

# Chapter 7

## Attics and Roofs



### Key Points to Learn

The energy efficiency of roofs and attics can usually be improved by

- installing a wind barrier at the eaves to prevent wind penetration into the roof cavity
- air sealing to eliminate or reduce air movement through the ceiling around plumbing stacks, electrical outlets, at partition-wall top plates, chimneys, flues, and around attic access hatches
- increasing insulation thickness in cathedral ceilings
- eliminating gaps in the insulation, particularly at truss struts
- increasing insulation at the eaves
- reducing thermal bridging through structural members

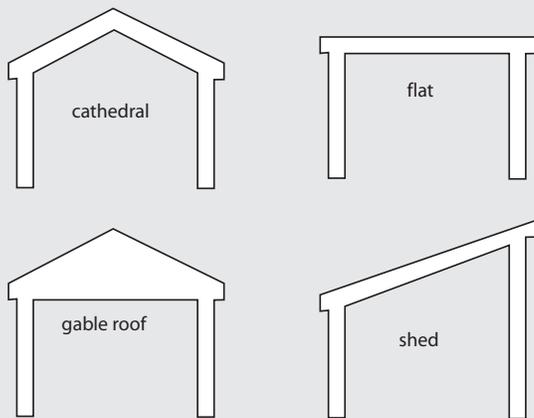
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## Hot Roof Versus Cold Roof

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A hot roof may be a flat, cathedral, or shed roof with no natural ventilation in the roof cavity. In a commercial roof, rigid insulation may be placed on the top of the decking. In a residence, the rafters may be packed with insulation, leaving no air space for natural ventilation of the cavity. Even a gable roof may be a hot roof if adequate ventilation has not been provided.



**Figure 7.1:** Types of hot roof profiles. Photo at top shows structural insulated panels used for a cathedral roof on a timber frame house.

Ceilings are usually the best-insulated part of conventional houses. Attic spaces are easy to insulate with low-cost blown or batt insulations. The insulation levels in the attics of energy-efficient houses usually reach R-values of 38 to 60 (12 to 18 inches of blown or batt insulation). However, the insulation quantity alone does not determine its effectiveness.

There are two basic types of roofs used in Alaska. They are commonly called a cold roof and a hot roof.

Cold roofs have a ventilated cavity (attic) above the insulation, and hot roofs do not. This cavity generally consists of lumber rafters or trusses with a 4:12 to 6:12 slope and a flat ceiling. A 6-mil polyethylene air-vapor barrier is installed under the insulation. For the roof to be classified as cold, continuous 2-inch vent slots must be installed at the eaves for natural eave-to-eave ventilation. Also, louvres are installed at the gables. In some situations it may be acceptable to use ridge vents.

A hot roof is simply a roof without ventilation. The important distinction between these two roof types is in their application. A properly designed and constructed cold roof with a well-ventilated roof cavity should have no ice dams or icicles along the eaves (Figure 7.2). The cold roof design is the best option for the Railbelt and in South-central, Interior, and Southeast, or any climatic region in the circumpolar north or south that has a long cold winter when snow remains on a building's roof for more than two weeks. Often the period of snow cover can be as much as four to five months.

## Ice Dams

A hot roof can cause accumulated snow to melt gradually under certain conditions. The water will then flow toward the eaves on a sloping roof. When the water reaches the eaves it will refreeze and build up as an ice dam. As the ice dam increases in height, the surface of the water may become deeper and broader (Figure 7.3).

Water formed behind ice dams may leak under asphalt shingles or over the flashing, accumulate, and freeze in the roof cavity. Also the water may leak through any seam in the roofing.

It is important to note that architectural design that employs multiple levels and roofs can lead to roof sections that are not easily vented. This can be avoided by using vertical vent ducts to other vented roof sections from the top of unvented sections to assure full natural ventilation. All reasonable efforts should be made to avoid hot roof conditions in all new residential construction, and to eliminate unvented roof conditions whenever possible in retrofits (except in western and northern coastal Alaska and the Aleutians). Possible consequences of an unvented roof are:

- Over a period of five to ten years, excess moisture in an improperly ventilated roof cavity may cause delamination of the plywood decking. Over a longer period, it may even cause rotting and structural deterioration of the rafters. During a period of abnormally deep snowfall, the roof could collapse.
- Water leaking into the roof cavity may seep through the insulation and through holes in the vapor retarder and cause water stains on the ceiling.
- Water leaking into the roof cavity may become trapped as a result of inadequate roof ventilation. With higher levels of insulation, the dew point temperature at the deck will

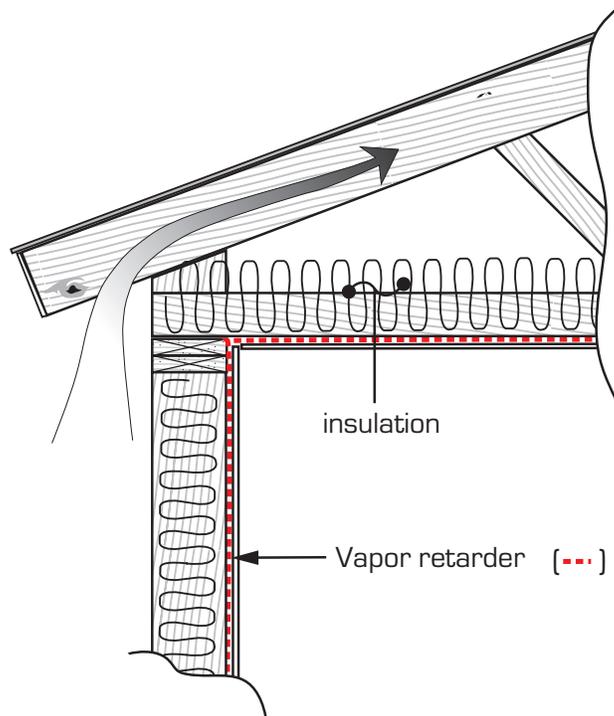


Figure 7.2: Cold roof with vent

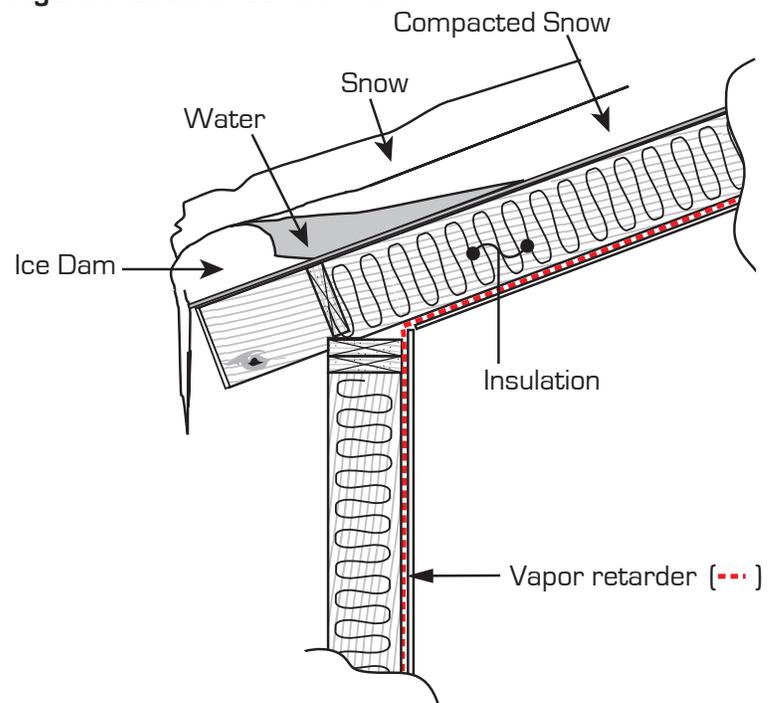
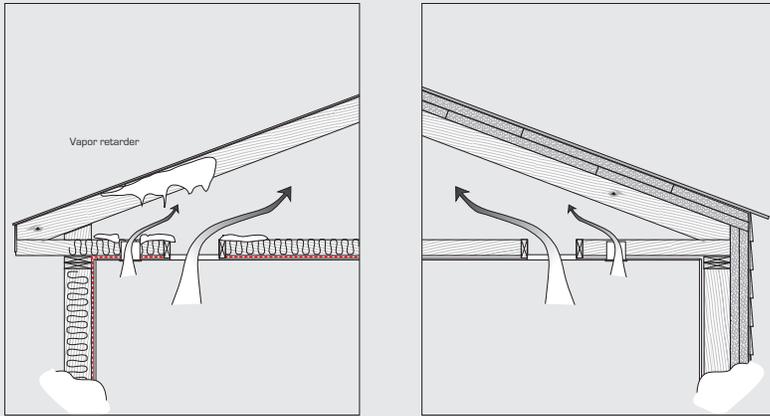


Figure 7.3: Ice dam formation on a hot roof. If the roof cavity is filled with insulation, there is no ventilation. The surface temperature of roof deck may rise above freezing as the depth of snow increases. Water building up behind the ice dam may leak under shingles or over flashing into the roof cavity. Water trapped in the roof cavity eventually causes the plywood deck to delaminate and causes decay of the rafters. Water leaking into the roof cavity may eventually seep through the vapor retarder and stain the ceiling.



**Figure 7.4:** An arctic hot roof vs. a conventional roof

In the North, tight envelope construction is one way to prevent building degradation and significantly reduce maintenance and energy costs.

Conventional systems have been installed with a polyethylene vapor barrier above the ceiling, below the roof structure and insulation. Poor installation, degradation of the polyethylene vapor retarder, and openings for ceiling fixtures, electrical outlets, etc. compromise the air-vapor retarder and allow moisture-laden air to pass through. In the North, roof systems that rely on venting to purge moisture, such as open attics and ventilated cathedral ceilings, seldom vent moisture before it condenses and turns into frost.

become lower and moisture in the roof cavity may form heavy masses of ice on the underside of the plywood deck. Sometimes the rafters of a gable roof are completely filled with frost and ice.

- In the spring or during unseasonably warm weather, the large accumulation of ice will suddenly melt. The water will seep through the insulation and accumulate on the air-vapor retarder. This can ultimately cause the ceiling to collapse with a flood of water.

## Hot-roof Designs Can Be the Right Choice

In western and northern coastal Alaska and the Aleutians, a hot roof design may be the best alternative. However, it must be a very tight hot roof to be effective and must be used with the following cautions and constraints:

- Blowing snow must not penetrate the hot roof for the same reason it shouldn't get into a cold roof. The roof must be tightly constructed.
- The design strategy relies on wind to clear the roof of accumulated snow to prevent ice dams. This strategy requires a relatively high average annual wind speed (above 10 mph, although the precise average wind speed adequate to regularly sweep accumulated snow off the roof has not been established).
- If a large snow accumulation does occur, the snow should always be removed.

## Hot-roof Design Elements

A continuous membrane air and vapor barrier on the warm side of nonorganic insulation, but still on the outside of the structure and decking is essential. This stops moisture-laden interior air traveling through the insulation to the dew point, where condensation occurs. The colder the climate, the more important the quality of installation of the barrier. The arctic hot roof (Figure 7.4) membrane and insulation are on the exterior side of the structural members. This placement achieves the following:

- Potential for damage from condensation is virtually eliminated.
- Interior finishes can be applied directly to the structural framing, with no need for additional strapping or protection for the membrane.
- Penetration of the membrane by mechanical and electrical systems is reduced to elements that must exit

the building, while a secure utility chase is created between structural members.

- With fewer penetrations and the application of the membrane directly above a rigid deck surface, good quality installation is easier.
- Thermal bridging between the structural members and the roof cover is eliminated.

The hot roof system has been used successfully in the North in apartments, houses, and larger buildings for about 15 years.

There are four basic components in a successful hot roof design:

1. Roof deck for continuous, rigid support for the membrane, eliminating the problem of the barrier “drumming” as air moves back and forth through the roof assembly.
2. Continuous membrane as both the air and the vapor retarder, on the warm side of the insulation. Modified bitumen membrane (MBM), a single-ply, torched-on membrane, is a strong sheet material that remains flexible at temperatures as low as -40 degrees F. It has proven to be very suitable in this application. When properly installed and sealed, MBM maintains its integrity and is not susceptible to moisture degradation.
3. Two layers of rigid insulation that are impervious to degradation from moisture. Installing insulation panels at right angles to each other and attaching one layer with “z-girts” and the other with screws minimizes thermal breaks. This also reduces penetration of the membrane.
4. Roof cover that serves as ultraviolet protection and sheds moisture.

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## Moisture Accumulation

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Moisture can occur in ceilings in two ways. First and most important, moisture accumulates when warm moist air rises into the attic space through air leakage paths and condenses on cold surfaces. Second, vapor diffusion will cause water vapor to move into the attic. During the winter in colder regions frost may build up in the insulation, which leads to problems in the spring when the frost melts. Moisture problems can be greater in a well-insulated attic because the air immediately above the insulation is much colder than in poorly insulated attics. The cooler air will not absorb much moisture.

The only effective way to reduce condensation in roof and attic spaces is to prevent it from entering in the first place. This is accomplished by installing a continuous air-vapor retarder. The colder the climate, the more important the quality of the installation of the air-vapor retarder. This detail is perhaps the most crucial in roof/ceiling construction. Building in good vapor retarder and air sealing at the roof/ceiling solves many other heat loss and air leakage problems. A good air/vapor retarder at the top of a building makes everything else work better.

- The warm moist air from inside the building is kept from getting into the attic/roof cavity, so it doesn't need to be removed by attic ventilation.
- No air leakage out the top of the building means no air leaks at the bottom. Air leakage is therefore much easier to control.
- Lower air leakage means healthful moisture levels are easier to maintain in the indoor environment.

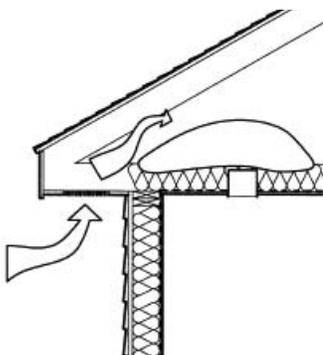
Ventilation of the attic and roof space is required in any climate where wind is not a major factor. Ventilation

helps exhaust any moisture or water vapor in those spaces and helps cool it in the summer. Attic ventilation is usually accomplished by having a continuous soffit ventilation strip as well as some gable end or other attic ventilation. The common commercially available ridge-cap vent can suffice, but this can be blocked by snow in winter. The most practical roof ventilation solution is the use of gable-end vents in roof systems where this is feasible, rather than ridge-cap vents.

In regions of Alaska where fine, blowing snow is a problem, it is better to seal the attic. This means a hot roof design may be necessary. If moisture from inside the house is prevented from getting into the roof cavity, and there is sufficient insulation to keep snow on the roof surface from melting, there is no need for roof ventilation.

Consider the amount of snowfall and the wind conditions of a particular location when you decide whether or not to build a hot roof. The insulating value of snow is approximately R-5 per inch. Where the snowfall regularly accumulate on the roof and that snow is likely to remain on the roof for considerable time during the winter, the surface temperature of the roof melt the snow. This leads to ice damming and leaks in the roof.

In western and northern coastal Alaska, wind is a dominant factor and may regularly clear the roofs of snow, so ice damming is not a problem, but snow blowing into the attic through the vents can be (Figure 7.5). Local wind conditions should be considered when deciding if a hot roof is appropriate for a given location.



**Figure 7.5:** Snow gets in through roof vents in windy areas.

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## Air-vapor Retarder Detailing for Ceiling and Roof

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The air-vapor retarder must be continuous. Basic considerations include:

- Carry the air-vapor retarder over the top plates of partition walls.
- Seal around chimney and flue penetrations.
- Provide flexible air- and vapor-tight seals around plumbing penetrations (Figure 7.6).
- Eliminate attic access hatches and use gable-end ventilation of the roof.
- Minimize electrical boxes in the ceiling. When using a polyethylene air-vapor retarder, cross-strapping will provide a cavity for wiring and electrical boxes on the inside of the air-vapor retarder (Figure 7.7). Always be certain that the seams in the polyethylene ceiling air-vapor retarder are supported with solid backing. No seams or joints in the polyethylene air-vapor retarder should ever be made without this backing support.
- Whenever possible, avoid using recessed light fixtures that require a ceiling penetration.

### Moisture Damage

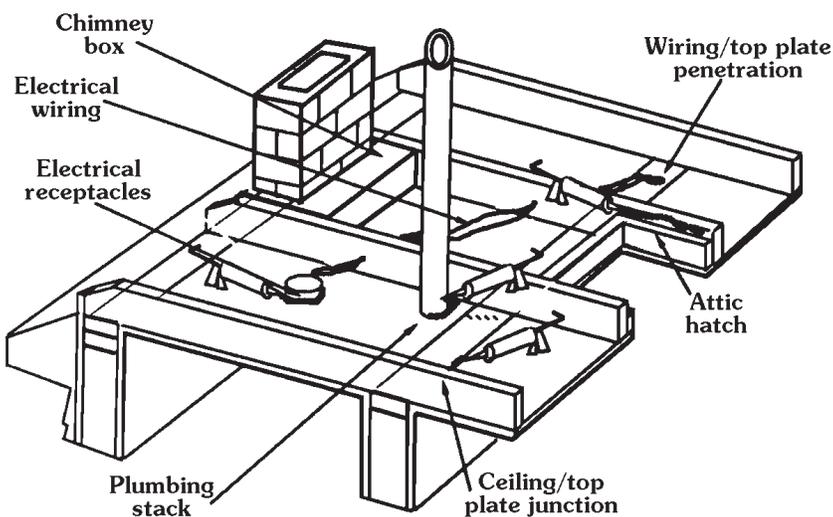
Sagging of ceiling finishes can occur in both conventional and energy-efficient houses.

Ceiling sag is caused when the drywall on the ceiling is damp and, as a very viscous fluid would, it sags. The rate of sag is a function of the moisture content of the drywall and the weight the drywall is supporting. Consequently, the amount of sag is time dependent, but it is also related to the spacing of supports and the thickness of the drywall.

### Ceiling Sag

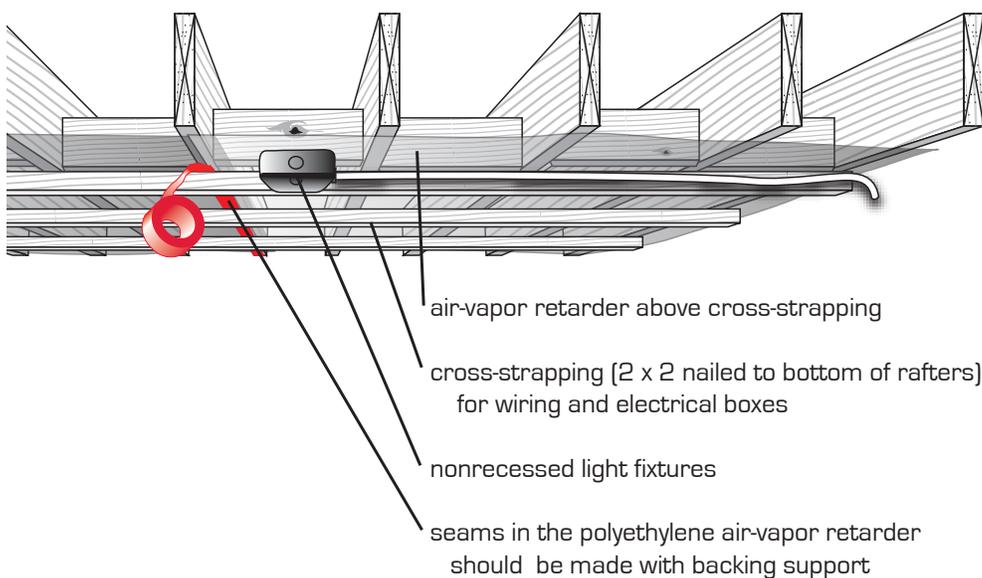
In order to keep sag to a minimum, when the drywall is installed it should be completely dry and the following precautions taken to keep it dry:

- Keep the drywall warm: provide heat and insulation.
- Keep the relative humidity low.
- Don't install heavy insulation until the drywall is dry.



**Figure 7.6:** Sealing penetrations in the attic

- Keep the spacing of supports close together.
- Use thicker drywall:  $\frac{5}{8}$  inch minimum;  $\frac{3}{4}$  inch desirable.
- Avoid using water-based texture finishes.
- Provide ventilation during construction. In the winter months, this can be done with a large heat recovery ventilator to minimize heating costs.
- If a polyethylene air-vapor retarder is used, the attic must be insulated before the heat is turned on. Otherwise, the water vapor will condense on the polyethylene.



**Figure 7.7:** Ceiling air-vapor barrier detailing

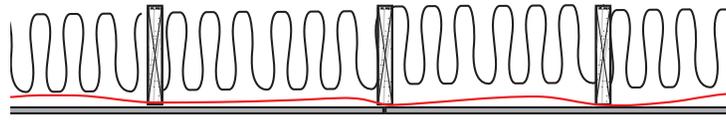
• insulation not installed before heating house causes moisture to condense at cold air-vapor barrier



- $\frac{1}{2}$  inch sheetrock too thin for span
- humidity too high

**Figure 7.8:** Causes of ceiling sag

• install insulation before heating house prevents moisture from condensing at cold air-vapor barrier



- $\frac{5}{8}$  inch sheetrock recommended for span (building codes usually specify adequate size)

• ventilate house to remove moisture



**Figure 7.9:** Preventing ceiling sag

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## Ceiling Penetrations

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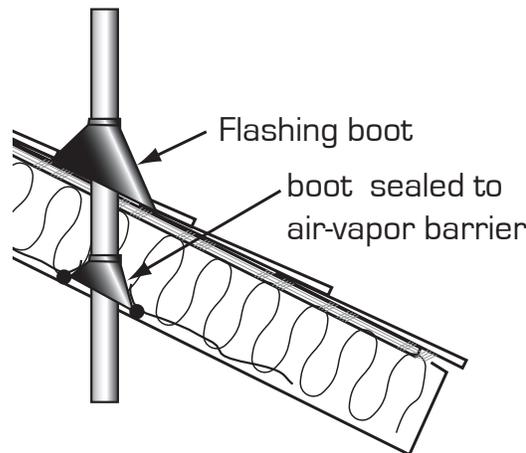
Place as much plumbing as possible in interior partition walls rather than exterior walls. Minimizing plumbing in exterior walls makes it easier to produce an airtight assembly and allows more insulation. To prevent air leakage where plumbing stacks penetrate the ceiling at partition wall top plates, make an airtight and vapor-tight flexible seal. The reason for flexible sealing of plumbing penetrations is that plumbing stacks move because of thermal expansion and contraction and because of shrinkage and settlement of the house frame. Plumbing expansion joints will minimize thermal expansion and contraction.

One of the most effective ways to handle this is to pass the plumbing stack through a rubber gasket such as EPDM, which is sealed to the air-vapor barrier with acoustical sealant or gasketing and clamped down with a plywood collar (Figures 7.10 and 7.11). The hole in the rubber is cut  $\frac{1}{2}$  inch smaller in diameter than the plumbing stack diameter and forms a tight friction fit when the plumbing stack is pushed through.

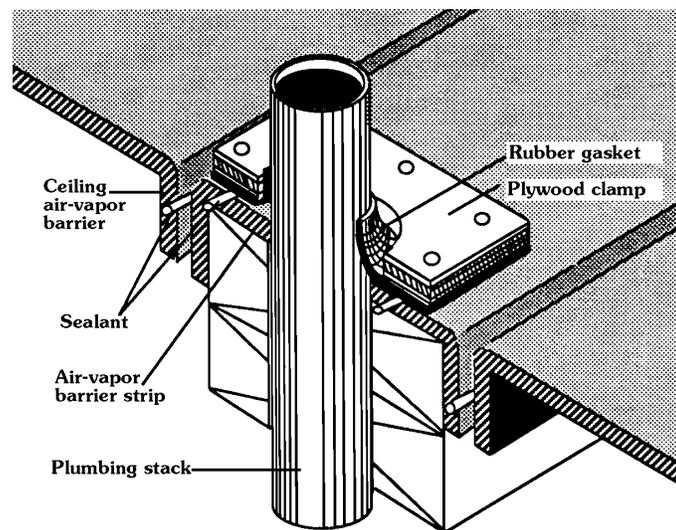
An equally effective option involves a permanent rigid seal of the stack to the air-vapor barrier and a more flexible plumbing system. This may involve an expansion joint in the stack or several bends close to the vent in the attic.

### Electrical Penetrations

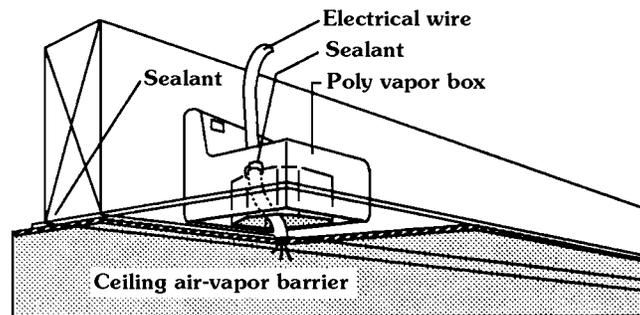
Wiring penetrations of the ceiling often occur through partition-wall top plates and can be sealed directly to the air barrier and top plate with acoustical sealant (Figure 7.7). Some caulking materials may react with the wiring sheathing, and so this method may not be acceptable to electrical inspectors, in which case a rubber gasket, as described for plumbing stacks, could be used.



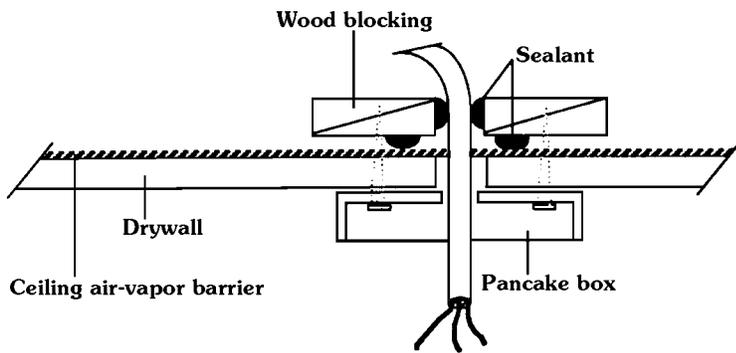
**Figure 7.10:** Detail of a plumbing stack in a cathedral roof



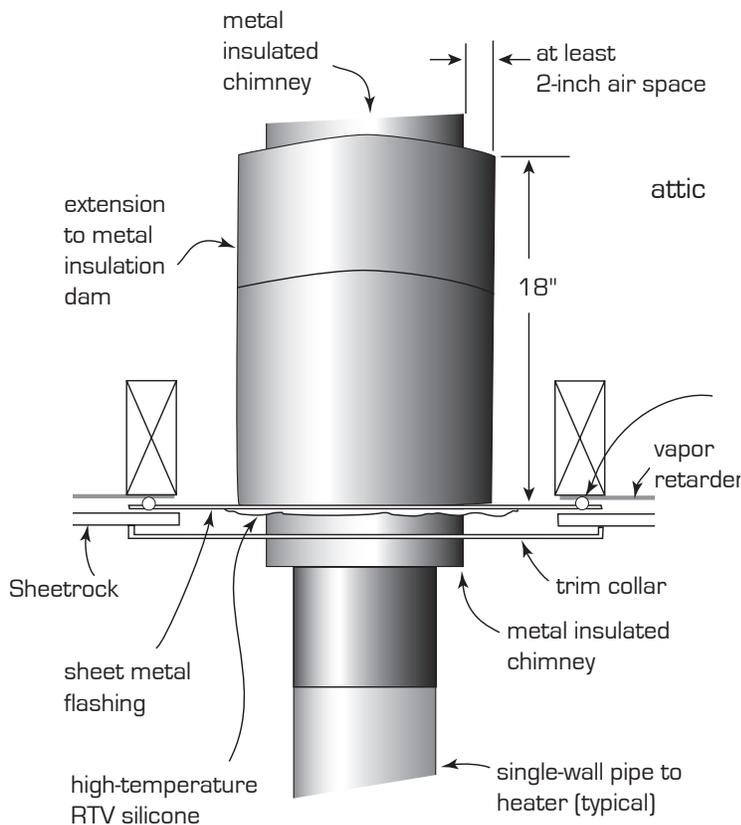
**Figure 7.11:** Detail of plumbing stack penetration through top plates



**Figure 7.12:** Using a polyethelene "hat" to seal an electrical box in the ceiling



**Figure 7.13:** Shallow “pancake” electrical box in ceiling



**Figure 7.14:** Sealing a chimney where it goes through the ceiling

Electrical boxes for lighting fixtures can be sealed in one of the following ways:

- Placing the electrical box in a pre-fabricated polyethylene envelope (poly hat) (Figure 7.12).
- Placing the electrical box in a site-built wood box wrapped in 6-mil polyethylene.
- Placing the electrical box within a strapped cavity.
- Using a pancake surface-mounted electrical box (Figure 7.13).
- Do not use recessed lights in top-floor ceilings.

### Attic Access Hatch

The most effective method for constructing an attic hatch access in an energy-efficient house is to locate the attic access in a gable end. If the access must pass through the ceiling air barrier (as in a hip roof), the hatch frame must be sealed to the ceiling air barrier and the access door weather-stripped, insulated, and latched.

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## Interior Partitions and Ceilings

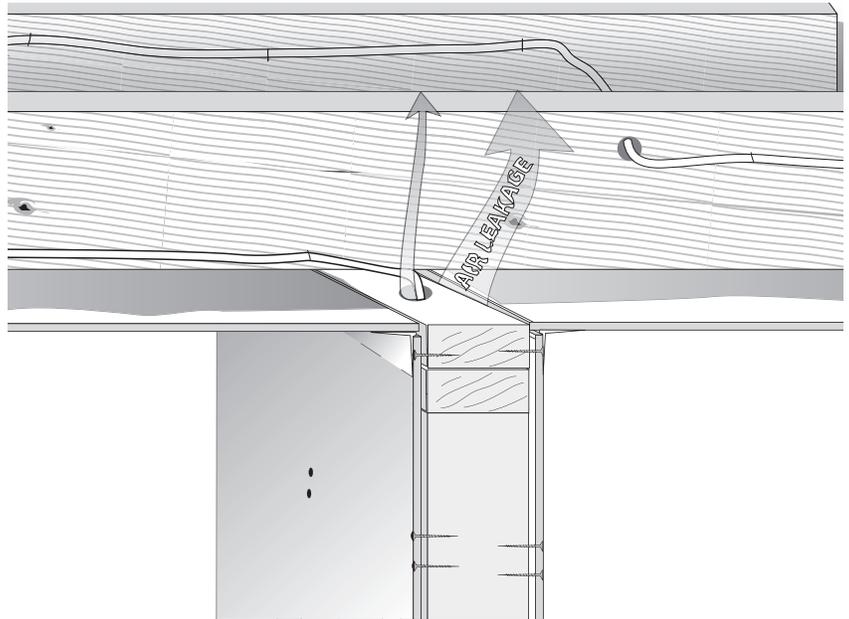
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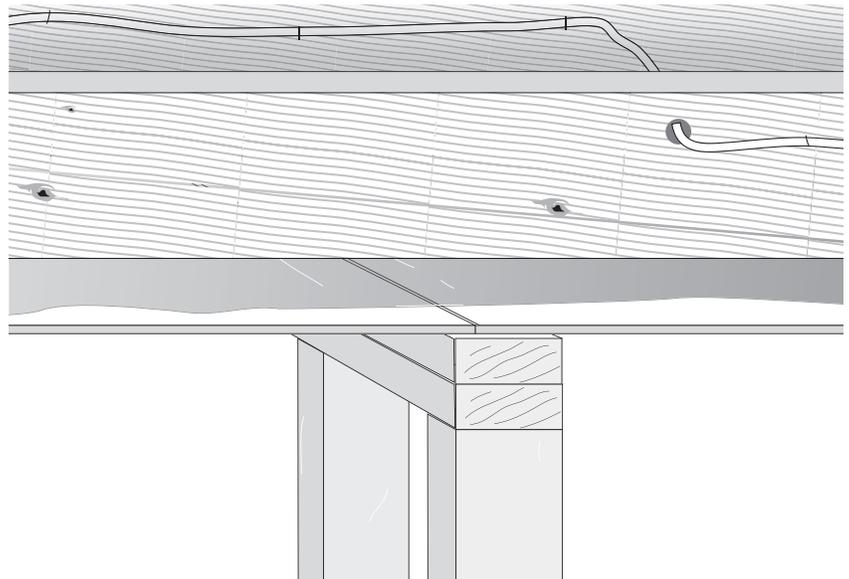
Interior partition construction can have a large effect on the energy efficiency of a ceiling. A lot of air movement can occur at the junction of the ceiling and partition wall (Figure 7.15). This problem can be corrected by incorporating a good air barrier. The primary methods of making the air barrier continuous over partitions are:

- Applying polyethylene and drywall across an entire clear span ceiling before erecting interior partitions (Figure 7.16).
- Standard-length studs can be used for interior partition walls if a 1 x 4 shim plate is placed on top of the exterior wall top plate (Figures 7.17 and 7.18). This raises the trusses and allows enough room for  $\frac{5}{8}$ -inch thick drywall and for tilting the partitions into place. Alternatively, studs will need to be cut  $\frac{5}{8}$  inch shorter. Drywall can be taped before the wall is raised.
- Place a 24-inch wide strip of 6-mil polyethylene between the partition-wall top plates (Figures 7.19 and 7.20), which is later sealed to the ceiling air barrier in each room.

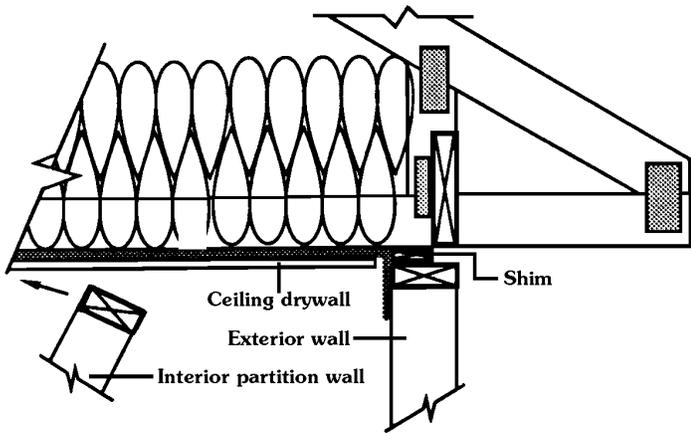
In the case of the drywall air barrier, the interior partition walls can be cut  $\frac{3}{4}$  inch short and temporarily held in place. After the drywall is slipped through the gap, the wall is anchored.



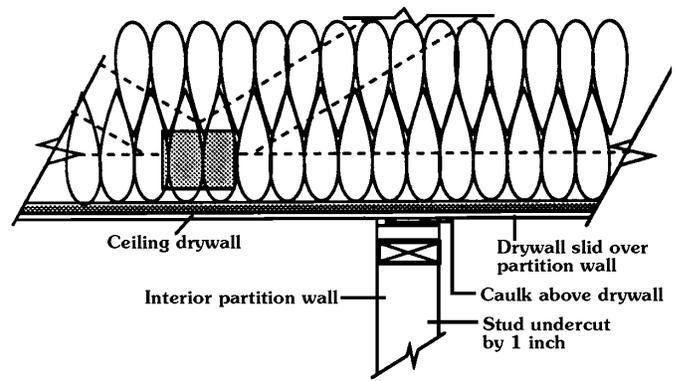
**Figure 7.15:** Air leaks around the top of partition walls and through holes in top plates that were drilled for wiring.



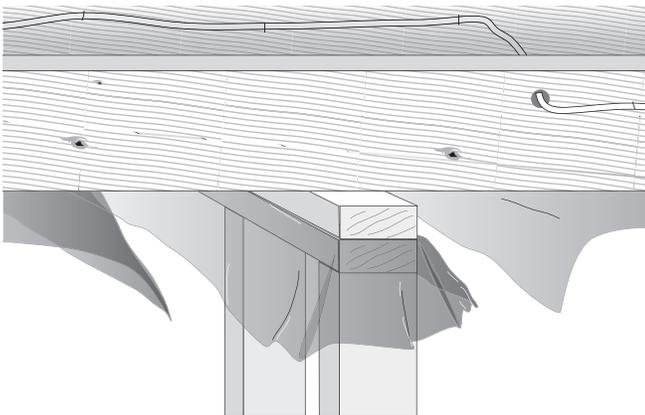
**Figure 7.16:** Applying polyethelene vapor barrier and drywall on the ceiling before putting up interior walls.



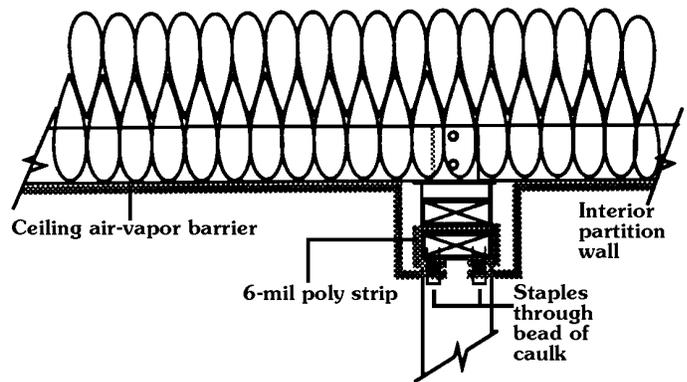
**Figure 7.17:** Using shorter stud length to fit under ceiling drywall



**Figure 7.18:** Using a shim to make the exterior wall taller to allow for ceiling drywall and standard-length studs for interior walls.



**Figure 7.19:** Putting a polyethelene tab between the wall top plates to be sealed to the ceiling vapor retarder later



**Figure 7.20:** Placing a strip of polyethelene between the top plates of an interior wall, to be sealed to the rest of the ceiling air-vapor barrier.

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## Roof Trusses

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Most builders use prefabricated roof trusses. A major weakness of conventional roof trusses is there is less space for insulation at the eaves.

### Raised Heel Trusses

The use of raised heel trusses (Figure 7.21) will solve this problem. While costs associated with a raised heel truss (manufacturing cost, extra siding, extra insulation) may total from \$100 to \$300 per house, energy savings and the prevention of surface condensation justifies the investment by eliminating poorly or inadequately insulated intersections in the building envelope, such as the roof-to-wall connection.

#### Advantages

- Allows full insulation depth in all areas of the ceiling.
- Provides a clear span and allows for a continuous air-vapor barrier.

#### Disadvantages

- Slightly higher cost than conventional truss, but often competitive.
- More siding will be required because of larger soffit.

### Drop Chord Truss

This truss consists of a conventional truss onto which is hung a second lower chord (Figure 7.22).

#### Advantages

- Can help reduce truss uplift, although it does not eliminate concern about the reaction of the wood.
- Provides full depth insulation up to the perimeter walls.
- Gives a clear span ceiling and a continuous air-vapor retarder.

#### Disadvantages

- Requires taller studs.
- Requires extra siding.
- Requires blocking at the ceiling and wall junction to attach the air-vapor retarder.

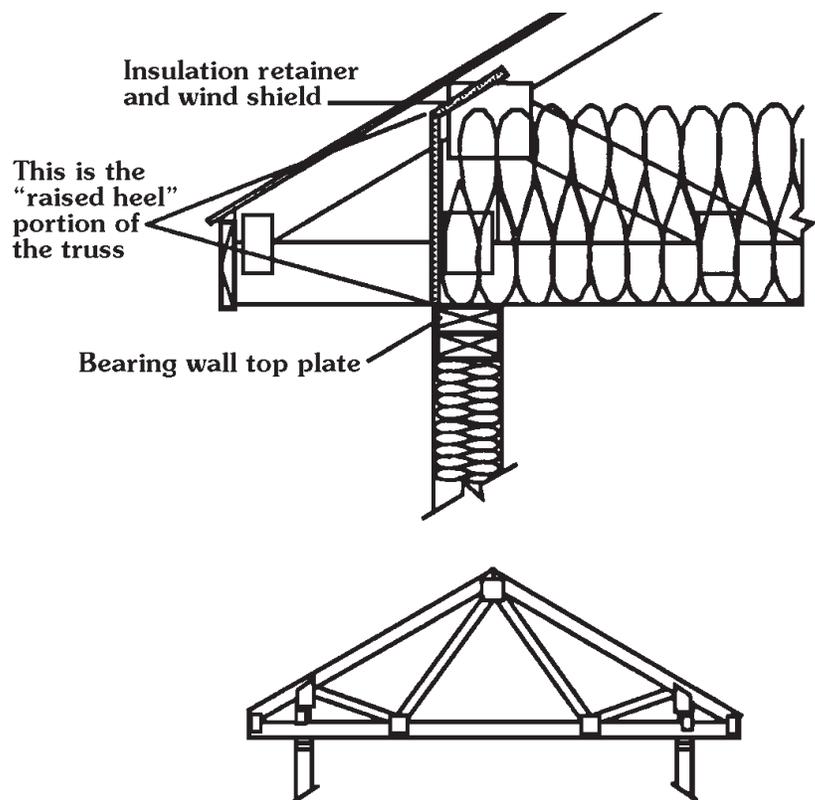


Figure 7.21: Raised-heel roof truss with insulation properly installed

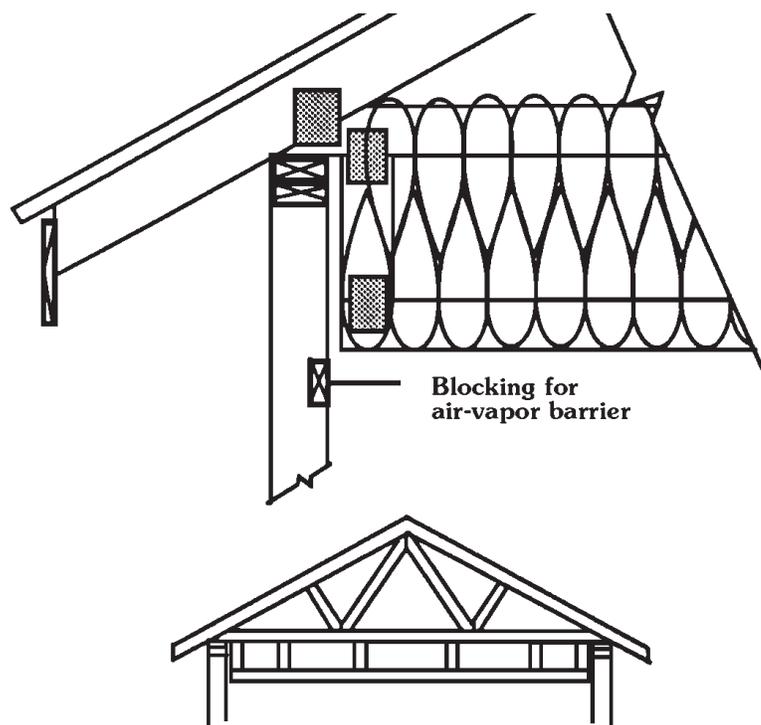


Figure 7.22: Drop Chord Truss

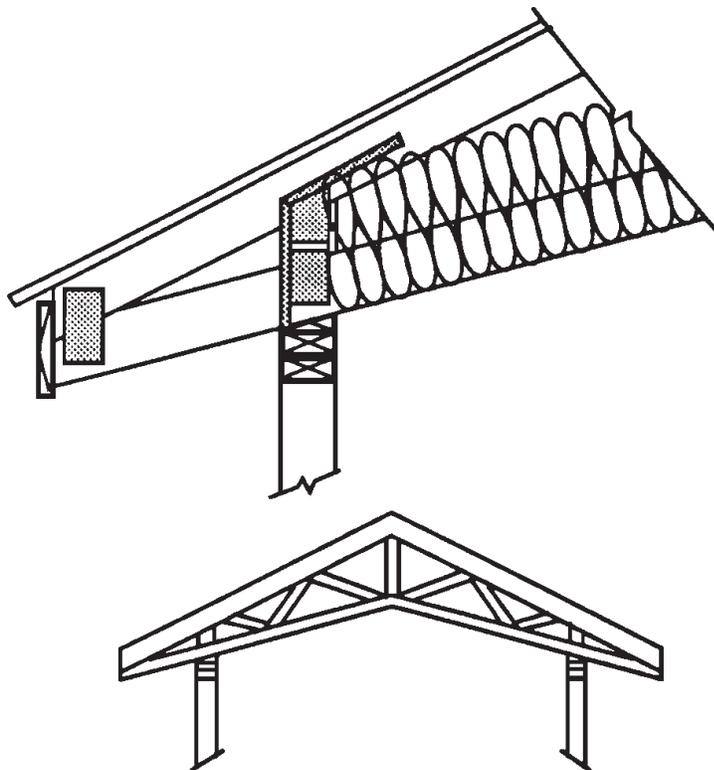


Figure 7.23: Scissor truss

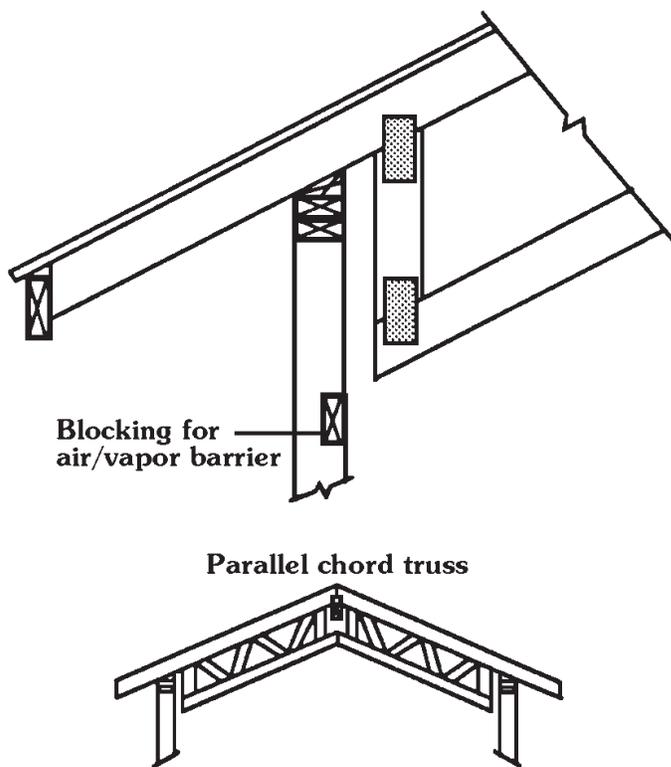


Figure 7.24: Parallel chord truss

## Scissor Truss

The lower chords of a scissor truss are sloped rather than horizontal. This allows the builder to construct a house with cathedral ceilings without the need for a central load-bearing beam or wall. Scissor trusses can be modified to accommodate higher insulation levels by constructing them with a raised heel (Figure 7.23).

### Advantages

- More easily insulated to high levels than other types of cathedral ceiling.
- In many cases, can be insulated with blown insulation.

### Disadvantages

- Costs may be higher than other methods of construction.
- Difficult to insulate between chords, unless using blown insulation.

## Parallel Chord Trusses

Parallel chord trusses consist of parallel chords of wood which are joined by an open web of wood, or steel braces, or a solid web of plywood (Figure 7.24). This type of truss permits high levels of insulation in cathedral ceilings.

### Advantages

- Allows for large amounts of insulation in cathedral ceilings and also can provide ventilation without purlins.
- Can provide large, clear spans and allow for application of a continuous air-vapor barrier.

### Disadvantages

- Higher cost than dimension lumber.
- With a web of steel braces, heat losses due to thermal bridging can be high.
- Difficult to insulate between chords, but blown insulation may help with this problem.

## Roof Truss Uplift

In some houses with roof trusses, an upward movement of the ceiling occurs during the winter months, resulting in damage to interior finishes, particularly to interior walls (Figures 7.25 and 7.26). This can result from several things:

- Different moisture contents in the lower and upper chords of the truss.
- Some pieces of lumber expand and shrink much more than the average. If the upper chord of a truss is made of a piece of lumber that has high expansion and contraction characteristics (reaction wood), truss uplift can occur every winter.
- The drying out of the lower chord. In this case, the truss uplift will usually occur only once.

Proper grading of lumber and proper drying of wood can eliminate truss uplift, but the following steps can be taken by the builder to minimize the effects of truss uplift:

- Provide adequate ventilation to the attic area.
- Locate attic vents to ensure good air flow.
- Ensure that the soffit vents are not blocked by insulation.
- When applying drywall, connect the ceiling drywall to the partition-wall top plates with drywall clips. Fasten the drywall to the ceiling at a distance far enough away from the partition so that, in the event the truss rises, the drywall can absorb the deflection without cracking (Figure 7.27).
- Buy trusses that are dry.
- Keep the trusses dry.

In areas with permafrost where the house is built on pilings, opposite effects can occur when parallel-chord floor trusses are used for the floor and the roof: the floor may bow downward while the roof bows upward.

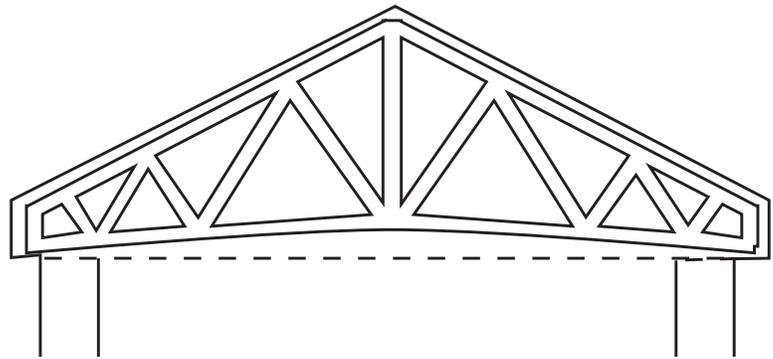
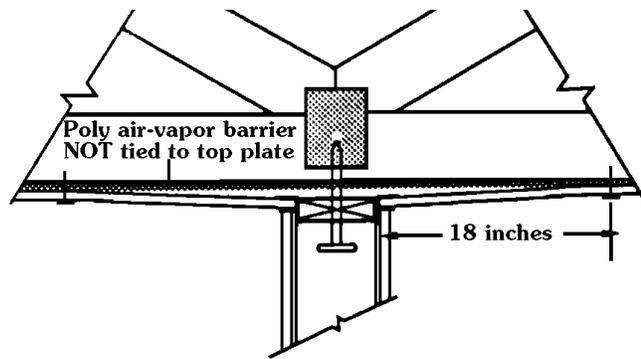


Figure 7.25: Roof truss uplift



Figure 7.26: Damage caused by roof truss uplift



The interior partitions need lateral support at the top. This should be a metal lag screw through a hole drilled oversize in the top plate into the roof truss or blocking between the trusses.

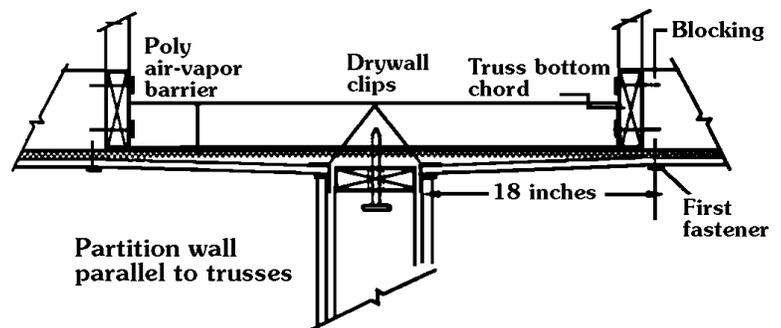


Figure 7.27: Drywall details to avoid damage or ugly cracking from roof truss uplift.

## Attic Space Framing

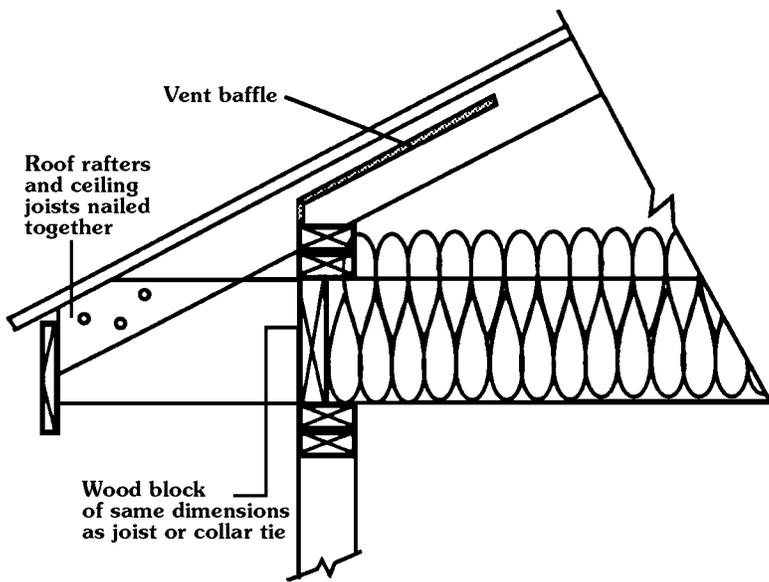


Figure 7.28: Framing an attic using dimensional lumber.

A method of framing an attic space using standard dimension lumber is illustrated in Figure 7.28. Note that the ceiling joists must extend beyond the wall and to the rafter at the eaves to produce a triangulated structure. However, this may not be required in all cases.

The recommended Canadian rafter roof design is described in the following quotation and shown in Figure 7.29. In a rafter-framed attic with a slope less than 4 in 12, the roof loads are carried by beams and not by trusses. The roof rafters and the ceiling joists must be sized to carry the vertical loads imposed by snow and other loads. With this system the loads from the rafters are carried to interior partitions by braces at angles greater than  $45^\circ$ , dwarf walls, and ceiling joists. This reduces the outward thrust of the roof so that continuous ties between the lower ends of opposing rafters are not necessary.

### Advantages

- Allows higher insulation levels at the edge of the ceiling.

### Disadvantages

- In most cases, more expensive to construct than trusses.

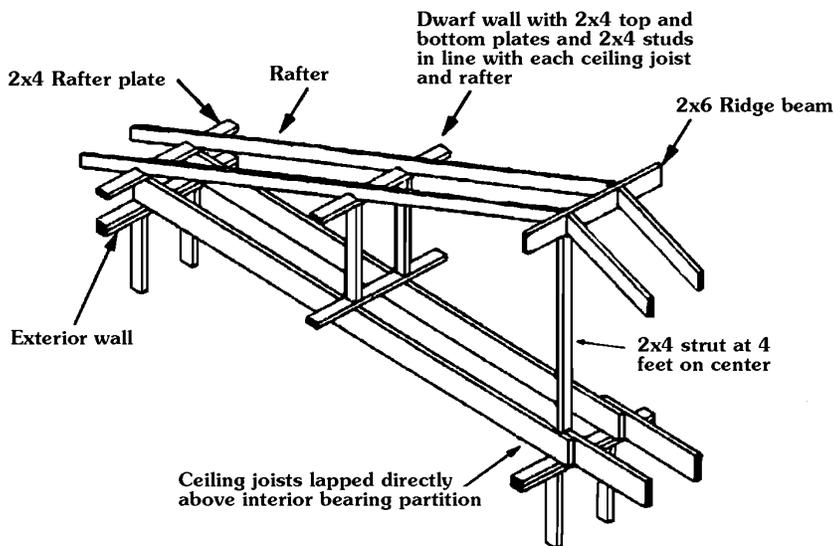


Figure 7.29: Rafter roof design from Harold Orr, Canadian Wood-Framed House Construction (CMHC Pub NHA 5031M, May 1985).

## Cathedral Ceilings and Conversion to Cold Roof

Suppose you encounter an older house with an existing cathedral ceiling that is unventilated and has a hot roof problem. If it also is older than 15 years and has asphalt shingle roofing or other roofing material that may be nearing the end of its useful life, you may be able to replace the roof and at the same time convert the old cathedral hot roof into a cold roof.

One method of accomplishing this transition is illustrated in Figure 7.30. Ceiling joists of 2 x 12 (these could also be 2 x 10s or some other dimensional lumber) are commonly used in rafter roofs, and they should be inspected before considering this method of achieving a cold roof. The old roof rafters must be structurally sound. When replacing the roof surface, a new ventilation space can be built above the insulation in the following way: after tearing off the roofing and sheathing, 2 x 3s (2 x 2s are typically of poor quality and are not suggested for this use) are first nailed to the top of each rafter and parallel to them, to give at least 1 1/2 inches of air space above the insulation. Then a second layer of 2 x 3s (1 x 4s can also be used) are nailed to the rafters and perpendicular to them to allow for attachment of sheathing and

roofing. This alternative assures a cold, ventilated roof with adequate ventilation parallel to each rafter space when tied to appropriate ventilation, and still allows a cathedral ceiling design. The soffit is enclosed under the eave and a 2-inch continuous strip vent is added to the underside of the eave to allow ventilation air to enter the cold cavity above the insulation. This retrofit yields a new cold roof system applied over the old hot roof with minimal additional expense. If you used another deeper truss or rafter over the old roof (first assuring that it is structurally sound) even more insulation could be added before the new roof surface is added.

### Advantages

- In some areas, this is lower cost than parallel chord trusses.

### Disadvantages

- Limited to a maximum of R-40
- Reduced insulation values at the ceiling joists

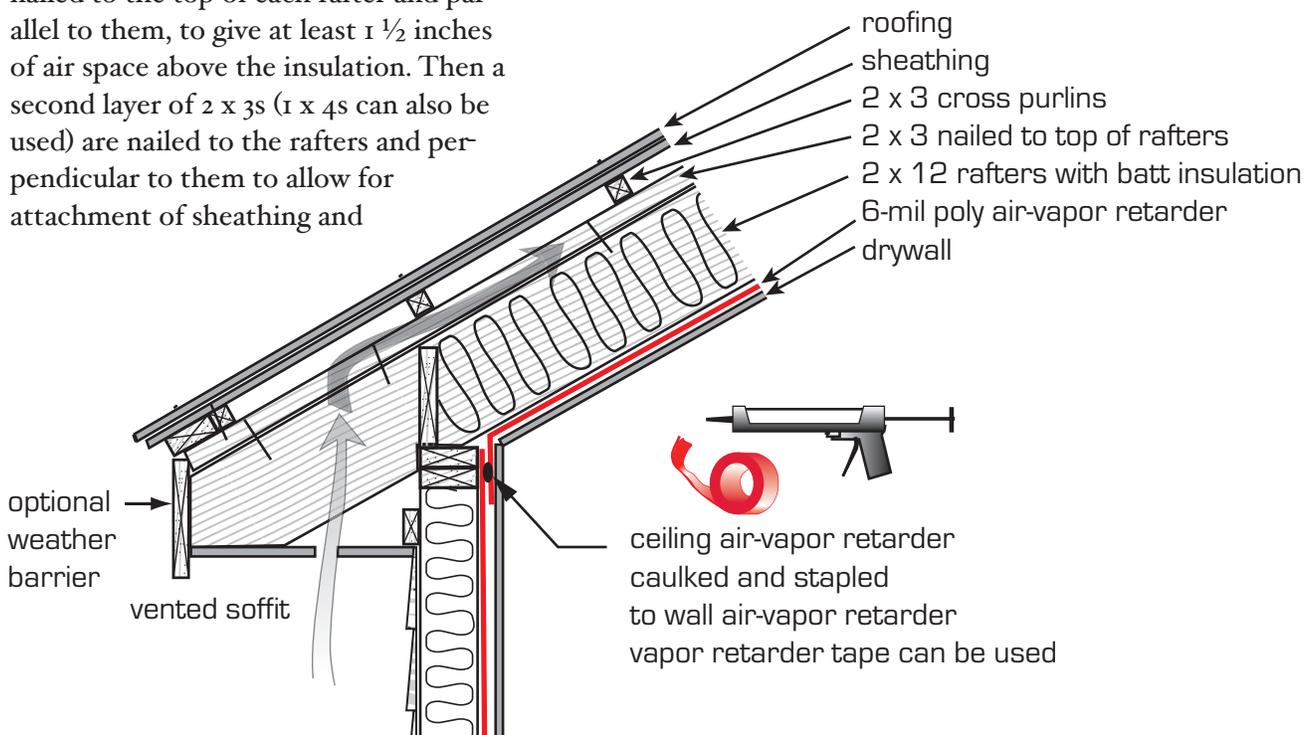
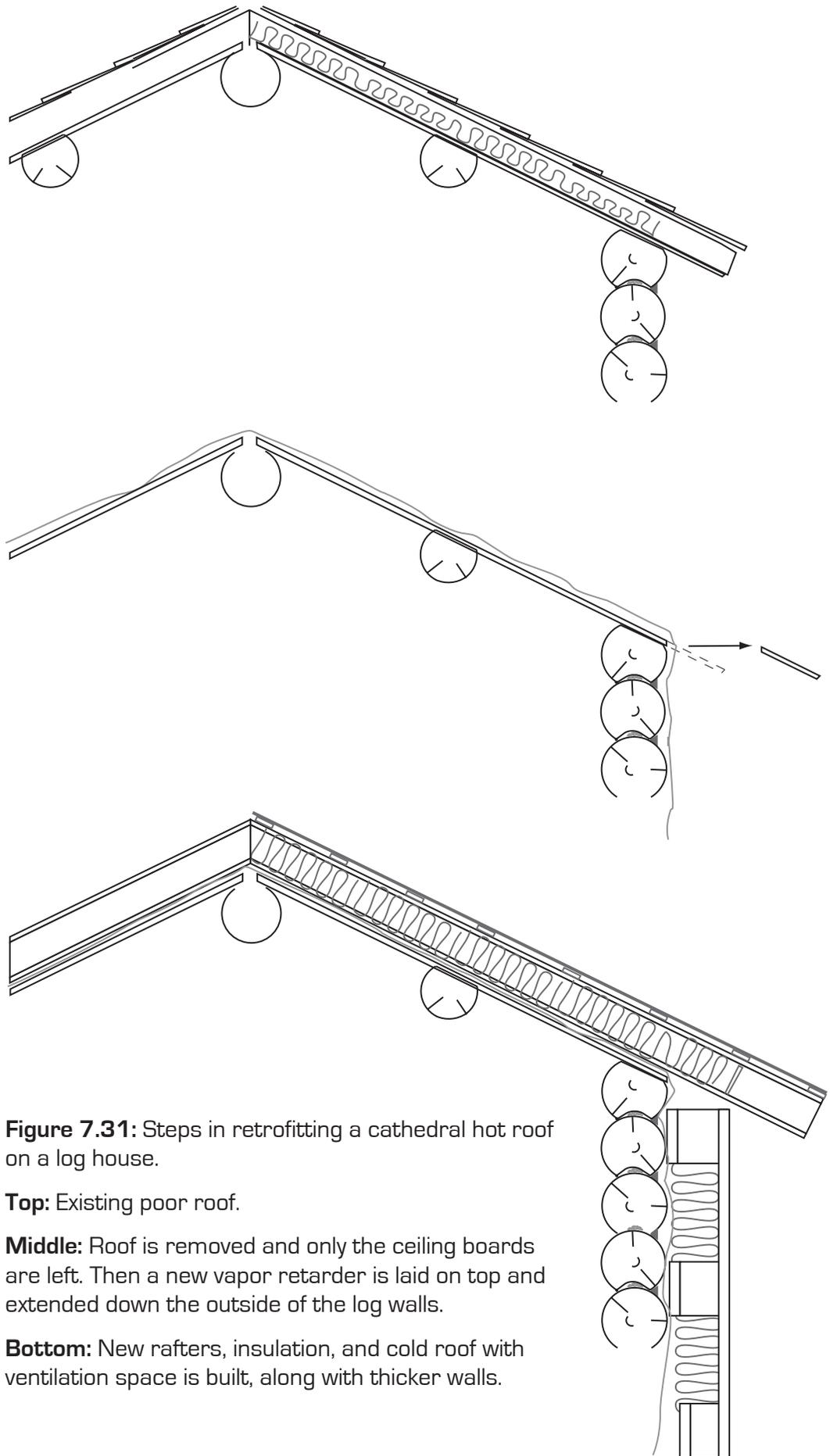


Figure 7.30: Converting a hot cathedral roof into a cold roof.



**Figure 7.31:** Steps in retrofitting a cathedral hot roof on a log house.

**Top:** Existing poor roof.

**Middle:** Roof is removed and only the ceiling boards are left. Then a new vapor retarder is laid on top and extended down the outside of the log walls.

**Bottom:** New rafters, insulation, and cold roof with ventilation space is built, along with thicker walls.