

# Basic Roof Framing

## Objectives

After reading this chapter, you'll be able to:

- Identify the basic roof styles.
- Understand the basic terms relating to roof-frame carpentry.
- Develop framing plans for a gable roof, hip roof, and variations that include valleys.
- Lay out a common rafter, using at least one of the four basic methods.
- Lay out ceiling joists.
- Recognize when special ceiling framing may be required.

## Terms

bird's mouth  
pitch  
rafter  
ridge board  
slope  
span  
tail  
total rise  
total run  
unit rise  
unit run



In this chapter, you will be introduced to common types of roofs, the basics of roof framing, and the skills of laying out and cutting a rafter. In following chapters, you will learn more about advanced roof framing, roof sheathing, and roof assembly.

Roof framing begins after the house walls have been framed. In most cases, the walls have also been sheathed to increase their strength and stiffness. For information on additional roof framing options, refer to Chapter 31, "Roof Edge Details." Nominal 2" lumber is generally used for roof framing. It should normally not exceed 19 percent moisture content. Some builders use engineered lumber instead, such as I-joists (see Chapter 17, "Engineered Lumber"). This and following chapters describe roof framing using conventional lumber. Using I-joists requires the same basic understanding of rafter layout and roof design. Installation details for I-joists are given in Section 22.2.

## Planning a Roof

**R**oof framing is considered the most complicated frame carpentry in a house because of all the angles involved. It may also seem difficult to learn because of the special terms. However, it is important to understand that even the most complex roofs are based on a few standard designs.

### ROOF STYLES

The main purpose of a roof is to protect the house in all types of weather with a minimum of maintenance. A roof must be strong to withstand snow and wind loads. The parts must be securely fastened to each other.

Another consideration is appearance. A roof should add to the attractiveness of the home. Roof styles are used to create different architectural effects. A carpenter must understand and be able to frame roofs in various styles.

#### Fig. 22-1.

The basic roof styles used for homes and small buildings are gable, hip, flat, and shed.

**Fig. 22-2.** Variations are associated with architectural styles of different regions or countries. Some of these include the gambrel roof, the mansard roof, and the Dutch hip roof.

### Gable Roof

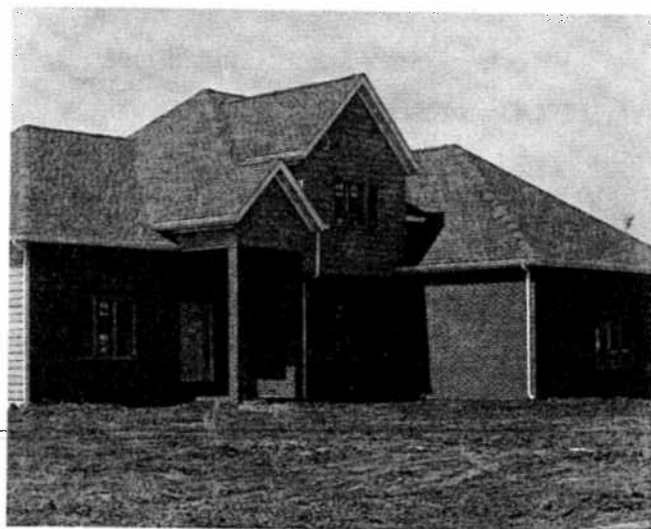
The *gable roof* has two sloping sides that meet at the top to form a gable at each end. (A *gable* is the triangular wall enclosed by the sloping ends of the roof.) A gable roof may include *dormers* (upright window projections) that add light and ventilation to second-floor rooms or the attic. The gable roof is the most common type of roof.

### Hip Roof

A *hip roof* slopes at the ends of the building as well as at the two sides. The slope on all sides results in an even overhang all around the building and gives a low appearance. Because there is no siding above the overhang, maintenance needs are reduced. The hip is also a very



A



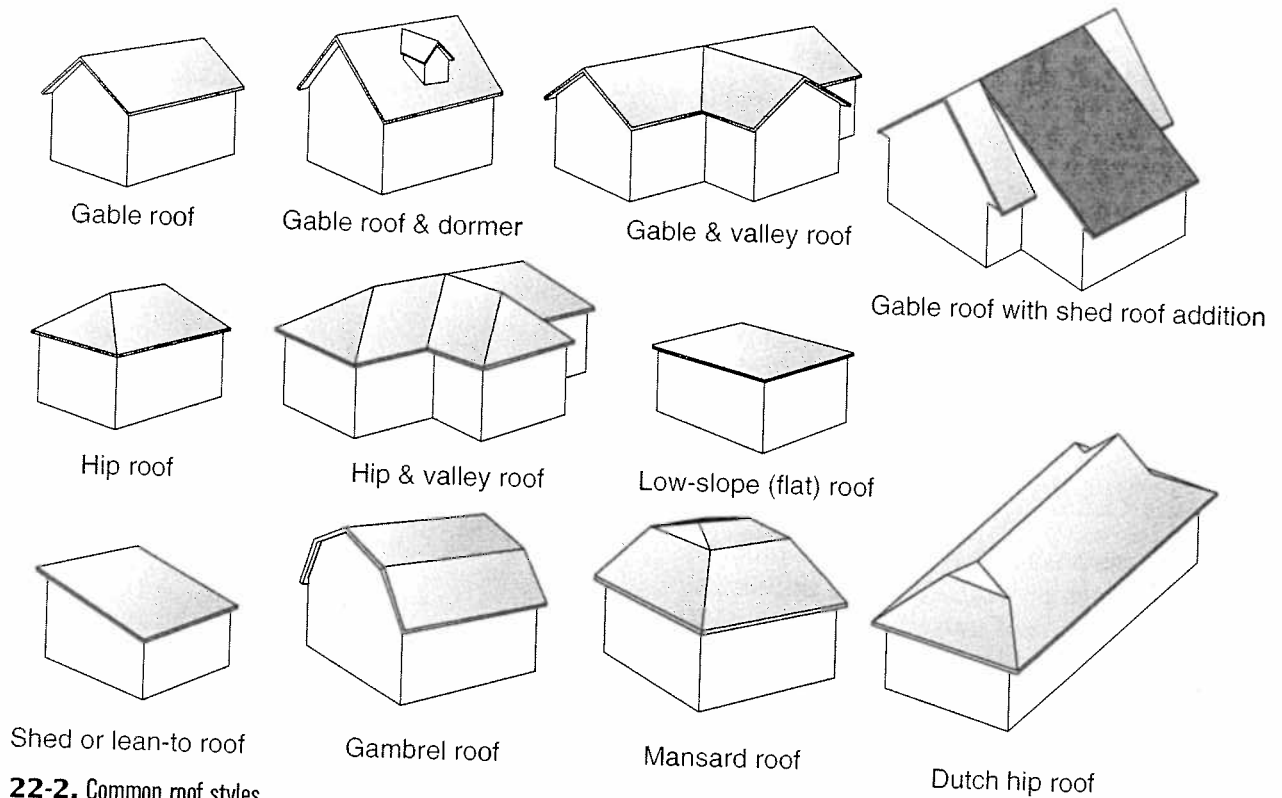
B

**Fig. 22-1.** The gable roof compared with the hip roof. *A.* The gable roof is a common roof style in homebuilding. This one includes gabled dormers. *B.* The hip roof presents a slope on all sides.

strong roof and is often found in regions where severe storms are common. All of these factors make it a popular choice.

### Low-Slope Roof

Sometimes called a *flat roof*, a *low-slope roof* is not perfectly flat. Instead, the *rafters* (inclined members supporting the roof) are laid at a slight angle to encourage water to drain. Sheathing and roofing are applied to the top of the rafters.



**Fig. 22-2.** Common roof styles.

The ceiling material is applied to the underside of the rafters. Because a flat roof can be difficult to waterproof, it is found most often in dry climates.

## Shed Roof

Sometimes called a *lean-to roof*, the *shed roof* slopes in one direction only. A shed roof is often used for an addition to an existing structure. In this case, the roof may be attached to the side of the structure or to the roof.

## Gambrel Roof

The *gambrel roof* is a variation of the gable roof. It has a steep slope on two sides. A second slope begins partway up and continues to the top. This roof style was brought to North America by German immigrants who settled in New York and Pennsylvania. It is commonly used on barns.

## Mansard Roof

The *mansard roof* is a variation of the hip roof. It has steep slopes on all four sides.

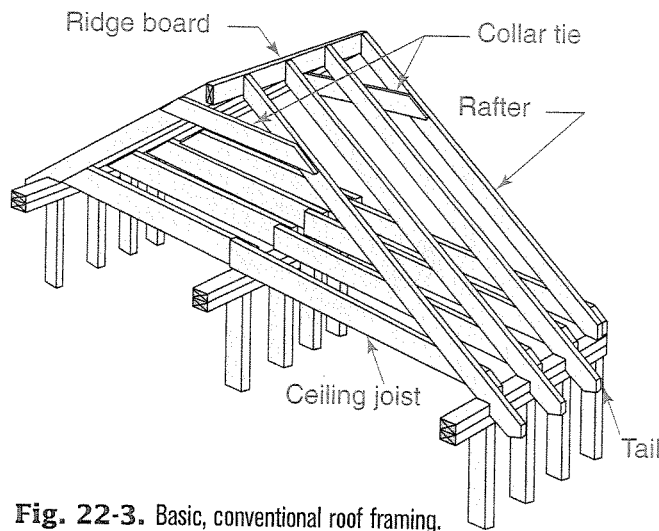
Partway up, a shallow second slope is developed and continues to the top where it meets the slopes from the other sides. The mansard roof style was brought to North America by the French who settled in Quebec, Canada.

## Dutch Hip Roof

A *Dutch hip roof* is related to both the gable roof and the hip roof. Basically, it is a hip roof with a small gable at each end near the top. Like a hip roof, it has an even overhang around the entire building. This protects the walls from rain. Like a gable roof, portions of a Dutch hip roof are formed by two slopes that meet at the top. A Dutch hip roof is more common on single-story houses than on two-story houses.

## ROOF FRAMING BASICS

Mastering the special terms used in roof framing will make it easier for you to understand roofing concepts. Also, become familiar with the *framing square*, which you will be using. Its short leg is called the *tongue*. Its long leg is called the *blade*, or *body*.



**Fig. 22-3.** Basic, conventional roof framing.

## Parts of a Roof

A basic, conventional roof consists of rafters, collar ties, ceiling joists, and a ridge board. **Fig. 22-3.** More complex roofs include valley rafters and jack rafters (see also Chapter 23, "Hip, Valley, and Jack Rafters").

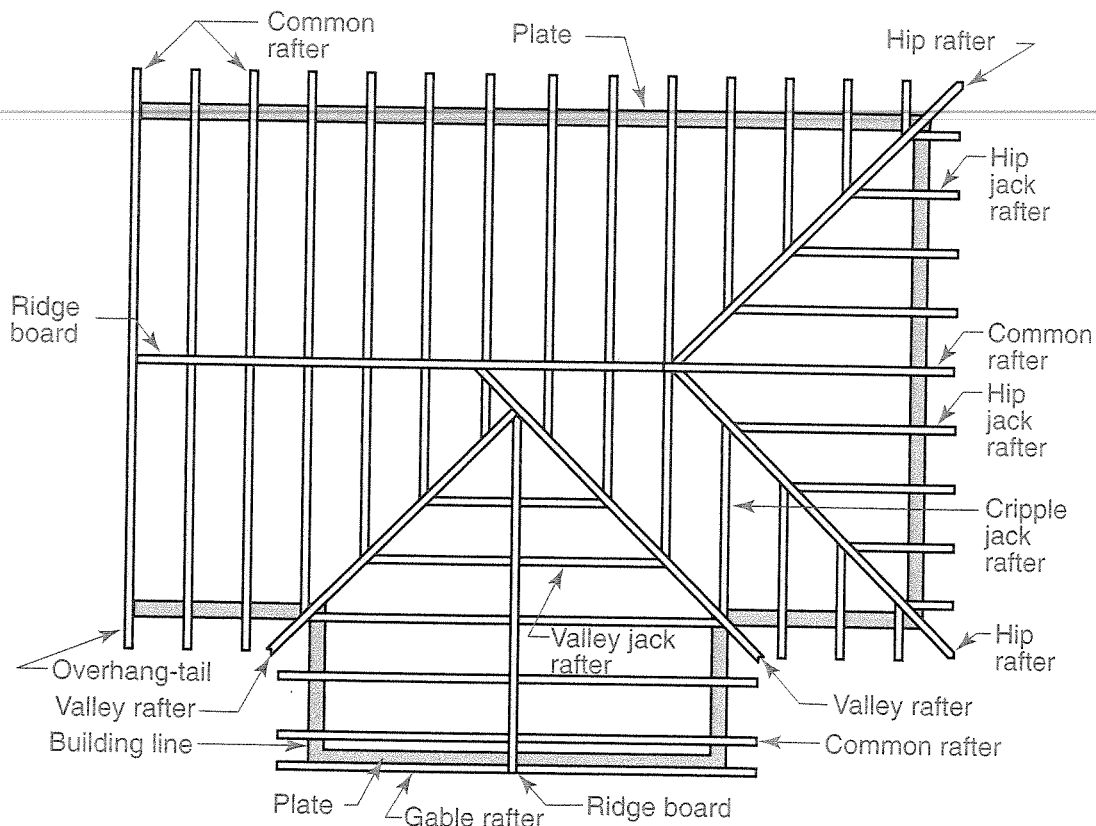
A **rafter** is an inclined member of the roof framework. Rafters serve the same purpose in the roof as joists in the floor or studs in the wall. They are usually spaced 16" or 24" apart. Rafters vary in depth depending on their length,

the distance they are spaced apart, their slope, and the kind of roof covering to be used. A **collar tie** is a horizontal tie that connects opposite pairs of rafters to help stiffen the roof. The **ridge board**, or **ridge**, is the horizontal piece that connects the upper ends of the rafters.

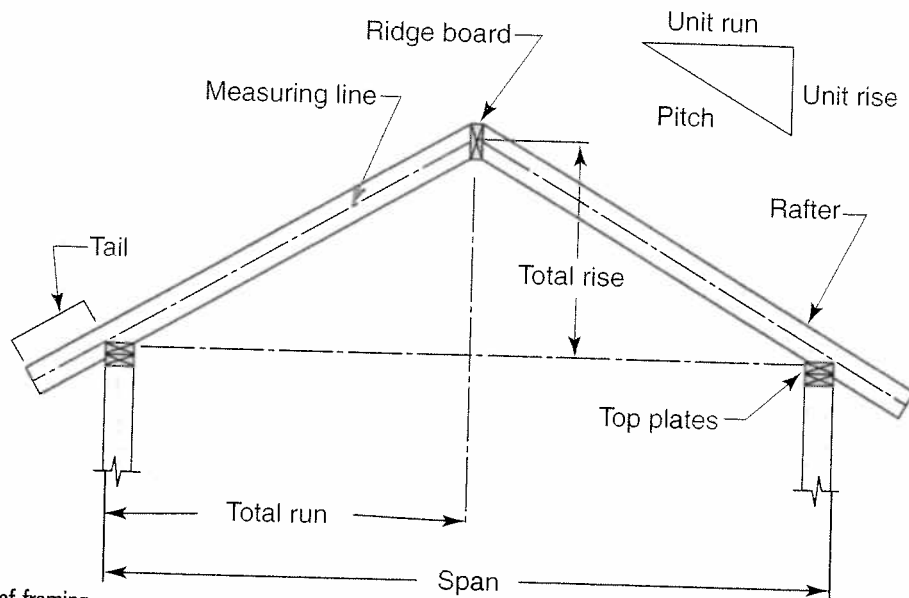
Rafters often extend beyond the exterior walls to form *eaves* (also called *overhangs*) that protect the sides of the house. The **tail** is the portion of the rafter that extends beyond the wall of the building to form the eave.

The following rafters are needed for framing the different roof styles (**Fig. 22-4**):

- **Common rafters** extend from the top plate to the ridge board at 90° to both.
- **Hip rafters** extend diagonally from the corners formed by the top plates to the ridge board.
- **Valley rafters** extend diagonally from the top plates to the ridge board along the lines where two roofs intersect.
- **Jack rafters**, also called *jacks*, never extend the full distance from the top plate to the ridge board. There are three kinds of jack rafters. *Hip jack rafters* extend from the top plate to a hip rafter. *Valley jack rafters* extend from the ridge board to a valley rafter. *Cripple jack rafters* extend between a hip rafter and a valley rafter or between two valley rafters.



**Fig. 22-4.** The parts of a roof frame as seen from above.



**Fig. 22-5.** Terms used in roof framing.

## Calculating Roof Slope

The slope of a roof must be calculated before construction can begin. It depends upon several factors, including the roof's span, run, and rise.

The distance between the outer edges of the top plates is the **span**. **Fig. 22-5.** It is measured at right angles to the ridge board.

The **total run** is one-half the span (except when the slope of the roof is irregular). The **unit run**, or *unit of run*, is a set length that is used to figure the slope of rafters. The **unit run** for a rafter that is at a 90° angle to the ridge (a common rafter) is always 12". The unit run for a rafter that is at a 45° angle to the ridge is 17". Refer to Fig. 22-4.

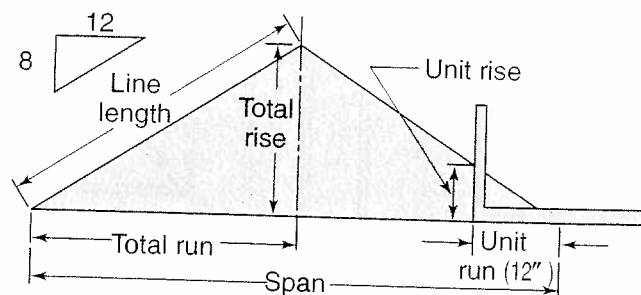
The *measuring line* is an imaginary line running from the outside wall to the top of the ridge. The **total rise** is the vertical distance from the top of the top plate to the upper end of the measuring line. The **unit rise** is the number of inches that a roof rises for every 12" of run (the unit run). As the unit rise varies, the slope of the roof changes. **Fig. 22-6.**

*Slope* and *pitch* are often used interchangeably, but they do not mean the same thing. **Slope** is a ratio of unit rise to unit run. **Pitch** is a ratio of total rise to span.

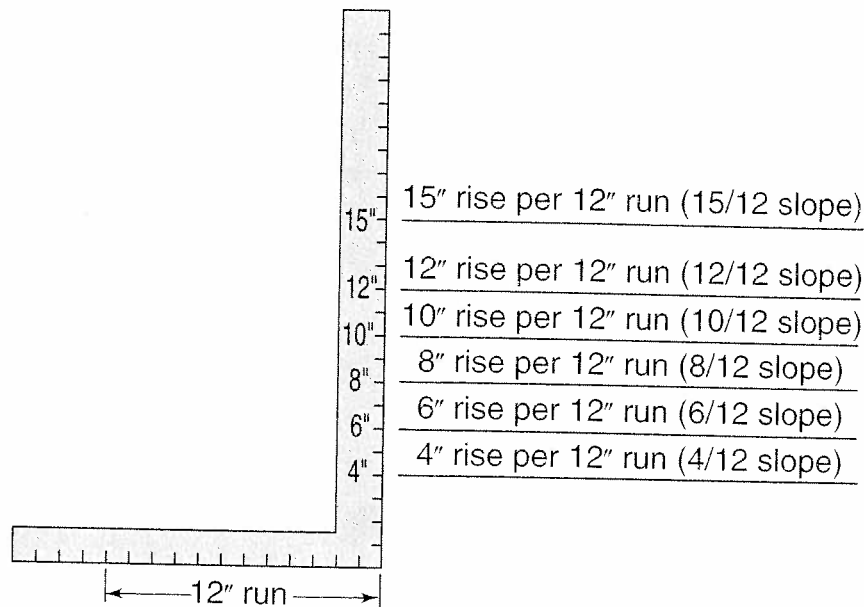
The triangular symbol above the roof in Fig. 22-6 shows the slope visually. When the slope is written out in words, the unit rise is separated from the unit run by a slash mark. For example,



Many carpenters use the terms *slope* and *pitch* as if they mean the same thing. Some construction dictionaries also consider these two terms to be synonymous. However, this is not precisely correct. *Slope* refers to a ratio of rise to run. *Pitch* refers to a ratio of rise to span. Either term can be used to describe the inclination (slant) of roofs and rafters, but *slope* is the term most suited to roof framing.



**Fig. 22-6.** A comparison of total and unit terms. The unit run of a common rafter is always 12". The rise in inches is variable, depending on the slope of the roof. In the example shown here, there are 8" of rise per unit of run.

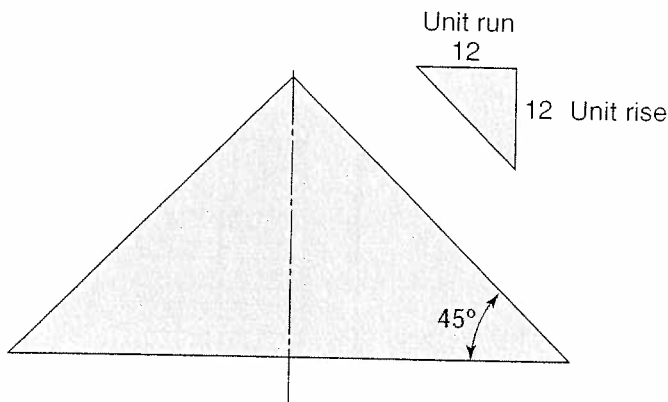


**Fig. 22-7.** A visual description of slope using a framing square.

a roof may have a unit rise of 6" and a unit run of 12". The information would be written "6/12 slope" and pronounced "six twelve slope" or sometimes "six in twelve slope." **Fig. 22-7.** The slope of a roof can also be given in degrees. For example, a roof with a 12/12 slope forms a 45° angle. **Fig. 22-8.** However, referring to degrees is not a common practice.

Plumb lines and level lines refer to the direction of a line on a rafter, not to any particular rafter cut. Any line that is vertical when the rafter is in its proper position is called a *plumb line*. Any line that is horizontal when the rafter is in its proper position is called a *level line*.

**Fig. 22-9.**

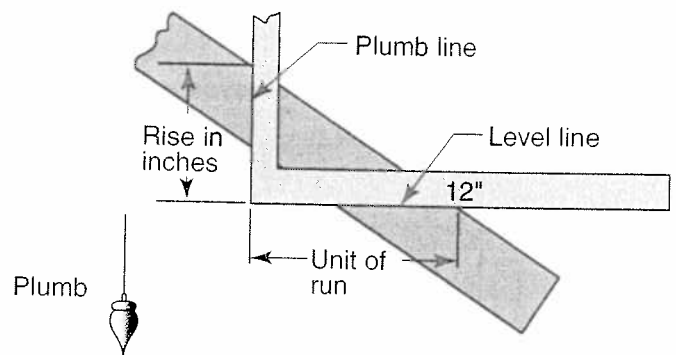


**Fig. 22-8.** A roof with a 12/12 slope is angled at 45° and has a 1/2 pitch.

## LAYING OUT A ROOF FRAMING PLAN

Before cutting rafters, the carpenter must determine what kinds are needed to frame the roof. A roof framing plan may be included in the set of building plans. If it is not included, you must lay one out for yourself.

If the plan is drawn to scale, the exact number of each kind of rafter can also be determined. However, the actual rafter length should be figured based on dimensions taken directly from the building.



**Fig. 22-9.** The framing square is used to lay out the plumb and level lines on a rafter. The plumb line is drawn along the tongue of the square. The level line is drawn along the body, or blade.

## Gable Roof

The gable roof framing plan is the simplest to develop. **Fig. 22-10.**

1. Lay out the outline of the building (A).
2. Determine the direction in which the rafters will run.
3. Draw the centerline at right angles to this direction (B). The centerline determines the location of the ridge line (C). This corresponds to the location of the ridge board.
4. Determine the distance between the rafters and lay out the roof frame plan (D).

1. Lay out the outline of the building (A).
2. Draw the centerline of the larger rectangle (B, arrow 1).
3. Draw the centerline of the smaller rectangle (B, arrow 2).
4. Draw 45° lines from the interior corners of the building to where the centerlines intersect (C).
5. Draw the ridge lines (D).
6. Determine the distance between the rafters and lay them out on the roof framing plan (E).

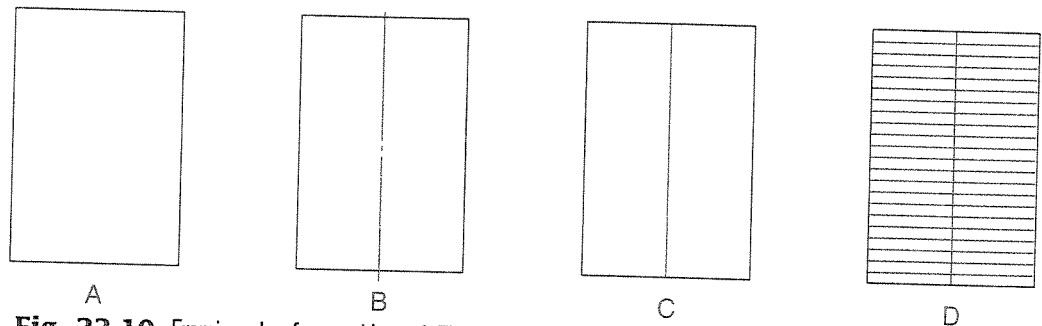
## Gable and Valley Roof

A gable and valley roof is simply two gable roofs that intersect. In the majority of cases they intersect at a 90° angle. The intersection creates two valleys. **Fig. 22-11.**

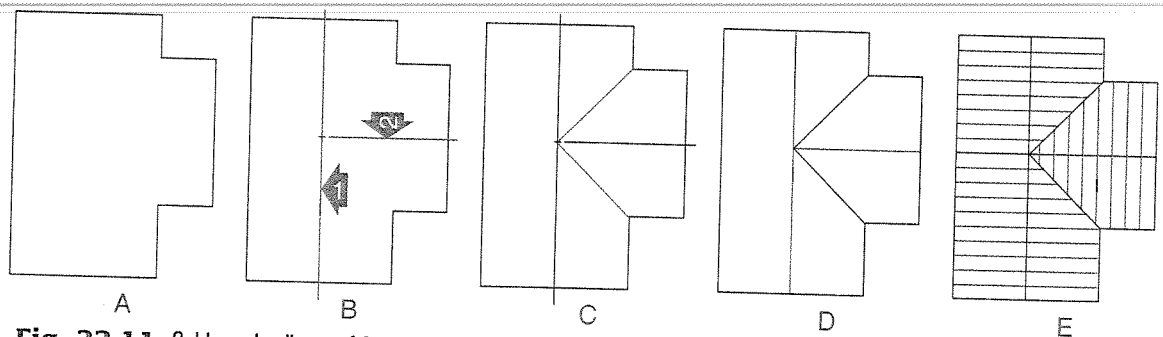
## Hip Roof

The angle at which the hip extends from each corner is usually 45°, but other angles are possible. **Fig. 22-12.**

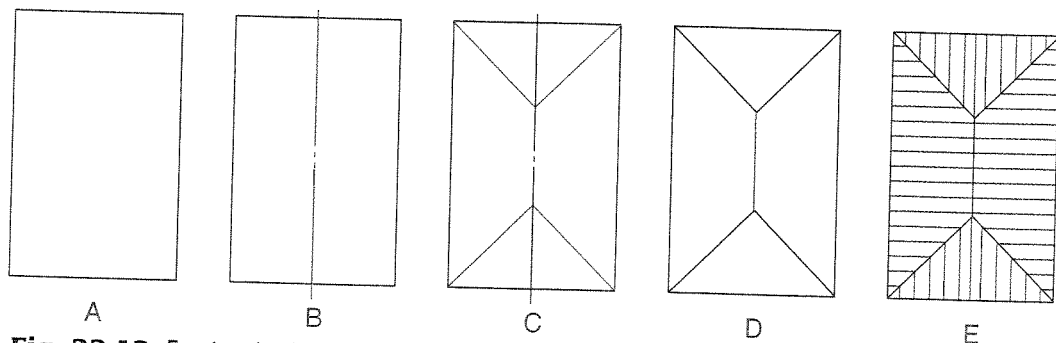
1. Lay out the outline of the building (A).



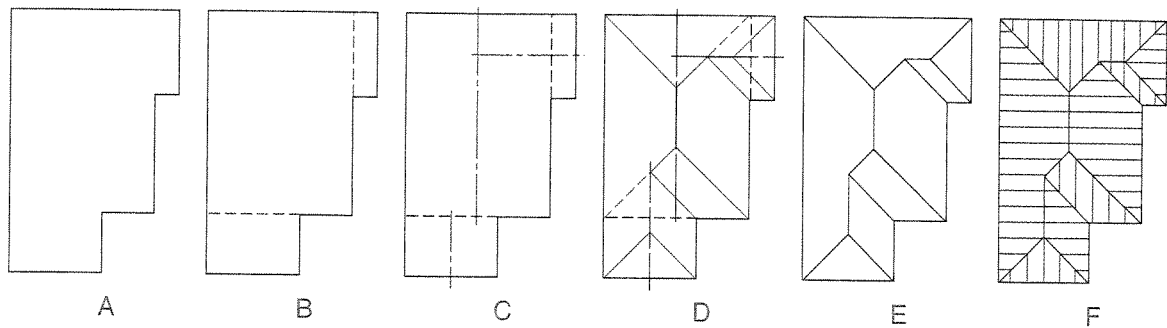
**Fig. 22-10.** Framing plan for a gable roof. The frame plan for a shed roof would be one-half of this.



**Fig. 22-11.** Gable and valley roof framing plan.



**Fig. 22-12.** Framing plan for a hip roof.



**Fig. 22-13.** Hip and valley roof framing plan.

2. Locate and draw a centerline (B).
3. Starting at each corner, draw a 45° line from the corner to the centerline (C). This establishes the location of the hip rafters.
4. Draw the ridge line between the intersecting points of the hip rafters (D).
5. Determine the distance between the rafters and lay them out on the roof framing plan (E).

### Hip and Valley Roof

A hip and valley roof can be quite complex. It is created when one or more hip roofs intersect at 90° angles. **Fig. 22-13.**

1. Lay out the outline of the building (A).
2. Outline the largest rectangle inside the building outline (B).
3. Draw centerlines for every rectangle formed inside the building outline (C).
4. Draw a 45° line from each inside and outside corner. Extend these lines to intersect with the centerlines (D). The lines indicate the location of the hip rafters on outside corners and valley rafters on inside corners.
5. The centerlines drawn in (C) connect the hip and valley rafters. Draw these as solid lines where the ridges will be located (E).
6. Figure the distance between the rafters and lay them out on the roof framing plan (F).

### SECTION 22.1

### Check Your Knowledge

1. Name the four basic roof styles used for homes.
2. The gambrel roof is a variation of which basic roof style?
3. Explain the difference between a plumb line and a level line.
4. What is the purpose of a roof framing plan?

### On the Job

Draw a roof framing plan for a house with the following characteristics:

- It will be the same width as the house shown in Fig. 22-10, but twice its length.
- The main roof will be a gable. Two other gable roofs will intersect with it, one on each long side of the house.
- The ridges of the intersecting gable roofs should meet the main ridge one-third of the distance from the end of the house.
- The side walls of one intersecting roof should be twice as long as the walls of the other.



## Roof Framing with Common Rafters

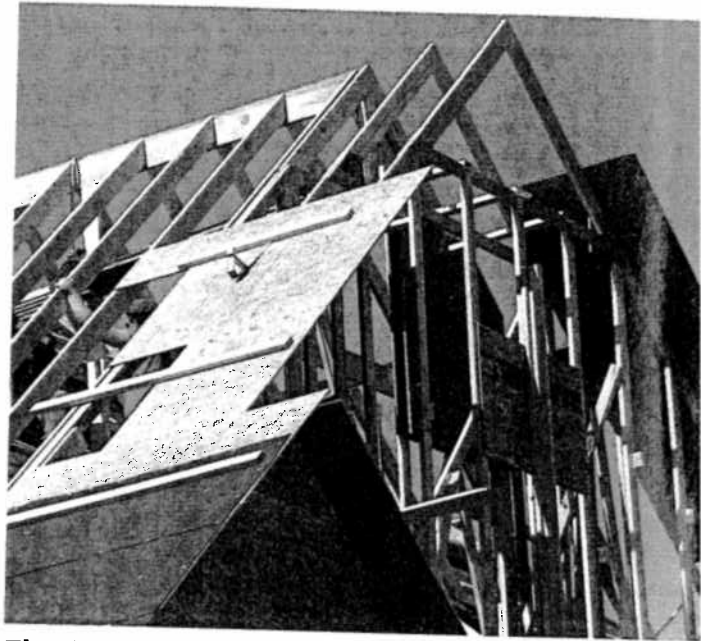
In trussed-roof construction, prefabricated trusses are attached as a unit. Their lower chords form the ceiling of the room, while the top chords form the roof. Trusses will be discussed separately in Chapter 25, "Roof Trusses."

In conventional roof construction, carpenters assemble the roof from individual ceiling joists and rafters. **Fig. 22-14.** The rafters should not be erected until the ceiling joists have been fastened in place (see Section 22.3). The ceiling joists act as a tie to prevent the rafters from pushing the exterior walls outward.

The following methods are used for a gable roof. Variations apply to gambrel, shed, and flat roofs.

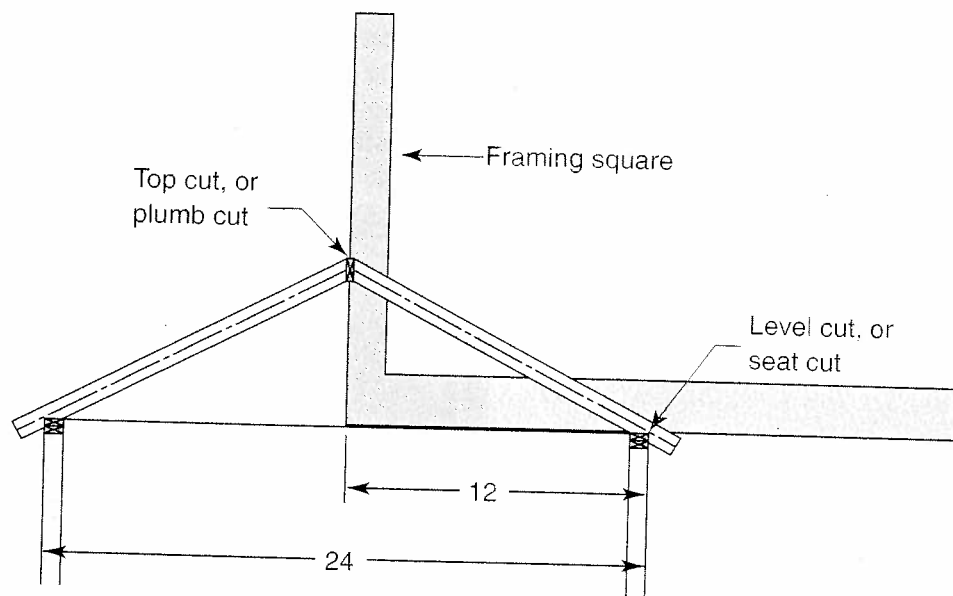
### LAYING OUT COMMON RAFTERS

The rafters form the skeleton of the roof. They must be carefully made and fitted if they are to support the roof's weight. The top of the rafter rests against the ridge board. The cut made in the rafter so it fits against the ridge is called a *plumb cut*. The bottom of the rafter rests on the plate. The cut made here is called a *level cut*, or *seat cut*. **Fig. 22-15.**

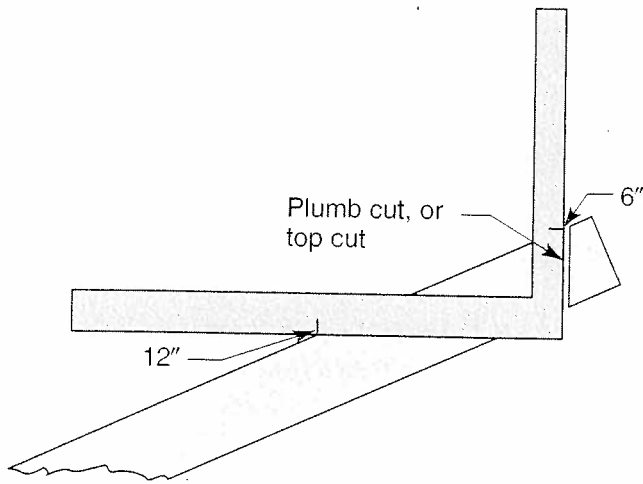


**Fig. 22-14.** A conventionally framed roof is installed piece by piece.

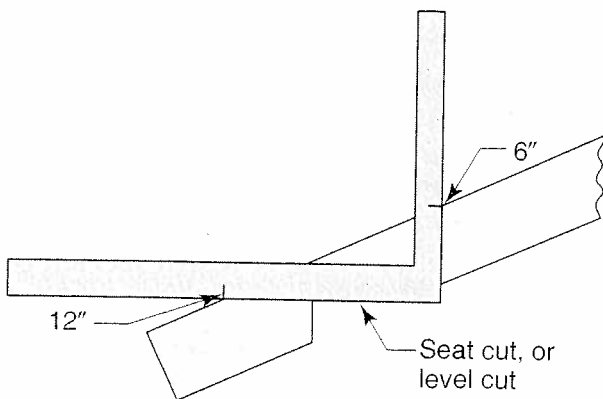
A line for the plumb cut is drawn using a framing square as a guide. **Fig. 22-16.** The unit run (12" mark) on the blade of the square is aligned with the edge of the rafter. The unit rise on the tongue of the square will correspond to the pitch of the roof. The unit rise is aligned on the same edge of the rafter. The line for the plumb cut is then drawn along the edge of the tongue.



**Fig. 22-15.** The framing square was enlarged to show its relationship to the roof and to the top and bottom cuts.



**Fig. 22-16.** A plumb line has been drawn for the plumb (top) cut on a roof with a 6" unit rise (1/4 pitch).

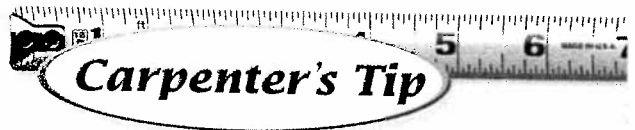


**Fig. 22-17.** A level line drawn for the seat cut. This cut is made for a roof with a 6" unit rise.

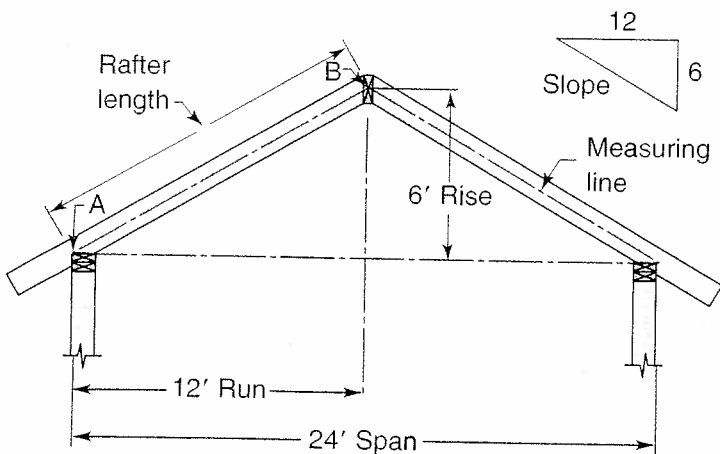
A line for the seat cut is drawn with the square in the same position on the rafter. A level line is drawn for the same roof pitch, except that the line is drawn along the body of the framing square. **Fig. 22-17.**

Look at **Figs. 22-18** and **22-19**. The *theoretical length* of a common rafter is the shortest distance between the outer edge of the plate (A) and a point where the measuring line of the rafter meets the ridge line (B). This length is found along the measuring line. It may be calculated in the following ways:

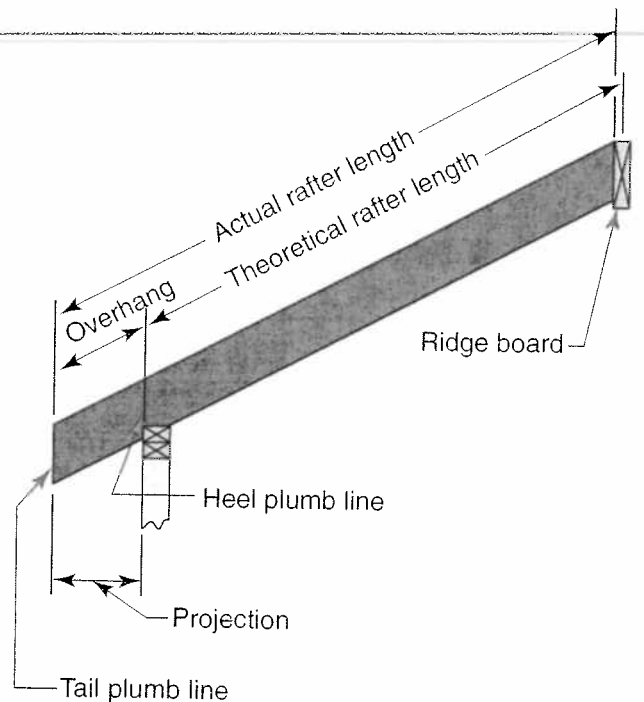
- By using the Pythagorean theorem.
- By using the unit length obtained from the rafter table on the framing square.



Instead of using a standard framing square for laying out roof framing, many carpenters use a triangular framing square. Smaller and more durable than a framing square, this tool can be used for the same purposes. It has a thickened lip along one side. This enables the carpenter to hold the tool against lumber and use it as a guide for a circular saw.



**Fig. 22-18.** The theoretical rafter length is measured from point A to point B.



**Fig. 22-19.** Actual and theoretical length of a common rafter.

# SAFETY FIRST

## Lifting Rafters

During the layout and assembly of a roof frame, a great volume of lumber must be handled. Rafters are much heavier than wall studs and far more unwieldy. Organize the work to minimize back strain. For example, have lumber delivered close to where it will be cut. Work with a helper to lift rafters into position.

- By stepping off the length with the framing square.
- By entering the rise and run into a calculator designed for solving construction problems.

## Pythagorean-Theorem Method

The Pythagorean theorem states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides (Fig. 22-20):

$$C^2 = A^2 + B^2$$

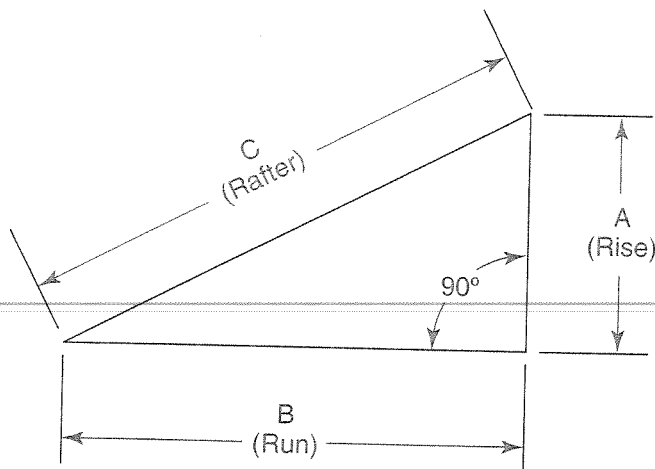


Fig. 22-20. The length of the rafter (C) is equal to  $\sqrt{A^2 + B^2}$ .

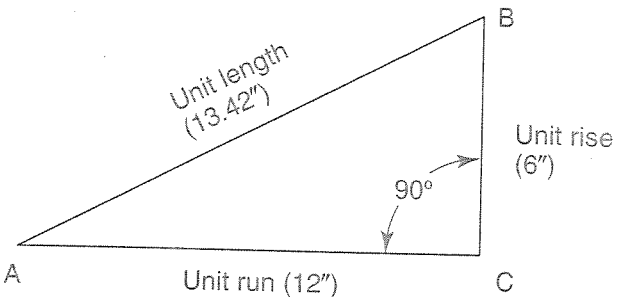


Fig. 22-21A. Unit length of the rafter is represented by the line AB. The length of this line can be found in the rafter table on the framing square.

The length of the hypotenuse (C) will be the square root of the sum of the square of the other two sides.

$$C = \sqrt{A^2 + B^2}$$

The rise, the run, and the rafter of a roof form a right triangle. The measuring line representing the rafter is the hypotenuse. The length of the rafter (C) can thus be calculated from the rise (A) and the run (B).

## Unit-Length Method

The unit-length method uses the rafter table on a framing square. *Unit length* is the length of a rafter per foot of run. It can be expressed as the hypotenuse of a right triangle. The unit run (12") is the base, and the unit rise (in inches per foot of run) is the altitude. Fig. 22-21A. Look at the rafter table on the framing square. Fig. 22-21B. The top line of the table reads: "Length

23	22	21	20	19	18	17
LENGTH COMMON RAFTERS PER FOOT RUN			21	63	20	81
" HIP OR VALLEY			"	"	"	"
DIFF IN LENGTH OF JACKS 16 INCHES CENTERS			24	74	24	02
" " " 2 FEET			43	3/4	41	3/8
SIDE CUT OF JACKS USE			6	11/16	6	15/16
" " HIP OR VALLEY			8	1/4	8	1/2
22	21	20	19	18	17	16

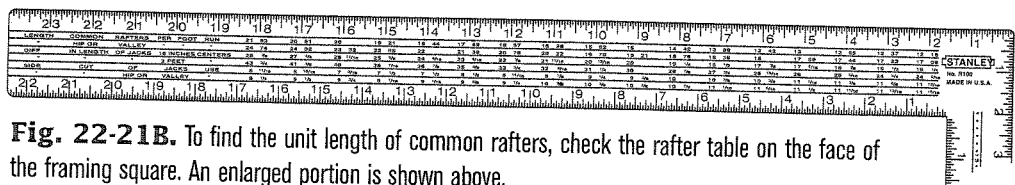
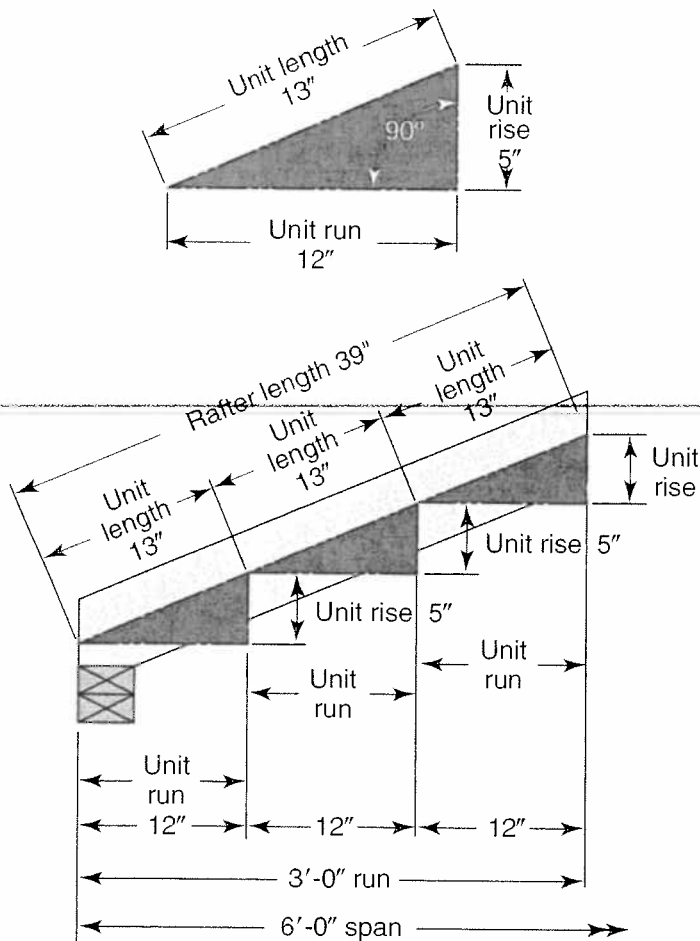


Fig. 22-21B. To find the unit length of common rafters, check the rafter table on the face of the framing square. An enlarged portion is shown above.

Common Rafters per Foot Run.” The inch markings along the top represent unit rise. For example, if you follow across the top line to the figure under 6 (for a unit rise of 6”), you will find the number 13.42. This is the unit length for a roof triangle with a unit run of 12” and a unit rise of 6”.

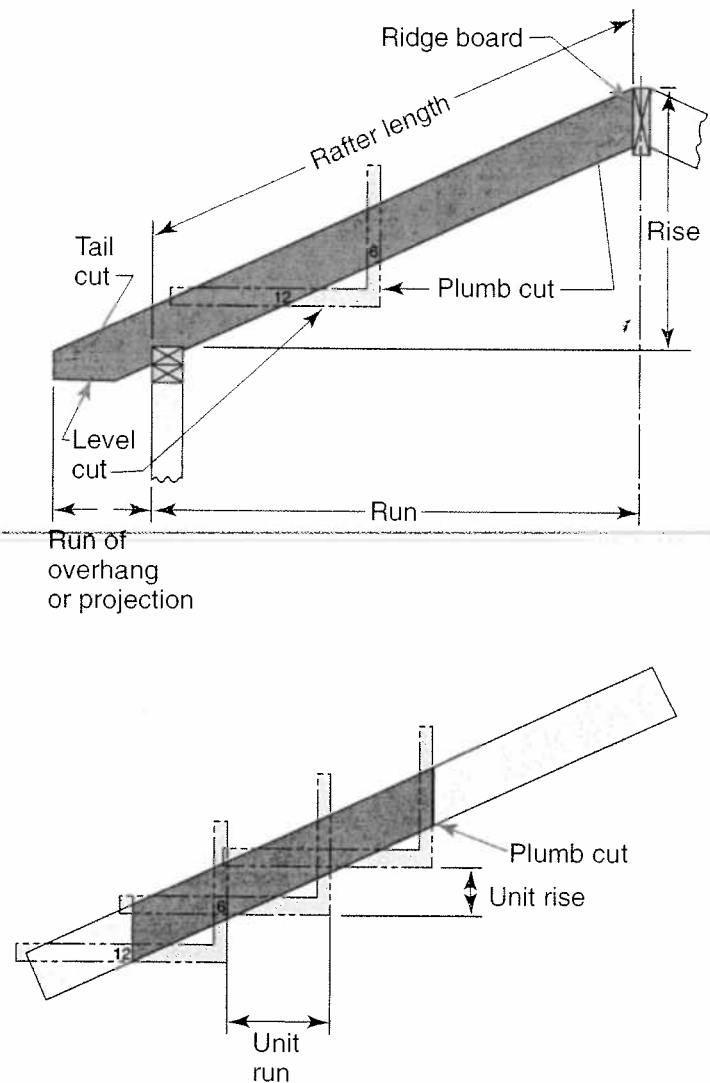
Let’s figure the total length of a rafter for a small building with a unit rise of 5”, a span of 6’, and a run of 3’. Look at the rafter table to obtain the unit length. For a unit rise of 5”, the unit length is 13” per unit run. The total length is the unit length times the total run. The total run of the building in this example is 3’. Therefore the total length of the common rafters is 39”. **Fig. 22-22.**



**Fig. 22-22.** The total theoretical length of a rafter is the total run times the unit length. In this example, the total run is 3’ and the unit length is 13”. Therefore, the length of the rafter is 39”.

## Step-Off Method

A third method for finding the theoretical rafter length is by using the framing square to “step off” the length. **Fig. 22-23.** Place the square on the rafter with the tongue along the plumb cut. Step off the length of the unit run on the rafter stock as many times as there are feet in the total run. In this case, it would be three times.

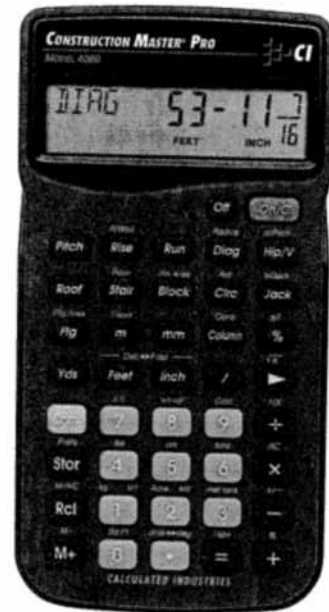


**Fig. 22-23.** Stepping off the length of a common rafter.

Often the total run of a building will not come out in even feet. For example, the run might be 3'-4". With the square at the first position, draw a line along the edge of the tongue to represent the plumb cut at the ridge board. **Fig. 22-24.** At the 4" mark on the blade, make a mark on the rafter along the level line—not along the edge. Then, starting at this mark, step off the unit run three times, for a total run of 3'-4". This is the theoretical length of the rafter.

## Calculator Method

Small, easy-to-use construction calculators are now common on job sites. **Fig. 22-25.** Measurements can be entered into the calculator in feet and inches, including fractions. If you know the rise and the run, you can easily determine the length of a common rafter by entering these figures into the calculator. You can also use the tool to calculate cuts for hip rafters and valley rafters.

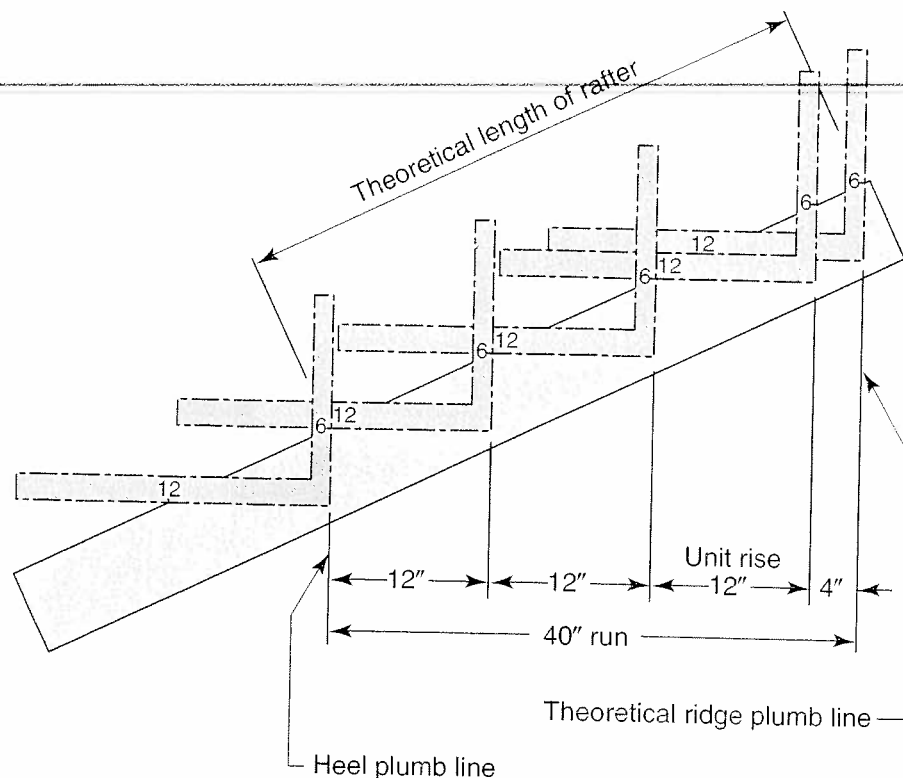


**Fig. 22-25.** A construction calculator is often used to solve roof framing problems. Dimensions can be entered in feet, inches, and fractions of an inch.

## COMPLETING THE LAYOUT

After the basic rafter layout is complete, additional work is required. The ridge allowance, rafter overhang, and bird's mouth must be con-

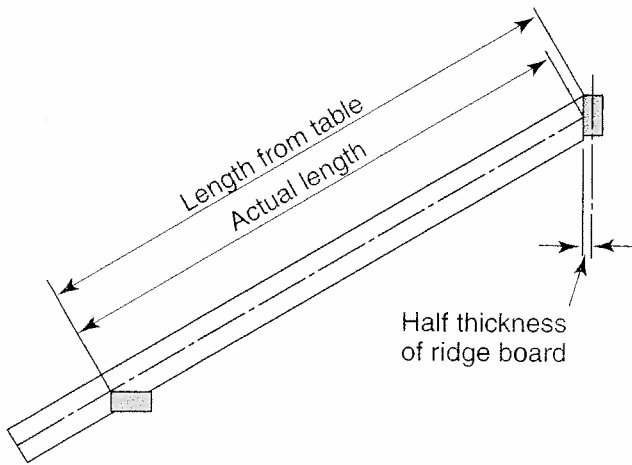
sidered. Layout of the ridge board will be discussed in Chapter 24, "Roof Assembly and Sheathing."



**Fig. 22-24.** Stepping off the rafter when the total run is not an even number of feet.

## Common Rafter Ridge Allowance

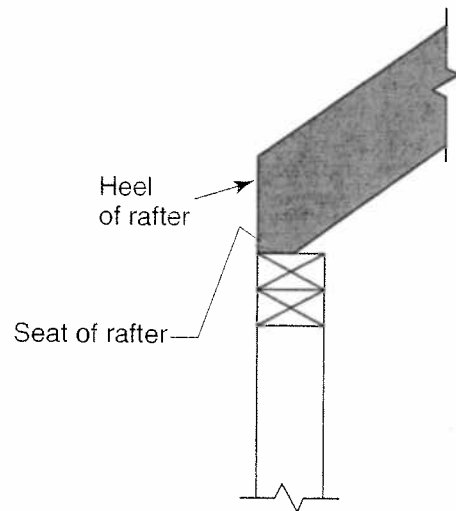
The theoretical rafter length does not take into account the thickness of the ridge board or the length of the overhang, if there is one. To cut a rafter without an overhang to its actual length, you must deduct one-half the thickness of the ridge board from the ridge end. **Fig. 22-26.** For example, if 2" material is used for the ridge board, its actual thickness is 1½". One-half of this is ¾". The ¾" is indicated along the level line, and the line for the actual ridge plumb cut is drawn. **Fig. 22-27.**



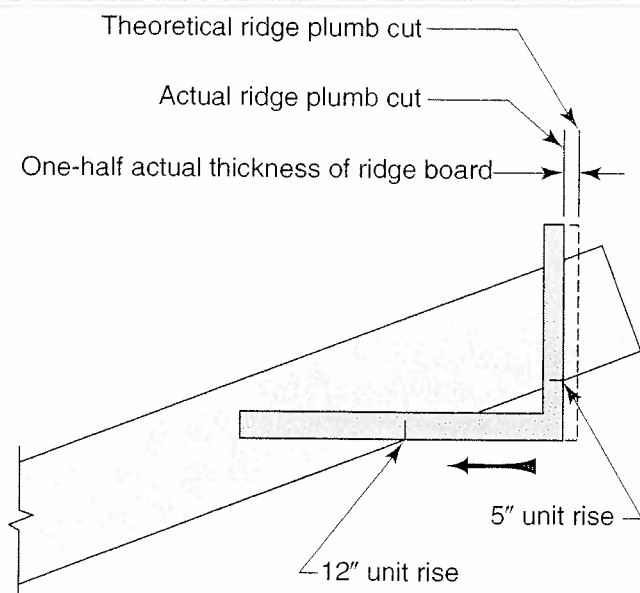
**Fig. 22-26.** Subtract one-half the actual thickness of the ridge board from the theoretical length of the rafter to obtain the rafter's actual length. If there is to be an overhang, this will be added later.

## Common Rafter Overhang

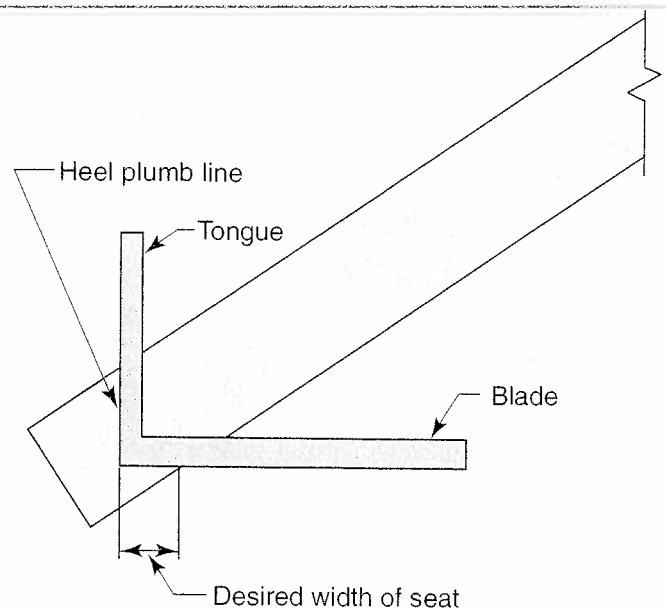
A roof may or may not have an overhang, or eave. If not, the rafter must be cut so that its lower end is even with the outside of the exterior wall. If the end is cut parallel to the ridge plumb cut, it is said to have a *heel*. **Fig. 22-28.** The portion of the rafter that rests on the plate is called the *seat*. To lay out the seat, place the tongue of the framing square on the heel plumb line. The rafter edge will intersect the correct seat width on the blade. **Fig. 22-29.** Indicate the seat by drawing a line from the heel plumb line along the blade.



**Fig. 22-28.** A rafter without an overhang rests on the exterior wall plate.



**Fig. 22-27.** Lay off one-half the thickness of the ridge board along the level line. Do not lay it off along the edge of the rafter.



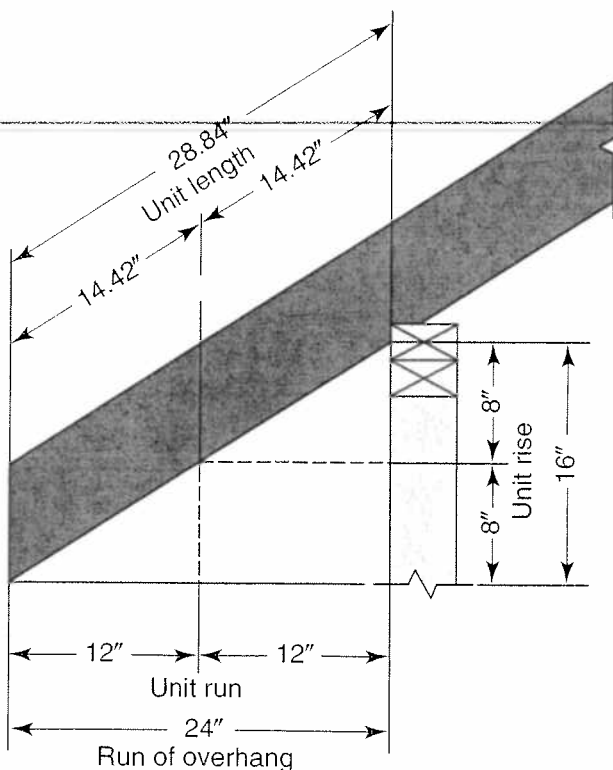
**Fig. 22-29.** Laying out the rafter seat.

A roof with wide overhangs provides protection for side walls and end walls. Though it adds slightly to the initial cost, this type of roof extension saves on maintenance later.

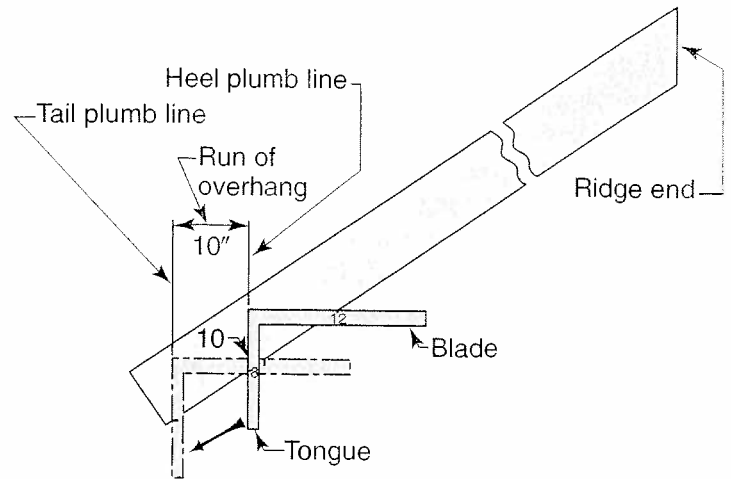
If the roof does have an overhang, the overhanging part of the rafter is the tail. Its length must be added to the length of the rafter. The length of the tail may be calculated as if it were a separate short rafter. Any of the methods used for finding rafter length may be used to find the length of the tail. For example, suppose the run of the overhang is 24" and the unit rise of the roof is 8". **Fig. 22-30.** Look at the rafter table on the framing square to find the unit length for a common rafter with a unit rise of 8". You will see the unit length is 14.42". Since the total run of the overhang is 24", the total length is 28.84", or  $28\frac{7}{32}$ ".

$$14.42 \text{ (inches per unit run)} \times 2 \text{ (units of run)} = 28.84"$$

Another way to lay out the overhang is with the framing square. Suppose the run of the overhang is 10". **Fig. 22-31.** Start the layout by plac-



**Fig. 22-30.** Calculating overhang. The length of the rafter overhang may be found by using the rafter table on the framing square.



**Fig. 22-31.** Laying out the run of the overhang directly on the rafter using the framing square.

ing the tongue of the square along the heel plumb line and setting the square to the pitch of the roof. In Fig. 22-31, the square is set to a unit rise of 8" and a unit run of 12". Move the square in the direction of the arrow, as shown, until the 10" mark of the blade is on the heel plumb line. Draw a line along the tongue. This will mark the tail cut. If fascia or soffits are to be added later, be sure to allow for them in figuring the length of the rafter tail.

Many carpenters do not cut the tail to the finished length until after the rafters have been fastened in place. Instead, a sufficient amount of material is allowed for the overhang. After the rafters are fastened in place, a chalk line is snapped on the top edge of all the rafters. A tail plumb line is then drawn down from this chalk line on each rafter and the tail is cut along the line.

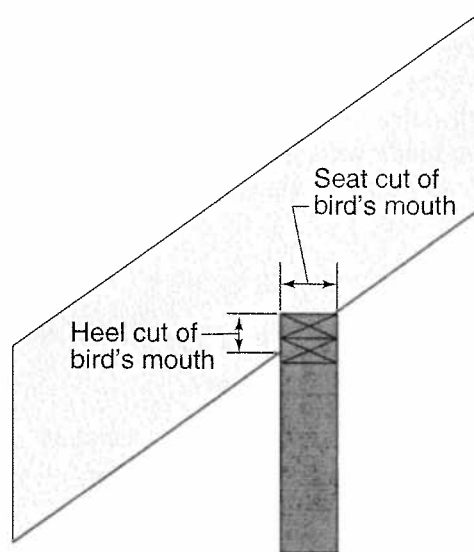
**from Another Angle**

Another method of cutting rafter tails is to place a square on the chalk mark and draw a line for a square cut. This can only be done when there is no requirement for gutters on the house. A square cut makes gutters very difficult to mount.

## Laying Out a Bird's Mouth

A **bird's mouth** is a notch made in a rafter with an overhang so that the rafter will fit against a plate. **Fig. 22-32.** The plumb cut for the bird's mouth, which bears against the side of the plate, is called the *heel cut*. The level cut, which bears on the top of the plate, is called the *seat cut*.

The size of the bird's mouth for a common rafter is usually stated in terms of the depth of the heel cut rather than the width of the seat cut. The bird's mouth is laid out much the same way as the seat cut for a rafter without an overhang. Measure off the depth of the heel on the heel plumb line, set the square, and draw the seat line along the blade. **Fig. 22-33.**



**Fig. 22-32.** The bird's mouth on a rafter with an overhang.

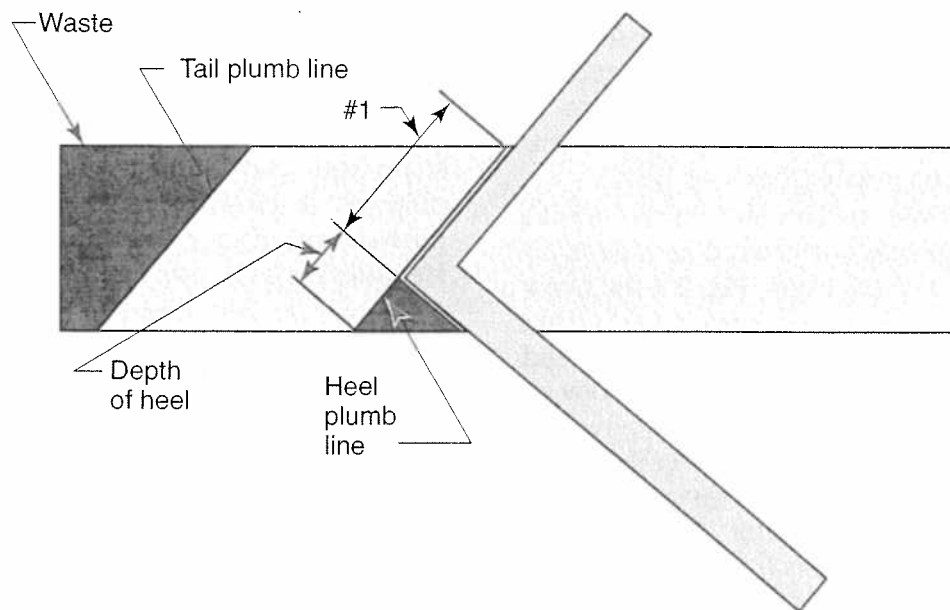
## CUTTING RAFTERS

To cut common rafters, the actual length of one rafter is laid out on a piece of stock. The crown of the rafter should be on the top edge. After the first rafter is cut, it is used as a pattern for cutting a second.

The two rafters are then tested on the building using the ridge board or a scrap piece of the same size material to see how the heel cut and the top cut fit. If they fit properly, one of these rafters can be used as a pattern to cut all the others needed.

Cut rafters should be distributed to their locations along the building. The rafters are usually leaned against the building with the ridge cut up. The workers on the building can then pull them up as needed and fasten them in position.

In large developments, houses must be built quickly. Carpenters using conventional roof framing methods instead of trusses, which are faster, must develop efficient work habits. One way in which they can speed their work without sacrificing quality is to gang-cut rafters. After the master rafter pattern has been established,



**Fig. 22-33.** Using the square to lay out a bird's mouth. For a common rafter on a gable roof, the depth of the heel cut is laid out along the heel plumb line. The length of the line at arrow #1 is the important dimension when laying out the bird's mouth for a hip and valley rafter, discussed later.



many pieces of rafter stock are clamped together atop sawhorses. Lines are marked across the edges of the stock to indicate heel cuts, plumb cuts, and bird's-mouth cuts. Then the cuts are made on a group of rafters at the same time, sometimes using special saws.



Rafter cutting is usually done with a circular saw. It is important not to overcut when making the bird's mouth. This will weaken the rafter. It is best to stop the heel cut and the seat cut short of each intersecting layout line. In other words, make partial cuts. Then finish the cut with a handsaw or jigsaw.

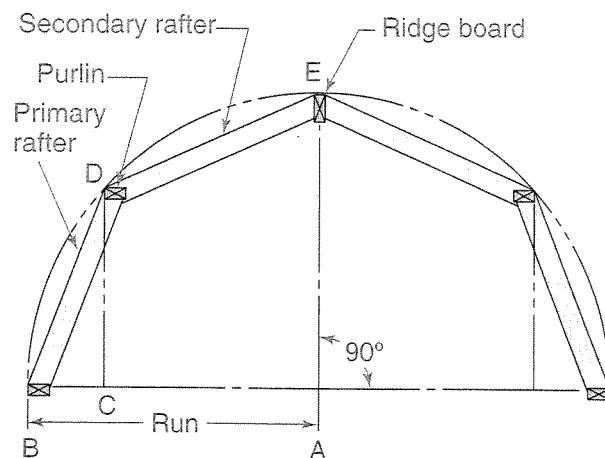
## GAMBREL, SHED, AND LOW-SLOPE ROOFS

Other kinds of roofs are framed using variations of the same basic techniques used to build a gable roof. These roofs include gambrel roofs, shed roofs, and flat, or low-slope, roofs.

### Framing a Gambrel Roof

The framing for a gambrel roof combines primary and secondary rafters. The lower (primary) rafter has a steep pitch, and the upper (secondary) rafter has a low pitch. If the pitches are known, the rafters may be laid out in the same manner as any common rafter.

The roof may also be laid out full size on the subfloor. Use the run of the building ( $AB$ ) as a radius and draw a semicircle. **Fig. 22-34.** Draw a perpendicular line from point  $A$  to intersect the semicircle at  $E$ . This locates the ridge line. Find the height of the walls from the plans. Draw a perpendicular line ( $CD$ ) to this length between the plate and the semicircle. Connect points  $B$  and  $D$  and points  $D$  and  $E$ . This gives the location and pitch of primary rafter  $BD$  and secondary rafter  $DE$ . From this layout the rafter patterns can be made and cut for test fitting on the building.



**Fig. 22-34.** The patterns for the rafters in the gambrel roof may be made by laying out the full-size roof on the subfloor.

### Framing a Shed Roof

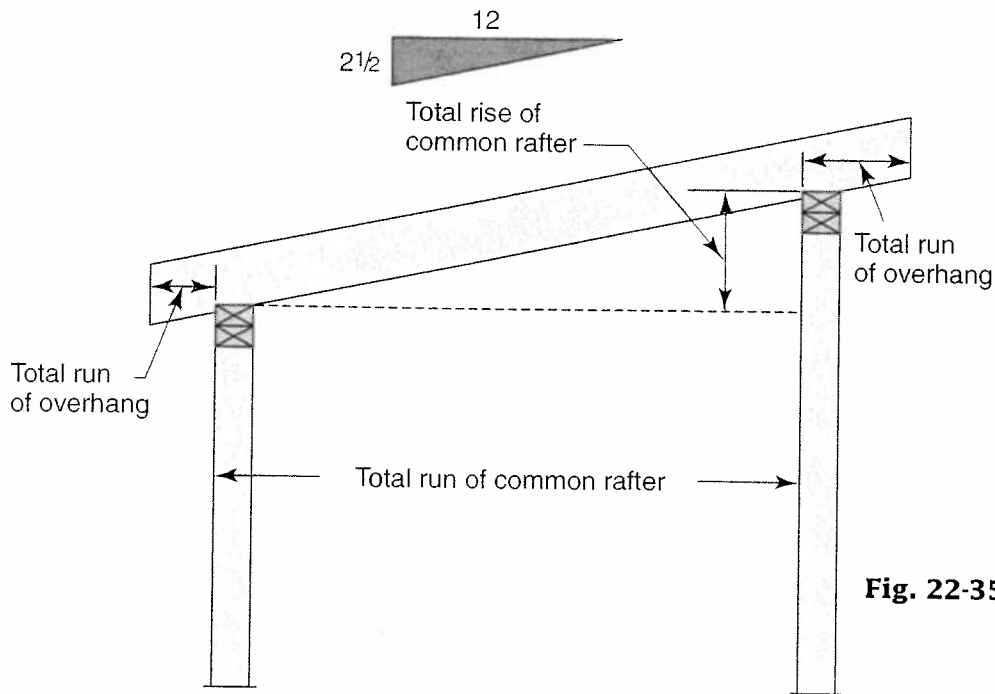
A shed roof is basically one-half of a gable roof. The full-length rafters in a shed roof are common rafters. The total rise is the difference in height between the walls on which the rafter will bear. The total run is equal to the span of the building minus the width of the top plate on the higher wall. **Fig. 22-35.** 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. They are laid out just like the bird's mouth on a gable roof common rafter.

### Framing a Low-Slope Roof

A low-slope roof has a slope of 3/12 or less. This includes so-called "flat" roofs, which actually have a slight slope to encourage water to drain off. A low-slope roof can be framed in the post-and-beam style (see Chapter 19, "Framing Methods") or with nominal 2" joists.

Low-slope roofs generally require larger rafters than roofs with steeper slopes, but the total amount of framing lumber is usually less. Where rafters also serve as ceiling joists, their size is based on both roof and ceiling loads. The size is given on the plans or determined from rafter span tables.

When there is an overhang on all sides of the house, lookout rafters are ordinarily used. **Fig. 22-36.** Lookout rafters project beyond the walls



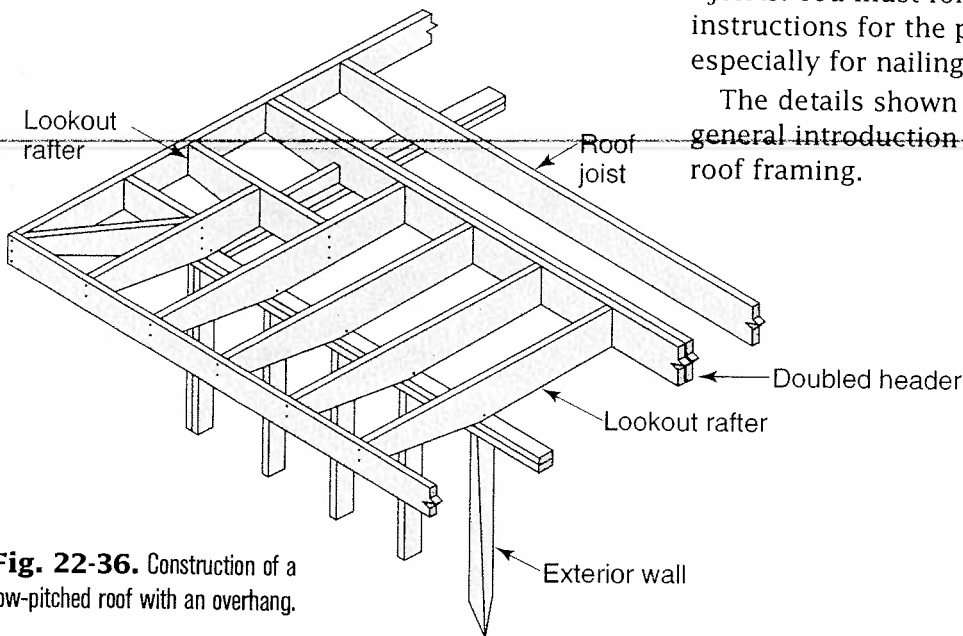
**Fig. 22-35.** Shed roof framing.

of the house, usually at 90° to the common rafters. Where they run perpendicular to common rafters, they are nailed to a double header and toenailed to the wall plate. The distance from the double header to the wall line is usually twice the overhang. Rafter ends may be capped with a header, which will serve as a nailing surface for trim.

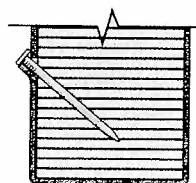
## USING I-JOIST RAFTERS

Laminated-veneer lumber can be used to build many portions of the house frame, including the roof. LVL lumber is also used in commercial wood framing. LVL I-joists can be used in place of lumber rafters. Various companies make I-joists. You must follow the manufacturer's instructions for the product you are using, especially for nailing. **Fig. 22-37.**

The details shown in **Fig. 22-38** provide a general introduction to the subject of I-joist roof framing.

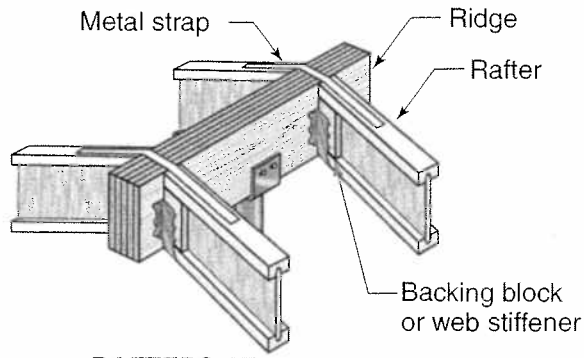


**Fig. 22-36.** Construction of a low-pitched roof with an overhang.

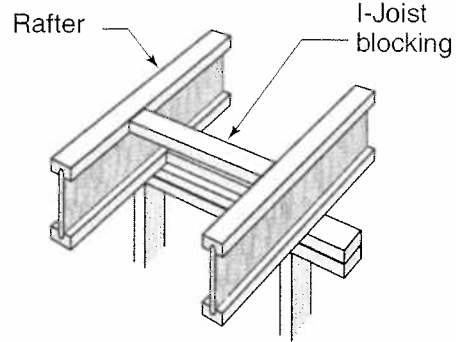


**Fig. 22-37.** The correct size of nail and the correct angle are important to avoid damage to the I-joist flanges.

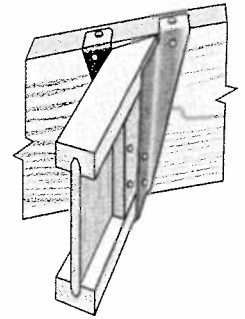




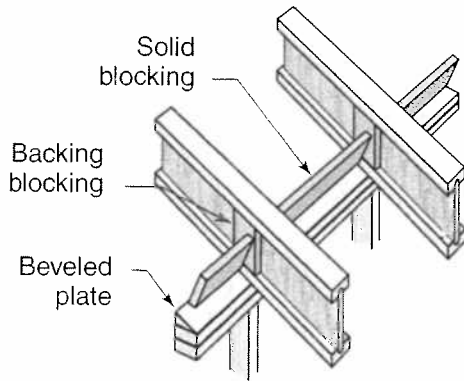
**RAFTERS AT STRUCTURAL RIDGE BEAM**



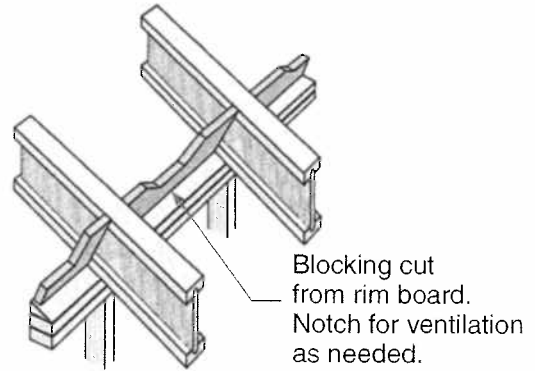
**RAFTERS AT WALL PLATE**



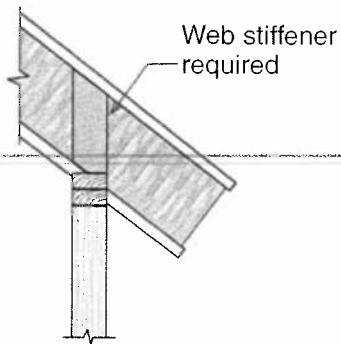
**JACK RAFTER**



**BLOCKING**

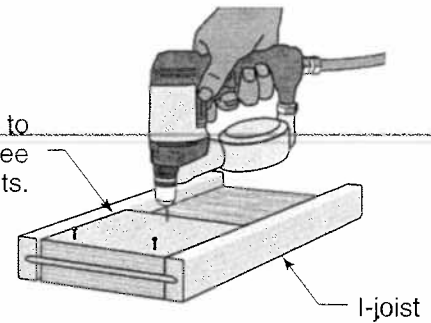


**BLOCKING**

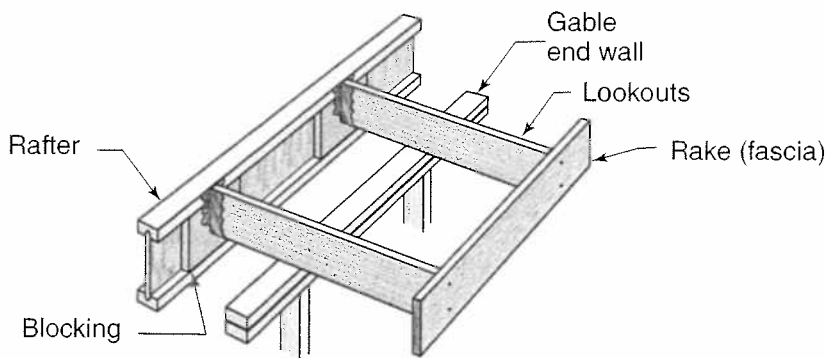


**RAFTER OVERHANG**

Stiffener: Attach to both sides with three 8d nails. Clinch points.



**WEB STIFFENERS**



**RAKE**

**Fig. 22-38.** Details for I-joist rafters. These are suggestions only. Always consult the manufacturer's instructions before installation.



## SAFETY FIRST

### Nailing Safety

Nailing rafters into place is often done under conditions that increase the possibility of injury. Be sure you have solid footing when nailing. Keep your hands safely away from the action. This caution applies both to hand nailing and power nailing.

## SECTION 22.2

### Check Your Knowledge

1. What prevents rafters from spreading and pushing out on the exterior walls?
2. State the Pythagorean theorem.
3. Name the parts of a bird's mouth and tell where they bear.
4. When making cuts for a bird's mouth, what mistake should you avoid?

### On the Job

Find the theoretical rafter length for a common rafter used in a roof with a 7/12 pitch and a span of 23'-6".

## SECTION 22.3

### Ceiling Framing

Ceiling joists are the parallel members that support ceiling loads. In the first story of a two-story house, the same framing serves as both ceiling and floor. **Fig. 22-39.** In other words, if you stood downstairs and looked up, you'd refer to it as the ceiling framing. However, if you stood upstairs and looked down, you'd call it the floor framing. The floor framing for the first story of a house is covered in Chapter 20, "Floor Framing."

The ceiling framing discussed in this chapter is directly related to the roof framing. It prevents walls from bowing outward by tying the lower ends of the rafters together. At the same time, it ties the walls of the house together and forms the floor of the attic.

### CEILING JOISTS

Ceiling framing for the top level of a house usually proceeds at the same time as roof framing. While the rafters are being laid out and cut, other carpenters cut and install the ceiling joists. Like floor joists, ceiling joists may be supported by girders or by bearing walls.



**Fig. 22-39.** Ceiling framing often supports a second floor.

## Sizing Ceiling Joists

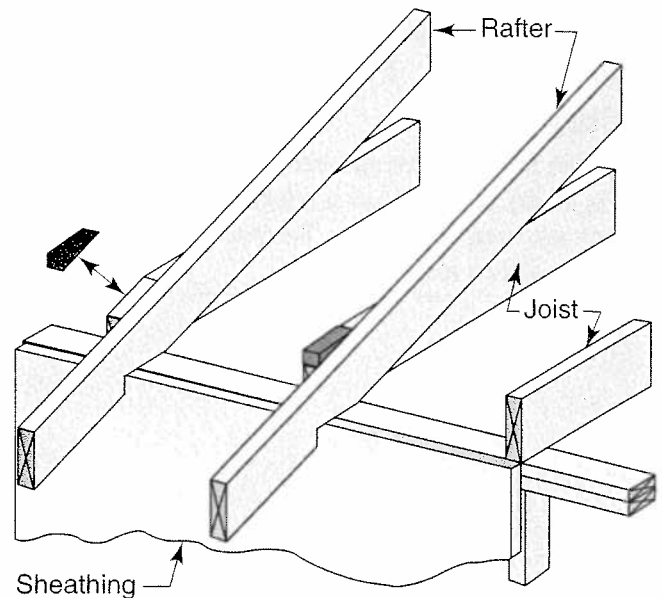
The size of the ceiling joists is determined by the distance they must span and the load they must carry. **Table 22-A.** The species and grade of wood must also be considered. The correct size for the joists will be found on the building plans. Spacing and span limitations must comply with local building codes.

## Layout

The layout for ceiling joists is determined as one lays out the rafters. Rafter spacing and placement are determined first. Ceiling joist spacing and placement are determined second.

Ceiling joists are usually placed across the width of the building and parallel to the rafters. The ends of the joists that rest on the exterior wall plates next to the rafters will usually project above the top edge of the rafter. **Fig. 22-40.** These ends must be cut off at an angle to match the angle of the rafters. This is best done before the joists are installed.

Installation begins at one end of the house and continues to the other end. The spacing of the joists is usually 16" or 24" OC. Extra joists are placed, as needed, without altering the spacing. For example, a ceiling joist will be needed at the inside edge of the plate on an end wall. This provides an edge nailing surface for the ceiling finish. **Fig. 22-41.** A second joist is usually located over the studs in the side wall. The

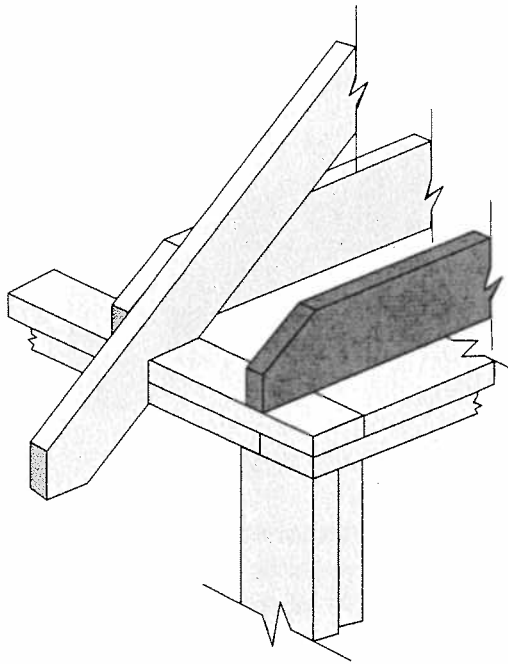


**Fig. 22-40.** The upper corners of the ceiling joists must be cut off at an angle to match the angle of the rafters. (This angle is the same as the pitch of the roof.) The joists should be cut off about  $\frac{1}{8}$ " below the rafter's top edge.

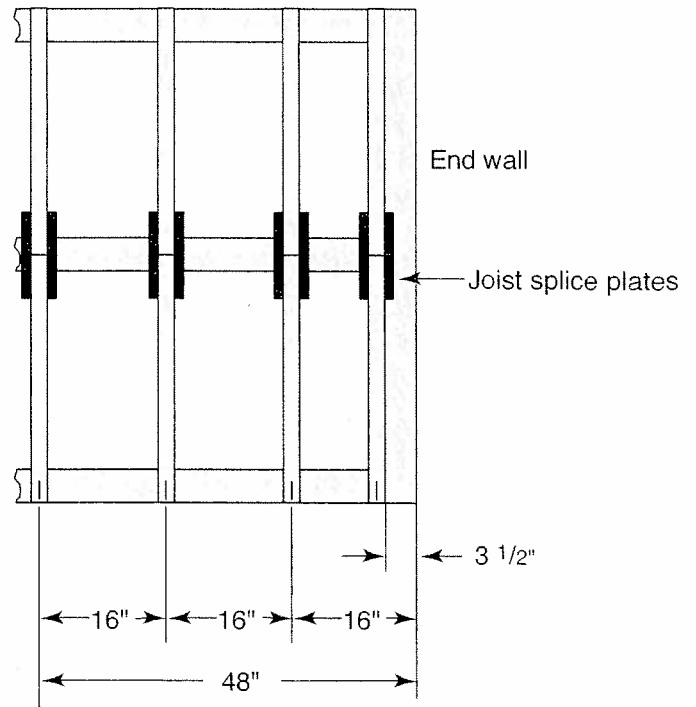
distance between the first two joists at this location will then be less than the normal OC spacing. **Fig. 22-42.** Each succeeding joist is spaced 16" or 24" on center.

Ceiling joists meet other ceiling joists from the opposite side of the building. The joists are offset  $1\frac{1}{2}$ " on the two outside walls so that they lap each other when they meet over the bearing

Size of Ceiling Joists (inches)	Spacing of Ceiling Joists (inches)	Maximum Allowable Span (feet and inches)			
		Group I	Group II	Group III	Group IV
2x4	12	11-16	11-0	9-6	5-6
	16	10-6	10-0	8-6	5-0
2x6	12	18-0	16-6	15-6	12-6
	16	16-0	15-0	14-6	11-0
2x8	12	24-0	22-6	21-0	19-0
	16	21-6	20-6	19-0	16-6

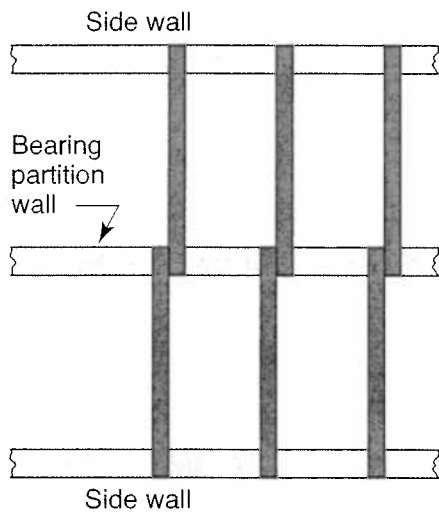


**Fig. 22-41.** A ceiling joist is set on the inside edge of the end wall to permit nailing of the material for the ceiling surface.

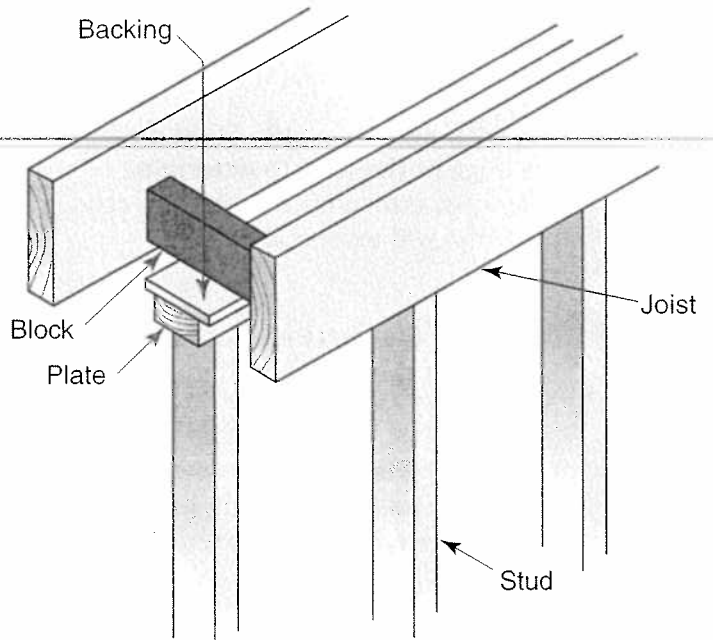


**Fig. 22-42.** The distance between the first two joists shown here is less than 16". The joists are butted end to end on the bearing wall. The butt joint must be reinforced.

partition wall. **Fig. 22-43.** This lap is face-nailed with three 16d nails. The joists are toenailed to the bearing wall plate with two 10d nails. Nonbearing partitions that run parallel to the ceiling joists are nailed to blocks installed between the joists. **Fig. 22-44.**



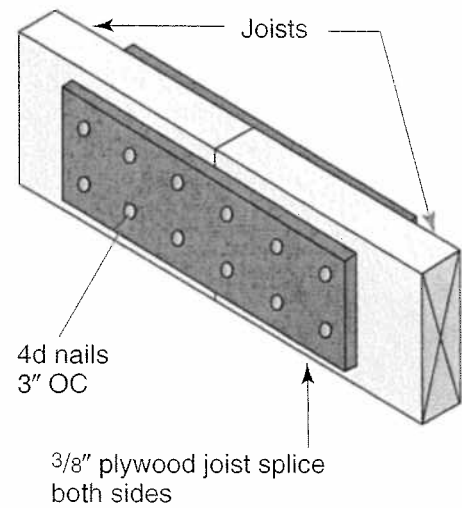
**Fig. 22-43.** Ceiling joists lapped on the bearing wall.



**Fig. 22-44.** A nonbearing wall is fastened to a block that has been nailed between the joists. Notice the 1x backing that has been attached to the top of the wall for nailing the ceiling material.

In an alternate method, the end of the joists butt against each other over a bearing wall. The ends that butt will have to be squared and cut off to length. Each joist end will be resting on just half of the wall plate. A plywood splice must be nailed securely to both sides of the joists to hold them together. **Fig. 22-45.** Metal connectors are also available for this purpose.

Steps for installing ceiling joists are given below.



**Fig. 22-45.** Ceiling joists butted end to end must be spliced together for strength. When solid lumber is used instead of plywood for a splice, it must be  $\frac{3}{4}$ " thick and at least 24" long.

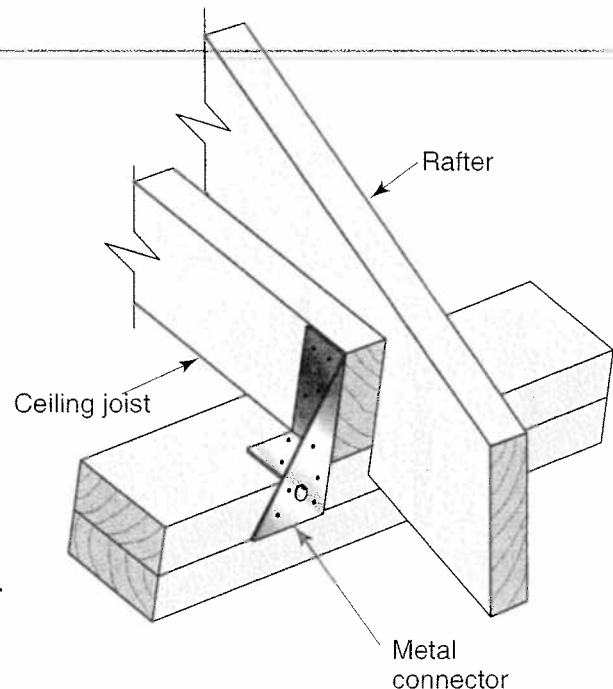
## STEP BY STEP

### *Installing Ceiling Joists*

The locations for ceiling joists are laid out like the locations for floor joists (see Chapter 20, "Floor Framing"). The spacing of the joists will be found on the building plans. Mark the plates for the correct spacing.

- Step 1** Cut each joist to length. Sight down the edge of the joist to determine where the crown is. Trim off the corners that will extend above the rafters.
- Step 2** Distribute the joists around the building so that they can be lifted into place.
- Step 3** Place each joist with the crown up. Align the end of the ceiling joist with the outside edge of the exterior wall plate.
- Step 4** At one end, toenail three 10d nails through the joist and into the plate or use a metal framing connector. **Fig. 22-46.**

- Step 5** Toenail the other end of the joist to a girder or bearing wall.
- Step 6** Nail lapped joists to each other with three 10d nails.



**Fig. 22-46.** A metal connector can be used to fasten the ceiling joist to the plate.

## SPECIAL CEILING FRAMING

Ceiling framing must often accommodate interruptions in the regular spacing of joists. Before beginning layout and installation, the carpenter should check the plans to identify these special situations.

### Hip Roofs

In the framing for a hip roof with a shallow slope, the first ceiling joist will interfere with the bottom edge of the rafters. *Stub joists* (short joists) installed at right angles to the regular joists will correct this situation. **Fig. 22-47.** Space the stubs 16" on center for attaching the finished ceiling. Locate them so that the rafters, when installed, may be nailed directly to their sides.

### Ceiling Openings

Openings in the ceiling may be required for a chimney or for access to the attic. These openings are often larger than the spacing between the joists and will require the cutting of one or

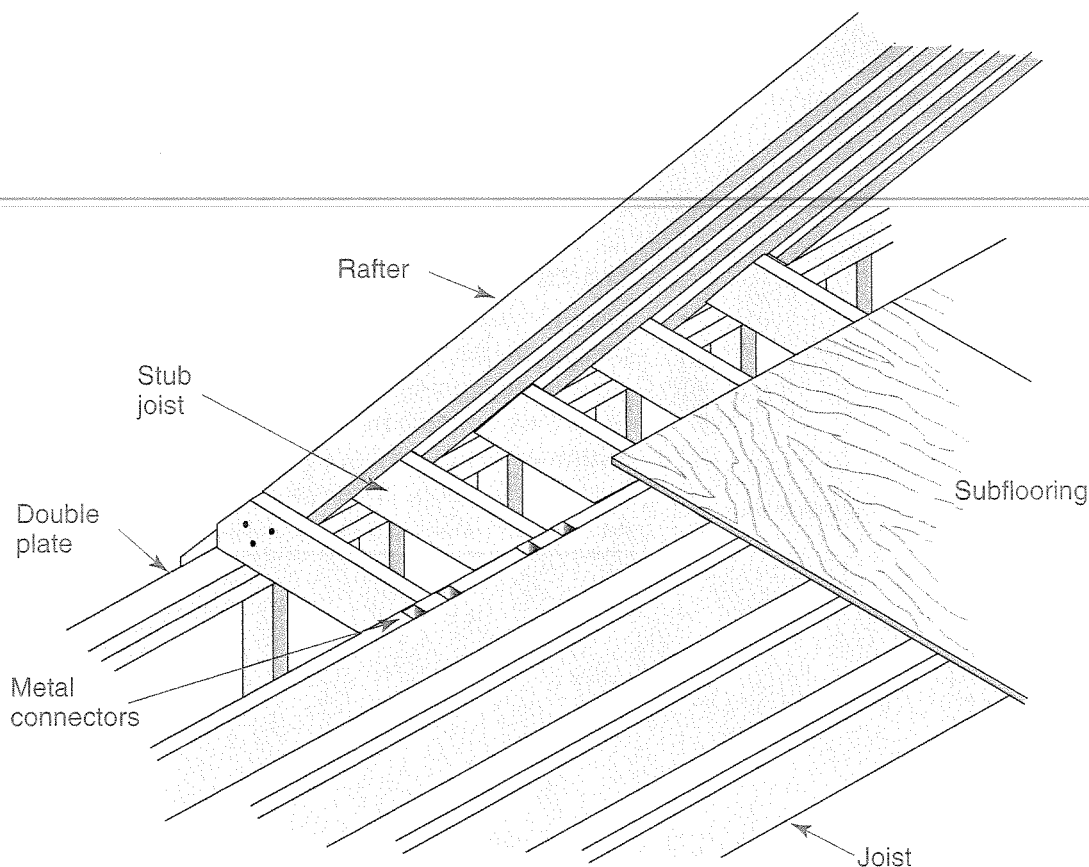
more joists. Such joists must be supported and framed as described in the section titled, "Framing Large Openings," in Chapter 20.

Building codes require that any framing, including ceiling framing, be kept at least 2" from the front and sides of masonry fireplaces, and at least 4" from the back.

### Framing Flush Ceilings

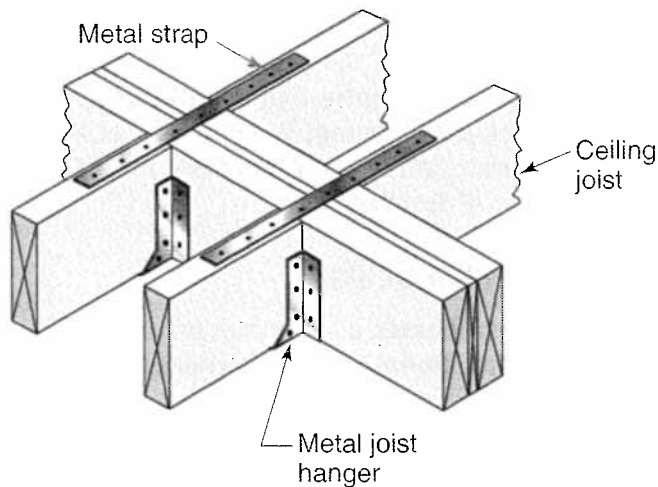
In the past, homes usually had many small rooms. Today, however, homeowners often prefer larger and more open living spaces. A combined kitchen and family room is common, for example. To visually tie the rooms together, *flush ceilings* are desirable. (The two ceilings flow together as one.) Because there is no partition, a girder is often needed to support the interior ends of the ceiling joists.

This support can be provided by a *flush girder*. A flush girder is usually built up from the same stock used to frame the rest of the ceiling. It can also be a glulam or LVL beam. Instead of resting on top of the girder, ceiling joists are fastened to the side with joist hangers.

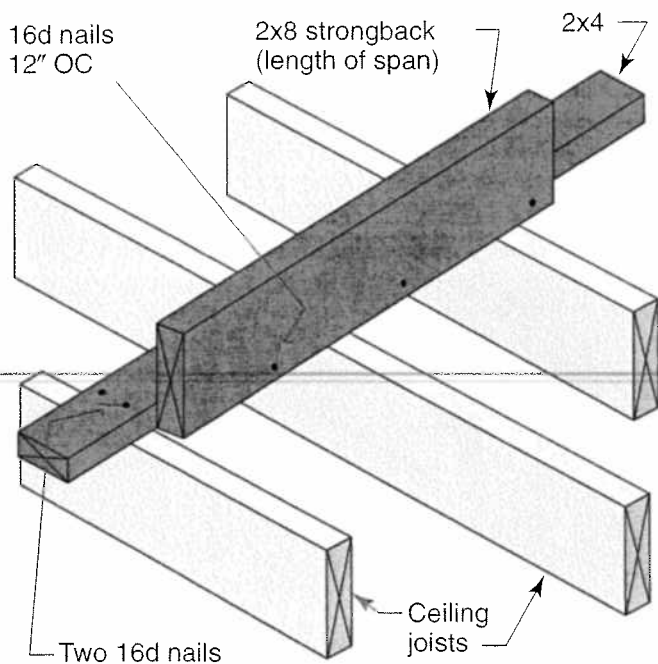


**Fig. 22-47.** Stub joists are securely anchored to the regular joists with metal framing connectors.





**Fig. 22-48.** Ceiling joists are fastened to a flush girder with joist hangers. The joints can be reinforced with metal straps.



**Fig. 22-49.** A strongback is used to give long joists additional support.

**Fig. 22-48.** Joist hangers are nailed to the girder with 10d or larger nails and to the joist with joist hanger nails. It is often easiest to fasten the hangers to the ends of the joists before raising the joists into place.

Another approach that can sometimes be used with shorter spans is to stiffen the ceiling joists with a member called a *strongback*. **Fig. 22-49.** The strongback should be nailed to the tops of the ceiling joists. However, this method will not eliminate the need for some kind of header.

## ESTIMATING

The methods for estimating the number of ceiling joists, as well as the material cost, are the same as for estimating floor joists. Refer to Chapter 20, "Floor Framing."

### SECTION 22.3

### Check Your Knowledge

1. What factors determine the size of ceiling joists?
2. How are ceiling joists arranged in relation to the building and rafters?
3. How much space must be left between ceiling joists and the front and sides of a masonry chimney?
4. How are joists attached to a flush girder?

### On the Job

Because roof trusses are prefabricated, it might be assumed that using them is less expensive than using conventional rafters. Find out if this is true by consulting a local builder or by calling a lumber company that sells roof trusses. Be sure to ask about the relative material costs as well as the labor costs for installation.

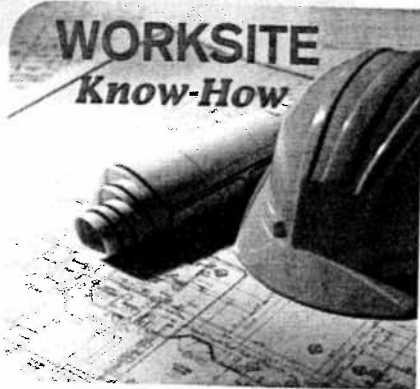
### Section Summaries

- 22.1 Planning a roof calls for an understanding of architectural styles, as well as how the individual pieces are assembled. A roof plan must be developed before any framing can begin.
- 22.2 There are four basic methods for laying out the cuts required for a common rafter. They include the Pythagorean theorem method, the unit length method, the step-off method, and the calculator method.
- 22.3 Ceiling framing is much like floor framing. However, it is often considered to be a part of roof framing.

### Review Questions

1. To what basic roof type is a mansard roof most similar?
2. Name the parts of a simple, conventional roof.
3. Name the four basic types of rafters.
4. What is the span of a roof?
5. Describe the process for laying out a plumb cut line on a rafter.
6. Where is the unit length found for a particular rafter?
7. Name the four methods for calculating the length of a common rafter.
8. What technique can carpenters use to speed up conventional roof construction without sacrificing quality?
9. Why must the upper corners of ceiling joists be cut off when they rest next to rafters?
10. When might openings in the ceiling framing be required?

### WORKSITE Know-How



**Protecting Other Workers from Ladders** When you're carrying a ladder, always be aware of where it is in relation to the people and objects around you. Passageways and doorways are especially dangerous because you don't know what might be on the other side. Be sure to proceed slowly. As you know, long ladders should always be carried horizontally. However, the front end should be high enough to clear the top of a person's head. The back should be kept closer to the ground.