

ATTICS AND ROOFS FOR NORTHERN RESIDENTIAL CONSTRUCTION

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 48 to 60 (12 to 18 inches of blown or batt insulation). The insulation quantity alone does not determine its effectiveness.

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 thickness at the eaves.
- reducing thermal bridging through structural members.

Moisture formation can occur in ceilings for two reasons. First, and most important, moisture accumulates when warm moist air rises into the attic space through air leakage paths and condenses on cold surfaces (see figure 1). 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.

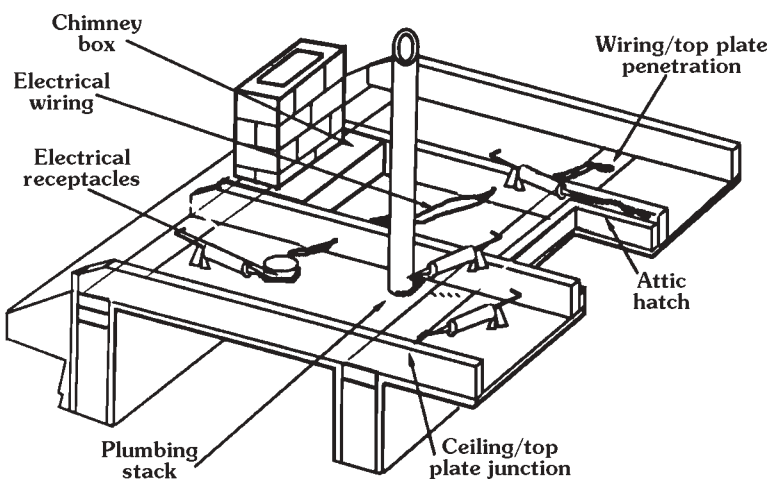


FIGURE 1 AIR AND HEAT LEAKAGE IN CONVENTIONAL ATTICS

1 MOISTURE FORMATION

The only effective way to reduce condensation in roof and attic spaces is to prevent it from entering in the first place. This is done by installing a continuous air and vapor barrier. The colder the climate, the more important the quality of the installation of the air-vapor barrier. This detail is perhaps the most crucial in roof/ceiling construction. Maintaining (by "building in") good vapor retarder and air sealing at the roof/ceiling, many other heat loss and air leakage problems are solved. 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 in the bottom. Air leakage is therefore *much* easier to control.
- lower air leakage means healthful moisture levels are easier to maintain.

Ventilation of the attic and roof space is generally required. It helps exhaust any moisture or water vapor in those spaces and aids summer cooling. This 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 practical roof ventilation solution is the use of gable-end vents in roof systems where this is feasible, rather than ridge-cap vents.

In colder regions of Alaska, where fine, blowing snow is a problem, it may be better to seal the attic. This means "hot roof" design may be necessary, that is, a roof without ventilation. 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 reason for roof ventilation.

The amount of snowfall and the wind conditions of a particular location should be primary factors to consider when deciding whether or not to build a hot roof. The builder should be aware that the insulating value of snow is approximately $R=0.5$ per inch. Where the snowfall accumulation on the roof can exceed 8 inches, the surface temperature of the roof might result in melting the snow and subsequent ice damming.

In western and northern coastal Alaska, wind is a dominant factor and may regularly clear the roofs of snow. Local wind conditions should be considered when deciding if a hot roof is appropriate for a given location.

The question of when and where to use a hot or cold roof design has always been a subject of consternation, controversy, and uncertainty in Alaska. For these reasons, a diversion into more discussion of these designs is warranted here. First the definition of hot and cold roofs needs clarification.

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. It generally consists of lumber rafters or trusses with a $\frac{4}{12}$ to $\frac{6}{12}$ slope and a flat ceiling. The roof is commonly insulated with 6 to 12 inches of fiberglass batts or blown-in fiberglass or cellulose. 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 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 maybe classified as a “hot” roof if adequate ventilation has not been provided. (Axel Carlson, *Roof Ice May Create Safety Hazards*, March 1988.)

The important lesson and distinction between these two roof types is in their application.

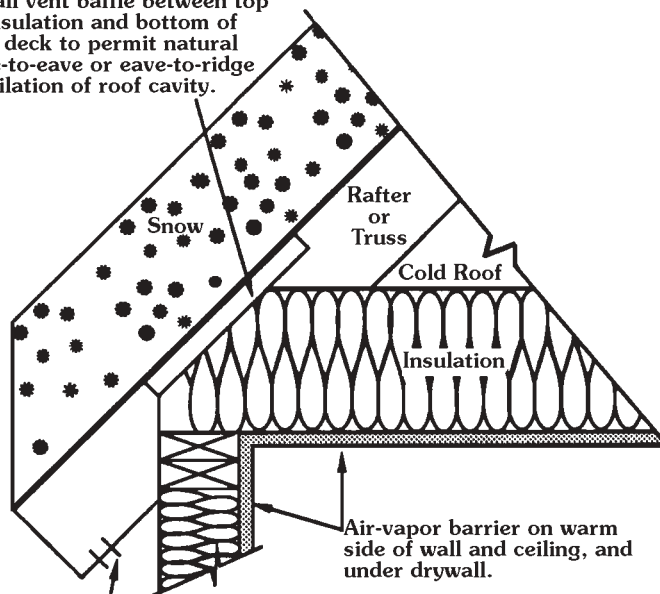
In new construction a properly designed and constructed cold roof with a well ventilated roof cavity should have no ice dams or icicles along the eaves (see figure 2). The cold roof design is the best option for the railbelt, southcentral, interior, and southeast Alaska climatic zones.

A hot roof causes accumulated snow to melt gradually. 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 (see figure 3).

2 HOT VERSUS COLD ROOFS

2.1 COLD ROOFS FOR ALASKAN HOMES

Install vent baffle between top of insulation and bottom of roof deck to permit natural eave-to-eave or eave-to-ridge ventilation of roof cavity.



Install 2-inch continuous screened vent slots along eaves to facilitate natural eave-to-eave or eave-to-ridge ventilation of roof cavity.

FIGURE 2 A FUNCTIONAL COLD ROOF DESIGN

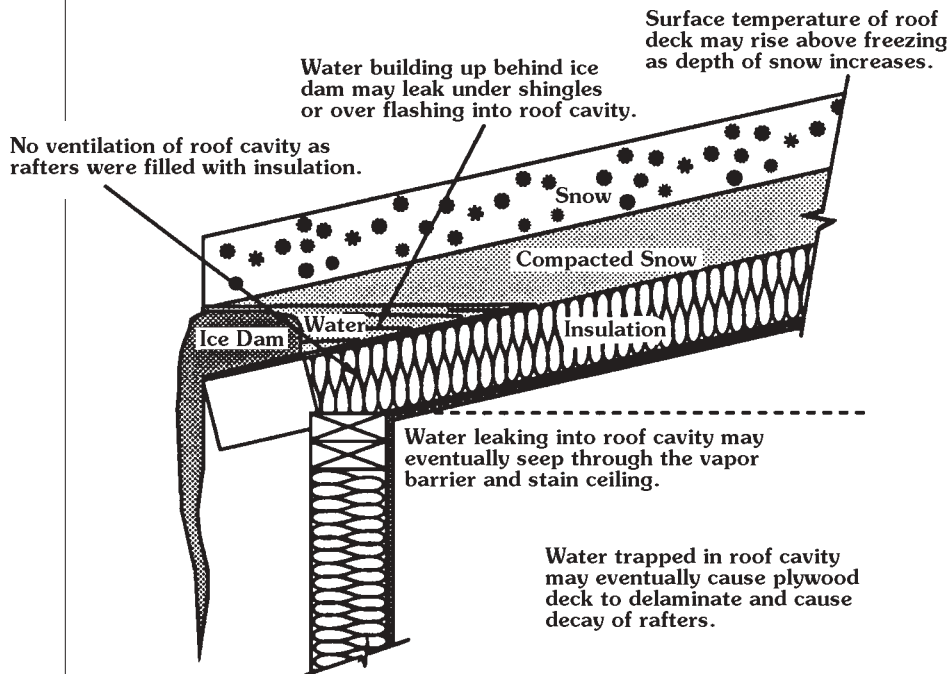


FIGURE 3 ICE AT EAVES OF A HOT CATHEDRAL ROOF

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. Obviously this is less desirable design for the regions where a cold roof design is appropriate.

It is important to note that architectural detailing and design which employ multiple levels and roofs can lead to roof sections which 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 it whenever possible in retrofit construction (except in Western and Northern coastal Alaska and the Aleutians).*

If this is not done possible consequences are:

- Over a period of five to ten years excess moisture in an improperly ventilated roof cavity may cause delamination of plywood deck. Over a longer period, it may even cause rotting and structural deterioration of the rafters. During a period of abnormally deep snow fall, the roof could collapse.
- Water leaking into the roof cavity may seep through the insulation and 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 become lower and moisture in the roof cavity may form heavy masses of ice on the bottom of the plywood deck. At times it has been observed that the rafters of a gable roof were 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.

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 design 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.

2.2 APPROPRIATE USE OF HOT ROOF DESIGNS

**3 AIR-VAPOR
RETARDER
DETAILING FOR
CEILING AND
ROOF**

- The design strategy relies on wind to clear the roof of accumulated snow. This strategy requires an average annual wind speed above 10 mph to be effective.
- In the event that a large snow accumulation does occur, the snow must be removed.

The air-vapor barrier must be continuous. Basic considerations which must be addressed include:

- Carrying the air-vapor barrier over the top plates of partition walls.
- Sealing around chimney and flue penetrations.
- Providing flexible air- and vapor-tight seals around plumbing penetrations.
- Placing attic access hatches on a gable end of the roof as an option.
- Minimizing electrical boxes in the ceiling. When using a polyethylene air-vapor barrier, cross-strapping will provide a cavity for wiring and electrical boxes on the inside of the air-vapor barrier. Always be certain that seams in the polyethylene ceiling air-vapor barrier are supported with solid backing. No seams or joints in the polyethylene air-vapor barrier should ever be made without this backing support.
- Whenever possible, avoid using recessed light fixtures.

**4 MOISTURE
DAMAGE**

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

**4.1 CEILING
SAGGING**

Ceiling sag is caused when the drywall on the ceiling has an elevated moisture content 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 inversely to the thickness of the drywall.

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 drywall is dry.
- Keep the spacing of supports close together.
- Use thicker drywall: $\frac{5}{8}$ inch minimum; $\frac{3}{4}$ inch desirable.
- Avoid the use of water-base 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 barrier is used, the attic must be insulated before the heat is turned on. Otherwise, the water vapor will condense on the polyethylene.

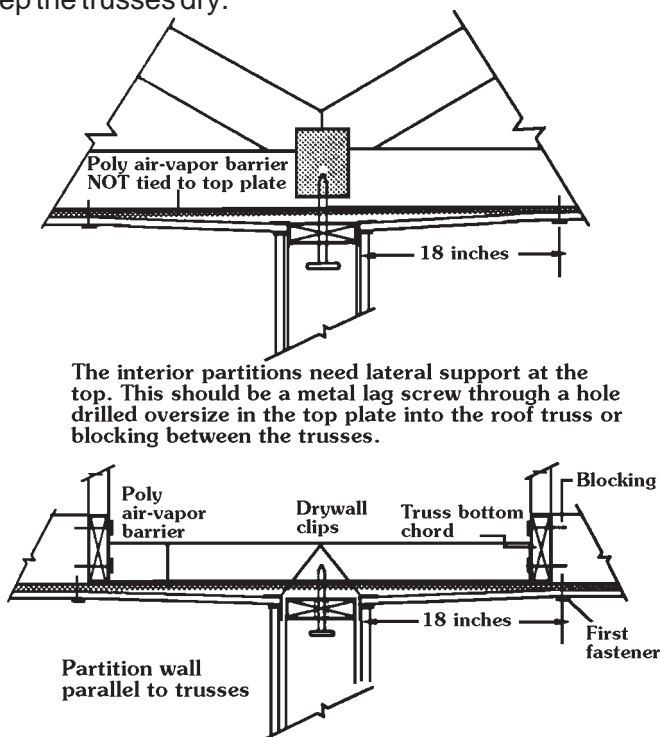
4.2 ROOF TRUSS UPLIFT

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. This can result from:

- 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 (see figure 4).
- Buy trusses that are dry.
- Keep the trusses dry.



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 4 PRECAUTION AGAINST TRUSS UPLIFT

• *Roof Trusses*

4.3 FLOOR TRUSSES AND PERMAFROST

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.

5 ROOF TRUSSES

Most builders use prefabricated roof trusses. One of the major weaknesses of conventional roof trusses is that space for insulation is minimized at the eaves.

5.1 RAISED HEEL TRUSSES

The use of raised heel trusses (see figure 5) 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 can justify the investment.

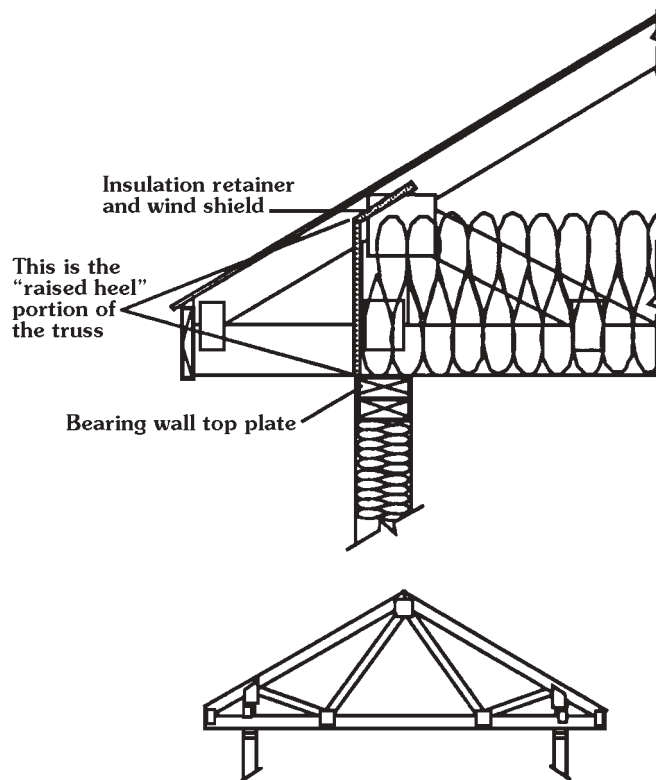


FIGURE 5 RAISED HEEL TRUSS

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.

This truss consists of a conventional truss onto which is hung a second lower chord (see figure 6).

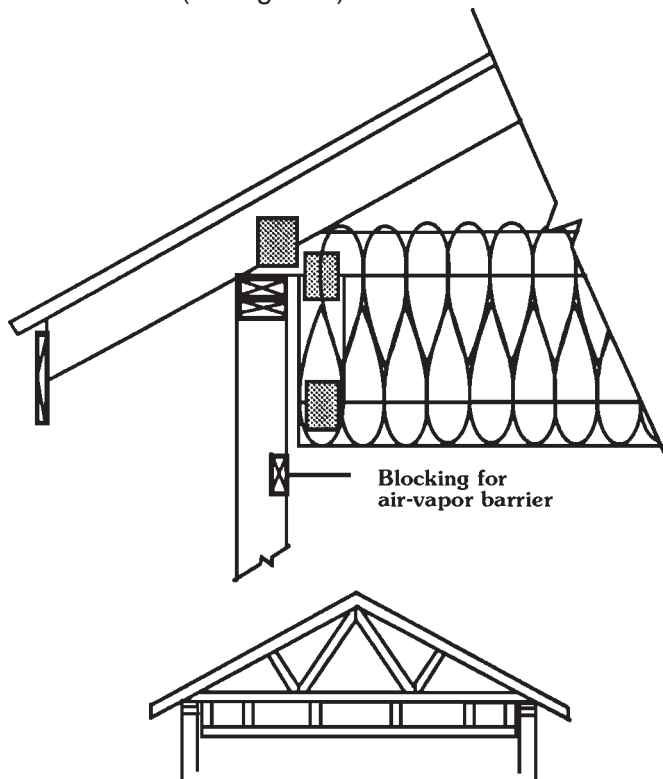


FIGURE 6 DROP CHORD TRUSS

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.
- Provides a clear span ceiling and the installation of a continuous air-vapor barrier.

Disadvantages

- Requires taller studs.
- Extra siding is required.
- Requires blocking at the ceiling and wall junction for air-vapor barrier attachment.

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 (see figure 7).

5.2 DROPPED CHORD TRUSS

5.3 SCISSOR TRUSS

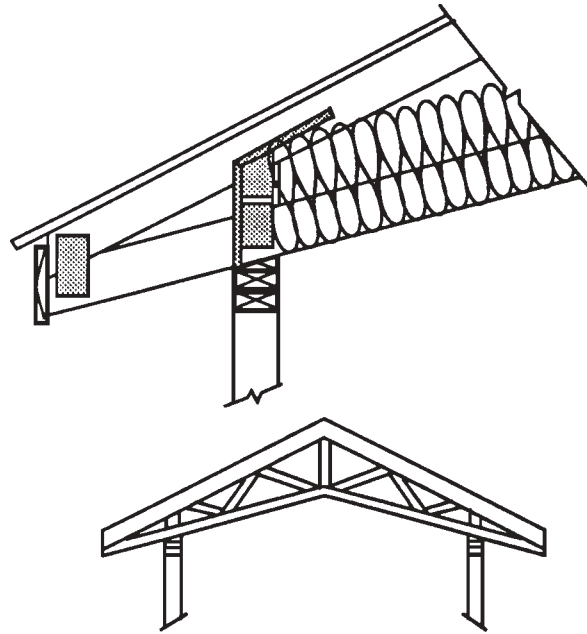


FIGURE 7 SCISSOR TRUSS

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 consist of parallel chords of wood which are joined by an open web of wood, or steel braces, or a solid web of plywood (see figure 8). 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.

5.4 PARALLEL CHORD TRUSSES

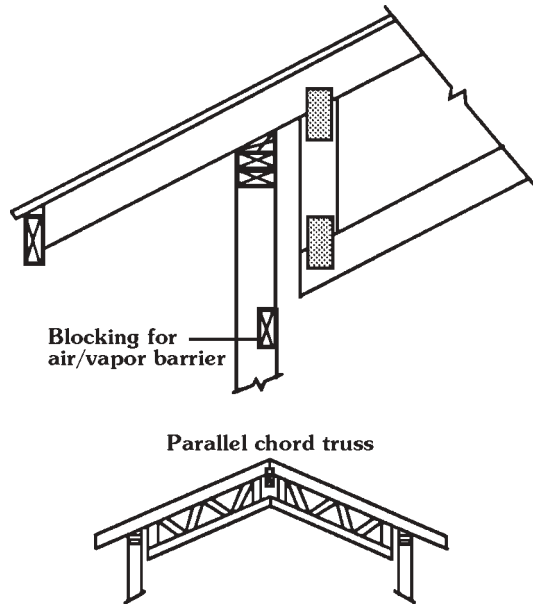


FIGURE 8 PARALLEL CHORD TRUSS

A method of framing an attic space using standard dimension lumber is illustrated in figure 9. 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.

6 ATTIC SPACE FRAMING

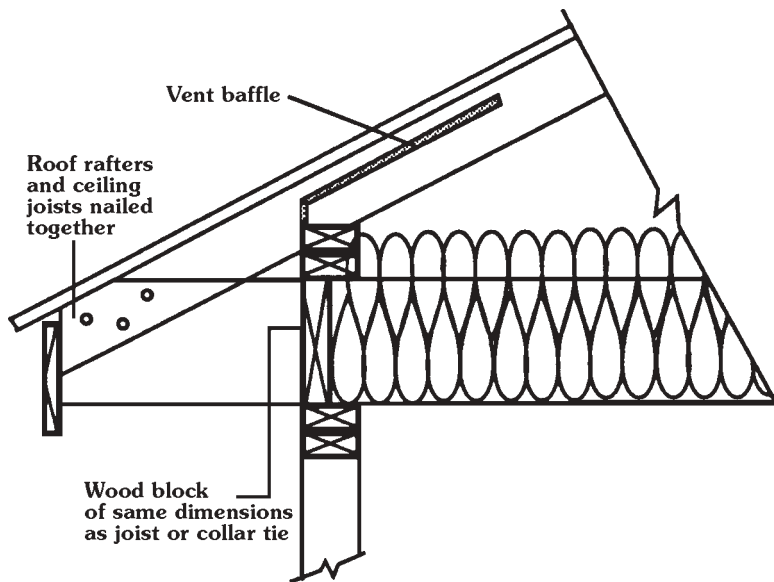


FIGURE 9 STICK-FRAMED RAISED HEEL

The recommended Canadian rafter roof design is described in the following quotation and shown in figure 10. From Harold Orr, *Canadian Wood-Framed House Construction* (CMHC Pub NHA 5031M, May 1985):

In a rafter-framed attic with a slope less than $\frac{4}{12}$, the roof loads are carried by beam action and not by truss actions. 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° , dwarf walls, and ceiling joists. "These methods of support reduce the outward thrust of the roof, continuous ties between the lower ends of opposing rafters are not necessary."

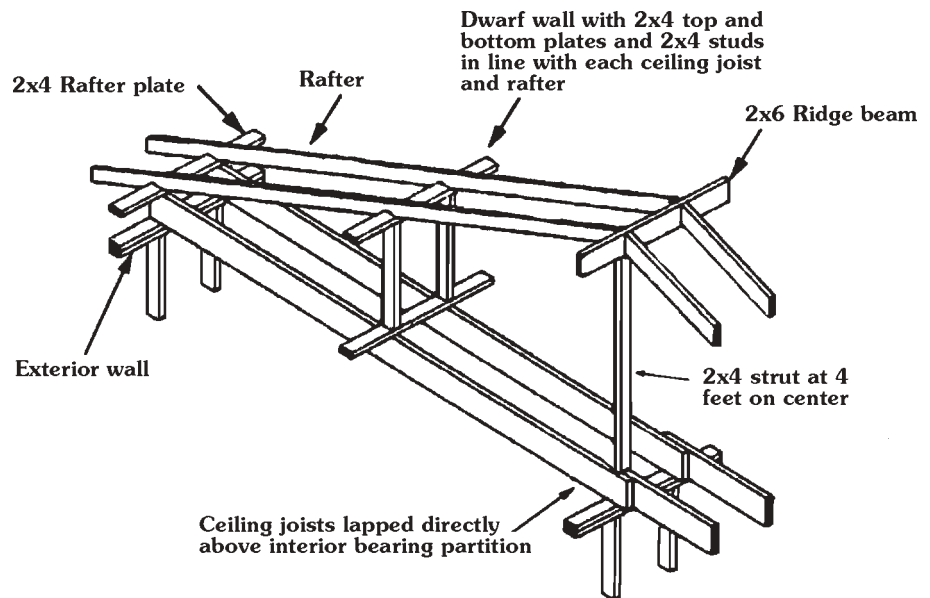


FIGURE 10 CANADIAN RAFTER ROOF DESIGN

From *Canadian Wood Framed House Construction* (CMHS Pub NHA 5031M, May 1985)

Advantages

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

Disadvantages

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

7 CATHEDRAL CEILING FRAMING

A method of framing a cathedral ceiling is illustrated in figure 11. Ceiling joists of 2x12 are used as rafters but if the two layers of R-11 batt insulation are desired, the entire rafter space will be filled with insulation. To allow for the proper ventilation space above the insulation, 2x2s are first nailed to the top of each rafter and parallel to them, to give at least $1\frac{1}{2}$ inches of air space above the insulation. Then a second layer of 2x2 (2x3s or 1x4s can also be used) are

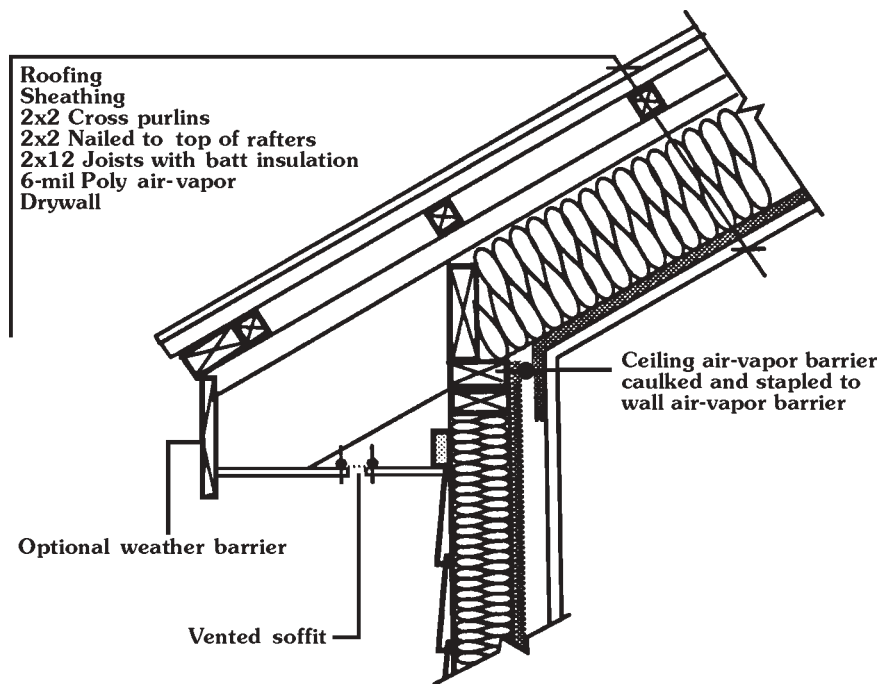


FIGURE 11 STICK-FRAMED CATHEDRAL CEILING

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.

Advantages

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

Disadvantages

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

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

- The application of polyethylene and drywall across an entire clear span ceiling before erecting interior partitions (see figure 12).
- Standard length studs can be used for interior partition walls if a 1x4 shim plate is placed on top of the exterior wall top plate. This raises the trusses and allows enough room for $\frac{5}{8}$ inch thick drywall and for tilting the partitions in place (see figure 13).

8 INTERIOR PARTITIONS AND CEILINGS

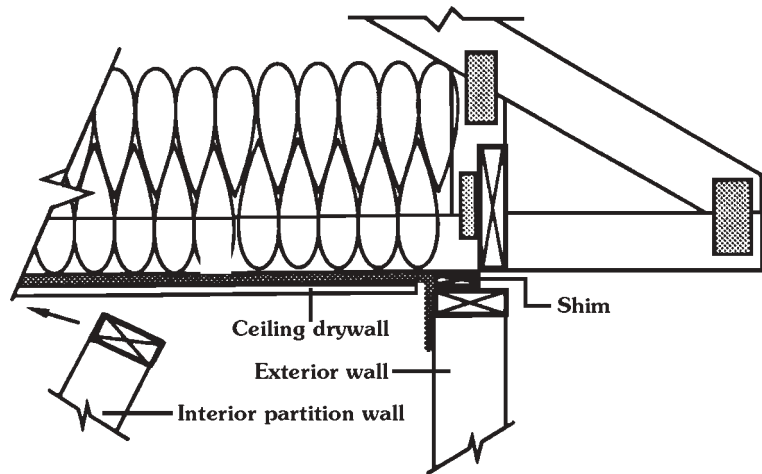


FIGURE 12 INTERIOR PARTITION WALLS: FRAMING AFTER DRYWALL

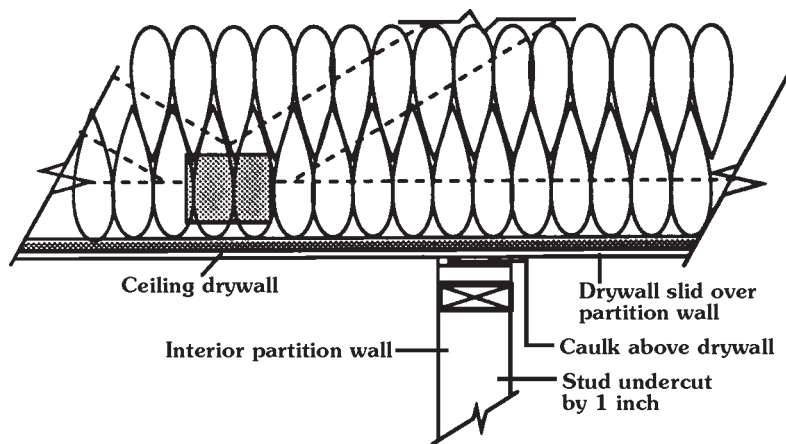


FIGURE 13 INTERIOR PARTITION WALLS: DRYWALL AIR BARRIER

Alternatively, studs will need to be undercut by $\frac{5}{8}$ inch. Drywall can be taped before the wall is raised.

- Placement of a 24-inch wide strip of 6-mil polyethylene between partition-wall top plates. The polyethylene strip is later sealed to the ceiling air barrier in each room (see figure 14).

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.

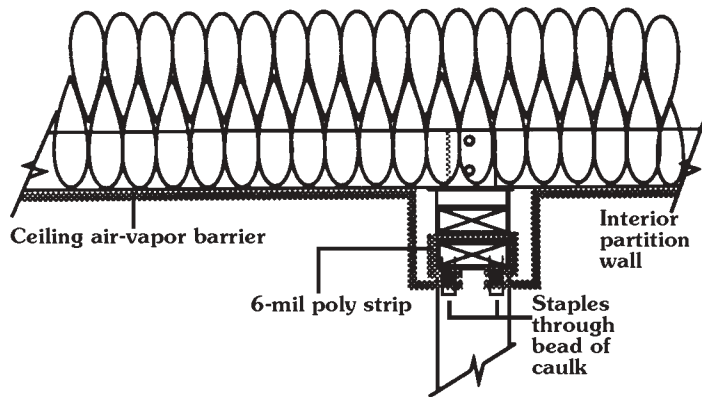


FIGURE 14 INTERIOR PARTITION BEARING WALL

Place as much plumbing as possible in interior partition walls rather than exterior walls. By minimizing plumbing in exterior walls, it is easier to produce an airtight assembly, and allow more insulation. To prevent air leakage where plumbing stacks penetrate the ceiling at partition wall top plates, an air- and vapor-tight flexible seal must be provided. The reason for requiring flexibility in the sealing of plumbing penetrations is that plumbing stacks move because of thermal expansion and contraction as well as 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 (see figure 15). 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 forced 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.

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. Some caulking materials may react with the wiring sheathing and for this reason this method may not be acceptable by electrical inspectors, in which case a rubber gasket, as described for plumbing stacks, could be used.

9 CEILING PENETRATIONS

9.1 PLUMBING

9.2 WIRING PENETRATIONS

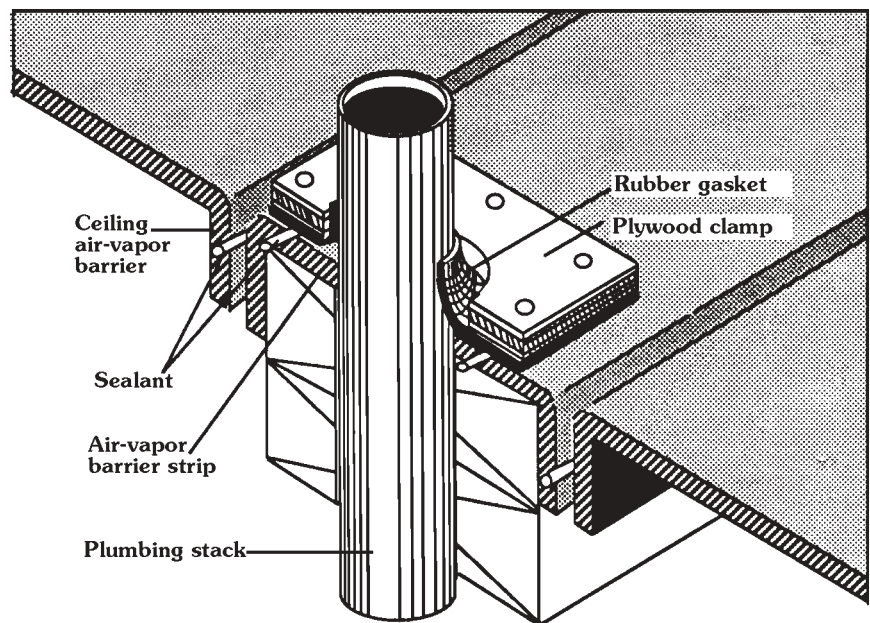


FIGURE 15 PLUMBING STACK

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

- Placing the electrical box in a prefabricated polyethylene envelope (poly hat) (see figure 16).
- 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 (see figure 17).
- Do not use recessed lights.

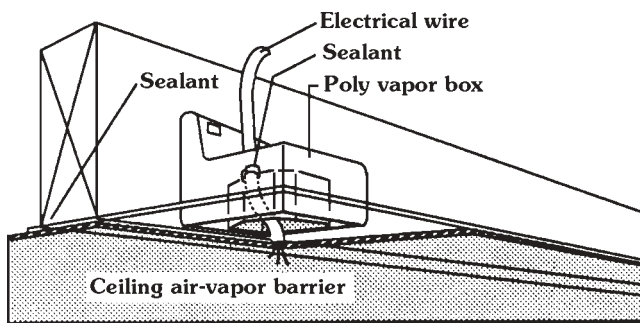


FIGURE 16 CEILING ELECTRICAL BOX

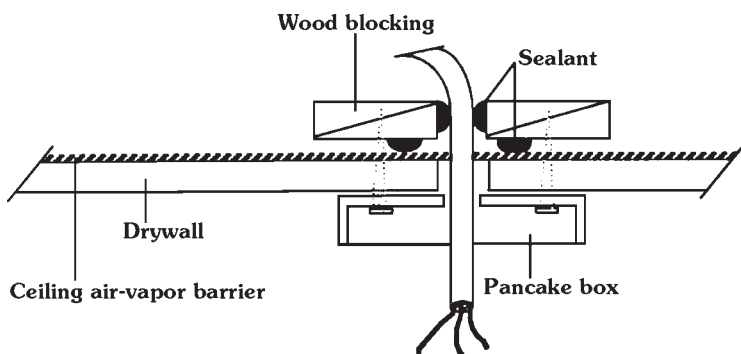


FIGURE 17 PANCAKE SURFACE MOUNT ELECTRICAL BOX

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.

9.3 ATTIC HATCH ACCESS

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BUILDING IN ALASKA

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