TVA/OP/ECR-82/98, 9-13-82, S52244.02 TVA/OP/ECR--82-98

DE83 900060

FIELD EXPERIENCES UNDERSCORE THE IMPORTANCE OF MOISTURE CONTROL IN ENERGY-EFFICIENT HOMES

by

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Abstract

Tennessee Valley Authority's (TVA) most successful energy conservation project to date is the Home Insulation Program (HIP) that was initiated in August 1977. TVA's HIP is this Nation's largest home weatherization effort; it provides free home energy audits and no-interest financing for weatherization measures. Homeowners, tenants, and landlords are eligible for participation through one of TVA's 160 power distributors. As of April 16, 1982, 589,737 living units had been surveyed and 288,820 of the living units had received interest-free loans for weatherization measures totaling approximately $277,000,000.

Early in 1980, the central office began receiving complaints from field offices that some weatherized homes were experiencing problems associated with either excessive or insufficient moisture. An investigation was initiated to evaluate and categorize those types of problems and recommend changes to procedures or field actions as required. To date, findings indicate that there are no intrinsic characteristics of the energy-efficient house that cause a moisture problem. Field surveys of houses with complaints have underscored the need for better control of moisture as the infiltration/exfiltration rates are reduced through weatherization. The solution to the problems encountered have generally been straight forward provided the moisture source can be readily identified. This paper will review the state-of-the-art for moisture control, provide relevant case studies, and recommend areas for further research and field study regarding the current construction practices and building codes in use.

Key Words

Residential, energy-conservation, insulation, moisture, condensation.

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I. Introduction

Tennessee Valley Authority (TVA) is a corporate agency of the United States Government. It was established by Act of Congress in 1933 to develop the Tennessee River system and to assist in the development of other resources of the Tennessee Valley and adjoining areas.(1)

The production and sale of electric power are part of TVA's resources development program. TVA is this Nation's largest electric utility with a capacity in service in excess of 32,300 megawatts. TVA supplies power at wholesale to 160 municipal and cooperative distributors and one privately owned electric system which in turn distribute power to over 2.8 million customers in part of seven states. TVA also supplies power directly to 50 industrial customers and several Federal, nuclear, aerospace, and military installations. The 1981 power sales were 115 billion kWh that generated revenues of $3.78 billion. The power is supplied by 109 hydro units, 63 coal-fired units, 48 combustion turbine units, 5 nuclear units, and 4 pumped storage units.(2)

Financially, the power program is separate from other TVA programs. It is required to be self-supporting and self-liquidating.(3) The average residential cost in 1981 was 4.07¢/kWh, while the newest rate effective in October 1982 will average approximately 4.8¢/kWh.(4)

Electric power rates began a dramatic upward spiral in the Tennessee Valley and across the Nation in the early 1970's. Rapidly rising fuel cost, worldwide inflation, high interest rates, and the sharp rise in construction costs contributed to the spiral. TVA's residential electric rate rose from 1.3 cents per kilowatthour in 1973 to about 4.8 cents per kilowatthour in 1982.

To help consumers cope with rising rates, TVA has undertaken one of the Nation's largest energy conservation programs. Conservation programs provide savings to the power system by enabling it to defer high cost new capacity and helping avoid utilizing high cost fuels. These savings can then be passed on to all consumers through rates lower than would otherwise be necessary. Conservation programs also provide the most immediate savings in consumer bills.

TVA's Home Insulation Program was initiated in August 1977 to help residential consumers in the TVA service area reduce the use of electricity by installing adequate insulation, weatherstripping, caulking, and storm windows. The program provides free energy surveys, with recommendations for improving energy efficiency and attractive financing for those that choose to take advantage of it. The loans are at zero percent interest and are repaid on the consumer's electric bill over a period of up to seven years. Homeowners, tenants, and landlords are eligible for participation through one of TVA's 160 power distributors.(5) As of April 16, 1982 589,737 living units had been surveyed and 288,820 of the living units had received interest-free loans for weatherization measures totaling approximately $277 million.

During the late summer of 1981, TVA's Conservation and Energy Management Branch (CEMB) learned that the seven TVA district offices were receiving customer complaints that weatherization measures installed under the Home Insulation Program appeared to be related to moisture problem either in or under weatherized structures. An investigation into the nature and the extent of the complaints was initiated.

II. Findings

From approximately 140 houses with noted complaints, 32 houses were selected from various Tennessee Valley locations that were thought to depict a wide variety of complaints. The 32 houses do not represent a statistically significant sample when compared to the 589,737 living units surveyed, 288,820 living units with weatherization measures financed under the HIP, or the 106,014 floor insulation jobs financed as of April 16, 1982. TVA's main concern was that these complaints might establish an early trend that warned of future problems. From these inspections performed to date, the incidence of moisture-related problems in residential structures appears to be more common and varied than anticipated, but not restricted to weatherized houses. The complaints investigated to date can be segregated into two basic groups: the first, those that appear related to problems of "excessive moisture" and the second, those that appear related to "excessive drying."

Before further discussing these findings, a brief introduction to wood and its properties, the wood/moisture relationships, causes of wood deterioration, and techniques for moisture control is necessary in order to understand the importance of moisture control and its complex nature.

III. Properties of Wood

Wood is our most renewable resource and the building product most adaptable to a multitude of uses. Wood has high strength relative to its weight in compression, tension, bending, and resistance to impact. Wood is divided into two types--hardwood and softwood. These classifications are botanical differences and are not related to the descriptive softness or hardness of wood. The properties of wood are determined by its physical and chemical composition and most characteristics of wood are related to its cellular structure.(6) The single word that bests describes the structure of wood is "porous."

The wood cells or fibers are primarily cellulose, cemented together with a material called lignin. Wood is approximately 70 percent cellulose, from 12 to 28 percent lignin, and up to 1 percent ash-forming materials (exclusive of free and absorbed water). These constituents give wood its strength, its hygroscopic properties, and its susceptibility to decay.(7)

IV. Wood Moisture Relationships

Wood is hygroscopic. In general use it expands when it absorbs moisture and shrinks when it loses moisture. The moisture content of wood is the weight of water it contains, expressed as a percentage of the weight of the wood when oven dry. Moisture in green wood is present in two forms: in the cellular cavities as free water and within the cell wall fibers as absorbed water. The point at which the fibers are still saturated, but the cell cavities are empty, is called the fiber saturation point (FSP), occurring in most species between 28 to 32 percent moisture content (MC).(8) The significance of this condition is twofold. First, wood shrinkage begins only below this point, and secondly, wood decay can occur only above this point.

Ideally, wood should be fabricated and installed at a moisture content as close as possible to the equilibrium moisture content it will attain in use to ensure that wood in service will experience only minor dimensional changes.(7) For wooden framing members of houses in the TVA service area, this is around 9 to 14 percent.(9)

V. Wood Deterioration

The serviceability of wood as a building material depends upon its protection from a variety of deteriorating agents. Wood can be degraded by biological agents such as fungi and insects, environmental agents such as sunlight, storms, and moisture, and physical agents such as fire, earthquakes, and chemicals.(8) The agent of primary concern within the scope of this paper is fungal attack. There are three major groups of fungi that attack wood. A detailed treatise on the groups and characteristics of wood inhabiting fungi is beyond the scope of this paper but are summarized as follows:

A. Surface staining fungi: referred to as molds or mildew. These fungi produce colorless hyphas within wood and colored fruiting bodies on the surface of wood. Surface staining fungi do not alter the mechanical properties, but indicate that the surface of the wood was at or above 20 percent moisture content at some time.

B. Sap-staining fungi: these fungi produce colored mycelia within the wood structures that produced a discoloration that cannot be removed by brushing or sanding the surface. They do not cause wood to decay and do not reduce the strength of wood; but like surface staining fungi, they increase its capacity to absorb moisture.

C. Decay fungi: these fungi cause reduction in wood strength and are commonly called "rots." These fungi attack both sapwood and heartwood by the production of a colorless mycelia mat that permeates the structures. They use the structural fibers (cellulose) for food thus cause the weakening. Early stages cannot be determined by visual examination while advanced stages produce gross changes in the characteristics of wood. Decay fungi can be grouped into four classes: soft rot, white rot, brown rot, and water-conducting rot.

   1. Soft-rot fungi occurs in wet conditions usually associated with cooling towers or marine environment and is of little concern to the homeowner.

2. White-rot fungi destroy the cellulose and lignin in hard woods imparting a white, bleached appearance. The wood is stringy when broken and feels spongy to the touch. The strength decreased gradually with little loss of properties in the early stages of decay. There is no abnormal shrinkage.
3. Brown-rot fungi are the principle cause of building decay in the U.S. predominately found attacking soft woods. The wood is brown in color, brittle, easily crushed, and shrinks abnormally upon drying and sometimes collapses.
4. Water-conducting rot is a specialized brown rot. It is unique among wood destroying fungi in that it can conduct water into wood that is below 20 percent moisture content through large water conducting strands called rhizomorphs. It has most of the appearance characteristics of brown rot except for the additional presence of rhizomorphs.

Fungus growth can develop in wood only if the following conditions are satisfied:

(1) an adequate food supply of organic material (which for decay fungi is the wood itself), (2) mild temperatures ranging from approximately 30°F to 104°F, (3) sufficient oxygen, (4) a wood moisture content in excess of the fiber saturation point (MC greater than approximately 30%), (5) and finally, seeds or spores of decay fungi, which are sufficiently available in the air, to germinate on any suitable host.(8)

Of these five requirements for fungal germination and growth, three are beyond the realm of practical control. Mild temperatures are provided by the environment, oxygen is readily available from the atmosphere, and spores are found almost everywhere. The only requirements that lend themselves to control are the availability of an adequate and suitable food supply and the moisture content. Wood can be rendered unsuitable to fungal growth by the addition of certain chemical uniformly distributed any one of three pressure treatments: creosote, pentachlorophenol, and water-borne salts (such as chromium-copper arsenate). Each type of pressure treatment has specific application and some limitations, but all have limited application in existing structures. The single condition that is the easiest and most practical to control is the moisture content of the wood.

VI. Moisture Control : Controlling excessive moisture is the key to preventing condensation that leads to molds and mildew problems and ultimately decay problems. This is accomplished by a combination of: controlling moisture at its source, and providing the proper ventilation.

A. Stopping or Redirecting Moisture at the Source

Water must be controlled to correct or prevent moisture condensation problems, whether originating from outside weather conditions (rain or snow) or from water vapor inside or below the house.

1. Correct Surface Drainage

All rain water should be directed and drained away from the house, whether the house is built over a basement, a crawl space, or on a slab. The ground should slope away from the house and water should not be allowed to collect within 3.1 meters (10 feet) of the house. Minimum grading specifications require a slope of 15 cm (6 inches) within 7.6 meters (25 feet) on all sides of the house. The drainage ditch (if any) that collects runoff water should also slope away from the house.

Water near the footing of the foundation should be collected in footing tiles having open joints and connected to an adequate storm sewer. If the storm sewer is not available, the drain tile should be directed into an open ditch that is lower than the footing or into a dry well that is filled with sand and gravel.

Roof runoff water should be prevented from collecting on the ground next to the house. A 3-foot overhang on 1-story (single-level) houses provides adequate protection. If the house contains 2 or more stories or the eave projection is less than 2 feet, gutters and downspouts should be installed. If the storm drain is subject to flooding, divert the downspout runoff water away from the house by concrete splash blocks at least 30 inches long. In some cases where diversion of runoff water is impossible, the water proofing of foundations or the installation of sump pumps is an alternative.

2. Clothes Dryer and Washer Moisture

Using electrically powered ventilation to exhaust moist air from a clothes dryer can be classified as eliminating moisture at the source. Clothes drying is one of the most important single sources of moisture originating in a normal household. As much as 12 kilograms (26.4 pounds) of water can be evaporated in a day by doing a week's laundry for a family of four.(7) An automatic clothes dryer should be connected to a short vent duct 2.5 meters (8 feet) long or less, preferably without any turns, leading to the outside of the house. The exhaust from a dryer should never be vented into the attic, utility room, conditioned living space, or crawl space.

Cooking and dishwashing can add up to 16 kilograms (35 pounds) of water to the house per week. Each shower bath can add 1.25 kilograms (1/2 pound) of water to the air.(7)

Water vapor added to the air by respiration from a family of four persons, after making normal allowance for children's time away at school and parents' time away at work, would be approximately 2.7 kilograms (6 pounds) per day. House plants are only a moderate source of moisture. A group of seven house plants, for instance, would only release .45 kilogram (1 pound) of water in 24 hours. Greenhouses and swimming pools that are attached to the house can be a constant source of excess moisture and require special analysis to avoid or control moisture and condensation problems.

3. Crawl Space Moisture

After the laundry, the most common source of moisture leading to condensation problems within the house is the water vapor evaporating from the surface of the ground in a crawl space. Such moisture can come from ground water or from misdirected surface runoff water. Moisture evaporates into the air of the crawl space even though the surface appears dry. It can enter the house structure through openings around heat ducts, wiring, and plumbing, and through the stud spaces in walls and attics, where it may condense on cooler surfaces. This problem will not occur if the house is built in an area with sandy or rocky subsoil which keeps the ground water at least 5.5 meters (18 feet) below the crawl space. Where the ground water is within 5.5 meters (18 feet) of the surface in a crawl space of a 30 square meters (1,000-square-feet) house, as much as 72 liters (19 gallons) of water can be released into the air of the crawl space during a single day.(10) In some houses this source of moisture may be easy to detect by fungus on wood floor joists and subflooring, damp earth, mold on ground, damp foundation walls, or condensation on water pipes.

In many houses, however, symptoms of excess moisture are not readily visible. In fact the ground may appear perfectly dry and contain large surface cracks. This lack of evidence merely indicates that the moisture is coming up by capillary action until it reaches one of the cracks. The moisture then evaporates and diffuses into all parts of the house. Vapor pressure differentials are the driving force for the movement of water vapor and may eventually lead to condensation anywhere in the house structure.

4. Crawl Space Ground Cover Vapor Barrier

Moisture from capillary rise can be reduced as much as 90 percent by installing a ground cover vapor barrier. It is best to use a barrier material that is not susceptible to damage by fungi, such as polyethylene film .15 mm (6 mils) thick. Roll roofing weighing 25 kilograms (55 pounds)per 3.1 square meters (100 square feet)is also a good vapor barrier, but is subject to deterioration from fungi. In new homes, the use of full coverage and lapped seams is recommended. In retrofit applications, approximately 80 percent of the ground area should be covered to control but not remove all moisture from the crawl space (8). The area to be covered should always include the dampest or lowest areas.

An effective vapor barrier exhibits a permeance rating (rate of water vapor transmission through a material measured in perms) of 57 nano gram per second, square meter, Pascal (1.0 grains per hour, square foot, inches of mercury vapor pressure difference).

In extremely damp crawl spaces, the ground cover (vapor barrier)
should be initially installed to cover only 50 percent of the ground surface area. Then about every 4 to 6 weeks the area covered by the ground cover vapor barrier should be increased in approximately 10 percent increments by unfolding the overlapped material or installing additional material until 80 percent coverage of the ground-surface area is attained, being sure the dampest areas are covered. This method will allow for gradual drying of the house structure. If moisture is removed from the house structure at too rapid a rate, moisture shock may result which can cause walls and ceilings to develop hairline crack, floors to separate, and other wood contraction problems to develop.

B. Ventilation

The most important reason for ventilating attic and crawl space areas is to complement the use of a vapor barrier in controlling the migration of moisture and to protect the structure and insulation from damage. Without sufficient ventilation, water vapor cannot adequately escape from the house structure and may, therefore, condense into liquid on surfaces at dew point temperatures. The water can then invade the insulation fibers and degrade the thermal resistance (R-value) of the insulation by replacing insulating airspaces with water. Since water is a good conductor of heat, the heat flow through the insulation will be increased causing the ability of the insulation to resist heat flow to be decreased. Over an extended period, excessive moisture not only will make insulation ineffective, but as previoulsy noted, promote fungal growth. Achieving "sufficient" ventilation will minimize these destructive processes provided the quantity of air flow necessary can be adequately determined to meet these minimal requirements.

Crawl space ventilation is generally provided by the installation of foundation ventilators.

A ventilator is any device that facilitates the movement of air through a wall or roof while restricting the entrance of water, insects, birds, and others. Basically, a ventilator is a covered hole in a wall or roof through which air can freely pass.

The ventilator must perform three functions:

- o Allow for passage of air and moisture.
- o Restrict entrance of weather elements (rain) into the house structure.

o Restrict entrance of insects, birds, and other small animals into the house structure.

Ventilators are classified in two categories--those that operate entirely by natural forces (static, gravity, or wind) and those that require electrical energy with which to operate (active).

As noted above, achieving "sufficient" ventilation will minimize the occurrence of excessive moisture and condensation. But, what exactly is "sufficient" ventilation and how does our determine its minimum value?

Determining the required ventilation for attics and crawl spaces in residential structures can be based on a variety of methods. ASHRAE provides one equation for calculating the total area for crawl space ventilation. (11)

$$a = (2L/100) + (A/300) \qquad (1)$$

where L = perimeter of crawl space, linear meter (feet)

A = area of crawl space, square meter (sq. ft.)

a = total net area of all vents, square meter (sq. ft.)

ASHRAE also notes that this vent area can be reduced to 10 percent of that calculated if a vapor barrier is used on the ground. Also available are the guidelines in the HUD Minimum Property Standards (MPS) (12) for natural ventilation openings as a fraction of floor area:

1/150 without ground cover

1/1500 with ground cover

with cross ventilation

The Southern Building Code (13) specifies a similar ratio while The Building Officials and Code Administrators International (BOCA) specifies 1/3 of 1 percent of the enclosed area.(14) The State Building Code of North Carolina (15) specifies in section 1702.8:

Without ground cover:

.6 square meters (2 sq. ft.)/30 linear meters (100 ln. ft.) of exterior wall + .3 square meters (1 sq. ft.)/27.9 square meters (300 sq. ft.) of crawl space area (2)

With ground cover:

0.3 square meters (1 sq. ft.)/30 linear meters (100 sq. ft.) of exterior wall + 0.3 square meters (1 sq. ft.)/55.7 square meters (600 sq. ft.) of crawl space area (3)

TVA presently uses the HUD-MPS guidelines recently modified to include a minimum of four ventilators in such locations to provide the best available cross ventilation.

Each of these methods is based on rule of thumb or historical numbers that have been handed down through the years and formulated on little, if any, analytical techniques that the authors can find.

VII. Discussion of Findings

The problems associated with "excessive moisture" will be addressed first because this can be the most structurally damaging and lead to devastating, even catastrophic, results. The incidences of excessive moisture that were observed can be categorized into three subgroups: those that appear to be related to either improper crawl space ventilation, or to improper control of either surface or free water, or combination thereof; those that are related to moisture condensation on the exterior of air-conditioning duct insulation; and those of undetermined origin.

A. Excessive Moisture

1. From the observations to date, the improper ventilation and improper control of water in a crawl space can have the most destructive consequences. In the houses examined, a house built over a below-grade crawl space with the minimum net free area for ventilation appears to be the most susceptible to excessive moisture accumulation that can lead to decay. This low profile style of house that appears to be built on a

concrete slab but, in fact, is built over an excavated crawl space, is the most difficult to provide adequate ventilation and consequently keep dry. Positioning for foundation vents are limited because of the location of large porches and garages/carports and the building practice of installing the vent within the end of the joist cavity. Although these houses meet the HUD-MPS (table 4-3.1) and The Southern Building Code (section 1302.5(e)) for ventilation, the authors have serious doubt that these net-free ventilation areas produce ventilation rates that are adequate in the many instances where houses are built over areas of high moisture content. Houses that meet the "letter of the code" do not appear to meet the "intent." The most frequently observed location for moisture condensation and accumulation was within stagnant crawl space areas without true <u>cross</u> ventilation. The word "cross" must be emphasized because having ventilation on two adjacent foundation walls does not appear to provide even marginal ventilation for the other side of the structure.

Significantly contributing to this apparent problem of lack of ventilation is the lack of proper control and removal of surface and rain water around the perimeter of the structure. The lack of proper grading, drainage, and the location or lack of downspouts contributes to a potentially damaging situation.

In houses with a below-grade crawl space, surface and other free water is believed to accumulate on top of the crawl space ground cover from either seepage through the foundation or through improperly located or protected vents. Once in the crawl space, this excess moisture is contained because the ground cover prohibits its perculation into the soil while the inadequate ventilation prohibits its evaporation and transport to the outside. This creates a "microclimate" where the water that does evaporate condenses on the cool floor joists and insulation above and "rains" back to the ground cover. Increased ventilation and better control of surface water appear to be logical approaches to remedy this problem.

2. The second group of "excessive moisture" occurrences is the condensation of moisture on the exterior of air-conditioning or heat pump duct insulation. This occurs during periods of extremely high humidity and high dew point temperature. The cool aluminum foil backing or plastic film utilized on duct insulation makes an ideal location for condensation when the necessary ambient conditions exist. Condensation was observed on numerous occasions but is considered to be a transitory phenomenon that does not appear to require specific corrective action provided the condensate does not saturate the insulation. The only alternatives appear to be mechanical

ventilation or additional insulation so that the surface of the backing will never reach the dew point temperature. These actions do not appear to be warranted at this time.

3. Two houses were examined that had moisture-related phenomena that were difficult to understand. These were grouped together as incidences of undetermined origin. Generally, there must be an undetermined source of moisture for incidents like these to occur, and several remedies are being tried with additional action to follow. Problems like these require individual attention and no general corrective action can be stated.

B. Excessive Drying

Related to the problem of excessive moisture is the occurrence of excessive drying. As was pointed out earlier, wood only shrinks as its moisture content falls below the fiber saturation point. The dimensional changes that occur in wood can be considered a linear function of moisture content between 30 percent with no shrinkage and 0 percent with maximum shrinkage. (6) The installation of a ground cover is recommended in crawl spaces in order to reduce the moisture accumulation in the substructural wood so conditions for decay are reduced. Also, a ground cover will help maintain a more uniform moisture content and thus minimize dimensional changes.(9) Some complaints investigated were related to dimensional changes that occurred when a ground cover was installed in an existing crawl space. Wood that had established a high equilibrium moisture content in service was rapidly dried and non-uniform dimensional changes occurred. These are typified by floors that develop buckling, doors that drag, floors that crack, and furniture that might become loose. Many occupants associate these incidents with an excessive moisture problem when, in fact, the opposite is true.

Generally, the incidents that occur from excessive drying are either cosmetic or aesthetic as compared to the destructive consequences that can occur from excessive moisture leading to decay. This is not an attempt to lessen the importance of excessive drying but an effort to keep the alternatives in perspective.

The use of some means of mechanical humidification is one technique that could be utilized in some instances of these excessively dry houses to assist in controlling the inside moisture level. By properly introducing the correct quantity of moisture, a stabilization in the dimensional characteristics of wood could be achieved. In extreme cases involving large dimensional changes or for the health of a certain occupant, mechanical humidification could help. This is not believed to be justified or would be acceptable in most cases.

C. General Observations

During the past decade, the single-family dwelling has been subjected to greater changes than occurred during the previous half century. The energy crisis focused the spotlight on energy efficiency both on the residential and the industrial sectors. The single-family residence has evolved from an elementary structure into a complex one with many simultaneously interacting variables. Unfortunately, construction practices and technology transfer have not kept pace with this progress. When combined with the general lack of homeowner and builder education in dealing with moisture, his lack of information has caused moisture-related problems to appear in alarming numbers.

In summary, the control of moisture within a house is a more delicate balance than anticipated between excessive and insufficient moisture. The best illustration the authors have developed to depict the overall interaction of moisture control is seen in Figure 1. The proper use of the elements of moisture control is essential for maintaining a proper balance in the control of house moisture. The dynamic nature of wood due to its affinity for water and the ever changing environment within which it exists make this proper balance difficult. The consequence of too little or too much moisture can tip the balance, but the effects of excessive moisture can be so much more damaging.

VIII. Conclusions

1. The national effort to conserve energy has lead to increased weatherization of residential structures. This has caused a reduction in the air change rates of these tighter houses and increased the importance of moisture control.
2. Crawl space ventilation appears to be a key element in the control of residential moisture problems. Predicting the required ventilation has become an increasingly complex matter. Old tried and true rules of thumb do not seem adequate in many energy-efficient structures because of the reduced infiltration and better thermal envelopes. An effort should be initiated to reevaluate the techniques for calculating crawl space ventilation requirements based on more scientific and analytical methods and further research continued on alternative approaches to conventional floor insulation.
3. A great deal of misinformation exists within the residential community of builders, contractors, architects, building inspectors, pest control operators, and homeowners on the importance of and techniques for residential moisture control. Moisture problems are entirely preventable. The techniques available are relatively simple and inexpensive if initially incorporated into the design and construction of a structure. There exists a great need for the transfer of this moisture control technology from the wood products area to the builders and users of residential construction.

4. No intrinsic characteristic has been identified that causes a moisture problem within either an energy efficient or typical house provided the construction practices utilized include proper allowance for the control of moisture.

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