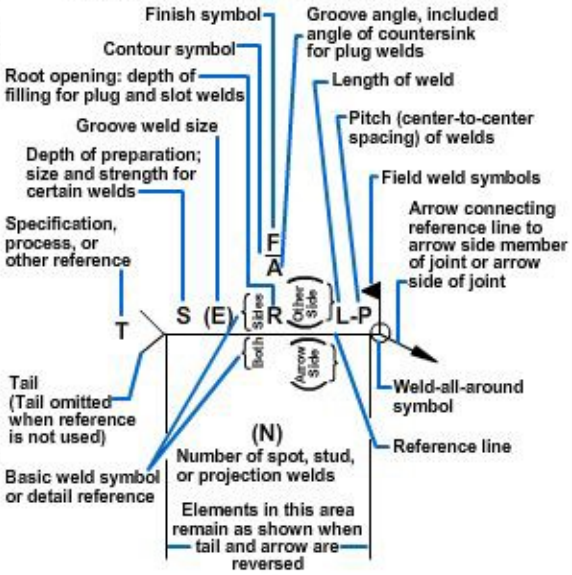
Location Significance	Fillet	Plug or Slot	Spot or Projection	Stud	Seem	Back or Backing	Surfacing	Flange Corner	Flange Edge
Arrow Side						Groove Weld Symbol			
Other Side				Not Used		Groove Weld Symbol	Not Used		
Both Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
No arrow side or other side significance	Not Used	Not Used		Not Used		Not Used	Not Used	Not Used	Not Used

Location Significance	Groove							Scarf for Brazed Joint
	Square	V	Bevel	U	J	Flare - V	Flare - Bevel	
Arrow Side								
Other Side								
Both Sides								
No arrow side or other side significance		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used

Supplementary Symbols

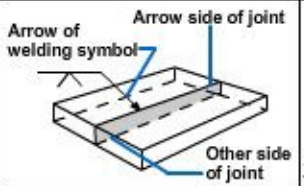
Weld all around	Field Weld	Melt Thru	Consumable Insert	Backing Spacer	Contour		
					Flush	Convex	Concave

Location of Elements of a Welding Symbol

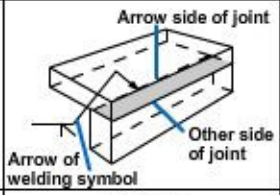


Basic Joints
Identification of Arrow Side and Other Side Joint

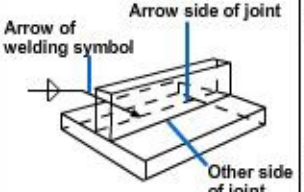
Butt Joint



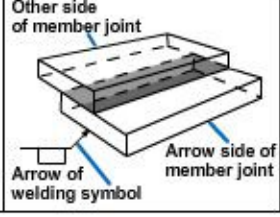
Corner Joint



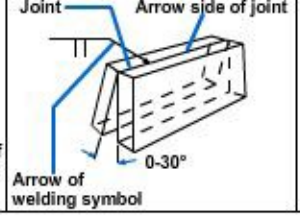
T - Joint



Lap Joint



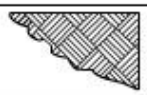
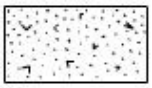
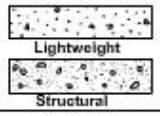
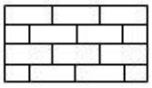
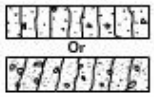
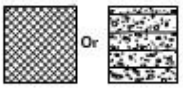
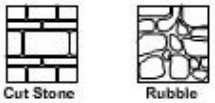
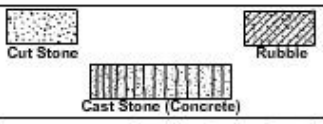
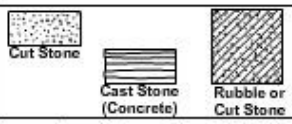
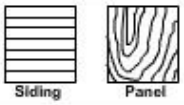
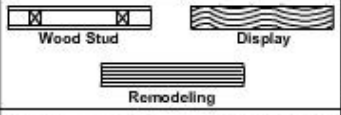
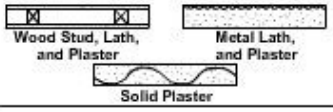
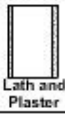
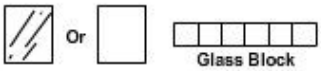
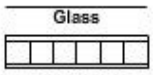
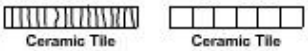
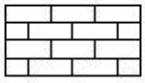
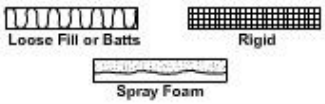
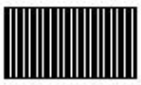
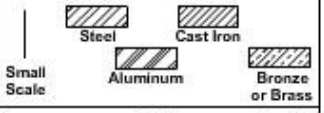
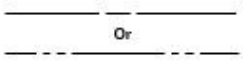
Edge Joint

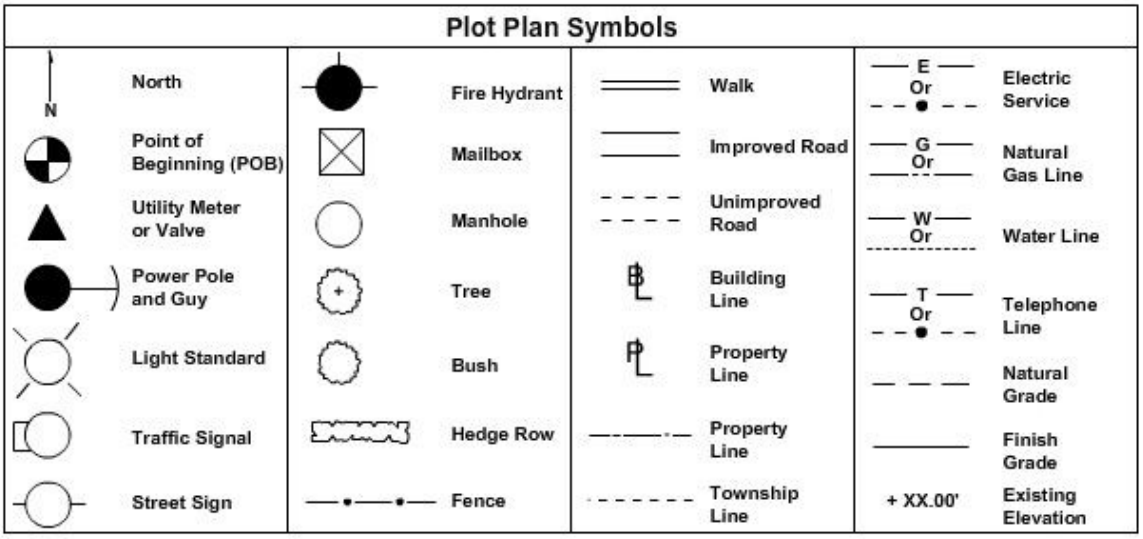


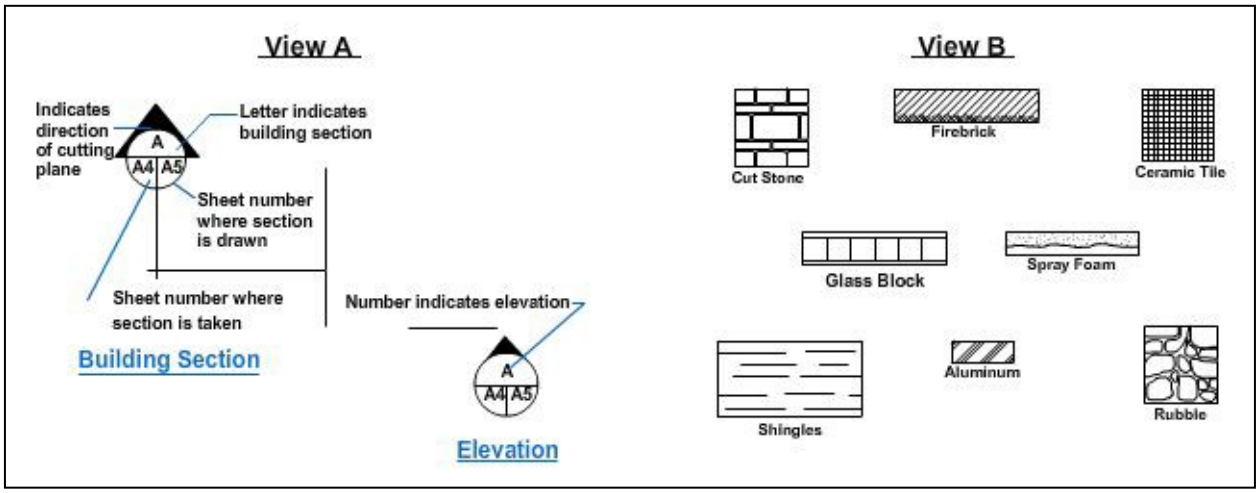
Process Abbreviations

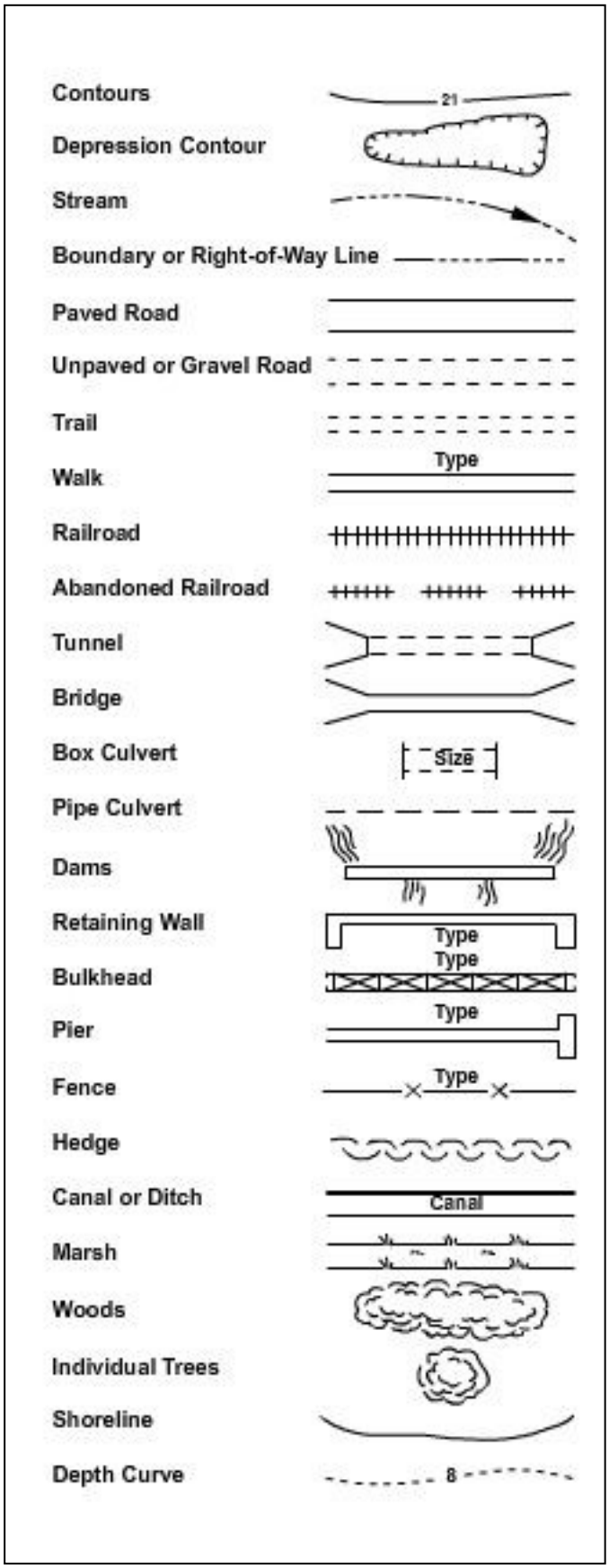
Where process abbreviations are to be included in the tail of the welding symbol, reference is made to Table 1. Designation of Welding and Allied Processes by Letters, of AWS A2.4-86.

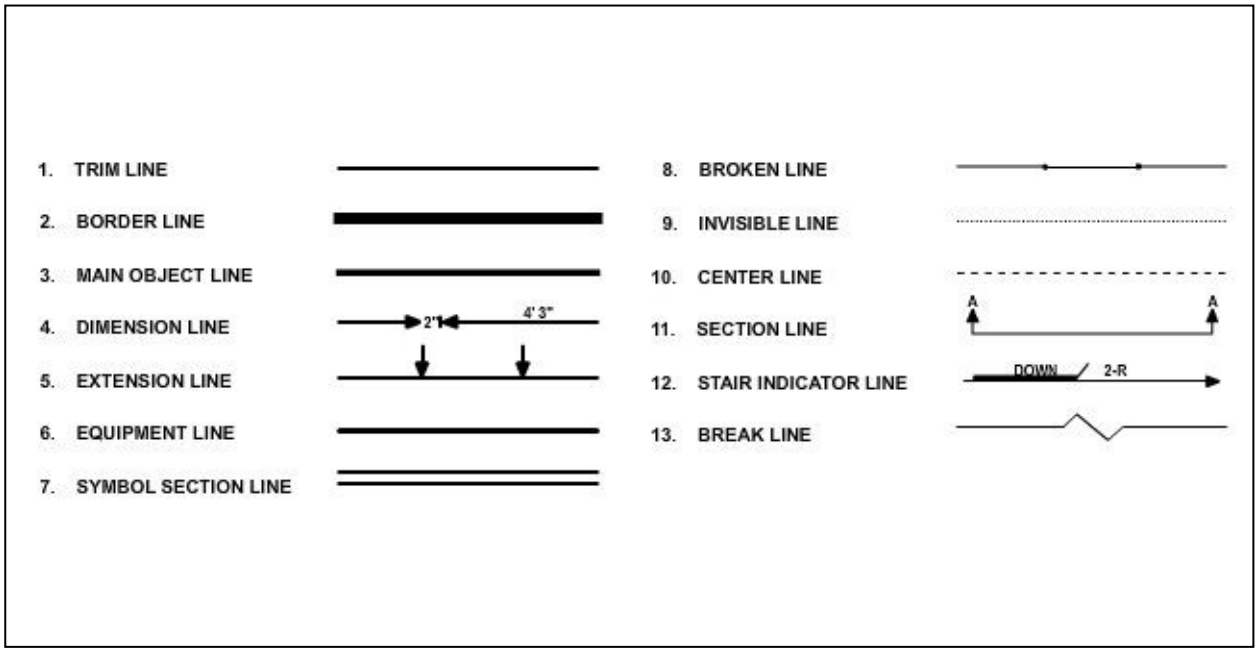
Architectural Symbols

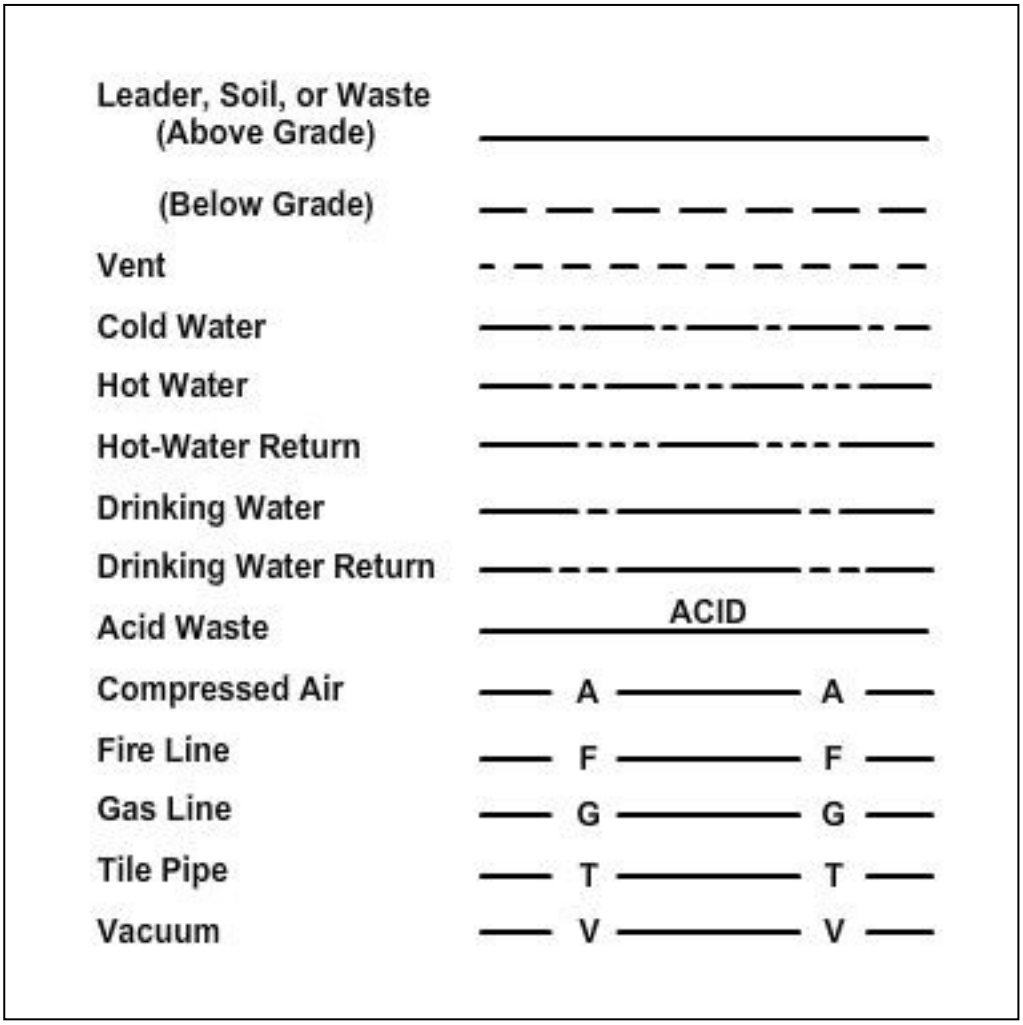
Material	Elevation	Plan	Section
Earth			
Brick	 With note indicating type of brick (common, face, etc.)	 Common or Face Firebrick	Same as Plan Views
Concrete		 Lightweight Structural	Same as Plan Views
Concrete Block		 Or	 Or
Stone	 Cut Stone Rubble	 Cut Stone Rubble Cast Stone (Concrete)	 Cut Stone Cast Stone (Concrete) Rubble or Cut Stone
Wood	 Siding Panel	 Wood Stud Display Remodeling	 Rough Members Finished Members Plywood
Plaster		 Wood Stud, Lath, and Plaster Metal Lath, and Plaster Solid Plaster	 Lath and Plaster
Roofing	 Shingles	Same as Elevation View	
Glass	 Or Glass Block	 Glass Glass Block	 Small Scale Large Scale
Facing Tile	 Ceramic Tile	 Floor Tile	 Ceramic Tile Large Scale Ceramic Tile Small Scale
Structural Clay Tile			Same as Plan Views
Insulation		 Loose Fill or Batts Rigid Spray Foam	Same as Plan Views
Sheet Metal Flashing		Occasionally Indicated by Note	
Metals Other Than Flashing	Indicated by Note or Drawn to Scale	Same as Elevation	 Steel Cast Iron Small Scale Aluminum Bronze or Brass
Structural Steel	Indicated by Note or Drawn to Scale	 Or	 Small Scale Rebars Large Scale L-Angles, S-Beams, etc.

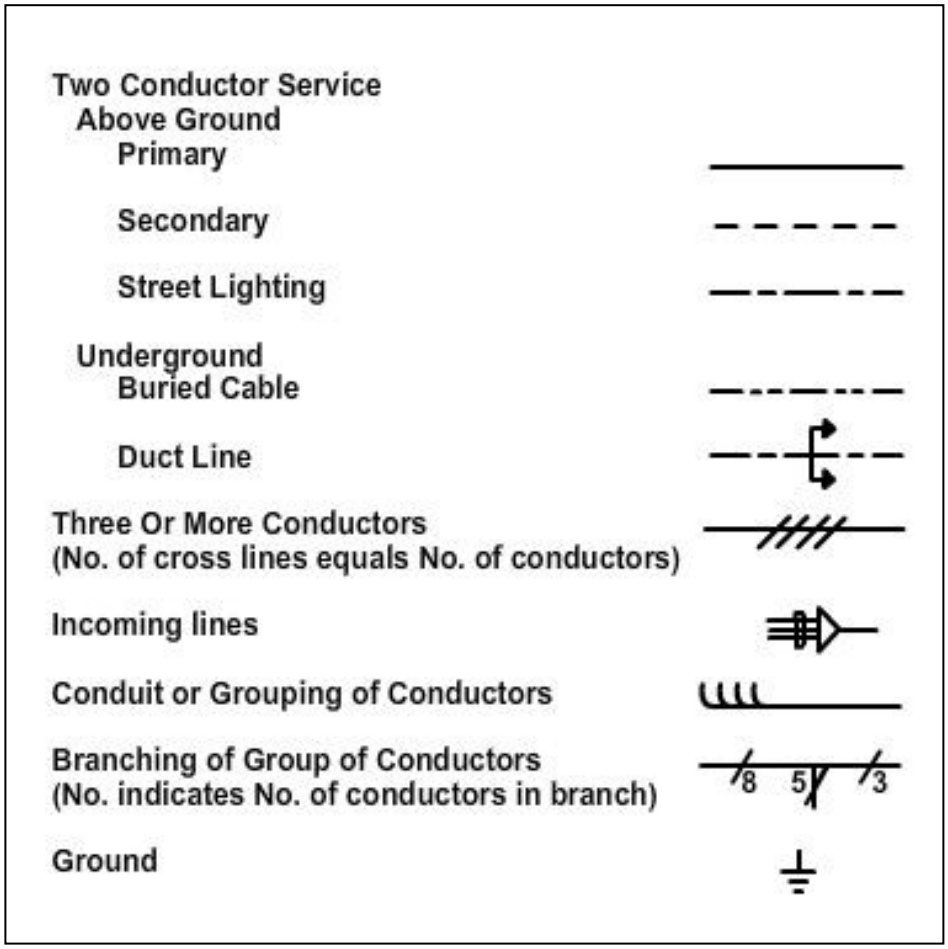

Plot Plan Symbols
North
Point of Beginning (POB)
Utility Meter or Valve
Power Pole and Guy
Light Standard
Traffic Signal
Street Sign
Fire Hydrant
Mailbox
Manhole
Tree
Bush
Hedge Row
Fence
Walk
Improved Road
Unimproved Road
Building Line
Property Line
Property Line
Township Line
E Or
Electric Service
G Or
Natural Gas Line
W Or
Water Line
T Or
Telephone Line
Natural Grade
Finish Grade
+ XX.00'
Existing Elevation

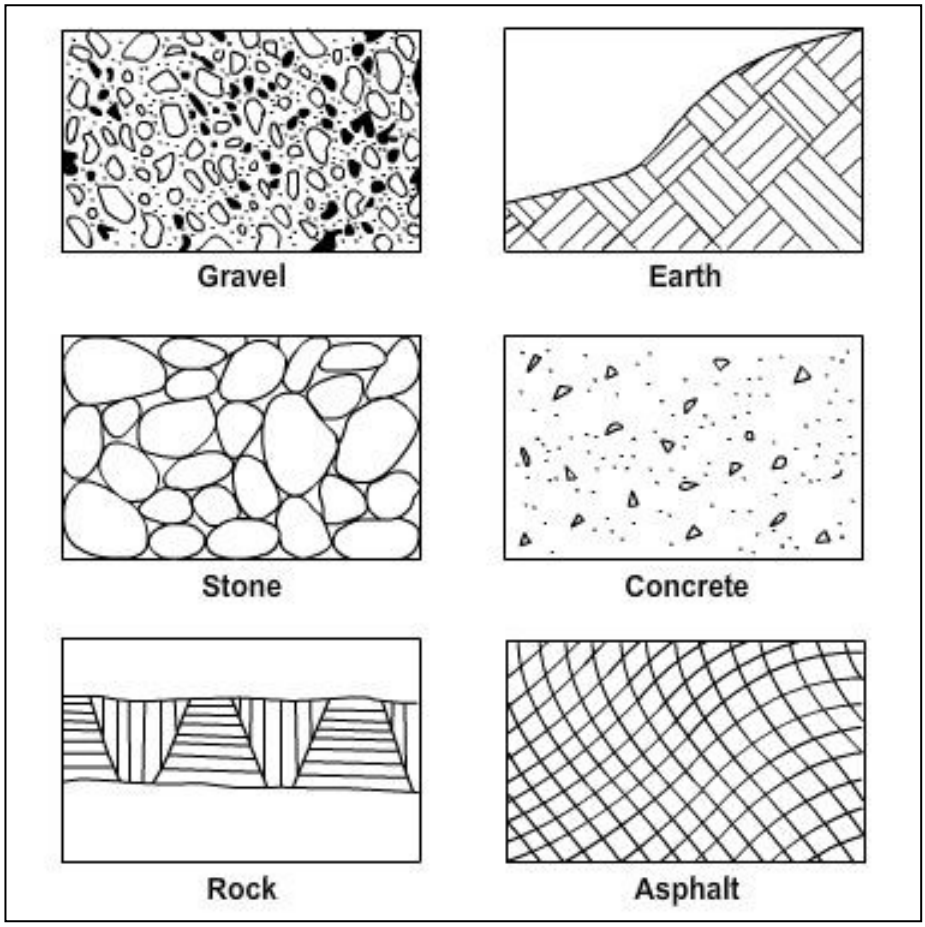

View A
Indicates direction of cutting plane
Letter indicates building section
A
A4 A5
Sheet number where section is drawn
Sheet number where section is taken
Building Section
Number indicates elevation
A
A4 A5
Elevation
View B
Cut Stone
Firebrick
Ceramic Tile
Glass Block
Spray Foam
Shingles
Aluminum
Rubble

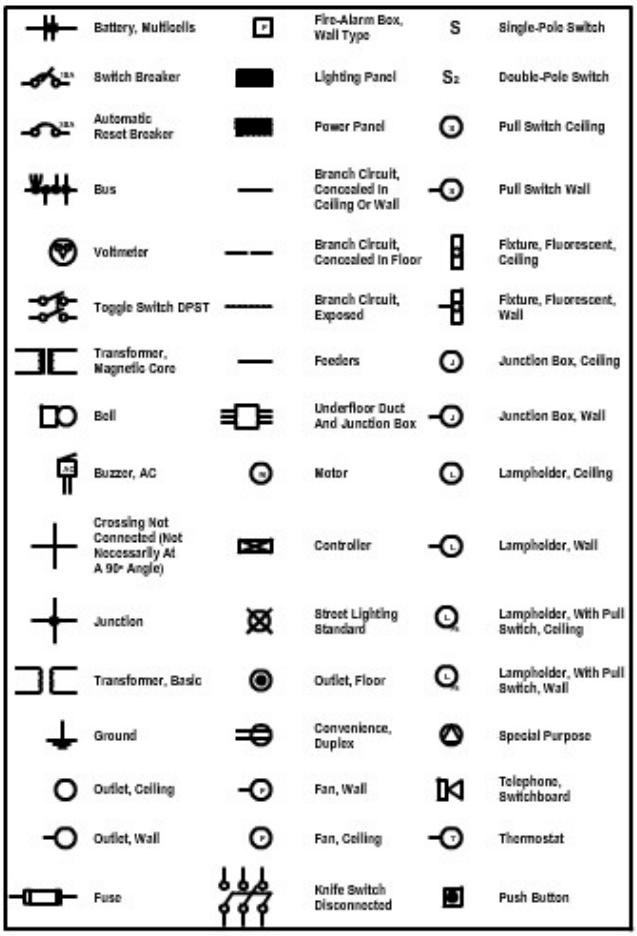

Contours
21
Depression Contour
Stream
Boundary or Right-of-Way Line
Paved Road
Unpaved or Gravel Road
Trail
Walk
Type
Railroad
Abandoned Railroad
Tunnel
Bridge
Box Culvert
Size
Pipe Culvert
Dams
Retaining Wall
Type
Bulkhead
Type
Pier
Type
Fence
Type
Hedge
Canal or Ditch
Canal
Marsh
Woods
Individual Trees
Shoreline
Depth Curve
8


1. TRIM LINE
2. BORDER LINE
3. MAIN OBJECT LINE
4. DIMENSION LINE
2'1"
4' 3"
5. EXTENSION LINE
6. EQUIPMENT LINE
7. SYMBOL SECTION LINE
8. BROKEN LINE
9. INVISIBLE LINE
10. CENTER LINE
11. SECTION LINE
A
A
12. STAIR INDICATOR LINE
DOWN
2-R
13. BREAK LINE


Leader, Soil, or Waste
(Above Grade)
(Below Grade)
Vent
Cold Water
Hot Water
Hot-Water Return
Drinking Water
Drinking Water Return
Acid Waste
ACID
Compressed Air
A
A
Fire Line
F
F
Gas Line
G
G
Tile Pipe
T
T
Vacuum
V
V


Two Conductor Service
Above Ground
Primary
Secondary
Street Lighting
Underground
Buried Cable
Duct Line
Three Or More Conductors
(No. of cross lines equals No. of conductors)
Incoming lines
Conduit or Grouping of Conductors
Branching of Group of Conductors
(No. indicates No. of conductors in branch)
8
5
3
Ground


Gravel
Earth
Stone
Concrete
Rock
Asphalt


Battery, Multicells
Switch Breaker
Automatic Reset Breaker
Bus
Voltmeter
Toggle Switch DPST
Transformer, Magnetic Core
Bell
Buzzer, AC
Crossing Not Connected (Not Necessarily At A 90° Angle)
Junction
Transformer, Basic
Ground
Outlet, Ceiling
Outlet, Wall
Fuse
Fire-Alarm Box, Wall Type
Lighting Panel
Power Panel
Branch Circuit, Concealed In Ceiling Or Wall
Branch Circuit, Concealed In Floor
Branch Circuit, Exposed
Feeders
Underfloor Duct And Junction Box
Motor
Controller
Street Lighting Standard
Outlet, Floor
Convenience, Duplex
Fan, Wall
Fan, Ceiling
Knife Switch Disconnected
S
Single-Pole Switch
S2
Double-Pole Switch
Pull Switch Ceiling
Pull Switch Wall
Fixture, Fluorescent, Ceiling
Fixture, Fluorescent, Wall
Junction Box, Ceiling
Junction Box, Wall
Lampholder, Ceiling
Lampholder, Wall
Lampholder, With Pull Switch, Ceiling
Lampholder, With Pull Switch, Wall
Special Purpose
Telephone, Switchboard
Thermostat
Push Button