Insulation Induced Exterior Paint and Siding Failures

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ABSTRACT

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INTRODUCTION

PEELING PAINT PROBLEMS on wood siding have been around for a long time. More recently complaints have increased, especially in homes that have had recently (within two years) blown insulation installed in their sidewalls. The increased problems did not seem to be insulation specific, that is, problems occurred with numerous different types of insulation, cellulose, fiberglass, tripolymer foam, etc. Blown cellulose was particularly singled out, but it was unclear whether this was because of the specific properties which made cellulose unique or simply because more sidewalls were being blown with cellulose than any other kind of blown insulation.

Even more recently, complaints began to appear regarding peeling paint and actual wood siding failures on new houses where wood siding had been installed over insulating sheathing, namely foil-faced isocyanurate and extruded polystyrene. Not only was paint peeling, but wood siding was cupping, warping, splitting and actually falling off walls. The siding manufacturers blamed the insulating sheathing manufacturers, and the insulating sheathing manufacturers blamed both the siding manufacturers for poor quality siding and the builders for not nailing the siding on properly. Committees were struck, a consensus was reached, and of course the poor builders were ultimately blamed. Recommendations were issued, but it was unclear which recommendations, if any, worked or why.

Yet, mystifyingly, there were thousands of older houses with blown insulations with no problems as well as thousands of new houses with insulating

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sheathing with no problems. Why were some houses experiencing failures and not others?

Ironically all of these problems and non-problems are interrelated. The author became directly involved in the issue while investigating weatherization induced moisture related housing problems in the Cleveland, Ohio area with researchers at the Housing Resource Centre. The Housing Resource Centre is located in Cleveland and is a storehouse of housing information, for both new and existing housing. The Center's mandate is to transfer appropriate building science technology to the practitioner, regardless of whether the practitioner is an architect, engineer, builder, renovator, contractor or do-it-yourselfer homeowner.

OBSERVATIONS

After a public radio station solicited a one hundred and fifty house survey, numerous site visits, and some detailed wall investigations where sidings, sheathings, and insulations were removed, the following categories of problems were encountered (Tables 1a and 1b):

Field investigations revealed that, in general, in each of the cases, moisture was present or there was visible evidence that moisture had been present, between the horizontal lapps of the exterior siding and/or between the siding and the sheathing where sheathing was present. In addition, in each of the cases the cavity insulation was dry, and the cavities themselves were dry, regardless of the type of insulation used, cellulose, fiberglass or foam.

In category 1 (peeling and blistering paint on the exterior of the south and west walls) the moisture problems were typically the worst. The portions of nails in the sheathing and siding were often seriously rusted, the exterior surface of the fiberboard sheathing was often saturated along with the back

Table 1a. Peeling and blistering paint on the exterior elevations of existing homes.

Category Number	Orientation	Wind Barrier	Exterior Sheathing	Typical Age, Years	Comment
1	S, W	Asphalt Paper	Impregnated fiberboard	15–30	Presence of foil backed gypsum no effect.
2	N, E	Non-impregnated paper	Asphalt paper or fiberboard	20–40	Sidewalls block wall insulation
3	Any	Non-impregnated paper	1 × 4 or 1 × 6 boards horizontal or diagonal		No problems

Table 1b. Problems with peeling and blistering paint on exterior elevation of new houses.

Category Number	Orien-tation	Wind Barrier	Exterior Sheathing	Typical Age, Years	Comment
4	S, W	Foil-face PIK extruded 1″ PS		1–2	4 or 6 mil PE Vapor Barrier

surface of the siding, or damp, mildewed or rotting. The interior surfaces of the fiberboard (at the insulation/sheathing interface) were typically dry. The cavity insulation was dry as previously noted.

In category 2 (minor peeling and blistering paint on the exterior of the north and east walls) the symptoms were similar to those described for category 1, only to a much lesser extent.

In category 3 (no problems) only traces of moisture were found between the horizontal lapps. The rough sawn board sheathing was found not to have any visible traces of moisture.

In category 4 (new homes with peeling, blistering paint and cupping and splitting siding on the exterior of the south and west walls), the moisture was concentrated at the interface formed by the back of the siding and the exterior surface of the insulating sheathing. The exterior or front surfaces of the siding were often dry, however the back surfaces were wet, damp or saturated, or there were indications that they once were. The wall cavities were dry, the cavity insulation was dry. The cavity insulation/insulating sheathing interface was dry.

ANALYSIS

What are the four mechanisms involved in explaining what was happening to the walls described in these four categories? It is obvious that insulation is involved in each of these cases, and in fact precipitated the problems, but how? It is also clear that each of the problems described is moisture related. However, is the moisture source internal or external and why did the moisture only become a problem after insulation was added? Does the addition of insulation cause moisture problems?

It was not possible to determine definitively from the patterns of moisture distribution whether, in the majority of cases described, the source of moisture was primarily external, internal or a combination of both. In fact, it is not as important to peg one moisture source over another as it is to realize that both exterior and interior sources of moisture were each capable of producing the problems described (except in category 4 where the moisture source is clearly exterior). It is probable in the majority of cases that both exterior and interior sources of moisture contribute to the failures described. What is *most* significant to realize is that an interior moisture source cannot be conveniently cited in all cases. And control of interior moisture *alone* cannot be relied upon to eliminate the paint and siding problems.

Where the source of moisture is external, rain water or surface condensation (dew) penetrates the siding under the influence of wind, and capillarity which can pull surface water on the siding exterior up between the horizontal lapps of the siding. The moisture now can migrate from between the lapps of the siding and the siding/building paper interface both towards the exterior (into the wood siding) and towards the interior (into the sheathing material).

Moisture is driven from siding/building paper interface into the siding typically at night, although it might be at a lower vapor pressure than the siding itself, the siding will likely not give off moisture to the exterior, but rather absorb moisture, both from the exterior and from the siding/building paper interface. This is a property of wood: it absorbs moisture according to the "relative humidity" as opposed to the actual vapor pressure. There may not be much moisture present in the outside air (i.e., a low vapor pressure), but the little moisture that is present may be close to the total amount of moisture the air can hold at that particular temperature (i.e., a high relative humidity). The wood siding "sees" this high relative humidity and either draws moisture from the exterior and/or does not give off moisture to the exterior. This phenomenon may be enhanced, where buildings are exposed, to clear sky irradiance (night sky radiation) where the siding can actually be at a temperature significantly lower than ambient conditions.

During the day, solar radiation can cause both evaporation to the exterior and drive moisture into the wall by raising the surface temperature to set up both a temperature gradient and a vapor pressure differential acting inwards. How far the moisture goes into the wall system depends on the construction of the wall, namely the vapor permeability of components, their moisture storage capability, and most significantly the temperature of each component in the wall system.

Where the source of moisture is internal, air leakage and vapor diffusion serve to carry moisture into a wall cavity. Where this moisture accumulates also depends on the construction of the wall, specifically the permeability of the individual components, their moisture storage capability and again most significantly their respective temperatures.

The more insulation that is added to a wall, the colder the interfaces between materials become at the exterior of a wall, namely the insulation/sheathing interface, the sheathing/building paper interface and building paper/siding interface. The adding of insulation to a wall cavity reduces the "drying potential" of the wall components to the exterior of the insulation and as such increases the rate of moisture buildup at the interfaces of these components.

Category One Cases

In the category 1 cases, moisture had always been finding its way into the walls from both internal and external sources. Regardless of which source, the moisture would accumulate at the siding/building paper interface. In spite of the moisture being held at the siding/building paper/sheathing interface by absorption and capillary effects, the potential for evaporation of this moisture, the "drying potential," was still sufficient to allow the moisture to dissipate to the exterior, prior to the addition of insulation to the wall cavities.

After the addition of cavity insulation, the drying potential was reduced and caused an increase in moisture accumulation at the siding/building paper interface. This increase ultimately caused peeling and blistering paint problems.

But why were these problems concentrated and/or more severe on the south and west elevations? The answer lies in the effect of solar radiation. The solar radiation had three effects. First, it served to dry the exterior surface of the siding through surface evaporation. This surface evaporation is of course inhibited by the paint film itself and enhanced by the buoyancy effects of warm, heated air passing up the exterior surface of the wood siding.

Second, it served to increase the temperature of the siding relative to the sheathing, thereby creating a vapor pressure gradient driving moisture into the wall. This moisture movement inward was retarded by permeability properties of the building paper and asphalt impregnated fiberboard. Therefore moisture moved from the siding into the sheathing where it was stored.

Third, it increased the stress on the paint surface itself leading to separations of the paint film from the wood siding substrait as the paint film was repeatedly stretched and contracted due to temperature cycling as well as the repeated swelling and shrinking of the siding due to cycling moisture content. The paint film separations lead to the creation of voids between the paint film and siding surface where moisture would accumulate when the vapor pressure gradient was again reversed at night and could lead to mechanical stress on the paint film when these water filled voids were heated during the day by solar radiation.

Category Two Cases

In the category 2 cases, where minor peeling and blistering paint was occurring on the north and east elevations, the mechanisms again are identical to the category 1 cases. The key to understanding this example is found in comparing the differing permeabilities of the building paper and fiberboard sheathing with those of the category 1 cases.

In the category 1 cases, the solar radiation served to push the accumulated moisture back into the wall on the south and west exposures. The greater impermeability of the building paper and asphalt impregnated fiberboard of the category 1 cases as compared with the category 2 cases, served to inhibit the inward flow of moisture so that it tended to remain at the siding/building paper and building paper/sheathing interfaces leading to the problems previously described. In the category 2 cases, the greater permeability of the building paper and sheathing allowed sufficient moisture to migrate from the siding/building paper interface on the south and west corners so as to reduce paint and siding problems. On the north and to a certain extent on the east exposures, solar radiation was reduced and did not serve to move moisture inward, away from the siding/building paper interface, as such, sufficient moisture accumulated to cause minor peeling and blistering paint problems.

Category Three Cases

In the category 3 cases, the houses experience no siding or paint problems after the addition of cavity insulation, due to the greater permeability and moisture storage capability of the non-impregnated building paper and rough sawn wood board acting as the sheathing, as well as the greater air leakage of the board sheathing as compared to the siding/building paper/ sheathing combinations described in the category 1, and 2 cases. When moisture accumulates at the siding/building interface as a result of the mechanisms previously described, it can easily migrate back into the wall and be stored in the wood sheathing under the influence of solar radiation and moisture gradient differences. However, the building paper and wood sheathing still sufficiently inhibit inward moisture migration from the siding/building paper interface to prevent the interior paint problems described in the category 2 cases.

Category Four Cases

In the category 4 cases, where extensive peeling, blistering paint, and splitting siding occurs, the culprit is exterior moisture combined with the relative impermeability of the insulating sheathing. The insulating properties of the insulating sheathing also have an effect, but are much less a factor than the vapor properties.

The wood siding becomes wetted, as a result of rain and capillary effects. Moisture accumulates at the back of the siding, and solar radiation attempts to drive the moisture into the wall. The relative impermeability of the foil-faced isocyanurate and extruded polystyrene insulating sheathings prevent the moisture from migrating inward from the siding/insulating sheathing interface. This leads to moisture accumulation at the rear surfaces of the siding. The influence of solar radiation leads to uneven drying where the front surfaces of the siding are dry and the back surfaces are wet. Often the paint and the wood sidings are unable to accommodate the stress so imposed, and failure results. In addition, the insulating properties of the insulating sheathing reduce heat flow from the interior of the building and increase the stress imposed by solar radiation by allowing a much faster temperature buildup by the wood siding.

While the installation of insulating sheathing serves to *reduce* the "drying potential" of the exterior siding by virtue of its relative impermeability and insulating properties, it conversely, dramatically serves to *increase* the drying potential of all the building components to its interior, namely the wall cavity itself. It is ironic that the installation of insulating sheathing reduces interior, or interstitial wall moisture problems, while at the same time may lead to an increase in siding or exterior wall moisture problems.

DISCUSSION

The problems occurred in the cases described as a result of a reduction in the "drying potential" of the exterior portion of each of the wall systems. This reduction was precipitated by the addition of cavity insulation in the first three categories sighted and the addition of insulating sheathing in the fourth category.

There still remain a few unaddressed points, such as why the cavity insulations which are linked to the most problems are of the blown or sprayed nature (blown cellulose, blown fiberglass and spray foam)? Another way of asking the question is: "Why do there seem to be fewer problems associated with batt insulations such as fiberglass and/or mineral wool?"

The answer may lie, although disagreement exists within the building science community, in considering the factors which influence the "drying potential." The difference in vapor pressure between a wall component interface and the ambient is not the only factor influencing the "drying potential."

From the examples given it is clear that the geometry of the exterior siding/building paper/sheathing combination is critical in inhibiting the drying by air circulation or drainage of condensed water at material/component interfaces. Solar radiation may either reduce or increase the "drying potential" in wall systems depending on the permeability and moisture storage ability of the various wall components. Finally, the pathways for air movement within a wall system also affect the "drying potential." Does the cavity insulation completely fill the cavity, thereby inhibiting convective loops and air circulation? Is an air barrier system present to prevent the through-flow of air which could alternatively dry or wet the cavity?

In summary, the following factors can influence the "drying potential" of a wall system:

1. Vapor pressure differentials between material interfaces
2. The geometry of the wall system components and how it affects the drying of wall components through air circulation, drainage and capillarity
3. Permeability and moisture storage capability of the wall system components
4. Air movement within and/or through the wall system
5. Solar radiation

Blown or sprayed cavity insulations reduce air movement within a wall cavity more effectively than batt insulations. Again, it is ironic that, because these blow or sprayed cavity insulations may be "better" than batt insulations, their use possibly leads to more siding and paint failures because they reduce the "drying potential" of the siding/building paper/sheathing interfaces more than batt insulations.

In addition, since these insulations serve to reduce rate of changes, their use often results in higher moisture levels within indoor air and the higher interior moisture level, often results in more moisture migrating to the siding/building paper/sheathing/insulation interfaces.

The argument can also be made that the major difference between the performance of batt insulations and blown insulations relates to the orientation of the insulation fibers, not to air movement. In the case of fiberglass batts, their superior quality to "drain" condensed water away from the batt/sheathing interface, is often cited as the reason that fewer paint/siding problems appear with their use. The hydrophobic nature of fiberglass relative to cellulose is also a factor to be considered.

And finally considering applications of sprayed cellulose insulation, where water is added to facilitate installation, one may consider a "one-time" moisture "shock" to the wall system which may be sufficient to lead to a failure. However, it is significant to point out that such a failure would happen immediately after insulation has been added, whereas most failures appear a year or two later.

RECOMMENDATIONS

Wall cavity insulation is here to stay, and insulating sheathing is here to stay. What is necessary are recommendations which take into account their effect on drying potential and compensate for it. To compensate for the drying potential reduction that insulations cause (see Figure 1), one should in-

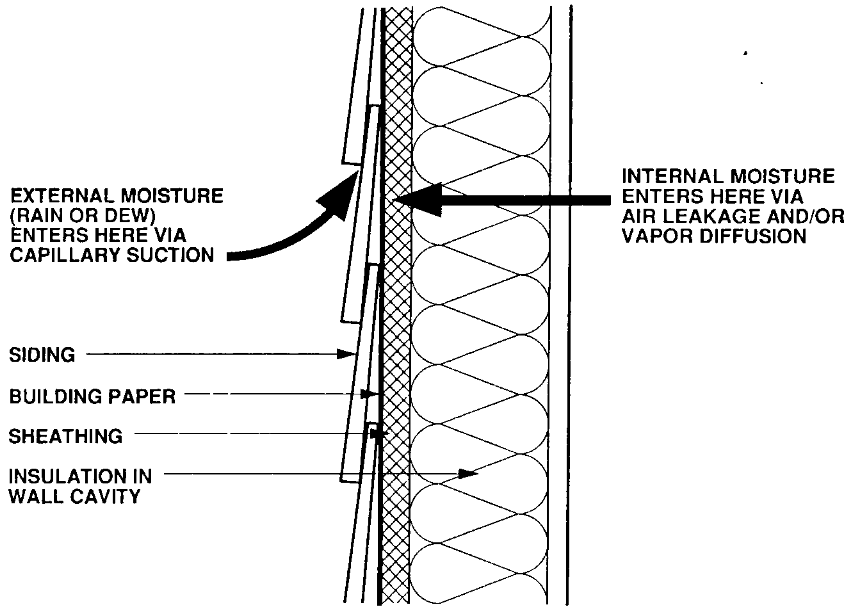

FIGURE 1.

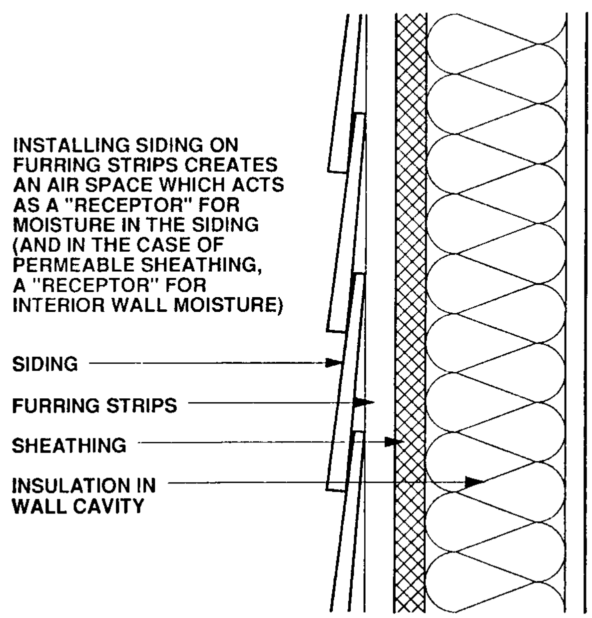

FIGURE 2.

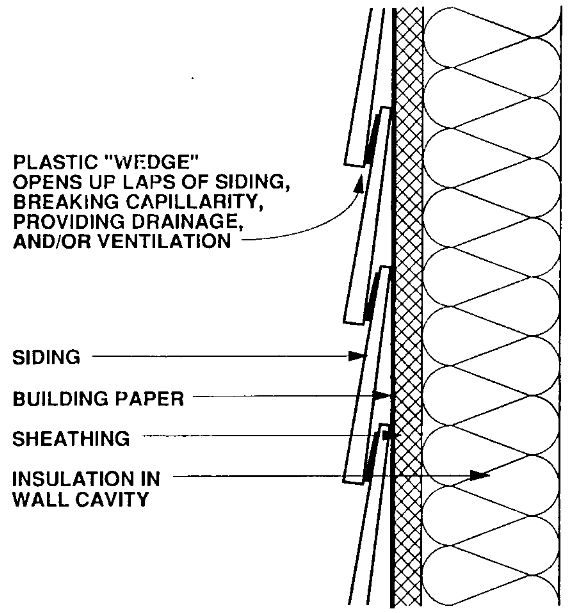

FIGURE 3.

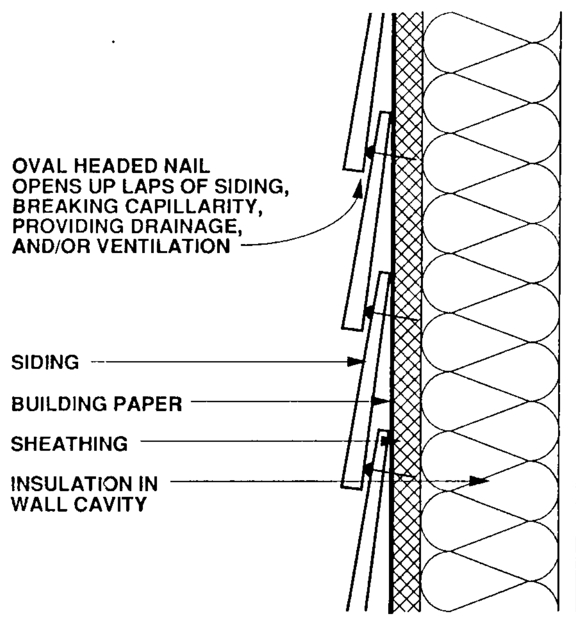

FIGURE 4.

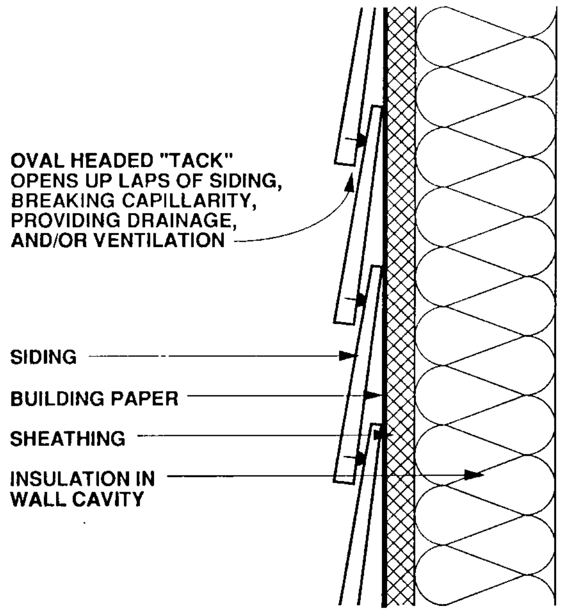

FIGURE 5.

crease the drying potential by manipulating the geometry of the siding/building paper interface to promote drying of the components by evaporation, air circulation, drainage as well as providing a capillary break. This strategy is shown in Figures 2, 3, 4 and 5.

Figure 2 shows that installing wood sidings on furring strips provides an air space immediately behind the siding which promotes drying of the siding by air circulation, facilitating the drainage of condensed water as well as providing a capillary break. This air space is critical when using insulating sheathings which are impermeable and/or have no moisture storage capability (i.e., foil-faced isocyanurates, extruded polystyrenes). It is of course also effective where standard sheathings are used. With standard sheathings, the technique has the promise of providing dramatically increased paint life.

Figure 3 shows how plastic wedges to separate the lapps of sidings in retrofit situations after blown insulations are installed in wall cavities. The separation of the siding lapps facilitates drainage and drying as well as providing a capillary break. It is important to install the wedges at each stud where the siding is nailed to provide a continuous gap between each piece of siding and not between the studs as is often suggested by the manufacturers (of the wedges) instructions. The same action can be achieved by double nailing of siding with "round-headed" nails as was the traditional practice many years ago. The protrusions of the round heads provide a continuous gap at the laps of horizontal siding which promotes the drainage of condensed water, drying via air circulation as well as providing a capillary break (see Figure 4). Figure 5 illustrates the use of oval-headed tacks to achieve the effect described previously.

Small vents through siding sheathing, as is commonly recommended, is a potential formula for disaster. These vents do not serve to increase the drying potential of the wall system, but rather serve to increase wall moisture problems by increasing rain penetration, and/or promoting air leakage. This solution is not recommended by the author.

The practice of "back-priming" of siding has also been recommended. This practice does reduce the amount of moisture absorbed by the back of the siding by both capillarity (the paint fills the capillary pores in the wood) and vapor diffusion/relative humidity. This practice does not eliminate the problems, but does reduce their magnitude. In order to be completely effective, the practice should be coupled with the use of an air space behind the siding. However, once an air space has been provided, it is probably not necessary to "back-prime" the siding. It can also be argued that "back-priming" can only be effective if the paint film applied to the rear of the siding is more impermeable than the paint film on the exterior surface (i.e., prime the front of the siding and paint the back). Although this approach may seem to have technical merit, its practicality and cost effectiveness are questionable.

The choice of "vapor permeable" paints, such as latex-based exterior paints as an exterior finish helps in reducing peeling paint/siding problems. However, there currently exists no paint which is sufficiently permeable, flexible and durable to resist the new stresses imposed on wood sidings as a result of insulation induced reductions in drying potential.

To date, in the retrofit applications that the author has been involved with, the use of wedges to alleviate the problems described have been successful. Their use has not led to insects using the openings created to build nests, etc., as had been a concern. Perhaps the moisture reduction makes the siding less attractive to these creatures.

CONCLUSIONS

The following conclusions may be drawn:

1. The installation of cavity insulation and insulating sheathing may reduce the "drying potential" at the exterior wood siding/building paper/sheathing interfaces leading to potential paint and siding failures.
2. The geometry at the interior siding surface can be changed in order to facilitate drainage, drying and capillarity reduction.

3. Cavity insulation should be installed only after considering the effects of "drying potential" reduction and if necessary, in existing or new housing after compensation strategies have been implemented.
4. The use of insulating sheathings is desirable from the perspective of reducing interstitial moisture condensation in the wall cavities. However the use of insulating sheathings results in drying potential reduction of the exterior siding and must also be coupled with strategies which compensate for it.