CHAPTER 2

ROOF FRAMING

In this chapter, we will introduce you to the fundamentals of roof design and construction. But, before discussing roof framing, we will first review some basic terms and definitions used in roof construction; we will then discuss the framing square and learn how it's used to solve some basic construction problems. Next, we'll examine various types of roofs and rafters, and techniques for laying out, cutting, and erecting rafters. We conclude the chapter with a discussion of the types and parts of roof trusses.

TERMINOLOGY

LEARNING OBJECTIVE: Upon completing this section, you should be able to identify the types of roofs and define common roof framing terms.

The primary object of a roof in any climate is protection from the elements. Roof slope and rigidness are for shedding water and bearing any extra additional weight. Roofs must also be strong enough to withstand high winds. In this section, we'll cover the most common types of roofs and basic framing terms.

TYPES OF ROOFS

The most commonly used types of pitched roof construction are the gable, the hip, the intersecting, and the shed (or lean-to). An example of each is shown in figure 2-1.

Gable

A gable roof has a ridge at the center and slopes in two directions. It is the form most commonly used by the Navy. It is simple in design, economical to construct, and can be used on any type of structure.

Hip

The hip roof has four sloping sides. It is the strongest type of roof because it is braced by four hip rafters. These hip rafters run at a 45° angle from each corner of the building to the ridge. A disadvantage of the hip roof is that it is more difficult to construct than a gable roof.

Intersecting

The intersecting roof consists of a gable and valley, or hip and valley. The valley is formed where the two different sections of the roof meet, generally at a 90° angle. This type of roof is more complicated than the

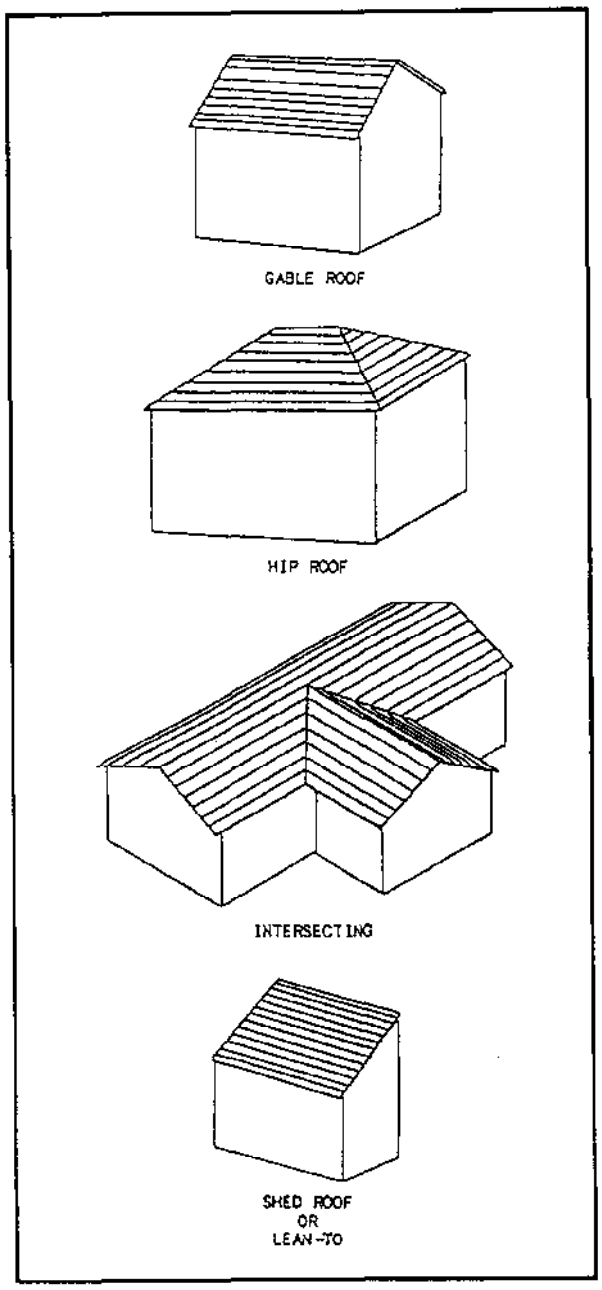


Figure 2-1.—Most common types of pitched roofs.

other types and requires more time and labor to construct.

Shed

The shed roof, or lean-to, is a roof having only one slope, or pitch. It is used where large buildings are framed under one roof, where hasty or temporary construction is needed, and where sheds or additions are erected. The roof is held up by walls or posts where one wall or the posts on one side are at a higher level than those on the opposite side.

FRAMING TERMS

Knowing the basic vocabulary is a necessary part of your work as a Builder. In the following section, we'll cover some of the more common roof and rafter terms you'll need. Roof framing terms are related to the parts of a triangle.

Roof

Features associated with basic roof framing terms are shown in figure 2-2. Refer to the figure as you study the terms discussed in the next paragraphs.

Span is the horizontal distance between the outside top plates, or the base of two abutting right triangles.

Unit of run is a fixed unit of measure, always 12 inches for the common rafter. Any measurement in a horizontal direction is expressed as run and is always measured on a level plane. Unit of span is also fixed, twice the unit of run, or 24 inches. Unit of rise is the distance the rafter rises per foot of run (unit of run).

Total run is equal to half the span, or the base of one of the right triangles. Total rise is the vertical distance from the top plate to the top of the ridge, or the altitude of the triangle.

Pitch is the ratio of unit of rise to the unit of span. It describes the slope of a roof. Pitch is expressed as a fraction, such as 1/4 or 1/2 pitch. The term "pitch" is gradually being replaced by the term "cut." Cut is the angle that the roof surface makes with a horizontal plane. This angle is usually expressed as a fraction in which the numerator equals the unit of rise and the denominator equals the unit of run (12 inches), such as 6/1 2 or 8/12. This can also be expressed in inches per foot; for example, a 6- or 8-inch cut per foot. Here, the unit of run (12 inches) is understood. Pitch can be converted to cut by using the following formula: *unit of span (24 in.) x pitch* = unit of rise. For example,

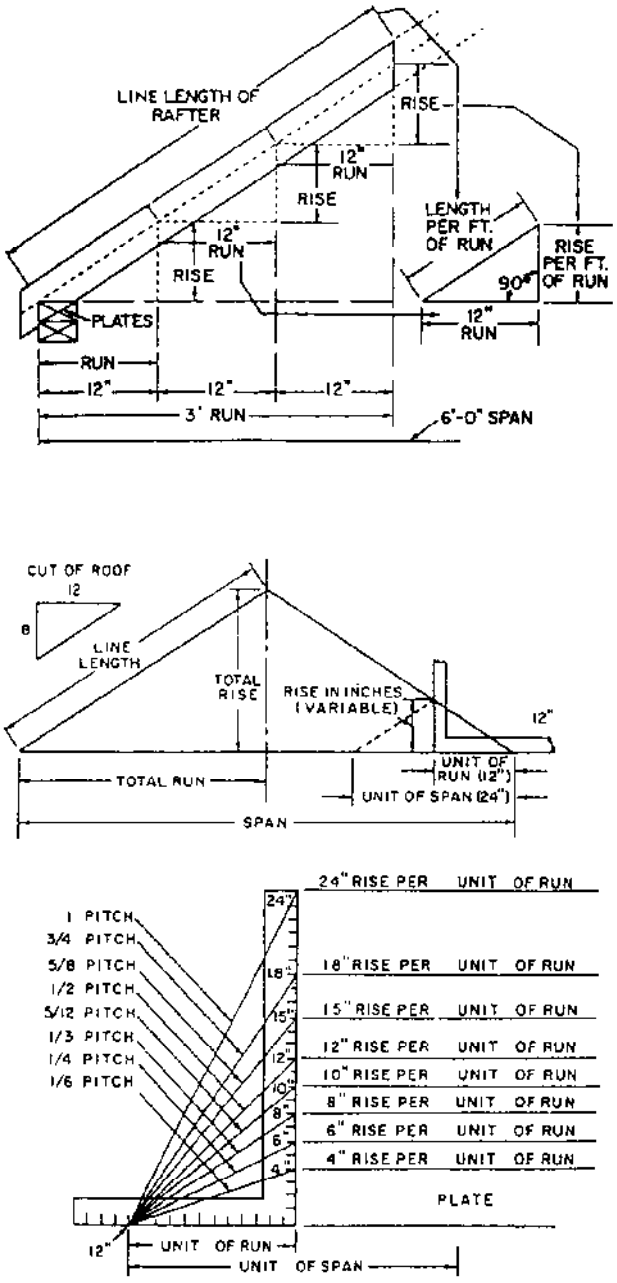
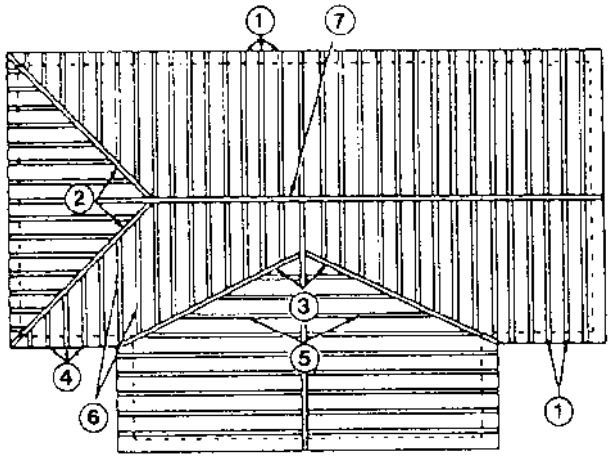


Figure 2-2.—Roof framing terms.

1/8 pitch is given, so 24 x 1/8 equals 3, or unit of rise in inches. If the unit of rise in inches is 3, then the cut is the unit of rise and the unit of run (12 inches), or 3/12.

Line length is the hyptenuse of the triangle whose base equals the total run and whose altitude equals the total rise. The distance is measured along the rafter from the outside edge of the top plate to the centerline of the ridge. Bridge measure is the hypotenuse of the triangle with the unit of run for the base and unit of rise for the altitude.



1. Common rafters
2. Hip rafters
3. Valley rafters
4. Hip jack
5. Valley jacks
6. Cripple jacks
7. Ridgeboard

Figure 2-3.-Rafter terms.

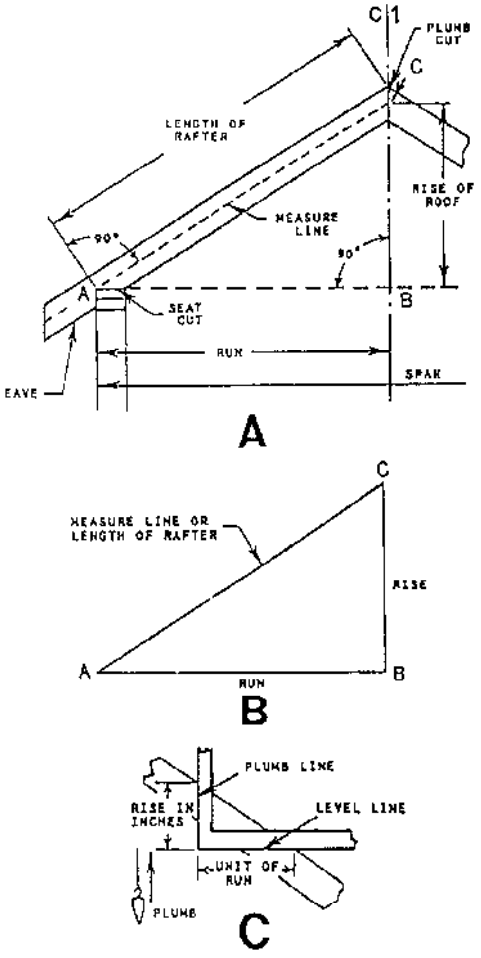


Figure 2-4.—Rafter layout.

Rafter

The members making up the main body of the framework of all roofs are called rafters. They do for the roof what the joists do for the floor and what the studs do for the wall. Rafters are inclined members spaced from 16 to 48 inches apart. They vary in size, depending on their length and spacing. The tops of the inclined rafters are fastened in one of several ways determined by the type of roof. The bottoms of the rafters rest on the plate member, providing a connecting link between the wall and the roof. The rafters are really functional parts of both the walls and the roof.

The structural relationship between the rafters and the wall is the same in all types of roofs. The rafters are not framed into the plate, but are simply nailed to it. Some are cut to fit the plate, whereas others, in hasty construction, are merely laid on top of the plate and nailed in place. Rafters usually extend a short distance beyond the wall to form the eaves (overhang) and protect the sides of the building. Features associated with various rafter types and terminology are shown in figure 2-3.

Common rafters extend from the plate to the ridgeboard at right angles to both. Hip rafters extend diagonally from the outside corner formed by perpendicular plates to the ridgeboard. Valley rafters extend from the plates to the ridgeboard along the lines where two roofs intersect. Jack rafters never extend the full distance from plate to ridgeboard. Jack rafters are subdivided into the hip, valley, and cripple jacks.

In a hip jack, the lower ends rest on the plate and the upper ends against the hip rafter. In a valley jack the lower ends rest against the valley rafters and the upper ends against the ridgeboard. A cripple jack is nailed between hip and valley rafters.

Rafters are cut in three basic ways (shown in fig. 2-4, view A). The top cut, also called the plumb cut, is made at the end of the rafter to be placed against the ridgeboard or, if the ridgeboard is omitted, against the opposite rafters. A seat, bottom, or heel cut is made at the end of the rafter that is to rest on the plate. A side cut (not shown in fig. 2-4), also called a cheek cut, is a bevel cut on the side of a rafter to make it fit against another frame member.

Rafter length is the shortest distance between the outer edge of the top plate and the center of the ridge line. The cave, tail, or overhang is the portion of the

rafter extending beyond the outer edge of the plate. A measure line (fig. 2-4, view B) is an imaginary reference line laid out down the middle of the face of a rafter. If a portion of a roof is represented by a right triangle, the measure line corresponds to the hypotenuse; the rise to the altitude; and, the run to the base.

A plumb line (fig. 2-4, view C) is any line that is vertical (plumb) when the rafter is in its proper position. A level line (fig. 2-4, view C) is any line that is horizontal (level) when the rafter is in its proper position.

FRAMING SQUARE

LEARNING OBJECTIVE: Upon completing this section, you should be able to describe and solve roof framing problems using the framing square.

The framing square is one of the most frequently used Builder tools. The problems it can solve are so many and varied that books have been written on the square alone. Only a few of the more common uses of the square can be presented here. For a more detailed discussion of the various uses of the framing square in solving construction problems, you are encouraged to obtain and study one of the many excellent books on the square.

DESCRIPTION

The framing square (fig. 2-5, view A) consists of a wide, long member called the blade and a narrow, short member called the tongue. The blade and tongue form a right angle. The face of the square is the side one sees when the square is held with the blade in the left hand, the tongue in the right hand, and the heel pointed away from the body. The manufacturer's name is usually stamped on the face. The blade is 24 inches long and 2 inches wide. The tongue varies from 14 to 18 inches long and is 1 1/2 inches wide, measured from the outer corner, where the blade and the tongue meet. This corner is called the heel of the square.

The outer and inner edges of the tongue and the blade, on both face and back, are graduated in inches. Note how inches are subdivided in the scale on the back of the square. In the scales on the face, the inch is subdivided in the regular units of carpenter's measure (1/8 or 1/16 inch). On the back of the square, the outer edge of the blade and tongue is graduated in inches and twelfths of inches. The inner edge of the tongue is graduated in inches and tenths of inches. The inner edge of the blade is graduated in inches and thirty-seconds of

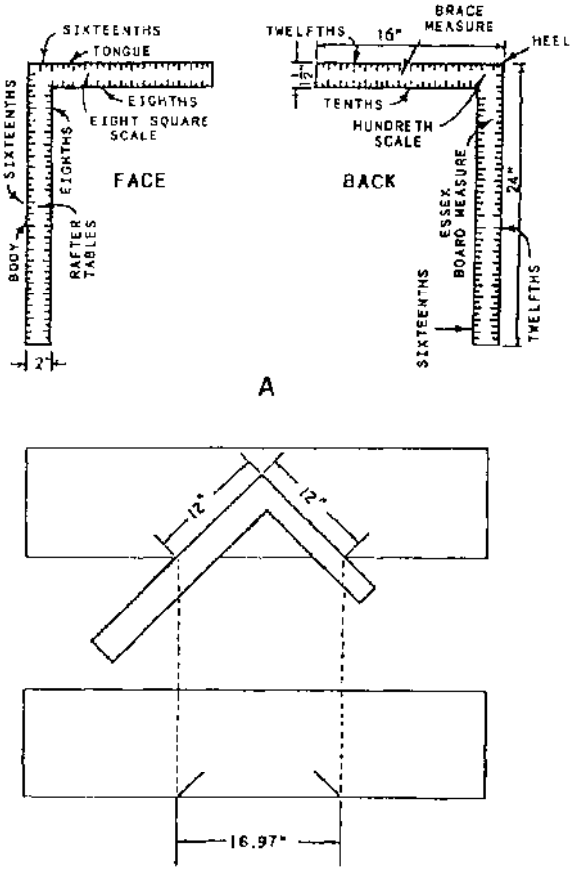


Figure 2-5.—Framing square: A. Nomenclature; B. Problem solving.

inches on most squares. Common uses of the twelfths scale on the back of the framing square will be described later. The tenths scale is not normally used in roof framing.

SOLVING BASIC PROBLEMS WITH THE FRAMING SQUARE

The framing square is used most frequently to find the length of the hypotenuse (longest side) of a right triangle when the lengths of the other two sides are known. This is the basic problem involved in determining the length of a roof rafter, a brace, or any other member that forms the hypotenuse of an actual or imaginary right triangle.

Figure 2-5, view B, shows you how the framing square is used to determine the length of the hypotenuse of a right triangle with the other sides each 12 inches long. Place a true straightedge on a board and set the square on the board so as to bring the 12-inch mark on

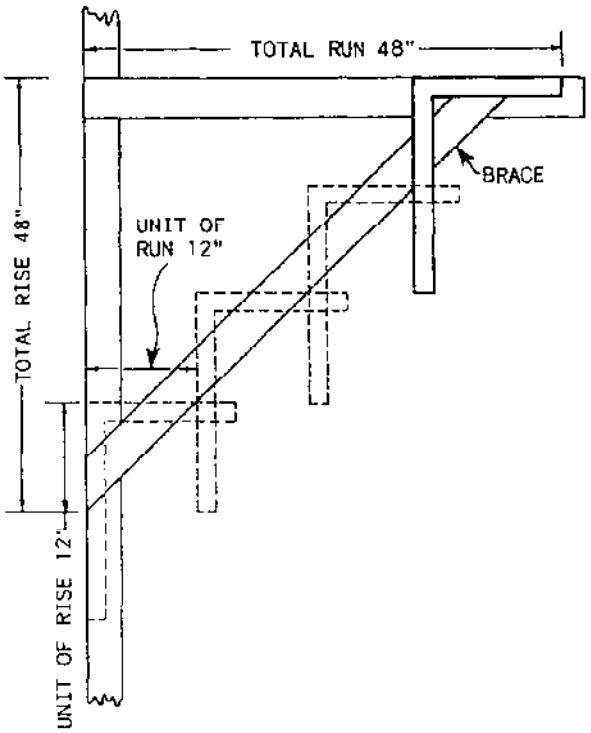


Figure 2-6.—"Stepping off" with a framing square.

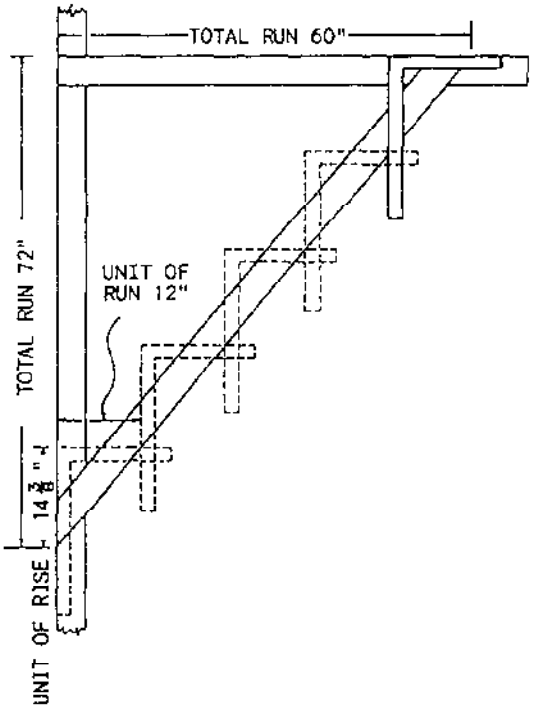


Figure 2-7.–"Stepping off" with a square when the unit of run and unit of rise are different.

the tongue and the blade even with the edge of the board. Draw the pencil marks as shown. The distance between these marks, measured along the edge of the board, is the length of the hypotenuse of a right triangle with the other sides each 12 inches long. You will find that the distance, called the bridge measure, measures just under 17 inches—16.97 inches, as shown in the figure. For most practical Builder purposes, though, round 16.97 inches to 17 inches.

Solving for Unit and Total Run and Rise

In figure 2-5, the problem could be solved by a single set (called a cut) of the framing square. This was due to the dimensions of the triangle in question lying within the dimensions of the square. Suppose, though, you are trying to find the length of the hypotenuse of a right triangle with the two known sides each being 48 inches long. Assume the member whose length you are trying to determine is the brace shown in figure 2-6. The total run of this brace is 48 inches, and the total rise is also 48 inches.

To figure the length of the brace, you first reduce the triangle in question to a similar triangle within the dimensions of the framing square. The length of the vertical side of this triangle is called unit of rise, and the length of the horizontal side is called the unit of run. By a general custom of the trade, unit of run is always taken as 12 inches and measured on the tongue of the framing square.

Now, if the total run is 48 inches, the total rise is 48 inches, and the unit of run is 12 inches, what is the unit of rise? Well, since the sides of similar triangles are proportional, the unit of rise must be the value of *x* in the proportional equation *48:48::12:x*. In this case, the unit of rise is obviously 12 inches.

To get the length of the brace, set the framing square to the unit of run (12 inches) on the tongue and to the unit of rise (also 12 inches) on the blade, as shown in figure 2-6. Then, "step off" this cut as many times as the unit of run goes into the total run. In this case, 48/12, or 4 times, as shown in the figure.

In this problem, the total run and total rise were the same, from which it followed that the unit of run and unit of rise were also the same. Suppose now that you want to know the length of a brace with a total run of 60 inches and a total rise of 72 inches, as in figure 2-7. Since the unit of run is 12 inches, the unit of rise must be the value of *x* in the proportional equation *60:72::12.x*. That is, the proportion 60:72 is the same as the proportion 12:x. Working this out, you find the unit of rise is

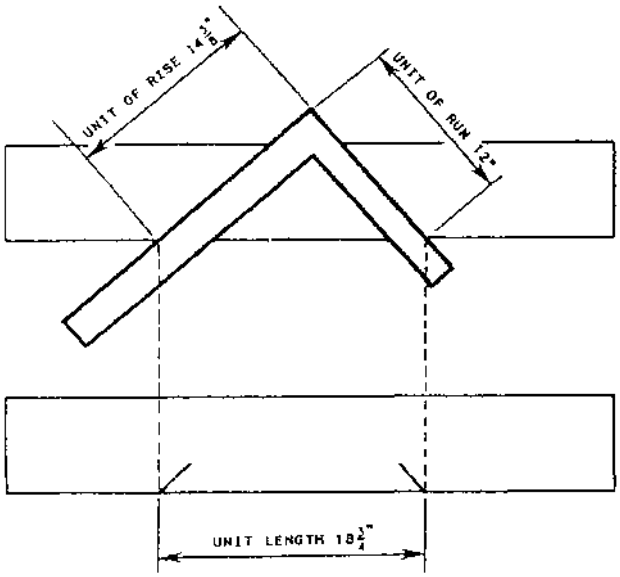


Figure 2-8.-Unit length.

14.4 inches. For practical purposes, you can round this to 14 3/8.

To lay out the full length of the brace, set the square to the unit of rise (14 3/8 inches) and the unit of run (12 inches), as shown in figure 2-7. Then, step off this cut as many times as the unit of run goes into the total run (60/12, or 5 times).

Determining Line Length

If you do not go through the stepping-off procedure, you can figure the total length of the member in question by first determining the bridge measure. The bridge measure is the length of the hypotenuse of a right triangle with the other sides equal to the unit of run and unit of rise. Take the situation shown above in figure 2-7. The unit of run here is 12 inches and the unit of rise is 14 3/8 inches. Set the square to this cut, as shown in figure 2-8, and mark the edges of the board as shown. If you measure the distance between the marks, you will find it is 18 3/4 inches. Bridge measure can also be found by using the Pythagorean theorem: $(a^2 + b^2 = c^2)$. Here, the unit of rise is the altitude *(a),* the unit or run is the base *(b),* and the hypotenuse *(c)* is the bridge measure.

To get the total length of the member, you simply multiply the bridge measure in inches by the total run in feet. Since that is 5, the total length of the member is 18 3/4 x 5, or 93 3/4 inches. Actually, the length of the hypotenuse of a right triangle with the other sides 60 and 72 inches long is slightly more than 93.72 inches, but 93 3/4 inches is close enough for practical purposes.

Once you know the total length of the member, just measure it off and make the end cuts. To make these cuts at the proper angles, set the square to the unit of run on the tongue and the unit of rise on the blade and draw a line for the cut along the blade (lower end cut) or the tongue (upper end cut).

SCALES

A framing square contains four scales: tenths, twelfths, hundredths, and octagon. All are found on the face or along the edges of the square. As we mentioned earlier, the tenths scale is not used in roof framing.

Twelfths Scale

The graduations in inches, located on the back of the square along the outer edges of the blade and tongue, are called the twelfths scale. The chief purpose of the twelfths scale is to provide various shortcuts in problem solving graduated in inches and twelfths of inches. Dimensions in feet and inches can be reduced to 1/12th by simply allowing each graduation on the twelfths scale to represent 1 inch; for example, 2 6/12 inches on the twelfths scale may be taken to represent 2 feet 6 inches. A few examples will show you how the twelfths scale is used.

Suppose you want to know the total length of a rafter with a total run of 10 feet and a total rise of 6 feet 5 inches. Set the square on a board with the twelfths scale on the blade at 10 inches and the twelfths scale on the tongue at 6 5/12 inches and make the usual marks. If you measure the distance between the marks, you will find it is 11 11/12 inches. The total length of the rafter is 11 feet 11 inches.

Suppose now that you know the unit of run, unit of rise, and total run of a rafter, and you want to find the total rise and the total length. Use the unit of run (12 inches) and unit of rise (8 inches), and total run of 8 feet 9 inches. Set the square to the unit of rise on the tongue and unit of run on the blade (fig. 2-9, top view). Then, slide the square to the right until the 8 9/12-inch mark on the blade (representing the total run of 8 feet 9 inches) comes even with the edge of the board, as shown in the second view. The figure of 5 10/12 inches, now indicated on the tongue, is one-twelfth of the total rise. The total rise is, therefore, 5 feet 10 inches. The distance between pencil marks (10 7/12 inches) drawn along the tongue and the blade is one-twelfth of the total length. The total length is, therefore, 10 feet 7 inches.

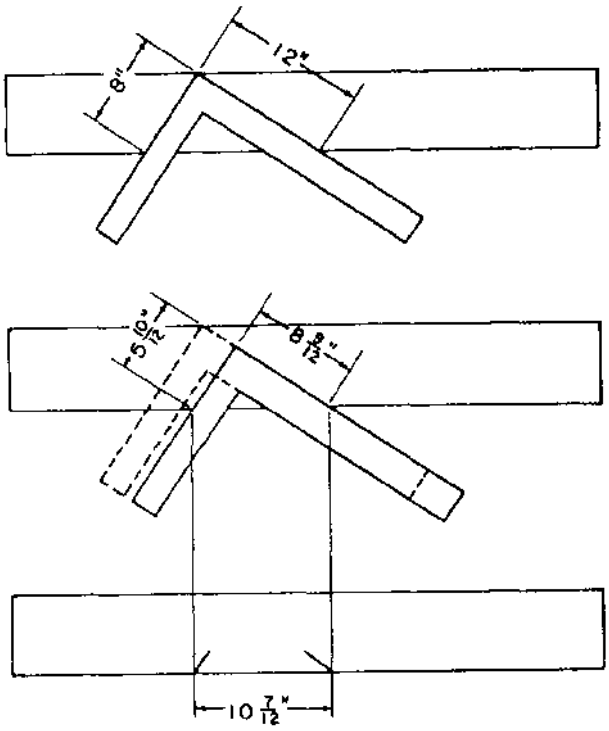


Figure 2-9.-Finding total rise and length when unit of run, unit of rise, and total run are known.

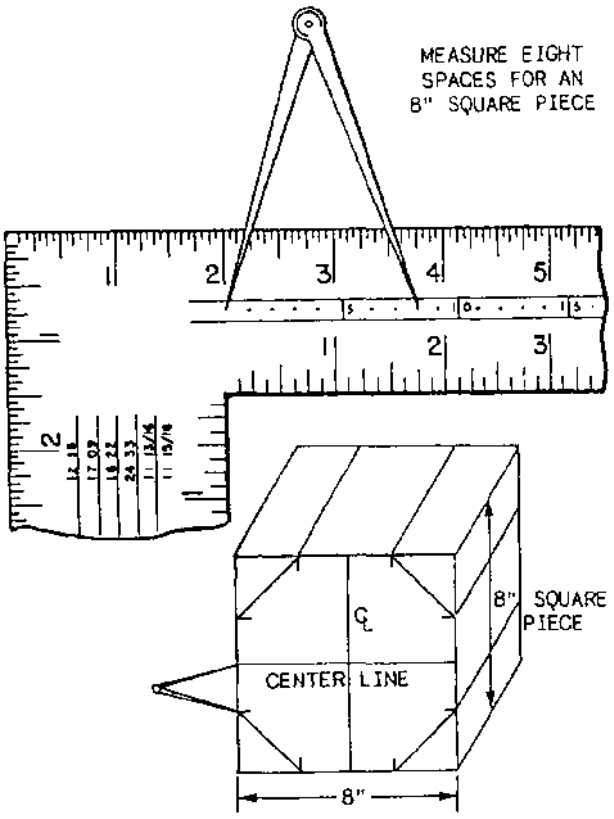


Figure 2-10.—Using the octagon square.

The twelfths scale may also be used to determine dimensions by inspection for proportional reductions or enlargements. Suppose you have a panel 10 feet 9 inches long by 7 feet wide. You want to cut a panel 7 feet long with the same proportions. Set the square, as shown in figure 2-9, but with the blade at 10 9/12 inches and the tongue at 7 inches. Then slide the blade to 7 inches and read the figure indicted on the tongue, which will be 4 7/12 inches if done correctly. The smaller panel should then be 4 feet 7 inches wide.

Hundredths Scale

The hundredths scale is on the back of the tongue, in the comer of the square, near the brace table. This scale is called the hundredths scale because 1 inch is divided into 100 parts. The longer lines indicate 25 hundredths, whereas the next shorter lines indicate 5 hundredths, and so forth. By using dividers, you can easily obtain a fraction of an inch.

The inch is graduated in sixteenths and located below the hundredths scale. Therefore, the conversion from hundredths to sixteenths can be made at a glance without the use of dividers. This can be a great help when determining rafter lengths, using the figures of the rafter tables where hundredths are given.

Octagon Scale

The octagon scale (sometimes called the eight-square scale) is located in the middle of the face of the tongue. The octagon scale is used to lay out an octagon (eight-sided figure) in a square of given even-inch dimensions.

Let's say you want to cut an 8-inch octagonal piece for a stair newel. First, square the stock to 8 by 8 inches and smooth the end section. Then, draw crossed center lines on the end section, as shown in figure 2-10. Next, set a pair of dividers to the distance from the first to the eighth dot on the octagon scale, and layoff this distance on either side of the centerline on the four slanting sides of the octagon. This distance equals one-half the length of a side of the octagon.

When you use the octagon scale, set one leg of the dividers on the first dot and the other leg on the dot whose number corresponds to the width in inches of the square from which you are cutting the piece.

FRAMING SQUARE TABLES

There are three tables on the framing square: the unit length rafter table, located on the face of the blade; the

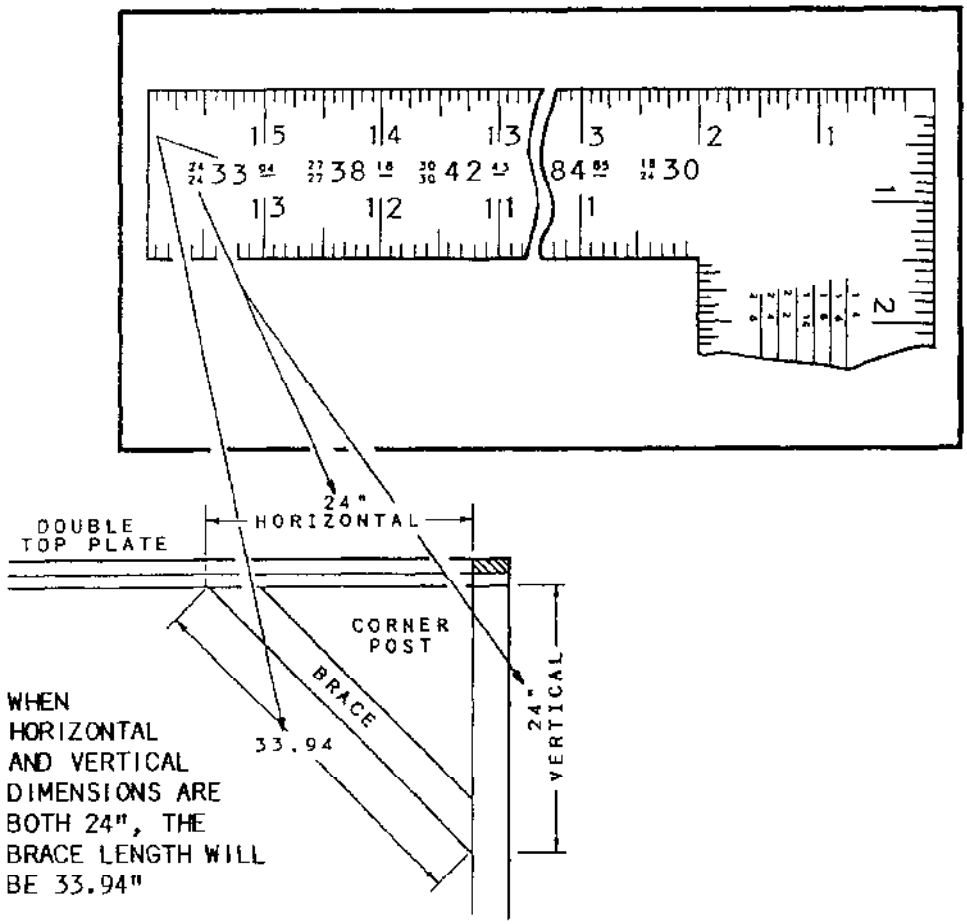


Figure 2-11.-Brace table.

brace table, located on the back of the tongue; and the Essex board measure table, located on the back of the blade. Before you can use the unit length rafter table, you must be familiar with the different types of rafters and with the methods of framing them. The use of the unit length rafter table is described later in this chapter. The other two tables are discussed below.

Brace

The brace table sets forth a series of equal runs and rises for every three-units interval from 24/24 to 60/60, together with the brace length, or length of the hypotenuse, for each given run and rise. The table can be used to determine, by inspection, the length of the hypotenuse of a right triangle with the equal shorter sides of any length given in the table. For example, in the segment of the brace table shown in figure 2-11, you can see that the length of the hypotenuse of a right triangle with two sides 24 units long is 33.94 units; with two sides 27 units long, 38.18 units; two sides 30 units long, 42.43 units; and so on.

By applying simple arithmetic, you can use the brace table to determine the hypotenuse of a right triangle with equal sides of practically any even-unit length. Suppose you want to know the length of the hypotenuse of a right triangle with two sides 8 inches long. The brace table shows that a right triangle with two sides 24 inches long has a hypotenuse of 33.94 inches. Since 8 amounts to 24/3, a right triangle with two shorter sides each 8 inches long must have a hypotenuse of 33.94 ÷3, or approximately 11.31 inches.

Suppose you want to find the length of the hypotenuse of a right triangle with two sides 40 inches each. The sides of similar triangles are proportional, and any right triangle with two equal sides is similar to any other right triangle with two equal sides. The brace table shows that a right triangle with the two shorter sides

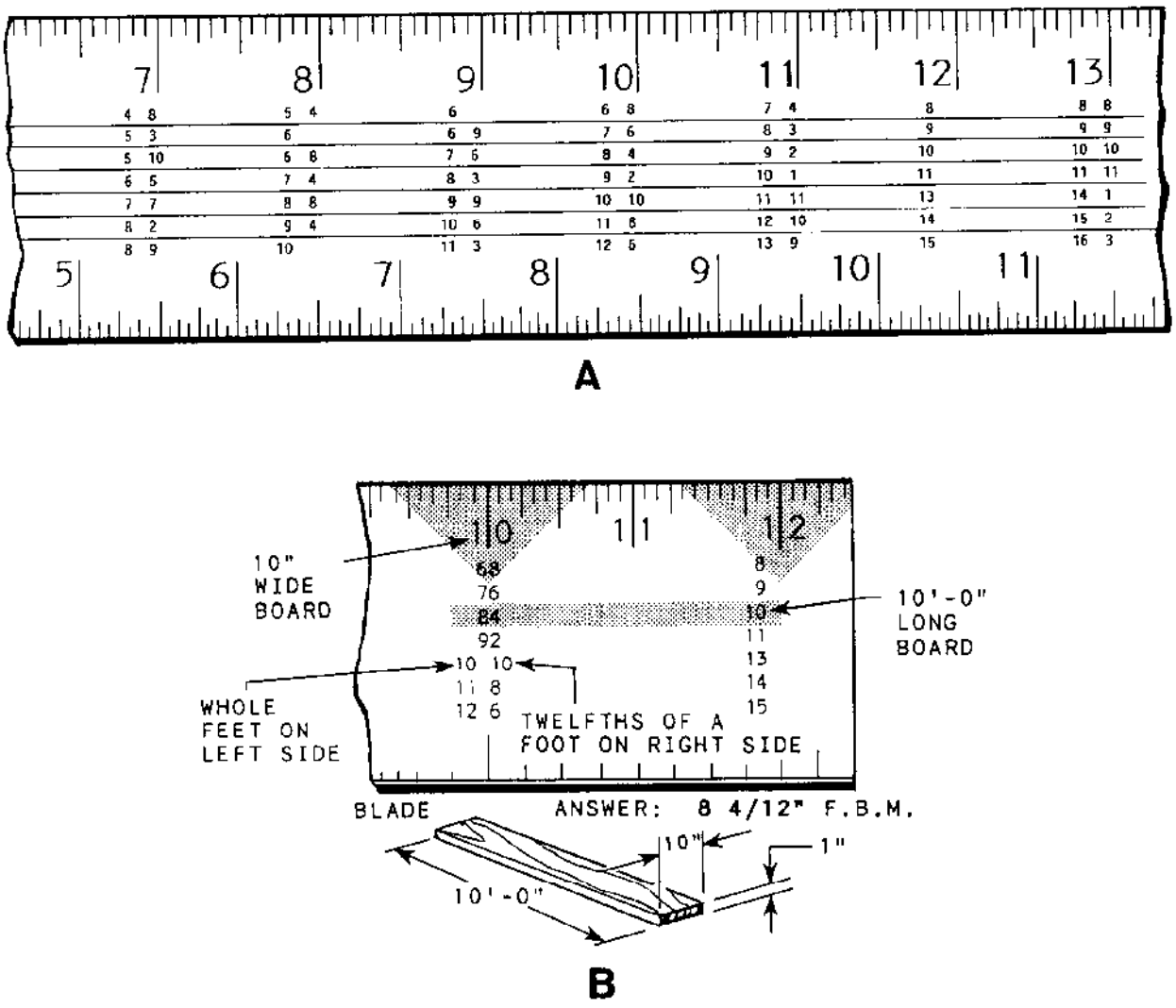


Figure 2-12.-Segment of Essex board measure table.

being 30 inches long has a hypotenuse of 42.43 inches. The length of the hypotenuse of a right triangle with the two shorter sides being 40 inches long must be the value of *x* in the proportional equation *30.42.43::40:x,* or about 56.57 inches.

Notice that the last item in the brace table (the one farthest to the right in fig. 2-11) gives you the hypotenuse of a right triangle with the other proportions 18:24:30. These proportions are those of the most common type of unequal-sided right triangle, with sides in the proportions of 3:4:5.

Essex Board

The primary use of the Essex board measure table is for estimating the board feet in lumber of known dimensions. The inch graduations (fig. 2-12, view A) above the table (1, 2, 3, 4, and so on) represent the width in inches of the piece to be measured. The figures under the 12-inch graduation (8, 9, 10, 11, 13, 14, and 15, arranged in columns) represent lengths in feet. The figure 12 itself represents a 12-foot length. The column headed by the figure 12 is the starting point for all calculations.

To use the table, scan down the figure 12 column to the figure that represents the length of the piece of lumber in feet. Then go horizontally to the figure directly below the inch mark that corresponds to the width of the stock in inches. The figure you find will be the number of board feet and twelfths of board feet in a 1-inch-thick board.

Let's take an example. Suppose you want to figure the board measure of a piece of lumber 10 feet long by 10 inches wide by 1 inch thick. Scan down the column (fig. 2-12, view B) headed by the 12-inch graduation to 10, and then go horizontally to the left to the figure directly below the 10-inch graduation. You will find the figure to be 84, or 8 4/12 board feet. For easier calculating purposes, you can convert 8 4/12 to a decimal (8.33).

To calculate the cost of this piece of lumber, multiply the cost per board foot by the total number of board feet. For example, a 1 by 10 costs $1.15 per board foot. Multiply the cost per board foot ($1. 15) by the number of board feet (8.33). This calculation is as follows:

$1.15
× 8.33

$9.5795 (rounded off to $9.58).

What do you do if the piece is more than 1 inch thick? All you have to do is multiply the result obtained for a 1-inch-thick piece by the actual thickness of the piece in inches. For example, if the board described in the preceding paragraph were 5 inches thick instead of 1 inch thick, you would follow the procedure described and then multiply the result by 5.

The board measure scale can be read only for lumber from 8 to 15 feet in length. If your piece is longer than 15 feet, you can proceed in one of two ways. If the length of the piece is evenly divisible by one of the lengths in the table, you can read for that length and multiply the result by the number required to equal the piece you are figuring. Suppose you want to find the number of board feet in a piece 33 feet long by 7 inches wide by 1 inch thick. Since 33 is evenly divisible by 11, scan down the 12-inch column to 11 and then go left to the 7-inch column. The figure given there (which is 65/12, or 6.42 bd. ft.) is one-third of the total board feet. The total number of board feet is 6 5/12 (or 6.42) x 3, or 19 3/12 (or 19.26) board feet.

If the length of the piece is not evenly divisible by one of the tabulated lengths, you can divide it into two tabulated lengths, read the table for these two, and add the results together. For example, suppose you want to find the board measure of a piece 25 feet long by 10 inches wide by 1 inch thick. This length can be divided into 10 feet and 15 feet. The table shows that the 10-foot length contains 8 4/12 (8.33) board feet and the 15-foot length contains 12 6/12 (12.5) board feet. The total length then contains 8 4/12 (8.33) plus 12 6/12 (12.5), or 20 10/12 (20.83) board feet.

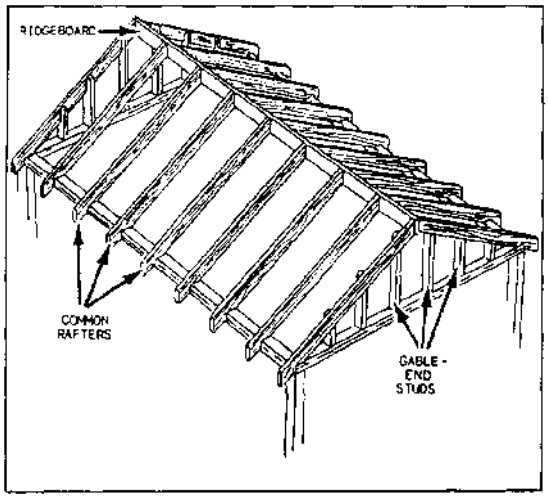


Figure 2-13.—Framework of a gable roof.

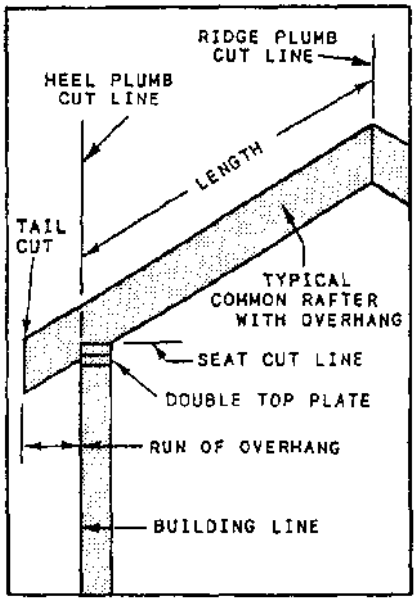


Figure 2-14.—Typical common rafter with an overhang.

DESIGNS

LEARNING OBJECTIVE: Upon completing this section, you should be able to describe procedures for the layout and installation of members of gable, hip, intersecting, and shed roof designs.

As we noted earlier, the four most common roof designs you will encounter as a Builder are gable, hip, intersecting, and shed. In this section, we will examine

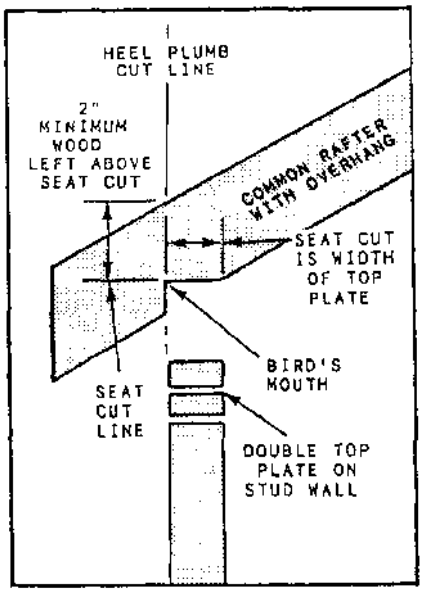


Figure 2-15.—A "bird's-mouth" is formed by the heel plumb line and seat line.

various calculations, layouts, cutting procedures, and assembly requirements required for efficient construction.

GABLE

Next to the shed roof, which has only one slope, the gable roof is the simplest type of sloping roof to build because it slopes in only two directions. The basic structural members of the gable roof are the ridgeboard, the common rafters, and the gable-end studs. The framework is shown in figure 2-13.

The ridgeboard is placed at the peak of the roof. It provides a nailing surface for the top ends of the common rafters. The common rafters extend from the top wall plates to the ridge. The gable-end studs are upright framing members that provide a nailing surface for siding and sheathing at the gable ends of the roof.

Common Rafters

All common rafters for a gable roof are the same length. They can be precut before the roof is assembled. Today, most common rafters include an overhang. The overhang (an example is shown in fig. 2-14) is the part of the rafter that extends past the building line. The run of the overhang, called the projection, is the horizontal distance from the building line to the tail cut on the rafter. In figure 2-14, note the plumb cuts at the ridge, heel, and tail of the rafter. A level seat cut is placed where the rafter rests on the top plate. The notch formed by the seat and heel cut line (fig. 2-15) is often called the bird's-mouth.

The width of the seat cut is determined by the slope of the roof: the lower the slope, the wider the cut. At least 2 inches of stock should remain above the seat cut. The procedure for marking these cuts is explained later in this chapter. Layout is usually done after the length of the rafter is calculated.

CALCULATING LENGTHS OF COMMON RAFTERS.— The length of a common rafter is based on the unit of rise and total run of the roof. The unit of rise and total run are obtained from the blueprints. Three different procedures can be used to calculate common rafter length: use a framing square printed with a rafter table; use a book of rafter tables; or, use the step-off method where rafter layout is combined with calculating length.

Framing squares are available with a rafter table printed on the face side (fig. 2-16). The rafter table makes it possible to find the lengths of all types of rafters for pitched roofs, with unit of rises ranging from 2 inches to 18 inches. Let's look at two examples:

Example 1. The roof has a 7-inch unit of rise and a 16-foot span.

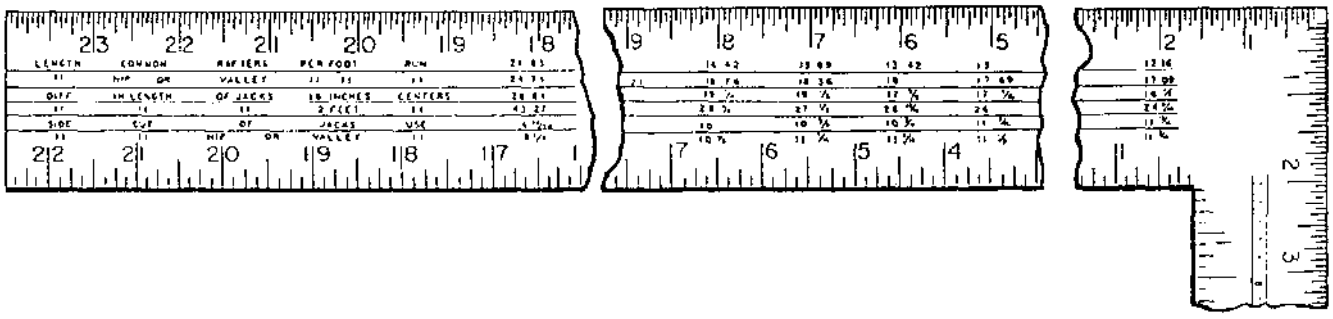


Figure 2-16.—Rafter table on face of a steel square.

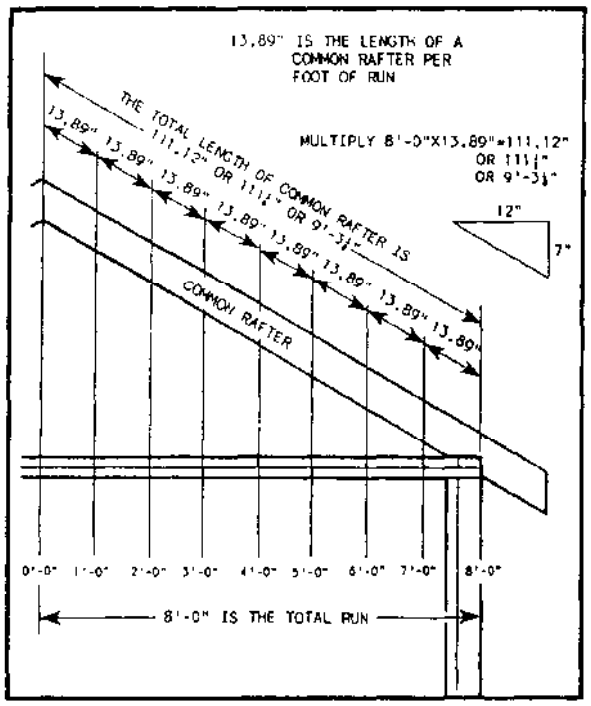


Figure 2-17.—Rafter length.

Look at the first line of the rafter table on a framing square to find LENGTH COMMON RAFTERS PER FOOT RUN (also known as the bridge measure). Since the roof in this example has a 7-inch unit of rise, locate the number 7 at the top of the square. Directly beneath the number 7 is the number 13.89. This means that a common rafter with a 7-inch unit of rise will be 13.89 inches long for every unit of run. To find the length of the rafter, multiply 13.89 inches by the number of feet in the total run. (The total run is always one-half the span.) The total run for a roof with a 16-foot span is 8 feet; therefore, multiply 13.89 inches by 8 to find the rafter length. Figure 2-17 is a schematic of this procedure.

If a framing square is not available, the bridge measure can be found by using the Pythgorean theorum using the same cut of 7/12: $7^2 + 12^2 = 193^2$; the square root of 193 is 13.89.

Two steps remain to complete the procedure.

Step 1. Multiply the number of feet in the total run (8) by the length of the common rafter per foot of run (13.89 inches):

$$\begin{array}{r} 13.89 \text{ inches} \\ \times \quad 8 \\ \hline 111.12 \text{ inches} \end{array}$$

Step 2. To change .12 of an inch to a fraction of an inch, multiply by 16:

$$\begin{array}{r} .12 \\ \times \ 16 \\ \hline 1.92 \end{array}$$

The number 1 to the left of the decimal point represents 1/16 inch. The number .92 to the right of the decimal represents ninety-two hundredths of 1/16 inch. For practical purposes, 1.92 is calculated as being equal to 2 x 1/16 inch, or 1/8 inch. As a general rule in this kind of calculation, if the number to the right of the decimal is 5 or more, add 1/16 inch to the figure on the left side of the decimal. The result of steps 1 and 2 is a total common rafter length of 111 1/8 inches, or 9 feet 3 1/8 inches.

Example 2. A roof has a 6-inch unit of rise and a 25-foot span. The total run of the roof is 12 feet 6 inches. You can find the rafter length in four steps.

Step 1. Change 6 inches to a fraction of a foot by placing the number 6 over the number 12:

$$\frac{6}{12} = \frac{1}{2}$$ (1/2 foot = 6 inches).

Step 2. Change the fraction to a decimal by dividing the bottom number (denominator) into the top number (numerator):

$$\frac{1}{2} = .5$$ (.5 foot = 6 inches).

Step 3. Multiply the total run (12.5) by the length of the common rafter per foot of run (13.42 inches) (fig. 2-16):

$$\begin{array}{r} 12.5 \\ \times \ 13.42 \\ \hline 167.75 \text{ inches.} \end{array}$$

Step 4. To change .75 inch to a fraction of an inch, multiply by 16 (for an answer expressed in sixteenths of an inch).

.75 x 16 = 12

$$12 = \frac{12}{16} \text{ inch, or } \frac{3}{4} \text{ inch.}$$

The result of these steps is a total common rafter length of 167 3/4 inches, or 13 feet 11 3/4 inches.

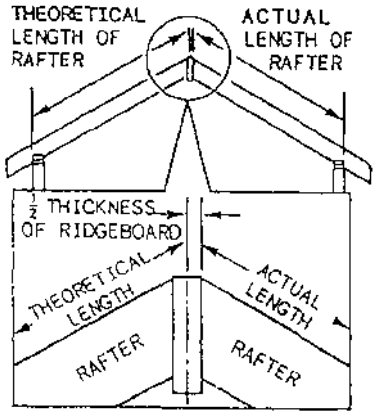


Figure 2-18.—The actual (versus theoretical) length of a common rafter.

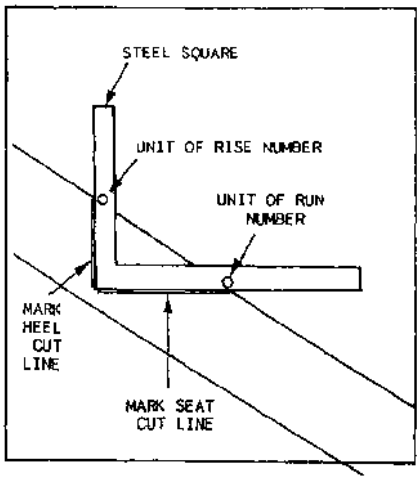


Figure 2-19.-Steel square used to lay out plumb and seat cuts.

SHORTENING.— Rafter length found by any of the methods discussed here is the measurement from the heel plumb line to the center of the ridge. This is known as the theoretical length of the rafter. Since a ridgeboard, usually 1 1/2 inches thick, is placed between the rafters, one-half of the ridgeboard (3/4 inch) must be deducted from each rafter. This calculation is known as shortening the rafter. It is done at the time the rafters are laid out. The actual length (as opposed to the theoretical length) of a ratler is the distance from the heel plumb line to the shortened ridge plumb line (fig. 2-18).

LAYING OUT.— Before the rafters can be cut, the angles of the cuts must be marked. Layout consists of marking the plumb cuts at the ridge, heel, and tail of the rafter, and the seat cut where the rafter will rest on the wall. The angles are laid out with a framing square, as shown in figure 2-19. A pair of square gauges is useful in the procedure. One square gauge is secured to the tongue of the square next to the number that is the same as the unit of rise. The other gauge is secured to the blade of the square next to the number that is the same as the unit of run (always 12 inches). When the square is placed on the rafter stock, the plumb cut can be marked along the tongue (unit of rise) side of the square. The seat cut can be marked along the blade (unit of run) side of the square.

Rafter layout also includes marking off the required overhang, or tail line length, and making the shortening calculation explained earlier. Overhang, or tail line length, is rarely given and must be calculated before laying out rafters. Projection, the horizontal distance from the building line to the rafter tail, must be located from drawings or specifications. To determine tail line length, use the following formula: bridge measure (in inches) times projection (in feet) equals tail line length (in inches). Determine the bridge measure by using the rafter table on the framing square or calculate it by using the Pythagorean theorem. Using figure 2-20 as a guide, you can see there are four basic steps remaining.

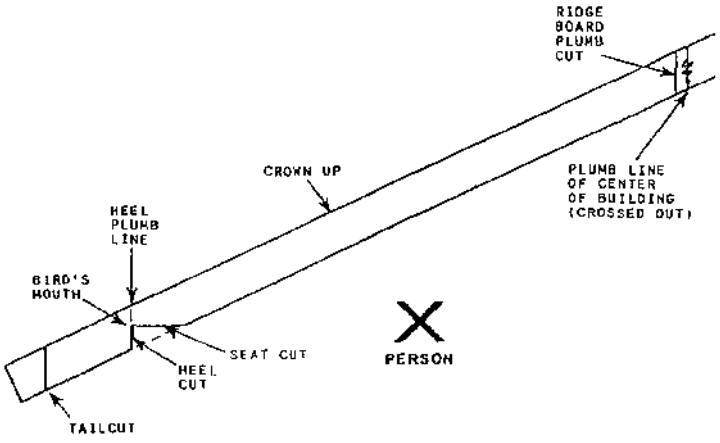


Figure 2-20.—Laying out a common rafter for a gable roof.

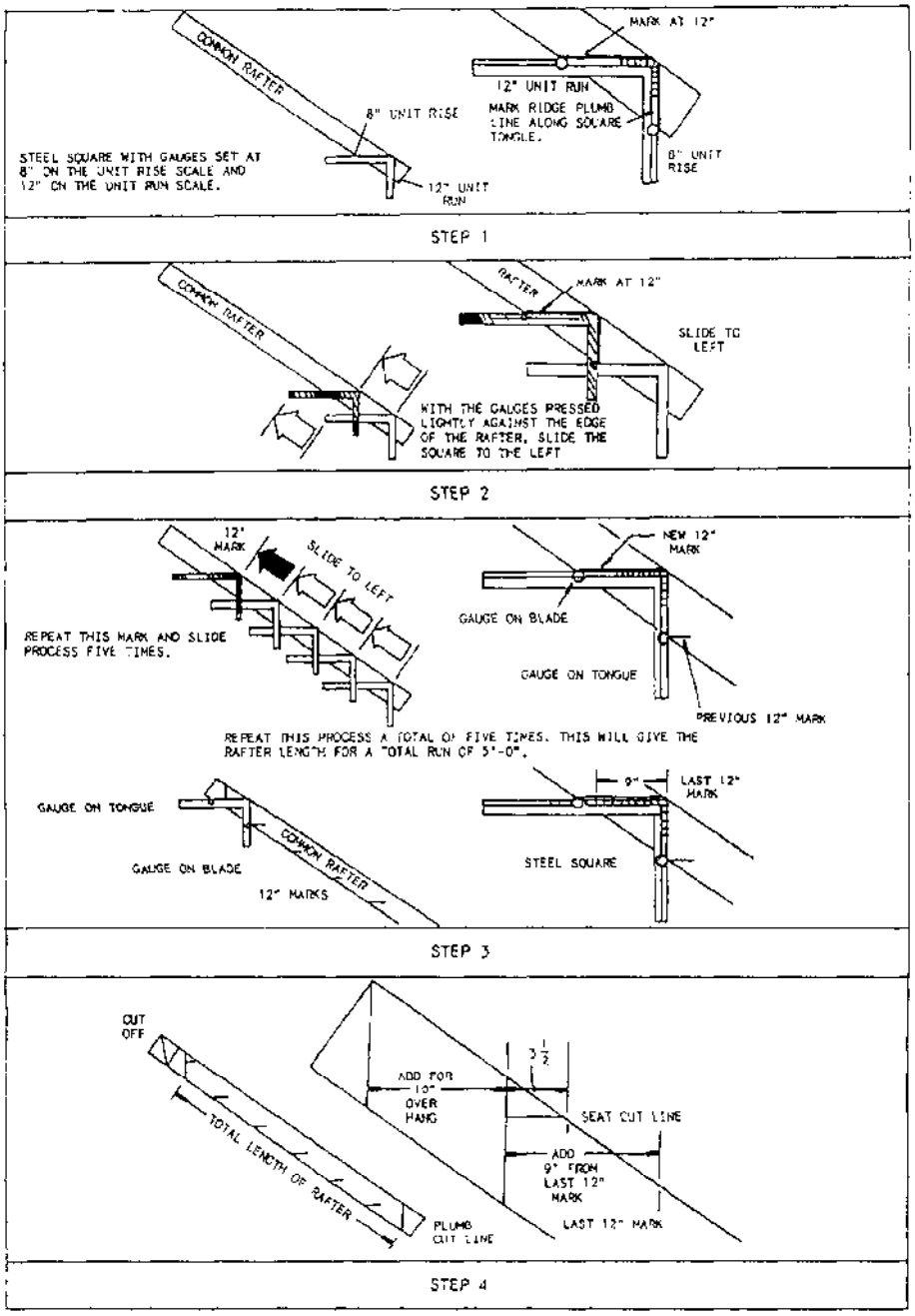


Figure 2-21.-Step-off method for calculating common rafter length.

Step 1. Lay out the rafter line length. Hold the framing square with the tongue in your right hand, the blade in the left, and the heel away from your body. Place the square as near the right end of the rafter as possible with the unit of rise on the tongue and the unit of run on the blade along the edge of the rafter stock. Strike a plumb mark along the tongue on the wide part of the material. This mark represents the center line of the roof. From either end of this mark, measure the line length of the rafter and mark the edge of the rafter stock. Hold the framing square in the same manner with the 6 on the tongue on the mark just made and the 12 on the blade along the edge. Strike a line along the tongue, his mark represents the plumb cut of the heel.

Step 2. Lay out the bird's-mouth. Measure 1 1/2 inches along the heel plumb line up from the bottom of the rafter. Set the blade of the square along the plumb line with the heel at the mark just made and strike a line along the tongue. This line represents the seat of the bird's-mouth.

Step 3. Lay out the tail line length. Measure the tail line length from the bird' s-mouth heel plumb line. Strike a plumb line at this point in the same manner as the heel plumb line of the common rafter.

Step 4. Lay out the plumb cut at the ridgeboard. Measure and mark the point along the line length half the thickness of the ridgeboard. (This is the ridgeboard shortening allowance.) Strike a plumb line at this point. This line represents the plumb cut of the ridgeboard.

Step-Off Calculations and Layout

The step-off method for rafter layout is old but still practiced. It combines procedures for laying out the rafters with a procedure of stepping off the length of the rafter (see fig. 2-21). In this example, the roof has an 8-inch unit of rise, a total run of 5 feet 9 inches, and a 10-inch projection.

First, set gauges at 8 inches on the tongue and 12 inches on the blade. With the tongue in the right hand, the blade in the left hand, and the heel away from the body, place the square on the right end of the rafter stock. Mark the ridge plumb line along the tongue. Put a pencil line at the 12-inch point of the blade.

Second, with the gauges pressed lightly against the rafter, slide the square to the left. Line the tongue up with the last 12-inch mark and make a second 12-inch mark along the bottom of the blade.

Third, to add the 9-inch remainder of the total run, place the tongue on the last 12-inch mark. Draw another mark at 9 inches on the blade. This will be the total length of the rafter.

Last, lay out and cut the plumb cut line and the seat cut line.

Roof Assembly

The major part of gable-roof construction is setting the common rafters in place. The most efficient method is to precut all common rafters, then fasten them to the ridgeboard and the wall plates in one continuous operation.

The rafter locations should be marked on the top wall plates when the positions of the ceiling joists are laid out. Proper roof layout ensures the rafters and joists tie into each other wherever possible.

The ridgeboard like the common rafters, should be precut. The rafter locations are then copied on the ridgeboard from the markings on the wall plates (fig. 2-22). The ridgeboard should be the length of the building plus the overhang at the gable ends.

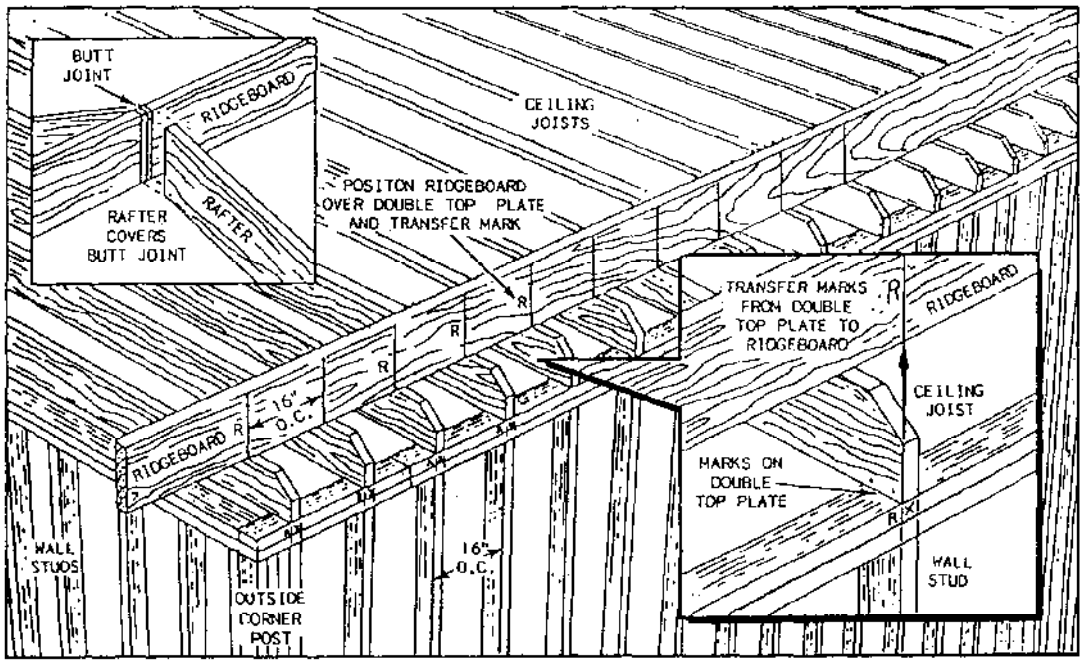


Figure 2-22.—Ridgeboard layout.

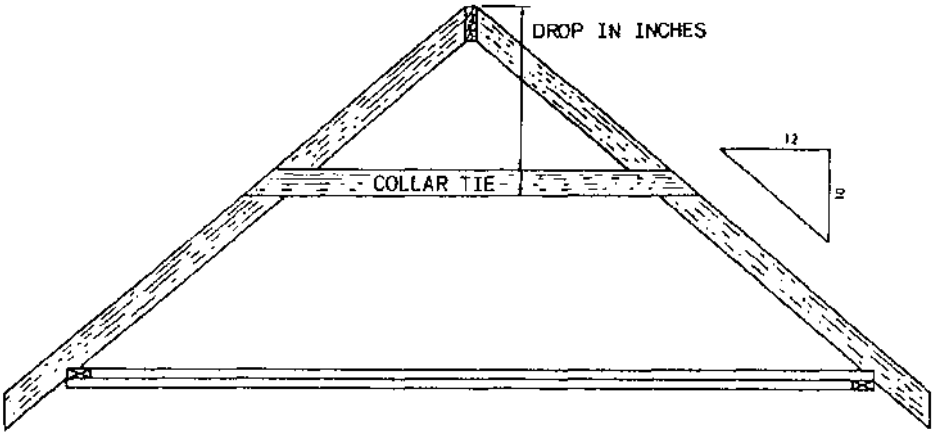


Figure 2-23.—Calculation for a collar tie.

The material used for the ridgeboard is usually wider than the rafter stock. For example, a ridgeboard of 2- by 8-inch stock would be used with rafters of 2- by 6-inch stock. Some buildings are long enough to require more than one piece of ridge material. The breaks between these ridge pieces should occur at the center of a rafter.

One pair of rafters should be cut and checked for accuracy before the other rafters are cut. To check the first pair for accuracy, set them in position with a 1 1/2-inch piece of wood fitted between them. If the rafters are the correct length, they should fit the building. If, however, the building walls are out of line, adjustments will have to be made on the rafters.

After the first pair of rafters is checked for accuracy (and adjusted if necessary), one of the pair can be used as a pattern for marking all the other rafters. Cutting is usually done with a circular or radial-arm saw.

COLLAR TIE.— Gable or double-pitch roof rafters are often reinforced by horizontal members

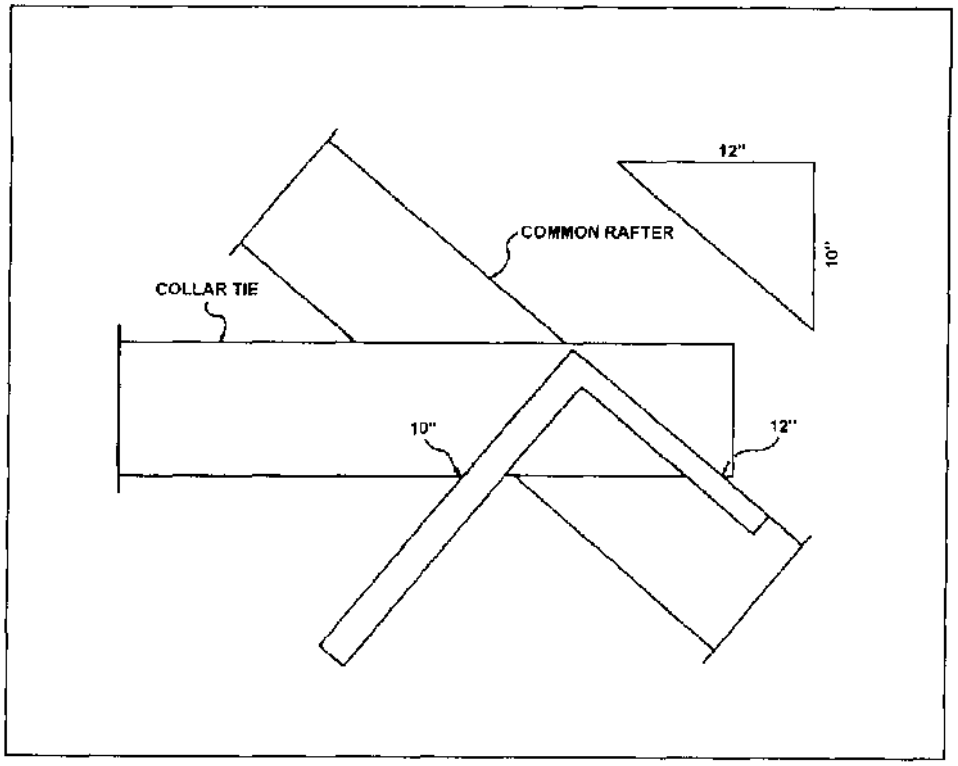


Figure 2-24.—Laying out end cut on a collar tie.

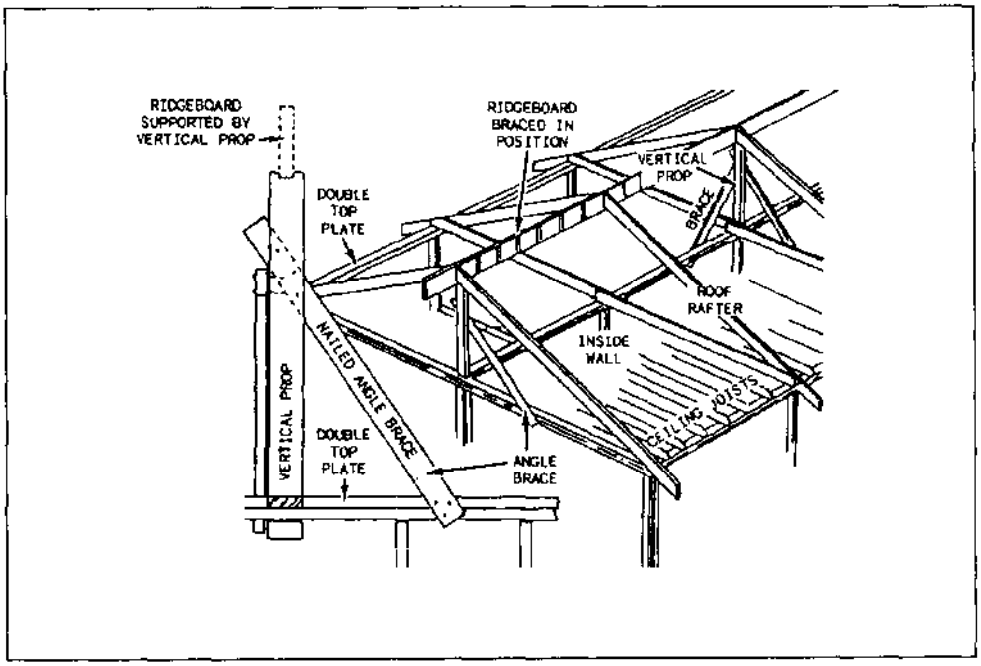


Figure 2-25.-Setting up and bracing a ridgeboard when only a few workers are available.

called collar ties (fig. 2-23). In a finished attic, the ties may also function as ceiling joists.

To find the line length of a collar tie, divide the amount of drop of the tie in inches by the unit of rise of the common rafter. This will equal one-half the length of the tie in feet. Double the result for the actual length. The formula is as follows: Drop in inches times 2, divided by unit or rise, equals the length in feet.

The length of the collar tie depends on whether the drop is measured to the top or bottom edge of the collar tie (fig. 2-23). The tie must fit the slope of the roof. To obtain this angle, use the framing square. Hold the unit of run and the unit of rise of the common rafter. Mark and cut on the unit of run side (fig. 2-24).

METHODS OF RIDGE BOARD ASSEMBLY.— Several different methods exist for setting up the ridgeboard and attaching the rafters to it. When only a few Builders are present, the most convenient procedure is to set the ridgeboard to its required height (total rise) and hold it in place with temporary vertical props (fig. 2-25). The rafters can then be nailed to the ridgeboard and the top wall plates.

Plywood panels should be laid on top of the ceiling joists where the framing will take place. The panels provide safe and comfortable footing. They also provide a place to put tools and materials.

Common rafter overhang can be laid out and cut before the rafters are set in place. However, many Builders prefer to cut the overhang after the rafters are fastened to the ridgeboard and wall plates. A line is snapped from one end of the building to the other, and the tail plumb line is marked with a sliding T-bevel, also called a bevel square. These procedures are shown in figure 2-26. The rafters are then cut with a circular saw.

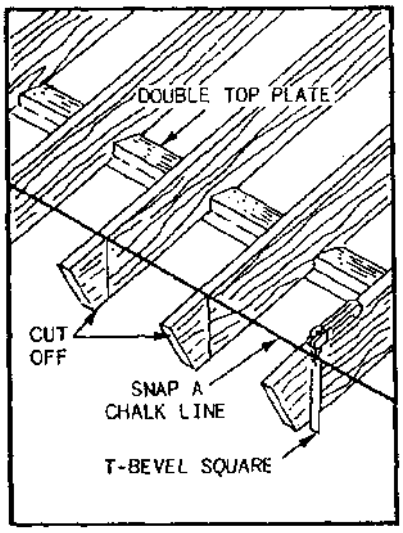


Figure 2-26.-Snapping a line and marking plumb cuts for a gable-end overhang.

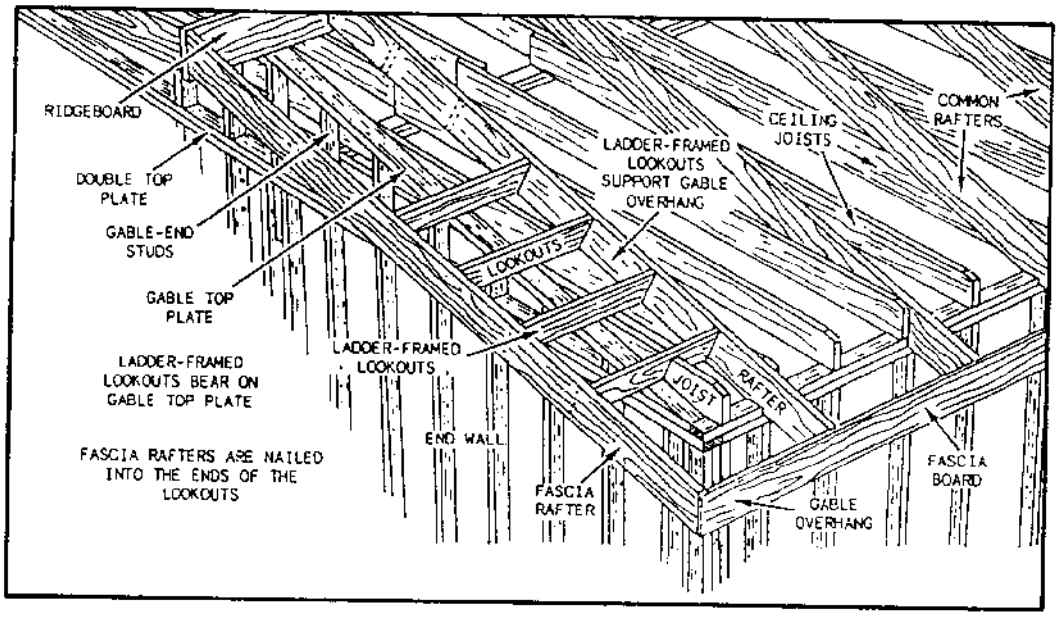


Figure 2-27.-Gable-end overhang with the end wall framed under the overhang.

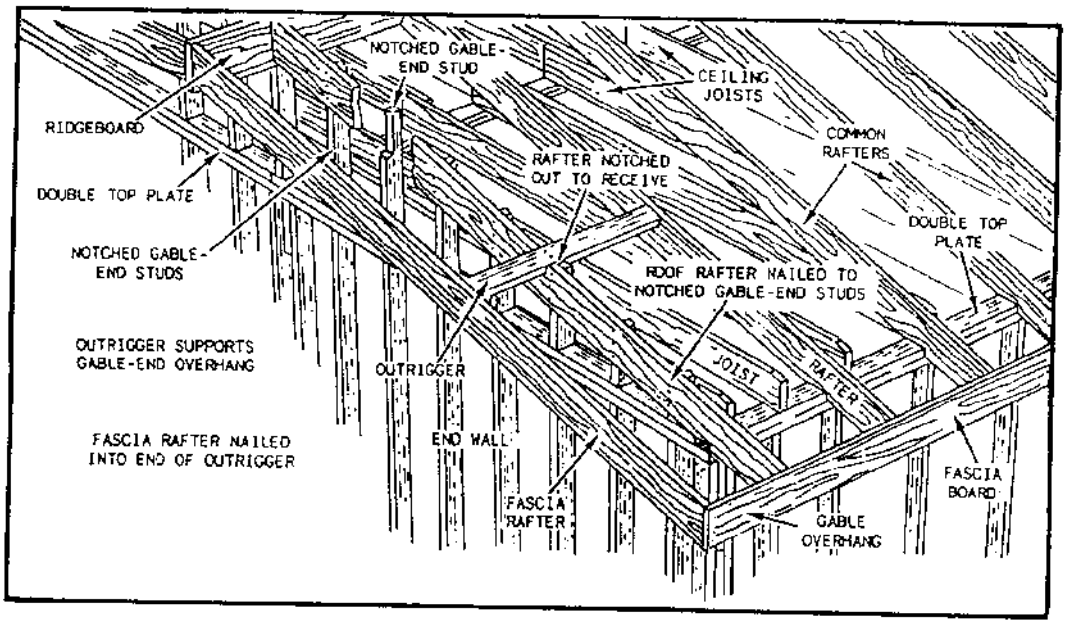


Figure 2-28.-Gable-end overhang with the end wall framed directly beneath the rafters.

This method guarantees that the line of the overhang will be perfectly straight, even if the building is not.

Over each gable end of the building, another overhang can be framed. The main framing members of the gable-end overhang are the fascia, also referred to as "fly" (or "barge") rafters. They are tied to the ridgeboard at the upper end and to the fascia board at the lower end. Fascia boards are often nailed to the tail ends of the common rafters to serve as a finish piece at the edge of the roof. By extending past the gable ends of the house, common rafters also help to support the basic rafters.

Figures 2-27 and 2-28 show different methods used to frame the gable-end overhang. In figure 2-27, a fascia rafter is nailed to the ridgeboard and to the fascia board. Blocking (not shown in the figures) rests on the end wall and is nailed between the fascia rafter and the rafter next to it. This section of the roof is further strengthened when the roof sheathing is nailed to it. In figure 2-28, two common rafters arc placed directly over the gable

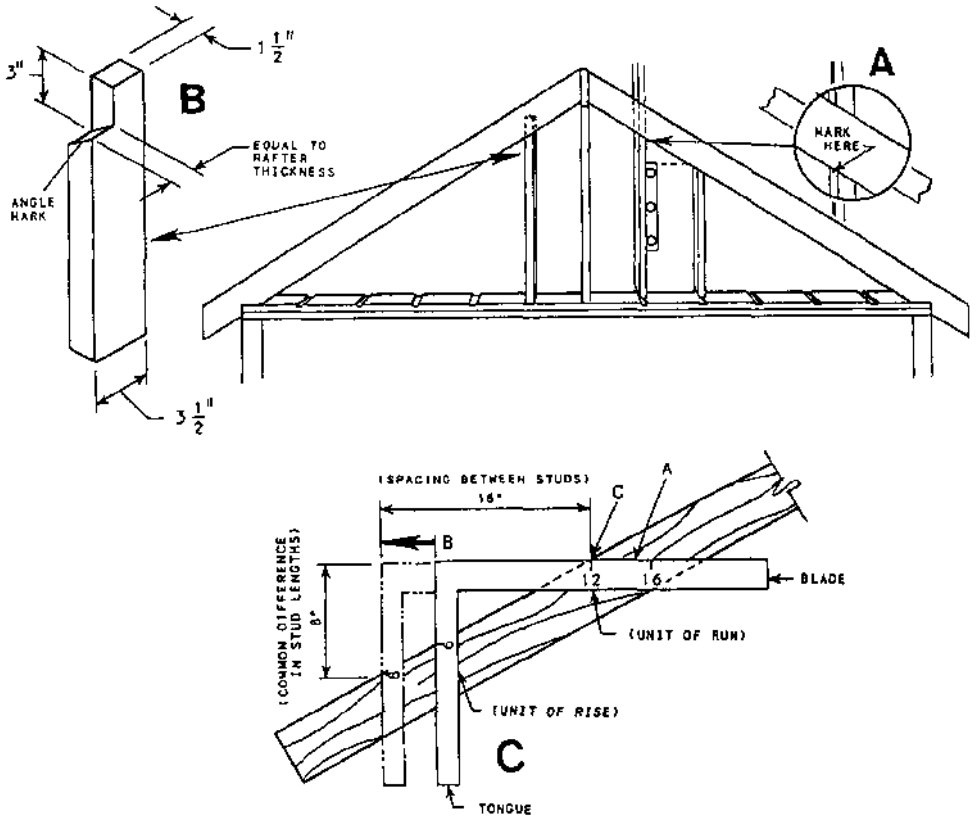


Figure 2-29.—Calculating common difference of gable-end studs.

ends of the building. The fascia rafters (fly rafters) are placed between the ridgeboard and the fascia boards. The gable studs should be cut to fit against the rafter above.

End Framing

Gable-end studs rest on the top plate and extend to the rafter line in the ends of a gable roof. They may be placed with the edge of the stud even with the outside wall and the top notched to fit the rafter (as shown in fig. 2-28), or they maybe installed flatwise with a cut on the top of the stud to fit the slope of the rafter.

The position of the gable-end stud is located by squaring a line across the plate directly below the center of the gable. If a window or vent is to be installed in the gable, measure one-half of the opening size on each side of the center line and make a mark for the first stud. Starting at this mark layout the stud spacing (that is, 16 or 24 inches on center [OC]) to the outside of the building. Plumb the gable-end stud on the first mark and mark it where it contacts the bottom of the rafter, as shown in figure 2-29, view A. Measure and mark 3 inches above this mark and notch the stud to the depth equal to the thickness of the rafter, as shown in view B. The lengths of the other gable studs depend on the spacing.

The common difference in the length of the gable studs may be figured by the following method:

$$\frac{\text{24 inches (OC spacing)}}{\text{12 inches (unit of run)}} = 2$$

and, 2 x 6 inches (unit of rise) or 12 inches (common difference).

The common difference in the length of the gable studs may also be laid out directly with the framing square (fig. 2-29, view C). Place the framing square on the stud to the cut of the roof (6 and 12 inches for this example). Draw a line along the blade at A. Slide the square along this line in the direction of the arrow at B until the desired spacing between the studs (16 inches for this example) is at the intersection of the line drawn at A and the edge of the stud. Read the dimension on the tongue aligned with the same edge of the stud (indicated by C). This is the common difference (8 inches for this example) between the gable studs.

Toenail the studs to the plate with two 8d nails in each side. As the studs are nailed in place, care must be taken not to force a crown into the top of the rafter.

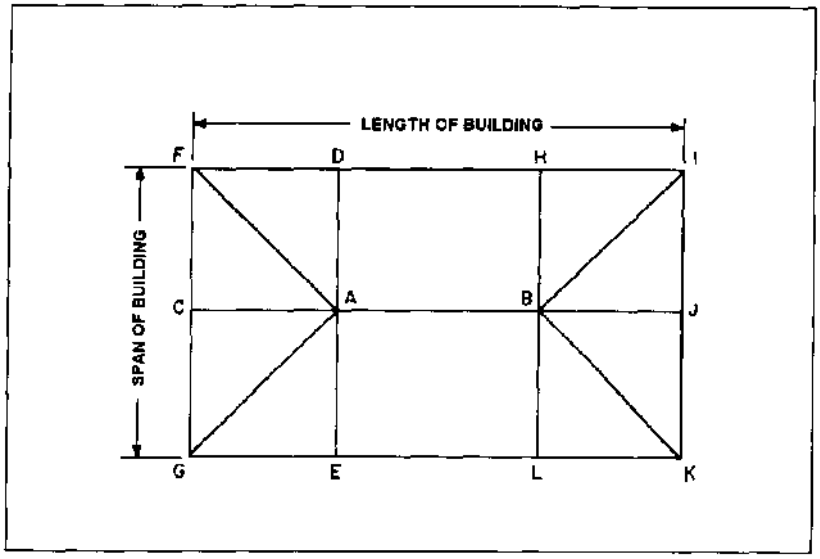


Figure 2-30.—Equal-pitch hip roof framing diagram.

HIP

Most hip roofs are equal pitch. This means the angle of slope on the roof end or ends is the same as the angle of slope on the sides. Unequal-pitch hip roofs do exist, but they are quite rare. They also require special layout methods. The unit length rafter table on the framing square applies only to equal-pitch hip roofs. The next paragraphs discuss an equal-pitch hip roof.

The length of a hip rafter, like the length of a common rafter, is calculated on the basis of bridge measure multiplied by the total run (half span). Any of the methods previously described for a common rafter may be used, although some of the dimensions for a hip rafter are different.

Figure 2-30 shows part of a roof framing diagram for an equal-pitch hip roof. A roof framing diagram may be included among the working drawings; if not, you should lay one out for yourself. Determine what scale will be used, and lay out all framing members to scale. Lay the building lines out first. You can find the span and the length of the building on the working drawings. Then, draw a horizontal line along the center of the span.

In an equal-pitch hip roof framing diagram, the lines indicating the hip rafters (AF, AG, BI, and BK in figure 2-30) form 45° angles with the building lines. Draw these lines at 45°, as shown. The points where they meet the center line are the theoretical ends of the ridge piece. The ridge-end common rafters AC, AD, AE, BH, BJ, and BL join the ridge at the same points.

A line indicating a rafter in the roof framing diagram is equal in length to the total run of the rafter it represents. You can see from the diagram that the total run of a hip rafter (represented by lines AF-AG-BI-BK) is the hypotenuse of a right triangle with the altitude and base equal to the total run of a common rafter. You know the total run of a common rafter: It is one-half the span, or one-half the width of the building. Knowing this, you can find the total run of a hip rafter by applying the Pythagorean theorem.

Let's suppose, for example, that the span of the building is 30 feet. Then, one-half the span, which is the same as the total run of a common rafter, is 15 feet. Applying the Pythagorean theorem, the total run of a hip rafter is:

$$\sqrt{(15^2 + 15^2)} = 21.21 \text{ feet.}$$

What is the total rise? Since a hip rafter joins the ridge at the same height as a common rafter, the total rise for a hip rafter is the same as the total rise for a common rafter. You know how to figure the total rise of a common rafter. Assume that this roof has a unit of run of 12 and a unit of rise of 8. Since the total run of a common rafter in the roof is 15 feet, the total rise of common rafter is the value of x in the proportional equation $12:8::15:x$, or 10 feet.

Knowing the total run of the hip rafter (21.21 feet) and the total rise (10 feet), you can figure the line length by applying the Pythagorean theorem. The line length is:

$\sqrt{(21.21^2 + 10^2)}$ = 23.45 feet, or about 23 feet 5 3/8 inches.

To find the length of a hip rafter on the basis of bridge measure, you must first determine the bridge measure. As with a common rafter, the bridge measure of a hip rafter is the length of the hypotenuse of a triangle with its altitude and base equal to the unit of run and unit of rise of the rafter. The unit of rise of a hip rafter is always the same as that of a common rafter, but the unit of run of a hip rafter is a fixed unit of measure, always 16.97.

The unit of run of a hip rafter in an equal-pitch roof is the hypotenuse of a right triangle with its altitude and base equal to the unit of run of a common rafter, 12. Therefore, the unit of run of a hip rafter is:

$$\sqrt{(12^2 + 12^2)} = 16.97$$

If the unit of run of a hip rafter is 16.97 and the unit of rise (in this particular case) is 8, the bridge measure of the hip rafter must be:

$$\sqrt{(16.97^2 + 8^2)} = 18.76$$

This means that for every unit of run (16.97) the rafter has a line length of 18.76 inches. Since the total run of the rafter is 21.21 feet, the length of the rafter must be the value of x in the proportional equation *16.97:18.76::21.21:x,* or 23.45 feet.

Like the unit length of a common rafter, the bridge measure of a hip rafter can be obtained from the unit length rafter table on the framing square. If you turn back to figure 2-16, you will see that the second line in the table is headed LENGTH HIP OR VALLEY PER FT RUN. This means "per foot run of a common rafter in the same roof." Actually, the unit length given in the tables is the unit length for every 16.97 units of run of the hip rafter itself. If you go across to the unit length given under 8, you will find the same figure, 18.76 units, that you calculated above.

An easy way to calculate the length of an equal-pitch hip roof is to multiply the bridge measure by the number of feet in the total run of a common rafter, which is the same as the number of feet in one-half of the building span. One-half of the building span, in this case, is 15 feet. The length of the hip rafter is therefore *18.76* x *15,* or 281.40 inches—23.45 feet once converted.

You step off the length of an equal-pitch hip roof just as you do the length of a common rafter, except that you set the square to a unit of run of 16.97 inches instead of to a unit of run of 12 inches. Since 16.97 inches is the same as 16 and 15.52 sixteenths of an inch, setting the square to a unit of run of 17 inches is close enough for most practical purposes. Bear in mind that for any plumb cut line on an equal-pitch hip roof rafter, you set the square to the unit of rise of a common rafter and to a unit of run of 17.

You step off the same number of times as there are feet in the total run of a common rafter in the same roof; only the size of each step is different. For every 12-inch step in a common rafter, a hip rafter has a 17-inch step. For the roof on which you are working, the total run of common rafter is exactly 15 feet; this means that you would step off the hip-rafter cut (17 inches and 8 inches) exactly 15 times.

Suppose, however, that there was an odd unit in the common rafter total run. Assume, for example, that the total run of a common rafter is 15 feet 10 1/2 inches. How would you make the odd fraction of a step on the hip rafter?

You remember that the unit of run of a hip rafter is the hypotenuse of a right triangle with the other side each equal to the unit of run of a common rafter. In this case, the run of the odd unit on the hip rafter must be the hypotenuse of a right triangle with the altitude and base equal to the odd unit of run of the common rafter (in this case, 10 1/2 inches). You can figure this using the Pythagorean theorem

$$\sqrt{(10.5^2 + 10.5^2)}$$

or you can set the square on a true edge to 10 1/2 inches on the blade and measure the distance between the marks. It comes to 14.84 inches. Rounded off to the nearest 1/16 inch, this equals 14 13/16 inches.

To layoff the odd unit, set the tongue of the framing square to the plumb line for the last full step made and measure off 14 13/16 inches along the blade. Place the tongue of the square at the mark, set the square to the hip rafter plumb cut of 8 inches on the tongue and 17 inches on the blade, and draw the line length cut.

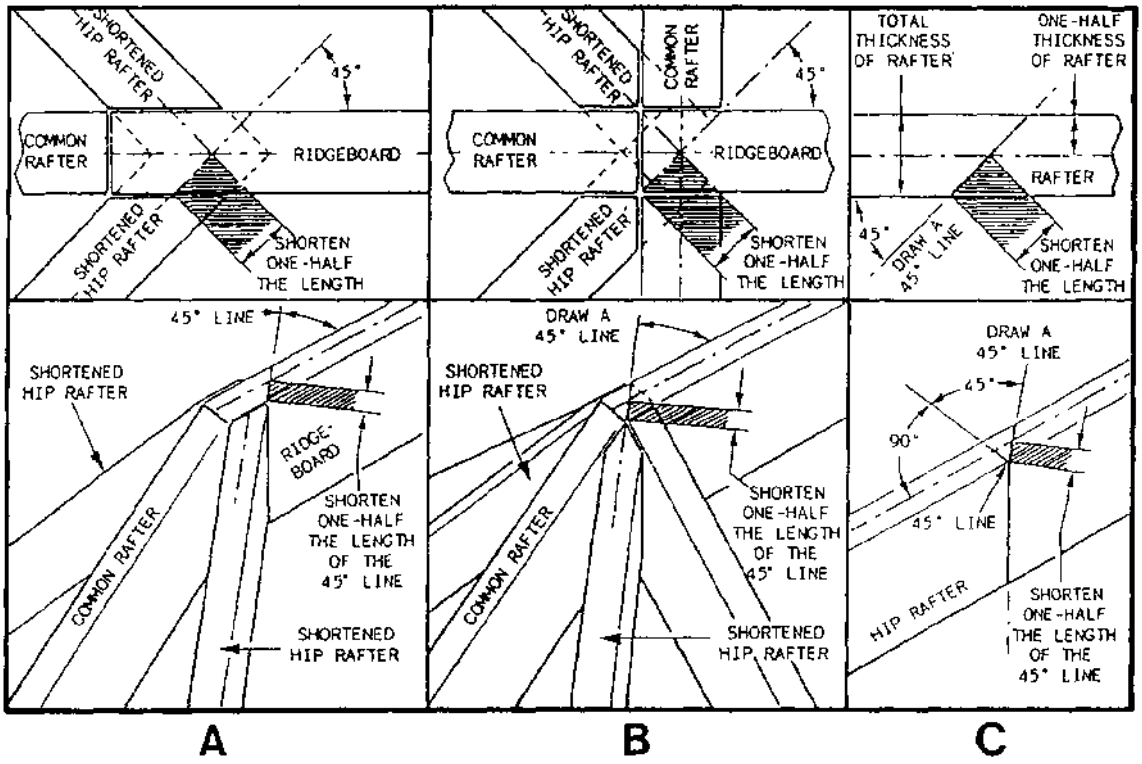


Figure 2-31.-Shortening a hip rafter.

Rafter Shortening Allowance

As in the case with a common rafter, the line length of a hip rafter does not take into account the thickness of the ridge piece. The size of the ridge-end shortening allowance for a hip rafter depends upon the way the ridge end of the hip rafter is joined to the other structural members. As shown in figure 2-31, the ridge end of the hip rafter can be framed against the ridgeboard (view A) or against the ridge-end common rafters (view B). To calculate the actual length, deduct one-half the 45° thickness of the ridge piece that fits between the rafters from the theoretical length.

When no common rafters are placed at the ends of the ridgeboard the hip rafters are placed directly against the ridgeboard. They must be shortened one-half the length of the 45° line (that is, one-half the thickness of the ridgeboard When common rafters are placed at the ends of the ridgeboard (view B), the hip rafter will fit between the common rafters. The hip rafter must be shortened one-half the length of the 45° line (that is, one-half the thickness of the common rafter).

If the hip rafter is framed against the ridge piece, the shortening allowance is one-half of the 45° thickness of the ridge piece (fig. 2-31, view C). The 45° thickness of stock is the length of a line laid at 45° across the thickness dimension of the stock. If the hip rafter is framed against the common rafter, the shortening allowance is one-half of the 45° thickness of a common rafter.

To lay off the shortening allowance, first set the tongue of the framing square to the line length ridge cut line. Then, measure off the shortening allowance along the blade, set the square at the mark to the cut of the rafter (8 inches and 17 inches), draw the actual ridge plumb cut line. (To find the 45° thickness of a piece of lumber, draw a 450 line across the edge, and measure the length of the line and divide by 2.)

Rafter Projection

A hip or valley rafter overhang, like a common rafter overhang, is figured as a separate rafter. The projection, however, is not the same as the projection of a common rafter overhang in the same roof. The projection of the hip or valley rafter overhang is the hypotenuse of a right triangle whose shorter sides are each equal to the run of a common rafter overhang (fig. 2-32). If the run of the common rafter overhang is

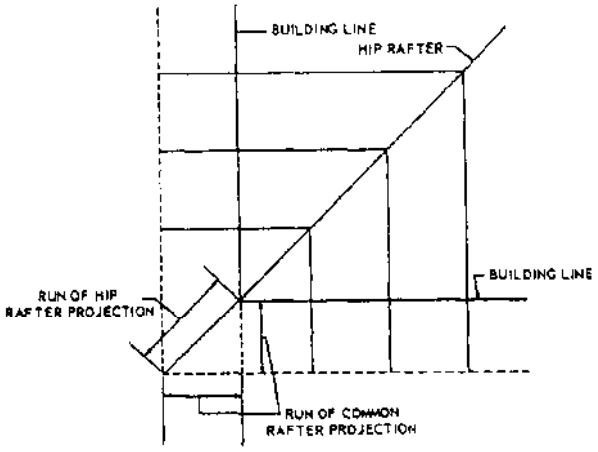


Figure 2-32.—Run of hip rafter projection.

18 inches for a roof with an 8-inch unit of rise, the length of the hip or valley rafter tail is figured as follows:

1. Find the bridge measure of the hip or valley rafter on the framing square (refer to figure 2-16). For this roof, it is 18.76 inches.
2. Multiply the bridge measure (in inches) of the hip or valley rafter by the projection (in feet) of the common rafter overhang:

   18.76 inches (bridge measure)
   × 1.5 feet (projection of the common rafter)
   28.14, or 28 1/8 inches.

3. Add this product to the theoretical rafter length.

The overhang may also be stepped off as described earlier for a common rafter. When stepping off the length of the overhang, set the 17-inch mark on the blade of the square even with the edge of the rafter. Set the unit of rise, whatever it might be, on the tongue even with the same rafter edge.

Rafter Side Cuts

Since a common rafter runs at 90° to the ridge, the ridge end of a common rafter is cut square, or at 90° to the lengthwise line of the rafter. A hip rafter, however, joins the ridge, or the ridge ends of the common rafter, at other than a 90° angle, and the ridge end of a hip rafter must therefore be cut to a corresponding angle, called a side cut. The angle of the side cut is more acute for a high rise than it is for a low one.

The angle of the side cut is laid out as shown in figure 2-33. Place the tongue of the framing square

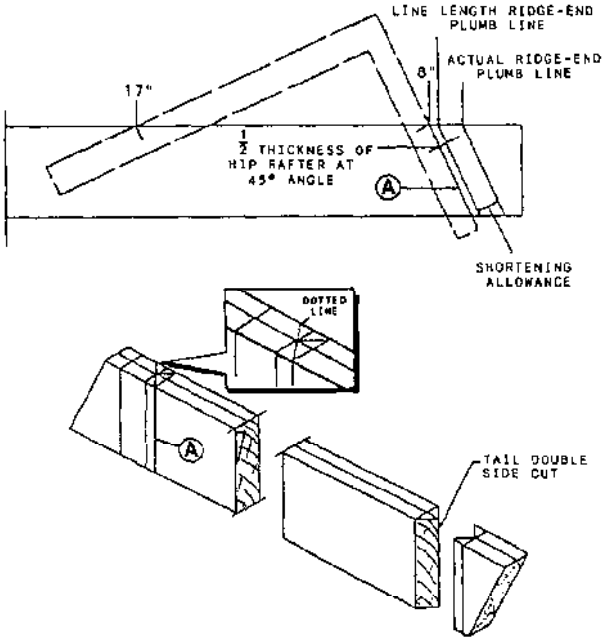


Figure 2-33.—Laying out hip rafter side cut.

along the ridge cut line, as shown, and measure off one-half the thickness of the hip rafter along the blade. Shift the tongue to the mark, set the square to the cut of the rafter (17 inches and 8 inches), and draw the plumb line marked "A" in the figure. Then, turn the rafter edge-up, draw an edge centerline, and draw in the angle of the side cut, as indicated in the lower view of figure 2-33. For a hip rafter to be framed against the ridge, there will be only a single side cut, as indicated by the dotted line in the figure. For one to be framed against the ridge ends of the common rafters, there will be a double side cut, as shown in the figure. The tail of the rafter must have a double side cut at the same angle, but in the reverse direction.

The angle of the side cut on a hip rafter may also be laid out by referring to the unit length rafter table on the framing square. (Look ahead to figure 2-41.) You will see that the bottom line in the table is headed SIDE CUT HIP OR VALLEY USE. If you follow this line over to the column headed by the figure 8 (for a unit of rise of 8), you will find the figure 10 7/8. If you place the framing square faceup on the rafter edge with the tongue on the ridge-end cut line, and set the square to a cut of 10 7/8 inches on the blade and 12 inches on the tongue, you can draw the correct side-cut angle along the tongue.

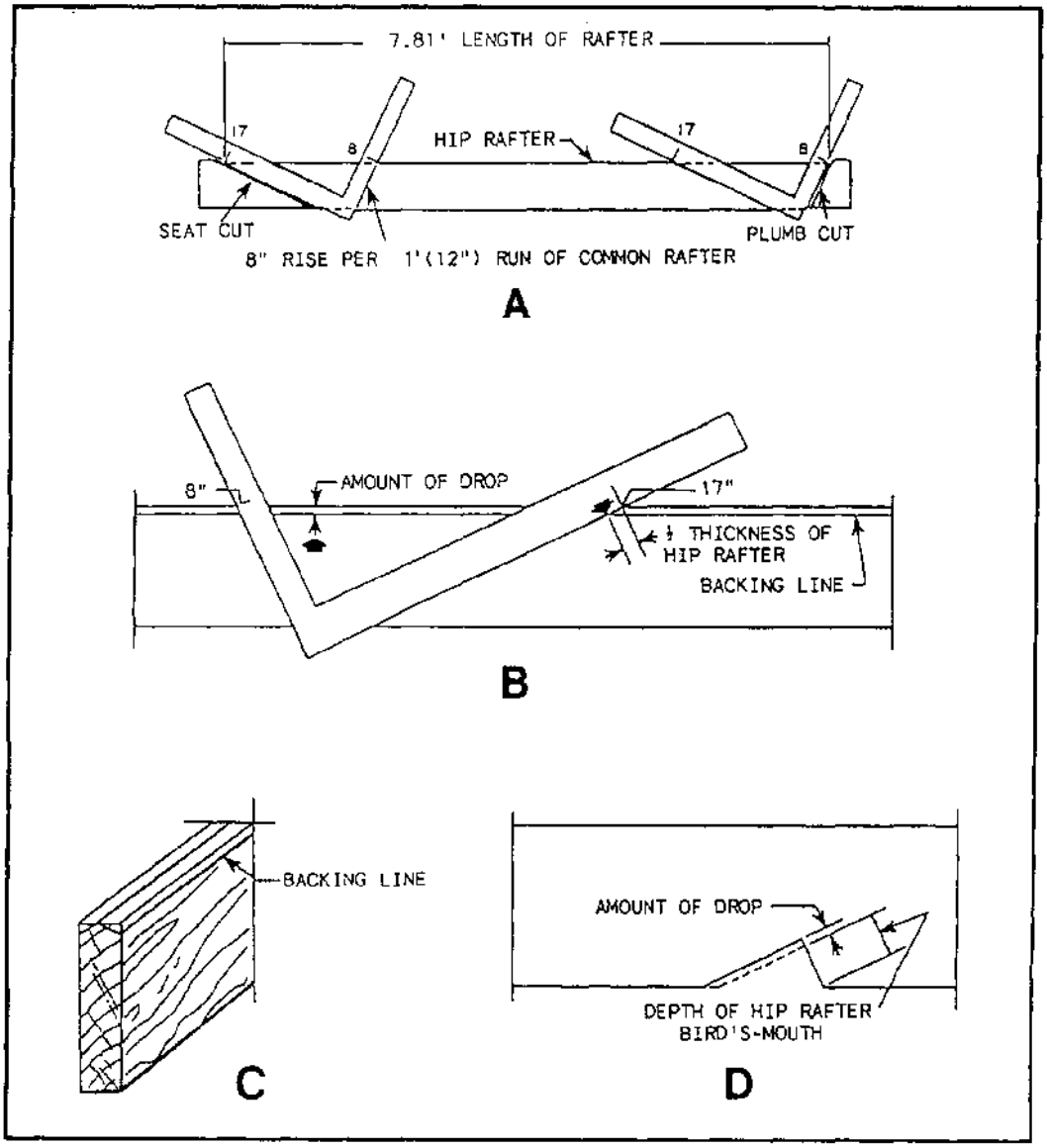


Figure 2-34.-Backing or dropping a hip rafter: A. Marking the top (plumb) cut and the seat (level) cut of a hip rafter; B. Determining amount of backing or drop; C. Bevel line for backing the rafter; D. Deepening the bird's-mouth for dropping the rafter.

Bird's-Mouth

Laying out the bird' s-mouth for a hip rafter is much the same as for a common rafter. However, there are a couple of things to remember. When the plumb (heel) cut and level (seat) cut lines are laid out for a bird's-mouth on a hip rafter, set the body of the square at 17 inches and the tongue to the unit of rise (for example, 8 inches-depending on the roof pitch) (fig. 2-34, view A). When laying out the depth of the heel for the bird's-mouth, measure along the heel plumb line down from the top edge of the rafter a distance equal to the same dimension on the common rafter. This must be done so that the hip rafter, which is usually wider than a common rafter, will be level with the common rafters.

If the bird's-mouth on a hip rafter has the same depth as the bird's-mouth on a common rafter, the edge of the hip rafter will extend above the upper ends of the jack rafters. You can correct this by either backing or dropping the hip rafter. Backing means to bevel the top edges of the hip rafter (see fig. 2-35). The amount of backing is taken at a right angle to the roof surface on

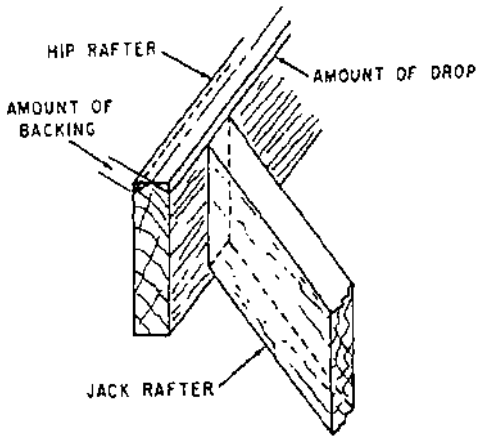


Figure 2-35.-Backing or dropping a hip rafter.

the top edge of the hip rafters. Dropping means to deepen the bird's-mouth so as to bring the top edge of the hip rafter down to the upper ends of the jacks. The amount of drop is taken on the heel plumb line (fig. 2-34, view D).

The backing or drop required is calculated, as shown in figure 2-34, view B. Set the framing square to the cut of the rafter (8 inches and 17 inches) on the upper edge, and measure off one-half the thickness of the rafter from the edge along the blade. A line drawn through this mark and parallel to the edge (view C) indicates the bevel angle if the rafter is to be backed. The perpendicular distance between the line and the edge of the rafter is the amount of the drop. This represents the amount the depth of the hip rafter bird's-mouth should exceed the depth of the common rafter bird's-mouth (view D).

INTERSECTING

An intersecting roof, also known as a combination roof, consists of two or more sections sloping in different directions. A valley is formed where the different sections come together.

The two sections of an intersecting roof mayor may not be the same width. If they are the same width, the roof is said to have equal spans. If they are not the same width, the roof is said to have unequal spans.

Spans

In a roof with equal spans, the height (total rise) is the same for both ridges (fig. 2-36). That is, both sections are the same width, and the ridgeboards are the same height. A pair of valley rafters is placed where the slopes of the roof meet to form a valley between the two sections. These rafters go from the inside corners formed by the two sections of the building to the corners

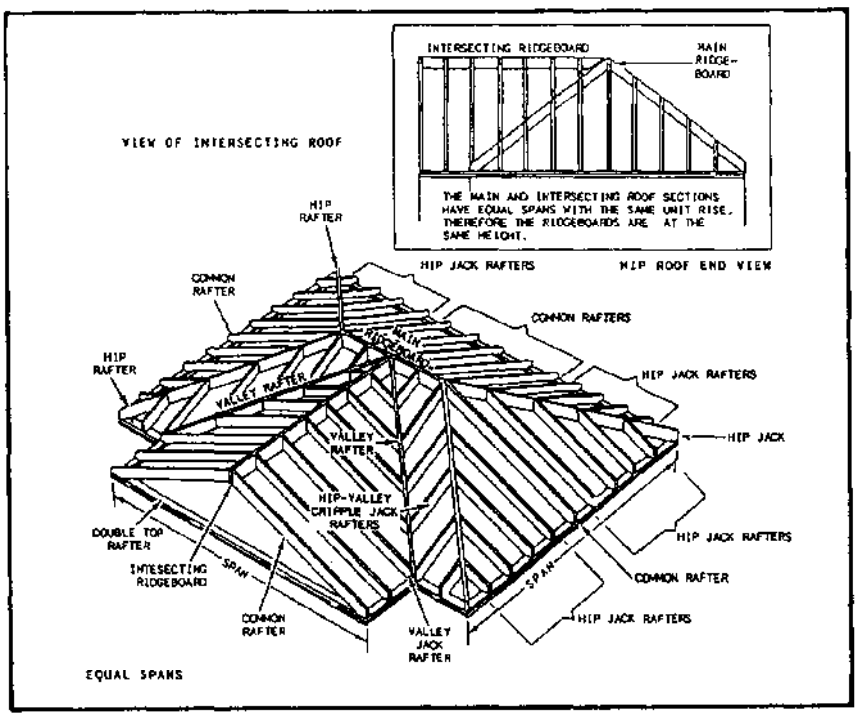


Figure 2-36.-Intersecting roof with equal spans.

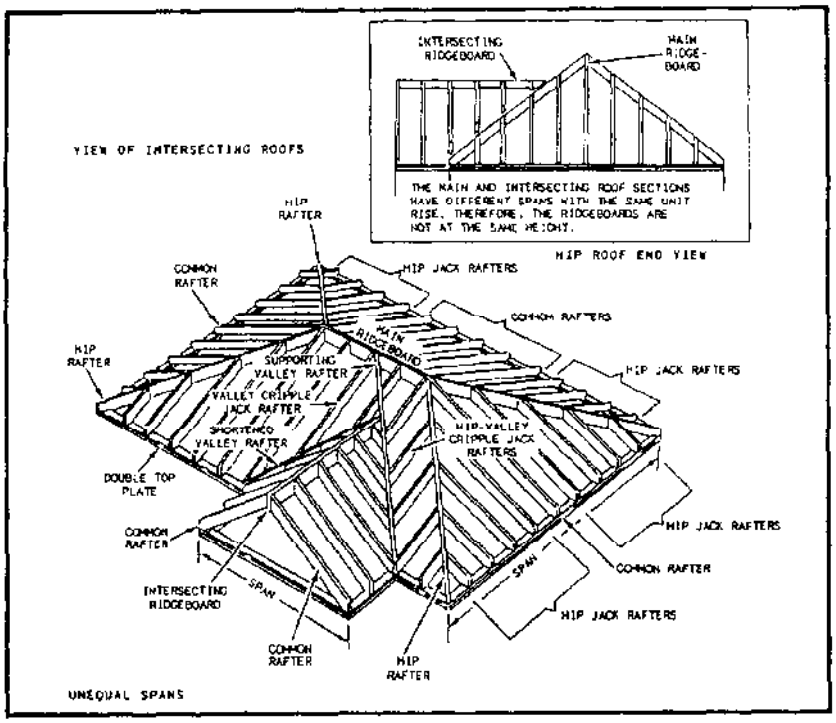


Figure 2-37.—Intersecting roof with unequal spans.

formed by the intersecting ridges. Valley jack rafters run from the valley rafters to both ridges. Hip-valley cripple jack rafters are placed between the valley and hip rafters.

An intersecting roof with unequal spans requires a supporting valley rafter to run from the inside corner formed by the two sections of the building to the main ridge (fig. 2-37). A shortened valley rafter runs from the other inside comer of the building to the supporting valley rafter. Like an intersecting roof with equal spans, one with unequal spans also requires valley jack rafters and hip-valley cripple jack rafters. In addition, a valley cripple jack rafter is placed between the supporting and shortened valley rafters. Note that the ridgeboard is lower on the section with the shorter span.

Valley Rafters

Valley rafters run at a 45° angle to the outside walls of the building. This places them parallel 10 the hip rafters. Consequently, they are the same length as the hip rafters.

A valley rafter follows the line of intersection between a main-roof surface and a gable-roof addition or a gable-roof dormer surface. Most roofs having valley rafters are equal-pitch roofs, in which the pitch of the addition or dormer roof is the same as the pitch of the main roof. There are unequal-pitch valley-rafter roofs, but they are quite rare and require special framing methods.

In the discussion of valley rafter layout, it is assumed that the roof is equal pitch. Also, the unit of run and unit of rise of an addition or dormer common rafter are assumed to be the same as the unit of run and rise of a main-roof common rafter. In an equal-pitch roof, the valley rafters always run at 45° to the building lines and the ridge pieces.

Figure 2-38 shows an equal-span framing situation, in which the span of the addition is the same as the span of the main roof. Since the pitch of the addition roof is the same as the pitch of the main roof, equal spans bring the ridge pieces to equal heights.

Looking at the roof framing diagram in the figure, you can see the total run of a valley rafter (indicated by AB and AC in the diagram) is the hypotenuse of a right triangle with the altitude and base equal to the total run of a common rafter in the main roof. The unit of run of a valley rafter is therefore 16.97, the same as the unit of run for a hip rafter. It follows that figuring the length of an equal-span valley rafter is the same as figuring the length of an equal-pitch hip roof hip rafter.

A valley rafter, however, does not require backing or dropping. The projection, if any, is figured just as it is for a hip rafter. Side cuts are laid out as they are for a

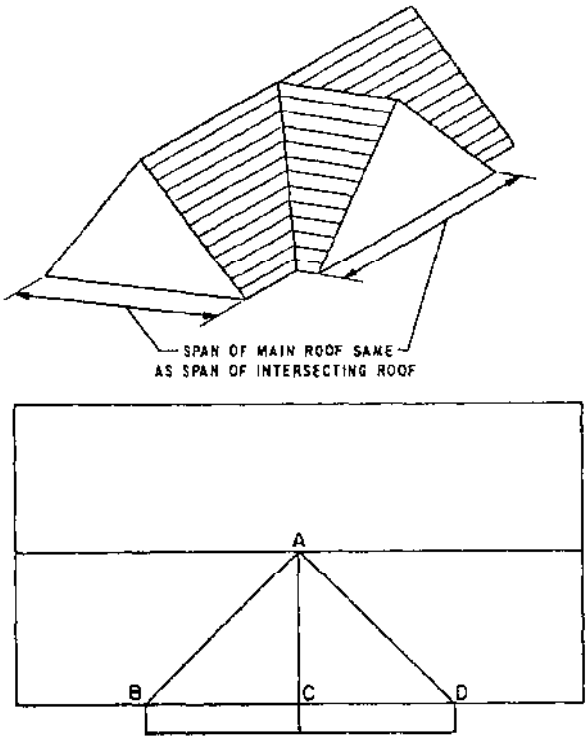


Figure 2-38.-Equal-span intersecting roof.

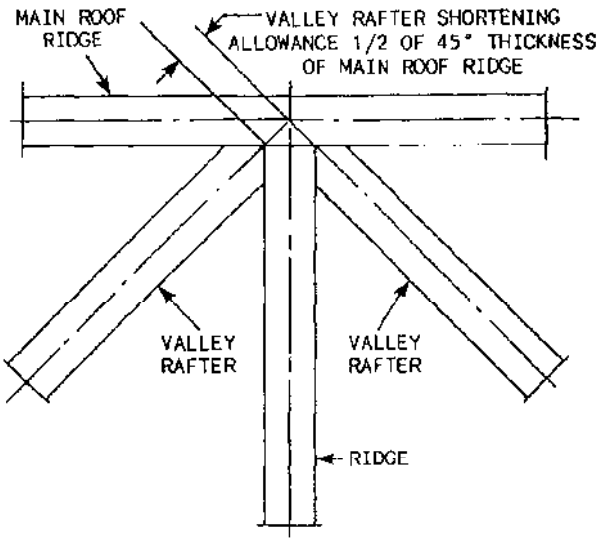


Figure 2-39.-Ridge-end shortening allowance for equal-span intersecting valley rafter.

hip rafter. The valley-rafter tail has a double side cut (like the hip-rafter tail) but in the reverse direction. This is because the tail cut on a valley rafter must form an inside, rather than an outside, corner. As indicated in figure 2-39, the ridge-end shortening allowance in this framing situation amounts to one-half of the 45° thickness of the ridge.

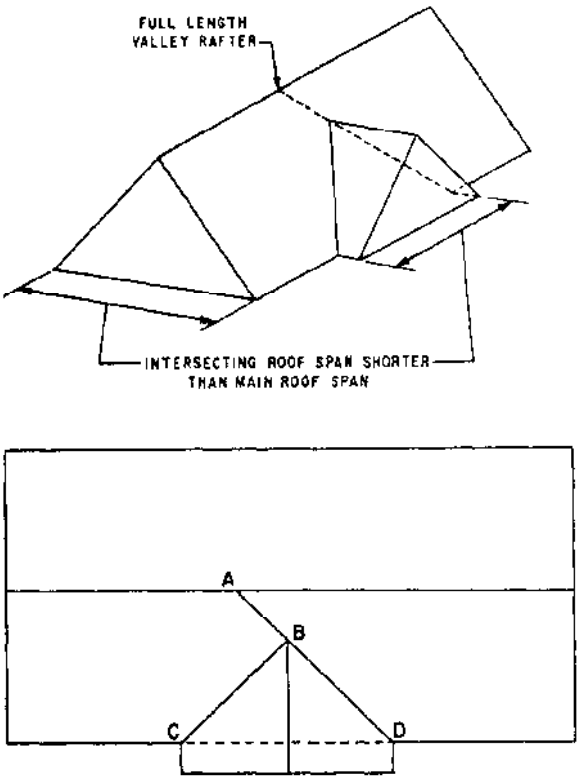


Figure 2-40.-Equal pitch but unequal span framing.

Figure 2-40 shows a framing situation in which the span of the addition is shorter than the span of the main roof. Since the pitch of the addition roof is the same as the pitch of the main roof, the shorter span of the addition brings the addition ridge down to a lower level than that of the main-roof ridge.

There are two ways of framing an intersection of this type. In the method shown in figure 2-40, a full-length valley rafter (AD in the figure) is framed between the top plate and the main-roof ridgeboard. A shorter valley rafter (BC in the figure) is then framed to the longer one. If you study the framing diagram, you can see that the total run of the longer valley rafter is the hypotenuse of a right triangle with the altitude and base equal to the total run of a common rafter in the main roof. The total run of the shorter valley rafter, on the other hand, is the hypotenuse of a right triangle with the altitude and base equal to the total run of a common rafter in the addition. The total run of a common rafter in the main roof is equal to one-half the span of the main roof. The total run of a common rafter in the addition is equal to one-half the span of the addition.

Knowing the total run of a valley rafter, or of any rafter for that matter, you can always find the line length by applying the bridge measure times the total run.

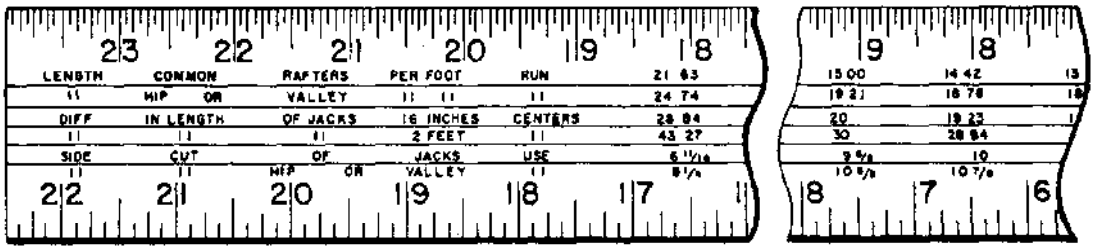


Figure 2-41.-Rafter table method.

Suppose, for example, that the span of the addition in figure 2-40 is 30 feet and that the unit of rise of a common rafter in the addition is 9. The total run of the shorter valley rafter is:

$$\sqrt{(15^2 + 15^2)} = 21.21 \text{ feet.}$$

Referring to the unit length rafter table in figure 2-41, you can see the bridge measure for a valley rafter in a roof with a common rafter unit of rise of 9 is 19.21. Since the unit of run of a valley rafter is 16.97, and the total run of this rafter is 21.21 feet, the line length must be the value of *x* in the proportional equation *16.97:19.21::21.21:x,* or 24.01 feet.

An easier way to find the length of a valley rafter is to multiply the bridge measure by the number of feet in one-half the span of the roof. The length of the longer valley rafter in figure 2-40, for example, would be 19.21 times one-half the span of the main roof. The length of the shorter valley rafter is 19.21 times one-half the span of the addition. Since one-half the span of the addition is 15 feet, the length of the shorter valley rafter is 15 x 9.21 = 288.15 inches, or approximately 24.01 feet.

Figure 2-42 shows the long and short valley rafter shortening allowances. Note that the long valley rafter has a single side cut for framing to the main-roof ridge piece, whereas the short valley rafter is cut square for framing to the long valley rafter.

Figure 2-43 shows another method of framing an equal-pitch unequal-span addition. In this method, the inboard end of the addition ridge is nailed to a piece that hangs from the main-roof ridge. As shown in the framing diagram, this method calls for two short valley rafters (AB and AC), each of which extends from the top plate to the addition ridge.

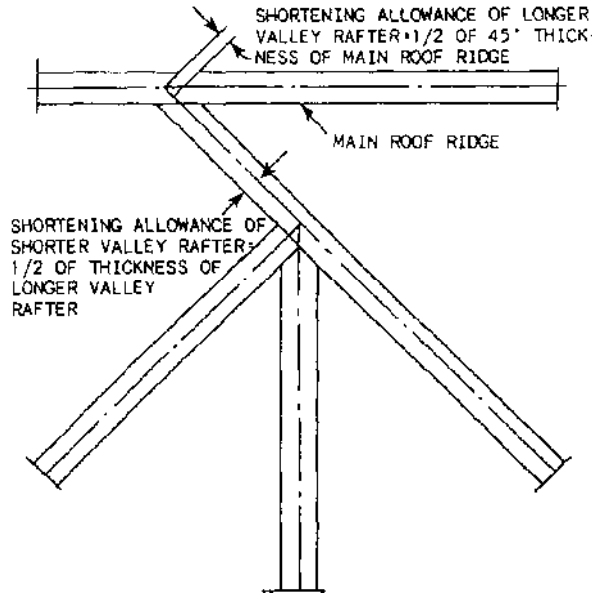


Figure 2-42.-Long and short valley rafter shortening allowance.

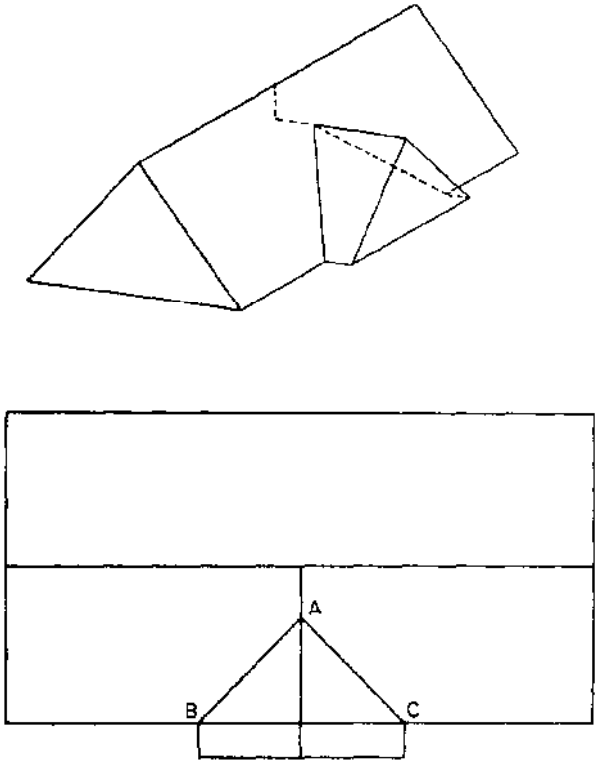


Figure 2-43.-Another method of framing equal-pitch unequal-span intersection.

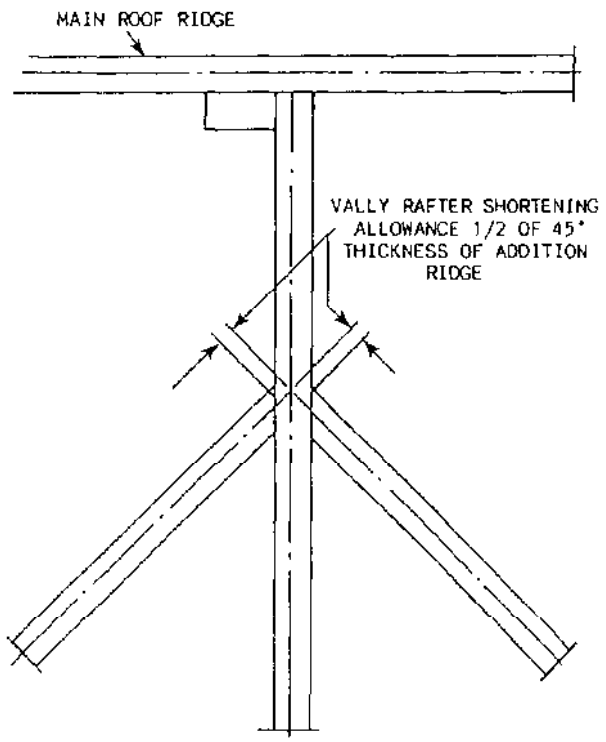


Figure 2-44.-Shortening allowance of valley rafters suspended ridge method of intersecting roof framing.

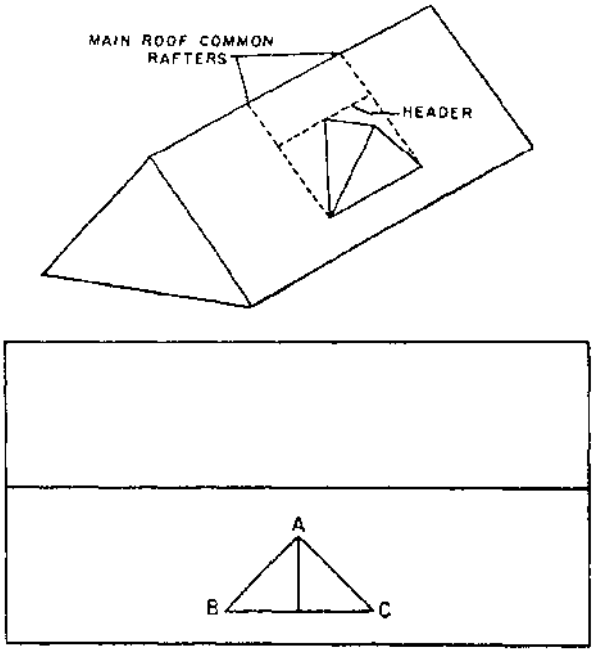


Figure 2-45.—Method of framing dormer without sidewalk.

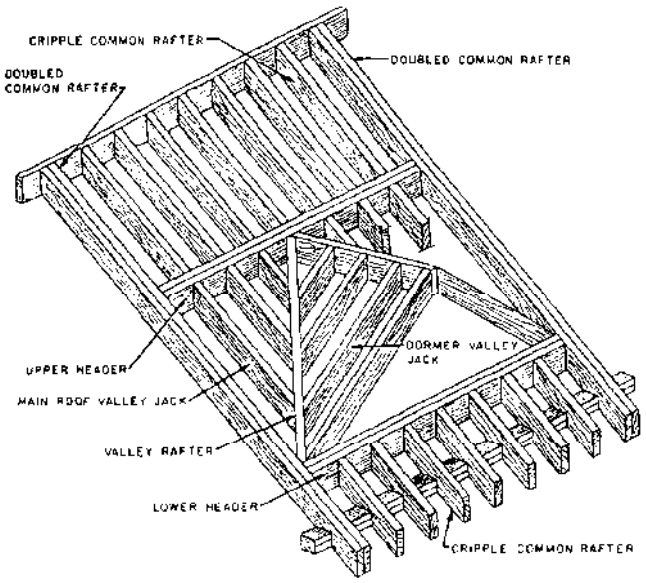


Figure 2-46.—Arrangement and names of framing members for dormer without sidewalls.

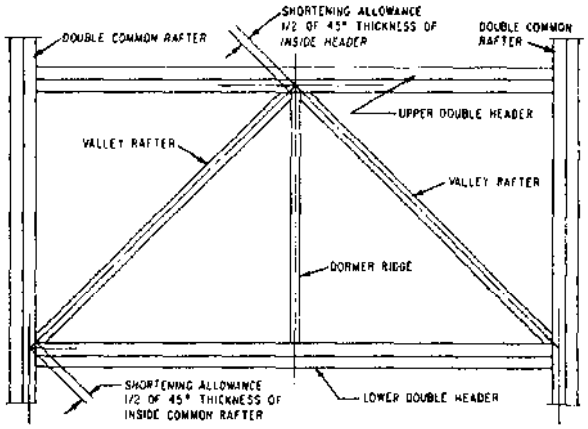


Figure 2-47.—Valley rafter shortening allowance for dormer without sidewalls.

As indicated in figure 2-44, the shortening allowance of each of the short valley rafters is one-half the 45° thickness of the addition ridge. Each rafter is framed to the addition ridge with a single side cut.

Figure 2-45 shows a method of framing a gable dormer without sidewalls. The dormer ridge is framed to a header set between a pair of doubled main-roof common rafters. The valley rafters (AB and AC) are framed between this header and a lower header. As indicated in the framing diagram, the total run of a valley rafter is the hypotenuse of a right triangle with the shorter sides equal to the total run of a common rafter in the dormer. Figure 2-46 shows the arrangement and names of framing members in this type of dormer framing.

The upper edges of the header must be beveled to the cut of the main roof. Figure 2-47 shows that in this

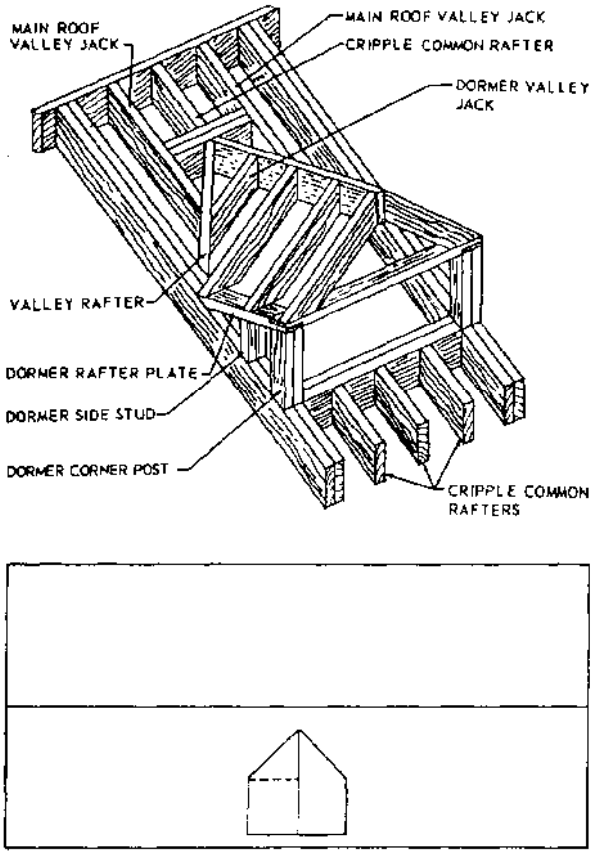


Figure 2-48.—Method of framing gable dormer with sidewalls.

method of framing, the shortening allowance for the upper end of a valley rafter is one-half the 45° thickness of the inside member in the upper doubled header. There is also a shortening allowance for the lower end, consisting of one-half the 45° thickness of the inside member of the doubled common rafter. The figure also shows that each valley rafter has a double side cut at the upper and lower ends.

Figure 2-48 shows a method of framing a gable dormer with sidewalls. As indicated in the framing diagram, the total run of a valley rafter is again the hypotenuse of a right triangle with the shorter sides each equal to the run of a common rafter in the dormer. You figure the lengths of the dormer corner posts and side studs just as you do the lengths of gable-end studs, and you lay off the lower end cutoff angle by setting the square to the cut of the main roof.

Figure 2-49 shows the valley rafter shortening allowance for this method of framing a dormer with sidewalls.

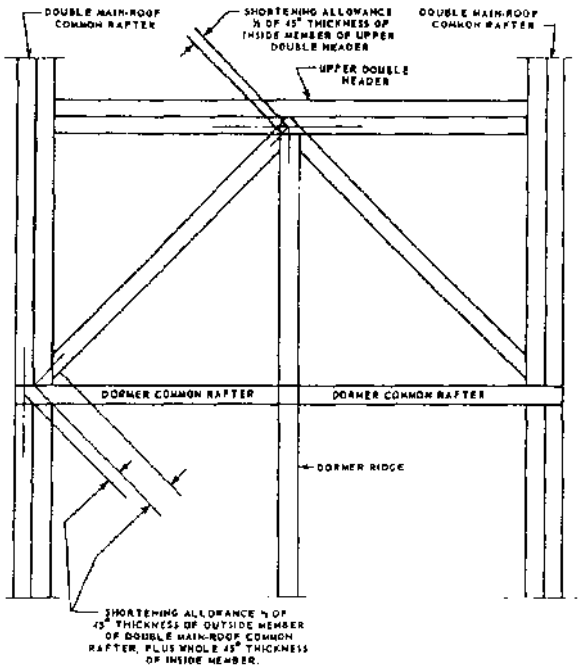


Figure 2-49.-Valley rafter shortening allowance for dormers with sidewalls.

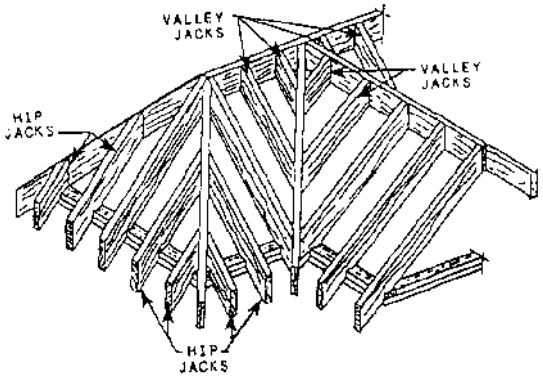


Figure 2-50.-Types of jack rafters.

Jack Rafters

A jack rafter is a part of a common rafter, shortened for framing a hip rafter, a valley rafter, or both. This means that, in an equal-pitch framing situation, the unit of rise of a jack rafter is always the same as the unit of rise of a common rafter. Figure 2-50 shows various types of jack rafters.

A hip jack rafter extends from the top plate to a hip rafter. A vane y jack rafter extends from a valley rafter to a ridge. (Both are shown in fig. 2-51.) A cripple jack rafter does not contact either a top plate or a ridge. A

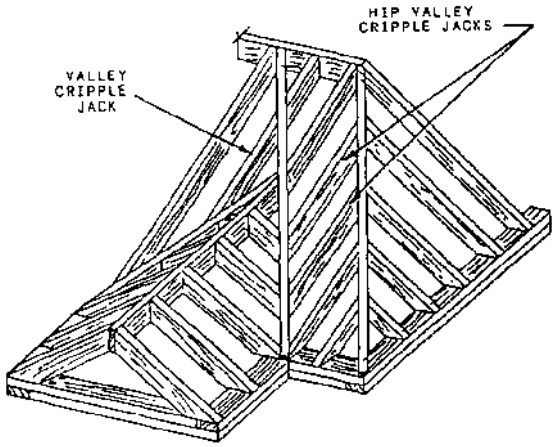


Figure 2-51.—Valley cripple Jack and hip-valley cripple jack.

valley cripple jack extends between two valley rafters in the long and short valley rafter method of framing. A hip-valley cripple jack extends from a hip rafter to a valley rafter.

LENGTHS.— Figure 2-52 shows a roof framing diagram for a series of hip jack rafters. The jacks are always on the same OC spacing as the common rafters.

Now, suppose the spacing, in this instance, is 16 inches OC. You can see that the total run of the shortest jack is the hypotenuse of a right triangle with the shorter sides each 16 inches long. The total run of the shortest jack is therefore:

$$\sqrt{(16^2 + 16^2)} = 22.62 \text{ inches.}$$

Suppose that a common rafter in this roof has a unit of rise of 8. The jacks have the same unit of rise as a common rafter. The unit length of a jack in this roof is:

$$\sqrt{(12^2 + 8^2)} = 14.42 \text{ inches.}$$

This means that a jack is 14.42 units long for every 12 units of run. The length of the shortest hip jack in this roof is therefore the value of x in the proportional equation *12:14.42::16:x,* or 19.23 inches.

This is always the length of the shortest hip jack when the jacks are spaced 16 inches OC and the common rafter in the roof has a unit of rise of 8. It is also the common difference of jacks, meaning that the next hip jack will be 2 times 19.23 inches.

The common difference for hip jacks spaced 16 inches OC, or 24 inches OC, is given in the unit length

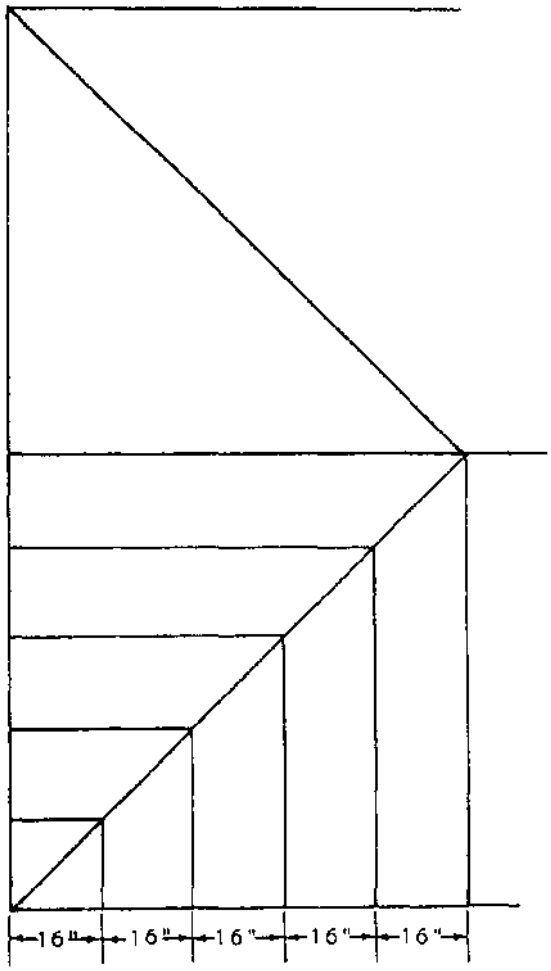


Figure 2-52.—Hip jack framing diagram.

rafter table on the framing square for unit of rise ranging from 2 to 18, inclusive. Turn back to figure 2-41, which shows a segment of the unit length rafter table. Note the third line in the table, which reads DIFF IN LENGTH OF JACKS 16 INCHES CENTERS. If you follow this line over to the figure under 8 (for a unit of rise of 8), you'll find the same unit length (19.23) that you worked out above.

The best way to determine the length of a valley jack or a cripple jack is to apply the bridge measure to the total run. The bridge measure of any jack is the same as the bridge measure of a common rafter having the same unit of rise as the jack. Suppose the jack has a unit of rise of 8. In figure 2-41, look along the line on the unit length rafter tables headed LENGTH COMMON RAFTER PER FOOT RUN for the figure in the column under 8; you'll find a unit length of 14.42. You should know by this time how to apply this to the total run of a jack to get the line length.

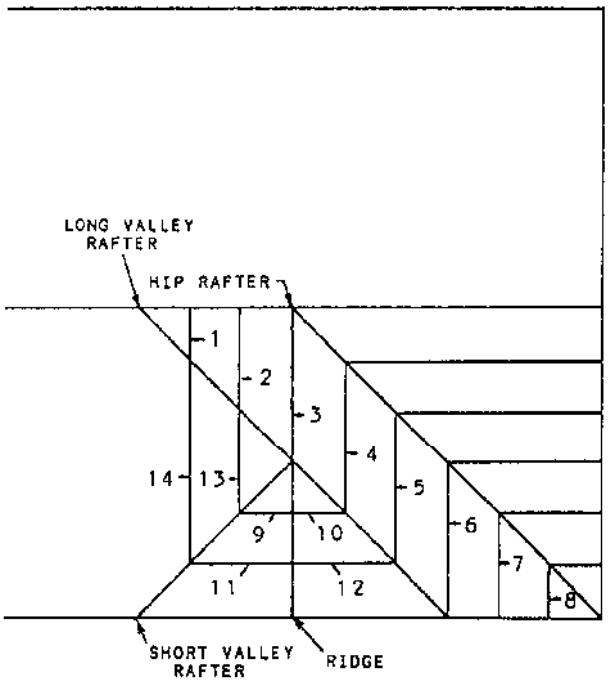


Figure 2-53.—Jack rafter framing diagram.

The best way to figure the total runs of valley jacks and cripple jacks is to lay out a framing diagram and study it to determine what these runs must be. Figure 2-53 shows part of a framing diagram for a main hip roof with a long and short valley rafter gable addition. By studying the diagram, you can figure the total runs of the valley jacks and cripple jacks as follows:

- The run of valley jack No. 1 is obviously the same as the run of hip jack No. 8, which is the run of the shortest hip jack. The length of valley jack No. 1 is therefore equal to the common difference of jacks.
- The run of valley jack No. 2 is the same as the run of hip jack No. 7, and the length is therefore twice the common difference of jacks.
- The run of valley jack No. 3 is the same as the run of hip jack No. 6, and the length is therefore three times the common difference of jacks.
- The run of hip-valley cripple Nos. 4 and 5 is the same as the run of valley jack No. 3.

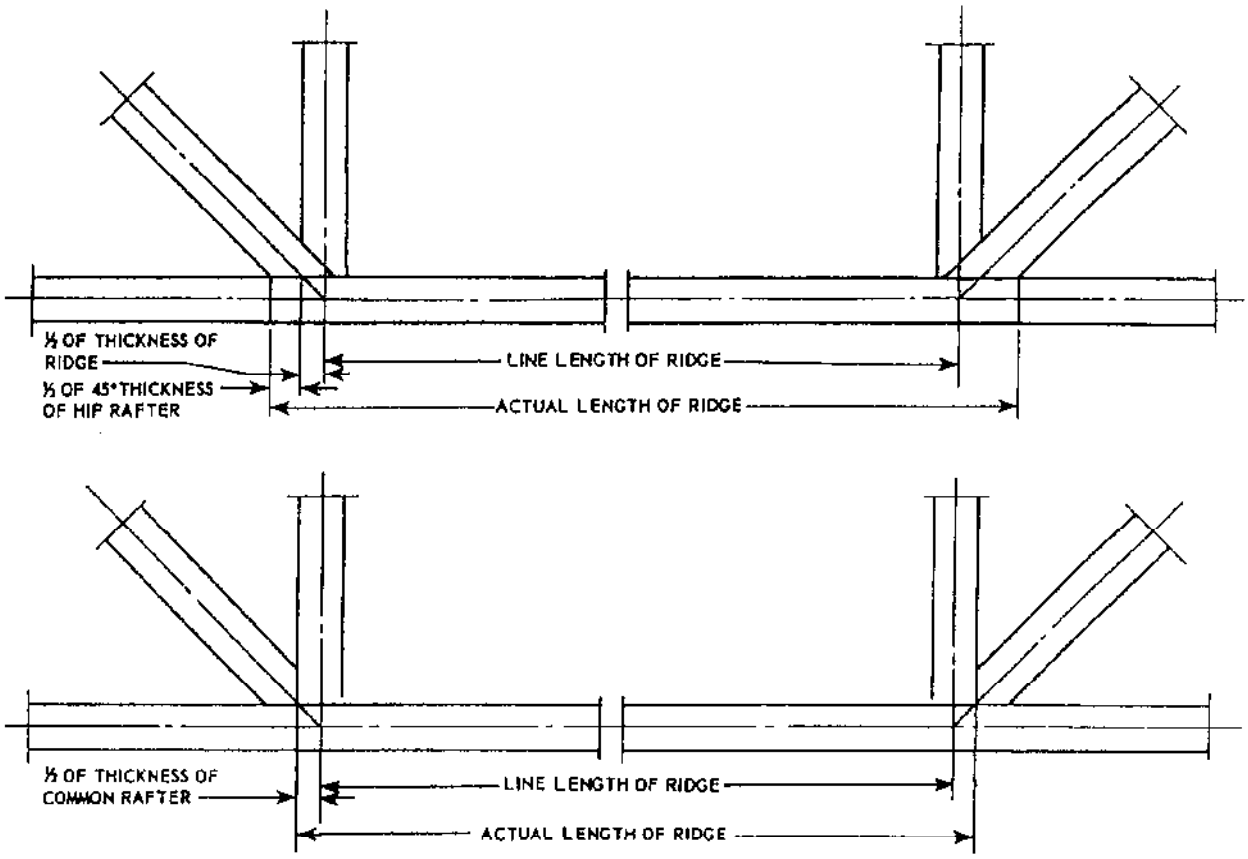


Figure 2-54.-Line and actual lengths of hip roof ridgeboard.

- The run of valley jack Nos. 9 and 10 is equal to the spacing of jacks OC. Therefore, the length of one of these jacks is equal to the common difference of jacks.
- The run of valley jacks Nos. 11 and 12 is twice the run of valley jacks Nos. 9 and 10, and the length of one of these jacks is therefore twice the common difference of jacks.
- The run of valley cripple No. 13 is twice the spacing of jacks OC, and the length is therefore twice the common difference of jacks.
- The run of valley cripple No. 14 is twice the run of valley cripple No. 13, and the length is therefore four times the common difference of jacks.

SHORTENING ALLOWANCES.— A hip jack has a shortening allowance at the upper end, consisting of one-half the 45° thickness of the hip rafter. A valley jack rafter has a shortening allowance at the upper end, consisting of one-half the 45° thickness of the ridge, and another at the lower end, consisting of one-half the 45° thickness of the valley rafter. A hip-valley cripple has a shortening allowance at the upper end, consisting of one-half the 45° thickness of the hip rafter, and another at the lower end, consisting of one-half the 45° thickness of the valley rafter. A valley cripple has a shortening allowance at the upper end, consisting of one-half the 45° thickness of the long valley rafter, and another at the lower end, consisting of one-half the 45° thickness of the short valley rafter.

SIDE CUTS.— The side cut on a jack rafter can be laid out using the same method as for laying out the side cut on a hip rafter. Another method is to use the fifth line of the unit length rafter table, which is headed SIDE CUT OF JACKS USE (fig. 2-41). If you follow that line over to the figure under 8 (for a unit of rise of 8), you will see that the figure given is 10. To lay out the side cut on a jack set the square faceup on the edge of the rafter to 12 inches on the tongue and 10 inches on the blade, and draw the side-cut line along the tongue.

BIRD'S-MOUTH AND PROJECTION.— A jack rafter is a shortened common rafter; consequently, the bird's-mouth and projection on a jack rafter are laid out just as they are on a common rafter.

Ridge Layout

Laying out the ridge for a gable roof presents no particular problem since the line length of the ridge is equal to the length of the building. The actual length includes any overhang. For a hip main roof, however, the ridge layout requires a certain amount of calculation.

As previously mentioned, in an equal-pitch hip roof, the line length of the ridge amounts to the length of the building minus the span. The actual length depends upon the way the hip rafters are framed to the ridge.

As indicated in figure 2-54, the line length ends of the ridge are at the points where the ridge centerline and the hip rafter center line cross. In the figure, the hip rafter is framed against the ridge. In this method of framing, the actual length of the ridge exceeds the line length, at each end, by one-half the thickness of the ridge, plus one-half the 45° thickness of the hip rafter. In the figure, the hip rafter is also framed between the common rafters. In this method of framing, the actual length of the ridge exceeds the line length at each end by one-half the thickness of a common rafter.

Figure 2-55, view A, shows that the length of the ridge for an equal-span addition is equal to the length of the addition top plate, plus one-half the span of the building, minus the shortening allowance at the

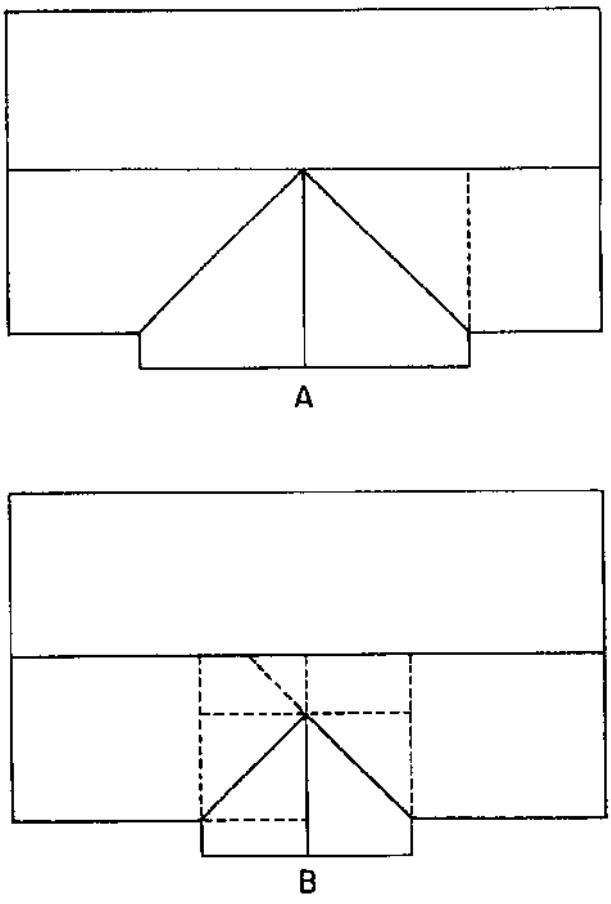
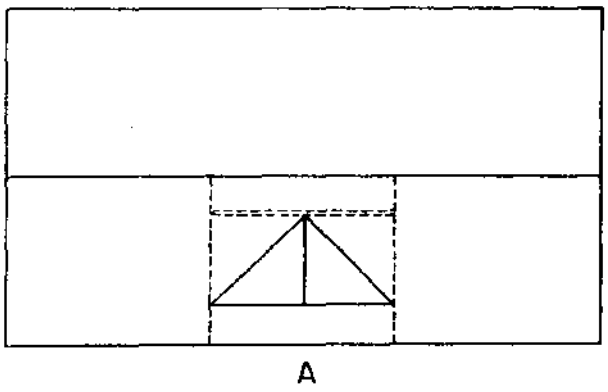


Figure 2-55.—Lengths of addition ridge.



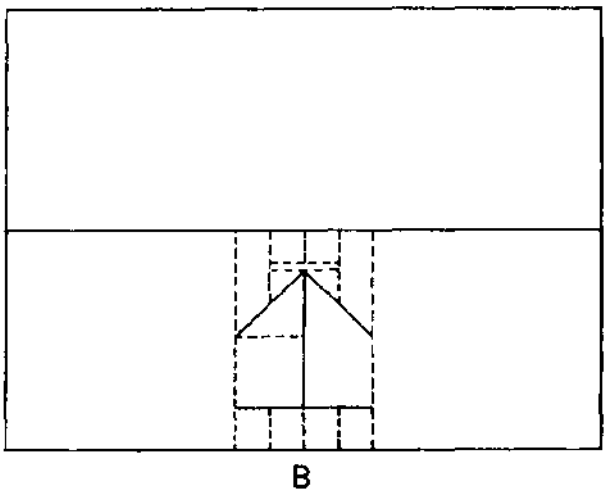


Figure 2-56.-Lengths of dormer ridge.

main-roof ridge. The shortening allowance amounts to one-half the thickness of the main-roof ridge.

View B shows that the length of the ridge for an unequal-span addition varies with the method of framing the ridge. If the addition ridge is suspended from the main-roof ridge, the length is equal to the length of the addition top plate, plus one-half the span of the building. If the addition ridge is framed by the long and short valley rafter method, the length is equal to the length of the addition top plate, plus one-half the span of the addition, minus a shortening allowance one-half the 45° thickness of the long valley rafter. If the addition ridge is framed to a double header set between a couple of double main-roof common rafters, the length of the ridge is equal to the length of the addition sidewall rafter plate, plus one-half the span of the addition, minus a shortening allowance one-half the thickness of the inside member of the double header.

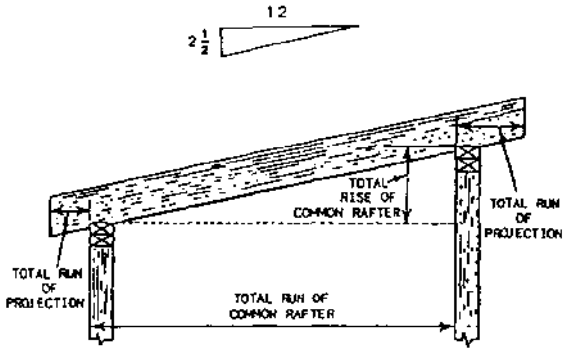


Figure 2-57.-Shed roof framing.

Figure 2-56, view A, shows that the length of the ridge on a dormer without sidewalls is equal to one-half the span of the dormer, less a shortening allowance one-half the thickness of the inside member of the upper double header. View B shows that the length of the ridge on a dormer with sidewalls is the length of the dormer rafter plate, plus one-half the span of the dormer, minus a shortening allowance one-half the thickness of the inside member of the upper double header.

SHED

A shed roof is essentially one-half of a gable roof. Like the full-length rafters in a gable roof, the full-length rafters in a shed roof are common rafters. However, the total run of a shed roof common rafter is equal to the span of the building minus the width of the top plate on the higher rafter-end wall (fig. 2-57). Also, the run of the overhang on the higher wall is measured from the inner edge of the top plate. With these exceptions, shed roof common rafters are laid out like gable roof common rafters. A shed roof common rafter has two bird's-mouths, but they are laid out just like the bird's-mouth on a gable roof common rafter.

For a shed roof, the height of the higher rafter-end wall must exceed the height of the lower by an amount equal to the total rise of a common rafter.

Figure 2-58 shows a method of framing a shed dormer. This type of dormer can be installed on almost any type of roof. There are three layout problems to be solved here: determining the total run of a dormer rafter; determining the angle of cut on the inboard ends of the dormer rafters; and determining the lengths of the dormer sidewall studs.

To determine the total run of a dormer rafter, divide the height of the dormer end wall, in inches, by the

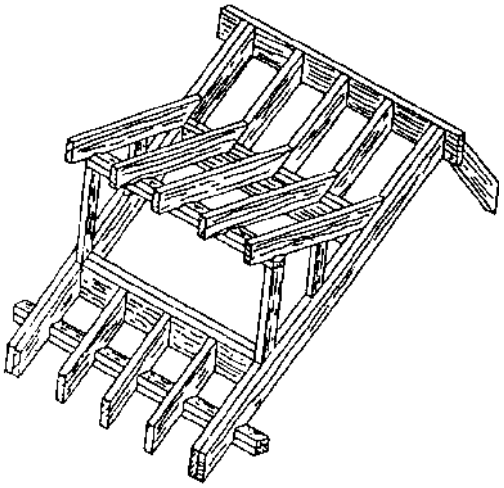


Figure 2-58.-Method of framing a shed dormer.

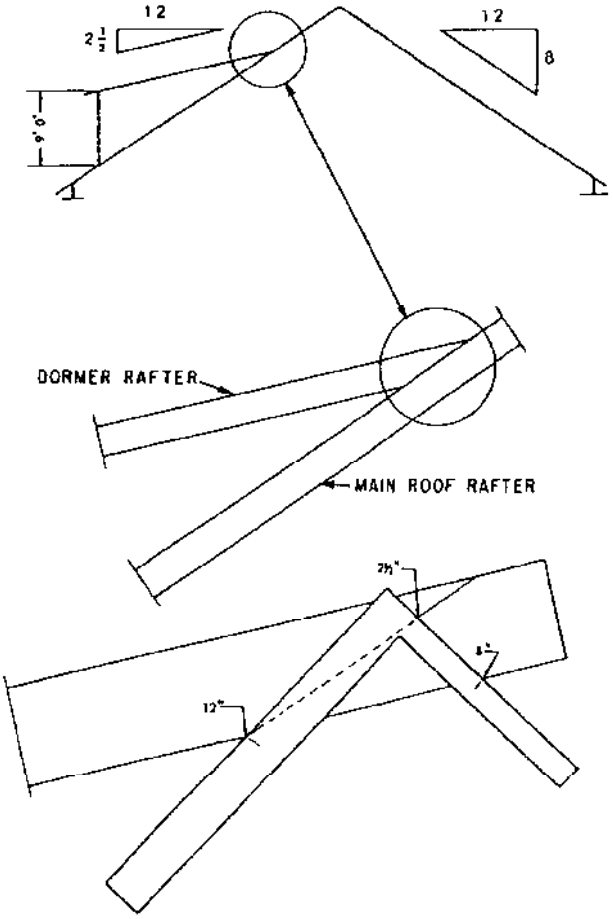


Figure 2-59.-Shed dormer framing calculation.

difference between the unit of rise of the dormer roof and the unit of rise of the main roof. Take the dormer shown in figure 2-59, for example. The height of the dormer end wall is 9 feet, or 108 inches. The unit of rise of the main roof is 8; the unit of rise of the dormer roof is 2 1/2; the difference is 5 1/2. The total run of a dormer rafter is therefore 108 divided by 5 1/2, or 19.63 feet. Knowing the total run and the unit of rise, you can figure the length of a dormer rafter by any of the methods already described.

As indicated in figure 2-59, the inboard ends of the dormer rafters must be cut to fit the slope of the main roof. To get the angle of this cut, set the square on the rafter to the cut of the main roof, as shown in the bottom view of figure 2-59. Measure off the unit of rise of the dormer roof from the heel of the square along the tongue as indicated and make a mark at this point. Draw the cutoff line through this mark from the 12-inch mark.

You figure the lengths of the sidewall studs on a shed dormer as follows: In the roof shown in figure 2-59, a dormer rafter raises 2 1/2 units for every 12 units of run. A main-roof common rafter rises 8 units for every 12 units of run. If the studs were spaced 12 inches OC, the length of the shortest stud (which is also the common difference of studs) would be the difference between 8 and 2 1/2 inches, or 5 1/2 inches. If the stud spacing is 16 inches, the length of the shortest stud is the value of *x* in the proportional equation *12:5 1/2::16:x,* or 7 5/16 inches. The shortest stud, then, will be 7 5/16 inches long. To get the lower end cutoff angle for studs, set the square on the stud to the cut of the main roof. To get the upper end cutoff angle, set the square to the cut of the dormer roof.

INSTALLATION

Rafter locations are laid out on wall plates and ridgeboards with matching lines and marked with X's, as used to lay out stud and joist locations. For a gable roof, the rafter locations are laid out on the rafter plates first. The locations are then transferred to the ridge by matching the ridge against a rafter plate.

Rafter Locations

The rafter plate locations of the ridge-end common rafters in an equal-pitch hip roof measure one-half of the span (or the run of a main-roof common rafter) away from the building comers. These locations, plus the rafter plate locations of the rafters lying between the ridge-end common rafters, can be transferred to the ridge by matching the ridgeboads against the rafter plates.

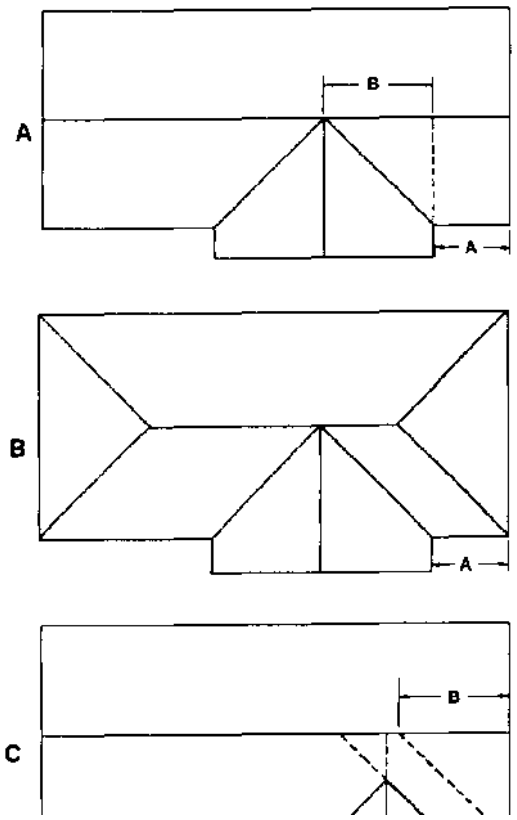


Figure 2-60.-Intersection ridge and valley rafter location layout.

The locations of additional ridge and valley rafters can be determined as indicated in figure 2-60. In an equal-span situation (views A and B), the valley rafter locations on the main-roof ridge lie alongside the addition ridge location. In view A, the distance between the end of the main-roof ridge and the addition ridge location is equal to A plus distance B, distance B being one-half the span of the addition. In view B, the distance between the line length end of the main-roof ridge and the addition ridge location is the same as distance A. In both cases, the line length of the addition ridge is equal to one-half the span of the addition, plus the length of the addition sidewall rafter plate.

Figure 2-60, view C, shows an unequal-span situation. If framing is by the long and short valley rafter method, the distance from the end of the main-roof ridge to the upper end of the longer valley rafter is equal to distance A plus distance B, distance B being one-half the span of the main roof. To determine the location of the inboard valley rafter, first calculate the unit length of the longer valley rafter, or obtain it from the unit length rafter tables. Let's suppose that the common rafter unit of rise is 8. In that case, the unit length of a valley rafter is 18.76.

The total run of the longer valley rafter between the shorter rafter tie-in and the rafter plate is the hypotenuse of a right triangle with the altitude and base equal to one-half of the span of the addition. Suppose the addition is 20 feet wide. Then, the total run is:

$$\sqrt{(10^2 = 10^2)} = 14.14 \text{ feet.}$$

You know that the valley rafter is 18.76 units long for every 16.97 units of run. The length of rafter for 14.14 feet of run must therefore be the value of x in the proportional equation $16.97:18.76::14.14:x$, or 15.63 feet. The location mark for the inboard end of the shorter valley rafter on the longer valley rafter, then, will be 15.63 feet, or 15 feet 7 9/16 inches, from the heel plumb cut line on the longer valley rafter. The length of the additional ridge will be equal to one-half the span of the addition, plus the length of the additional sidewall top plate, minus a shortening allowance one-half the 45° thickness of the longer valley rafter.

If framing is by the suspended ridge method, the distance between the suspension point on the main-roof and the end of the main-roof ridge is equal to distance A plus distance C. Distance C is one-half the span of the addition. The distance between the point where the inboard ends of the valley rafters (both short in this method of framing) tie into the addition ridge and the outboard end of the ridge is equal to one-half the span of the addition, plus the length of the additional ridge (which is equal to one-half of the span of the main roof), plus the length of the addition sidewall rafter plate.

Roof Frame Erection

Roof framing should be done from a scaffold with planking not less than 4 feet below the level of the main-roof ridge. The usual type of roof scaffold consists of diagonally braced two-legged horses, spaced about 10 feet apart and extending the full length of the ridge.

If the building has an addition, as much as possible of the main roof is framed before the addition framing is started. Cripples and jack rafters are usually left out until after the headers, hip rafters, valley rafters, and ridges to which they will be framed have been installed. For a gable roof, the two pairs of gable-end rafters and the ridge are usually erected first.

Two crewmembers, one at each end of the scaffold, hold the ridge in position. Another crewmember sets the gable-end rafters in place and toenails them at the rafter plate with 8d nails, one on each side of a rafter. Before we proceed any further, see table 2-1 as to the type and

Table 2-1.—Recommended Schedule for Nailing the Framing and Sheathing of a Wood-Frame Structure

JOINING	NAILING METHOD	NAILS		
		Nr.	Size	Placement
Header to joist	End-nail	3	16d	
Joist to sill or girder	Toenail	2 3	10d or 8d	
Header and stringer joist to sill	Toenail		10d	16 in. OC
Bridging to joist	Toenail each end	2	8d	
Ledger strip to beam, 2 in. thick		3	16d	At each joist
Subfloor, boards: 1 by 6 in. and smaller 1 by 8 in.		 2 3	 8d 8d	 To each joist To each joist
Subfloor, plywood: At edges At intermediate joists			 8d 8d	 6 in. OC 8 in. OC
Subfloor (2 by 6 in., T&G) to joist or girder	Blind nail (casing) and face-nail	2	16d	
Soleplate to stud, horizontal assembly	End-nail	2	16d	At each stud
Top plate to stud	End-nail	2	16d	
Stud to soleplate	Toenail	4	8d	
Soleplate to joist or blocking	Face-nail		16d	16 in. OC
Doubled studs	Face-nail, stagger		10d	16 in. OC
End stud of intersecting wall to exterior wall stud	Face-nail		16d	16 in. OC
Upper top plate to lower top plate	Face-nail		16d	16 in. OC
Upper top plate, laps and intersections	Face-nail	2	16d	
Continuous header, two pieces, each edge			12d	12 in. OC
Ceiling joist to top wall plates	Toenail	3	8d	
Ceiling joist laps at partition	Face-nail	4	16d	
Rafter to top plate	Toenail	2	8d	
Rafter to ceiling joist	Face-nail	5	10d	
Rafter to valley or hip rafter	Toenail	3	10d	
Ridgeboard to rafter	End-nail	3	10d	
Rafter to rafter through ridgeboard	Toenail Edge-nail	2 4	10d 8d	
Collar tie to rafter: 2-in. member 1-in. member	 Face-nail Face-nail	 2 3	 12d 8d	
1-in. diagonal let-in brace to each stud and plate (four nails at top)		2	8d	
Built-up corner studs: Studs to blocking Intersecting stud to corner studs	 Face-nail Face-nail	 2	 10d 6d	 Each side 12 in. OC
Built-up girders and beams, three or more members	Face-nail		20d	32 in. OC, each side
Wall sheathing: 1 by 8 in. or less, horizontal 1 by 6 in. or greater, diagonal	 Face-nail Face-nail	 2 3	 8d 8d	 At each stud At each stud

Table 2-1.-Recommended Schedule for Nailing the Framing and Sheathing of a Wood-Frame Structure—Continued

JOINING	NAILING METHOD	NAILS		
		Nr.	Size	Placement
Wall sheathing, vertically applied plywood: 3/8 in. and less thick 1/2 in. and over thick	 Face-nail Face-nail		 6d 8d	 6 in. edge 12 in. intermediate
Wall sheathing, vertically applied fiberboard: 1/2 in. thick 25/32 in. thick	 Face-nail Face-nail		1 1/2-in. roofing nail 3 in. from edge and 1 3/4-in. roofing nail 6 in. intermediately spaced	
Roof sheathing, boards, 4-, 6-, 8-in. width	Face-nail	2	8d	At each rafter
Roof sheathing, plywood: 3/8 in. and less thick 1/2 in. and over thick	 Face-nail Face-nail		 6d 8d	 6 in. edge and 12 in. intermediate

size nails used in roof framing erection. Each crewmember on the scaffold then end-nails the ridge to the end of the rafter. They then toenail the other rafter to the ridge and to the first rafter with two 10d nails, one on each side of the rafter.

Temporary braces, like those for a wall, should be set up at the ridge ends to hold the rafter approximately plumb, after which the rafters between the end rafters should be erected. The braces should then be released, and the pair of rafters at one end should be plumbed with a plumb line, fastened to a stick extended from the end of the ridge. The braces should then be reset, and they should be left in place until enough sheathing has been installed to hold the rafters plumb. Collar ties, if any, are nailed to common rafters with 8d nails, three to each end of a tie. Ceiling-joist ends are nailed to adjacent rafters with 10d nails.

On a hip roof, the ridge-end common rafters and ridges are erected first, in about the same manner as for a gable roof. The intermediate common rafters are then filled in. After that, the ridge-end common rafters extending from the ridge ends to the midpoints on the end walls are erected. The hip rafters and hip jacks are installed next. The common rafters in a hip roof do not require plumbing. When correctly cut and installed, hip rafters will bring the common rafters to plumb. Hip rafters are toe nailed to plate comers with 10d nails. Hip jacks are toe nailed to hip rafters with 10d nails.

For an addition or dormer, the valley rafters are usually erected first. Valley rafters are toe nailed with 10d nails. Ridges and ridge-end common rafters are erected next, other addition common rafters next, and valley and cripple jacks last. A valley jack should be held in position for nailing, as shown in figure 2-61. When properly nailed, the end of a straightedge laid along the top edge of the jack should contact the centerline of the valley rafter, as shown.

TRUSSES

LEARNING OBJECTIVE: Upon completing this section, you should be able to describe the types and parts of roof trusses, and explain procedures for fabricating, handling, and erecting them.

Roof truss members are usually connected at the joints by gussets. Gussets are made of boards, plywood, or metal. They are fastened to the truss by nails, screws, bolts, or adhesives. A roof truss is capable of supporting loads over a long span without intermediate supports.

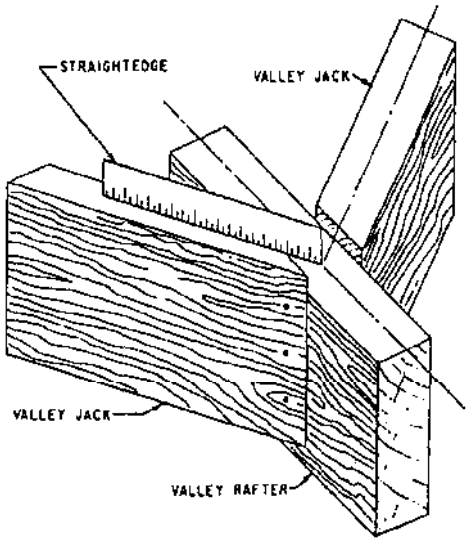


Figure 2-61.-Correct position for nailing a valley jack rafter.

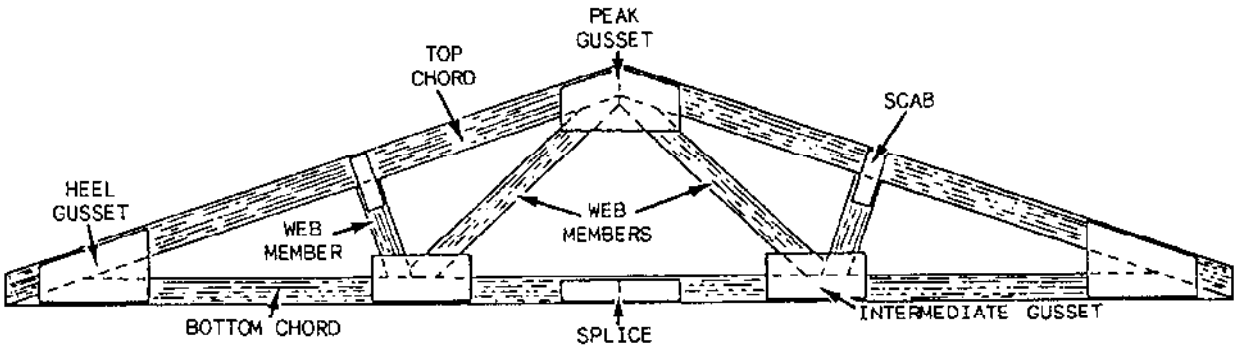


Figure 2-62.—Truss construction.

Roof trusses save material and on-site labor costs. It is estimated that a material savings of about 30 percent is made on roof members and ceiling joists. When you are building with trusses, the double top plates on interior partition walls and the double floor joists under interior bearing partitions are not necessary. Roof trusses also eliminate interior bearing partitions because trusses are self-supporting.

The basic components of a roof truss are the top and bottom chords and the web members (fig. 2-62). The top chords serve as roof rafters. The bottom chords act as ceiling joists. The web members run between the top and bottom chords. The truss parts are usually made of 2- by 4-inch or 2- by 6-inch material and are tied together with metal or plywood gusset plates. Gussets shown in this figure are made of plywood.

TYPES

Roof trusses come in a variety of shapes. The ones most commonly used in light framing are the king post, the W-type (or fink), and the scissors. An example of each is shown in figure 2-63.

King Post

The simplest type of truss used in frame construction is the king-post truss. It consists of top and bottom chords and a vertical post at the center.

W-Type (Fink)

The most widely used truss in light-frame construction is the W-type (fink) truss. It consists of top and bottom chords tied together with web members. The W-type truss provides a uniform load-carrying capacity.

Scissors

The scissor truss is used for building with sloping ceilings. Many residential, church, and commercial buildings require this type of truss. Generally, the slope of the bottom chord of a scissor truss equals one-half the slope of the top chord.

DESIGN PRINCIPLES

A roof truss is an engineered structural frame resting on two outside walls of a building. The load carried by the truss is transferred to these outside walls.

Weight and Stress

The design of a truss includes consideration of snow and wind loads and the weight of the roof itself. Design also takes into account the slope of the roof. Generally, the flatter the slope, the greater the stresses. Flatter slopes, therefore, require larger members and stronger connections in roof trusses.

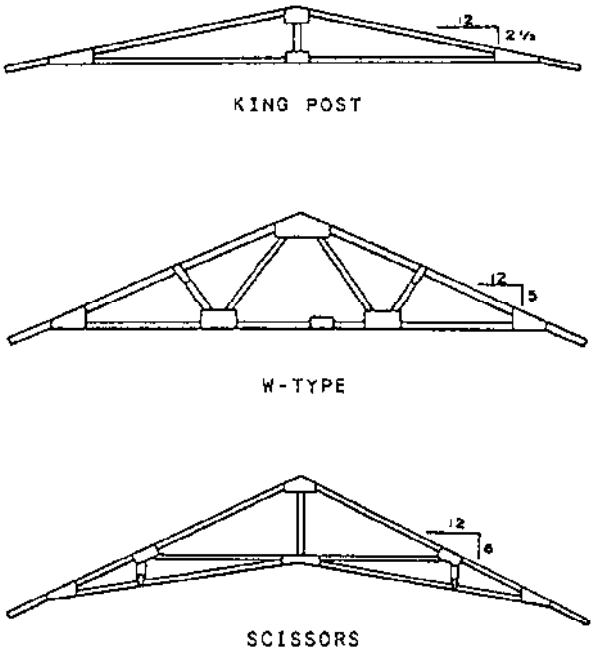


Figure 2-63.—Truss types.

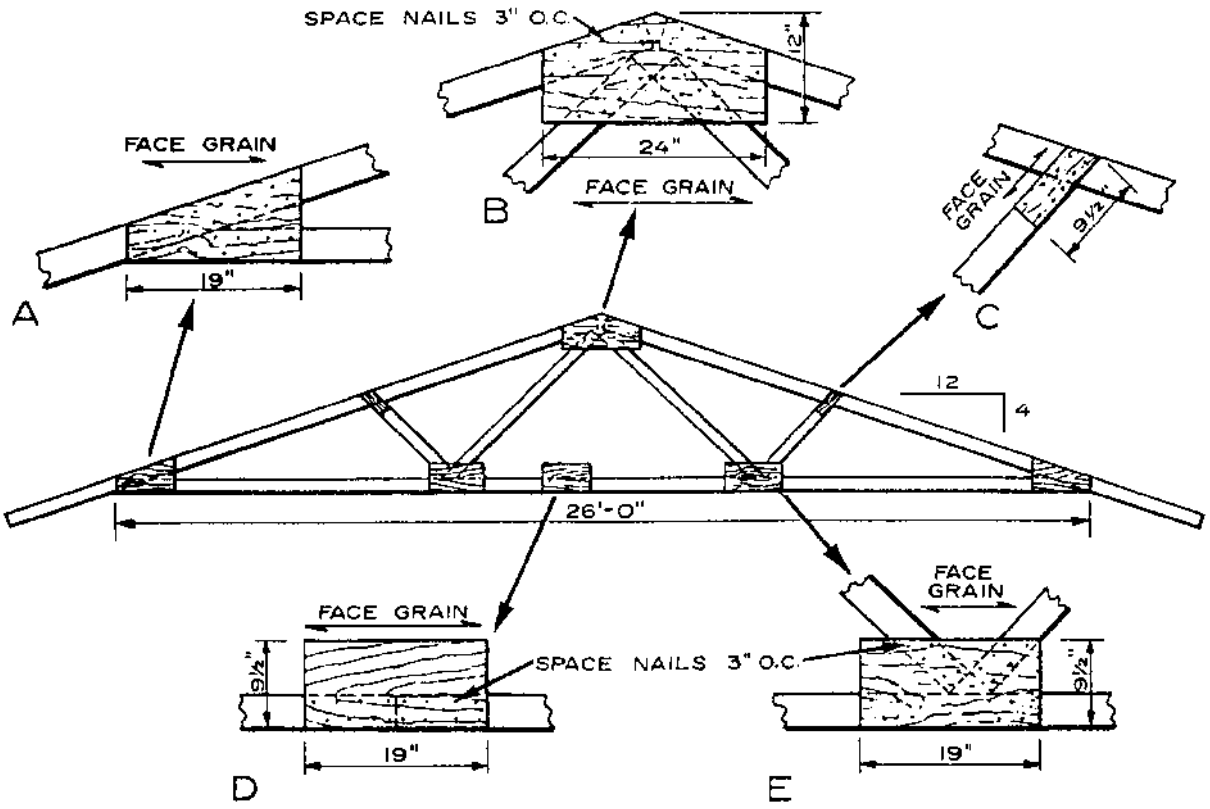


Figure 2-64.-Plywood gussets.

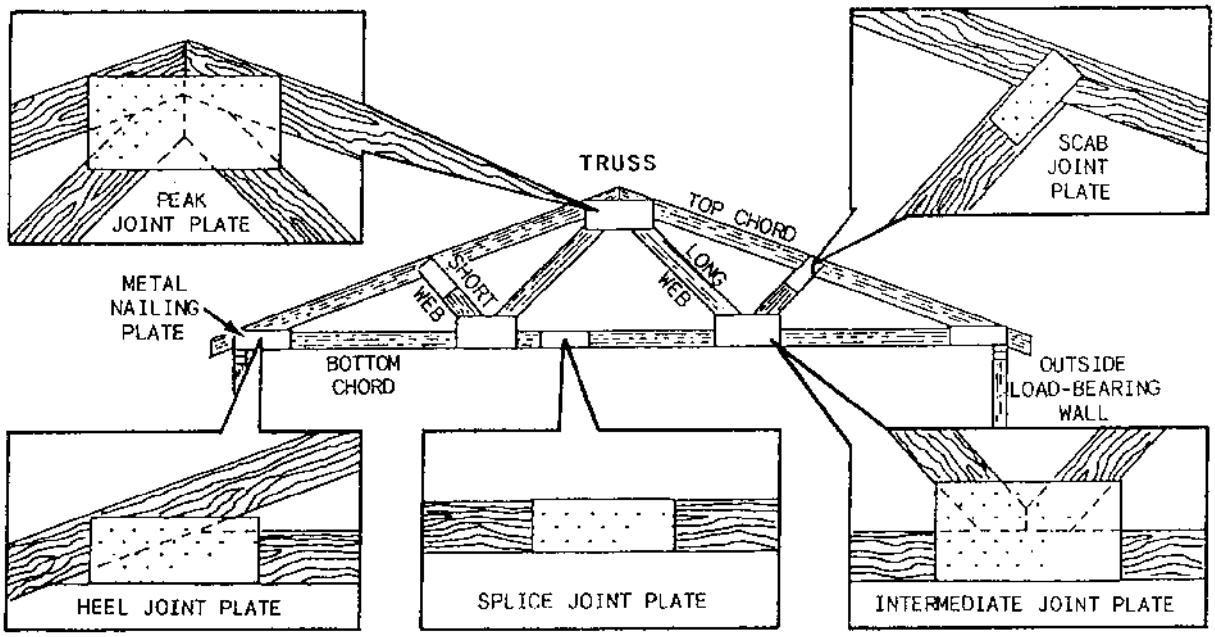


Figure 2-65.-Metal gusset plates.

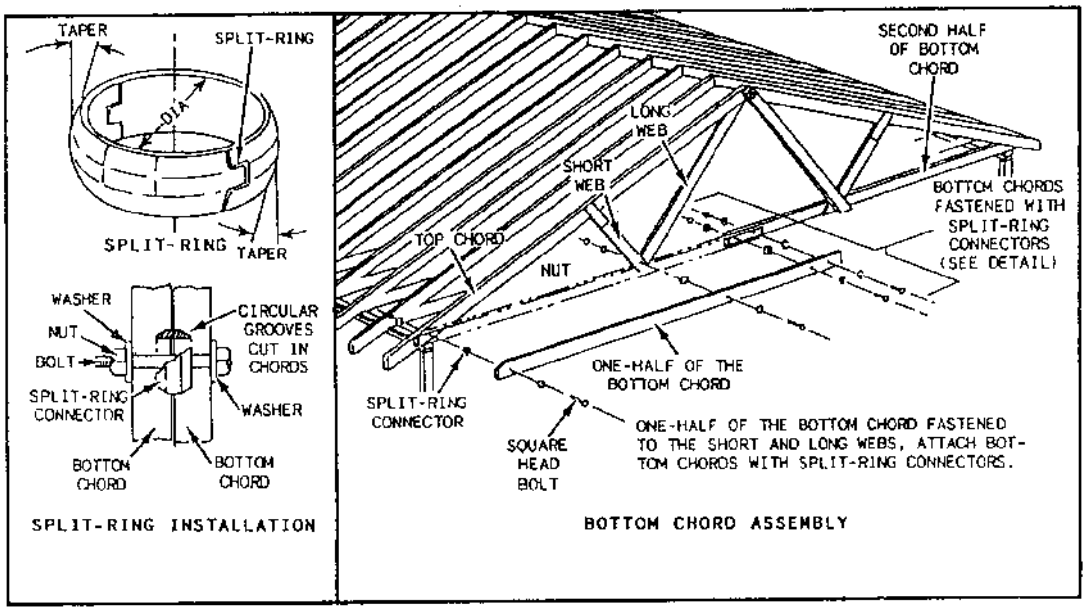


Figure 2-66.-Truss members fastened together with split-ring connectors.

A great majority of the trusses used are fabricated with plywood gussets (fig. 2-64, views A through E), nailed, glued, or bolted in place. Metal gusset plates (fig. 2-65) are also used. These are flat pieces usually manufactured from 20-gauge zinc-coated or galvanized steel. The holes for the nails are prepunched. Others are assembled with split-ring connectors (fig. 2-66) that prevent any movement of the members. Some trusses are designed with a 2- by 4-inch soffit return at the end of each upper chord to provide nailing for the soffit of a wide box cornice.

Tension and Compression

Each part of a truss is in a state of either tension or compression (see fig. 2-67). The parts in a state of tension are subjected to a pulling-apart force. Those under compression are subjected to a pushing-together force. The balance of tension and compression gives the truss its ability to carry heavy loads and cover wide spans.

In view A of figure 2-67, the ends of the two top chords (A-B and A-C) are being pushed together (compressed). The bottom chord prevents the lower ends (B and C) of the top chords from pushing out; therefore, the bottom chord is in a pulling-apart state (tension). Because the lower ends of the top chords cannot pull apart, the peak of the truss (A) cannot drop down.

In view B, the long webs are secured to the peak of the truss (A) and also fastened to the bottom chord at points D and E. This gives the bottom chord support along the outside wall span. The weight of the bottom chord has a pulling-apart effect (tension) on the long webs.

In view C, the short webs run from the intermediate points F and G of the top chord to points D and E of the bottom chord. Their purpose is to provide support to the top chord. This exerts a downward, pushing-together force (compression) on the short web.

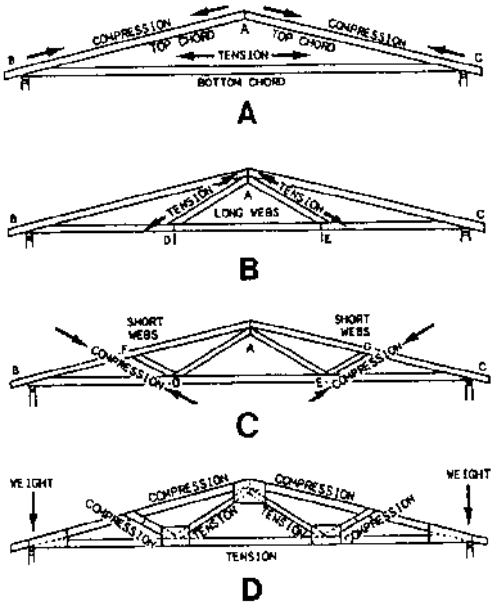


Figure 2-67.—Tension and compression in a truss.

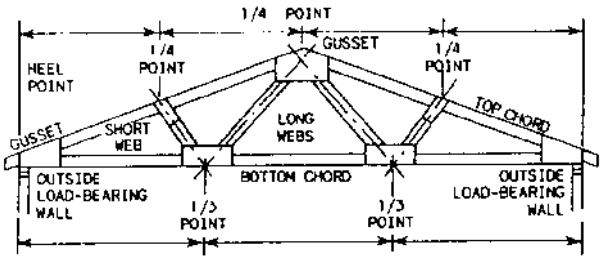


Figure 2-68.-Layout for a W-type (fink) truss.

In view D, you can see that the overall design of the truss roof transfers the entire load (roof weight, snow load, wind load, and so forth) down through the outside walls to the foundation.

Web members must be fastened at certain points along the top and bottom chords in order to handle the stress and weight placed upon the truss. A typical layout for a W-type (fink) truss is shown in figure 2-68. The points at which the lower ends of the web members fasten to the bottom chord divide the bottom chord into

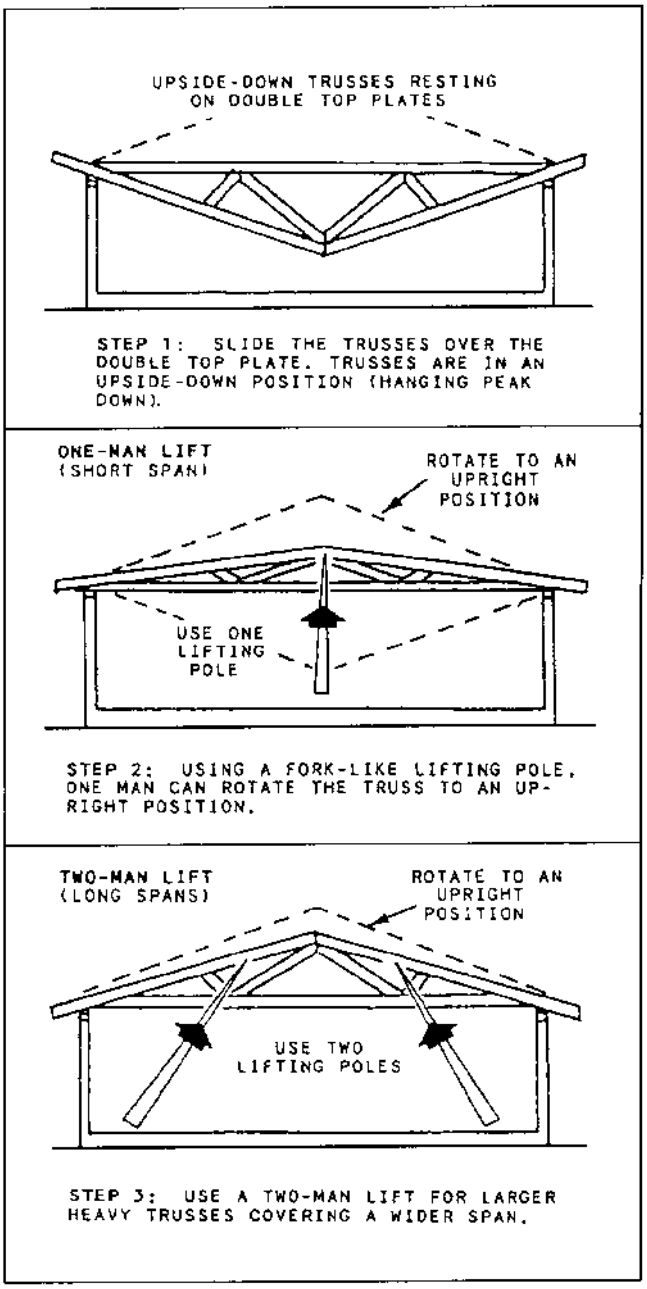


Figure 2-69.—Placing trusses by hand.

three equal parts. Each short web meets the top chord at a point that is one-fourth the horizontal distance of the bottom chord.

FABRICATION

The construction features of a typical W-truss are shown in figure 2-64. Also shown are gusset cutout sizes and nailing patterns for nail-gluing. The span of this truss is 26 feet and roof cut is 4/12. When spaced 24 inches apart and made of good- quality 2- by 4-inch members, the trusses should be able to support a total roof load of 40 pounds per square foot.

Gussets for light wood trusses are cut from 3/8- or 1/2-inch standard plywood with an exterior glue line, or from sheathing-grade exterior plywood. Glue is spread on the clean surfaces of the gussets and truss members. Staples are used to supply pressure until the glue is set. Under normal conditions and where the relative humidity of air in attic spaces tends to be high, a resorcinol glue is applied. In areas of low humidity, a casein or similar glue is used. Two rows of 4d nails are used for either the 3/8- or 1/2-inch-thick gusset. The nails are spaced so that they are 3 inches apart and 3/4 inches from the edges of the truss members. Gussets are nail-glued to both sides of the truss.

Plywood-gusset, king-post trusses are limited to spans of 26 feet or less if spaced 24 inches apart and fabricated with 2- by 4-inch members and a 4/12 roof cut. The spans are somewhat less than those allowed for W-trusses having the same-sized members. The shorter span for the king-post truss is due, in part, to the unsupported upper chord. On the other hand, because it has more members than the king-post truss and distances between connections are shorter, the W-truss can span up to 32 feet without intermediate support, and its members can be made of lower grade lumber.

INSTALLATION

Trusses are usually spaced 24 inches OC. They must be lifted into place, fastened to the walls, and braced. Small trusses can be placed by hand, using the procedure shown in figure 2-69. Builders are required on the two opposite walls to fasten the ends of the trusses. One or two workers on the floor below can push the truss to an upright position. If appropriate equipment is available, use it to lift trusses into place.

In handling and storing completed trusses, avoid placing unusual stresses on them. They were designed to carry roof loads in a vertical position; thus it is important that they be lifted and stored upright. If they must be handled in a flat position, enough support should be used along their length to minimize bending deflections. Never support the trusses only at the center or only at each end when they are in a flat position.

Bracing

After the truss bundles have been set on the walls, they are moved individually into position, nailed down, and temporarily braced. Without temporary bracing, a truss may topple over, cause damage to the truss, and possibly injure workers. A recommended procedure for bracing trusses as they are being set in place is shown in figure 2-70. Refer to the figure as you study the following steps:

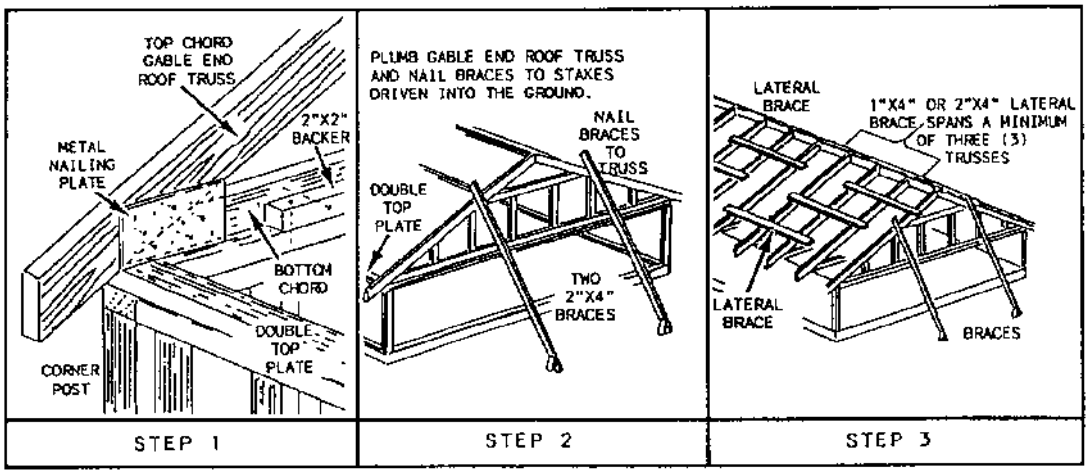


Figure 2-70.—Installing roof trusses and temporary bracing.

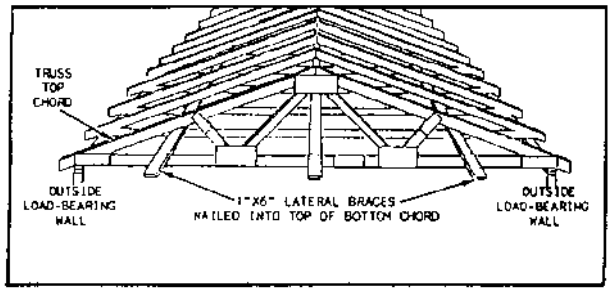


Figure 2-71.—Permanent lateral bracing in a truss.

Step 1. Position the first roof truss. Fasten it to the double top plate with toenails or metal anchor brackets. A 2- by 2-inch backer piece is sometimes used for additional support.

Step 2. Fasten two 2 by 4 braces to the roof truss. Drive stakes at the lower ends of the two braces. Plumb the truss and fasten the lower ends of the braces to the stakes driven into the ground.

Step 3. Position the remaining roof trusses. As each truss is set in place, fasten a lateral brace to tie it to the preceding trusses. Use 1 by 4 or 2 by 4 material for lateral braces. They should overlap a minimum of three trusses. On larger roofs, diagonal bracing should be placed at 20-foot intervals.

The temporary bracing is removed as the roof sheathing is nailed. Properly nailed plywood sheathing is sufficient to tie together the top chords of the trusses. Permanent lateral bracing of 1- by 4-inch material is recommended at the bottom chords (fig. 2-71). The braces are tied to the end walls and spaced 10 feet OC.

Anchoring Trusses

When fastening trusses, you must consider resistance to uplift stresses as well as thrust. Trusses are fastened to the outside walls with nails or framing anchors. The ring-shank nail provides a simple connection that resists wind uplift forces. Toe nailing is sometimes done, but this is not always the most satisfactory method. The heel gusset and a plywood gusset or metal gusset plate are located at the wall plate and make toenailing difficult. However, two 10d nails on each side of the truss (fig. 2-72, view A) can be used

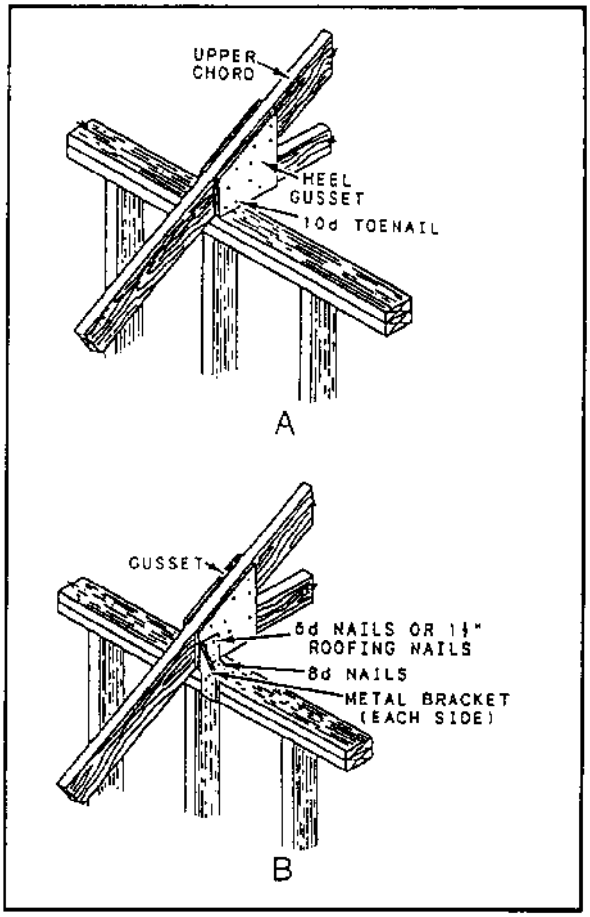


Figure 2-72.—Fastening trusses to the plate: A. Toenailing; B. Metal bracket.

in nailing the lower chord to the plate. Predrilling may be necessary to prevent splitting. Because of the single-member thickness of the truss and the presence of gussets at the wall plates, it is usually a good idea to use some type of metal connector to supplement the toenailings.

The same types of metal anchors (fig. 2-72, view B) used to tie regular rafters to the outside walls are equally effective for fastening the ends of the truss. The brackets are nailed to the wall plates at the side and top with 8d nails and to the lower chords of the truss with 6d or 1 1/2-inch rooting nails.

INTERIOR PARTITION INSTALLATION

Where partitions run parallel to, but between, the bottom truss chords, and the partitions are erected before the ceiling finish is applied, install 2- by 4-inch blocking

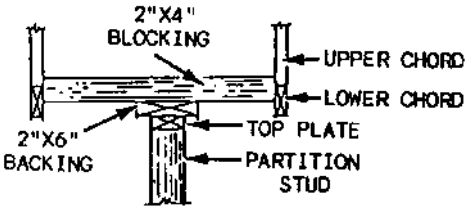


Figure 2-73.-Construction details for partitions that run parallel to the bottom truss chords.

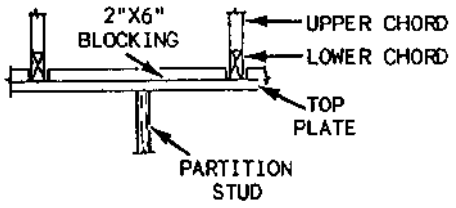


Figure 2-74.-Construction details for partitions that run at right angles to the bottom of the truss chords.

between the lower chords (fig. 2-73). This blocking should be spaced not over 4 feet OC. Nail the blocking to the chords with two 16d nails in each end. To provide nailing for lath or wallboard, nail a 1- by 6-inch or 2- by 6-inch continuous backer to the blocking. Set the bottom face level with the bottom of the lower truss chords.

When partitions are erected tier the ceiling finish is applied, 2- by 4-inch blocking is set with the bottom edge level with the bottom of the truss chords. Nail the blocking with two 16d nails in each end.

If the partitions run at right angles to the bottom of the truss chords, the partitions are nailed directly to lower chord members. For applying ceiling finish, nail 2- by 6-inch blocking on top of the partition plates between the trusses (fig. 2-74).

RECOMMENDED READING LIST

NOTE

Although the following reference was current when this TRAMAN was published, its continued currency cannot be assured. You therefore need to ensure that you are studying the latest revision.

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