3

House System

Moisture related failures, indoor air quality problems, combustion back-drafting, sooty "ghost" stains on walls and carpets, mold and mildew in homes—callbacks of these types have increased dramatically in recent years. They are often blamed on houses that are "over-insulated" or "too tight." Although these problems were unusual in the days when houses were leaky and uninsulated, they are not *caused* by these factors alone. In fact, it is rare to find a failure of this sort which is caused by any single factor. These problems are usually the result of the different components of the house interacting, as a system, in ways that were not foreseen by the builder or designer.

Over the last century, the introduction of new materials such as plywood sheathing and housewraps has changed the way houses are built. Houses are tighter, and there are many more pollutants found inside, generated by the occupants and by the building materials themselves. As energy costs have risen, insulation has become a necessity. The advent of central heating systems with automatic controls has contributed to increased consumer demand for comfort in their homes, and heating systems have become more efficient. In addition to advances in building construction, consumer lifestyle changes have altered homeowners' expectations. People want houses that are bigger and better, with more features than ever before. All of these things have an effect on each other, and on the operation of the house system.

It is becoming widely recognized that many of the failures and warranty callbacks in new houses are a result of mis-applying new technologies or materials—not because they were installed "wrong," but because nobody predicted the effect that a change in one area might have on some other part of the the house. Often, the complexities of a building make it difficult to find the source of a problem, even after it occurs. Consider the following example (a true story):

Building Failure Case Study

A homeowner calls in a building science specialist to help with a moisture problem during the heating season. The house has condensation and mold in the attic and living space. The specialist arrives at the property, and an interview of the client shows that this is an ongoing problem; in fact, it has gotten worse. The customer had previously consulted with several contractors and the local utility company, and was informed that the solution to the moisture in his attic was to add ventilation. When he asked how much ventilation to add, he was told, "You can't over-ventilate an attic." He was also warned that soffit vents would do him no good if they were blocked by insulation. So he installed extra soffit ventilation and pulled the insulation back from the eaves to allow free air flow. Since the hip roof did not have much ridge area, the homeowner installed two turbine vents to satisfy the need for upper ventilation.

On inspecting the house, the specialist finds the following:

- The roof sheathing is damp and spotted with mold.
- The roof has continuous soffit vents and two turbine vents.
- The fiberglass batts in the attic have been pulled away from the eaves approximately 18".
- There is black mold growing on the second floor ceilings in rectangular patterns around the house perimeter.
- The relative humidity in the living space is measured to be higher than normal for winter conditions.
- The bathroom exhaust fans are vented outdoors, but have a very low air flow rate and are rarely used.
- A blower door test confirms that the building is fairly tight, but there is still communication between the attic and the living space, by means of top plates and an open plumbing chase.
- The clothes dryer in the basement has a vent to outside, but the hose is disconnected.
- There is a piece of plywood in the basement loosely covering a sump, which leads to a small stream running underneath the building.

It is clear to the specialist what has happened. First, the turbine vents drew air not only through the soffit vents as intended, but also drew more air than ever from the house into the attic. With the high levels of humidity in the living space, combined with the fact that leaks into the attic had never been sealed, the turbines were moving moisture into the attic even more quickly than before. Second, in his effort to open up the soffit vents, the homeowner removed the insulation. This created a cold surface all around the perimeter of his upstairs ceiling for moisture to condense, and mold to grow on. No one thought to look in the basement when diagnos-

ing the problem, but this is where the source of the moisture was lurking all the time.

The specialist wrote up a repair punch list as follows:

- Cover the sump in the basement with a gasketed cover to discourage the water from evaporating into the house.
- Re-connect the dryer hose.
- Seal leaks into the attic, to minimize the path for moisture to reach the attic.
- Replace the turbine vents with standard roof vents.
- Re-insulate the perimeter of the attic.
- Install baffles to allow free air movement through soffit vents and to direct the air over, rather than through, the insulation.
- Install a continuous running, low-level exhaust fan in one bathroom, to ensure the proper ventilation rate.

When the building was inspected the following year, the moisture was gone and the occupants were healthier and more comfortable.

Why did this building fail? The answer lies in the the fact that nobody evaluated how one aspect of the building's construction might affect another part of the building. Additionally, nobody evaluated the effects of occupant behavior on the performance of the building. When the foundation was built, it was noted that the underground water might cause flooding problems, so the decision was made to include a sump. When the framing, exterior shell, and interior finish were installed, each contractor took enough care that the building ended up with a relatively air-tight shell. But the builder did not realize that by doing these two things successfully, they had created a highway for moisture to pass through the interior wall cavities directly from basement to attic. Bathroom fans were installed and properly vented outside, but nobody predicted that the occupants wouldn't use them.

Why was the moisture problem mis-diagnosed? This is primarily because the contractors making the assessment took too narrow a view when evaluating the house. If a problem occurs in the attic, it is easy to assume that you will find the answer by looking in the attic. However, the house system is complex enough that this is often not the case.

The House as a System

When one component of the building fails, or is even out of tune, it can set off a chain reaction with unexpected results. To successfully avoid these kinds of failures, it is necessary to take a systems approach to the design and construction of buildings. Every trade may do its job properly, but if nobody is paying attention to the issues of moisture sources and

ventilation, a house can end up with serious mold and mildew problems. Every aspect of a home may meet the required codes, but there can still be carbon monoxide spillage into the living space. The construction supervisor may do a fine job of managing all the subcontractors, but if no one considers the interactions of the individual parts of the building, or thinks about how the building will perform when occupied, all this hard work may be inadequate.

It is easy to look at the house as a collection of components: foundation, frame, mechanical services, drywall, trim, fixtures and finishes. But there is more to a building than this. Figure 3.1 shows a schematic of the house system with some of its interactions.

The first step to understanding the house system is to realize that the building structure itself, and the mechanical systems in it, interact with each other and with the people in the building. People turn thermostats up and down, they move switches and valves, they build walls, cut holes, and leave windows and doors open or closed. Both the building and the mechanical systems also interact with the immediate environment around the house: how cold or hot is it, which direction is the sun shining from, how much wind or rain. These environmental factors change the building directly, causing parts of it to get hot or cold, or to get wet, and to dry out; and they also affect how comfortable people are inside, causing them to act in different ways relative to the building.

It is not necessary to make a study of every interaction that can happen in a building based on this concept. However, it is important for someone to take responsibility for the house as a whole system, and to think about common ways that the components in a house interact under everyday situations. It is imperative that house designers and general contractors learn the basics of the house as a system if they want to avoid these problems.

Fortunately, there has been much research in recent years and a growing body of field experience based on new construction, testing, weatherization and remediation work. Ice dams, indoor air quality problems, radon, nail pops in drywall, freezing pipes, combustion safety and backdrafting problems can all be reduced by understanding the basics of moisture and air movement. These effects can be understood on a level sufficient to avoid the most common problems, as long as someone is thinking past the individual parts and looking at the whole.

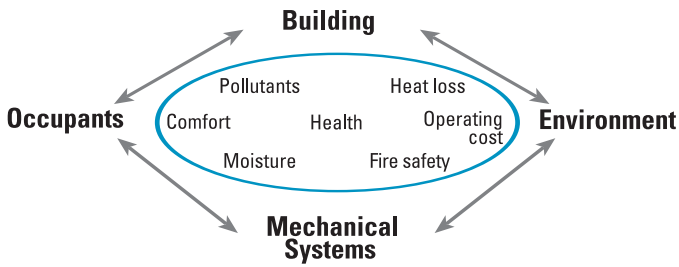
Going Further

This guide attempts to include details that are consistent with good building science as well as applicable codes. However, it is beyond the scope of this guide to address the subjects of moisture and air movement in much

detail. Many of the sources listed in Appendix B contain excellent information on building science and house system interactions. EEBA has more detailed information on building failures, along with their causes and solutions.

FIGURE 3.1

The House as a System



A house is more than just a collection of parts. The structure and mechanical systems interact with the occupants, with each other, and with the immediate surroundings in numerous complex ways.