Prevention of Air & Water Infiltration

A Systems Approach

Prepared by the Construction Codes & Standards Committee
Of the Log & Timber Homes Council,
Building Systems Councils,
National Association of Home Builders

PREVENTION OF AIR & WATER INFILTRATION – A SYSTEMS APPROACH

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PREVENTION OF AIR & WATER INFILTRATION – A SYSTEMS APPROACH

1 FOREWARD

An average log home has nearly 1-1/2 feet of joint for every foot of log in the walls. If the wall is 12 log courses high, there may be a half-mile of joint to seal. Keeping those joints sealed from the elements is the major priority and challenge for every log home producer and builder. A well-sealed log wall minimizes air infiltration that can affect thermal performance as measured by higher energy costs. Protecting joints from water is the key to the endurance of the structure, and this protection includes windblown rain. The happiness and well-being of the homeowner and the continued growth and success of the log home producer and builder will ultimately revolve around the design and quality application of the sealing system.

A properly sealed log home also makes surface maintenance much easier. When the seal is inadequate, moisture may enter the log wall via normal flow down the face of the wall, capillary action, or due to wind pressure. The moisture can collect on a surface of a log or migrate to other areas of the wall. In some cases, this moisture can be drawn into the wood to an outer surrounding surface warmed by the sun. When certain coatings or sealers are applied to the exterior surface, an undesirable buildup of moisture can occur under the finish. The consequence of this moisture buildup is a costly maintenance process where the finish and any damaged wood is removed and the wall refinished.

The key to success can be found in the concept "system". That's because no one component alone can promise to deliver a successful seal between individual logs. Instead, a combination of these elements working together is necessary to achieve a consistent, durable seal. The system components include joinery design (e.g., patterns for applications of a sealant like caulk or foam gaskets), log shape, proper installation, and other elements that will be discussed in this paper.

The approaches to sealing a log home are as varied as the log home producers in existence today. The fact that there is not one universal log sealing design (i.e., triple, double, single tongue and groove; Swedish cope; spline and miter; chink; etc.) confirms that there is no single method of sealing. The single common denominator that delineates and distinguishes a quality manufacturer from a competitor is the seal at the log joint within the context of a "sealing system". The proprietary nature of the sealing system is recognized in the graphics in this paper. For more specific details, please refer to the information provided by the log home supplier.

The basic sealing system checklist should include the following considerations:

- ❑ The properties of the logs (section properties, stress grade, mechanical properties of the species used)
- ❑ The moisture content of the logs
- ❑ Type and placement of sealant materials and fasteners
- ❑ Joint design
- ❑ Accuracy & consistency in the milling process
- ❑ Construction techniques
- ❑ Building design and location
- ❑ Weather conditions during the building process

Successful log building systems have considered all of the variables above. The log producer, the building designer, the sealant manufacturer, the fastener manufacturer, the construction crew, and the homeowner all play important interrelated roles in the sealing equation. The degree of sealing success with minimal field complaints will greatly depend on how critically each of the individual sealing elements are evaluated, managed, and coordinated by all concerned. The strength of the log sealing system will always rely on the integrity of the individual parts and their ability to work together.

As proof of the success of a sealing system, ask the log producer/builder about their history with blower door testing and/or infrared photography. These are critical elements verifying HERS ratings by BPI or RESNET certified energy auditors and are incorporated into the ENERGY STAR® certifications. Such testing/certification continues to demonstrate that log homes can perform at very high levels = low energy consumption.

2 AIR & WATER INFILTRATION

While only 2% of the cost of building relates to air infiltration and waterproofing, 90% of the problems occur due to failures permitting infiltration. Researchers have identified air infiltration in a leaky home (defined today as above 7 air changes per hour) as a major energy conservation issue. The research indicates that as much as 30% of the annual energy bill for heating is used to heat cold outside air that has entered the home.

Log building has faced many criticisms about thermal performance because solid wood cannot claim the same values as that of insulation products based on testing developed to evaluate insulation products. Despite the "R-Value" debate, log home owners testify that their home is more energy efficient than their friends' and neighbors' framed homes. For many years, this benefit of log walls was attributed to thermal mass, but perhaps air leakage had a bigger role? U.S. Department of Energy (DOE) documents tell us why…

"A tight house will:

- Have lower heating bills due to less heat loss
- Have fewer drafts and be more comfortable
- Reduce the chance of mold and rot because moisture is less likely to enter and become trapped in cavities.
- Have a better performing ventilation system
- Potentially require smaller heating and cooling equipment capacities."

2.1 Where Does Infiltration Occur?

Warm air leaking into your home during the summer and out of your home during the winter can waste a substantial portion of your energy dollars. One of the quickest dollar-saving tasks you can do is caulk, seal, and weatherstrip all seams, cracks, and openings to the outside. You can save 10% or more on your energy bill by reducing the air leaks in your home. [i]

DOE studies have identified the most prolific sources of air infiltration. Leading at nearly 25%, air infiltration at sole plates is the greatest culprit. That is followed in decreasing order by wall outlets, exterior windows, vent hoods, fireplaces (dampers, chimney flashing), recessed lights, exterior doors, dryer vents, and duct systems. Add seams around pipes and other penetrations of the building envelope to arrive at over 200 square inches of leaks in an average home. Equally important are roof systems with heavy timber and exposed tongue and groove (T&G) systems. When these systems penetrate or pass above the supporting wall, they are notorious for air leakage that require appropriate sealing techniques.

The illustration below was published by DOE Energy Efficiency & Renewable Energy (EERE) for residential construction in both existing homes and new code-compliant construction circa 2011. DOE has created an immense resource of information on their website, Building America Solution Center (*http://energy.gov/eere/buildings/building-america-solution-center*). For the many elements of air sealing trouble spots that are common to all construction, it is recommended that a local Home Energy Rating System (HERS) certified professional be consulted. For the log and timber portion, the professional should become familiar with the design and construction references provided in this document.

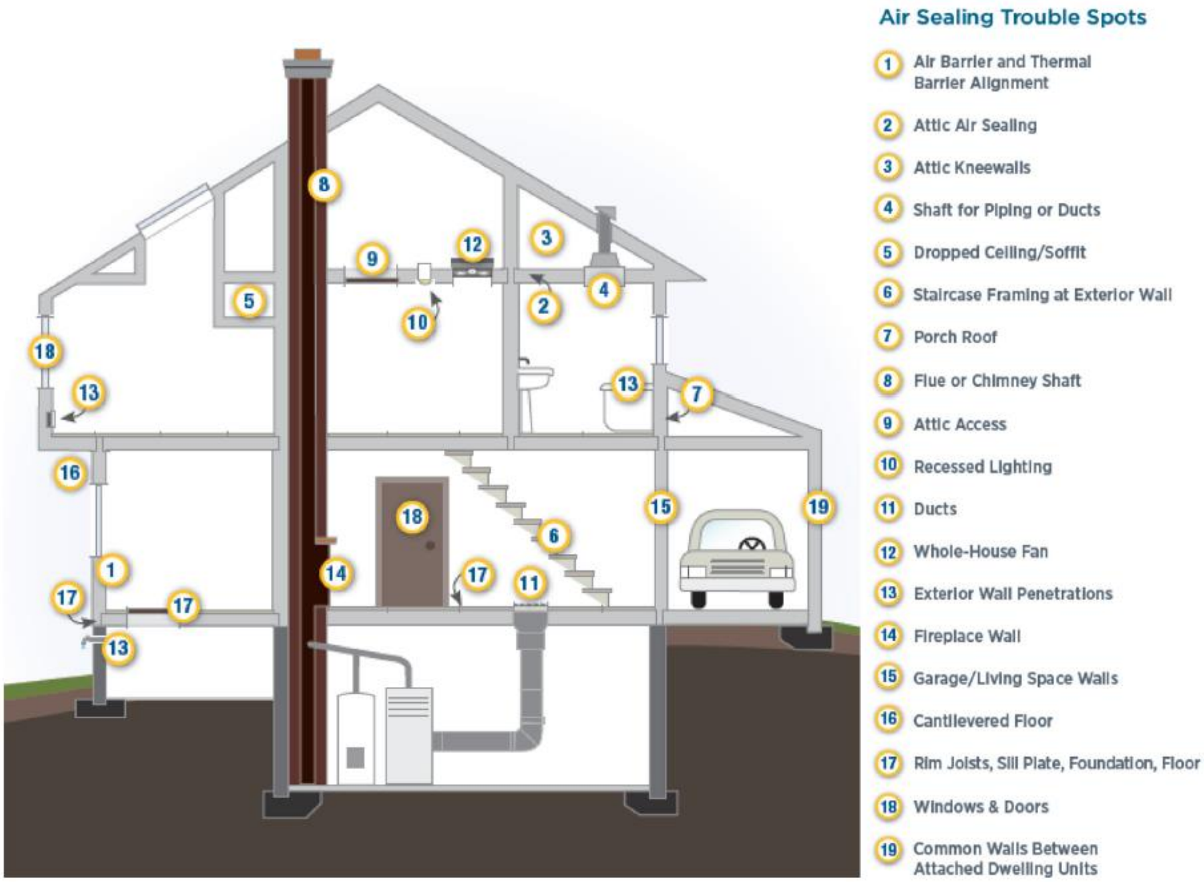

Figure 2.1.1.1: From EERE Air Leakage Guide – Sources of air leakage in residential construction – all methods of construction.

2.1.1 Key Points

Figure 2.1 outlines the many areas where builders need to pay attention to the details of construction. The Air Leakage Guide from which the illustration is taken, identifies important areas of planning, testing, ventilation and HVAC sizing that are now included in the 2015 ICC International Energy Conservation Code (IECC). The IECC has changed quite a bit since 2011, but the fundamentals have not.

For the purposes of this paper, the focus is on elements affecting the log and timber construction. The resources listed at the end of this paper provide guidance to address leakage in other elements of a home.

Discussions of ventilation and HVAC sizing have long been critical to log home performance, but they are beyond the scope of this paper. The one point that will be reinforced is this -- due to typical moisture released from building materials during construction when the home is first enclosed and heat applied, ventilation is needed. Ventilation needs to be capable of removing that moisture before it condenses on material surfaces, usually windows.

One of the advantages of log wall construction is that the solid wood provides the air barrier and thermal barrier alignment in one assembly. Add the drainage plane requirement of the ICC International Residential Code (IRC), and the log wall should be recognized as multi-functional, green wall assembly!

In February 2000, DOE's Office of Building Technology published the Technology Fact Sheet "Air Sealing: Seal air leaks and save energy." In this document, the principles of air sealing are well summarized and still relevant 14 years later. A table presents a comparison of a 1300 sf home in Atlanta, GA referencing 12 air changes per hour at 50 Pascal pressure difference (12 ACH50) and 6 ACH50. A 21.5% savings on heating and a 9.1% savings on cooling resulted by reducing air leakage.

Today's codes are requiring significantly tighter new home construction!

2.2 Building Code Requirements

Building has been governed by regulations for eons… from the days of Hammurabi's Code (see http://www.ushistory.org/civ/4c.asp). In the United States, model code agencies evolved to provide guidance to state and local jurisdictions to establish minimum requirements for construction. Today, there are six primary model code documents currently adopted by those jurisdictions – the ICC (International Codes Council) International Codes (I-Codes), BOCA National Codes, ICBO Uniform Codes, NFPA 5000, NFPA's Life Safety Code, and SBCCI Standard Codes. Life safety and fire safety had been the primary focus of these codes, but energy conservation and green construction codes have emerged to take a large role.

The 2015 I-Codes are now available (http://shop.iccsafe.org/codes/2015-international-codes-and-references.html). Relating to energy performance, two of the codes work together for residential construction – Chapter 4 of the International Energy Conservation Code (IECC) and Chapter 11 of the International Residential Code for One & Two Family Dwellings (IRC). In recent code development cycles, these chapters have been aligned to set insulation levels, glazing requirements, allowable air exchange rates, and a new building performance level. However, requirements for ventilation and moisture control have been moved to the building code, such as Chapter 7 of the IRC. For this reason, this paper will focus on the IRC as it covers all aspects of home building in one volume.

Requirements for limiting air leakage have been in the IRC for a long time, and the sections are modified every code cycle. In 2000, the IRC requirement called for durable sealants that allow for differential expansion and contraction of construction materials. That wording is well-suited for log building and was stated as

> "All joints, seams, penetrations; site-built windows, doors, and skylights; openings between window and door assemblies and their respective jambs and framing; and other sources of air leakage (infiltration and exfiltration) through the building thermal envelope shall be caulked, gasketed, weatherstripped, wrapped, or otherwise sealed to limit uncontrolled air movement."

The 2015 IRC incorporates the same changes as the 2015 IECC that focus on testing rather than visual inspection to verify that the thermal envelope has been constructed to restrict air leakage. It is updated in Section N1102.4 Air Leakage to

> "The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections N1102.4.1 through N1102.4.4."

The subsections of N1102.4 include:

- ❑ *Building thermal envelope -- installation of sealants and testing and verification to "an air leakage rate of not exceeding five air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with ASTM E 779 or ASTM E 1827 and reported at a pressure of 0.2 inches w.g. (50 Pascals)."*
- ❑ *Fireplaces – requiring "tight-fitting flue dampers or doors, and outside combustion air." Tight-fit for doors is defined in UL standards 127 for factory-built units and 907 for masonry construction.*
- ❑ *Fenestration air leakage – Windows, skylights, and sliding glass doors shall be rated to 0.3 cfm or less and swinging doors*

2.2.1 Key Definitions

Some key definitions taken from the 2015 IRC are below.

> **Air Barrier**. Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.
>
> **Continuous Air Barrier.** A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.
>
> **Continuous Insulation (ci).** Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior *or is integral to any opaque surface of the building envelope*.
>
> **Infiltration**. The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both.

Water-Resistive Barrier. A material behind an exterior wall covering that is intent to resist liquid water that has penetrated behind the exterior covering from further intruding into the exterior wall assembly.

Vapor Permeable. The property of having a moisture vapor permeance rating of 5 perms (2.9×10^{-10} kg/Pa●s●m^2) or greater, when tested in accordance with the desiccant method using Procedure A of ASTM E96.

2.2.2 ICC400 in the IRC

Since the 2009 edition of the IRC, Section R301.1.1 *Alternative provisions* has recognized *ICC Standard on the Design and Construction of Log Structures (ICC400).* This reference effectively added ICC400 to the IRC as the building code for log structures.

The latest issue of the standard is ICC400-2012, and its changes from the 2007 edition includes Section 306 *Infiltration*. This may seem to be a redundant section considering that Section 305.1 *Weather protection* covers joint design, moisture control and air leakage, extreme conditions, kerfs, assembly instructions, and sealant materials. Because ICC400-2012 also contains the important Section 304 *Provision for Settling*, Section 306 reinforces the "system" approach to log design and construction. The success of the system is its response to each section of the standard.

2.2.3 Vapor Retarders and Exterior Coverings

The discussion of vapor retarders (a.k.a., vapor barriers) is an on-going debate. It is apparent to building scientists that the presence and location of a vapor barrier changes by climate zone, and can vary with the weather patterns of changing seasons. The beauty of a log wall is that there is no hidden cavity to protect, therefore a vapor barrier is a moot point. As an assembly with one massive material exposed to both interior conditioned air and outside air, it is likely the best suited for all climate zones and seasonal weather!

IRC Section R703 *Exterior Coverings* provides minimum requirements for water resistance, barriers, siding products, attachments, wood shakes and shingles, exterior plaster, stone and masonry veneer, and flashing. In 2015, this section includes an exception for log walls that are designed and constructed in accordance with ICC400. The requirements in both the IRC and ICC400 are intended to provide a drainage plane and control water and moisture from entering the wall.

Relating to wood construction, the code further discusses protection against decay (Section R317) and protection against termites (Section R318). This discussion is developed further in the Log & Timber Homes Council white paper *Preservation & Maintenance of Log Buildings*.

For more climate-specific guidance, go to http://energy.gov/eere/buildings/building-america-climate-specific-guidance. This site has several links to case studies and investigations of how assemblies respond to the environment.

It is quite clear that the building codes reflect the research and studies performed over the last several decades and are requiring design and building professionals to pay attention to both the issue of energy conservation and of building durability.

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2.2.4 Air Barrier and Insulation Installation

In IRC Chapter 11, Table N1102.4.1 (IECC R402.4.1.1), a footnote states "In addition, inspection of log walls shall be in accordance with the provisions of ICC-400." This wording was approved as a floor amendment during the 2012 ICC Code Development Cycle hearings. The purpose was to recognize the differences that log walls present vs. frame walls. For example, it is impractical to apply a continuous air barrier to a log wall, and the log wall sealing system is effectively accomplishing the same thing.

Table N1102.4.1 sets the requirements for all of the elements of the thermal envelope that would apply to all methods and materials of construction. It may not directly apply to log wall design and construction, but the principles that are presented are the same for log walls as any other type.

Look at the requirement for sealing walls with some explanations provided by results of a study published by Owens Corning and *Green Builder* magazine.[ii]

- ❑ *Corners and headers shall be insulated*
- ❑ *The junction of the foundation and sill plate shall be sealed.*
  …This joint is often addressed with a sill gasket by the framer (for example Owens Corning's FoamSealIR), which is sandwiched between the bottom plate … for the very purpose of air sealing.
- ❑ *The junction of the top plate and top of exterior walls shall be sealed.*
  This joint was shown to leak an amount that ranged from 0.07 to 0.6 CFM50 per foot of joint (includes the leakage from both the top and the bottom joints), which results in approximately 0.04 to 0.4 ACH50 for the whole-house result. This range is driven by differences in how well the drywall is sealed to the interior finishes (window/door and base trim), which dictates the exit path of the air from the wall cavity. This matters because of what was stated above—namely, the air leakage associated with most exterior wall joints must negotiate the joint on the exterior skin of the wall (the sheathing layer) and the interior skin of the wall (the drywall layer). Once the air passes the exterior skin associated with the plate to sheathing joint, it must also pass the interior skin through drywall penetrations (electrical outlets and switches, plumbing fixtures, etc.) and terminations (bottom of the wall, windows, doors, etc.). However, these terminations can occasionally (and unintentionally) be well-sealed with caulk by the painter or finish carpenter for aesthetic reasons. Such sealing, however, is of questionable durability, since such caulks are almost always low performing (that is, low flexibility, resulting in cracking).

  Bottom Plate-to-Subfloor: Numerous independent measurements in this investigation showed the leakage associated with this joint to be relatively small (0.1 CFM50 on average and up to 0.1 ACH50 for the whole house)… It is possible that this joint can be quite large/leaky in some localized cases where the wall is constructed on the floor; tilted up into place and potentially have some construction debris (wood chips, fasteners, etc.) lodged between the bottom plate and the subfloor.
- ❑ *Knee walls shall be sealed.*
- ❑ *The space between window/door jambs and framing and skylights and framing shall be sealed.*
- ❑ *Rim joists shall be insulated and include the air barrier.*
  This joint was shown to leak an average amount of 0.86 CFM50 per foot of band joint (includes the leakage from both the upper and lower joints), which results in approximately 0.4 ACH50 for the whole-house result. It is notable that the band joist joints are the only wall joints that are not meaningfully constrained by drywall, which makes them important contributors to air leakage. The air leakage associated with all other exterior wall joints must negotiate the joint on the exterior skin of the wall (the sheathing layer) and the interior skin of the wall (the drywall layer). Once the air passes the exterior skin associated with the band joist it typically encounters a large, open space in the floor system, where it travels relatively unimpeded.
- ❑ *Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.*

For log building, these requirements are adapted in Section 4 of this paper.

The last note may be the most revealing. The specific example made in the EERE Air Leakage Guide is as follows:

> "Steven Winter Associates, a Building America research team lead, used a blower door test and infrared cameras to investigate high energy bill complaints at a 360-unit affordable housing development and found nearly twice the expected air leakage. Infrared scanning revealed an air leakage path on an exterior second story wall above a front porch. Steven Winter Associates found that, while the wall between the porch and the attic had been insulated with unfaced fiberglass batts, wall board had never been installed. The insulation was dirty from years of wind-washing as wind carried dust up through the perforated porch ceiling, through the insulation, into the attic and into the wall above. Crews used rigid foam cut to fit and glued in place with expandable spray foam to seal each area. Blower door tests showed the change reduced overall envelope leakage by 200 CFM50. At a cost of $267 per unit, this fix resulted in savings of $200 per year per unit, for a payback of less than two years."

2.3 How to Find the Air Leaks

Contractors have the option of using blower door tests, infrared scanners, and/or tracer gases to identify the source of air leaks and measure building tightness.

2.3.1 Blower Door Testing

For residential construction a portable fan capable of creating a pressure difference is typically used to verify performance. The verification method is ASTM E779 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization Method.

Blower door devices include a fan mounted on an insert that fits inside a doorway, allowing negative pressure to be generated inside a building to measure air leakage. Applying this test to log and timber home construction can be extremely beneficial as the material package is typically intended to provide a structurally sound weather-tight shell quickly. Once enclosed, the interior work can proceed.

It is recommended that the builder, contractor or other knowledgeable and experienced tradesman use the blower door equipment before the interior finish work begins. This provides an opportunity to find and remedy all air leaks before finish materials are applied. While the IRC does not require a certified party to perform the test, the final approval by the building official having jurisdiction may request that the test be performed by an independent third party. In this case, refer to Energy Star® (www.energystar.gov) providers first as there may be financial incentives to certifying the house to Energy Star® standards. The two primary organizations that train and certify individuals for whole-house testing are RESNET (Residential Energy Services Network, www.resnet.us) and BPI (Building Performance Institute, Inc., www.bpi.org).

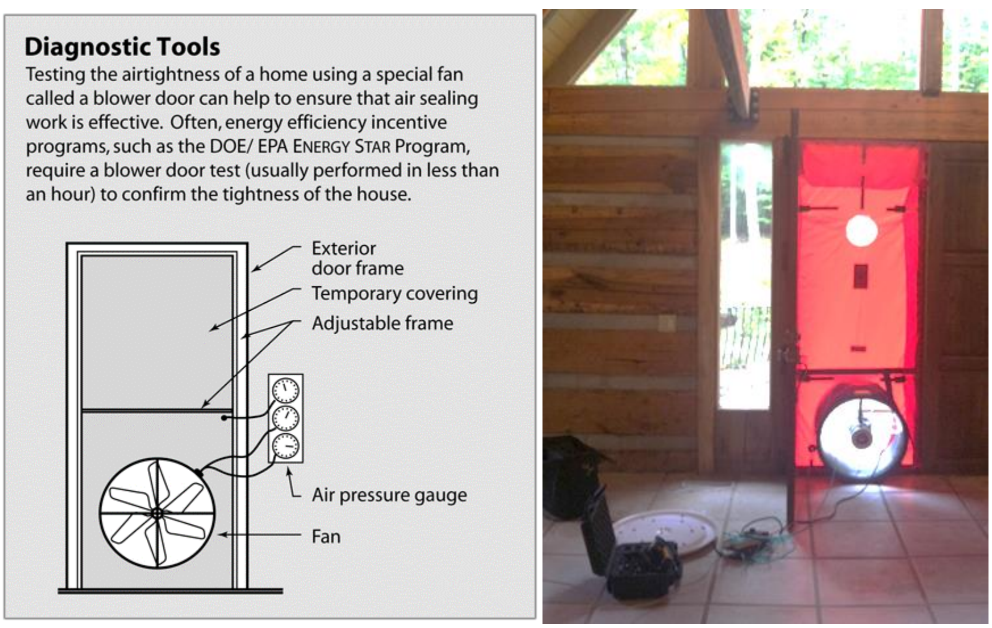

Figure 2.3.1.1 Blower door set up (source: DOE EERE)

2.3.2 Infrared Imaging

Infrared photographs create a visual indication of heat leaks from a building.

Thermography uses special thermal infrared devices that measure the different levels of heat being radiated through a building envelope and show a color-coded thermogram image. The progression of colors corresponds to the surface temperature. Black areas indicate well-insulated or unheated areas.

Thermal camera use is highly recommended to identify where the leakage areas occur. To properly identify the occurrence, a temperature differential must exist. This tool should be conducted after the heating, ventilation and air conditioning systems are installed and operating but before trim is installed.

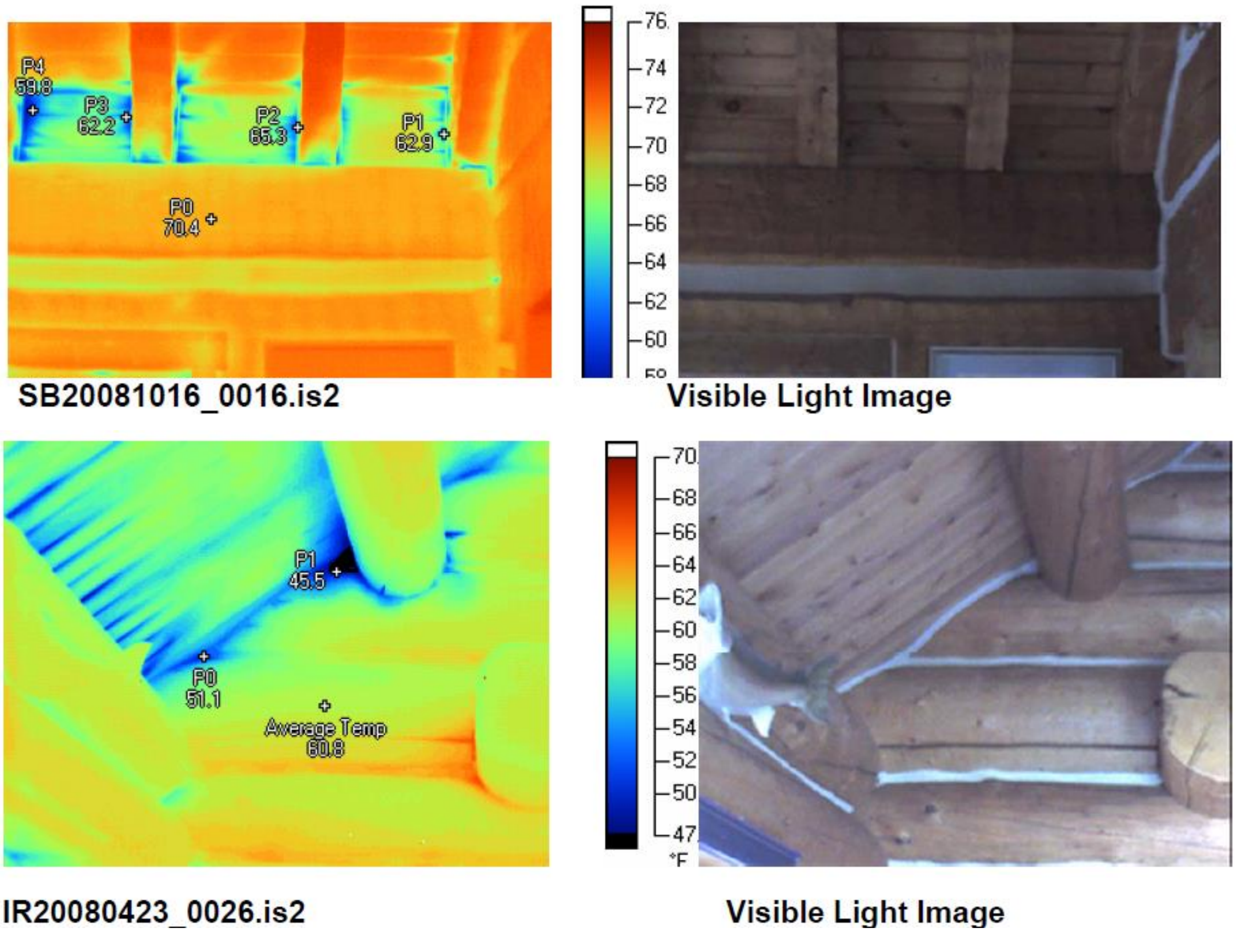

Figure 2.3.2.1 Infrared photos indicating air leakage above the log wall to the roof deck (courtesy Tracy Hansen, Stormbusters, Inc.). Top photos show leakage in the "birdblock" area above the log wall and between rafters. The bottom photos show leakage where decking bears on the log wall in a purlin roof system.

2.3.3 Duct Leakage

The issue of duct leakage came to the forefront in recent code cycles due to the increased energy usage and cost associated with inefficient distribution of forced air systems. The 2015 IRC addresses duct leakage in Section N1103, with testing requirement specified in N1103.3.3. The code provides an exception for ducts that are contained entirely within the thermal envelope on the assumption that the conditioned air is contributing to the indoor environment. Even when located in the conditioned space, improperly designed or installed ductwork will not deliver the conditioned air to the intended location, resulting in cold spots in the house.

Duct construction is covered in the 2015 IRC Section M1601. This section covers design and installation requirements, including sizing, sealing and more.

3 USING SEALING SYSTEMS TO CONTROL ENTRY

Managing air and water penetration of log buildings is similar to that described below for wood siding. This text is taken from *The Ins and Outs of Caulking*, published by the Forest Products Laboratory's Advanced Housing Research Center.

> "Wood-based siding is expected to shed water, but it is usually not expected to act as a perfect barrier. Individual pieces of siding in good condition resist water penetration, but water can potentially enter between pieces, where siding meets trim or window or door casing, at penetrations through walls, and at intersections of walls with roofs and decks. In addition, when horizontal lap or shingle siding is exposed to rain, water can be expected to rise up the back of siding as a result of capillary flow and wind-driven rain. Water that is absorbed into siding or that wets the back of siding through capillary rise or minor leaks will eventually evaporate. However, evaporation is not immediate—the siding will retain the water temporarily."

By contrast, the log wall *IS REQUIRED* to act as a perfect barrier.

When the log home industry talks about infiltration, they are clearly talking about limiting both air and water from entering the log wall. Since the log wall is the total defense against the weather, air and water have to be recognized as a dual entity and often as teammates.

A well designed sealing system will be one that stops the penetration or migration of air and moisture. It will restrict the surfaces that may allow water to collect and yet manage the drainage and allow evaporation.

3.1.1 Keys to Log Home Suitability

Sealant products used in modern log homes should conform to several criteria:

- Flexible to maintain elasticity and resiliency necessary for log movement
- Aesthetically pleasing, such as available in wood-tone colors
- Easily tooled, applied, and cleaned-up
- Available in user-friendly sizes and water-resistant containers
- Strong enough to withstand the construction process
- Stainable if designed to be used on exteriors
- Cost efficient for the task with long shelf life
- Durability – ability to withstand UV-radiation, ozone, freeze-thaw cycles, moisture and associated development of mold and mildew
- Early weather resistance and minimal cure times
- Impermeable to air flow and water (no absorption permitted)
- Properly sized to the joint.

3.2 Types of Joints

Joints are defined by the extent of movement as working or non-working joints. Non-working joints are typically either static or rigid joints, while working joints are designed for movement (up to 12.5% or up to 25%). The type of joint and extent of movement are defined by the type of log building system used.

They are sealed with materials that are intended to

- Protect against intrusion into the joint by any outside element
- Prevent infiltration by air or water
- Absorb movement (expansion or contraction)

3.3 Material Implications

Log grade and properties, moisture content, milling accuracy and consistency, and choice of sealants, fasteners, and joinery are all parameters to decisions regarding the sealing of logs. Milling accuracy and dimensional stability are critical in designing the tolerance and dimensions of the joint and sealant. If the placement of the sealant (in a groove, on a tongue, etc.) is not aligned with a corresponding groove, the best sealant will fail.

It is important to remember that movement and shrinkage occur to some extent in all log and heavy timber assemblies. Logs brought in from the environment and incorporated into a structure that is climate controlled will lose moisture and shrink in three dimensions; width, height, and length. This is true whether logs are air-dried, kiln-dried, or standing dead. It is true regardless of shape or size --6x12, 6x8, or round. The sheer weight of building materials will also compress wood fibers. Once set in place, the individual logs shrink away from one another at varying rates, potentially opening a seam that was closed when construction was done. The key to building an air and watertight envelope is to build using a continuous sealing system designed to absorb the anticipated movement. Further challenges arise in making this sealing system palatable in conjunction with the design of the structure and mechanically compatible with the fastening system used in the log structure.

If a log producer could guarantee that each log would be perfectly straight, and that it was milled into its final form after it was dried to the equilibrium moisture content of the area in which it will ultimately be constructed, there will be few problems during the sealing and/or construction process. Ideally, this would result in minimal movement and tight joinery. Sealing logs under these conditions requires less material, and since movement is less, the sealant system is more likely to perform adequately.

Reality is that all logs adjust to the conditions at the building site first, and then adjust to the conditions imposed on them by the inhabitants when the heating and air conditioning systems are used.

3.3.1 Adhesives

Adhesives are not practical options as sealants because they are not intended to be flexible. While certain adhesives perform well with rigid frame construction, they are not conducive to working joints. They work best when applied at the proper temperature onto clean and dry surfaces, which are not always the case with log construction.

One note of interest is that many construction adhesives will create a wood-to-wood bond that is stronger than the bond between wood fibers themselves. Therefore, failure between the pieces of wood is almost always above or below the bond line.

3.3.2 Sheet Barriers

Sheet barriers are often used to seal the seams created between building assemblies. Larger sheets may be used for faster installation and offer few seams to tape. Smaller sheets of flashing are more appropriate for specific applications such as around chimneys where they penetrate the roof, between the roof and dormer walls, and around window and doors to seal the jamb to wall connection.

Polyethylene sheets have been used for vapor barriers for years, but the sheet can disintegrate over time if not properly protected. House wrap products have been developed to provide barriers to air infiltration.

Various flexible membrane flashing products (metal or vinyl) under roofing, siding, and at intersections of different construction assemblies are effective to move air and water away from the joint.

Several adhesive tape products have been developed to seal the seams of continuous insulation and multi-purpose sheathing products. Where they are protected by trim or other logs, tapes may offer an option for some seams in log walls.

Flashing is often used in combination with a caulking product to insure the seal. An example would be the use of a silicone caulk around the joint created by metal flashing and a masonry chimney.

3.3.3 Joint Fillers

Joint fillers are used in deep joints where the depth of the joint must be controlled, where resilience is needed for working joints, or where a bond breaker is required.

3.3.3.1 Rigid Foam Insulation

Rigid foam insulation is an effective product to seal very large openings where both insulation and air/vapor barrier properties are needed. Not appropriate around materials that will reach high temperatures, rigid foam is often used around plumbing chases, attic access covers, etc.

3.3.3.2 Backer Rod

Backer rod is effectively used in several ways to seal against infiltration.

- ❑ Crack filler – Use round, closed cell or bicellular foam, sized slightly larger than the crack it is to fill. Commonly available in ¼" to 4" diameter and in coils and straight lengths, the foam can be pressed into the void. This is effective for long, narrow voids that may vary in width.
- ❑ Support filler – Trapezoid and convex shaped foam products are frequently used to support caulking to insure the shape of the caulking seal. Properly selected backer material will not allow the caulk to bond to it and will not affect the performance of the caulk as the joints moves.

Caulk backer rod is a flexible, closed-cell or bicellular foam material that is formed into long, narrow lengths, generally of circular cross section. Backer rod is inserted into gaps, cracks, or joint reservoirs where seals are to be made; then the rod is sealed over.[iii]

Where depth of a crack is shallow and backer rod cannot be used, bond-breaker tape is sometimes used to prevent three-sided adhesion. [iv]

3.3.4 Chinking

Chinking is a joint sealing option used in the log building industry. Only its relation to stucco and synthetic stucco systems bring it into the world of conventional construction.

Modern chinking is manufactured to mimic the old style mortar that was used in the infancy of the modern log home industry. Much like mud and straw, mortar-based materials did not work very well to seal out air and water. Mortar does not adhere to wood.

Like caulking products, modern chinking materials are specially formulated elastomeric materials, which adhere to wood, metals, and mortar. When used between logs and properly applied, chinking will stretch and absorb minor movement between logs, forming an air and watertight barrier, which is resistant to mold, mildew, ozone, extreme temperatures, and is aesthetically pleasing. Modern products come ready to use, are available in different colors, and are commonly available. All products on the market today are water clean-up and must be applied to dry logs with a surface temperature of 40 degrees and rising. As most chink joints are fairly large in size, cure rates are fairly slow and freshly applied chinking should be protected from the elements and from physical damage until cured. As most chinking is applied after sealers or stains are applied to logs, compatibility with the chosen chinking is imperative as adhesion can be affected.

3.3.4.1 Chinking Joint Design

In order for any chinking material to properly perform in a log home, the joints must be properly designed and the chinking properly installed. Whether logs are round, square, milled or handcrafted, two-point adhesion is imperative. This means that the material is bonded only to the top and bottom log face in a joint reservoir and not to a third face.

Backer rods of various width, composition and design are commonly used as temporary filler between logs. Backer rods limit the depth of the applied sealant, resist the sealant to form the proper shape, and act as a bond breaker to prevent third-side adhesion.

Joint width should be a minimum of four times the anticipated movement of the logs.

- For joints 1” in width or more, the depth should be 3/8” to ½”. The depth of joints less than 1” wide should be half the width, but no less than ¼”.
- One exception to this rule is the Appalachian style log, which commonly uses a Styrofoam backing material between the logs. These joints can be 4” or more in width. The chinking depth on this design can be ¼” in the body of the joint, but must be at least 3/8” at the point of log contact.
- Logs with a milled chink joint and log siding installed over OSB or plywood should incorporate a bond breaker tape to achieve two-point adhesion.

3.3.4.2 Chinking Application

The vast majority of chinking is supplied in 5-gallon pails. The material can be applied to log walls via bulk caulking guns, common grout bags, by hand or with a commercial grade-chinking pump. However it is applied, all chinking material must be tooled to ensure proper adhesion to the logs and for appearance sake. Chinking is tooled by various methods, depending upon the style of the logs used. With round logs, the product is commonly tooled into place using small trowels, foam paintbrushes, and water that is sprayed on the surface to make tooling the product easier. With square logs, chinking is usually tooled into a flat joint using putty knives. Regardless of style, a good chinking job will be applied at the proper thickness, will be aesthetically pleasing, and will have a well-designed joint incorporating two-point adhesion.

3.4 Wet Seal vs. Dry Seal vs. Hybrid

Caulk relies on adhesion while gasket relies on expansion or compression to seal the joint. Therefore, most log home manufacturers use a combination of all three methods. For instance, a company may use chinking on all of the horizontal joints, sealant or caulking on butt joints and corners and gaskets over windows and doors. Or they may employ a double tongue and groove log with caulking on the outside groove, gasket on the inside groove and chinking on a milled exterior chinking groove, or other combinations.

Which is best? While all properly designed and installed methods work, the most dependable method is the exterior one. This is due to the fact that an exterior seal is readily accessible and can be inspected and repaired if necessary. Interior methods rely on competent installation at time of log wall erection, and in case of later need of repair, accessibility will be a factor, forcing sealing to be accomplished from the exterior by caulk or other method. Some joints, such as over windows and doors, where movement can be extreme, clearly call for a large gasket with low compression and deflection value because movement can exceed the parameters of a wet seal.

3.4.1 Caulking

Caulking is used in both exterior and interior applications to seal between logs, in checks or cracks, around windows and doors, around corners, at log butt ends, between other joinery, on flashing, around wall penetrations, and in any number of other applications. Unlike chinking, caulking is usually used to cover gaps in wood or in transition from one material to another to make them appear to blend together and is usually available in a variety of colors. Modern caulking products are elastomeric, mold and mildew resistant, have excellent adhesive properties to a wide variety of substrates, and when properly applied can provide an excellent barrier to air, water and insect infiltration.

Caulking is also used to seal logs in tongue and groove style logs, usually by applying a bead of material to the tongue of the bottom log. Two-point adhesion can be achieved in this application by insuring that proper headspace is left between the tongue and the groove and the joint is not over-filled and the material is not simply squeezed out.

The design of the joint should ensure that the caulking material is placed as closely as possible to the exterior of the log to prevent water infiltration into checks or cracks. Caulk barriers whether internal or external should be continuous and extend through butt joints and corners and around windows and doors to provide a continuous seal throughout the structure.

The selection process must consider the type of joint, surface preparation at time of application, and compatibility of caulk and substrate. The key elements of a caulked joint are adhesion and cohesion.

- Adhesion is the ability to stick to the surface of the materials creating the joint (substrates). Selection considerations include the compatibility of the caulk with the substrate, the conditions at time of application (e.g., temperature, presence of moisture, dirt, or other residue on the substrate), and any treatment.
- Cohesion is the ability to hold together. Selection considerations include the type of sealant compared to the type of joint, the curing properties of the caulk, and the thickness and elasticity of the material being applied. Use caulk that will remain flexible enough throughout its service life to satisfy the application. ASTM Standard C920 identifies two weather-resistant caulk classes; Class 25 has high flexibility and Class 12-1/2 has lower flexibility.

The National Bureau of Standards developed classifications for sealants to describe their purpose and usefulness:

- Type 1 caulks – self-leveling; for horizontal, traffic-bearing joints
- Type II caulks – non-sag; for vertical or non-traffic-bearing horizontal joints
- TT-S-00230 caulks – pre-mixed, one-part, ready-to-use
- TT-S-00227 caulks – two-part caulks that must be mixed for each application; Class A caulks are for joint movement of up to 50% of the original size; Class B are for joint movement of up to 25%.

Caulking products are commonly available, but most are designed for conventional housing and are not all compatible with log homes. There are many different materials used in caulking to maximize its effectiveness between similar materials. In the log home industry, the basic materials used for the wood-to-wood joint are usually acrylic, butyl, silicone, or urethane. Each of these materials has inherent pros and cons and the reader should refer to the chart in the Appendix for caulking choices for specific applications. See Appendix, *Pros & Cons of the Typical Sealant Types Available* for more information.

Do not use caulk that has been stored for excessive periods or beyond the indicated shelf life. If it is difficult to force the caulk from the tube, the shelf life has probably been exceeded. However, the ease of dispensing caulk from the tube does not necessarily indicate freshness. Some caulks that have exceeded their shelf life may be pumped easily from the tube but fail to cure. Latex caulk that has been frozen in storage should be discarded.

3.4.1.1 Caulking Joint Design

Two-point adhesion is imperative for caulking material to properly perform in joints where movement is anticipated. Applying caulk in a joint that is too deep (depth cannot exceed width and is actually best when it is half the width) or one that allows the caulk to adhere to three surfaces will undoubted fail; it's just a matter of time. For both adhesion and cohesion in a moving joint, it is best to promote an hourglass shape using a backer rod.

For proper adhesion on both sides of the joint, make sure the surfaces are dry, free of frost, and clean (no dirt or loose materials). For wood that has been treated (especially with a water repellent), apply the caulk on a small piece of the treated wood to test its adhesion. A priming material can enhance caulk adhesion; information from the caulk vendor will indicate whether priming is necessary.

3.4.1.2 Caulking Application

The caulked joint can also be affected by how it is applied. Cut a 45-degree angle on the nozzle of the tube, beginning with a small tip. If it is too small, cut some more of the nozzle (the converse will not be a possibility). PUSH the gun along the crack with the angled nozzle running fairly flat along the surface. Do not let the bead get bigger than the nozzle tip. Remove the excess with solvent and a rag.

Tooling the caulk bead with a putty knife, spatula, bare finger, or rag provides a smooth, finished appearance and forces the caulk into the joint. Often, water or a combination of soap and water are used to help smooth and press the caulk into place.

Apply caulk within the range of acceptable application temperatures as indicated by the manufacturer. In some cases, the choice of caulk will be determined by temperature at application.[v] It is generally recommended that caulk be applied to the cool side of a building on a hot day and conversely to the warm side on a cold day.

3.4.2 Gaskets

Gaskets designed for uses in log building may come in rolls with an adhesive on one side. They are used most often between the log courses and around wall openings to seal the rough frame/buck. The adhesive is used to aid in placement during log stacking and not to seal the log.

The key elements for gasket use in the log wall are:

- ❑ High performance products cost more than some sealants, but are a relatively small cost compared to the overall project. Yet, when low cost products fail, the cost to repair can be significant.
- ❑ The seal must be continuous. Ends of gasket tape need to be lapped (about 1 inch) to be sure the splice is sealed. Even transitions from horizontal to vertical need to be continuous.
- ❑ Gaskets should be placed at the least vulnerable point on the bearing surfaces so that water drains away from the sealant
- ❑ Size the gasket to the joint size after settlement and shrinkage have opened the joint.

Dry, preformed foam gasket is used instead of caulk because of ease of application, neatness, cleanliness, low cost, and uniformity of application (it cannot be squeezed out of the joint). The factors that should be considered when selecting a gasket are:

- ❑ Compression – The force required to close the joint.
- ❑ Compression recovery – The ability to return to the original form after being compressed.
- ❑ Durability – Resistance to elements that will cause failure, such as the brittleness that can occur from UV-radiation or ozone exposure.
- ❑ Water absorption – Or lack of… the ability to stop moisture.
- ❑ Compatibility – How will it react with wood treatments, protective coating products, caulks, etc.? Is it better to apply it to bare wood and treat around it, or treat first and apply sealant afterward?
- ❑ Ease of installation – Adhesive backed tapes stay in place while setting the next log course.

Density and cell structure are two of the key elements of selection. Product options include

- ❑ Low Density Closed Cell – PVC, polyolefin, polyethylene
- ❑ High Density Closed Cell – neoprene, EPDM, polyurethane, polyolefin, polyethylene
- ❑ Open Cell – Made from polyurethane or polyester polyurethane, open cell urethane foam degrades rapidly from UV-radiation and ozone. Open cell foams are not appropriate in log walls unless they are impregnated with a sealant or sealed with an impermeable coating.
- ❑ Saturated Tape Products – In compression joints, saturated open cell gaskets out-perform caulks, mastics, and backer rod as the foam structure reinforces the impregnated sealant. The saturants range from ashphaltic bitumen to petroleum-based liquid adhesive to neoprene rubber; some can make handling the gasket a bit unpleasant. The opposite of closed cell, these products are most effective when compressed 50% to 90%. Limitations include the need to keep the material warm in cold weather, but cool in hot weather.
- ❑ Butyl tape – Rather than relying on compression recovery to seal the joint, butyl relies on its adhesion and elastic qualities to maintain the seal.

Low density closed cell foams have very poor recovery and do not provide an adequate seal in joints that move. Once compressed, the shape of the foam is set and over 50% compression can result in destruction of the cell structure.

Relying on their elasticity to recover and maintain a positive seal between surfaces, high density closed cell foams are designed for as little as 25% compression. They exhibit the highest level of recovery from compression, but are much more difficult to compress and are not very moldable. Their advantage is that they require less compression to perform well. The disadvantage may be that the density of the material makes it undesirable to compress it more than 50% to 60%, as it is likely to hold the joint apart.

EPDM (ethylene propylene diene monomer) is a synthetic rubber with exceptional resistance to UV-radiation, oxidation, air pollution, and extremes in temperature. It can be made into a hard, stiff, solid form, a bulb or hinge shape for better compression, or a skinned, closed cell extrusion.

Open cell products are sometimes useful to fill voids, but they require additional treatment to eliminate air and water passage. The advantage of open cell foam is that is can compress to a very small size. When fully wrapped with an impermeable plastic skin, open cell foam becomes an excellent product to fill a joint that will compress over time.

Unlike caulking (and chinking), dry preformed foam gaskets seal by expansion or compression to fill voids within a joint and rely on their "memory" to seal the space. Other gaskets are used over windows and doors to fill settling spaces. Various types of building gaskets have been used to seal between building assemblies or to block small openings. An example of the former would be gaskets used between the sole plate of the exterior wall and the subfloor. An example of the latter would be a gasket to seal an electrical outlet against air infiltration. Gaskets may also be effective in sealing the hole made to allow a pipe or vent to pass through the building envelope.

3.4.2.1 Joinery Design Considerations

When sealing between logs with gaskets, joint design and proper gasket sizing is most important. The key to gasket joint design is to size it to fill the joint without excessive compression, yet with adequate recovery to fill the joint as it opens. Common considerations are compression recovery, compression force, water absorption, compatibility with substrates, and resistance to UV-radiation.

Correct headspace must exist between the tongue and groove to prevent crushing the gasket and to avoid having the gasket hinder log placement. The gasket must also be deep enough in its' expanded state to completely fill the voids in anticipated log movement. In sealing butt joints, a 'well' or groove should be routed to accommodate the gasket in its' compressed state, otherwise, logs will be held apart and gaskets will be over-compressed.

Gaskets are best for joints or small cracks with controllable or predictable movement. Tolerances in the joint will need to be compared to the allowable compression of the gasket and its ability to recover. Gaskets are available in an assortment of sizes to best suit the application. The size of the gasket in its compressed and expanded sizes determines the sizes of voids it can fill.

Some common uses for gaskets elsewhere in construction are

- ❑ Sill plate to foundation wall
- ❑ Box sill to sill plate
- ❑ Sub floor to box sill
- ❑ Exterior wall to sub floor
- ❑ Roof assembly to exterior wall

3.4.2.2 Application

One advantage to gaskets and tapes is that they can be installed in most conditions. Adhesive-backed products may be difficult to work with on frozen or dirty surfaces, but a few well-place tacks will keep the material in place while the next piece is installed. Overlap ends to provide a continuous line of sealant. Cut the ends of the gasket using sharp shears or knife, wetting either with water or silicone spray to make cutting easier. Do not pull or stretch tape during installation as it may result in uneven thickness of the product.

3.4.3 Expanding Foam Sealants

Spray-on expansive foam products are typically polyurethane foams that are high- or low-pressure systems. They are available in cans or other larger metal pressurized containers and are dispensed into voids, cracks or joints where they expand and harden to a rigid mass.

Spray foam sealants, if properly applied, have played a key role in improving overall energy efficiency. Their use is highly effective in appropriate applications. However all foams are not the same. The cell structure is the first major difference.

- ❑ Open cell
  - Lower density requires less material, hence lower cost.
  - Insulation value: The aged R-value will be available from the manufacturer/supplier, but is often in the range of R3 to R5 per inch of thickness.
  - Permeable to air and water.
- ❑ Closed cell
  - Insulation value: The aged R-value will be available from the manufacturer/supplier, but is often in the range of R6 to R7 per inch of thickness.
  - Impervious to air and water.

Polyurethane foams come in many sizes and are intended for different construction and other applications.

- For smaller volume applications, one-component rigid polyurethane foam is appropriate.
  - The size of the job should be less than 4 cubic inches of volume since these products are moisture-cured, and it takes atmospheric moisture to allow them to harden. If the job is larger than the size of a fist then the moisture cannot get to the center of the foam to allow it to properly cure.
  - One-component products are available in a single package where a straw is attached to the aerosol can. This is for the smallest applications.
- For higher usage applications, which are still small uses of rigid foam, “gun foam” is normally used where the aerosol is attached to a dispensing applicator.
- For window and door applications, low-pressure foams are preferred to diminish the chance of bowing the window or door.
- For larger volume applications, two-component foam is recommended.
  - It is a chemically cured material.
  - Disposable kits are available to the homeowner in sizes ranging from one cubic foot of rigid polyurethane foam up to fifty cubic feet of foam.
  - They have the ability to insulate, sound deaden, stop air and water infiltration, inhibit rodent infestation, and do not support mold growth.

3.4.3.1 Joinery Design Considerations

Newer, low-pressure foams can be effective in log home construction when applied with consideration to the following characteristics:

- Best for sealing larger voids that are protected from sunlight and moisture
- Effective in static joints, but they lose effectiveness in high movement joints
- Generally a poor choice for log home sealants as most dry fairly hard and have poor or no elasticity
- Straw foam is difficult to control with a tendency to over-fill most joints and spill out onto logs where they are very difficult to remove. Gun foam is easier to control.

The void should be contained such that the foam fills and seals cracks without oozing through them. They have been used as backing material for chinking with some degree of success, but blisters in synthetic chinking material have occurred due to out-gassing.

These products can be effective, but tend to be messy and some safety concerns arise. Applications should consider the condition of the material surfaces adjacent to the void (moisture content, free of dirt/debris, temperature), temperature at nozzle (especially on 2-part applications), and depth of the void. Industry standards recommend applying in 1” to 2” lifts (layers), and not to fill the full depth at one time. The rate of expansion of the foam is important as rapid expansion can generate undesirable pressure. Around windows, this pressure can impact the operation of the window. Heat of the reaction is also a consideration as improper applications have developed into building fires. Most suppliers offer products with a shelf life between 9 – 18 months, so make sure to use the oldest product first for proper inventory rotation.

4 JOINERY ELEMENTS OF LOG STRUCTURES

ICC400 requires that the log wall provide protection against the weather, limiting air and water infiltration, and at the same time accommodating settling.

Each producer of a log building system has developed a proprietary system can provide an explanation of how and why that proprietary system performs. It is recommended that the following content be used as a guide when investigating various log building systems. The supplier of the log wall system should provide details of how and where these joints are designed to seal the joints.

4.1 Horizontal Joint Design

Horizontal joinery for log walls includes four critical points: The base course, the interior log-on-log courses, the header and sill courses at openings, and the top of the wall to whatever is above it. Universally, continuity of the sealant is critical. Special care must be taken during construction to ensure that sealants are not torn or smeared during log wall erection so that voids are not formed.

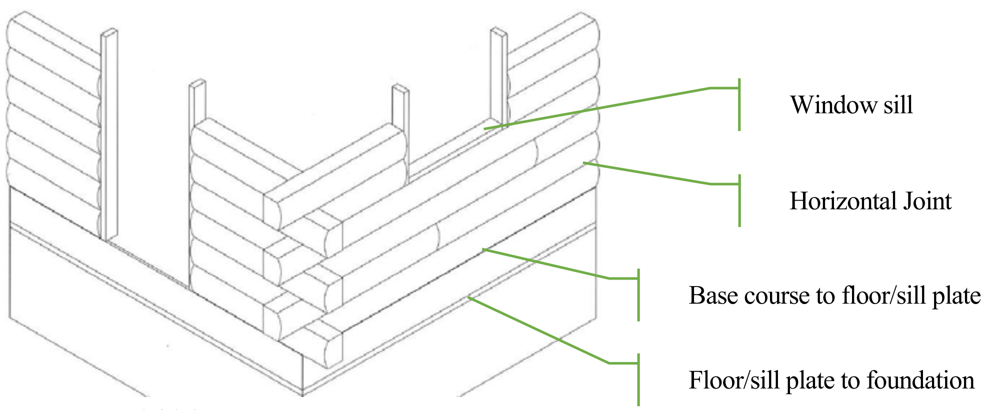

Figure 3.4.3.1 Horizontal joints in a log wall

4.1.1 Primary Design Elements

4.1.1.1 Bearing Surfaces

No sealant should be located at load-bearing areas. The wood-to-wood bearing capacity is important for structural purposes. In some systems, compression of bearing points onto the log below it may be an intentional part of the joint design.

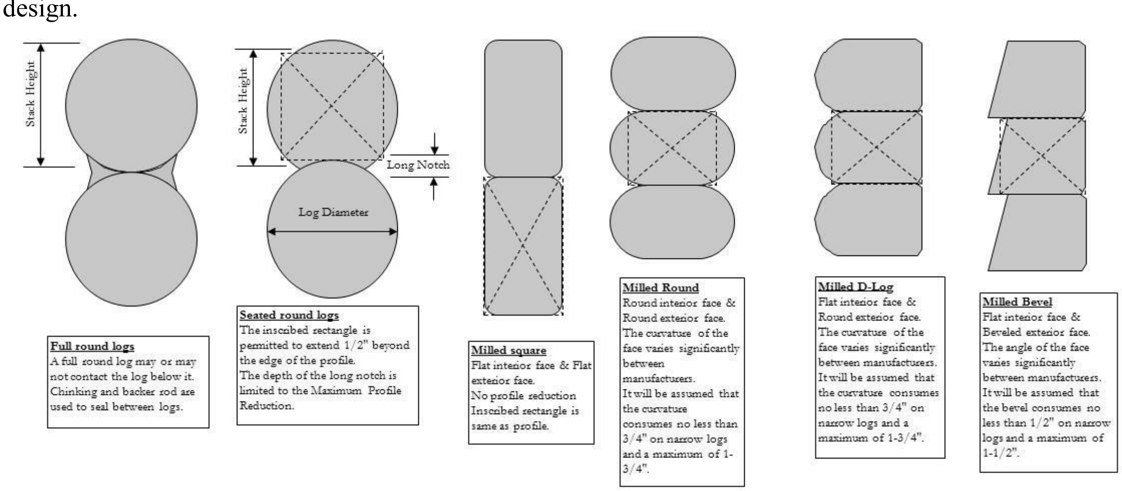

Fig. 4.2.3.1 Interior Log-on-Log Courses

4.1.1.2 Sealing Line

As a dynamic joint between two log surfaces, the sealing line should be properly designed to allow the sealant to contact both log surfaces with proper tolerance for compression and recovery when and if the joint becomes larger.

Typical of tongue and groove (T&G) joinery between logs, the sealing line is on top of the tongue and compressed within the groove. The tolerance in the joinery dimensions controls the extent of compression. Continuity for the full length of the log course is critical (e.g., across butt joints, careful overlap at ends of gasket tape segments, etc.).

The section on butt joints in 0 Vertical Seams talks about the seam and the ends of individual logs comprising a single course. There is a horizontal seam aspect to these joints as well. Sealants should be used to eliminate the potential for air and water to move through the log wall via the seam at a butt joint. From the sealing line protecting the length of the log course, the butt joint creates a seam that runs perpendicular to the outer edge on the top of the log. Knowing that the butt joint can be a source for air leakage, it is important that it be protected.

4.1.1.3 Fastening Notes

Fastener locations in the log wall assembly vary by system design. Some systems use bolts where the logs are pre-bored with holes larger than the fastener. Other systems use dowel-type fasteners that nail or screw one log to the previous, with counter-sunk heads so that the fastener heads will not hold up the next log during construction or later as the logs season. Relative to the sealing system, the choice and application of a fastening system must account for differential movement of the logs and required withdrawal capacity to maintain proper compression of sealants in the joint.

Regardless of the fastening system used, the sealing line must protect against the potential for air or water to reach and enter the fastener location. For dowel-type fasteners located to the outside of the sealing line, the well created by the counter-sunk head must be filled with or covered by a sealant product. Bolt holes should be aligned to the inside of the sealing line or otherwise sealed.

4.1.2 ICC400 Defines the Base Course

ICC400 defines two primary ways a log wall is started. While the industry may apply various names to it, ICC400 refers to the first course in terms of its relationship to the supporting element. When the base course of the log wall bears directly on the sill plate (preservative-treated sill anchored to the foundation stem wall), it is called a "Sill Log". When the base course bears directly on the subfloor assembly, ICC400 refers to it as the "Bottom Plate Log".

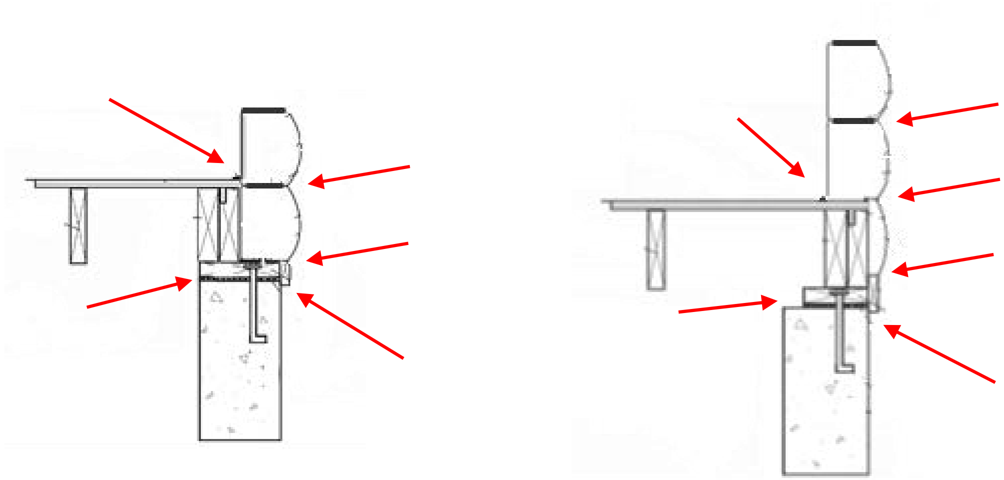

Fig. 4.2.1.1 Examples of sill log (left) and bottom plate log (right). The arrows point to potential sources of air and water leaks. Log suppliers and builders have various methods and materials they use to seal these locations. Ask them for their details/construction manual.

In both cases, there is a seam between the bottom of the base log and the supporting element that must be sealed against air and water intrusion. All protection required by the IRC against decay (Section R317) and termites (Section R318) apply.

The seal between the base course and the supporting element needs to be a compressible gasket that will fill voids between the two surfaces. Data sheets for this gasket should document resistance to entry of air, moisture and insects. DOE's Building America program recommends a continuous flashing across all horizontal seams under siding past the lowest edge, over sheathing, and extending past the sill plate. This flashing design also applies to wall construction above the log wall so that water is sure to drain to the outside face of the log wall.

4.1.3 Interior Log-on-Log Courses

Once the base log has been set, subsequent courses are installed according to the house design and log building system. The design and construction of the horizontal seal between logs employs the primary elements discussed in 4.1.1. The horizontal joint considers alignment of the logs and differential movement of the log below and above as well as the log being placed. A drip edge or other means of drainage from one log to the exterior face of the log below insures the drainage plane.

4.1.3.1 Handling of Ledges

In some log systems, the width of a lower log may be greater than the log above it, creating a potential for water to collect at the seam. Combined with wind pressure, this can become a problem for intrusion as capillary action is likely to move water into the joinery.

Where a ledge is created when the logs are stacked horizontally, a draw knife can be used to slope the ledge away from the joint, promoting drainage.

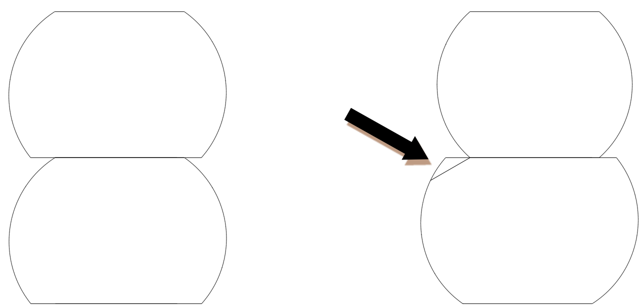

Fig. 4.1.3.1. Example of stacking logs to create overhangs or ledges. Slope ledges on outside to promote drainage.

When using a chinked log wall system with an insulated space between logs, apply backer rod and chinking to insure that the top of the lower log is protected by draining water past the log corner.

4.1.3.2 Filling Voids of Non-Contact Systems

Chink-style log wall systems include:

- Rectangular log styles in both milled and un-milled varieties. Dovetail systems often have larger chinking joint filled with rigid insulation and/or backer rod and then chinked.
- Round logs in both milled and un-milled style. Round logs have smaller gaps usually filled with a backing material and then chinked or caulked.

In both cases, care must be taken that chinking or caulking materials are applied at the correct thickness throughout the joints. In general, most materials are applied at a rate of depth equaling one half the width, but no more than one half of an inch. Sealant manufacturers should be consulted for details and guidelines.

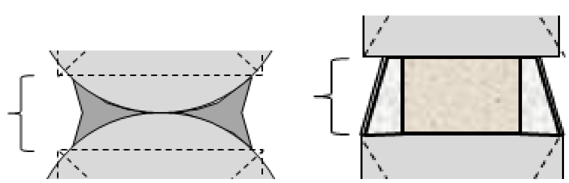

Fig. 4.1.3.2. Fully round logs may vary in relation to the log below from touching to separate like its rectangular counterpart. (Illustration courtesy of TimberLogic LLC).

An externally caulked or chinked system must be designed and installed to insure proper depth, width and adhesion of the caulking material. Caulking material should be placed as close as possible to the outside of the joint to seal out wind driven rain, insects and air. Drip edges can serve to ward off moisture which runs down log walls and can serve to hide a caulk groove if aesthetically desirable. Drip edges are not a substitute for proper sealing.

4.1.4 Header & Sill Courses at Openings

The sealing system at windows involves two horizontal conditions and a vertical condition. The combination of these seams is best discussed together in section 4.3 Wall Openings: Windows, Doors & Fireplaces.

4.1.5 Sealing Above the Log Wall

As noted in Section 2.3, areas above and below the wall are major areas of concern for two reasons. First, there is a need to provide redundant barriers as the seam is open to the inside unimpeded. Second, the EERE study showed that insulation alone in a cavity is not sufficient to restrict airflow.

One of the most notorious places for air leakage in log and timber structures is where the T&G decking/ceiling material passes over the wall. The pattern to the inside visible face of the deck/ceiling promotes a series of gaps that must be addressed by the sealing system.

Purlin systems run parallel to the ridge so that the purlins go over/through the endwall to support the overhangs. Rafter systems run perpendicular to the ridge and go over/through the sidewall. When the framing materials go through the wall, they are managed as notches as discussed in section 4.5 Notches. When they go over the wall, we are concerned with the continuity of the air barrier from the top of the log wall to the ceiling material.

Often with lumber rafters that bear directly on the log wall, a ceiling material is applied to the inside of the seat notch (aka., birdsmouth notch) and soffit material is installed on the exterior. In this case, the air seal is a line of sealant (gasket or caulk) at the outside joint of the soffit to the log wall, often incorporating a frieze board.

With beam and deck ceilings, there is a space between the framing timber and the roof deck, which doubles as the ceiling. The gap that is formed has traditionally been either filled with a segment of log or had a sandwich of insulation and trim boards installed. In either case, the trick is to fill the gap completely and seal all of the edges to eliminate infiltration. The difficulty can be seen clearly in the images in section 2.3 How to Find the Air Leaks. Knowing that the log/timber framing will likely change in dimension, the seal must accommodate that change.

Beam and deck ceilings provide distinct challenges. Typically, the decking is applied over the rafters with the V-groove pattern facing down. That pattern continues over the log wall (end walls with rafter systems; side walls with purlin systems) and requires the builder to apply a seal in each joint of the decking to fill the V-groove. Some builders use caulk in the groove before setting the next piece of decking in place over the log wall. Others use gasket that can compress tight but still fill the entire void of the V-groove. A kerf cut into the decking can allow flashing to be installed to block the void and be held in place by a ledger board.

PREVENTION OF AIR & WATER INFILTRATION – A SYSTEMS APPROACH

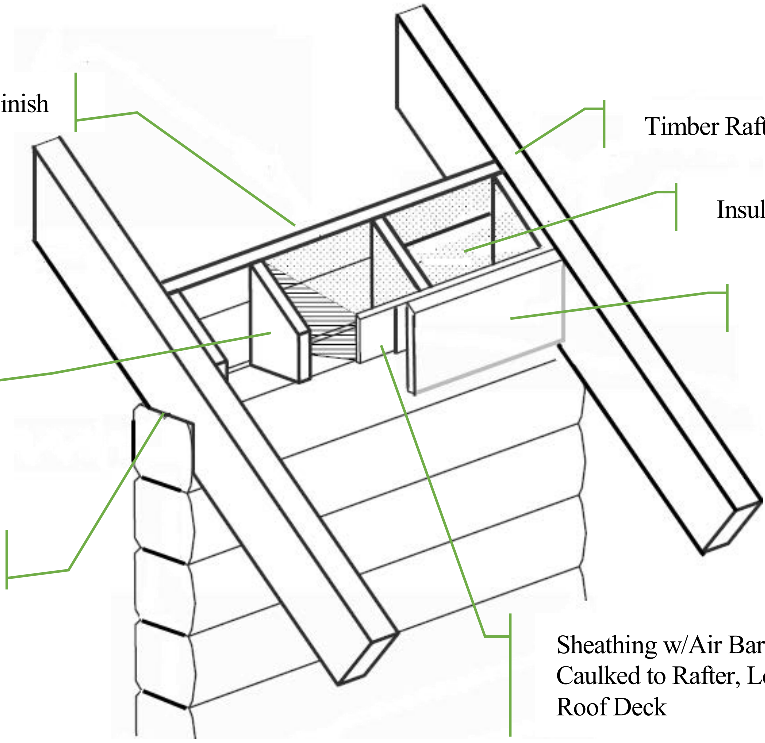

Figure 4.1.5.1 Rafters to Log Wall: An air seal is required at the bottom side of decking and between log/timber rafters when used.

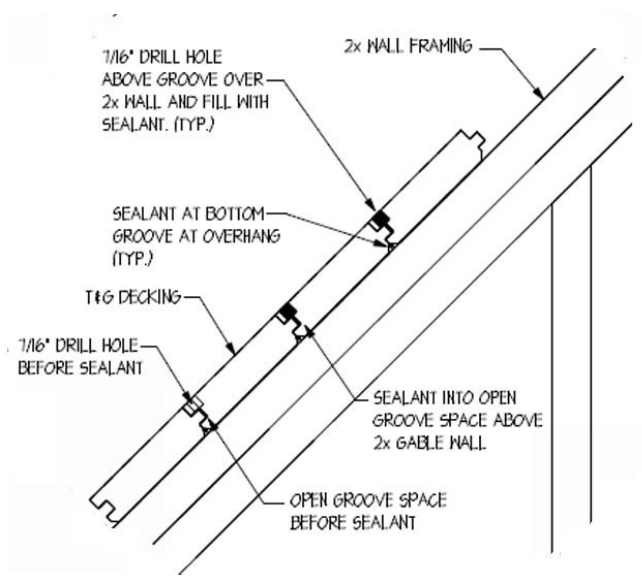

Figure 4.1.5.2 The seal between the gable end wall and T&G decking is critical. Some systems use a gasket while others use a drill and caulk method. The detail illustrates a framed gable, but the same technique is applicable to any wall construction where T&G decking passes over it.

4.2 Vertical Seams

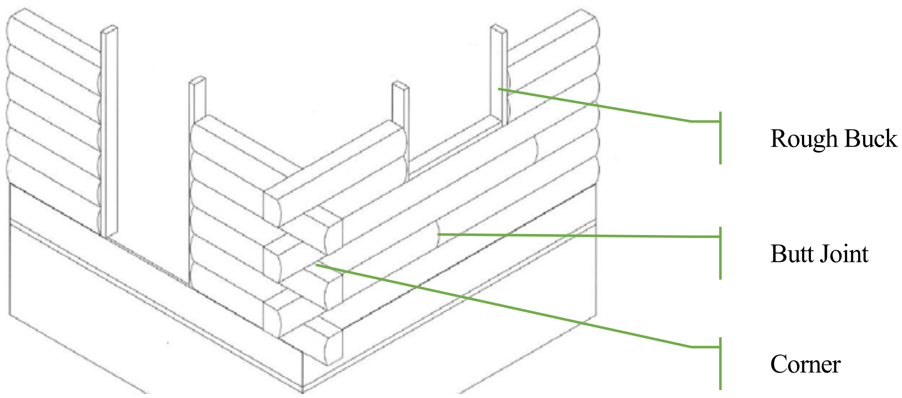

Figure 4.1.5.1 Vertical Seams

4.2.1 Butt Joints

Butt joints occur where multiple log lengths are needed in a particular course to span a length of wall (between corners, corner to door/window opening, etc.). Along each course of the log wall, each log building system provides for continuity of structure, thermal barrier and seal against air and water intrusion. The method applied to the connection of two ends of a contiguous logs involves the following considerations:

- *The dual role of protecting the joint both vertically and horizontally presents a challenge to the joint design. This is best accomplished by using a combination of gaskets, caulking, splines, and proper positioning of fasteners.*
- *Fastening at each end will tie the wall together to unify the assembly and resist rotation at the butt joint. The standard fastening schedule defines the distance from the end of each log for holding the log in place. Some systems employ fastening to tie log ends together (e.g., toenailing).*

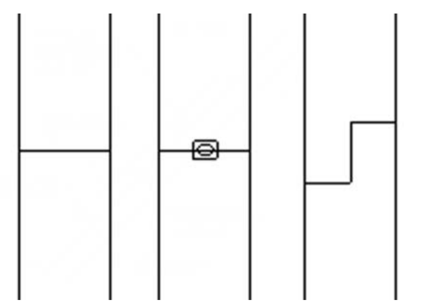

Figure 4.2.1.1 Examples of types of butt joints: Square trim, spline, and scarf.

Joinery design must accommodate both radial and longitudinal change in dimension. Radial change will affect sealing the butt joint in the vertical direction. Longitudinal shrinkage is considered to be nominal if any, but the butt joint can experience an opening stress if severe cross grain appears near the end of the log (e.g., localized slope of grain crossing the face of the log within a short length of the face). Dimensional change associated with seasoning in the area of steep slope of grain and large knots will be similar to that of radial shrinkage rates and can contribute to a larger gap at butt joints as logs acclimate. Log grading practices can be employed to help control this effect.

Techniques for alignment of the log ends vary from square cut ends to spline systems to scarf joints.

- Square trimmed log ends must include a shallow kerf or dado to provide a well for caulk or gasket. Without some relief, the caulk will be squeezed out of the joint and will be so flat as to be ineffective long term while a compressed gasket will hold the joint apart.

- Splined joints may have a dado notched into each end for the purposes of inserting a 2x2 wood spline. Kerf cuts could allow for plywood or PVC spline. Or a hole can be drilled on site so that a 1" oak dowel can be inserted. Typically, each of these approaches uses caulk in the spline area, the spline material is short enough to allow settling, and caulk is applied over the top of the spline to a depth even with the top of the log.
- Scarf joints are used for additional strength and assurance that air cannot simply pass through the joint. Often relief is incorporated in the joint to allow for caulk, gasket or even a spline.
- In each case, when butt joints are actually left apart ¼" it will allow a backer rod to be installed at the outside edge and caulk can be applied at the exterior over the backer rod. This is an example of redundant systems that can be superior in eliminating air and water infiltration.

4.2.2 Vertical Posts

Quite often, wall-logs will butt up to a vertical post. This is often found at an inside corner or at the edge of a large area of glazing. Perhaps it is a post that carries up to the roof beams. This connection must account for vertical movement of the log wall against a stationary vertical element. However, if the post is wood, the potential for dimensional change must also be accommodated.

To help restrain and align the ends of the logs at the post and to seal it at the same time, a spline system is often employed. The structural requirements are normally accounted for by the column of fasteners at the ends of the logs, so that the logs are resisting lateral loads at the joints. The spline material needs to be durable and strong enough to resist lateral loads applicable to the joint itself. Lumber and plywood splines protected by gasket seals to the outside have been effective solutions.

Load bearing posts offer the challenge of sealing around settling jacks. Held to the interior of the thermal envelope, the settling adjusting device can be trimmed in a variety of ways. In the exterior wall, the settling space needs to be insulated and sealed much like the settling gap over a window or door.

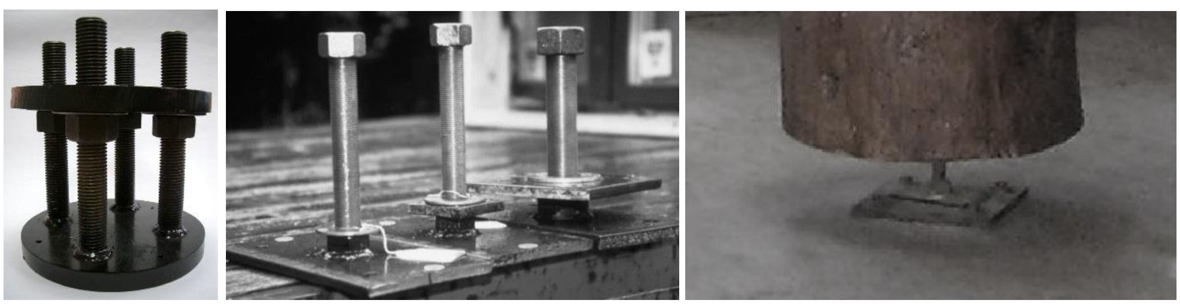

Fig. 4.3.2 Types of settling jacks.

4.2.3 Vertical Log Construction

It might be thought that vertical log construction would be easier from the standpoint of providing an effective seal. Actually, there is no difference in the need for a quality seal. In vertical log construction, the water will run down the full length of the joint. A drip edge does not exist, and the seal must account for dimensional change in the log profile.

4.3 Wall Openings: Windows, Doors & Fireplaces

Protection of wall openings is the same for all types of wall construction. The continuity of the drainage plane over and around the opening and the seal around the opening are equally critical. Both horizontal and vertical seams are to be sealed against air and water intrusion.

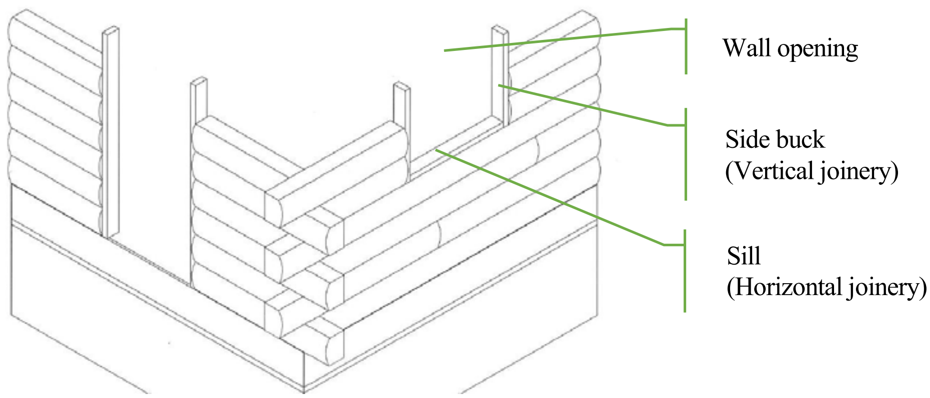

Figure 4.2.3.1 Wall openings

4.3.1 Manufactured Window and Door Units

Doors and windows and their sealing systems vary greatly, and *manufacturer's installation instructions must be followed*. The thermal performance of the window or door will be reported by the manufacturer, typically with ratings associated with the National Fenestration Rating Council (NFRC, www.nfrc.org).

4.3.2 Rough Frames or Bucks

The rough frame is also referred to as a window or door buck. It is built to the recommended rough stud opening specified by the window manufacturer. The rough stud opening allows for the window/door unit and a shim space on either side to square and hold the unit properly. The window buck provides the structure to which the window will be attached

4.3.3 The Horizontal Seams of an Opening

Above the window buck, the bottom of the header log protects the opening. The settlement space above window and door frames will only experience compression. Filling the original void should be done with a low-density foam or fiberglass insulation that will compress to a minimal thickness (e.g., ¼" to ½"). Most of the products of this type need to be wrapped in plastic or otherwise sealed to keep air and water from entering it.

> *The use of a flexible membrane flashing can be effective in covering this area by adhering the top of the membrane to the bottom of the header log (under the flashing/drip cap) and the bottom to the underside of the head of the buck frame. The sides also need to be sealed by adhering it to the log ends such that the exterior trim will protect and cover it.*

Traditional drip cap installation over windows and doors are essential to help move water cascading down the face of the log wall over the top of the header assembly (lower edge of log, settling gap, buck and window head). Window and door units, properly specified to wind ratings, will allow the cascading water to continue to the bottom of the unit where an integrated sill will act as another drip edge. Rigid flashing does a good job of moving water while flexible flashing underneath protects the settling gap against air and water intrusion. Both the rigid and flexible flashing should be continued beyond the extents of the window buck so that it also seals from the buck to the ends of the logs.

PREVENTION OF AIR & WATER INFILTRATION – A SYSTEMS APPROACH

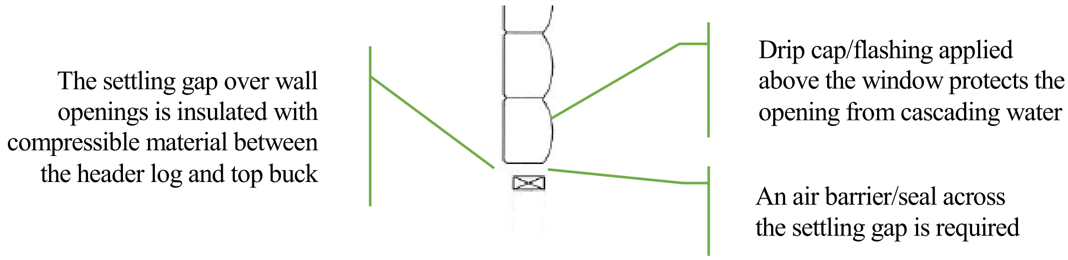

Fig. 4.4.3. Typical window buck shows settling gap between header log and buck.

The window unit will sit on the sill plate of the rough buck and be installed in the same manner as in any rough frame opening.

It should be noted that ICC400 Sections 406.4 Header logs and 406.5 Window sill log both require the respective log to extend beyond the edge of the window opening to provide connection to the wall assembly. This provides load path continuity around the window opening.

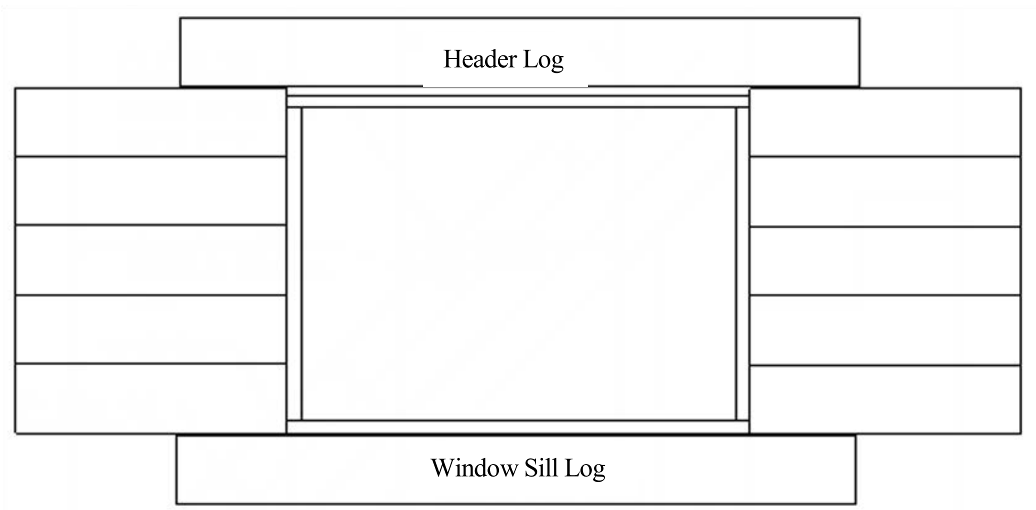

Fig. 4.3.3.3. Header logs and window sill logs need to extend past the wall opening. The header log requires sufficient length to accommodate bearing of the load on the log below. Both logs must extend to allow proper installation of fasteners.

4.3.4 The Vertical Seams of an Opening

A key element of protecting the window opening is taken from these standard details. Just as the sill pan is protecting the bottom of the opening, the flashing/sealing system needs to cover the shim space along the sides against air leakage in that shim space. Rigid flashing is excellent for controlling water and drainage. Flexible membrane flashings are excellent for controlling air flow. Exterior trim should be applied to protect both rigid and flexible flashing materials.

All flashing and sealing requirements provided by the window manufacturer applies to the installation of the window/door in the buck. This shim space is protected in exactly the same manner as with any other wall system and as specified by the respective manufacturer. The big difference is that it should carry beyond the buck so as to protect the seams between the buck and the log.

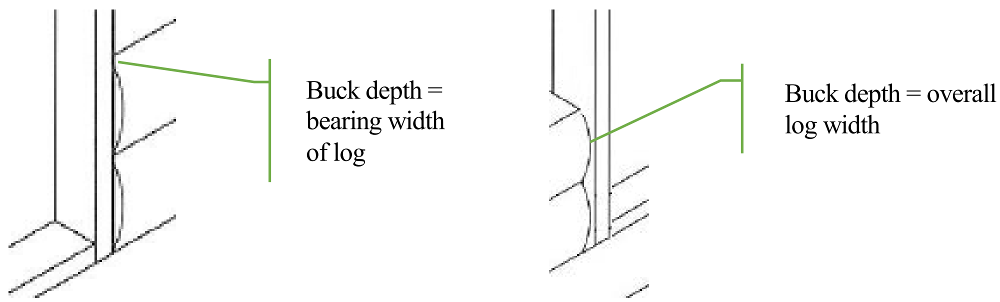

Figure 4.3.4.1 The depth of the rough buck relative to the log profile will affect the method of sealing and trim.

Joinery and mechanical connection of the buck to the log ends are often used to hold log ends in alignment. While this seam is often hidden by trim, a quality seal here will greatly improve the performance of the wall. When the gap between the log end and the buck is small, it is practical to defend this area with a gasket or backer rod. Insulating this area is not necessarily a requirement (defined as a gap/seam rather than a void), so long as it is carefully sealed to eliminate air passage into it.

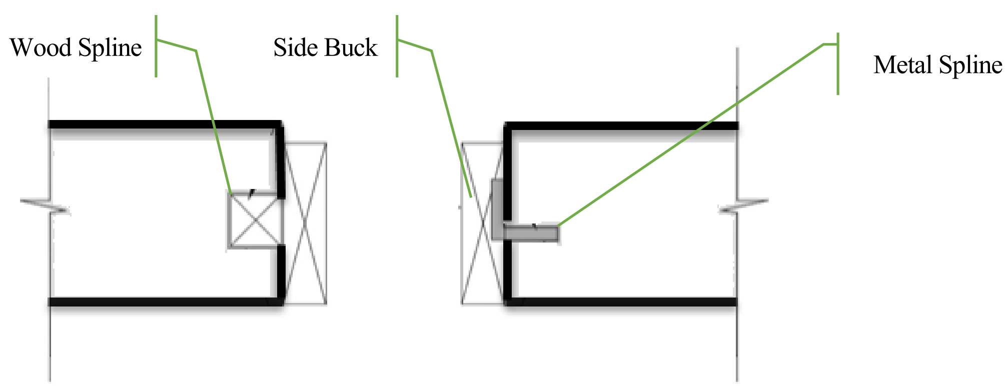

Figure 4.3.4.2 Options for connecting the log ends to the buck that offer alignment and vertical movement.

4.3.5 Fireplaces and Chimneys

Fireplaces provide a separate challenge, as they are rigid, do not settle with the log structure, and are attached to a structure, which will settle. They also often span the entire height of a structure from foundation to roof. Consequently, several methods of weatherproofing must be employed.

- ❑ Chimneys must be flashed and counter-flashed to roofs.
- ❑ By code, framing must be held away from masonry construction and metal flues. Most insulation products packed into the void do not provide a sufficient air barrier. For proper seal, insulation and moisture management, refer to sources of information in Section 6.

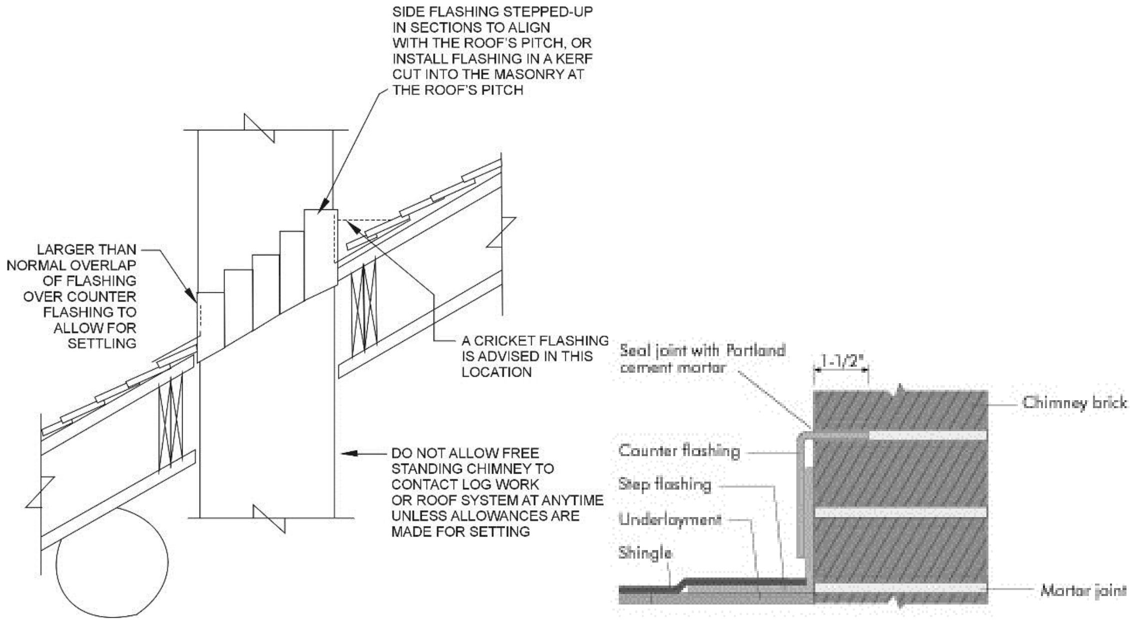

Fig. 4.3.3.4 Chimney flashing details (step-by-step) published by the APA Better Built Home program (2006).

Voids between masonry and log ends should be filled with backer rod and covered with caulk or chinking to prevent wicking of moisture into the logs. In situations such as these, it is important to understand and remember that the settling of a structure may warrant regular sealant maintenance.

The irregularities of log stress combined with climate, structure design, settling, and compression may very well exceed the physical limits of a sealant material. This is normal and in many cases likely.

4.4 Corner Joinery

There are many types of joints used to tie log walls together. Intersecting log walls at outside and inside corners must allow for differential settling, transfer design loads vertically and horizontally, and seal out air and water.

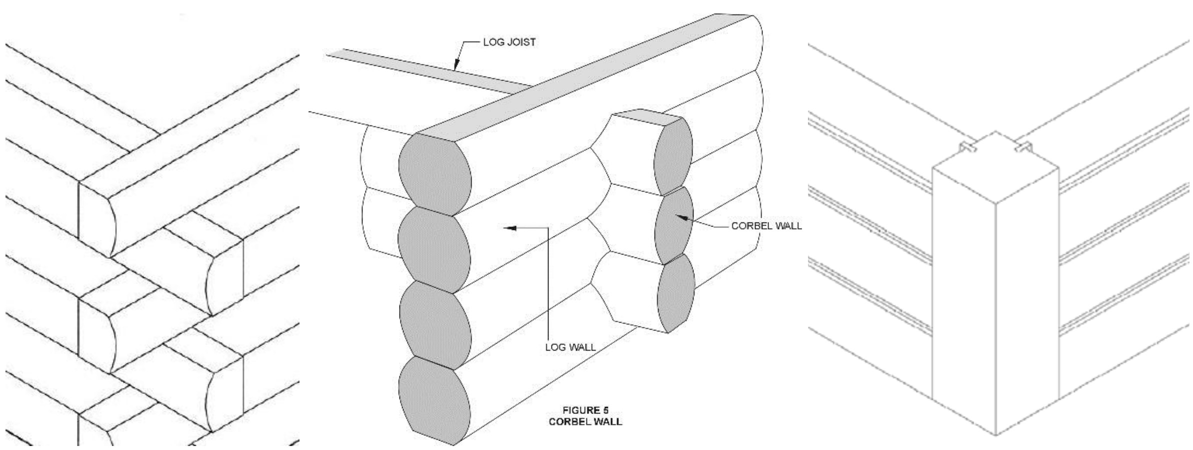

Fig. 4.5.1.1 Example of a Butt & Pass (left), an Interlocking (center, graphic by Randy Kaatz), and a Posted (right) corner.

4.4.1 Types of Corners

On a typical rectangular footprint, there will be four outside corners at right angles. If an extension is added to a side, it may add an exterior and an interior corner. In some systems, the logs may be milled to create a similar appearance, but often a posted corner is used at the inside corner so that interior partitions are easily attached.

Log corners can be categorized by the base course. When both intersecting log walls have a full height log as the first course, the most common corner style is called "butt and pass". Variations on sealing this corner are as many as those of butt joints, and the sealing considerations are similar. This corner technique covers one log end on every course.

The use of interlocking corners most often involves a half-log base course in one direction (often the end wall) and a full log base on the other. The style of interlocking corner may vary from log-on-log dovetail, coped, or v-notched to modified versions where spaces are designed between the logs. In each case, the continuity of the log wall provides the horizontal seal, and the notch requires specific gaskets and/or caulking to maintain a durable air/water tight joint.

The appeal of this type of the interlocking corner is the continuation of the solid log from the corner. The dovetail is distinct, but coped/v-notch corners can have plumb cuts for a square end of the wall or sweeping, decorative corbelled work. Sometimes, log builders will work to achieve an interlocking corner system with full logs in both directions to achieve this esthetic. The seal of this type of corner is considered when the joinery is designed and cut into the logs.

4.4.2 Water/Moisture Management

Experienced log builders know that it is important to promote drainage or drying at the corner. Many corner designs have round our angled surfaces that promote drainage. Interlocking corners use the same principles as the log wall to drain water down the face of the consecutive log courses. Stockade corners provide a gap that is easily dried by air flow around the corner.

This is the one area where the end grain of the log offers a weak point. Moisture gain and loss occurs more readily at the end of the log as the end grain can wick water into the piece. To a lesser extent, the same is true of knots on the exterior of the log wall. Therefore, it is recommended that careful treatment of knots and log ends be applied to promote long term durability of the piece.

4.5 Notches

Notches offer similar challenges to air tight construction as corners.

There are several types of notches used in log and timber construction. Notches are designed in a log wall to provide sufficient bearing and connection of a spanning member (beam, joist, rafter, etc.). When that is accomplished without interrupting the sealant line of the joinery, there is little need for more concern.

4.5.1 Joist/Beam Pockets

Pockets notched into the log wall such that the horizontal line of sealant is not disturbed. When the notch does not provide sufficient bearing under the end of the joist or beam, a structural post can be let into the interior of the log profile. The post can be fastened to the log wall through slotted holes to permit the fastener to move with the wall. Solid blocking in the floor under the post is recommended.

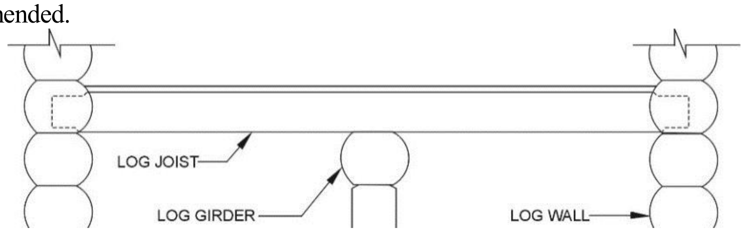

Fig. 4.5.1. Example of joist pockets in a log wall. Note that the pocket depth is limited to the inside edge of the horizontal seal. (Graphic: Randy Kaatz for the ICC IS-LOG committee)

4.5.2 Hangers

Architectural steel hangers (typically 3/16" or 1/4" thick welded connectors with predrilled bolt holes) are used to support the end of the joist or beam that is connecting to a log wall. These hangers are designed to provide proper bearing length, and the capacity of the hanger is established base on the size and number of fasteners. Typically, through bolts hold the bearing end in the hanger. Variation in load capacity will come from the fastener used to connect the hanger to the log wall (dowel type fasteners such as lag screws will have a lower design value to a bolt that extends through the log).

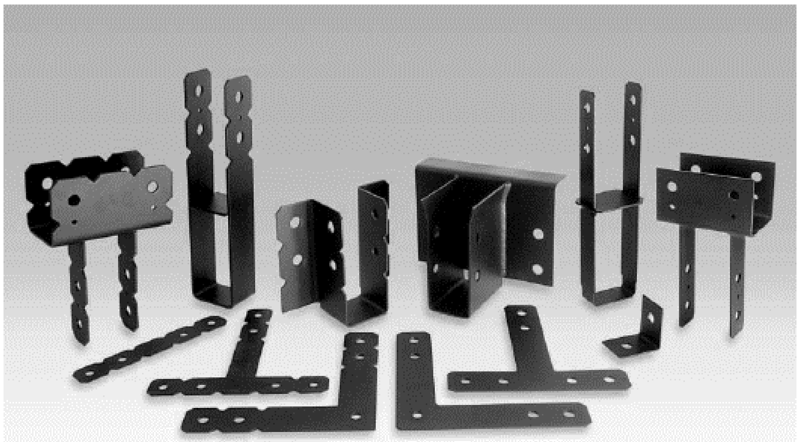

Fig. 4.6.1.2. Examples of architectural steel connectors available from Simpson Strong-Tie (www.strongtie.com/apg). Custom steel fabricators also produce similar products per engineered assembly details.

4.5.3 Pass-Thru Notches

When the log building style/esthetic allows the extension of structural logs/timbers to the exterior, a different dynamic exists. The joint must be designed for the proper fit at time of construction, allow for change as construction loads are applied, and then allow for shrinkage as the wood acclimates to the environment.

Unlike the previous types of connections of joists, beams, or similar structural members to the log wall, those that pass through or over the wall and extend to the outside must account for several dynamics.

- *Notches that reduce the cross-sectional area of the structural member over the bearing point should be checked to insure that sufficient area exists to carry the design load to the log wall. This topic is covered in ICC400 Section 302.2.4.4.*
- *As logs and timbers acclimate, the structural members will experience dimensional change as will the wall-logs adjacent to them. Some builders will apply a gasket around the structural member that will account for this differential movement. Others may use a spline technique or a modification of a mortise and tenon approach. Again, reduction of the cross-sectional area of the structural member must be evaluated.*
- *Protection of the exposed end of the structural member is critical. Concealed under a roof overhang or where a small extension from the log surface occurs, a piece of flashing that extends over the top to provide a drip edge will be effective. The exterior seam of the log wall over the extended structural member requires sealing/flashing to insure that water drains past the member and intrusion is not possible.*

4.5.4 Intersecting Log Walls

When a log interior wall intersects the exterior log wall, the connection/joinery is similar to a notch rather than a corner. For one, the weathering elements are immediate to a single face of the exterior wall. Sometimes the interior log wall is designed to fit into a pocket type notch in the interior of the log wall and not pass through it, but many interlocking corner systems also employ interlocking joinery (pass-thru) for intersecting walls.

ICC400 recognizes that intersecting log walls are unique as noted in Section 302.2.4.2. It provides an Exception to 302.2.4.7 Spacing of notches and holes – "Wall logs, or sections of wall logs, when they are fully supported along their length."

4.6 Penetrations

While every effort is made to eliminate penetrations clear through any exterior wall, there are times when it is the only choice. When necessary, refer to the construction manual of the log package supplier first.

Penetrations in lower courses can be sealed as a non-working joint because the compression load from the structure above will hold lower logs tight. Upper courses will need to consider dimensional change when applying the sealing system. A protective hood that will drain water away from the opening is important as is an appropriate backdraft damper.

A counter-flashing double sleeve method can be used to seal the opening from the outside while allowing the vent or pipe to pass through. Backer rod and caulk is a good way to seal the perimeter of the opening.

5 COMPATIBILITY & DURABILITY OF PRODUCTS

5.1 Compatibility with Wood Treatments

There are many treatments used on logs from the time they are felled as trees to when they are actually incorporated into a structure as finished logs which are then stained, caulked, chinked, gasketed and sealed. These treatments vary from dipping or pressure treating logs in preservatives and/or biocides/fungicides prior to shipment to simple washing with bleaches or percarbonates after installation. Throughout these processes, each additional step or treatment must be compatible with the steps preceding.

Treatments and cleaners must be compatible with stains and preservatives, which in turn must be compatible with caulking and chinking.

- ***Bleach, commonly used to kill and remove mold, mildew and dirt accumulated during the construction process, can adversely affect some stain coatings.***
- *Some stain coatings contain wax or paraffinal oils that interfere with the adhesion of caulk and chinking.*
- *Conversely, some caulking products that contain silicone can interfere with the adhesion of future products that may be applied.*
- *Oxalic acid is contained in many commercial wood cleaners and performs very well, but if not properly removed from cleaned logs can have adverse effects on some of the newer stain coatings on the market today.*

If there is any doubt as to compatibility, the user should test the intended sealant with a sample of the treated material. If this is not convenient, consult with the log home manufacturer or the manufacturer of the product in question.

5.1.1 Moisture Content of Wood

The moisture content of wood is important to coatings and sealants for a number of reasons

5.1.1.1 Effects of Drying

The differential shrinkage that occurs as the wood acclimates to its built environment must be controlled by the design of the joint and sealant system.

The laws of physics dictate that as moisture leaves a log, that log will shrink. Higher moisture content during assembly of the structure translates into greater shrinkage of the log/timber. In the log wall or notches around framing timbers, such shrinkage can exceed the limitations of sealants. This is not to say that log homes cannot be built from 'green' wood, only that allowances must be made for more movement in the design of the sealant systems employed to seal the structure.

Proper joint design is critical. The design must account for tolerances when the wood is milled or crafted to its intended form, and it must account for the worst case scenario of shrinkage across two adjacent logs.

Again related to shrinkage, the log may experience checking. Checking is a natural occurrence of stress relief when the logs acclimate. While the check is not a threat for air infiltration, there is a concern regarding water entering and retained in the check. Treat all checks that open on the exterior faces to insure that the drainage plane is restored. For more information about proper treatment of checks, refer to the Log & Timber Homes Council's paper *Preservation & Maintenance of Log Structures*.

5.1.1.2 Bonding of Finishes and Sealants

Moisture content can also affect adhesion of sealants and protective finishes to the wood. It is generally desirable to install sealants to wood surfaces with the lowest possible moisture content. Most importantly, follow the instructions provided by the sealant/finish manufacturer as to application – temperature, condition of the wood surface, thickness of application, etc.

Products that are designed to perform without affect from moisture at the time of application should be used on surfaces with high moisture content. Be certain not to use a "sealer" or other protective finish that does not "breathe" – the protective finish must allow moisture to exit the wood and not be held under the coating.

In general, it is desirable to apply sealants to logs with the lowest moisture content possible.

5.2 Maintenance of Sealants and Gaskets

Chinking or caulking installed on the exterior of a structure that has performed well through the initial acclimating of the logs to the in-situ condition can be expected to last the life of the structure with only periodic washings to remove surface dirt. Annual inspections are advised for all exterior log wall surfaces.

5.2.1 Building Design and Construction

Perspective homeowners, with the aid of their log home manufacturer, begin the long-term maintenance of their log structure during the design phase. Log structures (and indeed all wood sided structures) should incorporate all means possible to minimize the effect of the elements on exposed wood. Large roof overhangs, proper guttering, drip edging on roof rakes, strategic placement of covered porches, placement and orientation of the structure on the building lot, elevation, and architectural features all contribute to the degree of maintenance the structure will require in the future.

As in all construction, the techniques and quality of construction are paramount. The construction manual of the log home manufacturer incorporates tried and proven methods for the construction of their log structures. These manuals cover techniques and methods for care of materials delivered to jobsites, building practices and methods, and rates of application and techniques for coatings, sealants, and preservatives.

5.2.2 Recommended Maintenance Practices

For more information on the maintenance of a log building, the discussion in the Log & Timber Homes Council white paper *Preservation & Maintenance of Log Buildings* is recommended.

6 FINAL NOTES

It is important to reiterate the key points of this document:

- *Blower door tests demonstrate that log homes can meet today's requirements for air-tightness. Infiltration rates of less than 0.6 air changes per hour and less are not uncommon. More and more, log home builders are complying with the latest Energy Star programs.*
- *Many of the sources of air infiltration are common to all buildings, regardless of methods and materials of construction. The builder needs to use appropriate testing to identify and remedy those leaks.*
- *When installing windows and doors or applying sealants and finishes, it is critical that the manufacturer's instructions be followed. Contact the supplier when questions arise.*
- *As a member of the Log & Timber Homes Council, each company must have a construction manual that describes how their respective and proprietary system is to be assembled.*
- *When roof systems with heavy timber and exposed tongue and groove (T&G) systems penetrate or pass above an exterior wall, they are notorious for air leakage that require appropriate sealing techniques.*

Like frame construction, log walls must put up a defense on the exposed outside surfaces first. But, unlike framed walls, there is seldom a cavity to defend. Despite the several hundred feet of seams, log buildings, like quality wood windows and doors, rely on the performance of the sealing system. Each log home manufacturer has established its own approach based on a philosophy that has evolved with experience.

The superior performance of log homes is due to the care and engineering that goes into the design, manufacturing, and construction. The horizontal and vertical seams in the log wall utilize concealed joinery as opposed to taped/caulked joints in sheathing products. Log & Timber Homes Council member companies are required to design their systems in accordance with ICC400 and provide assembly instructions to the builder/home owner regarding proper installation.

As with all high-performance homes, the next step is to install an appropriate ventilation system. Some locations may require a balanced ventilation system, which is recommended because the draw of outside air comes from a single, controlled point. Other jurisdictions may allow exhaust-only ventilation. This system will draw air from the home and create a negative pressure, potentially pulling air from undesirable places. Consult with a HVAC contractor to decide on the best ventilation system.

Supported by extremely qualified and knowledgeable suppliers, the modern log home is sealed with one or more of many excellent products and methods. The combination of products and expertise are used to assure our customers that their homes will be the best possible.

For more information, refer to

6.1 Sources of Information

6.1.1 Forest Products Laboratory

- The Ins and Outs of Caulking, Forest Products Laboratory, Advanced Housing Research Center, Madison, WI
- Wood Handbook: Wood as an Engineering Material (FPL–GTR–113), Forest Products Laboratory, Madison, WI

6.1.2 DOE's Energy Efficiency & Renewable Energy (EERE)

- EERE Air Leakage Guide, U.S. Dept. of Energy Building Energy Codes Program, PNNL-SA-82900, Sept. 2011
- Air Sealing, A Guide for Contractors to Share with Homeowners, Pacific Northwest National Laboratory & Oak Ridge National Laboratory, PNNL-19284, Apr. 2010.
- http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf

6.1.3 Industry Guides

- Consumer Guide to Home Energy Savings, American Council for an Energy-Efficient Economy, Washington, D.C. and Berkeley, CA; in cooperation with Home Energy magazine, Berkeley, CA.
- Construction Sealants and Adhesives, Panek, Julian R. and Cook, John Philip, John Wiley & Sons, NY, NY

6.1.4 Web Sites

Air Barrier Association of America (ABAA)	http://www.airbarrier.org
American Forest and Paper Association	http://www.afandpa.org/
American Plywood Association	http://www.apawood.org/
American Wood Council	http://www.awc.org/
Building Science Corporation	http://www.buildingscience.com/default.htm
Forest Products Laboratory, USDA	http://www.fpl.fs.fed.us/
Advanced Housing Research Center, FPL	http://www.fpl.fs.fed.us/research/centers/ahrc/index.shtml
The Forest Products Society	http://www.forestprod.org/
International Code Council (ICC)	http://www.iccsafe.org/
ENERGY STAR®, US Environmental Protection Agency (EPA)	http://www.energystar.gov
U.S. Department of Energy (DOE)	http://www.energy.gov
Building America Solution Center	http://energy.gov/eere/buildings/building-america-solution-center http://energy.gov/eere/buildings/building-america-climate-specific-guidance
DOE's Energy Efficiency and Renewable Energy Clearinghouse (EREC) and Network (EREN)	http://energy.gov/eere/efficiency/homes
Zero Energy Ready Home	http://energy.gov/eere/buildings/zero-energy-ready-home

7 APPENDIX

7.1 Pros & Cons of the Typical Sealant Types Available

Acrylic Latex Sealants

Note: The following are generalizations and not universally true of all acrylic latex sealants. Some "acrylics" are based on low-quality acrylic polymers or are heavily blended with non-acrylic polymers -- which reduce the overall performance. Note: An acrylic latex product that is "siliconized" may or may not actually perform better than one not making such a claim -- sometimes such claims are merely marketing hype. Note: Virtually all chinking products are made from acrylic latex.

Pros	Cons
Water cleanup	Sensitive to water until cured -- can wash out before curing completed
Low odor	It it's cold, should be tented and initially kept warm (at least for short time)
Low toxicity	Can take several days (or even weeks) to fully cure, depending on bead size and weather (especially if cool/cold and humid)
Extremely easy to apply, tool and work with (overall, the best to work with)	Cures worst in cold/cool, wet/humid weather
Non-flammable	Lower-performing brands often cannot handle as much movement as most solvent-based or reactive types of sealants
Very good or excellent adhesion to wood and most common surfaces	Can freeze solid, and (if the particular product is freeze-thaw stable, which some brands are not) must be completely thawed out before being used.
Excellent resistance to weathering -- resists UV light and oxidation very well	Some types not freeze-thaw stable & can't be package-frozen before use
Almost always meets the environmental regulations in all areas -- nationwide	Some shrinkage, but not severe
Easily paintable/stainable with latex and oil-based coatings	
Excellent flexibility and elasticity	
Modest in cost, compared to other polymer systems	
Can be applied to damp surfaces -- but not if surfaces are actively wet	
Cures best in warm, dry weather	
Fresh material typically adheres well to old, dried material of the same kind -- making repair easy and relatively inexpensive	

Polyurethane Sealants	
Pros	**Cons**
Usable in most weather conditions -- usable when cool* and wet (but must be applied to dry surfaces) -- not rain damageable	Often contains low levels of isocyanates -- with toxicity and sensitizing effects -- which for some people can be severe
Excellent adhesion to wood and most surfaces	Typically a very bad odor -- best to be used only on the exterior
Good to excellent flexibility and elasticity; elongation can be up to 4x the original size	Often sticky and difficult to tool and work with
Accepts virtually all latex or oil-based coatings well	Cleans up only with solvents
Fresh material typically adheres well to old, dried material of the same kind -- making repair easy and relatively inexpensive	1-part types can take several days (or even weeks) to cure -- depending on bead size and weather (especially when cold and low humidity or dry)
2-part versions can completely cure in a matter of a few hours -- in virtually all weather conditions	Can be very hard to apply in cold weather because the product is thick and pasty when cold (should be kept warm until just prior to being used)
Good to excellent resistance to weathering	Often contains solvents -- with potential toxicity and flammability hazards
Cures best in warm, humid weather	*1-part versions (the most common type) cure worst in cold, dry weather
Overall, can be a good choice for log homes, but the precautions of this listing should be carefully taken into account	Occasionally, the adhesion can be so high and the modulus also so high that substrate failure occurs, which is the worst type of failure to repair
All types freeze-thaw stable in the package [Note: The overall, package stability of 1-part urethanes is not good -- often curing in the tube]	Have little ability to "stress relax" when under tension -- never lessening the force applied to the sealant or the bond-line when flexed
Minimal shrinkage	1-part types packaged in non-plastic tubes are not very rugged

Silicone Sealants	
Pros	**Cons**
Most weather-resistant chemistry that is readily available (moisture, ozone, UV-radiation)	Typically, silicones have poor adhesion to wood (especially when wet)
Easily gunnable at virtually all temperatures -- even down to or below zero	Typically will not accept paint or stain (the "paintable" types often aren't very paintable/stainable & don't perform as well as the non-paintables)
Usable in most all kinds of weather -- with better curing properties than urethanes	The silicone oil plasticizers used in most sealants can migrate to adjoining surfaces and prevent those surfaces from being coatable
Relatively low in toxicity to work with -- much better than polyurethanes	Sometimes new silicone will not adhere to old, cured silicone, making repair difficult. [Note: Electrostatic charge on surface causes dirt pickup]
All types are freeze-thaw stable in the package	Many silicones are sticky and stringy to tool and work with
Minimal shrinkage	Many silicones have a strong acid odor (smelling like strong vinegar)
Long life	Overall, not a good choice for the log home industry
Chemically inert; no volatile off-gasing at high temperatures	Most types are fragile -- tearing easily ("unzipping") if slightly cut and stressed
	Little ability to "stress relax" -- never lessening the stress on the bond line/sealant
	Surface static electricity leads to much dust/dirt pickup over time.

Synthetic Rubber, Solvent-Based Sealants	
Pros	**Cons**
All weather application -- but should be kept warm until just prior to use for easiest gunning	Contains solvents that are hazardous and flammable -- however, usually a lower health risk than being exposed to isocyanates
Many are crystal clear -- the clearest sealants readily available	Sticky and difficult to tool
Excellent adhesion to wood and virtually all surfaces	Should be applied to dry surfaces
Very good weatherability	Bad odor -- best for the exterior (but odor typically dissipates quickly)
Readily accepts latex paints/stains right away and oil-based coatings within a week and, unlike silicones, does not cause adhesion problems of coatings on adjoining surfaces (because there is no plasticizer "bleed")	Cleans up only with solvents
Fresh material typically adheres well to old, dried material of the same kind -- making repair easy and relatively inexpensive	Significant shrinkage -- due to solvent evaporation
Readily cures in all types of weather -- no real limitations	
Good to excellent flexibility and elasticity	
Overall, a good choice for the log home industry when weather conditions require the use of an all-weather sealant	
Many or most brands have the ability to "stress relax" under tension	
All types are freeze-thaw stable in the package	

Butyl Sealants	
Pros	**Cons**
Excellent adhesion to wood and all other substrates	Little or no elastic properties -- stretches like chewing gum, but has no elastic recovery (readily fails when used in expansion/contraction joints)
Once dried, accepts latex and oil-based stains and paints	Usable only where there is little or no movement of the joint
Very good to excellent weatherability	Extremely sticky and messy to apply and tool -- with "cob-webbing" a major problem (perhaps the messiest sealant there is to work with)
The most water repellent sealant known	Solvent cleanup
All weather application -- but guns easier if kept warm until just prior to use	Solvent odor
The best use is in "shear" joints -- like between sheet metal used in HVAC, gutters, roof flashing, etc. (in such uses, butyl is the best)	Overall, not appropriate for most applications on log homes
All types are freeze-thaw stable in the package	

Oil-Based Sealants	
Pros	**Cons**
Excellent adhesion to wood and most all other substrates	Most versions ultimately cure hard as a rock, others stay "chewy" for a long period of time but have little or no elastic properties (unable to handle any significant expansion/contraction)
Immediately resistant to rain	Solvent cleanup required
All weather use -- but guns easier if kept warm until just prior to use	Some can contain enough solvent to be considered combustible
Moderate to good weatherability	Sticky to tool -- but not as bad as some other types of sealants
All types are freeze-thaw stable in the package	Overall, not a good choice for log homes, due to poor elasticity
Once dried, accepts latex and oil-based stains and paints	Can take several days or even weeks to cure (depending on bead size & weather)
Cheap -- generally, the cheapest available	

Polysulfide Sealants	
Polysulfide sealants are primarily used for commercial glazing, curtain walls, and solar collectors.	
Pros	**Cons**
All weather use -- but guns easier if kept warm until just prior to use	Not available through most channels of distribution, an industrial product
The best chemical resistance of all major types of sealants	Odor not very good (sulfur smell)-- should be used only on the exterior
Excellent adhesion to wood and most substrates -- including itself	Some contain solvents -- hazardous and combustible
2-part versions can completely cure in a few hours	Can be sticky and difficult to tool and work with
Immediately resistant to rain	1-part versions can take days or weeks to cure (in cold, dry weather)
Very good to excellent weatherability	Can be a bit more expensive than urethanes -- comparable to silicones
All types are freeze-thaw stable in the package	
Once dried, accepts latex and oil-based stains and paints	
Excellent elasticity and flexibility	
Overall, can perform well on log homes	
Minimal Shrinkage	

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[i] Energy Savers – Tips on Saving Energy & Money at Home, a DOE publication at http://www.eren.doe.gov/consumerinfo/energy_savers/insulation.html

[ii] Just How Airtight Are Your Homes? If You Aren't Sealing Key Areas, You Aren't Giving Your Customers an Energy-Efficient Home, Owens Corning and Green Builder magazine (Air Sealing Best Practices).

[iii] The Ins and Outs of Caulking, FPL Advanced Housing Research Center

[iv] The Ins and Outs of Caulking, FPL Advanced Housing Research Center

[v] The Ins and Outs of Caulking, FPL Advanced Housing Research Center