Infrared Imaging and Log Construction Thermal Performance

Eric G. Amhaus & Edward L. Fronapfel
Professional Investigative Engineers

ABSTRACT

This paper will review and discuss the benefits of infrared thermography as its thermal imaging technology applies to the investigation and inspection of log home construction. Specifically, this paper will discuss the results and findings of infrared imaging used to evaluate thermal performance properties of log structures. In addition, this paper will discuss the utilization of infrared imaging for mapping air leakage or infiltration when used in conjunction with blower door / fan pressurization testing.

Under the International Residential Code (IRC), the International Energy Conservation Code and American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standards, air tightness is a specified requirement in the design and construction of homes. In order to post evaluate a structure to determine compliance with such standards, blower door testing (ASTM E779-99: Standard Test Method for Determining Air Leakage by Fan Pressurization) may be performed to provide physical data to determine the quality or tightness of a building envelope, air leakage pathways and natural ventilation rates. However blower door testing alone does not provide a visual representation of exactly where these leakage points are individually occurring.

By combining the use of infrared thermography with blower door testing, a visual illustration of the air leakage in a structure during the de-pressurization testing can be physically obtained. These visual illustrations can be extremely useful to designers, builders and owners to enhance either log home or standard building construction practices as they relate to air tightness, ventilation, energy conservation, and weatherproofing.

INTRODUCTION

While designers, builders and owners can test homes for air tightness, leakage and energy ratings, by what current means can they visually identify where flawed or weak points in the building envelope occur during the blower door / fan pressurization test? With blower door testing, the use of a smoke stick or pencil can be used to help the test operator determine the locations of leakage; however, the smoke only acts as an indicator and does not provide a visual illustration or mapping of the leakage point(s).

Blower door testing is an accepted and ASTM approved test procedure for such air leakage analysis. For the purpose of this paper, the emphasis will be placed on testing log home construction. However, the principles for the application of infrared camera imaging in conjunction with the blower door testing remain the same for nearly all types of construction.

While ventilation of a structure is necessary for acceptable indoor occupant air quality, the proper type and method of ventilation is a key factor to a successful project. Uncontrolled or excessive natural air exchanges via inadequacies in the building envelope is not a good or desirable means of ventilating a structure or home. Hence the reason for such energy efficient programs as the International Energy Conservation Code and industry standard organizations such as ASHRAE. If the natural air exchanges across the building are minimal, then a tight building envelope exists and required ventilation requirements can be achieved by a properly designed and controlled mechanical system.

This paper will not venture into analyzing the thermal mass characteristics of logs, but rather discuss the finer points of wood-to-wood joinery conditions that are unique to log home construction, and how those joinery conditions can impact the energy efficiency and other related aspects of a log structure.

BACKGROUND

Blower door or fan pressurization testing of a structure consists of negatively pressurizing (or de-pressurizing) a building, unit or structure to identify natural ventilation rates, air leakage paths or the tightness and energy efficiency of a property. The testing is accomplished with a specialized blower door assembly, and with today's technology, all documentation can be collected and stored throughout the test on a portable laptop computer.

Figure 1. Blower door testing equipment/assembly installed for depressurization in main door opening.
Figure 2. Smoke pen utilization for air infiltration identification during blower door testing.

With wood being one of the best natural insulators, it can be easily understood why log building construction could provide improved energy efficient performance when compared to 2x framed walls. That being said, there is also a downside to log construction that must be dealt with to ensure that this desired energy performance is achieved in cold climate regions. Even a modestly sized log home can have several thousand feet of wood-to-wood joinery that must be properly designed and installed to minimize air leakage and ensure proper energy efficient performance.

If adequate gaskets and seals are not properly utilized and installed between log joinery, then a reduction in the energy efficiency of the home will be experienced due to increased air leakage. Furthermore, this open joinery can allow water vapor and possibly even free water (i.e. rain or melting snow) to enter from the exterior resulting in further problematic conditions such as leaks, condensation development, draftiness, etc. The reason visual inspection of the joinery is difficult or impossible after construction is the fact that these gaskets and seals are not visible upon completed construction as they are to be concealed inside the joinery grooves and notches between the logs.

Figure 3. Open / un-sealed butt joint between logs.
Figure 4. Open / un-sealed corner and successive joinery between logs.

Chinking (i.e. cement based mortar, specialty sealants, stucco, mud mortar, etc.) is a different means of sealing joints between logs and requires frequent maintenance especially during the first few years of a structures life due to the anticipated and expected shrinkage of the logs. As opposed to gaskets and seals, chinking is readily visible upon inspection.

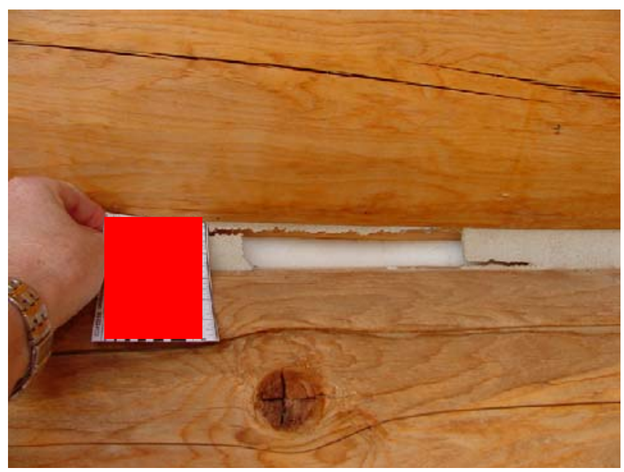

Figure 5. - Adhesively failed chinking at wood-to-wood log joinery.
Figure 6. – Failed and missing chinking with insulation between logs at horizontal wood-to-wood joinery.

Depending upon the specific type or method of log construction being undertaken, internally concealed seals or exposed chinking (and in some cases both) should be present and utilized. In either case, proper closure and sealing of the joinery is necessary to prevent both air/moisture infiltration and ex-filtration on log structures.

THE ROLE OF INFRARED

Infrared cameras can be used in conjunction with blower door testing to achieve a visual illustration of the air leakage locations and the relative degree of infiltration, whereas using a smoke stick an investigator is only able to determine if air is being drawn or moving at a location, infrared imaging gives the investigator the ability to visually document and express the air movement in the form of temperature differentials on the internal building materials.

The intensity of the thermal imaging depiction is obviously dependent on the temperature variance between the interior room/building temperature and the exterior ambient air temperature. The greater the temperature difference between the two (interior and exterior), the more vividly the infrared imagery will depict the relative amount of air infiltration and conversely ex-filtration that could occur.

Hence, the ideal time to accomplish such testing would be when you have the greatest differential between the interior and exterior temperatures.

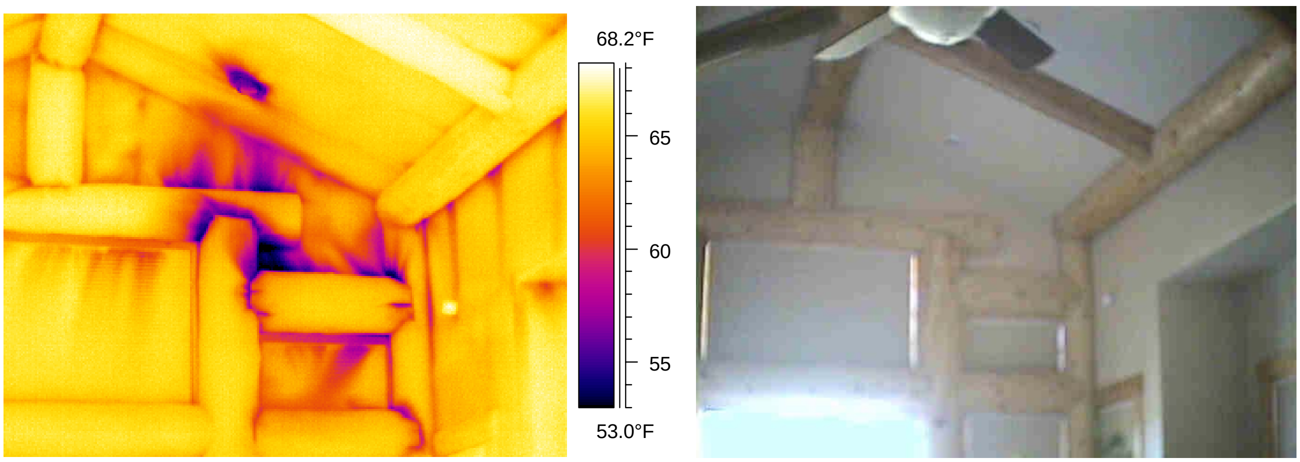

Figure 7 & 8. – Extensive air infiltration during depressurization at numerous wood-to-wood joinery locations where logs are exposed on interior of wall. Reference scale for temperature differential of 15.2°F between 68.2°F and 53.0°F.

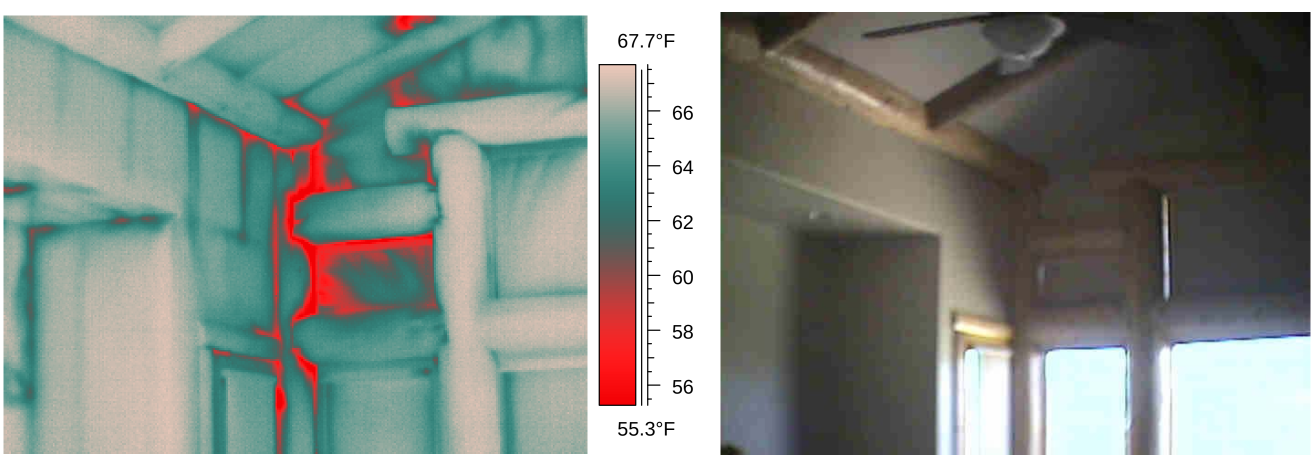

Figure 9 & 10. - Extensive air infiltration at wood-to-wood joinery in log assembly.

Once trained in the use and application of blower door testing or when teamed up with an engineer or specialist conducting blower door testing, an infrared thermographer can utilize an infrared camera to enhance the findings of such testing.

Immediately prior to initiating the blower door testing, a baseline infrared survey should be taken and images saved to provide a before test and during test comparison. It is recommended that all baseline infrared and digital images be saved and notated on an interior floor plan so any reference to location can be made at a later date/time if necessary. Baseline surveys should include a scan of the entire building

interior with infrared images taken at anticipated areas of air infiltration such as: exposed logs, wood-to-wood joinery, vertical log poles, field of walls, windows, doors, and wall penetrations.

Upon completion of the baseline infrared survey, interior and exterior ambient air temperatures should be taken and recorded so as to have a baseline temperature for both interior and exterior conditions.

Thermal imaging should commence immediately after the blower door fan starts and should be continued until the completion of all tests. Images should be taken frequently during the test, as after the blower door test ceases, temperatures of the internal building materials will quickly return to their normal/steady state.

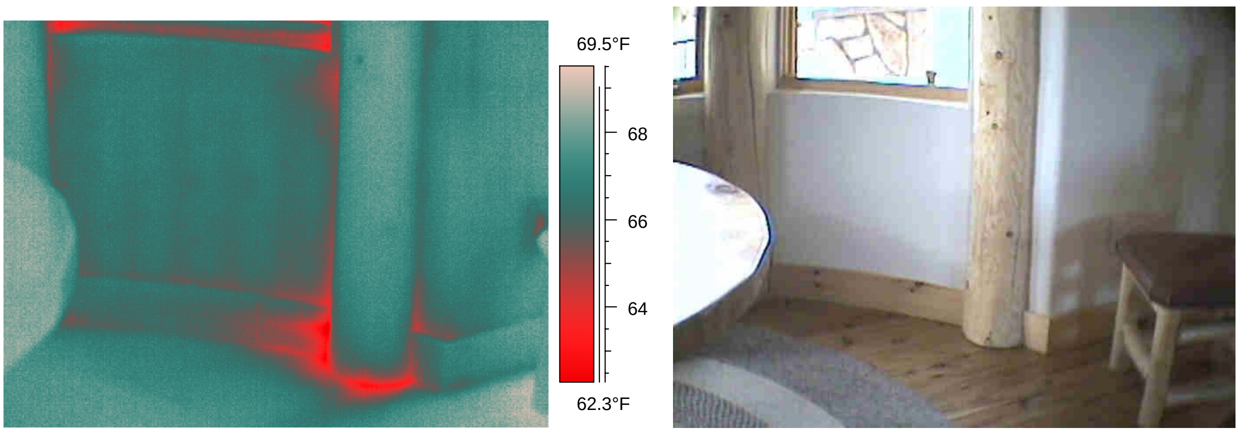

Figure 11 & 12. – Thermal imaging around log pole that illustrates air infiltration at the base of the pole at interior floor line during the blower door test. Note that half of this poles circumference is exposed on the outside of the wall and the other half creates an exposed log aesthetic on the interior.

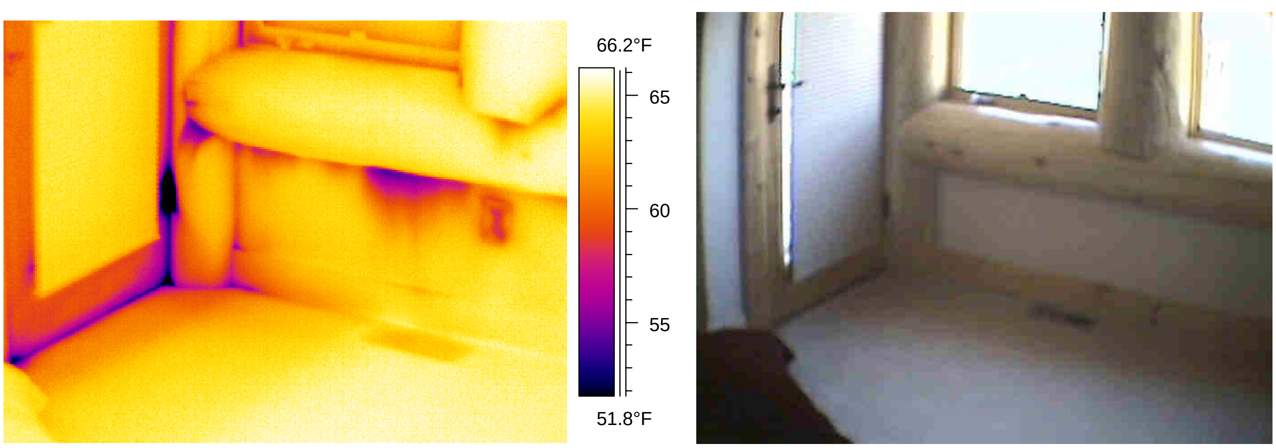

Figure 13 & 14. – Cooling patterns beneath log under window, at wood-to-wood joinery locations and along doorjamb. Cooling patterns illustrate air infiltration during blower door test. Note there is greater air infiltration under log than at electrical outlet in wall based on temperature differential.

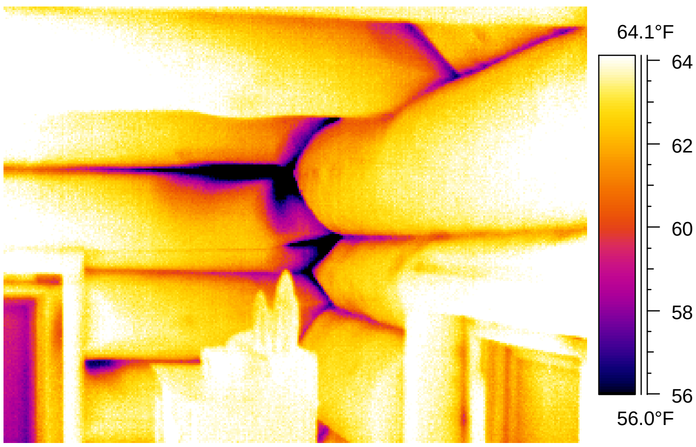

Figure 15 & 16. – Cooling patterns at corner joinery which extends at horizontal joints in log.

Many log homes not only incorporate an interior exposed log finish, but also have walls where the logs are not exposed on the interior, but a conventional drywall type finish is present. Infrared imaging of the walls should still be accomplished in these cases because air leakage could be occurring in the logs behind the drywall. While not the focus of this paper, in some cases a plastic vapor retarder may also be present behind the drywall. A vapor retarder should not be confused with an air barrier and a competent knowledge base of such systems is necessary to know when, where and how they should be installed and their function. Thermal imaging cameras should be able to detect air infiltration through a vapor retarder/air barrier; drywall or both if voids or openings exist that would allow such air movement to occur.

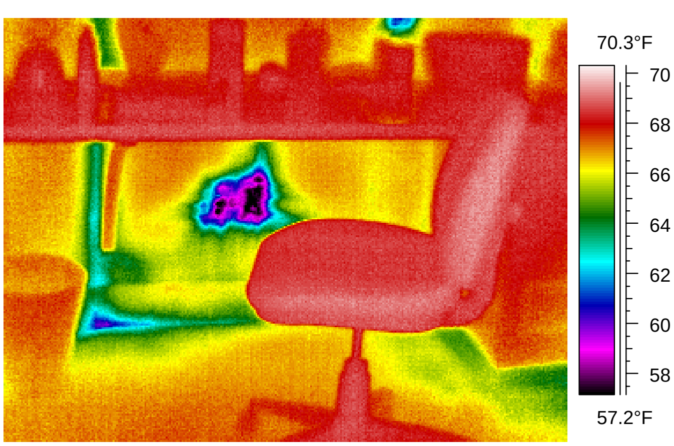

Figure 17 & 18. - Air infiltration at electrical outlet evidenced by significant cooling of outlet and surrounding materials during the blower door depressurization. Note that this indicates not only that a source for cold air in the logs behind this wall exists, but that the vapor retarder (if present) behind the drywall was not sealed at penetrations such as this outlet.

Another location where significant attention to detail is necessary to ensure proper sealing of the exterior log joinery is where internally exposed logs penetrate through exterior walls to the outside face of the facade. If not properly detailed for airtight closure, these locations very often serve as major air infiltration locations due to the nature in which the beam and surrounding exterior logs interface in such areas.

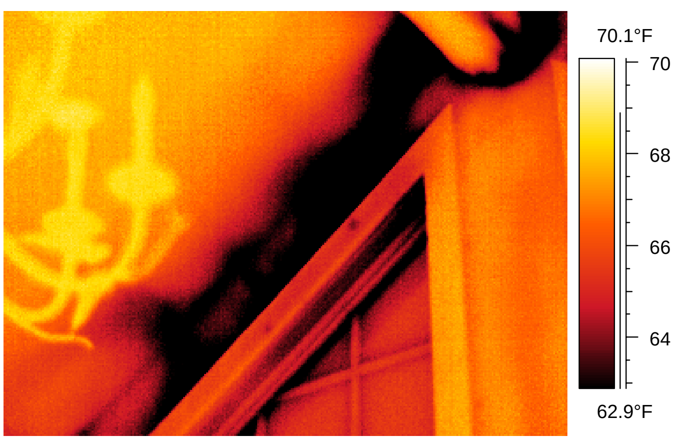

Figure 19 & 20. - Infrared cameras reveal substantial cooling during depressurization both around the ridge beam log and also at the sloped interface between the drywall and vaulted ceiling. Note that large openings existed between the log wall and roof soffit immediately opposite this image. These openings were permitting substantial air infiltration.

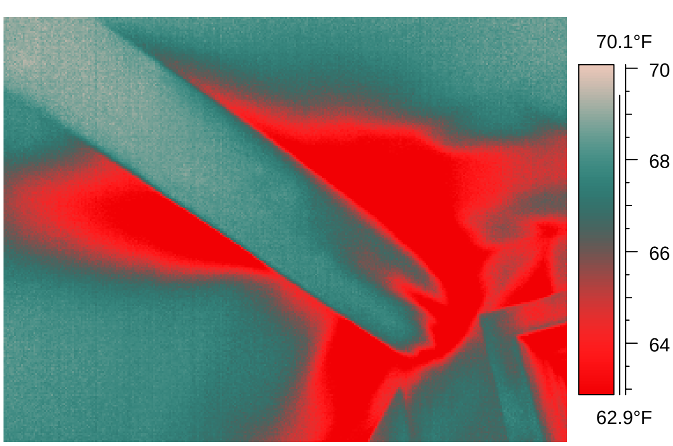

Figure 21 & 22. – Large cooling area clearly illustrates extent of air infiltration at top of beam where access is difficult and closure/sealing may have been altogether left out.

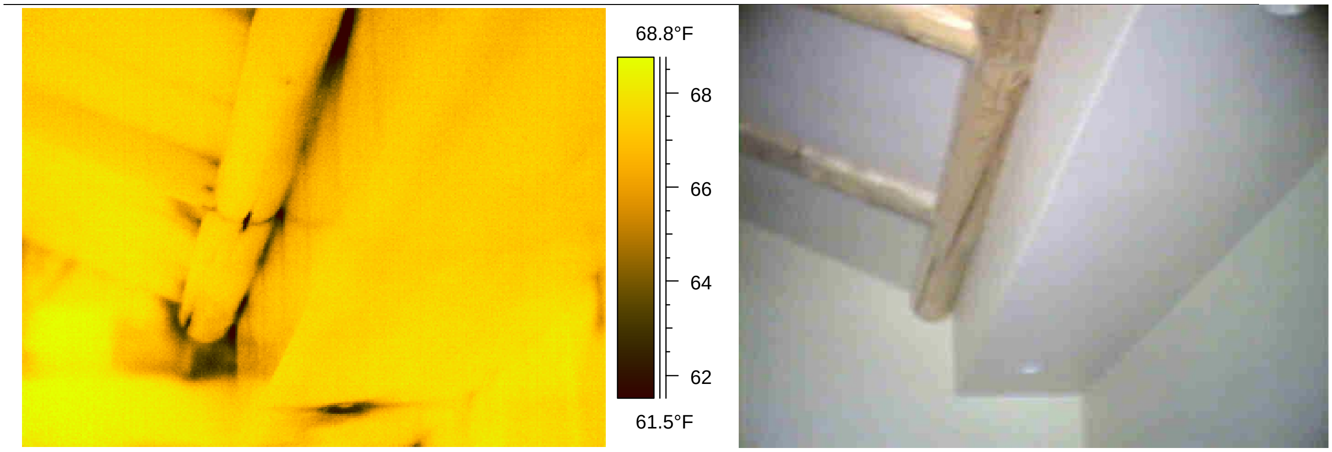

Figure 23 & 24. – Air infiltration observed as cooling at the end of log beam where it penetrates through the exterior wall, along the length of the beam at the interface with the drywall and at actual splits in the log itself.

In some testing cases, it is also necessary to mask windows, doors, attic accesses or other large type openings to remove them from the analysis and assess only the primary wall systems. ASTM has an individual test (ASTM E783-93: Standard Test Method for Field Measurement of Air Leakage Through Installed Windows and Doors) protocol for testing air infiltration through window and door assemblies.

SUMMARY

Thermal imaging cameras have proven to be extremely useful tools for achieving more accurate results when undergoing blower door / fan pressurization testing by offering a means to achieve a visual depiction of exact air leakage paths and relative degrees of infiltration/ex-filtration through a structures building envelope.

As it relates specifically to log home construction, thermal imaging may also be used to evaluate the different wood-to-wood joinery closure methods varying from insulation to foam tapes, backer rods, EPDM gaskets, chinking, etc. so as to determine the benefits and/or downsides to each of the different material types in the market place.

The visual data obtained from such infrared images can provide a designer, builder, owner or possibly even manufacturers of building closure materials with a plethora of valuable information to assess failure points in an existing structure for the development of a repair scope or to alter and improve building practices on future construction.

Therefore, not only is the application of infrared thermography useful in assessing log structures with blower door testing, but nearly any structure (wood framed, steel framed, masonry, etc.) where blower door testing is a feasible and an acceptable practice for a post mortem type analysis for air infiltration/ex-filtration through the exterior building envelope.

The commonplace and significant emphasis on building wraps, air barriers, vapor retarders and overall exterior skin closure in today’s construction market place yields a need for better and more precise analysis of such systems. Infrared imaging is a technology that is useful in this endeavor.

REFERENCES

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Robert W. Chambers; “Log Construction Manual – The Ultimate Guide to Building Handcrafted Log Homes”; pp 3-6; Copyright 2003

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