Table 13-4 – Estimating Floor Tile.

Square Feet of Floor	Number of Tiles	
	9” x 9”	12” x 12”
1	2	1
2	4	2
3	6	3
4	8	4
5	9	5
6	11	6
7	13	7
8	15	8
9	16	9
10	18	10
20	36	20
30	54	30
40	72	40
50	89	50
60	107	60
70	125	70
80	143	80
90	160	90
100	178	100
200	356	200
300	534	300
400	712	400
500	890	500

Waste Tile	
1 to 50 square feet	14%
50 to 100 square feet	10%
100 to 200 square feet	8%
200 to 300 square feet	7%
300 to 1,000 square feet	5%
Over 1,000 square feet	3%

To find the number of tiles required for an area not shown in this table, such as the number of 9 by 9 inch tiles required for an area of 550 square feet, add the number of tiles needed for 50 square feet to the number of tile needed for 500 square feet. The result will be 979 tiles, to which you must add 5 percent for waste. The total number of tiles required is 1,028.

When tiling large areas, work from several different boxes of tile. This will avoid concentrating one color shade variation in one area of the floor.

8.2.0 Sheet Vinyl Flooring

Because of its flexibility, vinyl flooring is very easy to install. Since sheets are available in 6- to 12-foot widths, many installations can be made free of seams. Flexible vinyl flooring is fastened down only around the edges and at seams. It can be installed over concrete, plywood, or old linoleum.

To install, spread the sheet smoothly over the floor. Let excess material turn up around the edges of the room. Where there are seams, carefully match the pattern. Fasten the two sections to the floor with adhesive. Trim the edges to size by creasing the vinyl sheet material at intersections of the floor and walls and cutting it with a utility knife drawn along a straightedge. Be sure the straightedge is parallel to the wall.

After the edges are trimmed and fitted, secure them with a staple gun, or use a band of double faced adhesive tape. Always study the manufacturer’s directions carefully before starting the work.

Test your Knowledge (Select the Correct Response)

8. What is the result of too heavily applied tile adhesive?

    A. Tile will not adhere.
    B. Adhesive will not set.
    C. Tiles will telegraph.
    D. Adhesive will bleed between tiles.

9.0.0 CARPET

Wall to wall carpeting can make a small room look larger, insulate against drafty floors, and do a certain amount of soundproofing. Carpeting is not difficult to install.

All carpets consist of a surface pile and backing. The surface pile may be nylon, polyester, polypropylene, acrylic, wool, or cotton. Each has its advantages and disadvantages. The type you select depends on your needs. Carpeting can be purchased in 9-, 12-, and 15-foot widths.

9.1.0 Measuring and Estimating

Measure the room in the direction in which the carpet will be laid. To broaden long, narrow rooms, lay patterned or striped carpeting across the width. For conventionally rectangular rooms, measure the room lengthwise. Include the full width of doorframes so the carpet will extend slightly into the adjoining room. When measuring a room with alcoves or numerous wall projections, calculate on the basis of the widest and longest points. This will result in some waste material, but is safer than ordering less than what you need.

Most wall-to-wall carpeting is priced by the square yard. To determine how many square yards you need, multiply the length by the width of the room in feet and divide the result by 9.

9.1.1 Underlayment

Except for so-called one-piece and cushion-backed carpeting, underlayment or padding is essential to a good carpet installation. It prolongs the life of the carpeting, increases its soundproofing qualities, and adds to underfoot comfort.

The most common types of carpet padding are latex (rubber), sponge rubber foams, soft and hardback vinyl foams, and felted cushions made of animal hair or of a combination of hair and jute. Of all types, the latex and vinyl foams are generally considered the most practical. Their waffled surface tends to hold the carpet in place. Most carpet padding comes in a standard 4 1/2 foot width.

Cushion-backed carpeting is increasing in popularity, especially with do-it-yourself homeowners. The high-density latex backing is permanently fastened to the carpet, which eliminates the need for a separate underpadding. It is nonskid and heavy enough to hold the carpet in place without the use of tacks. In addition, the foam rubber backing keeps the edges of the carpet from unraveling so that it need not be bound. Foam rubber is mildewproof and unaffected by water, so the carpet can be used in basements and other below-grade installations. It can even be laid directly over unfinished concrete.

The key feature of this backing, however, is the dimensional stability it imparts to the carpet. This added characteristic means the carpet will not stretch, nor will it expand and contract from temperature or humidity changes. Because of this, these carpets can be loose laid, with no need for adhesive or tacks to give them stability.

9.1.2 Preparing the Floor

To lay carpets successfully on wood floors, you must ensure that the surface is free of warps, and that all nails and tacks are either removed or hammered flush. Nail down any loose floorboards and plane down the ridges of warped boards. Fill wide cracks between floorboards with strips of wood or wood putty. Cover floors that are warped and cracked beyond reasonable repair with hardboard or plywood.

Stone or concrete floors that have surface ridges or cracks should be treated beforehand with a floor leveling compound to reduce carpet wear. These liquid compounds are also useful for sealing the surface of dusty or powdery floors. A thin layer of the compound, which is floated over the floor, will keep dust from working its way up through the underlayment and into the carpet pile.

The best carpeting for concrete and hard tile surfaces is the indoor-outdoor type. The backing of this carpet is made of a closed-pore type of either latex or vinyl foam, which keeps out most moisture. It is not wise to lay any of the standard paddings on top of floor tiles unless the room is well ventilated and free of condensation. Vinyl and asbestos floor tiles accumulate moisture when carpeting is laid over them. This condensation soaks through into the carpet and eventually causes a musty odor. It can also produce mildew stains.

9.1.3 Fastening Carpets

The standard fastening methods are with tacks or by means of tackless fittings. Carpets can also be loose laid with only a few tacks at entrances. Carpet tack lengths are 3/4 and 1 inch. The first is long enough to go through a folded carpet hem and anchor it firmly to the floor, as shown in *Figure 13-84*. The 1-inch tacks are used in corners where the folds of the hem make three thicknesses.

Figure 13-84 – Carpet installation using tacks.

Tackless fittings, shown in *Figure 13-85*, are a convenient fastening method. They consist of a 4-foot wooden batten with a number of spikes projecting at a 60° angle. The battens are nailed to the floor around the entire room, end to end and 1/4 inch from the baseboard, with the spikes facing toward the wall. The spikes grip the backing of the carpet to hold it in place. On stone or concrete floors, the battens are glued in place with special adhesives.

Figure 13-85 – Tackless Fitting for Doorway (Left) and Wall (Right).

Though cushion-backed carpeting can stay in place without fastening, securing with double-face tape is the preferred method. Carpets can also be attached to the floor with Velcro™ tape where the frequent removability of the carpet for cleaning and maintenance is a factor.

9.1.4 Carpet Installation

To install a carpet, you will need a hammer, large scissors, a sharp knife, a 3 foot rule, needle and carpet thread, chalk and chalk line, latex adhesive, and carpet tape. The only specialized tool you will need is a carpet stretcher, often called a knee kicker.

Before starting the job, remove all furniture and any doors that swing into the room. When cutting the carpet, spread it out on a suitable floor space and chalk the exact pattern of the room on the pile surface; then cut along the chalk line with the scissors or sharp knife.

Join unseamed carpet by placing the two pieces so the pile surfaces meet edge to edge. Match patterned carpets carefully. With plain carpets, lay each piece so the piles run the same way. Join the pieces with carpet thread, taking stitches at 18 inch intervals along the seam. Pull the carpet tight after each stitch to take up slack. Sew along the seam between stitches. Tuck any protruding fibers back into the pile. Carpet can also be seamed by cementing carpet tape to the backing threads with latex adhesive.

Open the carpet to room length and position it before starting to put down the padding. The pile should fall away from windows to avoid uneven shading in daylight. Fold one end of the carpet back halfway and put the padding down on the exposed part of the floor. Do the same at the other end. This avoids wrinkles caused by movement of the padding.

To tack, start at the corner of the room that is formed by the two walls with the fewest obstructions. Butt the carpet up against the wall, leaving about 1 1/2 inches up the baseboard for hemming. Attach the carpet temporarily with tacks about 6 inches from the baseboard along these two walls. Use the knee kicker to stretch the carpet, first along the length, then the width. Start from the middle of the wall, stretching alternately toward opposite comers. When the carpet is smooth, tack down the stretched area temporarily.

Cut slots for pipes, fireplace protrusions, and radiators. Trim back the padding to about 2 inches from the wall to leave a channel for the carpet hem. Fold the hem under and tack the carpet in place with a tack every 5 inches. Be sure the tacks go through the fold.

Figure 13-86 – Carpet installation using tackless fastenings.

When installing carpet, use tackless fastening strips, as shown in *Figure 13-86*. Position and trim the padding (*View B*) so that it meets the strip at the wall, but does not overlap the strip. Tack it down so it does not move. Lay out the carpeting and, using a knee-kicker, stretch the carpet over the nails projecting out of the tackless strip (*View C*). Trim the carpet, leaving a 3/8 inch overlap, which is tucked into place between the wall and the tackless strip (*View D*). (If you trim too much carpeting, lift the carpeting off the spikes of the tackless strip and use the knee-kicker to restretch the carpet (*View E*). Protect the exposed edge of the carpet at doorways with a special metal binder strip or bar (*View F*). The strip is nailed to the floor at the doorway and the carpet slipped under a metal lip, which is then hammered down to grip the carpet edge.

Tacks can be used as an alternative to a binder strip. Before tacking, tape the exposed edge of woven carpet to prevent fraying if the salvage has been trimmed off. Cement carpet tape to the backing threads with latex adhesive. Nonwoven or latex-backed carpet will not fray, but tape is still advisable to protect exposed edges. Any door that drags should be removed and trimmed.

When installing cushion-backed carpeting, you can eliminate several steps. For instance, you do not need to use tack strips or a separate padding. Although these instructions apply to most such carpeting, read the manufacturer's instructions for any deviation in technique or use of material.

To install a cushioned carpet, apply 2-inch wide double-face tape flush with the wall around the entire room, as shown in *Figure 13-87, view A*. Roll out and place the carpet.

Fold back the carpet and remove the protective paper from the tape. Press the carpet down firmly over the tape and trim away excess, as shown in *view B*. A metal binder strip or an aluminum saddle is generally installed in doorways, as shown in *view C*. If your room is wider than the carpet, you will have to seam two pieces together. Follow the manufacturer's recommendations.

Figure 13-87 – Installing cushion-backed carpeting.

Test your Knowledge (Select the Correct Response)

9. How many square yards of carpet are required to cover a room 24 feet by 48 feet?

   A. 76
   B. 98
   C. 114
   D. 128

10.0.0 PAINTING

The final stage of most construction projects is the application of protective coatings, or painting. As with all projects, you should follow the plans and specifications for surface preparation and application of the finish coat. The specifications give all the information you need to complete the tasks. But to have a better understanding of structural coatings, you need to know their purposes, methods of surface preparation, and application techniques.

10.1.0 Purposes of Structural Coatings

The protection of surfaces is the most important consideration in determining the maintenance cost of structures. Structural coatings serve as protective shields between the base construction materials and elements that attack and deteriorate them. Regularly programmed structural coatings offer long-range protection, extending the useful life of a structure.

10.2.0 Preventive Maintenance

The primary purpose of a structural coating is protection. This is provided initially with new construction and maintained by a sound and progressive preventive maintenance program. Programmed painting enforces inspection and scheduling. A viable preventive maintenance program helps ensure that minor problems are detected at an early stage, before they become major failures. An added advantage derived from preventive maintenance is the detection of faulty structural conditions or problems caused by leakage or moisture.

Resistance to moisture from rain, snow, ice, and condensation constitutes perhaps the greatest single protective characteristic of paint, the most common type of structural coating. Moisture causes metal to corrode and wood to swell, warp, or rot. Interior wall finishes of buildings can be ruined by moisture entering through neglected exterior surfaces. Porous masonry is attacked and destroyed by moisture. Paint films must be as impervious to moisture as possible to provide a protective, waterproof film over the surface to which they are applied. Paint also acts as a protective film against acids, alkalies, material organisms, and other damaging elements.

10.3.0 Sanitation and Cleanliness

Painting is an essential part of general maintenance programs for hospitals, kitchens, mess halls, offices, warehouses, and living quarters. Paint coatings provide smooth, nonabsorptive surfaces that are easily washed and kept free of dirt and foodstuffs. Adhering foodstuffs harbor germs and cause disease. Coating rough or porous areas seals out dust and grease that would otherwise be difficult to remove.

Odorless paints are used in these areas because conventional paint solvent odors are obnoxious to personnel. In food preparation areas, the odors may be picked up by nearby food.

10.4.0 Fire Retardance

Certain types of structural coatings delay the spread of fire and assist in confining a fire to its area of origin. Fire-retardant coatings should not be considered substitutes for conventional paints. The use of fire-retardant coatings is restricted to areas of highly combustible surfaces, and must be justified and governed by the specific agency’s criteria. Fire-retardant coatings are not used in buildings containing automatic sprinkler systems.

10.5.0 Camouflage

Camouflage paints have special properties that make them different from conventional paints. Their uses are limited to special applications. Do not use camouflage paints as substitutes for conventional paints. Use this paint only on exterior surfaces to render buildings and structures inconspicuous by blending them in with the surrounding environment.

10.6.0 Illumination and Visibility

White and light-tinted coatings applied to ceilings and walls reflect both natural and artificial light, and help brighten rooms and increase visibility. On the other hand, darker colors reduce the amount of reflected light. Flat coatings diffuse, soften, and evenly distribute illumination, whereas gloss finishes reflect more like mirrors and may create glare. Color contrasts improve visibility of the painted surface, especially when paint is applied in distinctive patterns. For example, white on black, white on orange, or yellow on black can be seen at greater distances than single colors or other combinations of colors.

10.7.0 Identification and Safety

Certain colors are used as standard means of identifying objects and promoting safety. For example, fire protection equipment is painted red. Containers for kerosene, gasoline, solvents, and other flammable liquids should be painted a brilliant yellow and marked with large black letters to identify their contents. Colors of signal lights and painted signs help control traffic safely by providing directions and other travel information.

10.8.0 Types of Coatings

As a Builder, you must consider many factors when selecting a coating for a particular job. One important factor is the type of coating, which depends on the composition and properties of the ingredients.

Paint is composed of various ingredients, such as pigment, nonvolatile vehicle (or binder), and solvent (or thinner). Other coatings may contain only a single ingredient.

10.8.1 Paint

In this section, we'll cover the basic components of paint (pigment, vehicles, and solvents) and explain the characteristics of different types of paint.

Paint is composed of two basic ingredients, pigment and a vehicle. A thinner may be added to change the application characteristics of the liquid.

Pigments are insoluble solids, ground finely enough to remain suspended in the vehicle for a considerable time after thorough stirring or shaking. Opaque pigments give the paint its hiding, or covering, capacity and contribute other properties; white lead, zinc oxide, and titanium dioxide are examples. Color pigments give the paint its color. These may be inorganic, such as chrome green, chrome yellow, and iron oxide, or organic, such as toluidine red and phthalocyanine blue. Transparent or extender pigments contribute bulk and also control the application properties, durability, and resistance to abrasion of the coating. There are other special purpose pigments, such as those enabling paint to resist heat, control corrosion, or reflect light.

The vehicle, or binder, of paint is the material holding the pigment together and causing paint to adhere to a surface. In general, paint durability is determined by the resistance of the binder to the exposure conditions. Linseed oil, once the most common binder, has been replaced mainly by the synthetic alkyd resins. These result from the reaction of glycerol phthalate and an oil and may be made with almost any property desired. Other synthetic resins, used either by themselves or mixed with oil, include phenolic resin, vinyl, epoxy, urethane, polyester, and chlorinated rubber. Each has its own advantages and disadvantages. When using these materials, it is particularly important that you follow the manufacturer's instructions exactly.

The only purpose of a solvent, or thinner, is to adjust the consistency of the material so that it can be applied readily to the surface. The solvent then evaporates, contributing nothing further to the film. For this reason, the cheapest suitable solvent should be used. This solvent is likely to be naphtha or mineral spirits. Although turpentine is sometimes used, it contributes little that other solvents do not and costs much more.

NOTE

Synthetic resins usually require a special solvent. It is important the correct one be used; otherwise, the paint may be spoiled entirely.

10.8.2 Types of Paint

Paints by far comprise the largest family of structural coatings you will be using to finish products, both interior and exterior. In the following section, we will cover some of the most commonly encountered types.

Oil-based paints consist mainly of a drying oil, usually linseed, mixed with one or more pigments. The pigments and quantities of oil in oil paints are usually selected on the basis of cost and their ability to impart to the paint the desired properties, such as durability, economy, and color. An oil-based paint is characterized by easy application and slow drying. It normally chalks in such a manner as to permit recoating without costly surface preparation. Adding small amounts of varnish tends to decrease the time it takes an oil-based paint to dry and to increase the paint's resistance to water. Oil-based paints are not recommended for surfaces submerged in water.

Enamels are generally harder, tougher, and more resistant to abrasion and moisture penetration than oil-based paints. Enamels are available in flat, semigloss, and gloss. The extent of pigmentation in the paint or enamel determines its gloss. Gloss is reduced by adding lower cost pigments called extenders. Typical extenders are calcium carbonate (whiting), magnesium silicate (talc), aluminum silicate (clay), and silica. The level of gloss depends on the ratio of pigment to binder.

Epoxy paints are a combined resin and a polyamide hardener that are mixed before use. When mixed, the two ingredients react to form the end product. Epoxy paints have a limited working, or pot, life, usually 1 working day. They are outstanding in hardness, adhesion, and flexibility, plus they resist corrosion, abrasion, alkali, and solvents. The major uses of epoxy paints are as tile-like glaze coatings for concrete or masonry, and for structural steel in corrosive environments. Epoxy paints tend to chalk on exterior exposure; low gloss levels and fading can be anticipated. Otherwise, their durability is excellent.

Latex paints contain a synthetic chemical, called latex, dispersed in water. The kinds of latex usually found in paints are styrene butadiene (also called synthetic rubber), polyvinyl acetate (PVA or vinyl), and acrylic. Latex paints differ from other paints in that the vehicle is an emulsion of binder and water. Being water-based, latex paints have the advantage of being easy to apply. They dry through evaporation of the water. Many latex paints have excellent durability. This makes them particularly useful for coating plaster and masonry surfaces. Careful surface preparation is required for their use.

Rubber-based paints are solvent thinned and should not be confused with latex binders, often called rubber-based emulsions. Rubber-based paints are lacquer-type products and dry rapidly to form finishes highly resistant to water and mild chemicals. They are used for coating exterior masonry and areas that are wet, humid, or subject to frequent washing, such as laundry rooms, showers, washrooms, and kitchens.

Portland cement mixed with several ingredients acts as a paint binder when it reacts with water. The paints are supplied as a powder to which the water is added before being used. Cement paints are used on rough surfaces, such as concrete, masonry, and stucco. They dry to form hard, flat, porous films that permit water vapor to pass through readily. When properly cured, cement paints of good quality are quite durable. When improperly cured, they chalk excessively on exposure and may present problems in repainting.

Aluminum paints are available in two forms, ready-mixed and ready-to-mix. Ready-mixed aluminum paints are supplied in one package and are ready for use after normal mixing. They are made with vehicles that will retain metallic brilliance after moderate periods of storage. They are more convenient to use and allow for less error in mixing than the ready-to-mix form.

Ready-to-mix aluminum paints are supplied in two packages, one containing clear varnish and the other the required amount of aluminum paste (usually two-thirds aluminum flake and one-third solvent). You mix just before using by slowly adding the varnish to the aluminum paste and stirring. Ready-to-mix aluminum paints allow a wider choice of vehicles and present less of a problem with storage stability. A potential problem with aluminum paints is moisture in the closed container.

CAUTION

When water is present, moisture may react with the aluminum flake to form hydrogen gas that pressurizes the container.

Pressure can cause the container to bulge or even pop the cover off the container. Check the containers of ready-mixed paints for bulging. If they bulge, puncture the covers carefully before opening to relieve the pressure. Be sure to use dry containers when mixing aluminum paints.

10.8.3 Varnishes

In contrast to paints, varnishes contain little or no pigment and do not obscure the surface to which they are applied. Usually a liquid, varnish dries to a hard, transparent coating when spread in a thin film over a surface, affording protection and decoration.

Of the common types of varnishes, the most important are the oils, including spar, flat, rubbing, and color types. These are extensively used to finish and refinish interior and exterior wood surfaces, such as floors, furniture, and cabinets. Spar varnish is intended for exterior use in normal or marine environments, although its durability is limited. To increase durability, exterior varnishes are especially formulated to resist weathering.

Varnishes produce a durable, elastic, and tough surface that normally dries to a high gloss finish that does not easily mar. A lower gloss may be obtained by rubbing the surface with very fine steel wool. It is simpler to use a flat varnish with the gloss reduced by adding transparent flatting pigments, such as certain synthetic silicas. These pigments are dispersed in the varnish to produce a clear finish that dries to a low gloss, but still does not obscure the surface underneath, that is, you can still see the grain of the wood.

10.8.4 Shellac

Shellac is purified lac formed into thin flakes and widely used as a binder in varnishes, paints, and stains. Lac is a resinous substance secreted by certain insects. The vehicle is wood alcohol. The natural color of shellac is orange, although it can be obtained in white. Shellac is used extensively as a finishing material and a sealant. Applied over knots in wood, it prevents bleeding.

10.8.5 Lacquers

Lacquers may be clear or pigmented and can be lusterless, semigloss, or glossy. Lacquers dry or harden quickly, producing a firm oil and water-resistant film. Many coats are required to achieve adequate dry film thickness. It generally costs more to use lacquers than most paints.

10.8.6 Stains

Stains are obtainable in four different kinds: oil, water, spirit, and chemical. Oil stains have an oil vehicle; mineral spirits can be added to increase penetration. Water stains are solutions of aniline dyes and water. Spirit stains contain alcohol. Chemical stains work by means of a chemical reaction when dissolved by water. The type of stain to use depends largely on the purpose, the location, and the type of wood being covered.

10.9.0 Surface Preparation

The most essential part of any painting job is proper surface preparation and repair. Each type of surface requires specific cleaning procedures. Paint will not adhere well, provide the protection necessary, or have the desired appearance unless the surface is in proper condition for painting. Exterior surface preparation is especially important because hostile environments can accelerate deterioration.

10.9.1 Metals

As a Builder, you are most likely to paint three types of metals: ***ferrous***, nonferrous, and galvanized. Improper protection of metals is likely to cause fatigue in the metal itself and may result in costly repairs or even replacement. Correct surface preparation prior to painting is essential.

Cleaning ferrous metals, such as iron and steel, involves the removal of oil, grease, previous coatings, and dirt. Keep in mind that once you prepare a metal surface for painting, it will start to rust immediately unless you use a primer or pretreatment to protect the surface.

The nonferrous metals are brass, bronze, copper, tin, zinc, aluminum, nickel, and others not derived from iron ore. Nonferrous metals are generally cleaned with a solvent type of cleaner. After cleaning, you should apply a primer coat or a pretreatment.

Galvanized iron is one of the most difficult metals to prime properly. The galvanizing process forms a hard, dense surface that paint cannot penetrate. Too often, galvanized surfaces are not prepared properly, resulting in paint failure. Three steps must be taken to develop a sound paint system.

1. Wash the galvanized surface with a solvent to remove grease, waxes, or silicones. Manufacturers sometimes apply these to resist white rust that may form on galvanized sheets stored under humid conditions. Mineral spirits or acid washes should definitely not be used at this stage.
2. Etch the surface with a mild phosphoric acid wash. Etching increases paint adhesion and helps overcome the stress forces generated by expansion and

contraction of the galvanized coating. After acid washing the surface, rinse it with clean water and allow it to dry. When using acid, remember that the situation can represent actual or potential danger to yourself and other employees in the area. Continuous and automatic precautionary measures minimize safety problems and improve both efficiency and morale of the crew.

3. Apply a specially formulated primer. Two basic types of primer are in common use, zinc-bound and cementitious resin. The zinc-bound type is used for normal exposure. Most types of finish can be used over this type of primer. Latex emulsion paints provide a satisfactory finish. Oil-based products should not be used over cementitious resin primers. A minimum of two coats of finish is recommended over each type of primer.

10.9.2 Concrete and Masonry

In Navy construction, concrete and masonry are normally not painted unless painting is required for damp-proofing. Cleaning concrete and masonry involves the removal of dirt, mildew, and ***efflorescence***, which is a white, powdery crystalline deposit that often forms on concrete and masonry surfaces.

Dirt and fungus are removed by washing with a solution of trisodium phosphate. The strength of the solution may vary from 2 to 8 ounces per gallon of water, depending upon the amount of dirt or mildew on the surface. Immediately after washing, rinse off all the trisodium phosphate with clear water. If using oil paint, allow the surface to dry thoroughly before painting.

For efflorescence, first remove as much of the deposit as possible by dry brushing with a wire brush or a stiff fiber brush. Next, wet the surface thoroughly with clear water; and then scrub with a stiff brush dipped in a 5 percent solution by weight of muriatic acid. Allow the acid solution to remain on the surface about 3 minutes before scrubbing, but rinse thoroughly with clear water immediately after scrubbing. Work on small areas not larger than 4 square feet. Wear rubber gloves, a rubber apron, and goggles when mixing and applying the acid solution. In mixing the acid, always add acid to water. Do not add water to acid, as this can cause the mixture to explode. For a very heavy deposit, the acid solution may be increased to 10 percent and allowed to remain on the surface for 5 minutes before it is scrubbed.

All defects in a concrete or masonry surface must be repaired before painting. To repair a large crack, cut the crack out to an inverted V shape and plug it with grout, which is a mixture of two or three parts of mortar sand, one part of Portland cement, and enough water to make it putty-like in consistency. After the grout sets, damp cure it by keeping it wet for 48 hours. If oil paint is to be used, allow at least 90 days for weathering before painting over a grout-filled crack.

10.9.3 Plaster and Walboard

Whenever possible, allow new plaster to age at least 30 days before painting if oil-based paint is being applied. Latex paint can be applied after 48 hours, although a 30-day wait is generally recommended. Before painting, fill all holes and cracks with spackling compound or patching plaster. Cut out the material along the crack or hole in an inverted V shape. To avoid excessive absorption of water from the patching material, wet the edges and bottom of the crack or hole before applying the material. Fill the opening to within 1/4 inch of the surface and allow the material to set partially before bringing the level up flush with the surface. After the material has thoroughly set, depending on the type of filler used, use fine sandpaper to smooth out the rough spots. Plaster and wallboard should have a sealer or a prime coat applied before painting. When working with old work, remove all loose or scaling paint, sand lightly, and wash off all dirt, oil, and stains. Allow the surface to dry thoroughly before applying the new finish coat.

10.9.4 Wood

Before being painted, a wood surface should be closely inspected for loose boards, defective lumber, protruding nail heads, and other defects or irregularities. Loose boards should be nailed tight, defective lumber should be replaced, and all nail heads should be countersunk.

A dirty wood surface is cleaned for painting by sweeping, dusting, and washing with solvent or soap and water. In washing wood, take care to avoid excessive wetting, which tends to raise the grain. Wash a small area at a time, then rinse and dry it immediately.

Wood that is to receive a natural finish, not concealed by an opaque coating, may require bleaching to a uniform or light color. To bleach, apply a solution of 1 pound of oxalic acid to 1 gallon of hot water. More than one application may be required. After the solution has dried, smooth the surface with fine sandpaper.

Rough wood surfaces must be sanded smooth for painting. Mechanical sanders are used for large areas, hand sanding for small areas. For hand sanding, you should wrap sandpaper around a rubber, wood, or metal sanding block. For a very rough surface, start with a coarse paper, about No. 2 or 2 1/2. Follow this with a No. 1/2, No. 1, or No. 1 1/2. You should finish with about a No. 2/0 grit. For fine work, such as furniture sanding, you should finish with a finer grit.

Sap or resin in wood can stain through a coat, or even several coats, of paint. Remove sap or resin by scraping or sanding. Knots in resinous wood should be treated with knot sealer.

Green lumber contains a considerable amount of water, most of which must be removed before use. This not only prevents shrinkage after installation, but prevents blistering, cracking, and loss of adhesion after paint is applied. Be sure all lumber used has been properly dried and kept dry before painting.

10.9.5 onditioners

Conditioners are often applied on masonry to seal a chalky surface to improve adhesion of water-based topcoats. Sealers are used on wood to prevent resin running or bleeding. Fillers are used to produce a smooth finish on open grained wood and rough masonry. *Table 13-5* presents the satisfactory treatments of the various surfaces.

Table 13-5 – Treatments of Various Substrates.

Mechanical	Wood	Metal		Concrete and Masonry	Plaster and Wallboard
		Steel	Other		
Hand cleaning	S	S	S	S	S
Power Tool Cleaning	S*	S	S	S	
Flame Cleaning		S			
Blast Cleaning			S		
Brush-Off		S		S	
All Other		S			
Chemical and Solvent			S		
Solvent Cleaning	S	S			
Alkali Cleaning		S		S	
Steam Cleaning		S		S	
Acid Cleaning		S		S	
Pickling		S			
Pretreatments					
Hot Phosphate		S			
Cold Phosphate		S	S		
Wash Primers		S			
Conditioners, Sealers, and Fillers					
Conditioners				S	
Sealers	S				
Fillers	S			S	

S – Satisfactory for use as indicated

* – Sanding only

Since water-thinned latex paints do not adhere well to chalky masonry surfaces, an oil-based conditioner is applied to the chalky substrate before latex paint is applied. The entire surface should be vigorously wire brushed by hand or power tools, then dusted to remove all loose particles and chalk residue. The conditioner is then brushed on freely to assure effective penetration and allowed to dry. Conditioner is not intended for use as a finish coat.

10.9.6 Sealers

Sealers are applied to bare wood like coats of paint. Freshly exuded resin, while still soft, may be scraped off with a putty knife and the area cleaned with alcohol. Remove hardened resin by scraping or sanding. Since sealer is not intended as a prime coat, it should be used only when necessary and applied only over the affected area. When previous paint becomes discolored over knots on pine lumber, the sealer should be applied over the old paint before the new paint is applied.

10.9.7 Fillers

Fillers are used on porous wood, concrete, and masonry to provide a smoother finish coat.

Wood fillers are used on open grained hardwoods. In general, hardwoods with pores larger than those found in birch should be filled. *Table 13-6* lists the characteristics of various woods and which ones require fillers. The table also contains notes on finishing. Filling is done after staining. Stain should be allowed to dry for 24 hours before the filler is applied. If staining is not warranted, natural (uncolored) filler is applied directly to the bare wood. The filler may be colored with some of the stain to accentuate the grain pattern of the wood.

Table 13-6 – Characteristics of Wood.

Name of Wood	Type of Grain			Notes on Finishing
	Soft	Hard		
	Closed	Open	Closed	
Ash		X		Requires filler
Alder	X			Stains well
Aspen			X	Paints well
Basswood			X	Paints well
Beech			X	Paints poorly, varnishes well
Birch			X	Paints and varnishes well
Cedar	X			Paints and varnishes well
Cherry			X	Varnishes well
Chestnut		X		Requires filler; paints poorly
Cottonwood			X	Paints well
Cypress			X	Paints and varnishes well
Elm		X		Requires filler; paints poorly
Fir	X			Paints poorly
Gum			X	Varnishes well
Hemlock	X			Paints fairly well
Hickory		X		Requires filler
Mahogany		X		Requires filler
Maple			X	Varnishes well
Oak		X		Requires filler
Pine	X			Variable depending on grain
Teak		X		Requires filler
Redwood	X			Paints well
Walnut		X		Requires filler
Note: Any type of finish may be applied unless otherwise specified				

To apply, you first thin the filler with mineral spirits to a creamy consistency, and then liberally brush it across the grain, followed by a light brushing along the grain. Allow it to stand 5 to 10 minutes until most of the thinner has evaporated. At this time, the finish will have lost its glossy appearance. Before it has a chance to set and harden, wipe the filler off across the grain using burlap or other coarse cloth, rubbing the filler into the pores of the wood while removing the excess. Finish by stroking along the grain with clean rags. All excess filler must be removed.

Knowing when to start wiping is important. Wipng too soon pulls the filler out of the pores. Allowing the filler to set too long makes it hard to wipe off. A simple test for dryness consists of rubbing a finger across the surface. If a ball is formed, it's time to wipe. If the filler slips under the pressure of the finger, it is still too wet for wiping. Allow the filler to dry for 24 hours before applying finish coats.

Masonry fillers are applied by brush to bare and previously prepared (all loose, powdery, flaking material removed) rough concrete, concrete block, stucco, or other masonry surfaces. The purpose is to fill the open pores in the surface, producing a fairly smooth finish. If the voids on the surface are large, you should apply two coats of filler, rather than one heavy coat. This avoids mud cracking. Allow 1 to 2 hours drying time between coats. Allow the final coat to dry 24 hours before painting.

10.10.0 Paint Mixing and Conditioning

Most paints used in the Navy are ready-mixed, meaning the ingredients are already combined in the proper proportions. When oil paint is left in storage for long periods of time, the pigments settle to the bottom. These must be remixed into the vehicle before the paint is used. The paint is then strained, if necessary. All paint should be placed in the paint shop at least 24 hours before use. This is to bring the paint to a temperature between 65°F and 85°F.

There are three main reasons to condition and mix paint. First, you need to redisperse, or reblend, settled pigment with the vehicle. Second, lumps, skins, or other impediments to proper application need to be eliminated. And, third, the paint must be brought to its proper application temperature.

10.10.1 Mixing

Paints should be mixed, or blended, in the paint shop just before they are issued. Mixing procedures vary among different types of paints. Regardless of the procedure used, try not to overmix; this introduces too much air into the mixture. *Table 13-7* outlines the types of equipment and remarks for various coatings.

Table 13-7 – Mixing Procedures.

Coating	Equipment	Remarks
Enamel, semigloss, or flat paints (oil type) Water-based paints (latex type)	Manual, propeller, or shaker Manual or propeller	Mix until homogenous. Use extreme care to avoid air entrapment.
Clear finishes	Manual, propeller, or shaker	Generally require little or no mixing.
Extremely viscous finishes; for example, coal tar paints	Drum type mixer	Use extreme care to avoid air entrapment.
Two-package metallic paints; for example, aluminum paints	Propeller	Add small amount of liquid to paste; mix well. Slowly add remainder of vehicle, while stirring, until coating is homogenous. With metallic powder, first make into a paste with solvent, and then proceed as above.
Two-Component Systems	Propeller, shaker, or drum type mixer	Mix until homogenous. Check label for special instructions.

Mixing is done by either a manual or mechanical method. The latter is definitely preferred to ensure maximum uniformity. Manual mixing is less efficient than mechanical in terms of time, effort, and results. It should be done only when absolutely necessary and be limited to containers no larger than 1 gallon. Nevertheless, it is possible to mix 1 gallon and 5 gallon containers by hand. To do so, first pour half of the paint vehicle into a clean, empty container. Stir the paint pigment that has settled to the bottom of the container into the remaining paint vehicle. Continue to stir the paint as you return the other half slowly to its original container. Stir and pour the paint from can to can. This process of mixing is called boxing paint. The mixed paint must have a completely blended appearance with no evidence of varicolored swirls at the top. Neither should there be lumps of undispersed solids or foreign matter. *Figure 13-88* illustrates the basic steps for boxing paint.

Figure 13-88 – Manual mixing and boxing of paint.

There are only three primary true pigmented colors: red, blue, and yellow. Shades, tints, and hues are derived by mixing these colors in various proportions. *Figure 13-89* shows a color triangle with one primary color at each of its points.

The lettering in the triangle indicates the hues that result when colors are mixed.

- **A -** Equal proportions of red and blue produce purple.
- **B -** Equal proportions of red and yellow produce orange.
- **C -** Equal proportions of blue and yellow produce green.
- **D -** Three parts of red to one part of blue produce carmine.
- **E -** Three parts of red to one part of yellow produce reddish orange.
- **F -** Three parts of blue to one part of red produce red-violet.
- **G -** Three parts of yellow to one part of red produce yellowish orange.
- **H -** Three parts of blue to one part of yellow produce bluish green.
- **I -** Three parts of yellow to one part of blue produce yellowish green.

Figure 13-89 – A color triangle.

Hues are known as chromatic colors, whereas black, white, and gray are achromatic (neutral) colors. Gray can be produced by mixing black and white in different proportions.

10.10.2 Thinning

When received, paints should be ready for application by brush or roller. Thinner can be added for either method of application, but the supervisor or inspector must give prior approval. Thinning is often required for spray application. Unnecessary or excessive thinning causes an inadequate thickness of the applied coating and adversely affects coating longevity and protective qualities. When necessary, thinning is done by competent personnel using only the thinning agents named by the specifications or label instructions. Thinning is not done to make it easier to brush or roll cold paint materials. They should be preconditioned (warmed) to bring them up to 65°F to 85°F.

10.10.3 Straining

Normally, paint in freshly opened containers does not require straining. But in cases where lumps, color flecks, or foreign matter are evident, paints should be strained after mixing. When paint is to be sprayed, it must be strained to avoid clogging the spray gun.

Skins should be removed from the paint before mixing. If necessary, the next step is thinning. Finally, the paint is strained through a fine sieve or commercial paint strainer.

10.10.4 Tinting

Try not to tint paint. This will reduce waste and eliminate the problem of matching special colors at a later date. Tinting also affects the properties of the paint, often reducing performances to some extent. One exception is the tinting of an intermediate coat to differentiate between that coat and a top coat; this helps assure you don't miss any areas. In this case, use only colorants of known compatibility. Try not to add more than 4 ounces of tint per gallon of paint. If more is added, the paint may not dry well or otherwise may perform poorly.

When necessary, tinting should be done in the paint shop by experienced personnel. The paint must be at application viscosity before tinting. Colorants must be compatible, fresh, and fluid to mix readily. Mechanical agitation helps distribute the colorants uniformly throughout the paint.

10.11.0 Application

The common methods of applying paint are brushing, rolling, and spraying. The choice of method is based on several factors, such as speed of application, environment, type and amount of surface, type of coating to be applied, desired appearance of finish, and the training and experience of the painters. Brushing is the slowest method, rolling is much faster, and spraying is usually the fastest by far. Brushing is ideal for small surfaces and odd shapes or for cutting in corners and edges. Rolling and spraying are efficient on large, flat surfaces. Spraying can also be used for round or irregular shapes.

Local surroundings may prohibit the spraying of paint because of fire hazards or potential damage from over spraying, or accidentally getting paint on adjacent surfaces. When necessary, adjacent areas not to be coated must be covered when spraying is performed. This results in loss of time and, if extensive, may offset the speed advantage of spraying.

Brushing may leave brush marks after the paint is dry. Rolling leaves a stippled effect. Spraying yields the smoothest finish, if done properly. Lacquer products, such as vinyls, dry rapidly and should be sprayed. Applying them by brush or roller may be difficult, especially in warm weather or outdoors on breezy days. The painting method requiring the most training is spraying. Rolling requires the least training.

10.12.0 Paint Failures

A coating that prematurely reaches the end of its useful life is said to have failed. Even protective coatings properly selected and applied on well prepared surfaces gradually deteriorate and eventually fail. The speed of deterioration under such conditions is less than when improper painting procedures are earned out. Inspectors and personnel responsible for maintenance painting must recognize signs of deterioration to establish an effective and efficient system of inspection and programmed painting. Repainting at the proper time avoids the problems resulting from painting either too soon or too late. Applying coatings ahead of schedule is costly and eventually results in a heavy buildup that tends to quicken deterioration of the coating. Applying a coating after it is scheduled results in costly surface preparation and may be responsible for damage to the structure, which may then require expensive repairs.

In the following sections, we'll look at some of the more common types of paint failures, the reasons for such failures, methods of prevention, and cures.

10.12.1 Surface Preparation Faults

Paint failures can result from many causes. Here we will look at some of the most common, which result from faults in surface preparation.

Alligatoring, shown in *Figure 13-90*, refers to a coating pattern that looks like the hide of an alligator. It is caused by uneven expansion and contraction of the undercoat. Alligatoring can have several causes: applying an enamel over an oil primer; painting over bituminous paint, asphalt, pitch, or shellac; and painting over grease or wax.

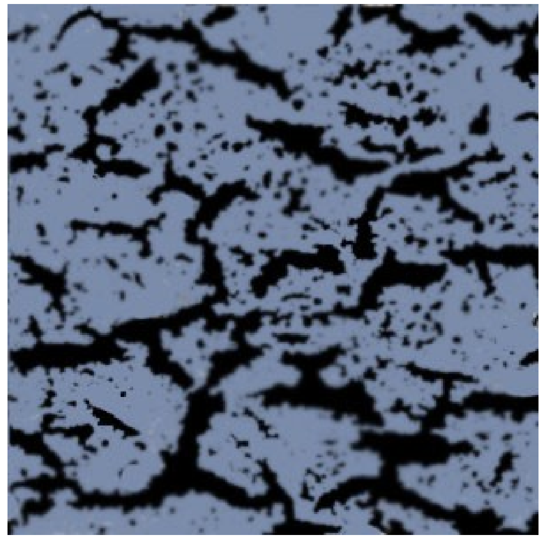

Figure 13-90 – Alligatoring.

Figure 13-91 – Peeling.

Peeling, shown in *Figure 13-91*, results from inadequate bonding of the topcoat with the undercoat or the underlying surface. It is nearly always caused by inadequate surface preparation. A topcoat peels when applied to a wet, dirty, oily or waxy, or glossy surface. All glossy surfaces must be sanded before painting. Also, the use of incompatible paints can cause the loss of adhesion. The stresses in the hardening film can then cause the two coatings to separate and the topcoat to flake and peel.

Blistering is caused by the development of gas or liquid pressure under the paint. Examples are shown in *Figure 13-92*. The root cause of most blistering, other than that caused by excessive heat, is inadequate ventilation plus some structural defect allowing moisture to accumulate under the paint. A prime source of this problem is the use of essentially porous major construction materials that allow moisture to pass through. Insufficient drying time between coats is another prime reason for blistering. All blisters should be scraped off, the paint edges feathered with sandpaper, and the bare places primed before the blistered area is repainted.

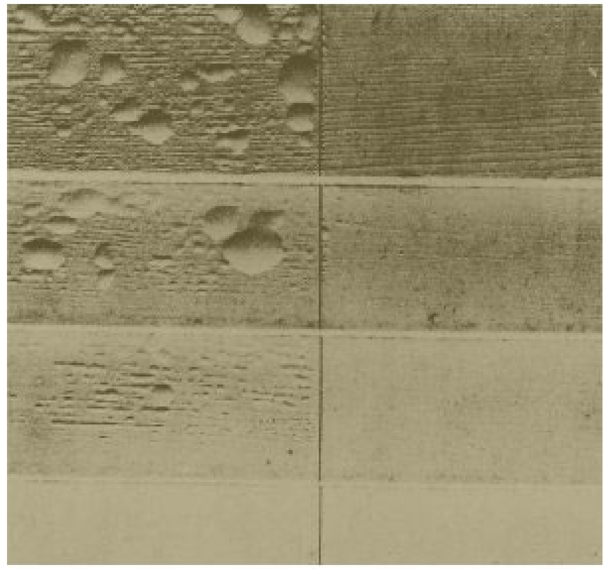

Figure 13-92 – Blistering.

Prolonged Tackiness – A coat of paint is dry when it ceases to be tacky to the touch. Prolonged tackiness indicates excessively slow drying. This may be caused by insufficient drier in the paint; a low quality vehicle in the paint; applying the paint too thickly; painting over an undercoat that is not thoroughly dry; painting over a waxy, oily, or greasy surface; or painting in damp weather.

Inadequate Gloss – Sometimes a glossy paint fails to attain the normal amount of gloss. This may be caused by inadequate surface preparation, application over an undercoat that is not thoroughly dry, or application in cold or damp weather.

10.12.2 Improper Application

One particular area you, as a Builder, have direct control over is application. It takes a lot of practice, but you should be able to eliminate the two most common types of application defects, crawling and wrinkling.

Crawling, shown in *Figure 13-93*, is the failure of a new coat of paint to wet and form a continuous film over the preceding coat. This often happens when latex paint is applied over high gloss enamel or when paints are applied on concrete or masonry treated with silicone water- repellent.

Figure 13-93 – Crawling.

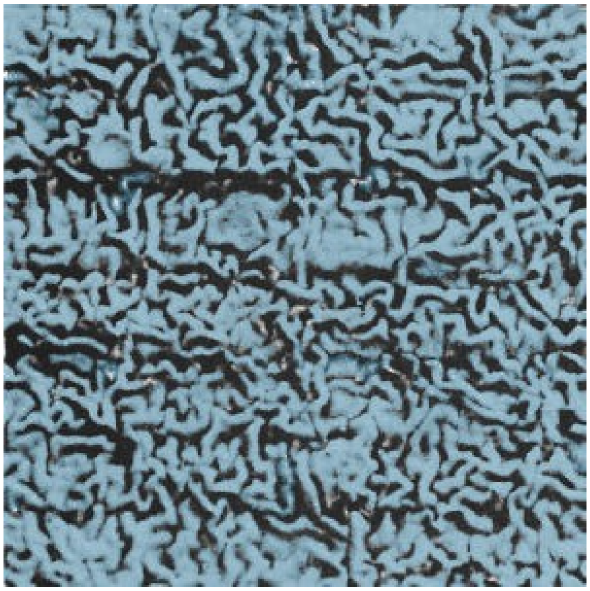

Figure 13-94 – Wrinkling.

When coatings are applied too thickly, especially in cold weather, the surface of the coat dries to a skin over a layer of undried paint underneath. This usually causes wrinkling, shown in *Figure 13-94*. Wrinkling can be avoided in brush painting or roller painting by brushing or rolling each coat of paint as thinly as possible. In spray painting, you can avoid wrinkling by keeping the gun in constant motion over the surface whenever the trigger is down.

10.12.3 Paint Defects

Not all painting defects are caused by the individual doing the job. It sometimes happens that the coating itself is at fault. Chalking, checking, and cracking are the most common types of product defects you will notice in your work as a Builder.

Chalking, shown in *Figure 13-95*, is the result of paint weathering at the surface of the coating. The vehicle is broken down by sunlight and other destructive forces, leaving behind loose, powdery pigment that can easily be rubbed off with the finger. This gradual wearing away reduces the thickness of the coating, which means the surface can be painted repeatedly without making the coating too thick for satisfactory service.

Chalking takes place rapidly with soft paints, such as those based on linseed oil. Chalking is most rapid in areas exposed to sunshine. In the Northern Hemisphere, for example, chalking is most rapid on the south side of a building. On the other hand, little chalking takes place in areas protected from sunshine and rain, such as under eaves or overhangs. Controlled chalking can be an asset, especially in white paints where it acts as a self-cleaning process and helps to keep the surface clean and white.

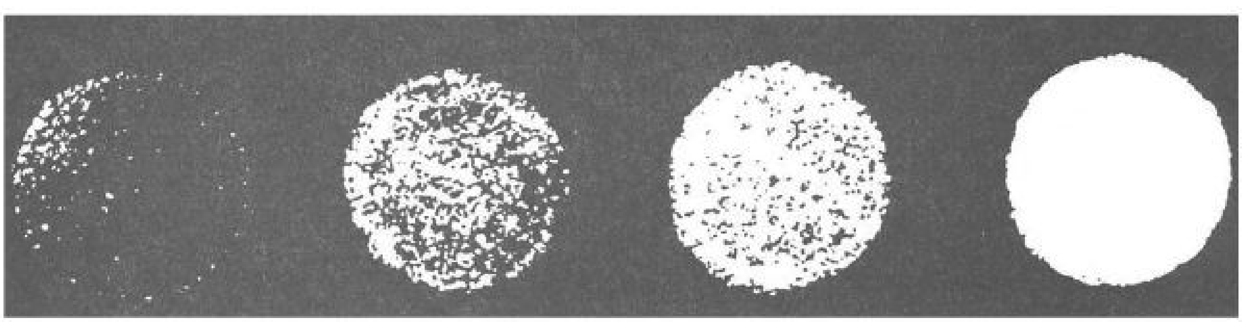

Figure 13-95 – Degrees of chalking.

Do not use a chalking or self-cleaning paint above natural brick or other porous masonry surfaces. The chalking will wash down and stain or discolor these areas.

Chalked paints are generally easier to repaint since the underlying paint is in good condition and requires little surface preparation. But this is not the case with water-thinned paints, which adhere poorly to chalky surfaces.

Checking and cracking are breaks in a coating formed as the paint becomes hard and brittle. Temperature changes cause the substrate and overlying paint to expand and contract. As the paint becomes hard, it gradually loses its ability to expand without breaking. Checking, shown in *Figure 13-96*, consists of tiny breaks in only the upper coat or coats of the paint film without penetrating to the substrate. The pattern is usually similar to that of a crow's foot.

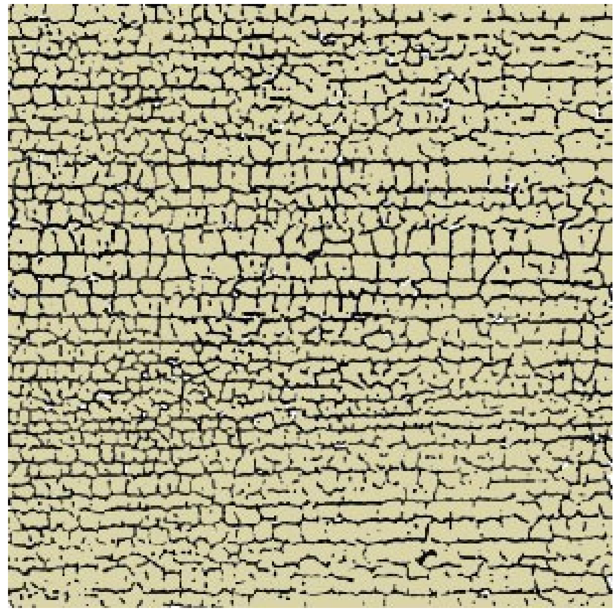

Figure 13-96 – Severe checking.

Figure 13-97 – Severe cracking.

Cracking is larger with longer breaks extending through to the substrate, as shown in *Figure 13-97*. Both result from stresses exceeding the strength of the coating. But, whereas checking arises from stress within the paint film, cracking is caused by stresses between the film and the substrate.

Cracking generally takes place to a greater extent on wood, due to its grain, than on other substrates. The stress in the coating is greatest across the grain, causing cracks to form parallel to the grain of the wood. Checking and cracking are aggravated by excessively thick coatings that have reduced elasticity. Temperature variations, humidity, and rainfall are also concerns for checking or cracking.

10.13.0 Wood Preservatives

There are three destructive forces against which most wood protective measures are directed: biological deterioration where wood is attacked by any of a number of organisms, fire, and physical damage. In this section, we will deal with protecting wood products against biological deterioration.

Damage to wood buildings and other structures by termites, wood bores, and fungi is a needless waste. The ability of wood to resist such damage can be greatly increased by proper treatment and continued maintenance. Wood defects are also caused by improper care after preservation treatment. All surfaces of treated wood that are cut or drilled to expose the untreated interior must be treated with a wood preservative.

10.13.1 Application Methods

There are two basic methods for treating wood, pressure and nonpressure. Pressure treatment is superior to nonpressure, but costly and time consuming. Building specifications dictate which method to use.

Pressure – The capacity of any wood to resist ***dry rot***, termites, and decay can be greatly increased by impregnating the wood with a general purpose wood preservative or fungicide. It is important to remember that good pressure treatment adds to the service life of wood in contact with damp ground. It does not, however, guarantee the wood will remain serviceable throughout the life of the building it supports.

Woods of different timber species do not treat with equal ease. Different woods have different capacities for absorbing preservatives or other liquids. In any given wood, sapwood is more absorbent than heartwood. Hardwoods are, in general, less absorbent than softwoods. Naturally, the extent to which a preservative protects increases directly with the depth it penetrates below the surface of the wood. As just mentioned, the best penetration is obtained by a pressure method. *Table 13-8* shows the ease of preservative penetration into various woods. In the table, E = easy, M = moderate, and D = difficult.

Table 13-8 – Preservative Penetration.

Species	Relative Ease of Getting Penetration Into	
	Sapwood	Heartwood
Pines (most species)	E	M to D
Ponderosa pine	E	M
White fir	E	M
Most other true firs	E to M	D
Eastern hemlock	M	D
Western hemlock	E	E to M
Redwood	M to D	M to D
Douglas fir (Coast)	E to M	M to D
Douglas fir (Rocky Mountain)	D	D
Western larch	E	D
Sitka spruce	M	M
Most other spruces	D	D
Western red cedar	D	D
White oak	E	D
Selected red oaks	E	E
Notes: E – Easy; M – Moderate; D – Difficult		

Nonpressure – Nonpressure methods of applying preservatives to a surface include dipping, brushing, and spraying. *Figure 13-98* shows how you can improvise long tanks for the dipping method. Absorption is rapid at first, then much slower. A rule of thumb holds that in 3 minutes wood absorbs half the total amount of preservative it will absorb in 2 hours. The extent of the penetration depends upon the type of wood, its moisture content, and the length of time it remains immersed.

Surface application by brush or spray is the least satisfactory method of treating wood from the standpoint of maximum penetration. It is more or less unavoidable in the case of already installed wood as well as treated wood that has been cut or drilled to expose the untreated interior.

Figure 13-98 – Improvised tanks for dip treating lumber.

10.13.2 Field Mixed Preservatives

Pentachlorophenol and ***creosote*** coal tar are likely to be the only field-mixed preservatives used by the Builder. The type of treatment or preservative depends on the severity of exposure and the desired life of the end product.

Preservatives can be harmful to personnel if improperly handled. When applying preservatives, you should take the following precautions:

- Avoid undue skin contact.
- Avoid touching your face or rubbing your eyes when handling pretreated material.
- Avoid inhaling toxic (poisonous) material.
- Work only in a properly ventilated space and use approved respirators.
- Wash with soap and water after contact.

10.14.0 Painting Safety

Every painting assignment exposes Builders to conditions and situations representing actual or potential danger. Toxic and flammable materials, pressurized equipment, ladders, scaffolding, and rigging always make painting a hazardous job. Hazards may also be inherent in the very nature of the environment, or result from ignorance or carelessness by the painter.

The main causes of painting accidents are unsafe working conditions or equipment, and careless personnel. The proper setting up and dismantling of equipment, the required safety checks, and the proper care of equipment may require more time than is spent using it. Nevertheless, safety measures must be taken.

10.14.1 Fire Hazards

Certain general rules regarding fire and explosion hazards apply to all situations. All paint materials should have complete label instructions stipulating the potential fire hazards and precautions to be taken. Painters must be advised and reminded of the fire hazards that exist under the particular conditions of each job. They need to be aware of the dangers involved and the need to work safely. Proper firefighting equipment must always be readily available in the paint shop, spray room, and other work areas where potential fire hazards exist. Electric wiring and equipment installed or used in the paint shop, including the storage room and spray room, must conform to the applicable requirements of the National Electrical Code (NEC) for hazardous areas.

10.14.2 Health Hazards

Many poisons, classified as toxic and skin-irritating, are used in the manufacture of paint. Although your body can withstand small quantities of poisons for short periods, overexposure can have harmful effects. Continued exposure to even small amounts may cause the body to become sensitized; subsequent contact, even in small amounts, may cause an aggravated reaction. The poisons in paint are definite threats to normally healthy individuals and serious dangers to persons having chronic illnesses or disorders. Health hazards can be avoided by a common sense approach of avoiding unnecessary contact with toxic or skin-imitating materials.

As with all tasks the Builder undertakes, safety must be a primary concern from the earliest planning stages to the final cleanup. Shortcuts, from personnel protection to equipment-related safety devices, should not be permitted. Follow the project safety plan, and consult all applicable safety manuals when involved with any paint operation. Remember: work safe, stay safe.

Test your Knowledge (Select the Correct Response)

10. Which of the following paint ingredients acts as the binder?

    A. Pigment
    B. Drier
    C. Vehicle
    D. Thinner

11. During the paint-mixing process, what is meant by boxing the paint?

    A. Pouring it back and forth from one container to another
    B. Mixing it with a mechanical agitator
    C. Mixing it with a paddle
    D. Cutting it with a suitable thinner

12. What is the recommended maximum amount of tint for one gallon of paint?

    A. 1 ounce
    B. 2 ounces
    C. 3 ounces
    D. 4 ounces

11.0.0 PANELING

Paneling is another form of interior finish that you might encounter. Types of paneling include plywood, hardboard, plastic ***laminates***, and solid lumber paneling.

11.1.0 Plywood

Most of the plywood used for interior walls has a factory-applied finish that is tough and durable. Manufacturers can furnish prefinished matching trim and molding that is also easy to apply. Color coordinated putty sticks are used to conceal nail holes.

Joints between plywood sheets can be treated in a number of ways. Some panels are fabricated with machine shaped edges that permit almost perfect joint concealment. Usually it is easier to accentuate the joints with grooves or use battens and strips. Some of the many different styles of battens are shown in *Figure 13-99*.

Figure 13-99 – Battens used for paneling joints.

Before installation, the panels should become adjusted (conditioned) to the temperature and humidity of the room. Carefully remove prefinished plywood from cartons and stack it horizontally. Place 1 inch spacer strips between each pair of face to face panels. Do this at least 48 hours before application.

Plan the layout carefully to reduce the amount of cutting and the number of joints. It is important to align panels with openings whenever possible. If finished panels are to have a grain, stand the panels around the walls and shift them until you have the most pleasing effect in color and grain patterns. To avoid mix-ups, number the panels in sequence after their position has been established.

When you cut plywood panels with a portable saw, mark the layout on the back side. Support the panel carefully and check for clearance below. Cut with the saw blade upward against the panel face. This minimizes splintering. This procedure is even more important when working with prefinished panels.

Plywood can be attached directly to the wall studs with nails or special adhesives. Use 3/8 inch plywood for this type of installation. When studs are poorly aligned or when the installation is made over an existing surface in poor condition, it is usually advisable to use furring. Nail 1 by 3 or 1 by 4 inch furring strips horizontally across the studs. Start at the floor line and continue up the wall. Spacing depends on the panel thickness. Thin panels need more support. Install vertical strips every 4 feet to support panel edges. Level uneven areas by installing shimmies behind the furring strips. Prefinished plywood panels can be installed with special adhesive. The adhesive is applied and the panels are simply pressed into place; no sustained pressure is required.

Begin installing panels at a corner. Scribe and trim the edges of the first panel so it is plumb. Fasten it in place before fitting the next panel. Allow approximately 1/4 inch clearance at the top and bottom. After all panels are in place, use molding to cover the space along the ceiling. Use baseboards to conceal the space at the floor line. If the molding strips, baseboards, and strips used to conceal panel joints are not prefinished, they should be spray painted or stained a color close to the tones in the paneling before installation.

On some jobs, 1/4 inch plywood is installed over a base of 1/2 inch gypsum wallboard. This backing is recommended for several reasons. It tends to bring the studs into alignment. It provides a rigid finished surface. It improves the fire-resistant qualities of the wall. The plywood is bonded to the gypsum board with a compatible adhesive.

11.2.0 Hardboard

Through special processing, hardboard, also called fiberboard, can be fabricated with a very low moisture absorption rate. This type is often scored to form a tile pattern. Panels for wall application are usually 1/4 inch thick.

Since hardboard is made from wood fibers, the panels expand and contract slightly with changes in humidity. They should be installed when they are at their maximum size. The panels tend to buckle between the studs or attachment points if installed when moisture content is low. Manufacturers of prefinished hardboard panels recommend that they be unwrapped and placed separately around the room for at least 48 hours before application.

Procedures and attachment methods for hardboard are similar to those for plywood. Special adhesives are available as well as metal or plastic molding in matching colors. You should probably drill nail holes for the harder types.

11.3.0 Plastic Laminates

Plastic laminates are sheets of synthetic material that are hard, smooth, and highly resistant to scratching and wear. Although basically designed for table and countertops, they are also used for wainscoting and wall paneling in buildings.

Since plastic laminate material is thin, 1/32 to 1/16 inch, it must be bonded to other supporting panels. Contact bond cement is commonly used for this purpose. Manufacturers have recently developed prefabricated panels with the plastic laminate already bonded to a base or backer material. This base consists of a 1/32 inch plastic laminate mounted on 3/8 inch particleboard. Edges are tongue and grooved so that units can be blind nailed into place. Various matching corner and trim moldings are available.

11.4.0 Solid Lumber Paneling

Solid wood paneling makes a durable and attractive interior wall surface and may be appropriately used in nearly any type of room. Several species of hardwood and softwood are available. Sometimes grades with numerous knots are used to obtain a special appearance. Defects, such as the deep fissures in pecky cypress, can also provide a dramatic effect.

The softwood species most commonly used include pine, spruce, hemlock and western red cedar. Boards range in widths from 4 to 12 inches nominal size and are ***dressed*** to 3/4 inch. Board and batten or shiplap joints are sometimes used, but tongue and groove (T&G) joints combined with shaped edges and surfaces are more popular.

When solid wood paneling is applied horizontally, furring strips are not required; the boards are nailed directly to the studs. Inside corners are formed by butting the paneling units flush with the other walls. If random widths are used, boards on adjacent walls must match and be accurately aligned.

Vertical installations require furring strips at the top and bottom of the wall and at various intermediate spaces. Sometimes 2 by 4 inch blocking is installed between the studs to serve as a nailing base, as shown in *Figure 13-100*. Even when heavy T&G boards are used, these nailing members should not be spaced more than 24 inches apart.

Figure 13-100 – Vertical wood paneling.

Narrow widths (4 to 6 inches) of T&G paneling are blind nailed. The nailheads do not appear on finished surfaces, and you eliminate the need for countersinking and filling nail holes. This nailing method also provides a smooth, blemish-free surface. This is especially important when clear finishes are used. Drive 6d ***finishing nails*** at a 45° angle into the base of the tongue and on into the bearing point. Carefully plumb the first piece installed and check for the plumbness at regular intervals. For lumber paneling that is not tongue and groove, use 6d casing or finishing nails. Use two nails at each nailing member for panels 6 inches or less in width and three nails for wider panels.

Exterior wall constructions, where the interior surface consists of solid wood paneling, should include a tight application of building paper located close to the backside of the boards. This prevents the infiltration of wind and dust through the joints. In cold climates, insulation and vapor barriers are important. Base, corner, and ceiling trim can be used for decorative purposes or to conceal irregularities in joints.

Test your Knowledge (Select the Correct Response)

13. The degree of protection provided to wood by a wood preservative depends on which of the following conditions?

    A. The type of wood only
    B. The moisture content of the wood only
    C. The length of time the wood is treated only
    D. All of the above

12.0.0 HAZMAT/MATERIAL SAFETY DATA SHEETS (MSDS)

Many of the tasks described in this chapter require the use of hazardous materials. There are many factors in handling hazardous materials in maintenance, repair, and cleaning. Using hazardous materials may also produce hazardous waste. Hazardous materials can be used effectively and safely if you take care in their handling, storage, and disposal.

To help ensure safe management of hazardous materials, OSHA passed a regulation called the Hazard Communication Standard, 29 CFR 1910.1200. Since DOD and SECNAV have adopted that regulation, all civilian and military employees of the federal government must comply with it.

Since the hazardous materials you must use to do your job can be hazardous to your health and the environment if not handled properly, you have the right to be trained in the use of hazardous materials and to know any information about those materials that could threaten your safety or health.

To protect your rights and to ensure personnel comply with OSHA and Environmental Protection Agency (EPA) regulations, the Navy has developed a hazardous material control and management program. The current version of *Hazardous Material Control and Management (HMC&M), OPNAVINST* 4110, provides the details of this program. OPNAVINST 5100.23G, Chapter 7, and OPNAVINST 5100.19E, Chapter B3, also discuss hazardous material control and management.

12.1.1 What Is Hazardous Material?

Hazardous material is any material that, because of its quantity, concentration, or physical or chemical characteristics, may pose a real hazard to human health or the environment. Hazardous materials include the following categories:

- Aerosols
- Compressed gases
- Oxidizing materials
- Toxic or poisonous materials
- Flammable and combustible materials
- Corrosive materials, such as strong acids and alkalies

Separate directives cover some materials considered hazardous. They include mercury, asbestos, propellants, bulk fuels, ammunition, medical waste, and chemical, biological, and radiological materials.

12.2.0 What Is Hazardous Waste?

Hazardous waste is any discarded material (liquid, solid, or gas) that meets the definition of hazardous material. Only the Environmental Protection Agency or a state authority may designate material as hazardous waste.

12.3.1 Material Safety Data Sheets

Material Safety Data Sheets (MSDSs) are technical bulletins containing information about hazardous material. Manufacturers produce MSDSs based on their testing and research of their products. By law, they must provide these MSDSs to hazardous materials users, which tell the users how to use, store, and dispose of hazardous material. OPNAVINST 5100.19E requires all hands to follow these guidelines. MSDSs must be in English and contain at least the following information about the material:

- Identity
- Hazardous ingredients
- Physical and chemical characteristics
- Physical hazards
- Reactivity
- Health hazards
- Precautions for safe handling and use
- Control measures
- Routes of entry into the body
- Emergency and first-aid procedures for exposure
- Date of preparation of the MSDS or last change
- Name, address, and phone number of a responsible party who can provide additional information on the hazardous material and appropriate emergency procedures

Manufacturers may use any format or arrangement of this information, but every MSDS must include all of the items. Every hazardous material user must be trained on the precautions associated with that material. MSDSs must be available upon request to any user. If you have a question, check with your command's hazardous material/hazardous waste coordinator.

More information on hazardous materials and MSDSs is available in the Naval Safety Supervisor Non Resident Training Course (NRTC), NAVEDTRA 14167F.

Test your Knowledge (Select the Correct Response)

14. Material can be designated as hazardous waste by which of the following commands?

    A. EPA or State Agency
    B. NSC
    C. OSHA
    D. NSSC

Summary

In this chapter you learned about the finishes that make a building durable, habitable, and pleasing to look at. You learned about topics ranging from exterior finishes and trim to interior wall finishes, including drywall, plaster, ceramic tile, paint, and paneling. You also learned about acoustic ceilings and various floor finishes, including wood flooring, resilient flooring, and carpeting. You learned that many of the installations described in this chapter include the use of hazardous materials, which need to be handled with care to ensure the safety of the crew.

Review Questions (Select the Correct Response)

1. For exterior trim fasteners, which of the following types of screws or nails is/are preferred?

   A. Galvanized steel only
   B. Stainless steel only
   C. Aluminum only
   D. All of the above

2. What part of a gable roof projects beyond the end wall on an upward slope?

   A. Rake
   B. Eave
   C. Fascia
   D. Ledger

3. On a roof with no overhang, what type of cornice is normally used?

   A. Open
   B. Gable
   C. Closed
   D. Simple

4. **(True or False)** In closed cornice construction, the underside of the eaves is exposed.

   A. True
   B. False

5. Which of the following components provides a nailing base for soffit material?

   A. Lookout
   B. Frieze board
   C. Rafter
   D. Plancier

6. Wood soffit panels should be fastened using nails in what (a) size and (b) spacing?

   A. (a) 6d (b) 6 inches
   B. (a) 6d (b) 8 inches
   C. (a) 4d (b) 8 inches
   D. (a) 4d (b) 6 inches

7. In drywall construction, nail pops result from which of the following factors?

   A. Stud misalignment
   B. Studs drying out
   C. Improper size nails
   D. Chemical reaction with coatings in nails

8. To align ceiling joists in an unfinished attic, what type of structural member should you use?

   A. Ribbon board
   B. Ledger
   C. Strongback
   D. Ridge beam

9. The most common size gypsum board has what (a) thickness and (b) type edges?

   A. (a) 1/2 inch (b) tapered
   B. (a) 1/2 inch (b) beveled
   C. (a) 5/8 inch (b) beveled
   D. (a) 5/8 inch (b) square

10. What type of drywall is also called greenboard or blueboard?

   A. PB
   B. WR or MR
   C. BB
   D.X

11. What type of drywall edge(s) may be left exposed?

   A. Tapered
   B. Square only
   C. Beveled only
   D. Square and beveled

12. When studs are spaced 24 inches OC, what thickness of drywall is recommended for quality wall construction?

   A. 1/4 inch
   B. 3/8 inch
   C. 1/2 inch
   D. 5/8 inch

13. What is the best reason for using a convex head hammer when driving drywall nails?

   A. To leave the nail head flush with the surface
   B. To dimple the material without tearing the paper
   C. To drive the nail at an angle
   D. To countersink the nail

14. For the best drywall finish, you should apply the topping coat with which of the following drywall tools?

    A. Finishing trowel
    B. Bow trowel
    C. 12 inch knife
    D. 16 inch knife

15. What length of smooth shanked nail should be used when installing double layers of 1/2 inch drywall?

    A. 1 inch
    B. 1 3/4 inches
    C. 2 inches
    D. 2 1/4 inches

16. What minimum length type W screw should you use when installing 1/2 inch drywall to wood studs?

    A. 5/8 inch
    B. 3/4 inch
    C. 1 inch
    D. 1 1/8 inches

17. Which of the following metal beads is installed to protect drywall from edge damage?

    A. Stop
    B. Corner
    C. Casing
    D. Edge

18. Single nailed drywall should be installed with what OC nail spacing on the (a) walls and (b) ceiling?

    A. (a) 6 inches (b) 8 inches
    B. (a) 8 inches (b) 6 inches
    C. (a) 7 inches (b) 8 inches
    D. (a) 8 inches (b) 7 inches

19. After the first application of joint compound to a joint, what should be the next step?

    A. Allow the joint compound to dry.
    B. Feather the joint.
    C. Tape the joint.
    D. Sand the joint.

20. Select from the following list the proper sequence for taping a gypsum drywall joint.

    a. Apply a coat of joint compound to bury tape.
    b. Press tape into center of joint.
    c. Allow compound to dry.
    d. Sand edges.
    e. Spread a bed of joint compound about 4 inches wide.

A. b, e, d, a, c
B. e, b, a, c, d
C. a, b, e, d, c
D. b, a, e, c, d

21. When you are repairing gypsum drywall, holes larger than what minimum diameter in inches should be cut back to the center of the nearest studs?

A. 2
B. 4
C. 6
D. 8

22. Which of the following plaster binding materials should NOT be exposed to severe moisture?

A. Portland cement
B. Lime
C. Gypsum

23. Which of the following statements best describes gypsum gauging plaster?

A. Contains lime putty which increases the dimensional stability of the plaster while drying and provides initial surface hardness
B. Has a high density, yields a highly polished surface, and provides crack resistance when used with fine sand
C. Contains finely ground gypsum with or without aggregate
D. Contains no admixtures and is designed to reduce sound

24. Gauging material is added to lime plaster for which of the following reasons?

A. To induce shrinkage and produce early strength only
B. To induce late strength and counteract shrinkage tendencies only
C. To produce early shrinkage tendencies only
D. All of the above

25. Portland cement plaster should NOT be applied directly over what type of walls?

A. Exterior masonry
B. Interior masonry
C. Interior or exterior metal lath covered
D. Gypsum tile or plasterboard

26. When the aggregate material is excessively fine grain, why is the plaster strength reduced?

A. The smaller quantity of water required raises the water to cement ratio and increases the dry set time.
B. The greater quantity of water required raises the cement to water ratio and reduces the dry set density.
C. Less binder paste is used because of the lack of space between particles of the fines, resulting in a weak mixture.
D. More binder paste is needed to coat all particle surfaces, resulting in sufficient fines to close all voids and leaving a rich but unstable mixture.

27. Which of the following aggregates should be used in acoustical plaster?

A. Perlite only
B. Vermiculite only
C. Perlite or vermiculite
D. Sand

28. To provide a good key, wood lath plaster base should have what minimum spacing?

A. 1/4 inch
B. 3/8 inch
C. 1/2 inch
D. 5/8 inch

29. What is the main purpose of the 3/4 inch holes in perforated gypsum lath?

A. To allow for easy installation
B. To allow for expansion or the mortar
C. To provide ventilation for interior walls
D. To provide a mechanical key for the mortar

30. What type of lath is considered the most versatile?

A. Metal
B. Gypsum
C. Wood
D. Insulation

31. What length of blued gypsum lath nail is recommended for installing 1/2 inch gypsum lath?

A. 1 inch
B. 1 1/8 inches
C. 1 3/16 inches
D. 1 1/4 inches

32. What is the minimum end lap for wire lath?

    A. 1 inch
    B. 1 1/2 inches
    C. 2 inches
    D. 2 1/2 inches

33. What is the purpose of a casing bead?

    A. To reinforce the lath and inside corners
    B. To reinforce the door and window casings
    C. To provide room for expansion between plaster edges and the edges of baseboards
    D. To provide a finished edge around openings

34. To minimize shrinking and cracking around the upper corners of doors and windows, you should install which of the following items?

    A. Plaster grounds
    B. Expanded metal lath strips
    C. Base screeds
    D. Casings beads

35. What are the recommended material and proportions for two-coat plaster used on a masonry or concrete base?

    A. Gypsum plaster 1:2.5
    B. Lime plaster using lime putty 1:3
    C. Portland cement 1:5
    D. Lime plaster using hydrated lime 1:7.5

36. You should not apply a lime finish to which of the following base coats?

    A. Gypsum
    B. Portland cement
    C. Gypsum vermiculite
    D. Lime

37. When mortar materials are mixed by hand, what is the maximum time in minutes that mixing should continue after all the materials have been blended?

    A. 5
    B. 10
    C. 15
    D. 20

38. After all ingredients for plaster have been added, what minimum time in minutes should a mixing machine be allowed to mix?

A. 3
B. 5
C. 7
D. 10

39. Normally, what is the specified flatness tolerance of a plastered surface?

A. 1/16 inch in 4 feet
B. 1/8 inch in 10 feet
C. 1/4 inch in 8 feet
D. 1/2 inch in 16 feet

40. What tool is used for carrying mortar?

A. Rectangular trowel
B. Darby
C. Angle trowel
D. Hawk

41. To improve adhesive bonds, what tool should be used to make furrows between coats?

A. Darby
B. Browning brush
C. Cork float
D. Scarifier

42. On a typical plastering crew, which of the following individuals normally mixes the plaster?

A. Crew leader
B. Tender
C. Plasterer
D. Supervisor

43. Which of the following statements is applicable to the fog spray curing of Portland cement plaster?

A. The finish coat should be applied at least 3 days after the brown coat is applied.
B. The finish coat should be spray cured for 48 hours after its application.
C. The brown coat should be fog sprayed for 48 hours followed by the same treatment for the scratch coat.
D. The scratch coat should be fog sprayed for 24 hours and the brown coat fog sprayed for 36 hours.

44. Throwing plaster on a surface with a brush produces which of the following textures?

    A. Stippled
    B. Travertine
    C. Dash coat
    D. Pebble

45. Which of the following statements best defines stucco?

    A. A combination of cement, sand, and water that, when applied, resembles concrete having a hard, strong, fire-resistant surface which resists rot and fungus and retains color
    B. A combination of masonry cement, sand, and water that, when applied, resembles cement having a medium hard surface which requires frequent painting to prevent rot and fungus
    C. A combination of cement, sand, and water that, when applied, needs a plasticizing material to act as sealer in preventing rot and fungus
    D. A combination of masonry cement, sand, and water that, when applied, produces a smooth, hard surface which, if not painted immediately after application, will begin to mildew

46. When using an acid wash to prepare a concrete surface for stucco, you should use one part acid to how many parts of water?

    A. 6
    B. 10
    C. 12
    D. 20

47. Which of the following factors is most likely to cause discoloration in a stucco finish coat?

    A. Using stainless steel flashing
    B. Not retempering the mortar
    C. Failing to completely mix the finish coat materials
    D. Using different proportions of materials

48. How many basic ceramic tile installation methods are there?

    A. One
    B. Two
    C. Three
    D. Four

49. What is the minimum soaking time for tile when using the cement mortar installation method?

A. 30 minutes
B. 45 minutes
C. 1 hour
D. 2 hours

50. Which of the following types of grout should be used when sanitation is important?

A. Latex
B. Furan resin
C. Epoxy
D. Drywall

51. How many parts of hydrated lime and sand should be used with three parts of cement for a float coat of a mortar bed setting for ceramic tile?

A. 1 part lime and 7 parts sand
B. 6 parts lime and 10.5 parts sand
C. 3 parts lime and 10.5 parts sand
D. 8 parts lime and 21 parts sand

52. Most acoustical ceilings have what main purpose?

A. Sound absorption
B. Light reflection
C. Flame resistance
D. Appearance enhancement

53. Assume the dimensions of a ceiling are 16 feet 8 inches by 10 feet 2 inches. When calculating the material requirements, what dimensions should you use?

A. 16 feet 0 inches by 10 feet 0 inches
B. 16 feet 8 inches by 10 feet 2 inches
C. 17 feet 0 inches by 11 feet 0 inches
D. 18 feet 0 inches by 12 feet 0 inches

54. Assume you are laying out the grid pattern for a ceiling. How should the main tees run?

A. Parallel to the joists
B. At a 45º angle to the joists
C. Perpendicular to the joists
D. In a crisscross pattern between the joists

55. Assume a new acoustical ceiling will be installed 14 inches lower than the old ceiling. The suspension wires should be cut with what minimum length in inches?

A. 14
B. 16
C. 18
D. 20

56. In a suspension ceiling system, where on the main tee should the first tie wire be installed?

A. 2 feet from either end
B. 4 feet from either end
C. At the first cross tee connection
D. At the center

57. When installed, which of the following components require the use of splice plates?

A. Aluminum main tees only
B. Steel main tees only
C. Aluminum and steel main tees
D. Aluminum cross tees

58. When installing acoustical panels, why should you work from several cartons at the same time?

A. All the panels may not be the same direction.
B. Every other panel in a carton has a different edge cut.
C. The color, pattern, or texture may vary slightly.
D. Not all panels can be cut or used as border panels.

59. When installing 12 inch square ceiling tile in a 15 foot 8 inch-wide room, what pattern should you use in terms of rows and size?

A. 15 full rows and two 4 inch tiles
B. 15 full rows and one 8 inch tile
C. 14 full rows and one 10 inch tile
D. 14 full rows and two 10 inch tiles

60. Subfloor boards are normally laid over joists in what direction?

A. Parallel
B. Diagonal
C. Perpendicular

61. Building paper is used over subfloors to reduce which of these?

A. Noise and dust only
B. Dust and air flow only
C. Air flow and noise only
D. All of the above

62. At which of the following angles should nails be driven through the tongue of tongue and groove flooring?

A. 30º to 35º
B. 35º to 40º
C. 40º to 45º
D. 45º to 50º

63. How can you prevent splitting the tongue when nailing tongue and groove flooring?

A. By using cut nails
B. By predrilling the nail holes
C. By using chisel point nails
D. By waxing the nail shanks

64. A vapor barrier is installed under a concrete slab before it is poured. Is any further preparation required for the later installation of wood flooring?

A. Yes
B. No

65. What is the expansion allowance for hardboard underlayment when laid next to a vertical surface?

A. 1/8 to 3/8 inch
B. 3/8 to 1/2 inch
C. 1/2 to 5/8 inch
D. 5/8 to 3/4 inch

66. Nail spacing for 1/2 inch plywood underlayment should not exceed what OC (a) edge and (b) field spacing?

A. (a) 4 inches (b) 8 inches
B. (a) 5 inches (b) 8 inches
C. (a) 6 inches (b) 10 inches
D. (a) 8 inches (b) 10 inches

67. Before laying vinyl tile on a floor surface, you should square off the floor, apply the adhesive, and then begin laying the tile from which of these directions?

A. Center of the floor working towards the walls
B. Center of a continuous wall working towards the center of the floor
C. Corner of the floor working towards the opposite corner
D. Stairway or door opening working towards the opposite wall

68. Which of the following factors is an advantage of using carpeting instead of other types of floor covering?

A. It absorbs sound.
B. It lasts longer.
C. It reduces maintenance.
D. It is cheaper.

69. When installing cushion-backed carpeting, which of the following items is/are required?

A. Tack strips only
B. Double-faced tape only
C. Additional padding only
D. All of the above

70. In paint, which of the following ingredients provides the coloring?

A. Drier
B. Pigment
C. Thinner
D. Vehicle

71. Which of the following chemical compounds are NOT synthetic resins?

A. Napthas
B. Phenolics
C. Epoxies
D. Chlorinated rubbers

72. What is the purpose of a paint solvent?

A. To give more body to the paint
B. To prevent blistering of the paint
C. To add gloss to the paint
D. To adjust the consistency of the paint

73. To increase resistance of oil-base paint to water and decrease drying time, you should add small amounts of what material to the paint?

    A. Linseed oil
    B. Polyester
    C. Varnish
    D. Naptha

74. Which of the following ratios determines the level of gloss in enamel paints?

    A. Pigment to binder
    B. Thinner to pigment
    C. Vehicle to binder
    D. Binder to drier

75. Of the following paint types, which is best suited to masonry surfaces?

    A. Oil base
    B. Enamel
    C. Epoxy
    D. Latex

76. In areas that require frequent washing, which of the following types of paint is normally preferable?

    A. Portland cement
    B. Latex
    C. Aluminum
    D. Rubber base

77. When a can of ready-mix aluminum paint is bulging, how should the pressure be released?

    A. By carefully removing the lid
    B. By carefully puncturing the lid
    C. By shaking the can in a vibrator
    D. By cooling the can

78. Which of the following materials does NOT obscure the surface to which it is applied?

    A. Varnish
    B. Primer
    C. Enamel
    D. Latex

79. Which of the following types of varnish is intended for exterior use?

A. Flat
B. Spar
C. Rubbing
D. Color

80. Which of the following materials is often used as a sealant over wood knots to prevent bleeding?

A. Lacquer
B. Stain
C. Shellac
D. Varnish

81. What type of stain contains alcohol as a vehicle?

A. Spirit
B. Chemical
C. Oil
D. Water

82. Which of the following advantages is gained by proper surface preparation?

A. Minimum repair only
B. Increased durability only
C. Ease of repainting only
D. All of the above

83. You should prepare a galvanized iron surface for painting with which of the following types of cleaners?

A. Acid wash
B. Solvent
C. Silicone
D. Latex emulsion

84. Dirt and fungus are best removed from concrete and masonry by washing with which of the following types of solutions?

A. Emulsion
B. Alkaline
C. Efflorescence
D. Trisodium phosphate

85. During the process of removing efflorescence from concrete, what should you do after scrubbing with an acid solution?

   A. Let the solution remain on the surface about 10 minutes.
   B. Let the solution dry and then dry brush.
   C. Rinse the surface thoroughly with clear water.
   D. Apply a second coat of the solution, and let it remain on the surface for 30 minutes.

86. What is the correct procedure for mixing muriatic acid and water?

   A. Add the acid to the water.
   B. Add the water to the acid.
   C. Add 15 percent acid to 85 percent water.
   D. Add half acid and half water.

87. To repair large defects in a concrete or masonry surface, which of the following grout mixtures should you use?

   A. Two parts mortar sand, 1 part Portland cement, 1 part water
   B. Two parts Portland cement, 2 parts mortar sand, 2 parts water
   C. Three parts mortar sand, 1 part Portland cement, enough water to make a putty-like consistency
   D. Two parts mortar sand, 1 part Portland cement, enough water to make a soupy consistency

88. Before painting, a plaster patch should set for what minimum time?

   A. 1 day
   B. 2 days
   C. 3 days
   D. Until thoroughly dry

89. When preparing dirty wood surfaces for painting, which of the following methods should you follow?

   A. Sweeping, dusting, and washing the surface with a solvent or water and soap
   B. Bleaching the surface with a solution of oxalic acid and water
   C. Sanding the surface to a uniform color
   D. Pretreating the surface with wood cleaner

90. Before painting, what is the procedure for sanding a rough wood surface?

   A. Start with a No. 1 sandpaper, follow up with a No. 2,and finish with a No. 3x
   B. Start with a No. 2 sandpaper, follow up with a No. 1, and finish with a No. 2/0 grit
   C. Start with a No. 3 sandpaper, follow up with a No. 2, and finish up with a No. 1
   D. Start with a No. 2 sandpaper and finish up with a No. 2 and 2/0 grit

91. When used on porous wood, concrete, and masonry, which of the following items produces a smooth finish floor coat?

A. Conditioner
B. Sealer
C. Filler
D. Latex paint

92. When applied to chalky bases, which of the following items improves adhesion of water-based paints?

A. Conditioner
B. Sealer
C. Filler
D. Latex paint

93. Which of the following items prevents resin from bleeding through applied paint coatings?

A. Conditioner
B. Sealer
C. Filler
D. Latex paint

94. Before applying filler to open grained wood, stain should be applied and allowed to dry for how many hours?

A. 12
B. 24
C. 36
D. 48

95. Before varnishing, you should use a filler on which of the following open grained woods?

A. Beech
B. Birch
C. Maple
D. Walnut

96. To mix two-package metallic paints, what method is recommended?

A. Shaker
B. Manual
C. Propeller
D. Berate

97. What are the three primary or true colors that are the basis for all subsequent shades, tints, and hues?

A. Blue, red, and green
B. Red, black, and white
C. Black, yellow, and white
D. Yellow, blue, and red

98. **(True or False)** Before its application by roller, a ready-mix paint must be thinned.

A. True
B. False

99. Strong sunlight on paint surfaces is most likely to cause which of the following problems?

A. Peeling
B. Blistering
C. Alligatoring
D. Chalking

100. Inadequate bonding and what other cause are the primary reasons for peeling?

A. High surface temperature
B. Improper mixing of paint
C. Inferior paint
D. Improper surface preparation

101. Temperature changes causing the substrate and overlaying paint film to expand and contract are most likely to result in which of the following conditions?

A. Checking and cracking
B. Peeling
C. Alligatoring
D. Blistering

102. Accumulation of moisture under paint is most likely to cause which of the following problems?

A. Crawling
B. Peeling
C. Blistering
D. Checking

103. Breaks in paint film extending through to the substrate indicate what type of paint failure?

A. Checking
B. Cracking
C. Peeling
D. Crawling

104. Spraying paint too thickly or moving the spray gun too slowly is most likely to cause which of the failing paint failures?

A. Chalking
B. Peeling
C. Blistering
D. Wrinkling

105. Failure of a gloss paint to attain its normal gloss is most likely to be caused by which of the following conditions?

A. Application in cold weather only
B. Inadequate surface preparation only
C. Application of the paint before the undercoat has dried only
D. Any of the above

106. What is the recommended minimum thickness of plywood panels used directly over framing members?

A. 1/4 inch
B. 3/8 inch
C. 1/2 inch
D. 5/8 inch

107. When you are installing vertical board panels, what is the maximum spacing in inches of furring strips?

A. 16
B. 24
C. 36
D. 48

108. What regulation ensures the safe and effective use of hazardous materials?

A. Material Safety Data Sheet instructions
B. Hazard Communicaiton Standard
C. Hazardous Materials User's Guide
D. DOD Hazardous Materials Information System

109. The Material Safety Data Sheet (MSDS) provides which of the following hazardous material information?

A. Price
B. Manufacture date
C. Transportation date
D. Health hazards

Trade Terms Introduced in this Chapter

Acoustical Tiles	Any tile composed of materials that absorb sound waves.
Alligatoring	A defect in a painted surface resulting from the application of a hard finish coat over a soft primer. The checked pattern is caused by the slipping of the new coat over the old coat. The old coat can be seen through the cracks.
Brads	Slender nails with small heads.
Casing	The trim around doors and windows.
Casing nails	2 penny (2d) to 40 penny (40d) nails with flaring heads.
Common nail	2 penny (2d) to 60 penny (60d) strong nails.
Cornice	The area under the eaves where the roof and sidewalls meet.
Creosote	A coal tar distillate used for preserving wood.
Dressed	Trimmed or planed; usually applied to lumber.
Dry rot	Fungus growth making wood soft or brittle.
Drywall	A system of interior wall finish using sheets of gypsum board and taped joints.
Eaves	The part of a roof projecting over the sidewall.
Efflorescence	A white powdery substance forming on masonry surfaces caused by calcium carbide in the mortar.
Fascia	The flat outside horizontal member of a cornice placed in a vertical position.
Ferrous	Any metal containing a high percentage of iron.
Finishing nails	2 penny (2d) to 20 penny (20d) sizes with small barrel-shaped heads.
Furring	Any extra material added to another piece or member to bring an uneven surface to a true plane and to provide additional nailing surface.
Hardwoods	A general term referring to any of a variety of broad-leaved, deciduous trees, and the wood from those trees. The term does not designate the physical hardness of wood, as some hardwoods are actually softer than some softwood (coniferous) species.
Hydration	The chemical reaction between cement and water causing the cement paste to harden and to bind the aggregates together to form mortar or concrete.
Joists	Members that makes up the body of the floor and ceiling frames.

Laminates	Any material formed by bonding together several layers or sheets with adhesive under pressure and sometimes with nails or bolts.
Mastic	(1) A thick, bituminous adhesive used for applying floor and wall tiles. (2) A waterproof caulking compound used in roofing that retains some elasticity after setting.
Pigments	Insoluble coloring substances, usually in powder form, mixed with oil or water to color paints.
Plywood	A flat panel made up of a number of thin sheets (veneers) of wood. The grain direction of each ply, or layer, is at right angles to the one adjacent to it. The veneer sheets are united under pressure by a bonding agent.
Rafter	A sloping roof member supporting the roof covering and extending from the ridge or the hip of the roof to the eaves.
Rake	The inclined position of a cornice; also the angle of slope of a roof rafter.
Sander	A machine designed to smooth wood and remove saw or lathe marks and other imperfections. Sanders range in size from hand-held to large drums or belts capable of surfacing a full-size panel.
Sash	The movable part of a window.
Soffits	The undersides of subordinate members of a building.
Softwoods	A general term referring to any of a variety of trees having narrow, needle-like or scale-like leaves, usually coniferous, and the wood from such trees. The term has nothing to do with the softness of the wood; some softwoods are harder than certain of the hardwood species.
Span	The shortest distance between a pair of rafter seats.
Stud	The vertical members of wooden forms or frames.
Specifications	Written instructions containing information about the materials, style, workmanship, and finish for the job.
Toenailed	To secure wood members with nails driven at an angle.
Trusses	Combination of members, such as beams, bars, and ties; usually arranged in triangular units to form a rigid framework for supporting loads over a span.
Wainscots	Wall coverings for the lower part of an interior wall; can be wood, glass, or tile.

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.

Basic Roof Framing, Benjamin Barnow, Tab Books, Inc., Blue Ridge Summit, Pa., 1986.

Carpentry, Leonard Keel, American Technical Publishers, Alsip, Ill., 1985.

Design of Wood Frame Structures for Permanence, National Forest Products Association, Washington, D.C., 1988.

Drywall: Installation and Application, W. Robert Harris, American Technical Publishers, Inc., Homewood, Ill., 1979.

Exterior and Interior Trim, John E. Ball, Delmar Publishers, Inc., Albany, N.Y., 1975.

Facilities Planning Guide, NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, Va., 1982.

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

Gypsum Construction Handbook, United States Gypsum Company, Chicago, Ill., 1987.

Handbook of Ceramic Tile Installation, Tile Council of America, Inc., Princeton, N.J., 1990.

Materials and Methods of Architectural Construction, John Wiley & Sons, New York, 1958.

Modern Carpentry, Willis H. Wagner, Goodheart-Wilcox Co., South Holland, Ill., 1983.

Paints and Protective Coatings, NAVFAC-MO-110, Departments of the Army, Navy, and Air Force, Washington, D.C., 1981.

Plastering Skills, F. Van Den Branden and Thomas L. Hartsell, American Technical Publishers, Inc., Alsip, Ill., 1984.

Wood Frame House Construction, L.O. Anderson, Forest Products Laboratory, U.S. Forest Service, U.S. Department of Agriculture, Washington, D.C., 1975.

Wood Preservation, NAVFAC-MO-312, Naval Facilities Engineering Command, Department of the Navy, Washington, D,C., 1968.

Seabee Planner's and Estimator's Handbook, NAVFAC P-405, Chapter 5, Naval Facilities Engineering Command, Alexandria, Va., 1983.

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Chapter 14

Expeditionary Structures

Topics

To hear audio, click on the box.

Overview

The primary responsibility of the Seabees is the construction of advanced bases during the early phases of crises and other emergency situations. As Builders, it is our job to move swiftly to hostility areas and build temporary facilities and structures to support U.S. military operations. We are expected to react expediently. The most widely used structure for expediency and as a temporary facility is the pre-engineered building. This chapter covers the process involved with the erection of such buildings, as well as wood frame tents, latrines, and the process of embarkation.

Heavy construction includes structures made of steel, timber, concrete, or a combination of these materials. Examples include trestles, timber piers, and waterfront structures. The requirement for heavy construction today is not as important as in earlier years, but the need to understand this type of construction still remains.

In this chapter, we will examine the materials used in building heavy structures. We will also discuss the methods and techniques of heavy construction, including shoring and excavation. In addition, we will look at the procedures used in maintaining the structures.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Explain the principles and procedures involved in the preparation and erection of pre-engineered metal buildings.
2. Identify the characteristics of wood frame tents, SEA huts, and field type latrines.
3. Identify the components of, preparation procedures for, and procedures used in the erection of a K-span building.
4. Identify the procedures and techniques used in preparing material for embarkation.

5. Identify the parts of a trestle, and describe the procedures for erecting bents and superstructures. Identify the types of piles used in heavy construction and state the procedures for constructing a timber pier.
6. Describe the uses of and construction methods for offshore, alongshore, wharfage, and below the water table construction.

Prerequisites

None

This course map shows all of the chapters in Builder Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Expeditionary Structures	↑	B
Finishes		U
Moisture Protection		I
Finish Carpentry		L
Rough Carpentry		D
Carpentry Materials and Methods		E
Masonry		R
Fiber Line, Wire Rope, and Scaffolding		
Concrete Construction		B
Site Work		A
Construction Management		S
Drawings and Specifications		I
Tools		C
Basic Math		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If

the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 PRE-ENGINEERED BUILDING (PEB)

The pre-engineered building (***PEB***) discussed here is a commercially designed structure, fabricated by the civilian industry to conform to armed forces ***specifications***. The advantage of a pre-engineered structure is that it is designed for erection in the shortest possible time. Each PEB is shipped as a complete building kit, including all necessary materials and instructions for erection.

The typical PEB is a 40 by 100 foot structure. A smaller 20 by 48 foot version of PEB uses the same erection principles. Layout and erection of either size PEB is normally assigned to Builders, working in conjunction with Steelworkers.

The basic pre-engineered metal building shown in *Figure 14-1* is 40 feet wide by 100 feet long. Although the unit length of the building is 100 feet, the length can be increased or decreased in multiples of 20 feet, which are called 20 foot bays. The true building length will be equal to the number of 20 foot bays plus 6 inches, since each end bay is 20 feet 3 inches. The building is 14 feet high at the eave and 20 feet 8 inches at the ridge.

Figure 14-1 – Completed 40 foot by 100 foot by 14 foot pre-engineered building.

Pre-engineered buildings are ideal for use as repair shops or warehouses because they have a large, clear floor area without columns or other obstructions, as well as straight sidewalls. This design allows floor to ceiling storage of material and wall to wall placement of machinery. The column-free interior also permits efficient shop layout and unhindered production flow.

After a building is up, it can be enlarged while in use by bays, providing additional space under one roof. If desired, buildings can be erected side by side in multiples. When a building is no longer needed it can be disassembled, stored, or moved to another location and re-erected because only bolted connections are used. The rigid frame is strong. It is designed for working loads of 20 pounds per square foot load, plus the dead load, and the load from a 70 mph wind.

The building can be easily modified to varying lengths and purposes by taking out or adding bays or by substituting various foundation and wall sections. A bay is the distance between two column centers or between the end wall and the first column center in from the end wall.

Formulas used to determine the number of bays, frames, and intermediate frames in a building are as follows:

Length divided by 20 = number of bays

Bays + 1 = total number of frames

Total number of frames - 2 = number of intermediate frames

1.1.0 Preplanning

A preplan of the erection procedures should be made based on a study of the working drawings or manufacturer's instructions. Preplanning should include establishing the most logical and expeditious construction sequence. Consider the manpower, equipment, rigging, and tools required. Everything necessary for erection should then be procured. The advantages of constructing and using jigs and templates for assembling parts of similar trusses, frames, and so on, should also be evaluated.

Builders should be familiar with the layout and erection procedures for the 40 by 100 foot PEB; we will use this as the model for our discussion. This building is prefabricated and shipped in compact crates ready for erection, along with an instruction manual. It is extremely important to follow the manual; you can easily install a part incorrectly.

1.1.1 omponent Parts

The component parts of a prefabricated structure are shipped knocked down (KD). A manufacturer's instruction manual accompanies each shipment. The manual contains working drawings and detailed instructions on how the parts should be assembled. Directions vary with different types of structures, but there are certain basic erection procedures that should be followed in all cases.

1.1.2 Working Drawings

The working drawings show which items are NOT prefabricated or included in the shipment. These must be constructed in the field. Make plans in advance for the procurement of necessary materials for these items. Foundations, for example, are often designated to be constructed in the field.

1.2.0 Foundations

In addition to the usual reasons for stressing the importance of a square and level foundation, there is another reason peculiar to the erection of a prefabricated structure. Prefabricated parts are designed to fit together without forcing. If the foundation is even slightly out of square or not perfectly level, many of the parts will not fit together as designed. Continuously check the alignment of the anchor bolts prior to, during, and after concrete is poured.

1.3.0 Pre-erection Work

Extensive pre-erection work is required before you start the actual erection of a building. After the building site is located and laid out by the Engineering Aids, it will be cleared and leveled by Equipment Operators. Batter boards are set up in pairs where each comer of the foundation is located. Builders fabricate the forms for concrete while Steelworkers are cutting, bending, tying, and placing reinforcing steel. If this particular building requires underslab utilities such as plumbing and electrical service, the Utilitiesman and Construction Electricians will also be on the jobsite. Last, all underslab work must be completed and pass all Quality Control inspections before concrete is placed and finished.

Most importantly as far as ease of erection is concerned, before the concrete is placed, templates for the anchor bolts are attached to the forms, and the anchor bolts are inserted through the holes in each. Then the forms are tied to make sure they remain vertical. It must be stressed at this point that the proper placement of the anchor bolts is absolutely critical in the erection of a PEB. You will only have a tolerance of plus or minus one eighth of an inch to work with. The threads of the bolts are greased, and the nuts are placed on them to protect the threads. Concrete is poured into the formwork and worked carefully into place around these bolts, so they will remain vertical and in place. Finally, according to the plans and specifications, the slab is poured.

While the foundation is being prepared, the crew leader will assign personnel/crews to perform various types of preliminary work, such as uncrating and inventorying all material on the shipping list, bolting up rigid-frame assemblies, assembling door eaves, and glazing windows. Box 1 contains the erection manual, the drawings, and an inventory list and should be opened first. If all of the preliminary work is done correctly, the assembly and erection of the entire building is accomplished easily and quickly.

All material, except the sheeting, should be uncrated and laid out in an orderly manner, so the parts can be located easily. Do not uncrate the sheeting until you are ready to install it. When opening the crates, use care not to cause any undue damage to the lumber. This is important since the lumber can be used for sawhorses and various other items around the jobsite.

In most situations, after the building foundation has been prepared, building materials should be placed around the building site near the location where they will be used, as shown in *Figure 14-2*. This action provides the greatest accessibility during assembly.

Figure 14-2 – Material layout.

Girts, purlins, eave struts, and brace rods should be equally divided along both sides of the foundation. Panels and miscellaneous parts which will not be used immediately should be placed on each side of the foundation on pallets or skids and covered with tarps or a similar type of covering until needed. Parts making up the rigid-frame assemblies are laid out ready for assembly and in position for raising.

Care should always be used in unloading materials. Remember that damaged parts will cause delays in getting the job done. To avoid damage, lower the materials to the ground slowly and do not drop them.

Figure 14-3 will help you identify the structural members of the building and their location. Each part has a specific purpose and must be installed in the location called for to ensure a sound structure.

Figure 14-3 – Structural members of a pre-engineered building.

CAUTION

Never omit any part called for on the detailed erection drawings.

Each of the members, parts, and accessories of the building is labeled by stencil, so it is not necessary to guess which one goes where. Refer to the erection plans to find the particular members you need as you work.

1.4.0 Erection

When all pre-erection work is completed, inspected, and passed by Quality Control, and your inventory is completed, you are ready to start erecting the PEB. This phase of our discussion will introduce you to the basic erection procedures. The reason for these instructions is to give you a general guide to follow. Keep in mind that the drawings provided by the manufacturer must be followed in all cases, even where they might differ from information in this training manual. The manufacturer's standard practice is to always pack an erection manual and a set of drawings in the small parts box (Box 1) shipped with each building.

1.4.1 Bolting Rigid Frames

Before bolting up the rigid-frame assembly, clean all the dirt and debris from the top of the foundation, and then lay out and bolt the base shoes firmly to the concrete. Use appropriate washers between the shoes and nuts. Lay out an assembled column and roof beam at each pair of base shoes as shown in *Figure 14-4*, using one bolt on each side of each base shoe to act as pivots in raising the frame. Use driftpins if needed to line up the holes.

1.4.2 Frame Erection

Use a ***gin pole*** to raise the end frame of the building. To prevent distortion of the frame when it is being raised, attach a bridle securely to each side of the frame below the splice connection and also to the ridge on the roof beam. Drop a driftpin in the frame to prevent the bridle from slipping up. Set up the gin pole with a block at the top. If a gin pole is not available, nail together three 2 x 6s, 20 feet long, from the longest shipping crate.

Figure 14-4 – Frame assembly.

Figure 14-5 – Frame erection.

Attach a tag line to the frame, as shown in *Figure 14-5*. Now, pull the end frame into the vertical position, using a crew of four or five people on the erection line. A tag person should have something to take a couple of turns around, such as a pole anchored to the ground. Then if the frame should go beyond the vertical, the tag person would be able to keep it from falling.

To get the frame started from the ground, it should be lifted by several people and propped up as high as practical. Bolt an eave strut to each column, as shown in *Figure 14-5*. The eave struts allow the frame to be propped at every stage of the lifting. After the frame is in a vertical position, install guy lines and props to it so it cannot move.

Now raise the second frame in the same way, and hold it vertically in place by installing purlins, girts, and brace rods.

A crane or other suitable type of power equipment can be used to hoist the frames into place where such equipment is available. When power equipment is used, the suggested procedure to comply with is as follows:

1. Raise the columns and bolt them to the base shoes and then brace them in plain.
2. Install all sidewall girts to keep the columns as rigid as possible.
3. Bolt the roof beams together and install the gable posts and end-wall header.
4. Secure the guy lines and tag lines to the roof beams, as shown in *Figure 14-6*. Attach a wire rope sling at approximately the center of each roof beam.

Figure 14-6 – Using power equipment.

5. Hoist the roof beams into position on top of the columns and bolt them in place.

6. When the second rigid-frame section is secured in position, install all of the roof purlins, the gable angles, and the louver angles. Attach the gable clips to the purlins before raising into position.
7. Install the brace rods and align the first bay.

NOTE

The first bay must be aligned before erecting additional bays.

1.4.3 Brace Rods

Brace rods must be installed in the first bay erected as shown in *Figure 14-7*. These rods are of paramount importance since they hold the frames in an upright position.

NOTE

The brace rods should never be omitted.

Figure 14-7 – Brace rods.

The diagonal brace rods are attached to the frames in the roof and sidewall through the slotted holes provided. Use a half-round brace rod washer and a flat steel washer under the nuts ar each end of the rods. With the rods installed, plumb each frame column with the carpenter's spirit level.

Check the distance diagonally from the upper corner of one frame to the lower corner of the adjacent frame. When this distance is the same for each rod, the columns will be plumb. After the sidewall rods are installed, install the roof rods. The length of the roof rods can be adjusted by tightening or loosening the turnbuckle. When the two diagonal measurements are the same, the end bay will be square.

After the two frames have been plumbed and braced square with the diagonal rods and the purlins, girts, and eave struts have been installed, the guy lines or props can be removed and the remaining frames of the building can be erected. To raise the next frame, attach blocks to the last frame raised.

- Do not omit the diagonal brace rods that are required in the last bay of the building.
- Be sure and bolt the girts, the purlins, and the eave struts to the inside holes of the end frames.
- Install the eave struts, the girts, and the purlins in each bay as soon as a frame is erected.
- Exercise care to see that the diagonal brace rods are taut and do not project beyond the flanges of the end frame to interfere with end-wall sheeting.

1.4.4 Sag Rods

Sag rods are used to hold the purlins and the girts in a straight line. First install the sag rods that connect the two purlins at the ridge of the building. Each rod must be attached from the top hole of one purlin through the bottom hole of the adjacent purlin. Use two nuts at each end of the sag rods, one on each side of each purlin. Adjust the nuts on these rods, so the purlins are held straight and rigid.

Next install the sag rods between the purlins below the ridge with the rod attached from the top hole of the upper purlin through the bottom hole of the lower purlin. Use two nuts on each end, one on each side of each purlin. Follow the same procedure with the sidewall sag rods.

Remember that the roof purlins should show a straight line from end to end of the building. Do NOT tighten the sag rods so much that the purlins are twisted out of shape.

1.4.5 Brace Angles and Base Angles

After two or more bays have been erected, part of the erection crew can be assigned to install the diagonal brace angles. To install the brace angles, lay the notched portion against the frame flange and bend it into position as shown in *Figure 14-8*. Diagonal brace angles are needed to support the inner flange of the frame. Be sure to install them so that they are taut.

⚠ CAUTION ⚠

Never omit diagonal brace angles. They are needed to support the inner flange of the frame. Install them so they are taut.

While some members of the crew are installing brace angles, other members can be installing base angles. When assigned this duty, first sweep off the top of the concrete foundation, so the base angles will set down evenly. Bolt the base angles in place with a flat steel washer under the nut. Leave the nuts loose to permit later adjustments after the wall sheeting has been applied.

Figure 14-8 – Diagonal brace angles.

1.4.6 End-Wall Framing, Doors, and Windows

Refer to the manufacturers' specifications for proper assembly and installation procedures for end-wall framing, doors (both sliding and roll-up), and windows, as these procedures will vary with available building options.

1.4.7 Sheeting

Sheeting, both sidewall and roof, must always be started at the end of the building toward which the prevailing winds blow. This action will ensure that the exterior joint in the side laps is away from the blowing of the prevailing winds. When installing roof sheeting, always use a generous amount of mastic on the upper side of all roof sheets just before moving them to the roof. Turn the sheet over and put a bead of mastic on the lip of one side of the corrugation and along one end, near the end but never more than one 1 inch from the end. Be sure to apply a horizontal bead of mastic between all sheets in the end laps, BELOW THE LAP HOLES. The roof sheets must be dry when mastic is applied. Mastic is extremely important, and care should be exercised whenever applying it to ensure a watertight seal. Apply generous beads, especially at the comers of the sheets. Finally, install the ridge cap ensuring proper watershed. As previously stated, the information in this manual is general information common to pre-engineered buildings.

1.4.8 Building Insulation

The pre-engineered building can be insulated by any of several methods. A blanket type of insulation, in 2 foot wide strips to match the width of the roof and wall sheets can be installed between the sheets and structural at the same time the sheeting is installed. Or a hardboard insulation can be applied directly to the inside surface of the structural, attaching it by helix nails or by sheet metal screws in holes prepared by drilling the structural. Or a wood framing can be prepared, attached to the structural, and a hardboard insulation is nailed to the wood.

1.5.0 Buildings Set Side by Side in Multiples

Pre-engineered buildings can easily be set up side by side to increase the working area under one roof. When this is done, the adjacent rigid frames should be bolted back to back with a channel spacer at each girt location as shown in *Figure 14-9*.

Figure 14-9 – Buildings side by side.

The eave struts are moved up the roof beam to the second set of holes to provide a gutter. This arrangement provides a space between eave struts. A field fabricated gutter can be installed.

Flat, unpainted galvanized steel of 24 to 26 gauge material should be used for the gutter, with the downspouts located as required. Gutter ends should be lapped and should be braze welded for watertightness. Note that wall sheets can be used to form a gutter if the outside corrugations are flattened and all of the end laps are braze welded.

Roof sheets must be cut shorter where they overhang the gutter. The corrugations can be closed with the continuous rubber closure with mastic applied to the top and bottom surfaces of the closure. An alternate method is to flatten the corrugations at the gutter and seal them with a glass fabric stripping set in plastic.

1.5.1 Interior Assembly

After the exterior members have been erected, work can begin on installing the interior assemblies. These include the liner panels, furring, hardboard flashing, and trim.

Figure 14-10 – Installing hardboard.

1.5.2 Liner Panels

Installation of the liner panels consists of installing furring strips, hardboard liner panels, and trim and battens. Various liner panel parts were shown earlier in *Figure 14-3*.

To install end walls properly, precut the liner panels according to the cutting diagrams. The hardboard must be installed with the smooth surface exposed and with a 1/8 inch gap between panels to allow for expansion, as shown in *Figure 14-10*. A scrap piece of hardboard or batten can be used as a shim or spacer to maintain the proper gap.

1.5.3 Base Furring

Nail the base furring to the floor 3 inches from each end and 2 feet 8 inches OC, with the inside edge 7 3/8 inches from the building structural line. You can get a better idea of this procedure by referring to *Figure 14-11*.

When base furring is to be used on a wood floor, use 8d box nails. Use 1 1/4 inch No. 9 concrete nails for a concrete floor. Drill the 2 by 2s and girts with a 5/32 inch bit so furring can be attached to the sidewall and eave girt with 2 inch panhead No. 10 sheet metal screws.

Figure 14-11 – Installing furring for the end wall liners.

Figure 14-12 – Nailing pattern for attaching hardboard to furring.

Attach the hardboard to the furring strips with 1 1/4 inch aluminum shingle nails on 4 inch centers at the sides and ends, as shown in *Figure 14-12*. Use 8 inch centers at the intermediate furring.

1.5.4 Vertical Furring

The vertical furring shown in *Figure 14-13* should be installed immediately after the base, corner, and gable furrings are in place. The center line of the furring on each side of the window should be in line with the center line of the end wall panel corrugations, as shown in the inserts. After the end wall hardboard has been installed, attach side and top flashing to the door.

Figure 14-13 – Placing furring for liners.

Attach flashing to the furring with 4d aluminum nails and to the door frames with 1/2 inch No. 10 sheet metal screws, as shown in *Figure 14-14*.

1.5.5 Sidewall and Ceiling Furring

After installing the end wall liner, install furring for the sidewall and ceiling. Cut the base so the end just clears the inside flange of the center frame column. Nail the furring in the same manner as the end walls.

Figure 14-14 – Side and top flashing for the doors of a PEB.

1.5.6 Hardboard Flashing

With the furring in place, you can now install the hardboard liner. Install the top and bottom hardboard flashing, as shown in *Figure 14-15*. Insert the outside edge into the retaining grooves in the window. Nail metal flashing angle and hardboard to the horizontal furring with 4d aluminum nails 1 foot 8 inches OC. Install side hardboard flashing and metal flashing angles using the same procedures discussed above.

Figure 14-15 – Top and bottom hardboard flashing.

The installed ceiling furring should intersect sidewall furring. When all the ceiling furring has been installed, the hardboard liner can be installed. Remember the 1/8 inch gap between panels. Attach the smoke stack assembly to the blocking and furring with 4d aluminum nails. Hand trim the hardboard flashing for the ends of the ventilator opening and attach the metal ventilator flashing as shown in *Figure 14-16*.

Figure 14-16 – Metal ventilator flashing.

1.5.7 Trim

Install the eave molding with the beveled edge against the ceiling panels. Attach each sidewall furring strip with 4d aluminum nails. Use quarter round molding to trim the ceiling to the end wall, end wall to sidewall, and walls to floor. Use metal ridge flashing, as shown in *Figure 14-17*, to trim the ridge of the ceiling liner. It can be attached to the ceiling furrings with 4d aluminum nails.

Figure 14-17 – Interior trim.

Check the drawings to make sure you are installing it correctly. Next, cut battens to the required length and attach them to the furring with 4d aluminum nails, 8 inches OC, as shown in *Figure 14-18*.

Figure 14-18 – Batten strip.

1.5.8 General Comments

Don’t be careless with bolts, nuts, and miscellaneous fasteners just because they are furnished in quantities greater than actual requirements. Be careful when using these fasteners to prevent scattering them on the ground. Each evening, empty your pockets of fasteners and other small parts before leaving the erection site.

An extra amount of mastic or sealant is also furnished with each PEB. Here, too, reasonable care in applying mastic to roof panels and roof accessories ensures an adequate supply.

Crating lumber can be used to construct an entrance platform and stairs at each end of a PEB. *Figure 14-19* shows one way this might be done.

Figure 14-19 – Crate platform.

1.6.1 Disassembly Procedures

Disassembly of the pre-engineered building should not be difficult once you are familiar with the erection procedures. In disassembling a building, be sure and clearly mark or number all of the parts. Then you will know where the parts go when reassembling the building. The main steps of the disassembly procedures are as follows:

1. Remove the sheeting.
2. Remove the windows, the door leaves, and the end wall.
3. Remove the diagonal brace angles and the sag rods.
4. Remove the braces, the girts, and the purlins.
5. Let down the frames.

1.6.1 Marking

It is obvious but worth repeating: In disassembling a building, be sure to clearly mark or number all parts. You will then know where the parts go when reassembling the building.

Carefully handling the building components during disassembly is very important. You may have to reuse these same components at another location. As you complete disassembly, protect those components from damage. Any damaged components will have to be replaced, and time might not be on your side.

2.0.0 WOOD FRAME CONSTRUCTION

There are three basic types of wood frame construction of concern to Builders: tents with wood frames for support, SEA huts developed in Southeast Asia during the Vietnam War, and field latrines.

2.1.0 Wood Frame Tents

Figure 14-20 shows working drawings for framing and flooring a 16 by 32 foot wood frame tent. Tents of this type are used for temporary housing, storage, showers, washrooms, latrines, and utility spaces at an advanced base.

Figure 14-20 – Framing and flooring plans for a 16 by 32 foot wood frame tent.

Tent floors consist of floor joists (16 foot lengths of 2 by 4s) and sheathing (4 by 8 foot sheets of 1/2 inch plywood). The supports for the floor framing are doubled 2 by 4 posts anchored on 2 by 12 by 12 mudsills. The wall framing members are 2 by 4 studs, spaced 4 feet OC. The roof framing members are 2 by 4 rafters, spaced 4 feet OC. The plates (2 by 4s) and the bracing members (1 by 6s) are fabricated in the field. A representative floor framing plan for a field type shower and a washroom is shown in *Figure 14-21*.

Figure 14-21 – Floor framing plan.

All field structures are derived from the 16 by 32 foot wood frame tent. If more tent space is needed, a 40 by 100 foot model is available. This tent is not difficult to assemble because it is put together without a floor. It can be erected without a strongback frame since it comes complete with ridge pieces, poles, stakes, and line, and does not require framing. But no matter how easy erection may seem, always read and follow the instructions.

2.2.0 SEA Hut

When the 16 by 32 foot wood frame tent is modified with a metal roof, extended rafters, and screened in areas, it is called a Southeast Asia (SEA) hut. An example of the completed product is shown in *Figure 14-22*. The SEA hut was originally developed in Vietnam for use in tropical areas by U.S. troops for berthing, but it can readily be adapted for any use in any situation. It is also known as a strongback because of the roof and sidewall materials.

Figure 14-22 – Completed SEA huts.

The SEA hut is usually a standard prefabricated unit, but the design can be easily changed to fit local requirements, such as lengthening the floor or making the roof higher. The standard prefabrication of a SEA hut permits disassembly for movement to other locations when structures are needed rapidly. As with all disassembly of buildings, ensure it is not damaged in the process.

2.3.0 Field Type Latrines

Temporary facilities for disposal of human waste are one of the first things to be constructed at an advanced base. A number of field type latrines are designed for this purpose. A 16 by 32 foot wood frame tent may be used to shelter the latrine.

2.3.1 Four-Seat

A prefabricated four-seat latrine box is shown in *Figure 14-23*.

Figure 14-23 – Prefabricated four-seat latrine box.

It can be collapsed for shipment, as shown in *Figure 14-24*.

Figure 14-24 – Latrine box collapsed for shipment.

2.3.2 Eight-Seat

A plan view of an eight-seat field type latrine is shown in *Figure 14-25*.

Figure 14-25 – Plan view of an eight-seat field type latrine.

Two four-seat boxes straddle a 3 by 7 foot pit. After the pit is dug, but before the boxes are placed, a 4 foot-wide margin around the pit is excavated to a depth of 6 inches, as shown in *Figure 14-26*.

Figure 14-26 – Margin of oil-soaked earth around latrine boxes.

A layer of oil-soaked burlap is laid in this excavation. Then the excavated earth is soaked with oil, replaced, and tamped down to keep surface water out. Two 4 foot 6 inch trough type urinals are furnished with the eight-seat latrine. Each is mounted in a frame constructed as shown in *Figure 14-27*.

Figure 14-27 – Frame for urinal trough.

A 2 inch urinal drainpipe leads from the downpipe on each urinal to a 6 by 6 foot urinal seepage pit. The seepage pit is constructed as shown in *Figure 14-28*.

As indicated in *Figure 14-25*, the eight-seat field type latrine can be expanded to a 16-seat field type latrine.

Figure 14-28 – Urinal seepage pit.

2.3.3 urnout Type

A complete plan view of a four-hole burnout field type latrine is shown in *Figure 14-29*. The waste goes into removable barrels. The waste is then disposed of at another location. This type of latrine is used at most advanced or temporary bases. The burnout latrine is kept in an orderly condition daily by the camp maintenance personnel or the assigned sanitation crew. It can be easily maintained by spreading lime over the waste material or using diesel fuel to bum the waste material.

Figure 14-29 – Burnout type four-hole latrine.

2.4.0 Maintenance

Once wood frame facilities are completed and occupied by the tenants, maintenance becomes the major priority. The life span of a facility is greatly increased with proper maintenance. Even though the majority of these buildings are temporary in nature, most can be dismantled and reassembled at another site. Establishment of a regularly scheduled maintenance program ensures the buildings are in a consistent state of readiness.

Test your Knowledge (Select the Correct Response)

1. When modified with a metal roof, extended rafters, and screened in areas, a 16 by 32 foot wood frame tent becomes what type of hut?

   A. Southeast Asia
   B. Caribbean
   C. Wood frame
   D. Tropical

3.0.0 K-SPAN

The K-span building is a newer form of construction in the Seabee community. The intended uses of these buildings are as flexible as the SEA huts discussed earlier. Training key personnel in the operation of the related equipment associated with the K-span is essential. Once trained, these same personnel, can instruct other members of the crew in the safe erection of a K-span. The following section gives you some, but not all, of the key elements associated with K-span construction. As with other equipment, always refer to the manufacturer's manuals.

3.1.0 Operating Instructions

The main component of the K-span system is the trailer-mounted machinery shown in *Figure 14-30*. This figure shows the primary components of the trailer as well as general operations.

Figure 14-30 – Trailer-mounted machinery for a K-span building.

The key element is the operator's station at the rear of the trailer, shown in *Figure 14-31*. The individual selected for this station must be able to understand the machine operations and manuals. From here, the operator controls all the elements required to form the panels. The operator must remain at the controls at all times. The forming of the panels is a complex operation that becomes easier with a thorough understanding of the manuals. From the placement of the trailer on site, to the completion of the curved panel, attention to detail is paramount.

Figure 14-31 – Rear of a K-span trailer.

As you operate the panel, you will be adjusting the various machine operating components. Make adjustments for thickness, radius, and the curving machine according to the manuals. Do not permit short cuts in adjustments. Any deviations in adjustments, or disregard for the instructions found in the operating manuals, will leave you with a pile of useless material and an inconsistent building.

3.2.1 Machinery Placement

To avoid setup problems, preplanning of the site layout is important. Uneven or sloped ground is not a concern as long as the bed of the trailer aligns with the general lay of the existing surface conditions. Using *Figure 14-32* as a guide, consider the following items when placing the machinery:

Allow maneuvering room for the towing of the trailer, or leave it attached to the vehicle.

The length of the unit is 27 feet 8 inches long by 7 feet 4 inches wide.

Allow enough room for run-out stands to hold straight panels. Stands have a net length of 9 feet 6 inches each.

Find point X: From the center of the curve, measure the distance equal to the radius in line with the front of the curved frame. From point X, scribe an arc equal to the radius. This arc will define the path of the curved panel. Add 10 feet for run-out stands and legs.

- Allocate room for a storage area required to store coil stock and access for equipment to load it onto the machine.
- Consider the direction the curved panels must be carried after being formed.
- Allocate a level area in which to lay the panels on the ground for seaming. The building will not be consistent if the panels are not straight when seaming is done.
- Allocate space required for crane operations.

Figure 14-32 – Machinery placement calculations.

3.3.0 Foundations

The design of the foundation for a K-span building depends on the building's size, existing soil conditions, and wind load. The foundations for the buildings are simple and easy to construct. With the even distribution of the load in a standard arch building, the size of the continuous strip footing is smaller and more economical than the foundations for conventional buildings.

The concrete forms and accessories provided are sufficient to form the foundations for a building 100 feet long by 50 feet wide. When a different configuration is required, forms are available upon request from the manufacturer.

The actual footing construction is based, as all projects are, on the building plans and specifications. The location of the forms, placement of steel, and the psi (pounds per square inch) of the concrete are critical. Since the building is welded to the angle in the footer prior to the concrete placement, all aspects of the footer construction must be thoroughly checked for alignment and square. Once concrete is placed, there is no way to correct mistakes.

As mentioned above, forms are provided for the foundation. Using *Table 14-1* as a guide, *Figure 14-33* gives you a simple foundation layout by parts designation. As noted in *Figure 14-33*, the cross pipes are not provided in the kit. They are provided by the contractor.

Table 14-1 – Concrete Forms Included in Kit.

Description (Each set of forms is sufficient to erect a building 100 feet long by 50 feet wide.)	Part Number
Side form panels, 1' x 10', 12 gauge steel	F-1
Transition panels, 1' x 12", 12 gauge steel	F-2
Transition panels, 1' x 28", 12 gauge steel	F-3
End wall caps, 1' x 15", 12 gauge steel	F-4
Side wall caps, 1' x 19", 12 gauge steel	F-5
Filler form, 1' x 12', 12 gauge steel	F-6
Sidewall inside stop, 1' x 12", 12 gauge steel	F-7
End wall inside stop, 1' x 12", 12 gauge steel	F-8
Stakes, 1/4" diameter, bar steel	F-9
All thread rod, 1/2-13 x 18"	F-10
Hex nuts, 1/2-13	F-11
Hex bolts, 1/8-16 x 1-1/2"	F-12
Hex nuts, 3/8-`6	F-13
Flat washers, 1/8" SAE	F-14
Corner angles, 2" x 2" x 12", steel angle	F-15

Figure 14-33 – Simple form assembly.

With the foundation forms in place, and the building panels welded to the attaching angle as shown in *Figure 14-34* at 12 inches OC, you are ready to place the concrete. When placing the concrete, remember that it is extremely important that it be well vibrated. This helps eliminate voids under all embedded items.

Figure 14-34 – Building foundation concept.

As the concrete begins to set, slope the top exterior portion of the concrete cap about 5 inches, as shown in *Figure 14-35*, to allow water to drain away from the building. The elevation and type of interior floor are not relevant as long as the finish of the interior floor is not higher than the top of the concrete cap.

Figure 14-35 – Concrete foundation for a K-span building.

3.4.1 Building Erection

With the placement of the machinery and forming of the building panels in progress, your next considerations are the placement and the weight-lifting capabilities of the crane. Check the crane’s weight-lifting chart for its maximum weight capacity. This dictates the number of panels you can safely lift at the operating distance. As with all crane operations, attempting to lift more than the rated capacity can cause the crane to turn over.

Attaching the spreader bar as shown in *Figure 14-36* to the curved formed panels is a crucial step. Failure to tightly clamp the panel can cause the panels to slip and fall with potential harm to personnel and damage to the panel.

Figure 14-36 – Spreader bar attachment.

With guide ropes attached as shown in *Figure 14-37* and personnel manning these ropes, lift the panels for placement.

Figure 14-37 – Guide rope diagram.

When lifting, consider the following points:

- Lift only as high as necessary.
- Position two crewmembers at each free end to guide each panel in place.
- Remind crewmembers to keep their feet out from under the ends of the arches.
- Never attempt lifting any sets of panels in high winds.

Place the first set of panels on the attaching angle of foundation and position it so there will be room for the end wall panels. After positioning the first set of panels, clamp them to the angle, plumb them with guide ropes, and secure the ropes to previously anchored stakes. Detach the spreader bar and continue to place panel sets. Seam each set to standing panels before detaching the spreader bar.

After about 15 panels (3 sets) are in place, measure the building length at both ends just above the forms and at the center of the arch. This measurement will seldom be exactly one foot per panel, it is usually slightly more, but it should be equal for each panel. Adjust the ends to equal the center measure. Panels are flexible enough to adjust slightly. Check these measurements periodically during building construction. Since exact building lengths are difficult to predict, the end wall attaching angle on the finishing end of the building should not be put in place until all panels are set. After the arches are in place, set the longest end wall panel in the form, plumb, and clamp it in place. Work from the longest panel outward and be careful to maintain plumb.

3.5.0 Construction Details

The K-span building system is similar to other types of pre-engineered or prefabricated buildings because windows, doors, and roll up doors can be installed only when building erection is completed. When insulation of the building is required, insulation boards, usually 4 by 8 feet, may be of any semi-rigid material that can be bent to match the radius of the building. The insulation is installed using clips, as shown in *Figure 14-38*.

Figure 14-38 – Insulation for a K-span building.

When the integrity of the end wall panels is continuous from ground to roof line, the end walls become self supporting. The installation of windows, shown in *Figure 14-39*, and aluminum and wood doors, shown in *Figures 14-40* and *14-41* respectively, presents no problem since the integrity of the wall system is not interrupted.

Figure 14-39 – Aluminum window installation.

Figure 14-40 – Aluminum door installation.

Figure 14-41 – Wood door installation.

The installation of the overhead door shown in *Figure 14-42* does present a problem because it interrupts the integrity of the wall system. This situation is quickly overcome by the easily installed and adjustable (height and width) door frame package that supports both the door and the end wall. This door frame package is offered by the manufacturer.

Figure 14-42 – Overhead door frame.

Keep in mind that the information provided in this section on the K-span building is minimal. During the actual construction of any K-span building, you must consult the manufacturer's complete set of manuals.

Test your Knowledge (Select the Correct Response)

2. What is the main component of the K-span system?

   A. Sheet metal stock
   B. Trailer-mounted machinery
   C. Crane
   D. Cretemobile

4.0.0 EMBARKATION

For a smooth, expedient mount-out, careful preplanning and organizing are required. Embarkation, whether by air, land, sea, or any combination thereof, is an all hands evolution. A successful move requires 100 percent support.

Flexibility is extremely important. Proper embarkation depends to a large extent on the mutual understanding of objectives and capabilities, and full cooperation in planning and execution by both the unit mobilizing and the organization providing the lift. Whenever possible, early communication and coordination between the two are extremely desirable.

4.1.0 Planning

Embarkation planning involves all measures necessary to assure timely and effective out loading of the amphibious task force and portions thereof. Planning for embarkation also applies to all unit moves, regardless of the method used for movement. These measures are determined by the availability of transportation and the transportation requirements of the unit moving. In amphibious embarkation, the OPNAV level in the chain of command determines overall shipping requirements and the embarkation schedules. This enables subordinate units to prepare detailed loading plans for individual ships. Planning requires constant coordination between commanders in the Navy and the Air Force; they must have a mutual understanding of the problems of each support group. In the final analysis, the embarkation plan must support the tactical deployment plan of the unit. In the case of an amphibious landing, it must support the tactical plan for landing and the scheme of maneuvers ashore.

Embarkation planning requires detailed knowledge of the characteristics, capabilities, and limitations of ships, aircraft, and amphibious vehicles, and their relationships to the troops, supplies, and equipment to be embarked. The planner must be familiar with transport types of amphibious ships, Military Sealift Command (MSC) ships, merchant ships, and cargo aircraft. MSC ships and merchant ships pose certain problems; basically, they are not designed, equipped, or have a crew large enough for amphibious operations. But, their use must be anticipated. The additional requirements of hatch crews, winchmen, cargo handling equipment, cargo nets, assault craft, and other facilities must be provided by the user.

4.1.1 Principles

Whether by ship during amphibious operations or by aircraft for assault force support operations, you must observe certain principles to ensure proper embarkation.

First, embarkation plans must support the plan for landing and the scheme of maneuvers ashore. Personnel, equipment, and supplies must be loaded so they can be unloaded at the time and in the sequence required to support operations ashore.

Second, embarkation plans must provide for the highest possible degree of unit self sufficiency. Troops should not be separated from their combat equipment and supplies. Weapons crews should be embarked on the same ship or aircraft with their weapons; radio operators with their radios; and equipment operators with their equipment. In addition, each unit should embark with sufficient combat supplies, such as ammunition, gasoline, and radio batteries, to sustain its combat operations during the initial period in the operational area. All personnel should have sufficient water and rations to sustain themselves for 24 hours.

Third, plans must provide for rapid unloading in the objective area. This can be achieved by a balanced distribution of equipment and supplies.

Fourth, and last, plans must provide for dispersion of critical units and supplies among several ships or aircraft. The danger of not doing so is obvious. If critical units and supplies are not dispersed, loss of one ship, or a relatively few ships or aircraft, could result in a major loss of combat capability. Accomplishment of the mission can be seriously jeopardized.

4.1.2 Team Planning

Effective embarkation planning by the embarkation team is dependent upon the early receipt of information from higher authority. Detailed planning begins with the determination of team composition and the assignment of shipping. The following information should be included in the team's embarkation planning:

- Designation of the team embarkation officer(s)
- Preparation and submission of basic loading forms by troop units of the embarkation team
- Preparation of the detailed loading plan
- Designation of the ship's platoon, billeting, messing, and duty officers during the period of the embarkation
- Designation and movement of advance parties and advance details to the embarkation area
- Establishment of liaison with the embarkation control office in the embarkation area
- Preparation of the schedule for movement of troops, vehicles, equipment, and supplies to the embarkation area
- Preparation of plans for the security of cargo in the embarkation area

Three basic embarkation plans are normally prepared by the various command levels within the landing force: the landing force embarkation plan, the group embarkation plan, and the unit embarkation plan.

4.1.2.1 Landing Force Embarkation Plan

The landing force embarkation plan includes the organization for embarkation; supplies and equipment to be embarked; embarkation points and cargo assembly areas; control, movement, and embarkation of personnel; and miscellaneous information. The landing force embarkation plan contains information from which the embarkation group commander prepares a more detailed plan.

4.1.2.2 Group Embarkation Plan

The group embarkation plan, prepared by the embarkation group commander, establishes the formation for embarkation units and assigns shipping to each embarkation unit. It contains the same information as the landing force embarkation plan, but in much greater detail. The group embarkation plan has attached to it or included within the embarkation organization a shipping assignment table.

4.1.2.3 Unit Embarkation Plan

The unit embarkation plan prepared by the embarkation unit commander establishes the formation of embarkation teams and assigns each embarkation team to a ship. It contains generally the same information as the group embarkation plan, but in greater detail. Attached to the unit embarkation plan is the unit embarkation organization and shipping assignment table. Naval construction force (NCF) units embarking alone outside of the landing force, either by amphibious means or by air, should prepare an embarkation plan incorporating all of the information necessary for proper embarkation by the unit.

4.2.0 Packaging

Standard boxing procedures are required to minimize shipping, packing, and repacking of allowance items and to establish uniformity among the NCF units. Present mobility requirements necessitate being partially packed for redeployment at all times. The best method of obtaining this state of readiness is to use packing boxes for day to day storage and for dispensing all types of battalion allowance items. Each NCF unit must fabricate mount-out boxes according to the Embarkation Manual, COMCBPAC/ COMCBLANTINST 3120.1, for all authorized allowance items within the unit's TOA that can be boxed. Existing boxes may be used if the color and marking codes conform to standard box markings.

4.2.1 Packing Lists

Packing lists must be prepared for each box. One copy is placed inside the box, one copy is mounted in a protective packet on the outside of the box, one copy is kept on file in the embarkation mount-out control center, and one copy is retained by the department to which the supplies or equipment belong. Packing lists must be sufficiently detailed to locate needed items without having to open and search several boxes.

4.2.2 ount-Out

When constructing mount-out boxes, observe the following considerations:

- Screw nails or flathead screws and glue must be used to assemble the boxes.
- Covers must be bolted to tapped metal inserts, as shown in COMCBPAC/COMCBLANTINST 3120.1, or an equivalent bolting method.
- Box interiors may be compartmented to suit the contents.
- Gross weight of the boxes should be limited to 250 pounds each for easy handling without material handling equipment.
- Boxes must be fabricated of 3/4 inch exterior grade plywood, reinforced with 2 by 4 ends.
- Special boxes for large items are authorized, but should conform to the criteria set forth in COMCBPAC/COMCBLANATINST 3120.1.
- Metal comers or other protection may be installed to prevent shipping damage.

4.2.3 Pre-positioned Stocks and Supplies

Because of the mobile nature of the NCF, it is necessary to pre-position certain supplies and equipment in anticipation of use in contingency mount-outs. These stocks include oil, gasoline, lubricants, rations, and ammunition, plus a full allowance of equipment. During a contingency mount-out, all or part of these pre-positioned stocks may be used. As part of the planning phase, NCF units should check the plan to be supported to determine the exact amount and types of supplies to be embarked and the location of the supplies.

Test your Knowledge (Select the Correct Response)

3. **(True or False)** Critical units and supplies must be kept together on one ship.

   A. True
   B. False

5.0.0 PILE DRIVING

A trestle is a braced framework of timbers, ***piles***, or steel members. It is typically built to carry a roadway across a depression, such as a gully, a canyon, or the valley of a stream. The two main parts of a trestle are the substructure, consisting of the supporting members, and the superstructure, consisting of the decking and the stringers on which the decking is laid.

The substructure of a timber trestle is a series of transverse frameworks called bents. Trestle bents are used on solid, dry ground, or in shallow water with a solid bottom. ***Pile bents*** are used in soft or marshy ground, or where the water is so deep or the current so swift that the use of trestle bents is impossible. The posts of a pile bent are ***bearing piles*** or vertical members driven into the ground.

The principal structural members in many waterfront structures are piles. There are different types of and uses for piles. The common terms used with piles and pile driving are explained below.

5.1.0 Nomenclature

The following terms are common to timber trestle construction.

5.1.1 Abutment

An ***abutment*** is the ground support at each of the extreme ends of a trestle superstructure. Examples are shown in *Figures 14-43* and *14-44*.

Figure 14-43 – Abutment sill and footing and abutment excavation.

Figure 14-44 10-2 – Placing and leveling abutment footings and abutment sill.

5.1.2 Bracing

The timbers used to brace a trestle bent are called transverse bracing, the timbers used to brace bents to each other are called longitudinal bracing. *Figure 14-45* shows both types for a two story trestle bent.

5.1.3 Cap

The cap is the uppermost transverse horizontal structural member of a bent. It is laid across the tops of the posts.

5.1.4 Decking

Decking is the structure laid on the girders to form the roadway across the trestle. It consists of a lower layer of timbers (flooring) and an upper layer of timbers (treadway).

Figure 14-45 – Two story trestle bent.

5.1.5 Footing

The footing is the supports placed under the sills. In an all timber trestle, the footings consist of a series of short lengths of plank. Whenever possible, however, the footings are made of concrete.

5.1.6 Girder

A girder is one of a series of longitudinal supports for the deck, which is laid on the caps. It is also called a stringer.

5.1.7 Post

A post is one of the vertical structural members.

5.1.8 Sill

The sill is the bottom transverse horizontal structural member of a trestle bent on which the posts are anchored, or the transverse horizontal member which supports the ends of the girders at an abutment.

5.1.9 Substructure

The substructure is the supporting structure of braced trestle bents, as distinguished from the superstructure.

5.1.10 Superstructure

The superstructure is the spanning structure of girders and decking, as distinguished from the substructure.

5.1.11 Trestle Bent

A trestle bent is a single story bent or a multi story bent and the support framework or substructure of a trestle. The parts of a single story bent are shown in *Figure 14-46*. A two story bent is shown above in *Figure 14-45*.

Figure 14-46 – Components of a single-story trestle bent.

5.2.0 Construction

After the center line of a trestle has been determined, the next step is to locate the abutment on each bank at the desired or prescribed elevation. The abutments are then excavated to a depth equal to the combined depths of the decking and the stringers, less an allowance for settlement. The abutment footings and the abutment sills are then cut, placed, and leveled, as shown in *Figure 14-44*.

The horizontal distance from an abutment sill to the first bent and from one bent to the next is controlled by the length of the girder stock. It is usually equal to the length of the stock, minus about 2 feet for overlap. Girder stock is usually in 14 foot lengths. The center to center horizontal distance between bents is usually 14 minus 2, or 12 feet.

To determine the locations of the seats for the trestle bents and the heights of the bents, shown in *Figure 14-47*, first stretch a tape from the abutment along the center line. Use a builder’s level or a line level to level the tape. Drop a plumb bob from the 12 foot mark on the tape to the ground. The position of the plumb bob on the ground will be the location of the first bent. The vertical distance from the location of the bob to the horizontal tape, less the thickness of a footing, will be the height of the first bent.

Figure 14-47 – Locating seats for trestle bents.

Next, stretch the tape from the location of the first bent, level it as before, and again drop a plumb bob from the 12 foot mark. The position of the plumb bob will be the location of the section bent. The vertical distance from the location of the bob to the horizontal tape, plus the height of the first bent, less the thickness of the footing, will be the height of the second bent.

Finally, stretch the tape from the location of the second bent and proceed as before. The vertical distance from the location of the bob to the horizontal tape, plus the height of the second bent, less the thickness of a footing, will be the height of the third bent, and so on.

5.3.0 Constructing a Trestle Bent

When a trestle bent is laid out and constructed, the length of the posts is equal to the height of the bent, less the combined depths of the cap and sill. In a four post bent, the centers of the two outside posts are located from 1 to 2 1/2 feet inboard of the ends of the sill, and the centers of the two inner posts are spaced equally distant between the other two.

Sills, caps, and posts are commonly made of stock that ranges in size from 12 by 12s to 14 by 16s. If a sill or cap is not square in a cross section, the larger dimension should be placed against the ends of the posts. The usual length for a sill or cap is 2 feet more than the width of the roadway on the trestle. The minimum width for a single lane trestle is 14 feet; for a two lane trestle, 18 feet.

5.3.1 Layout

Part of the terrain at an assembly site may be graded flat and used as a framing yard, or a low platform may be constructed for use as a framing platform. To assemble a bent, lay the posts out parallel and properly spaced, and set the cap and sill in position against the ends. Bore the holes for the driftpins through the cap and the sill into the ends of the posts, and drive in the driftpins. Cut a pair of 2 by 8 by 18 inch scabs for each joint and then spike, lag screw, or bolt the scabs to the joints.

Finally, measure the diagonals to determine the lengths of the transverse diagonal braces. Cut the braces to length and spike, lag screw, or bolt them to the sills, caps, and posts. Transverse diagonal bracing is usually made of 2 by 8 stock.

5.3.2 Trestle Bent Erection

After assembly, move the trestle bent to the abutment and set it in place on the footings at the seat. Carefully plumb the bent and temporarily brace it with timbers running from the top of the bent to stakes driven at the abutment. Lay the superstructure, the girders and decking, from the abutment out to the top of the first bent. Then bring the second bent out to the end of the superstructure and set it in place. Plumb the second bent and measure the diagonals to determine the lengths of the longitudinal diagonal braces between the first and second bents. Then cut the braces and spike, lag screw, or bolt them in place.

Then earn out the superstructure to the second bent, and then bring the third bent to the end of the superstructure. Repeat this procedure, usually by parties working out from both abutments, until the entire span is completed.

5.4.0 Superstructure

Timber girders are usually 10 by 16s, 14 feet long, spaced 3 feet 3 1/2 inches on center (OC). Various methods of fastening timber stringers to timber caps are shown in *Figure 14-48*.

Figure 14-48 – Methods of fastening timber stringers.

Various methods of fastening steel girders to timber caps are shown in *Figure 14-49*. This view also shows three ways of fastening a timber nailing anchorage for flooring to the top of a steel girder.

Figure 14-49 – Methods of fastening steel girders to timber caps.

Timber decking consists of two layers of 3 inch planks. Lay the lower layer, called the flooring, at right angles to the stringers and nail it with two 60d spikes to each stringer crossing. Lay the upper layer, called the tread and shown in *Figure 14-50*, securely and nail it at a 90° angle to the flooring.

Figure 14-50 – Details of superstructure of a timber trestle.

Cut most of the flooring planks and all of the tread planks to lengths that will bring the ends of the planks flush with the outer faces of the outside stringers. At 5 foot intervals along the superstructure, leave a flooring plank long enough to extend 2 feet 8 inches beyond the outer faces of the outside stringers. The extension serves as support for the curb risers, the curb, and the handrail posts, as shown in *Figure 14-50*. The curb risers consist of 3 foot lengths of 6 by 6 timbers, one of which is set in front of each handrail post as shown. Nail a continuous 2 by 6 handrail to 4 by 4 handrail posts. Each handrail post is supported by a 2 by 4 knee brace, as shown.

Set an end dam, such as that shown in *Figure 14-51*, at each end of the superstructure. This prevents the approach of the road to the trestle from washing out or eroding between the abutment and the girders.

Figure 14-51 – End dam.

5.5.0 Types of Piles

A pile is a load bearing member made of timber, steel, concrete, or a combination of these materials. It is usually forced into the ground to transfer the load to underlying soil or rock layers when the surface soils at a proposed site are too weak or compressible to provide enough support.

5.5.1 Timber Bearing

Timber bearing piles are usually straight tree trunks cut off above ground swell with the branches closely trimmed and the bark removed. Occasionally, sawed timbers may be used as bearing piles.

5.5.1.1 Characteristics

A good timber pile has the following characteristics:

- It is free of sharp bends, large or loose knots, shakes, splits, and decay.
- It is uniformly tapered from butt to tip.
- The centers of the butt and tip are end points of a straight line that lies within the body of the pile.

Cross section dimensions for timber piles should be as follows:

- Piles shorter than 40 feet, tip diameters between 8 and 11 inches, and butt diameters between 12 and 18 inches.
- Piles longer than 40 feet, tip diameters between 6 and 8 inches, and butt diameters between 13 and 20 inches. The butt diameter must not be greater than the distance between the pile leads.

5.5.1.2 Preparation for Driving

Timber piles can be damaged while being driven, particularly under hard driving conditions. To protect a pile against damage, cut the butt of the pile squarely so the pile hammer will strike it evenly and chamfer it. When a driving cap is used, the chamfered butt must fit the cap. When a cap is not used, the top end of the pile is wrapped with 10 or 12 turns of wire rope at a distance of about one diameter below the head of the pile as shown in *Figure 14-52, views A* and *B*. When a hole is bored in the butt of the pile, double wrappings are used, as shown in *view C*. The pile can also be wrapped or clamped if the butt is crushed or split. As an alternative to wrapping, two half rings of 3/8 inch steel are clamped around the butt as shown in *view D*.

The tip of the pile is cut off perpendicular to its axis. When driven into soft or moderately compressible soil, the tip of the pile may be left unpointed. A blunt end pile provides a larger bearing surface than a pointed end pile when used as an ***end bearing pile***. When driven, a blunt end pile that strikes a root or small obstruction may break through it.

Where soil is only slightly compressible and must be displaced, the tip of the pile is usually sharpened to the shape of an inverted truncated pyramid, as shown in *Figure 14-52*, *view A*. The blunt end is about 4 to 6 inches square; the length of the point is 1 1/2 to 2 times the diameter of the pile at its foot. A crooked pile may be pointed for driving, as shown in *view B*.

For hard driving, steel shoes are used to protect the pile tips. A manufactured shoe is shown in *view C*, and an improvised steel shoe is shown in *view D*.

Figure 14-52 – Preparation of timber piles for driving.

5.5.2 Steel Bearing

Steel ranks next to timber in importance, especially where the construction must accommodate heavy loads or the foundations are expected to be used over a long period of time. Steel is best suited for use as bearing piles where piles must be driven under any of the following conditions:

- Piles are longer than 80 feet.
- Column strength exceeds the compressive strength of timber.
- To reach bedrock for maximum bearing surface through overlying layers of partially decomposed rock.
- To penetrate layers of coarse gravel or soft rock, such as coral.
- To attain great depth of penetration for stability, for example, driving piles in a rock- bedded, swiftly flowing stream where timber piles cannot be driven deeply enough for stability.

One of the most common types of steel bearing piles is the pipe pile. An open end pipe pile is open at the bottom. A closed rid pipe pile is closed at the bottom. Another common type of steel pile is the H type, often seen as HP. When driving HPs, a special driving cap, shown in *Figure 14-53*, is used.

Figure 14-53 – HP bearing pile and special cap for driving.

5.5.3 Concrete

A concrete bearing pile may be cast in place or precast. A cast in place ***concrete pile*** may be a shell type or a shell-less type.

A shell type of cast in place pile is constructed as shown in *Figure 14-54*. A steel core, called a mandrel, is used to drive a hollow steel shell into the ground. The mandrel is then withdrawn, and the shell is filled with concrete. If the shell is strong enough, it may be driven without a mandrel.

Figure 14-54 – Shell type cast in place concrete pile.

A shell-less cast in place concrete pile is made by placing the concrete in direct contact with the earth. The hole for the pile may be made by driving a shell or a mandrel and shell, or it may be simply bored with an earth auger. If a mandrel and shell are used, the mandrel, and usually also the shell, are removed before the concrete is poured. In one method a cylindrical mandrel and shell are used, and only the mandrel is removed before the concrete is poured. The concrete is poured into the shell, after which the shell is extracted. This sequence of events is shown in *Figure 14-55*.

Figure 14-55 – Procedure for cast in ground concrete piles.

Casting in place is not usually feasible for concrete piles used in waterfront structures. Concrete piles for waterfront structures are usually precast. The cross section of precast concrete piles is usually either square or octagonal (eight sided). Square section piles run from 6 to 24 inches square. Concrete piles more than 100 feet long can be cast, but are usually too heavy for handling without special equipment.

5.5.4 Sheet

Sheet piles are special shapes of interlocking piles made of steel, wood, or formed concrete. They are widely used to form a continuous wall to resist horizontal pressures resulting from earth or water loads. Examples include retaining walls, cutoff walls, trench sheathing, ***cofferdams***, and ***bulkheads*** in wharves, docks, or other waterfront structures. Cofferdams exclude water and earth from an excavation so that construction can proceed easily. Cutoff walls are built beneath water retaining structures to retard the flow of water through the foundation.

Sheet piles may also be used in the construction of piers for bridges and left in place, Here, steel piles are driven to form a square or rectangular enclosure. The material inside is then excavated to the desired depth and replaced with concrete.

5.5.5 Timber Pier Piles

Working drawings for advanced base timber piers can be found on the internet on the Advanced Base Functional Component (ABFC View) of the Naval Facilities Engineering Command's Expeditionary Logistics Center (NAVFAC). The drawings include a bill of materials, showing the dimensions and location of all structural members, driftpins, bolts, and hardware. *Figures 14-56* and *14-58* are parts of NAVFAC Drawing No. 6028173; *Figure 14-57* is a part of NAVFAC Drawing 6028174.

The size of the pier is designated by its width. The width is equal to the length of a bearing ***pile cap***. Each part of a pier lying between adjacent pile bents is called a bay, and the length of a bay is equal to the OC spacing of the bents. The general plan shown in *Figure 14-56* shows that the advanced base 40 foot timber pier consists of one 13 foot outboard bay, one 13 foot inboard bay, and as many 12 foot interior bays as needed to meet requirements.

Figure 14-56 – General plan of an advanced base 40 foot timber pier.

Figure 14-57 – Cross section of an advanced base timber pier.

The cross section in *Figure 14-57* shows that each bent consists of six bearing piles. The bearing piles are braced transversely by diagonal braces. Additional transverse bracing for each bent is provided by a pair of batter piles. The batter angle is specified as 5 in 12. One pile of each pair is driven on either side of the bent, as shown in the general plan. The butts of the batter piles are joined to 12 inch by 12 inch by 14 foot longitudinal batter pile caps. Each of these is bolted to the undersides of two adjacent bearing pile caps with bolts in the positions shown in the part plan, *Figure 14-58*. The batter pile caps are placed 3 feet inboard of the center lines of the outside bearing piles in the bent. They are backed by 6 by 14 inch batter pile cap blocks, each of which is bolted to a bearing pile cap. Longitudinal bracing between bents consists of 14 foot lengths of 3 by 10 planks, bolted to the bearing piles.

Figure 14-58 – Part plan of an advanced base timber pier.

The superstructure shown in *Figure 14-57* consists of a single layer of 4 by 12 planks laid on 19 inside stringers measuring 6 inches by 14 inches by 14 feet. The inside stringers are fastened to the pile caps with driftbolts. The outside stringers are fastened to the pile caps with through bolts. The deck planks are fastened to the stringers with 3/8 by 8 inch spikes. After the deck is laid, 12 foot lengths of 8 by 10s are laid over the outside stringers to form the curbing. The lengths of curbing are distributed as shown in the general plan. The curbing is bolted to the outside stringers to form the curbing. The lengths of curbing are distributed as shown in the general plan. The curbing is bolted to the outside stringers with bolts. The pier is equipped with a fender system for protection against shock, caused by contact with vessels coming or lying alongside. Fender piles, spaced as shown in the part plan, are driven along both sides of the pier and bolted to the outside stringers with bolts. The heads of these bolts are countersunk below the surfaces of the piles. An 8 by 10 fender wale is bolted to the backs of the fender piles with bolts. Lengths of 8 by 10 fender pile chocks are cut to fit between the piles and bolted to the outside stringers and the fender wales. The spacing for these bolts is shown in the part plan.

As indicated in the general plan, the fender system also includes two 14 pile ***dolphins***, located 15 feet beyond the end of the pier. A dolphin is an isolated cluster of piles, constructed as shown in *Figure 14-59*. A similar cluster attached to a pier is called a pile cluster.

5.6.0 Pile Driving Techniques

When driving piles of any type, always watch both the pile and equipment. Care must be taken to avoid damaging the pile or the driving hammer. Watch the piles carefully for any indications of splitting or breaking below ground. The next section covers some of the more common problems you might encounter.

Figure 14-59 – Dolphins.

5.6.1 Springing and Bouncing

Springing means that the pile vibrates too much laterally. Springing may occur when a pile is crooked, when the butt has not been squared off properly, or when the pile is not in line with the fall of the hammer. Always make sure the fall of the hammer is in line with the pile axis. Otherwise, the head of the pile and the hammer may be severely damaged and much of the energy of the hammer blow lost.

Excessive bouncing may be caused by a hammer that is too light. However, it usually occurs when the butt of the pile becomes crushed or broomed, as when the pile meets an obstruction or penetrates to a solid footing. When a double acting hammer is being used, bouncing may result from too much steam or air pressure. With a closed end diesel hammer, if the hammer lifts on the upstroke of the ram piston, the throttle setting is probably too high. Back off on the throttle control just enough to avoid this lifting. If the butt of the timber pile has been crushed or broomed more than an inch or so, it should be cut back to sound wood before you drive it any more.

5.6.2 Obstruction and Refusal

When a pile reaches a level where 6 blows of a drop hammer or 20 blows of a steam or air hammer do not drive it more than an average of 1/8 inch per blow, the pile has either hit an obstruction or has been driven to refusal. In either case, further driving is likely to break or split the pile. Examples of typical damage are shown in *Figure 14-60*.

If the lack of penetration seems to be caused by an obstruction, 10 or 15 blows of less than maximum force may be tried. This may cause the pile to displace or penetrate the obstruction. For obstructions that cannot be disposed of in this manner, it is often necessary to pull (extract) the pile and clear the obstruction.

When a pile has been driven to a depth where deeper penetration is prevented by friction, the pile has been driven to refusal. It is not always necessary to drive a friction pile to refusal. Such a pile needs to be driven only to the depth where friction develops the required load bearing capacity.

Figure 14-60 – Types of pile damage caused by overdriving timber piles.

5.6.3 Straightening

Piles should be straightened when any misalignment is noticed during driving. The accuracy of alignment desirable for a finished job depends on various factors. Generally, though, a pile more than a few inches out of its plumb line should be trued. The greater the penetration along the wrong line, the harder to get the pile back into plumb. There are several methods of realigning a pile.

One method of realignment is to use pull from a block and tackle, with the impact of the hammer jarring the pile back into line, as shown in *Figure 14-61*. The straightening of steel bearing piles must include twisting the individual piles to bring the webs of the piles parallel to the center line of the bent.

Figure 14-61 – Realigning pile by pull on a line to a winch.

Another method of realignment is to use a jet as shown in *Figure 14-61*, either alone or with one of the other two methods shown above and below. ***Jetting*** a pile can be done with either water or air.

Figure 14-62 – Realigning pile by jetting.

When all piles in a bent have been driven, they can be pulled into proper spacing and alignment with a block and tackle and an aligning frame. *Figure 14-63* shows spacing and alignment for timber pile bents.

Figure 14-63 – Aligning framing used for timber pile bents.

Figure 14-64 shows spacing and aligning for steel pile bents.

Figure 14-64 – Aligning and capping steel pile bents.

5.6.4 Pulling

A pile that has hit an obstruction, has been driven in the wrong place, has been split or broken in driving, or is to be salvaged (steel sheet piles are frequently salvaged for reuse) is usually pulled (extracted). Pulling should be done as soon as possible after driving. The longer the pile stays in the soil, the more compact the soil becomes, and the greater the resistance to pulling will be.

Test your Knowledge (Select the Correct Response)

4. What are the two main components of a timber trestle?

   A. Bents and abutments
   B. Substructure and superstructure
   C. Bracing and caps
   D. Decking and footings

5. Which of the following piles is required when piles of 80 feet or longer are needed?

   A. Timber
   B. Steel
   C. Concrete
   D. Combination

6. What is the minimum amount in inches the butt of a wood pile can be crushed or broomed before you should cut it back to sound wood?

   A. 1
   B. 2
   C. 3
   D. 4

6.0.0 WATERFRONT STRUCTURES

Waterfront structures are broadly divided into three main categories: offshore structures creating a sheltered harbor, alongshore structures establishing and maintaining a stable shoreline, and wharfage structures allowing vessels to lie alongside for loading or unloading.

6.1.0 Offshore

Offshore structures include ***breakwaters*** and jetties. They are alike in construction and differ mainly in function.

6.1.1 Breakwaters and Jetties

In an offshore barrier, the breakwater interrupts the action of the waves of open water to create an area of calm water between it and the shore. A ***jetty*** works to direct and confine a current or tidal flow into a selected channel.

The simplest type of breakwater or jetty is the rubble mound, also called rock mound. An example is shown in *Figure 14-65*. The width of its cap may vary from 15 to 70 feet. The width of its base depends on the width of the cap, the height of the structure, and the slope of the inner and outer faces.

Figure 14-65 – Rubble mound breakwater/jetty.

Rubble mound breakwaters or jetties are constructed by dumping rock from either barges or railcars (running on temporary pile bent structures) and by placing upper rock and cap rock with floating cranes.

For a deepwater site or one with an extreme range between high and low tides, a rubble mound breakwater or jetty may by topped with a cap structure to form the composite type shown in *Figure 14-66*.

Figure 14-66 – Composite breakwater/jetty.

In this case, the cap structure consists of a series of precast concrete boxes called ***caissons***, each of which is floated over its final location and sunk into place by filling with rock. A single piece concrete cap is then cast in place on the top of each caisson. Breakwaters and jetties are sometimes built entirely of caissons. A typical caisson breakwater/jetty is shown in *Figure 14-67*. A jetty may also be constructed to serve as a wharfage structure. If so, it is still called a jetty.

Figure 14-67 – Caisson breakwater/jetty.

6.2.0 Alongshore

Alongshore structures include seawalls, ***groins***, and bulkheads. Their main purpose is to stabilize a shoreline.

6.2.1 Seawalls

Seawalls vary widely in details of design and materials, depending on the severity of the exposure, the value of the property to be protected, and other considerations. Basically they consist of some form of barrier designed to break up or reflect the waves and a deep, tight cutoff wall to preclude washing out of the sand or soil behind and under the barrier. The cutoff wall is generally constructed of timber, steel, or concrete sheet piling. *Figure 14-68* shows a rubble mound seawall. The stone protecting the shoreline against erosion is called riprap. Therefore, a rubble stone seawall is also called a riprap seawall.

Figure 14-68 – Riprap seawall.

Various types of cast in place concrete seawalls are the vertical face, inclined face, curved face, stepped face, and combination curved face and stepped face. The sea or harbor bottom along the toe (bottom of the outside face) of a seawall is usually protected against erosion (caused by the backpull of receding waves) by riprap piles against the toe.

6.2.2 Groins

Groins, built like breakwaters or jetties, extend outward from the shore. Again, they differ mainly in function. A groin is used where a shoreline is in danger of erosion caused by a current or wave action running obliquely against or parallel to the shoreline. It is placed to arrest the current or wave action or to deflect it away from the shoreline.

Groins generally consist of tight sheet piling of creosoted timber, steel, or concrete, braced with wales and with round piles of considerable length. Groins are usually built with their tops a few feet above the sloping beach surface that is to be maintained or restored.

6.2.3 Bulkheads

A bulkhead has the same general purpose as a seawall: to establish and maintain a stable shoreline. But, where a seawall is self contained, relatively thick, and supported by its own weight, a bulkhead is a relatively thin wall supported by a series of tie wires or tie rods running back to a buried anchorage, called a deadman. A timber bulkhead for a bridge abutment is shown in *Figure 14-69*. It is made of wood sheathing which is square edged, single layer planks, laid horizontally.

Figure 14-69 – Timber bulkhead for bridge abutment.

Most bulkheads, however, are made of steel sheet piles, an example of which is shown in *Figure 14-70*. The outer ends of the tie rods are anchored to a steel wale running horizontally along the outer face of the bulkhead.

This wale is usually made up of pairs of steel channels bolted together, back to back. A channel is a structural steel member with a U shaped section. Sometimes the wale is placed on the inner face of the bulkhead, and the piles are bolted to it.

Figure 14-70 – Constructed sheet pile bulkhead.

The anchorage shown in *Figure 14-70* is covered by backfill. In stable soil above the groundwater level, the anchorage may consist simply of a buried timber, a concrete deadman, or a row of driven and buried sheet piles.

A more substantial anchorage for each tie rod is used below the groundwater level. Two common types of anchorages are shown in *Figure 14-71*. In *view A*, the anchorage for each tie rod consists of a timber cap supported by a batter pile. In *view B*, the anchorage consists of a reinforced concrete cap supported by a pair of batter piles. As indicated in the figure, tie rods are supported by piles located midway between the anchorage and the bulkhead.

Figure 14-71 – Two types of tie rod anchorages for bulkheads.

Bulkheads are constructed from working drawings like those shown in *Figure 14-72*. The detail plan for the bulkhead shows that the anchorage consists of a row of sheet piles to which the inner ends of the tie rods are anchored by means of a channel wale.

Figure 14-72 – Working drawings for a steel sheet pile bulkhead.

In the figure, the construction sequence begins when the shore and bottom are first excavated to the level of the long, sloping dotted line. The sheet piles for the bulkhead and the anchorage are then driven. The supporting piles for the tie rods are driven next, after which the tie rods between the bulk and the anchorage are set in place and the wales are bolted on. The tie rods are prestressed lightly and uniformly, and the backfilling then begins.

The first backfilling operation consists of placing fill over the anchorage, out to the dotted line shown in the plan. The turnbuckles on the tie rods are then set to bring the bulkhead plumb, and the rest of the backfill is worked out to the bulkhead. After the backfilling is completed, the bottom outside the bulkhead is dredged to the desired depth.

6.3.0 Wharfage

As mentioned earlier, wharfage structures allow vessels to lie alongside for loading or unloading. ***Moles*** and jetties are the most typical forms.

6.3.1 Moles and Jetties

A mole is simply a breakwater that serves as a wharfage structure. The only difference is that its inner or harbor face must be vertical and its top must function as a deck. In a similar way, jetties also serve as wharfage structures.

6.4.0 Below the Water Table

When construction is carried on below the groundwater level, or when underwater structures like seawalls, bridge piers, and the like are erected, it is usually necessary to temporarily keep the water out of the construction area. This is typically done with well points, cofferdams, or caissons.

6.4.1 Well Points

Well points are long pipes thrust into the ground down to the level at which the water must be excluded. They are connected to each other by a pipeline system that heads up at a water pump. Well point engineers determine the groundwater level and the direction of flow of the groundwater, and the well point system is placed so as to cut off the flow into the construction area. Well pointing requires highly specialized personnel and expensive equipment.

6.4.2 Cofferdams

The cofferdam is a temporary structure, usually built in place, and tight enough so that the water can be pumped out of the structure and kept out while construction on the foundations is in progress. Common cofferdam types are earthen, steel sheeting, wooden sheathing, and crib. *Figure 14-73* shows a cofferdam under construction.

Figure 14-73 – Cofferdam under construction.

An earthen cofferdam is built by dumping earth fill into the water, shaped to surround the construction area without encroaching upon it. Because swiftly moving currents can carry the material away, earthen cofferdams are limited to sluggish waterways where the velocities do not exceed 5 feet per second. Use is also limited to shallow waters; the quantities of material required in deep waters would be excessive due to the flat slopes to which the earth settles when deposited in the water. For this reason, the earthen type is commonly combined with another type, such as sheathing or cribbing, to reduce the quantities of earthwork.

Steel is commonly used for cofferdam construction. Sheet piling is manufactured in many interlocking designs and in many weights and shapes for varying load conditions. The piling is driven as sheeting in a row to form a relatively tight structure surrounding the construction area. This pile wall is supported in several ways. It may be supported by a framework of stringers and struts. A cofferdam wall can consist of a double row of piles tied together with heavy steel ties and filled with earth. This can be square, rectangular, circular, or oval-shaped for stability around the construction area.

Wooden sheathing, instead of steel, is similarly used in cofferdam constructions. Interlocking timber sheathing is driven as a single wall and supported by stringers and cross struts between walls, or it is driven in double rows as a wall. The sheathing in each row is connected and tied with braces.

Wooden or concrete cribbing may be used in cofferdam construction. The cribbing offers stability to the cofferdam wall. It also provides watertightness when filled with earth and rock.

Movable cofferdams of timber, steel, or concrete have been built, but their uses and designs are very similar to those discussed under boxes and open caissons below.

6.4.3 Caissons

Caissons are boxes or chambers used for construction work underwater. There are three forms of caissons used in constructing foundations underwater: box, open, and pneumatic caisson. If the structure is open at the top and closed at the bottom, it is called a box caisson. If it is open both at the top and the bottom, it is an open caisson. If it is open at the bottom and closed at the top, and compressed air is used, it is a pneumatic caisson.

It is sometimes difficult to distinguish between a cofferdam and caisson. In general, if the structure is self contained and does not depend upon the surrounding material for support, it is a caisson. However, if the structure requires such support as sheathing or sheet piling, it is a cofferdam. Retaining walls and piers may be built of boxes of wood, steel, or reinforced concrete, floated into place and then filled with various materials. These are known as floating caissons. Open caissons may be constructed of wood or steel sheet piling.

The preceding information provides only a basic understanding of heavy construction. As with other phases of construction, specialized tools and equipment are required. The Table of Allowance (TOA) at your command will have these items. Follow all safety rules and manufacturer's recommendations for operations and maintenance.

Test your Knowledge (Select the Correct Response)

9. Breakwaters and jetties fall under which of the following types of structures?

   A. Offshore
   B. Alongside
   C. Wharfage
   D. Deepwater

10. Which of the following structures is a relatively thin wall supported by a series of tie rods running back to a deadman?

    A. Groin
    B. Bulkhead
    C. Seawall
    D. Caisson

Summary

You have learned about the primary responsibility of the Seabees, the construction of advanced bases during the early phases of crises and other emergency situations. You have learned about constructing pre-engineered buildings, as well as wood frame buildings and K-span buildings. You have learned about the principles of embarkation in order to get troops and supplies where they are needed, and you have learned about heavy construction, including trestles, timber piers, and waterfront structures.

Review Questions (Select the Correct Response)

1. What is the advantage of a pre-engineered building?

   A. Allows floor to ceiling storage of material
   B. Allows wall to wall placement of machinery
   C. Permits unhindered production flow
   D. All of the above

2. **(True or False)** A PEB is shipped with all materials and instructions necessary for erection.

   A. True
   B. False

3. The 40 by 100 foot, rigid frame, straight walled building can easily be disassembled, moved, and erected again without waste or damage because of what feature?

   A. Prestressed concrete pads
   B. Large metal C clamps
   C. Bolted connections
   D. Fiberboard panels

4. Before placing concrete for the foundation piers of a rigid frame building, which of the following tasks should you perform?

   A. Bolt the frames together only.
   B. Place templates and anchor bolts only.
   C. Uncrate the paneling only.
   D. All of the above

5. While the foundation is being prepared for a 40 by 100 foot rigid frame building, which of the following work assignments can you perform?

   A. Glaze the windows only.
   B. Bolt the rigid frame assemblies only.
   C. Assemble the door leaves only.
   D. Any of the above

6. Until ready to be used, which of the following materials should remain crated?

   A. Girts
   B. Panels
   C. Eave struts
   D. Brace rods

7. What should you do to ensure building materials are accessible during assembly of a PEB?

   A. Keep all building materials in one central location.
   B. Keep the building materials on trucks.
   C. Place the materials around the building site where they will be used.
   D. Maintain at least 50 feet of clearance between the stockpiles of building materials.

8. How is each of the members, parts, and accessories of the building marked so it is not necessary to guess which one goes where?

   A. Painted mark across the bottom of the part
   B. Notched at the base of each part
   C. Embossed mark on each part
   D. Labeled by stencil on each part

9. **(True or False)** Once all the parts have been laid out and checked, erection of a 40 by 100 foot PEB should begin with the center frame member.

   A. True
   B. False

10. Where must brace rods be installed to hold the frames in an upright position?

   A. In the first bay erected
   B. In the second bay erected
   C. In the center bay of the building
   D. In the last bay erected

11. Where must sheeting installation be started on the sidewall and roof?

   A. On the first bay erected
   B. On the last bay erected
   C. At the end of the building toward which the prevailing winds blow
   D. Sheeting installation can be started anywhere

12. **(True or False)** Pre-engineered buildings can be set up side by side to increase the working area under one roof.

   A. True
   B. False

13. When can the interior assemblies be installed for a PEB?

   A. After installing the interior lining
   B. After exterior members have been erected
   C. After installing exterior end wall panels
   D. After installing the roof panels

14. After placing the base, corner, and gable furrings of a PEB, what should you install next?

    A. Hardboard liners
    B. Eave moldings
    C. Batten strips
    D. Vertical furring

15. When installing hardboard in a PEB, you should ensure the gap between panels is what distance?

    A. 1/8 inch
    B. 1/4 inch
    C. 5/16 inch
    D. 3/8 inch

16. For the flooring of a wood frame tent, what material should you use?

    A. 3/8 inch fiberboard
    B. 5/8 inch pressboard
    C. 1/2 inch plywood
    D. 1/4 inch tempered Masonite™

17. Wall and roof framing members of a 16 by 32 foot wood frame tent should have what spacing in feet OC?

    A. 1 foot OC
    B. 2 foot OC
    C. 3 foot OC
    D. 4 foot OC

18. When two 4-seat latrine boxes are set up side by side, what size pit is required?

    A. 3 by 6 feet
    B. 2 by 6 feet
    C. 3 by 7 feet
    D. 4 by 8 feet

19. How many trough type urinals should be furnished with an 8-seat latrine?

    A. 1
    B. 2
    C. 3
    D. 4

20. What space requirements do you consider for K-span operations?

    A. Maneuvering room for the towing of the trailer
    B. Allocation of space required for crane operations
    C. Room for run-out stands to hold straight panels
    D. All of the above

21. **(True or False)** Concrete forms are included in the kit for a K-span building.

A. True
B. False

22. In a K-span building, installation of which of the following components presents a problem because it interrupts the integrity of the wall system?

A. Windows
B. Aluminum doors
C. Wood doors
D. Overhead doors

23. How many copies of the packing list must be made for each box?

A. 1
B. 2
C. 3
D. 4

24. Where must copies of the packing list be placed?

A. Inside the box
B. In a protective packet outside the box
C. On file in the embarkation mount-out control center
D. All of the above

25. Which of the following conditions normally indicates the need for steel piles?

A. The soil to be driven through is compressible.
B. Ninety-five foot piles are required.
C. Light loads must be supported.
D. A retaining wall is needed.

26. Which of the following features is used to designate the size of a pier?

A. Length
B. Height
C. Width
D. Diameter of the piling

27. A pier is protected against shock damage from a ship tied alongside by a system of ________.

A. batter piles
B. bearing piles
C. stringers
D. fender piles

28. Which of the following conditions normally require(s) trestle bents?

    A. Soft or marshy ground
    B. Swift currents
    C. Deep water
    D. Solid dry ground or shallow water

29. Which of the following is considered a vertical structural member?

    A. Post
    B. Cap
    C. Sill
    D. Girder

30. How much overlap in feet is figured in when calculating center to center horizontal distance between bents?

    A. 1
    B. 2
    C. 3
    D. 4

31. What is the usual length in feet of girder stock?

    A. 10
    B. 12
    C. 13
    D. 14

32. What is the minimum width in feet of a single lane trestle?

    A. 12
    B. 14
    C. 16
    D. 18

33. What size stock is used for transverse diagonal bracing?

    A. 2 x 2
    B. 2 x 4
    C. 2 x 6
    D. 2 x 8

34. In the placement of timber girders, the OC spacing is what distance?

    A. 3 feet 3 inches
    B. 3 feet 3 1/4 inches
    C. 3 feet 3 1/2 inches
    D. 3 feet 3 5/8 inches

35. How many layers of planking make up a timber deck?

A.1
B.2
C.3
D.4

36. **(True or False)** The timber decking consists of 3 inch planks.

A. True
B. False

37. At an abutment, which of the following items prevents the approach of road from washing out or eroding?

A. End cap
B. End wall
C. End dam
D. End curb

38. Which of the following is a load bearing member made of timber, steel, concrete, or a combination of these materials?

A. Coffer dam
B. Pile
C. Trestle
D. Pile bent

39. What is the tip diameter in inches of a pile shorter than 40 feet?

A. 8 to 11
B. 9 to 12
C. 10 to 13
D. 11 to 14

40. **(True or False)** The butt diameter of piles longer than 40 feet can be greater than the distance between the pile leads.

A. True
B. False

41. During a pile driving operation, which of the following actions is necessary to protect the pile from damage?

A. Cut the pile perpendicular to its axis.
B. Use steel shoes to protect the pile.
C. Sharpen the tip of the pile.
D. Cut the butt of the pile square and chamfer it.

42. Which of the following piles should be used to form a continuous wall to resist horizontal pressure resulting from earth or water loads?

A. Sheet pile
B. Precast pile
C. Cast in place pile
D. Open end pipe pile

43. Which of the following is constructed below water retaining structures to retard the flow of water through the foundation?

A. Cofferdams
B. Bulkheads
C. Cutoff walls
D. Trench sheathing

44. The working drawings for timber piers contain which of the following information?

A. Bill of materials only
B. Dimensions and location of all structural members only
C. Required driftpins, bolts, and hardware, and bill of materials only
D. All of the above

45. When the use of batter piles is required, what is the specified angle?

A. 5 in 12
B. 2 in 12
C. 3 in 12
D. 4 in 12

46. On a bridge, the inside stringers on the superstructure are fastened by what method?

A. Through bolts
B. Driftbolts
C. Spikes
D. Nails

47. Which of the following conditions exists when a pile vibrates too much laterally?

A. Leaning
B. Cracking
C. Bouncing
D. Springing

48. **(True or False)** Springing means that the pile vibrates too much vertically.

A. True
B. False

49. Waterfront structures are broadly divided into how many categories?

A. 1
B. 2
C. 3
D. 4

50. Which of the following structures works to direct and confine a current or tidal flow into a selected channel?

A. Breakwater
B. Jetty
C. Seawall
D. Groin

51. Of the following structures, which has the stabilization of a shoreline as its main purpose?

A. Rubble mound breakwater
B. Caisson
C. Seawall
D. Groin

52. How many various types of cast in place concrete seawalls are there?

A. 2
B. 3
C. 4
D. 5

53. Which of the following structures is placed to arrest a current and deflect it away from a shoreline?

A. Breakwater
B. Jetty
C. Groin
D. Seawall

54. How many types of caissons are used in constructing foundations underwater?

A. 1
B. 2
C. 3
D. 4

Trade Terms Introduced in this Chapter

Abutment	Masonry, timber, or timber and earth structures supporting the end of a bridge or an arch.
Bearing piles	A pile carrying a superimposed vertical load.
Breakwaters	A barrier constructed to shield the interior waters of a harbor from wave forces.
Bulkheads	A retaining wall, generally vertical.
Caissons	A watertight box structure surrounding work below water.
Cofferdams	A watertight enclosure.
Concrete pile	Piles made of concrete, either cast in place or precast.
Dolphins	A group of piles in water driven close (clustered) together and tied so that the group is capable of withstanding large lateral forces from vessels and other floating objects.
End bearing pile	A bearing pile deriving practically all its support from firm underlying stratum.
Gin pole	A gin pole is a rigid pole with a pulley on the top used for lifting.
Groins	A bulkhead, generally made of piling, built out from the shoreline perpendicular to the direction of the current or drift to cut off and prevent the carrying of beach materials along the shore.
Jetting	A method of forcing water around and under a pile to displace and lubricate the surrounding soil.
Jetty	A term designating various types of small wharf structures, such as a small boat jetty or a refueling jetty. In harbor protection works, a rock mound or other structure extending into a body of water to direct and confine the stream or tidal flow to a selected channel.
Moles	A massive stone or masonry breakwater constructed of concrete or steel sheet pile and constructed on the inner side of a jetty for unloading and loading ships.
PEB	Pre-engineered building.
Piles	Load bearing member made of timber, steel, concrete, or a combination of these materials; usually forced into the ground.

Pile bents	Two or more piles driven in a row transverse to the long dimension of the structure and fastened together by capping and (sometimes) bracing.
Pile cap	A structural member placed on top of a pile to distribute loads from the structure to the pile.
Specifications	Written instructions containing information about the materials, style, workmanship, and finish for the job.

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.

Automatic Building Machine Type K-Span Operating Manual, MIC-120 ABM, M.I.C. Industries, Inc.

Bailey Bridge, Field Manual 5-177, Headquarters, Department of the Army, Washington, D.C., 1986.

Naval Construction Force/Seabee Chief Petty Officer, NAVEDTRA 10600, Naval Education and Training Command, Pensacola, Fla., June 1989.

Naval Construction Force/Seabee Petty Officer First Class, NAVEDTRA 10601, Naval Education and Training Command, Pensacola, Fla., December 1989.

Pile Construction, Field Manual 5-134, Headquarters, Department of the Army, Washington, D.C., 1985.

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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. $\angle ZOY$ and $\angle ZOX$ 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. $\angle DAC$ and $\angle CAB$ 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. $\angle MOP$ and $\angle RON$ 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*.

Figure A-6 — Trapezoid.

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-7 — Parallelogram.

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-8 — Rectangle.

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

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:

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

Geometric Solids

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

Consider the solids 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

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

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	milliters	5
tablespoons	milliters	1 5
fluid ounces	milliters	3 0
cups	liters	0.24
pints	liters	0.47
quarts	liters	0.95
gallons	liters	3.8
milliters	teaspoons	0.2
milliters	tablespoons	0.067
milliters	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	16^{th}	32^{nd}	64^{th}	Decimal	Fraction	16^{th}	32^{nd}	64^{th}	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 $= \frac{kW}{kVA} = \frac{R}{Z}$

Single-Phase Circuits

kVA = $\frac{EI}{1{,}000} = \frac{kW}{PF}$ $kW = kVA \times PF$

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

P = E x I x PF

Two-Phase Circuits

I = $\frac{P}{2 \times E \times PF}$ $E = \frac{P}{2 \times I \times PF}$ $PF = \frac{P}{E \times I}$

kVA = $\frac{2 \times E \times I}{1{,}000}$ $\frac{kW}{PF}$ $kW = kVA \times PF$

P = 2 x E x I x PF

Three-Phase Circuits, Balanced Wye

I phase = I line

$E_L = \sqrt{3}\, E_P = 1.73\, E_P$

$E_P = \frac{E_L}{\sqrt{3}} = 0.577\, E_L$

Three-Phase Circuits, Balanced Wye

E phase = E line

$I_L = \sqrt{3}\, I_P = 1.73\, I_P$

$I_P = \frac{I_L}{\sqrt{3}} = 0.577\, I_L$

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

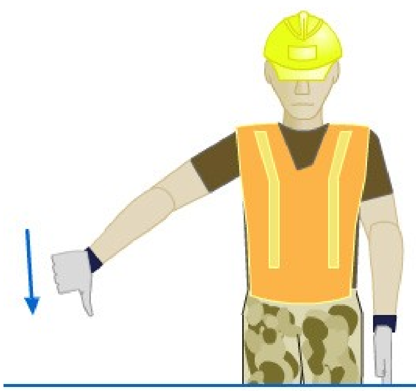
Raise Hoist Slowly
Hurry up and move out, double time, etc.

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

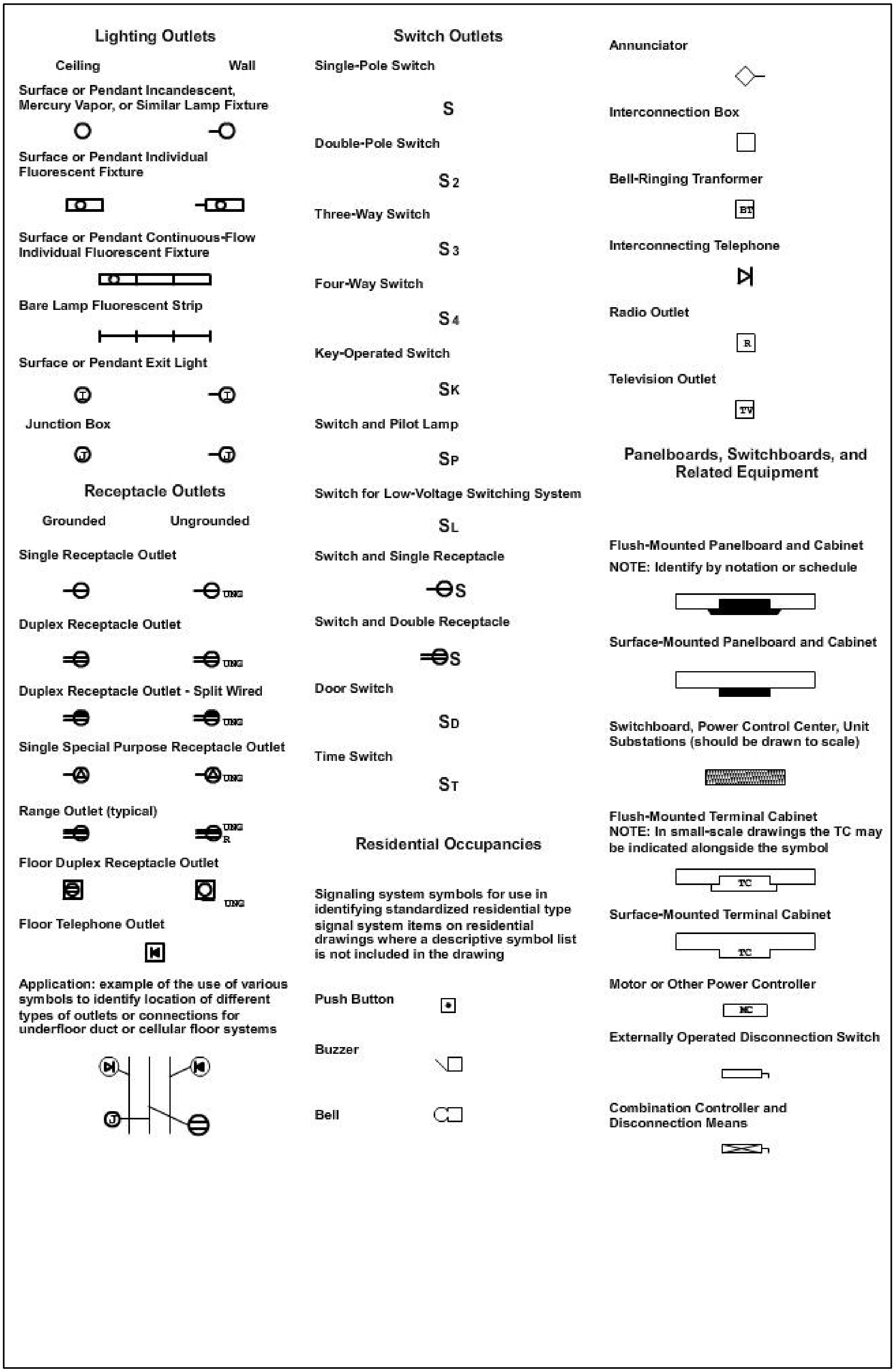
Crowd or Extend

Turn Right (Operator's Right)

Turn Left (Operator's Left)

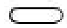
APPENDIX III

COMMON CONSTRUCTION SYMBOLOGY



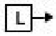
Remote Control Stations for Motors or Other Equipment

Push-button Stations in General

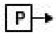


Float Switch - Mechanical

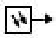
Limit Switch - Mechanical



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

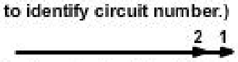
Note: Use heavy weight line to identify service and feed runs

Wiring Concealed in Floor

Wiring Exposed

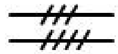
Branch Circuit Home Run to Panelboard

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:



3 wires;
4 wires; etc

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

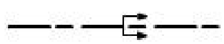
Transformer Pad

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.



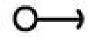
Streetlight Standard Fed from Underground Circuit

Electrical Distribution or Lighting Systems, Aerial

Pole

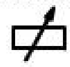
Pole, with Streetlight

Pole, with Down Guy and Anchor



Transformer

Transformer, Constant-Current



Switch, Manual

Circuit Recloser, Automatic

Circuit, Primary

Circuit, Secondary

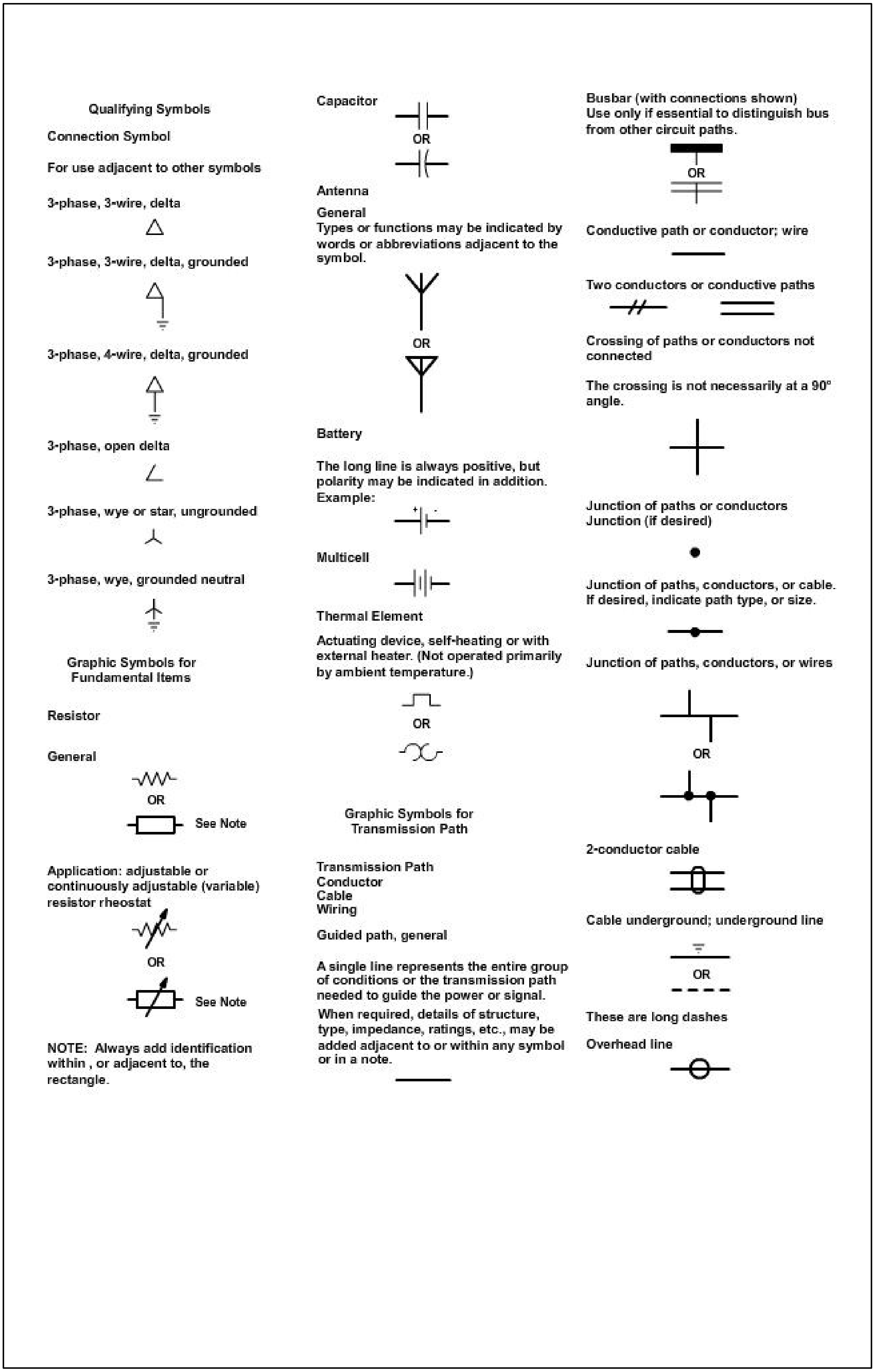
Circuit, Series Street Lighting

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
OR
See Note
Application: adjustable or continuously adjustable (variable) resistor rheostat
OR
See Note
NOTE: Always add identification within , or adjacent to, the rectangle.
Capacitor
OR
Antenna
General
Types or functions may be indicated by words or abbreviations adjacent to the symbol.
OR
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.)
OR
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.
OR
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
OR
2-conductor cable
Cable underground; underground line
OR
These are long dashes
Overhead line

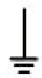
Circuit Return

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).



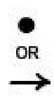
Chassis or frame connection, equivalent chassis connection (of printed-wiring boards)

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.

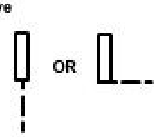
Graphic Symbols for Contacts, Switches, Contacts, and Relays

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.

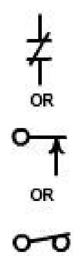
Locking

Nonlocking

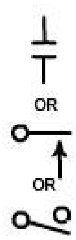
Basic Contact Assemblies

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.

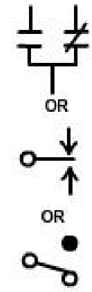
Closed contact (break)



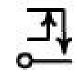
Open contact (make)



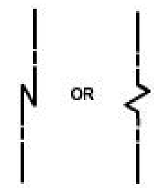
Transfer



Make-before-break

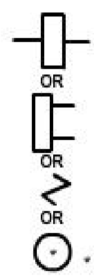


Magnetic Blowout Coil



Operating Coil

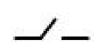
Relay Coil



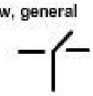
Switch

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

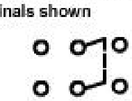
Single-throw, general



Double-throw, general



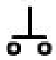
2-pole double-throw switch with terminals shown



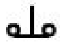
NOTE: The asterisk is not part of the symbol. Always replace the asterisk by a device designation.

Push button, Momentary or Spring-Return

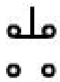
Circuit closing (make)



Circuit opening (break)



Two-circuit

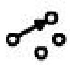


Selector or Multiposition Switch

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.

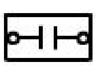


OR

Limit Switch
Sensitive Switch

NOTE: Identity by LS or other suitable note.

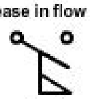
Track-type, circuit-closing contact



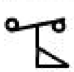
Track-type, circuit-opening contact

Flow-Actuated Switch

Closes on increase in flow

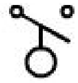


Opens on increase in flow

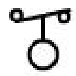


Liquid-Level-Actuated Switch

Closes on rising level

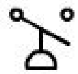


Opens on rising level

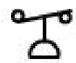


Pressure-or Vacuum-Actuated Switch

Closes on rising pressure



Opens on rising pressure



Temperature-Actuated Switch

Closes on rising temperature

Opens on rising temperature

Thermostat

Closes on rising temperature

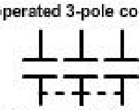
* See Note

Contactor

See also CIRCUIT BREAKER

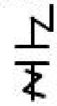
Fundamental symbols for contacts, coils, mechanical connections, etc, are the basis of contactor symbols and should be used to represent contactors on complete diagrams. Complete diagrams of contactors consist of combinations of fundamental symbols for control coils, mechanical connections, etc, in such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

Manually operated 3-pole contactor

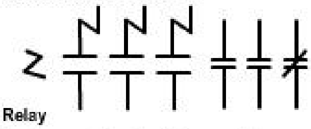


NOTE: The t° symbol shall be shown or be replaced by data giving the nominal or specific operating temperature of the device.

Electrically operated 1-pole contactor with series blowout coil



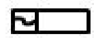
Electrically operated 3-pole contactor with series blowout coils; 2 open and 1 closed auxiliary contacts (shown smaller than the main contacts)



Relay

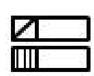
Fundamental symbols for contacts, mechanical connections, coils, etc, are the basis of relays on complete diagrams.

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

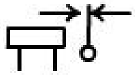


- SO Slow-operate
- SR Slow-release
- SW Sandwich-wound to improve balance to longitudinal currents

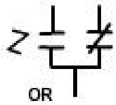
The proper poling for a polarized relay shall be shown by the use of + and - designations applied to the winding leads. The interpretation of this shall be that a voltage applied with the polarity as indicated shall cause the armature to move toward the contact shown nearer the coil on the diagram. If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

Basic

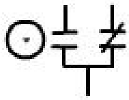
Relay with transfer contacts



OR



OR



Graphic Symbols for Terminals and Connectors

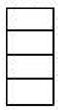
Terminals

Circuit terminal

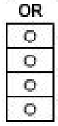
Terminal board or terminal strip, with 4 terminals shown; group of 4 terminals

Number and arrangement as convenient.

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

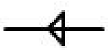


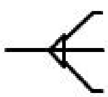
OR



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 asterisk is not part of the symbol. If desired, indicate the type of contacts: male (⟶) or female (—<).

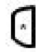
OR

OR

Plug (usually movable) OR

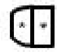
OR

OR

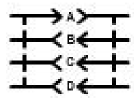


Separable connectors (engaged)

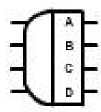
OR



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

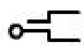


OR



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

 OR 

Magnetic-core inductor
Telephone loading coil

If necessary to show a magnetic core.

Tapped

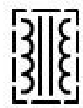
Adjustable inductor

Transformer

General

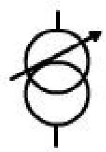
 OR  OR 

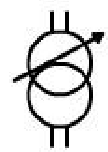
Shielded transformer with magnetic core shown



One winding with adjustable inductance

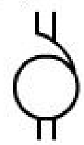
OR

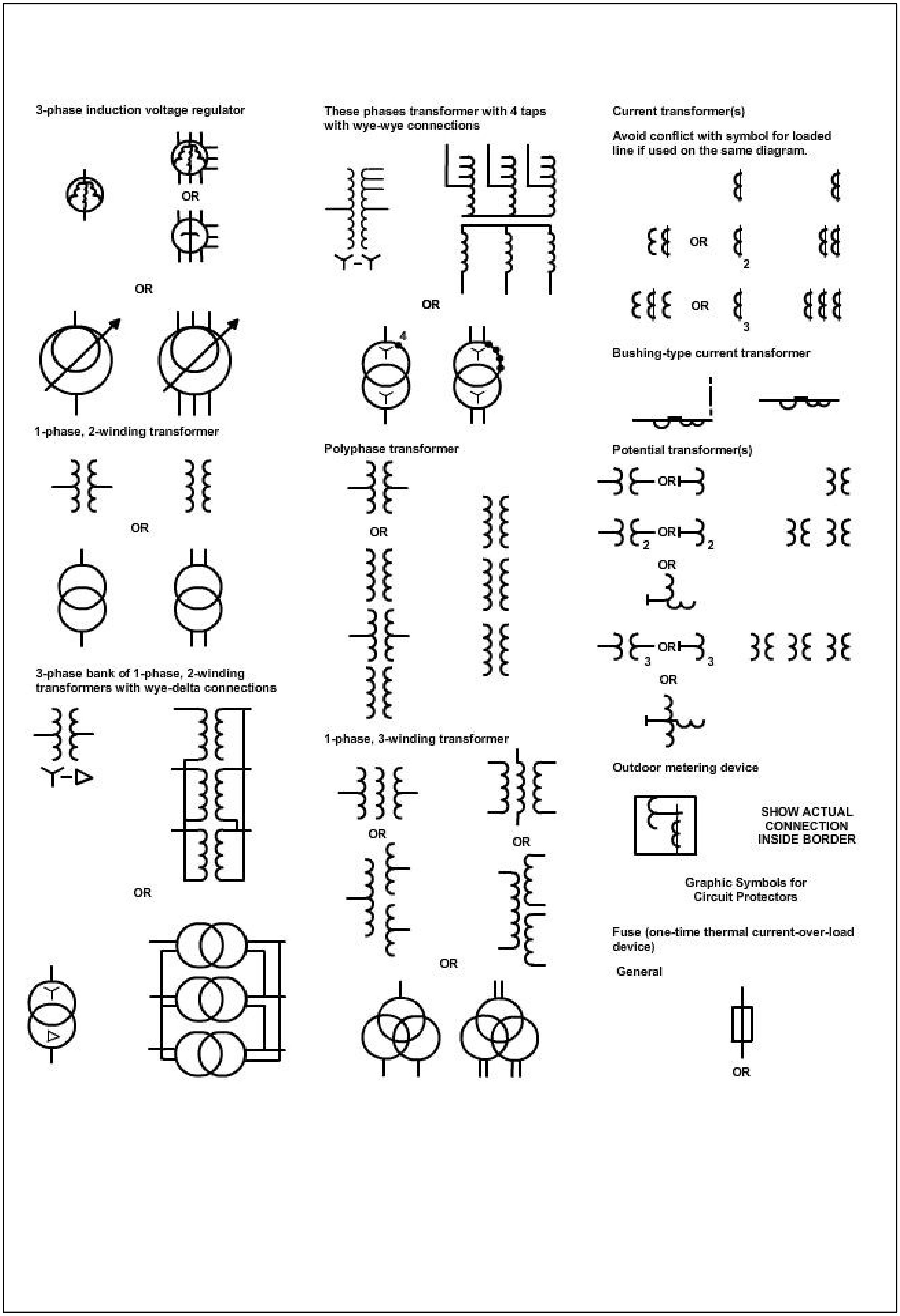


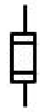


Adjustable mutual inductor; constant-current transformer

Autotransformer, 1-phase

 OR 

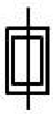

3-phase induction voltage regulator
OR
OR
1-phase, 2-winding transformer
OR
3-phase bank of 1-phase, 2-winding transformers with wye-delta connections
OR
These phases transformer with 4 taps with wye-wye connections
OR
4
Polyphase transformer
OR
1-phase, 3-winding transformer
OR
OR
OR
Current transformer(s)
Avoid conflict with symbol for loaded line if used on the same diagram.
OR
2
OR
3
Bushing-type current transformer
Potential transformer(s)
OR
OR
2
2
OR
OR
3
3
OR
Outdoor metering device
SHOW ACTUAL CONNECTION INSIDE BORDER
Graphic Symbols for Circuit Protectors
Fuse (one-time thermal current-over-load device)
General
OR



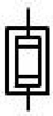
OR

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

High-voltage primary fuse cutout, oil



OR



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

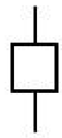
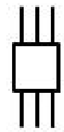
Circuit Breaker

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

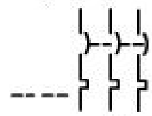
Network protector

Circuit breaker, other than covered by the above symbol

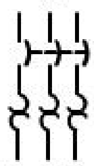
The symbol in the right column is for a 3-pole breaker.

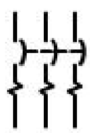
3-pole circuit breaker with thermal-overload device in all 3 poles

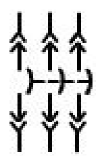
OR OR

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.

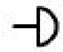
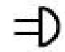
See RELAY COIL; OPERATING COIL and RELAY

Graphic Symbols for
Acoustic Devices

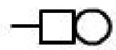
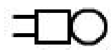
Audible-Signaling Device

Bell, electrical; telephone ringer

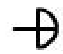
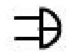
NOTE: If specific identification is required, the abbreviation AC or DC may be added within or adjacent to the symbol.

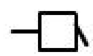
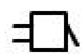
OR OR

Single-stroke

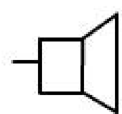
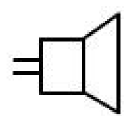
 

Buzzer

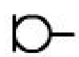
Loudspeaker
Horn, Electrical
Sirem

General

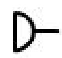
 

Microphone
Telephone Transmitter

General

OR OR

Handset
Operator's Set

General

Telephone Receiver
Earphone

General

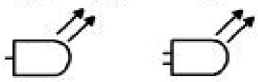
Headset, double

Headset, single

Graphic Symbols for Lamps and Visual-Signaling Devices

Lamp

Lamp, general; light source, general



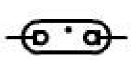
NOTE: This symbol may be used to represent one or more lamps with or without operating auxiliaries.

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

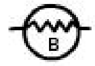


4-terminal

Incandescent lamp (incandescent-filament illuminating lamp

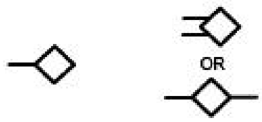
Ballest lamp; ballast tube

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

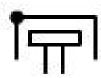


Visual-Signaling Device

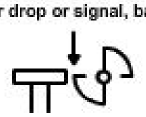
Annunciator (general)



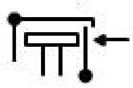
Annunciator drop or signal, shutter or grid type



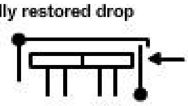
Annunciator drop or signal, ball type



Manually restored drop



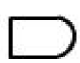
Electrically restored drop



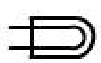
Communication switchgoard-type lamp; indicating lamp

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

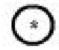
If confusion with other circular symbols may occur, the D-shape symbol should be used.



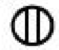
OR



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

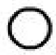
Galvanometer

OR

Graphic Symbols for Rotating Machinery

Rotating Machine

Basic



Generator (general)

Avoid conflict with symbols for galvanometer if used on the same diagram.

OR

Generator, direct-current

Generator, alternating-current

Motor (general)

OR

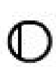
Motor, direct-current

Motor, alternating-current

Winding Connection Symbols

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

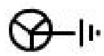
1-phase



2-phase

3-phase wye (ungrounded)

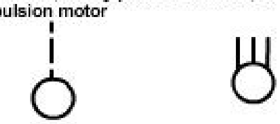
3-phase wye (grounded)



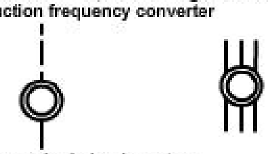
3-phase delta

Alternating-Current Machines

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



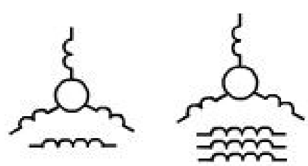
Wound-rotor induction motor, synchronous induction motor, induction generator, or induction frequency converter



1-phase shaded-pole motor

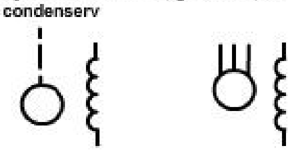
1-phase repulsion-start induction motor

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.

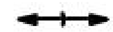
NOTE: The short parallel lines should be used only where there is insufficient space for the short dashes in series

OR

Mechanical Motion

Translation, one direction

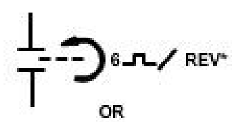
Translation, both directions



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.



OR

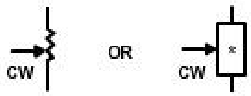
Rotation, both directions

Alternating or reciprocating

Rotation designation (applied to a resistor)

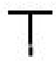
CW indicates position of adjustable contact at the limit of clockwise travel viewed from knob or actuator end unless otherwise indicated.

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



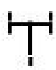
Manual Control

General



Operated by pushing

Operated by pushing and pulling (pudh-pull)



Graphic Symbols for Composite Assemblies

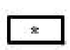
Circuit Assembly
Circuit Subassembly
Circuit Element

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.

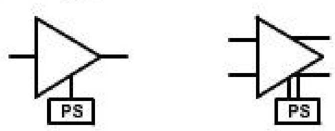
The symbol represents any method of amplification (electron tube, solid-state device, magnetic device, etc).

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

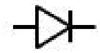
Application: amplifier with associated power supply



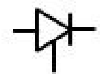
General

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.

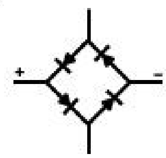
NOTE: This symbol represents any method of rectification (electron tube, solid-state device, electrochemical device, etc).



Controlled

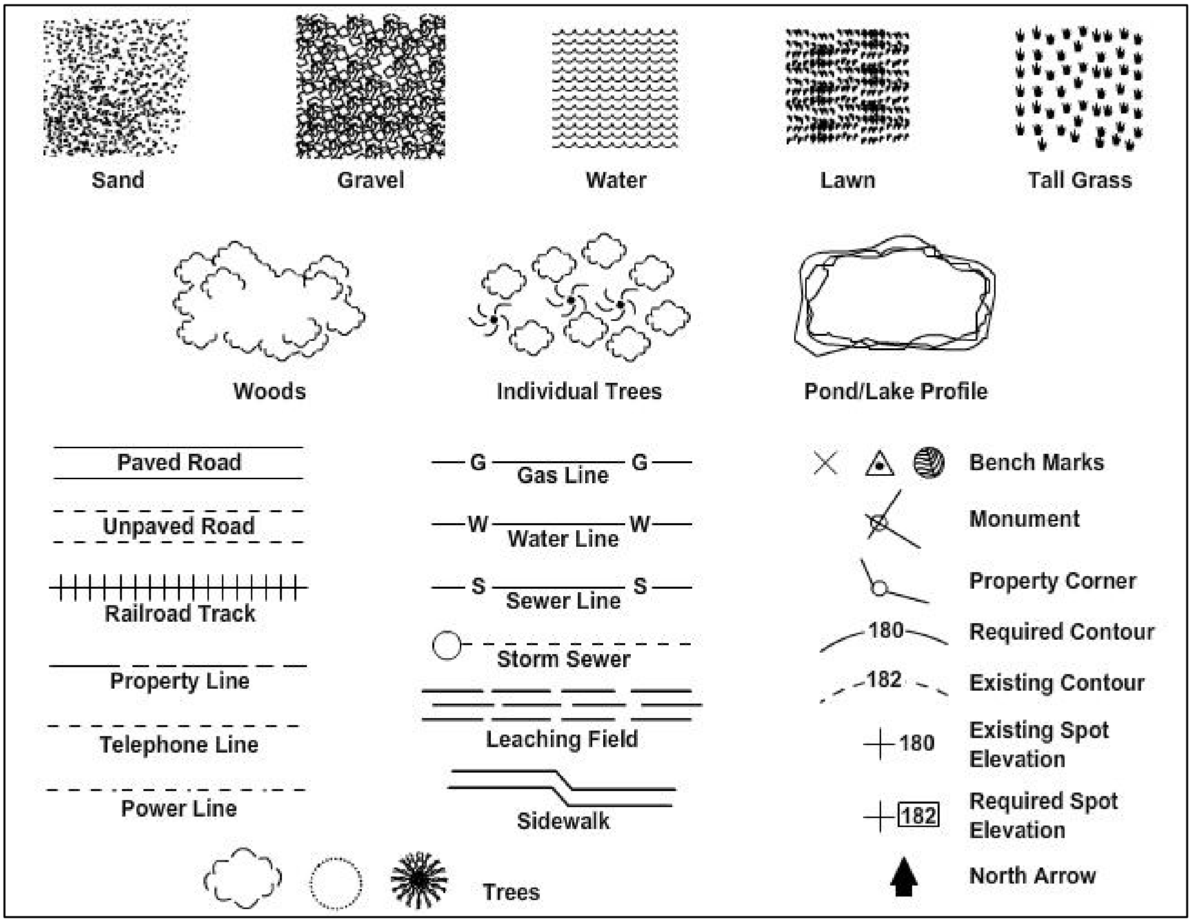


Bridge-type rectifier

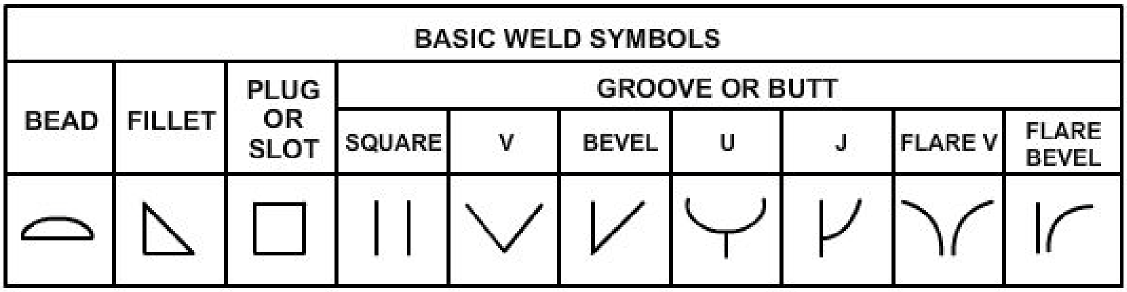


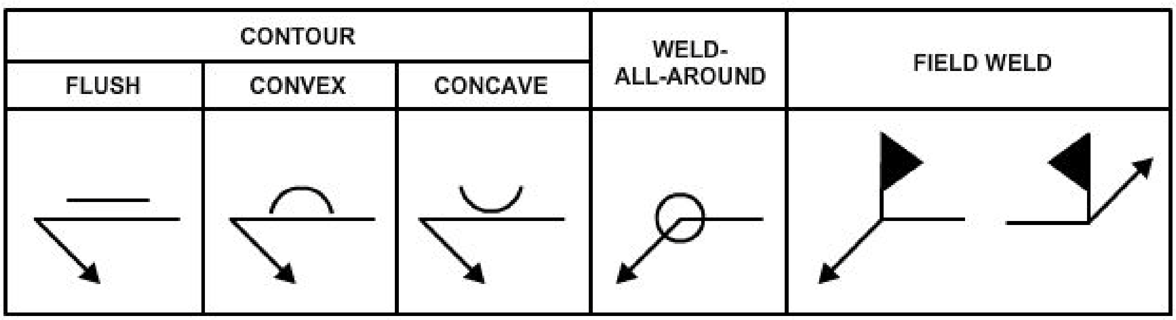
On connection or wiring diagrams, rectifier may be shown with terminals and plarity marking. Heavy line may be used to indicate nameplate or positive-polarity end.

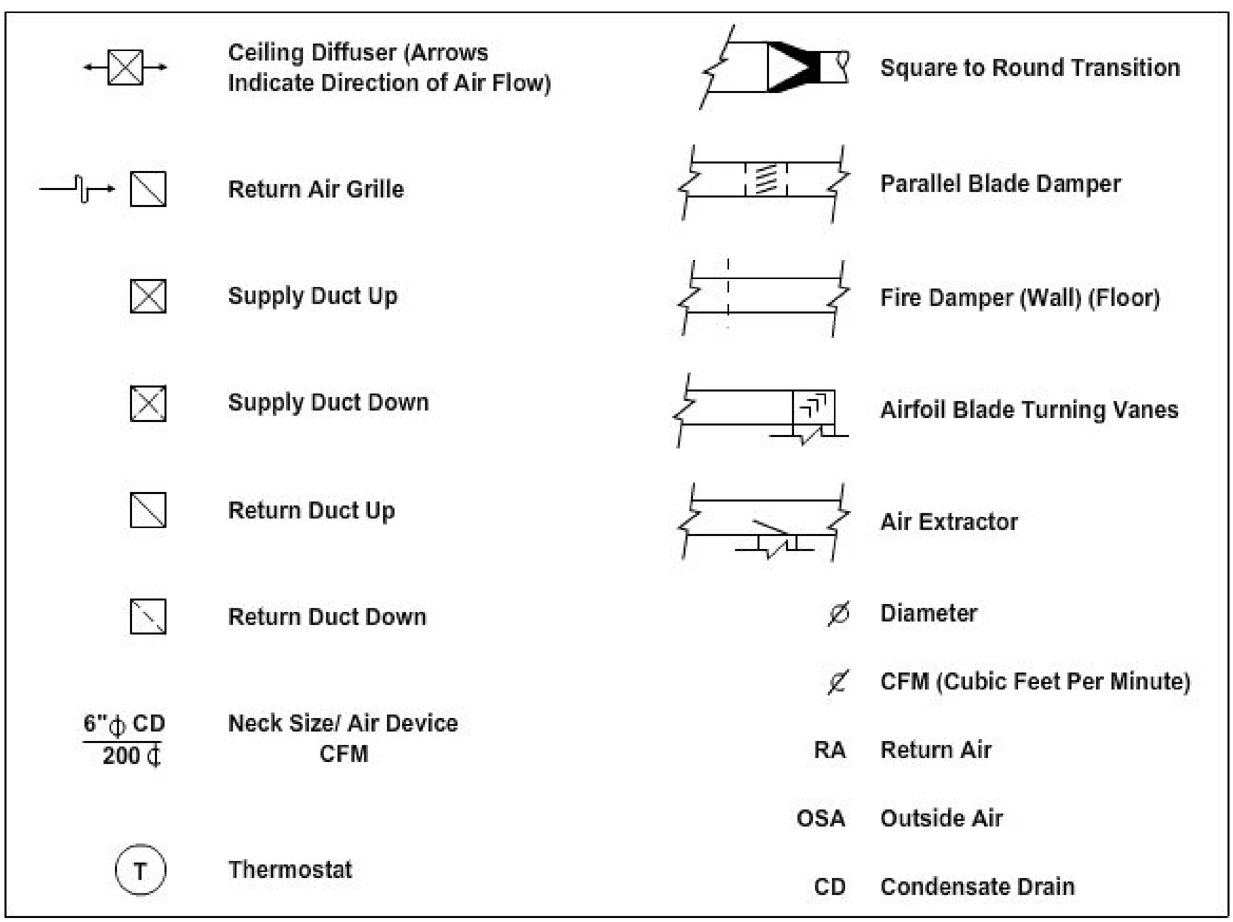
For connection or wiring diagram



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:			3x 3x
Equal Leg		L	L 3x 3x 1/4
Un-equal Leg		L	L 7x 4x 1/2
Tees, Structural: Cut From W-Shape		WT	WT 12x38
Cut From S-Shape		ST	ST 12x38
Cut From M-Shape		MT	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

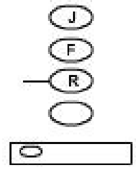

BASIC WELD SYMBOLS
BEAD
FILLET
PLUG OR SLOT
GROOVE OR BUTT
SQUARE
V
BEVEL
U
J
FLARE V
FLARE BEVEL


CONTOUR
FLUSH
CONVEX
CONCAVE
WELD-ALL-AROUND
FIELD WELD


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
T
Thermostat
Square to Round Transition
Parallel Blade Damper
Fire Damper (Wall) (Floor)
Airfoil Blade Turning Vanes
Air Extractor
Diameter
CFM (Cubic Feet Per Minute)
RA
Return Air
OSA
Outside Air
CD
Condensate Drain

General Outlets

- Junction Box, Ceiling
- Fan, Ceiling
- Recessed Incandescent, Wall
- Surface Incandescent, Ceiling
- Surface or Pendant Single Fluorescent Fixture

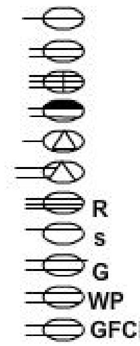


Switch Outlets

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}

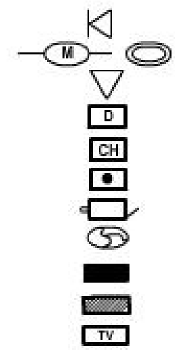
Receptacle Outlets

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



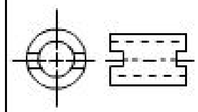
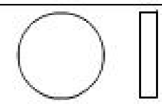
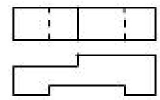
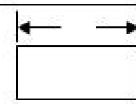
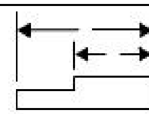
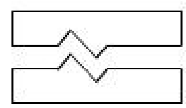
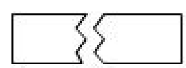
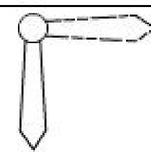
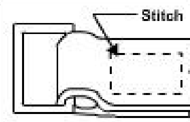
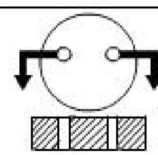
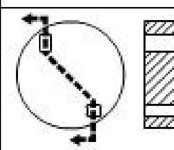
Auxiliary Systems

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



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	

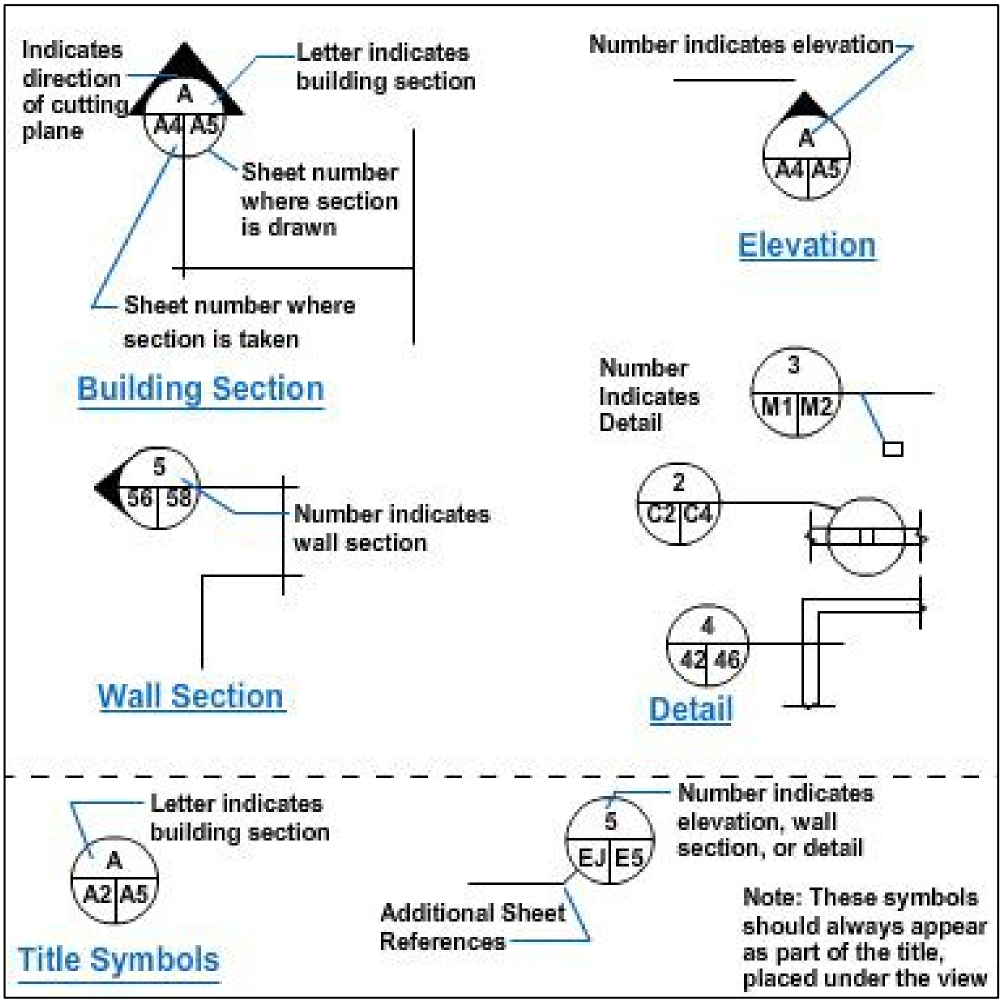
Valves

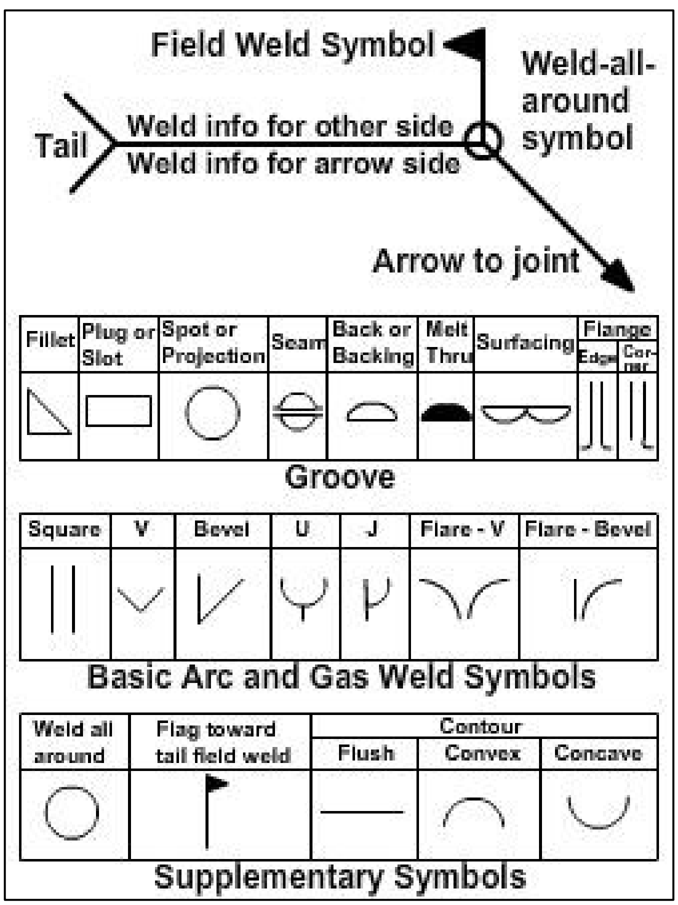
	Screwed	Soldered
Gate Valve		
Globe Valve		
Angle Glove Valve		
Angle Gate Valve		
Check Valve		
Angle Check Valve		
Stop Cock		
Safety Valve		
Quick Opening Valve		
Float Opening Valve		
Motor Operated Gate Valve		

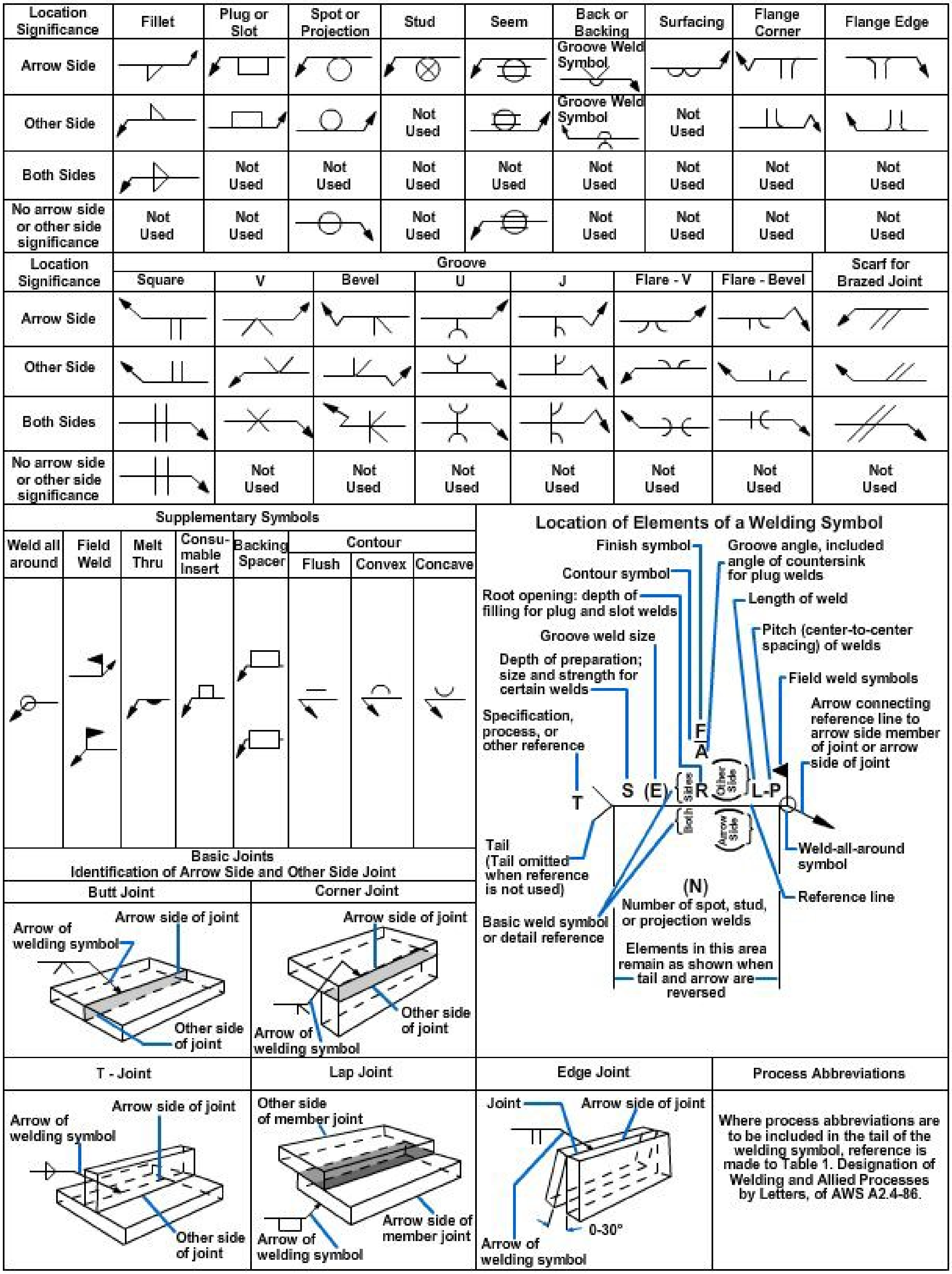
Pipe Fittings

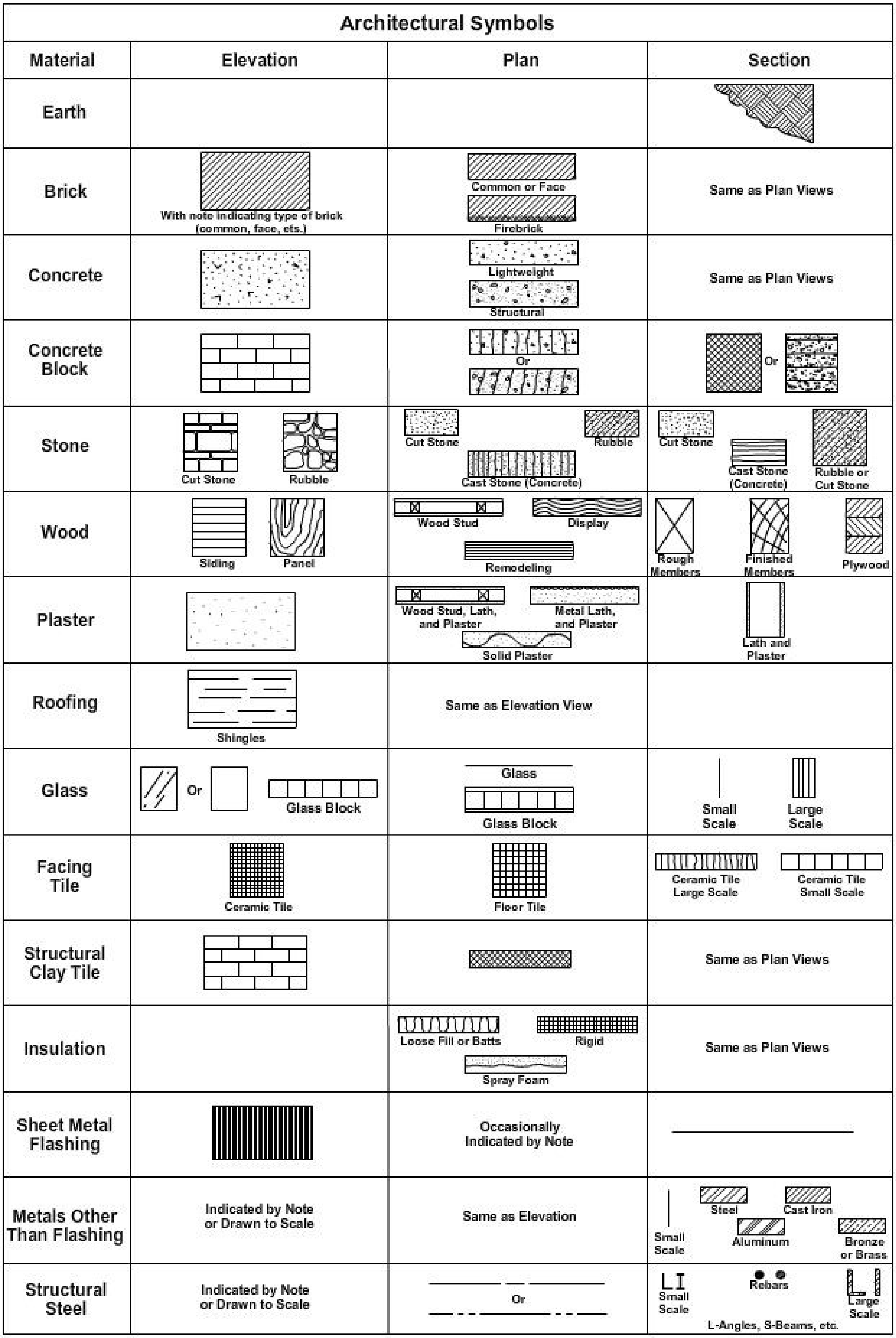
	Screwed	Soldered
Joint		
Elbow - 90		
Elbow - 45		
Elbow - Turned Up		
Elbow - Turned Down		
Elbow Long Radius		
Side Outlet Elbow- Outlet Down		
Side outlet Elbow - Outlet Up		
Base Elbow		
Double Branch Elbow		
Single Sweep Tee		
Double Sweep Tee		
Reducing Elbow		
Tee		
Tee - Outlet UP		
Tee - Outlet Down		
Side Outlet Tee - Outlet Up		
Side Outlet Tee - Outlet Down		
Cross		
Reducer		
Eccentric Reducer		
Lateral		
Expansion Joint Flanged		

	Battery, Multicells		Fire-Alarm Box, Wall Type	S	Single-Pole Switch
	Switch Breaker		Lighting Panel	S_2	Double-Pole Switch
	Automatic Reset Breaker		Power Panel		Pull Switch Ceiling
	Bus		Branch Circuit, Concealed In Ceiling Or Wall		Pull Switch Wall
	Voltmeter		Branch Circuit, Concealed In Floor		Fixture, Fluorescent, Ceiling
	Toggle Switch DPST		Branch Circuit, Exposed		Fixture, Fluorescent, Wall
	Transformer, Magnetic Core		Feeders		Junction Box, Ceiling
	Bell		Underfloor Duct And Junction Box		Junction Box, Wall
	Buzzer, AC		Motor		Lampholder, Ceiling
	Crossing Not Connected (Not Necessarily At A 90° Angle)		Controller		Lampholder, Wall
	Junction		Street Lighting Standard		Lampholder, With Pull Switch, Ceiling
	Transformer, Basic		Outlet, Floor		Lampholder, With Pull Switch, Wall
	Ground		Convenience, Duplex		Special Purpose
	Outlet, Ceiling		Fan, Wall		Telephone, Switchboard
	Outlet, Wall		Fan, Ceiling		Thermostat
	Fuse		Knife Switch Disconnected		Push Button

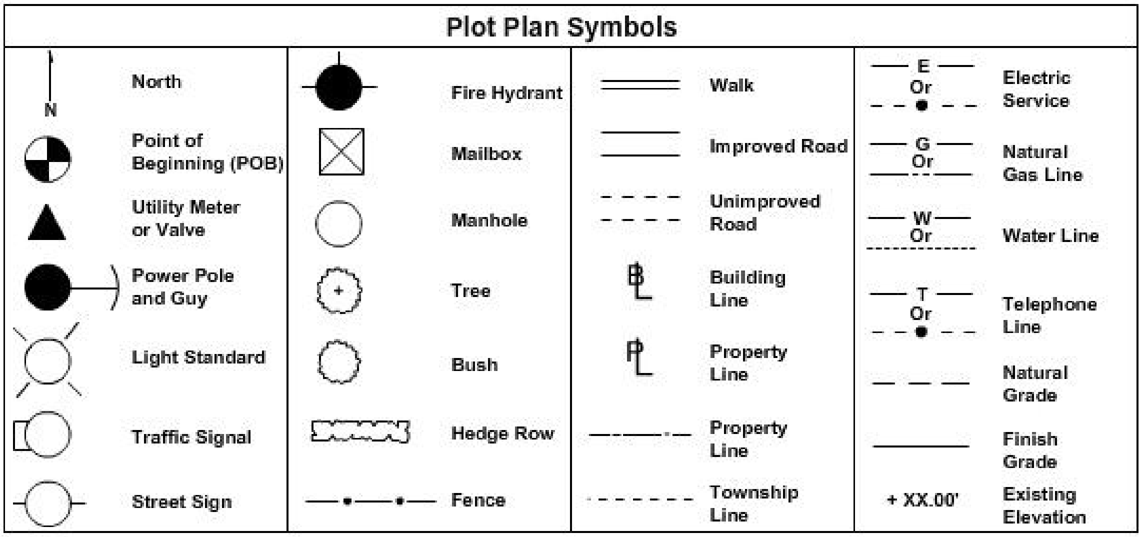

Indicates direction of cutting plane
Letter indicates building section
Sheet number where section is drawn
Sheet number where section is taken
Building Section
Number indicates elevation
Elevation
Number Indicates Detail
Detail
Number indicates wall section
Wall Section
Letter indicates building section
Title Symbols
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

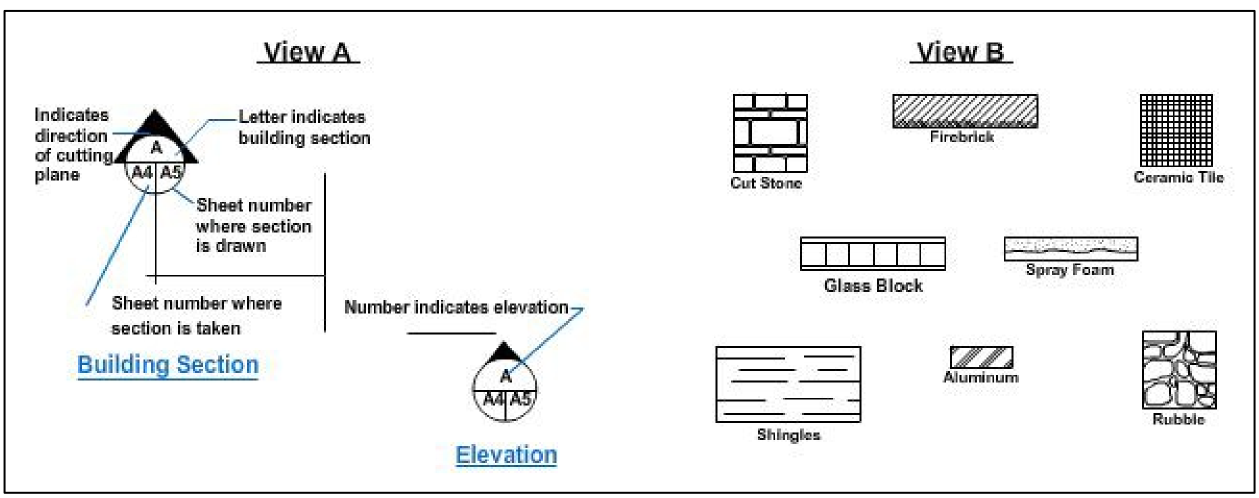

Field Weld Symbol
Weld-all-around symbol
Tail
Weld info for other side
Weld info for arrow side
Arrow to joint
Fillet
Plug or Slot
Spot or Projection
Seam
Back or Backing
Melt Thru
Surfacing
Flange
Edge
Corner
Groove
Square
V
Bevel
U
J
Flare - V
Flare - Bevel
Basic Arc and Gas Weld Symbols
Weld all around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

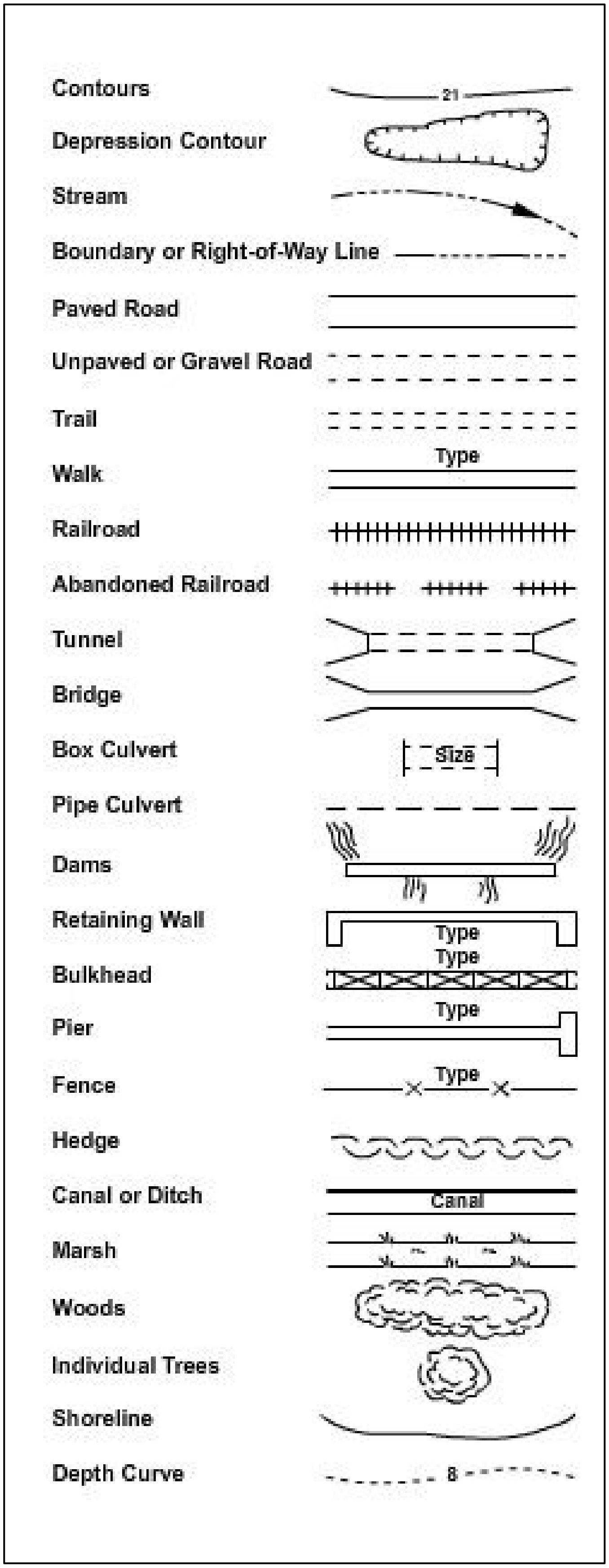

Location Significance
Fillet
Plug or Slot
Spot or Projection
Stud
Seem
Back or Backing
Surfacing
Flange Corner
Flange Edge
Arrow Side
Groove Weld Symbol
Other Side
Groove Weld Symbol
Not Used
Both Sides
Not Used
No arrow side or other side significance
Not Used
Location Significance
Groove
Square
V
Bevel
U
J
Flare - V
Flare - Bevel
Scarf for Brazed Joint
Arrow Side
Other Side
Both Sides
No arrow side or other side significance
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
Finish symbol
Groove angle, included angle of countersink for plug welds
Contour symbol
Root opening: depth of filling for plug and slot welds
Length of weld
Groove weld size
Pitch (center-to-center spacing) of welds
Depth of preparation; size and strength for certain welds
Field weld symbols
Arrow connecting reference line to arrow side member of joint or arrow side of joint
Specification, process, or other reference
F
A
T
S (E)
R
L-P
Both Sides
Other Side
Arrow Side
Tail (Tail omitted when reference is not used)
Weld-all-around symbol
(N)
Reference line
Basic weld symbol or detail reference
Number of spot, stud, or projection welds
Elements in this area remain as shown when tail and arrow are reversed
Basic Joints
Identification of Arrow Side and Other Side Joint
Butt Joint
Arrow of welding symbol
Arrow side of joint
Other side of joint
Corner Joint
Arrow side of joint
Other side of joint
Arrow of welding symbol
T - Joint
Arrow side of joint
Arrow of welding symbol
Other side of joint
Lap Joint
Other side of member joint
Arrow side of member joint
Arrow of welding symbol
Edge Joint
Joint
Arrow side of joint
0-30°
Arrow of welding symbol
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.



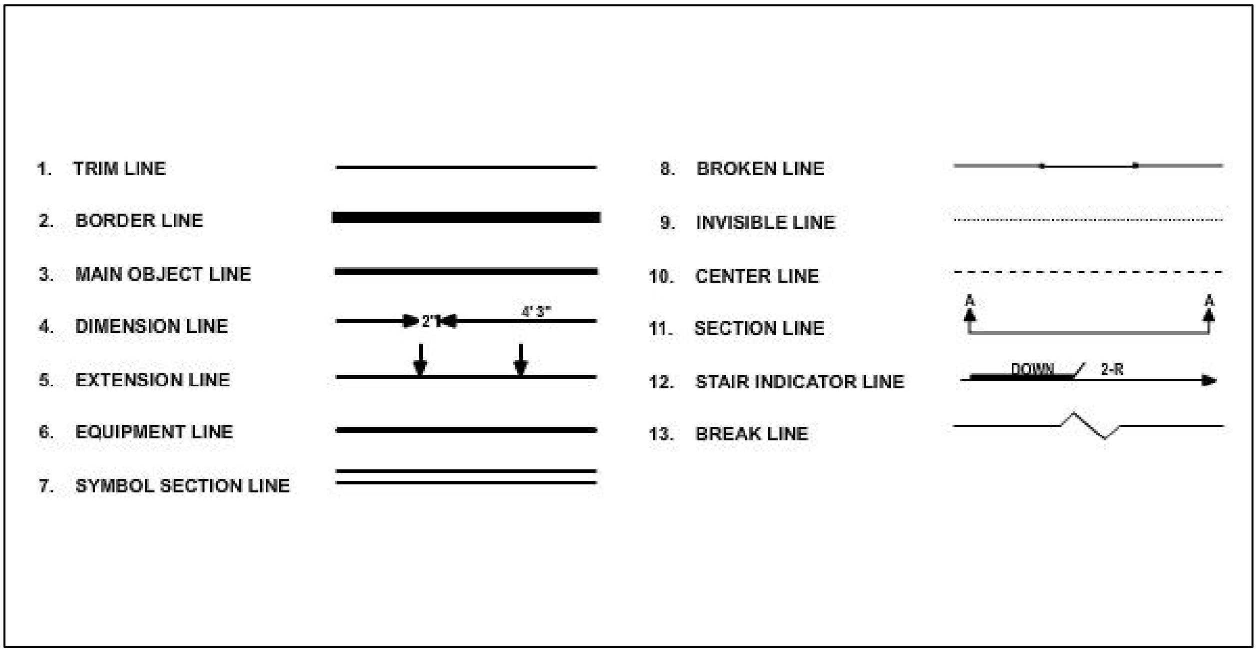
Architectural Symbols			
Material	**Elevation**	**Plan**	**Section**
Earth			
Brick	With note indicating type of brick (common, face, ets.)	Common or Face Firebrick	Same as Plan Views
Concrete		Lightweight Structural	Same as Plan Views
Concrete Block		Or	Or
Stone	Cut Stone Rubble	Cut Stone Rubble Cast 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	Small Scale Steel Cast Iron Aluminum Bronze or Brass
Structural Steel	Indicated by Note or Drawn to Scale	Or	Small Scale Rebars Large Scale L-Angles, S-Beams, etc.

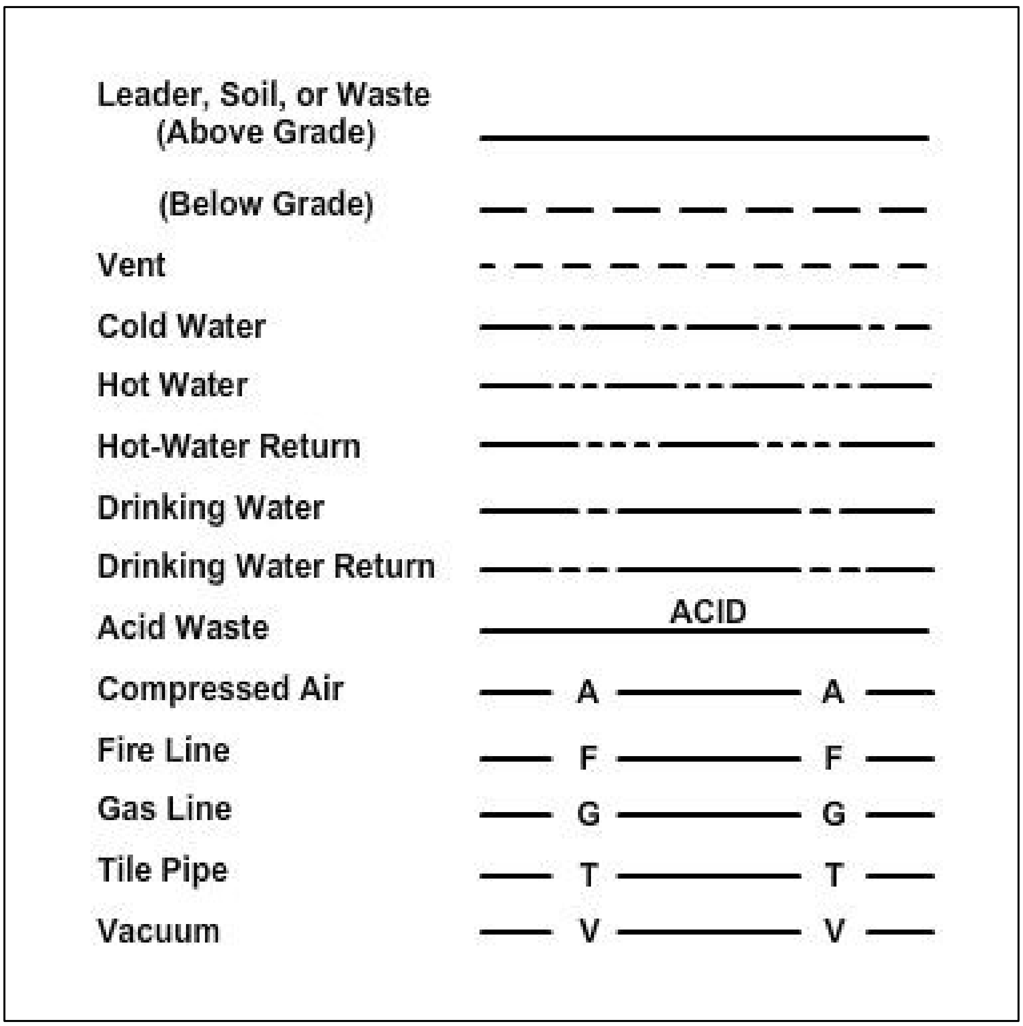

Plot Plan Symbols
N
North
Point of Beginning (POB)
Utility Meter or Valve
Power Pole and Guy
Light Standard
Traffic Signal
Street Sign
Fire Hydrant
Mailbox
Manhole
Tree
Bush
Hedge Row
Fence
Walk
Improved Road
Unimproved Road
Building Line
Property Line
Property Line
Township Line
E Or
Electric Service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

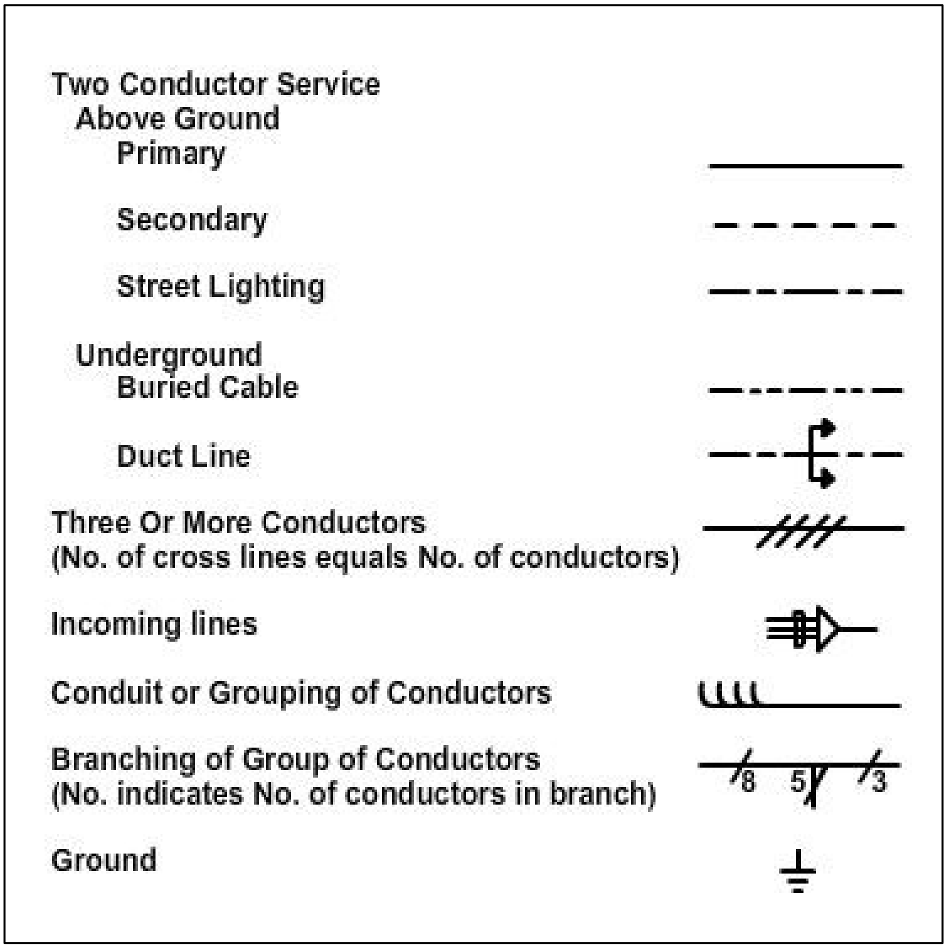

View A
Indicates direction of cutting plane
Letter indicates building section
A
A4 A5
Sheet number where section is drawn
Sheet number where section is taken
Building Section
Number indicates elevation
Elevation
View B
Cut Stone
Firebrick
Ceramic Tile
Glass Block
Spray Foam
Shingles
Aluminum
Rubble

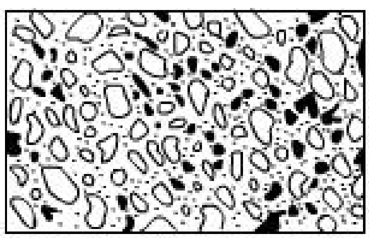


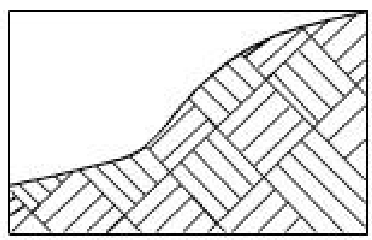
Contours
21
Depression Contour
Stream
Boundary or Right-of-Way Line
Paved Road
Unpaved or Gravel Road
Trail
Type
Walk
Railroad
Abandoned Railroad
Tunnel
Bridge
Box Culvert
Size
Pipe Culvert
Dams
Retaining Wall
Type
Type
Bulkhead
Type
Pier
Type
Fence
Hedge
Canal or Ditch
Canal
Marsh
Woods
Individual Trees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

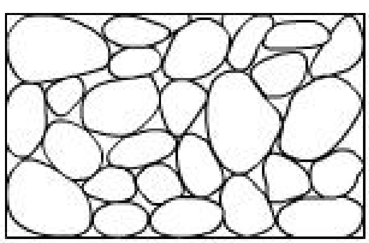

1. TRIM LINE
2. BORDER LINE
3. MAIN OBJECT LINE
4. DIMENSION LINE
2'1
4' 3"
5. EXTENSION LINE
6. EQUIPMENT LINE
7. SYMBOL SECTION LINE
8. BROKEN LINE
9. INVISIBLE LINE
10. CENTER LINE
11. SECTION LINE
A
A
12. STAIR INDICATOR LINE
DOWN
2-R
13. BREAK LINE

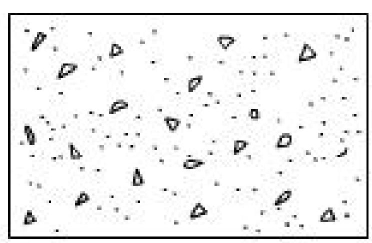

Leader, Soil, or Waste
(Above Grade)
(Below Grade)
Vent
Cold Water
Hot Water
Hot-Water Return
Drinking Water
Drinking Water Return
Acid Waste
ACID
Compressed Air
A
A
Fire Line
F
F
Gas Line
G
G
Tile Pipe
T
T
Vacuum
V
V

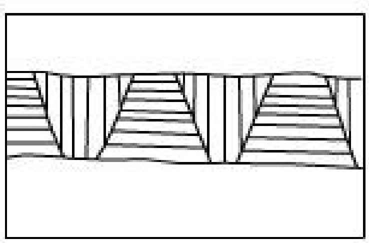


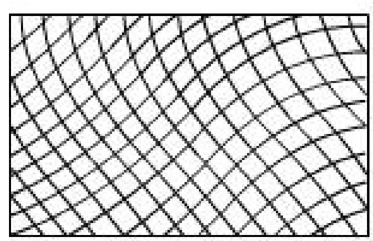

Gravel

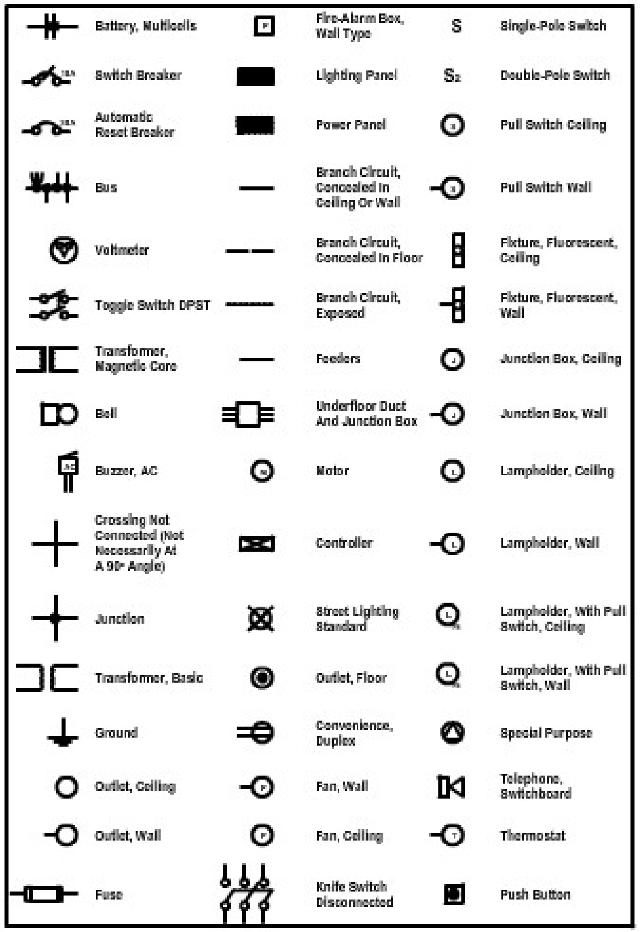

Earth


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
S_2
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