Municipal
Code Enforcement Officer
Training & Certification
Program

Building Standards

Energy Conservation

A CEO Reference Guide

State of Maine
Executive Department ~ State Planning Office
November 2000

Building Standards: Energy Conservation

This CEO Reference Guide should be used in conjunction with the Maine DECD Energy Conservation Division's publication:
Maine Guide to Energy Efficient Residential Construction
A Manual of Accepted Practices, 2nd Edition

First edition content developed by:

Andrew P. Wynn
Energy Conservation Division
Maine Department of Economic & Community Development

First edition editing by:

Linda J. Butler
CEO Training & Certification Program
Maine State Planning Office

Prepared for:

Municipal Code Enforcement Officer
Training & Certification Program
Maine State Planning Office

First printing: February 1992
Revised: November 1995
Second Printing: 1997
Third Printing: November 2000

ACKNOWLEDGMENTS

The Energy Crafted Home Program, a program to promote energy efficiency in new home construction, sponsored and funded by:

> Boston Edison Company; The Western Massachusetts Electric Company; Massachusetts Electric Company; Narragansett Electric Company; Commonwealth Electric Company; Cambridge Electric; Eastern Edison Company; Newport Electric Company; and Blackstone Valley Electric.

Central Maine Power Company:

> Good Cents Field Guide, a builders guide to energy efficient residential construction to meet the Good Cents Program guidelines.

Dedication

Andrew P. Wynn
1941 – 1997

This training manual is dedicated to Andrew P. Winn, energy specialist, colleague and friend, who died unexpectedly in January 1997. Andy coordinated the writing of the previous edition of this manual; he truly "owned" the information herein. He possessed an ecological stewardship that challenged those of us who knew him to see our work not so much as a career, but as a calling. It is with such spirit that this manual is made available to you.

CONTENTS

EDUCATIONAL OBJECTIVES

A number of major elements have been identified in this material as those which the reader should understand and retain a working knowledge of. An effort to highlight these elements within the material has been made. The following objectives are based upon these selected elements. They are presented here to help the reader organize his or her study of the topic and to assist the applicant for Basic Certification in preparation for the Building Standards Examination.

1. Know that any house operates at an equilibrium relative to energy. Energy is constantly put into it and energy constantly leaves.

2. Understand by what three mechanisms heat can be transferred from warm areas to cooler areas.

3. Be able to define conduction, convection, and radiation.

4. Be able to list the five basic factors affecting heat loss.

5. Be able to define what R-value is.

6. Be able to define what U-value is.

7. Be able to list the primary sources of moisture in a home.

8. Be able to define bulk moisture and capillary moisture.

9. Understand that the amount of water vapor a volume of air can hold is dependent upon air temperature; and that warm air an hold more water vapor than cold air.

10. Be able to describe the two primary ways by which water vapor can enter wall cavities.

11. Know which of the two ways by which water vapor can enter wall cavities is most significant to energy efficiency in a building.

12. Be able to describe the function of a vapor barrier and where in a wall assembly it should be installed.

13. Be able to describe the purpose of roof ventilation and what the basic physical requirement is on a building that allows ventilation to occur.

14. Understand the purpose of installing a mechanical ventilation system during construction of a building.

15. Know which, infiltration or exfiltration, may lead to moisture problems in a building and how this occurs.

16. Be able to define ACH (air changes per hour).

17. Know what two factors most significantly influence air leakage in homes.

18. Be able to briefly describe the four factors that control the pressure difference across the building envelope.

19. Know to what type of buildings the standards ASHRAE 90.1-1989 and ASHRAE 62-1989 apply in the State of Maine?

20. Know whether it is the responsibility of a building inspector to determine compliance of building design with ASHRAE 90.1 standard.

21. Be able to list the types of structures that must be in conformance with the residential energy efficiency standards.

22. Be able to define “substantially renovated” for the purpose of determining whether a multi-family dwelling must comply with the residential energy efficiency standards of the State of Maine.

23. Know whether a multi-family residence with at least 3 dwelling units must conform to any provisions of the ASHRAE 90 standard.

24. Know who is responsible for the general enforcement of the energy efficiency standards of the State of Maine.

25. Be able to describe the enforcement tool which the ECD may use to achieve conformance with State energy efficiency standards.

26. Be able to discuss what a CEO might do to encourage compliance with State of Maine energy efficiency standards.

I. INTRODUCTION

Energy efficiency in building construction has been an issue since the mid 1970's when concern about the continuing availability of reliable oil supplies and stable energy prices were forced upon us by the 1973 oil crisis. In spite of a recent history of oil price stability, other issues, such as escalating electricity costs, energy independence and concerns about environmental degradation, have kept energy efficiency issues in the forefront. In 1989 commercial, institutional, and residential buildings accounted for 36% of the primary energy consumption in the United States. The U.S. Department of Energy has a goal, for the year 2030, of increasing building energy efficiency so that even with an approximate doubling of economic growth there will be no increase in building energy consumption.

Maine has been slow to respond to the need for more efficient construction standards, and reluctant to impose the initial cost of this efficiency through regulation. Today, even with mandatory standards in place for commercial, institutional, and some residential construction, enforcement remains an issue. The local code enforcement officer can make a contribution in this respect. While responsibility for enforcement rests with the State, local procedure for the review and enforcement of other standards lends itself to easily include energy standards. Direct involvement with the standards will be limited. However, code enforcement officers should be aware of the requirements and aid in the education of designers, developers, builders and property owners.

The purpose of this manual is to familiarize code enforcement officers with current energy efficiency standards, both mandated and voluntary, and to provide a background in the basic science, which supports the concepts of energy efficiency. Resources of information are reviewed which include materials and methods used to achieve compliance with established standards. The issue of compatibility of these energy standards with national construction, safety, and access codes is covered. Enforcement of the standards is discussed.

The study of energy efficiency is technical and, at times, complex. This manual is not intended to instruct for the purpose of creating energy experts. Rather it is intended to provide a foundation of knowledge in the efficient use of energy in buildings. This will help local code officers understand the relationship of energy efficient techniques to the other aspects of the buildings they inspect.

Please note that this manual is intended to be used with the DECD Energy Conservation Division's publication *Maine Guide to Energy Efficient Residential Construction/A manual of Accepted Practices (2nd ed.)*

II. ESTABLISHMENT OF STANDARDS

In 1976, Congress directed the Department to establish national building energy efficiency standards for all new construction. In 1979, in order to forestall the imposition of federal standards, the Maine Legislature established voluntary standards that applied to new residential, commercial, and institutional building construction or substantial renovation. The State was responsible for administration and enforcement of the standards.

There was continued pressure on the Legislature to impose mandatory standards on new construction. In 1985, the Legislature require the Office of Energy Resources (OER) to develop regulations mandating minimum energy efficiency standards for all buildings, except single family residential, that were constructed or substantially renovated using any public funds. Municipalities were required to forward to the OER a "Notice of Intent" certifying the owner's commitment to comply with the standards. **Effective January 1, 1989 mandatory minimum standards for some new residential and all new commercial and institutional buildings, regardless of the source of funds, were adopted.** In April of 1989, the separate requirements for publicly funded buildings were repealed, thus eliminating the requirement for notification from municipalities.

Budget cutting measures led to the termination of the Office of Energy Resources effective January 1, 1990. **Responsibility for administration and enforcement of the energy efficiency standards was transferred to the newly created Energy Conservation Division in the Department of Economic and Community Development. Information or assistance with the energy efficiency standards can be obtained from this Division (telephone 287-8457 or 5714).**

Further modification was made to the standards, effective January 1, 1992. It is prohibited to install a primary electric heating system in multi-family residences constructed, renovated or remodeled with the use of any public funds.

III. ENERGY OVERVIEW

There are laws of physics which govern how energy is used in buildings. Understanding these principles and how they interrelate provides a background for evaluating techniques used to minimize energy use and the impact these actions may have on other components of the building. Unfortunately, we have a history of not rigorously analyzing building energy flows, and of designing techniques that address symptoms rather than the causes of high-energy use. At times, this has led to conflicting recommendations and confusion as to which techniques should be employed. Our understanding of these forces is constantly changing and expanding. This section will present the current level of understanding. Although this section discusses these principles as they affect houses, these same forces affect all buildings in the same ways, so try to concentrate on the principles and recognize how they are important in the design and construction of buildings.

THE HOUSE AS A SYSTEM

As few as ten years ago, builders looked at each part of a house, the foundation, floors, walls, roofs, windows and doors, plumbing and electrical systems, separately. Each component was designed with little regard for the way it affected the rest of the house and its functions.

We now know that **it makes more sense to look at the house as an interrelated system of people, building and environment (both local and global).** The house must provide an interior environment that is safe, healthful, and comfortable. The house itself must be durable and affordable, both in terms of initial cost and operating cost. Additionally, we expect that the house will not harm either the local or the global environment.

A house consists of an envelope and the sub-system it contains. We can look at the envelope as consisting of assemblies of parts and the sub-systems as a groups of components. These all interrelate to one another. A change to one part or component will affect the assembly it belongs to which will in turn affect the other assemblies or sub-systems.

The sub-systems are interconnected by the basic physics of airflow, heat flow and moisture flow. An understanding of these processes help people create houses that allow for improvement of control over the interactions of people, building and environment, regardless of the changes that take place in building materials, components and practices.

The building of a house will sometimes lead to conflict among the needs of people, the building, and the environment. Consequently, we have to establish priorities. A general view of our priorities considers the needs of people before the needs of buildings and those of buildings before the outdoor environment; we consider local concerns before regional or global; and we look at short-term concerns before long term ones.

Some of the many issues are:

People Priorities

- Safety – fire, smoke spread, security
- Health – indoor air quality

- Comfort – temperature, healthful humidity, odors, sound, vibrations, natural light
- Affordability – purchase price, cost to live in the house

Building Priorities

- Durable – moisture protection, and ability to dry out if it does get wet
- Maintainable – moisture again
- Adaptable to new occupants and conditions
- Decommissioning – won't cause harm when useful life is done (building is replaced)

Environmental Priorities

- Energy usage minimized – global warming
- Construction waste
- Storm water run-off
- Household waste
- Soil erosion
- Air pollution from heating system (wood stoves, fireplaces, etc.) – particulates and global warming
- CFC free materials – ozone depletion
- Embodied energy of building materials and energy to operate the building (embodied energy is the energy used to extract, transport, manufacture a product) – global warming.

Materials

- Functional
- Low toxic risk from its use, for example it doesn't off gas toxins into the interior environment (a roofing material or exterior wall sheathing that off gasses a toxin is less of a concern than interior materials that off-gas the same toxins)
- Rate of off-gassing of volatile organic compounds – the higher the rate the lower the exposure to the occupants and the higher to the workers.
- Recycled products – plastic or metal studs instead of wood

Code enforcement officers are accustomed to working with this concept. The short-term health and safety hazards (fire, for example) are of higher concern than long term ones (radon gas). Difficulties arise when basic information is not adequate. This manual provides a foundation in principles and illustrates techniques that take our general priorities into account.

The following is a summary of "house is a system" approaches to constructing and operating a building. Although all of the issues are not discussed thoroughly, the many issues suggested for consideration when deciding how to build a house include the following:

Health and Safety: Houses should exclude pollutants from conditioned spaces. This is accomplished by:

- Appropriate selection, installation, operation and maintenance of heating, cooling and ventilating equipment

- Controlling the air pressures between the conditioned and unconditioned spaces, as between rooms and interstitial spaces
- Appropriate selection, installation, and maintenance of building materials
- Appropriate maintenance and housekeeping practices.

Houses should be operated in a manner that removes pollutants from conditioned spaces. This is accomplished by the use of controlled mechanical ventilation. Building envelops and mechanical system ductwork should be constructed in a leak free manner in order to control air pressure differences.

Comfort: Houses should be comfortable with respect to temperature, humidity, odors, sound/vibration and light. This is accomplished by:

- Utilizing thermal insulation
- Efficient space conditioning systems
- Leak free building envelopes and mechanical system duct work
- Controlled mechanical ventilation and exclusion of pollutants
- Efficient glazing system design and lighting
- Appropriate operation, maintenance and housekeeping practices.

Affordability: Houses should be efficient with respect to their use of energy water and materials. This is accomplished by:

- Utilizing thermal insulation
- Efficient space conditioning systems, equipment and lighting
- Efficient glazing systems
- Controlled ventilation
- Controlling building envelop air leakage
- Optimizing orientation
- Optimizing landscaping
- Low flow water fixtures and appliances
- Selecting appropriate materials and construction, operation and maintenance practices.

Useful Service Life: Houses should be durable. This is accomplished by preventing houses from getting wet during construction and during their useful service life by appropriate design, construction, operation and maintenance. Houses, assemblies and materials should be allowed to dry if they get wet during construction and during their useful service life.

Environment: Houses should be built and operated with a minimum of waste. Materials should be selected with respect to their local and global impact. Houses should be constructed, operated and maintained so as to:

- Reduce construction water
- Reduce operating water
- Recycle construction waste
- Recycle operating waste

- Control soil erosion during site preparation and construction
- Infiltrate storm water back into site
- Control air pollution during construction and operation
- Avoid ozone depleting materials and systems
- Use materials from managed forests and managed mineral extraction and processing
- Reduce operating and embodied energy

ENERGY FLOW IN BUILDINGS

Any house operates at an equilibrium relative to energy. Energy is constantly put into it, and energy constantly leaves. Imagine the house as a container into which water (energy) is constantly poured (**Figure 1).** In an inefficient (leaky) house, the energy rapidly leaks out, so a lot must be poured in. With an energy-efficient house, the quantity of energy flowing in and out is much smaller.

Energy Flows In

There are several ways that energy gets into a house:

- **Purchased Fuel for Heating and Cooling –** This is the energy input that immediately comes to mind: the electricity, oil, gas, or wood used for space heating and the electricity (in some cases, gas) used for cooling. This energy input is pretty easy to measure – fuel delivery bills, electric or gas utility bills, and/or cords of wood.

- **Electricity for Appliances, Lighting, etc. –** In very energy-efficient houses, the energy input for appliances, lighting, etc., could become as large as (or even larger than) the energy input specifically provided for heating and cooling. This electrical energy often ends up as heat (called internal gains).

- **Internal Gains From Occupants –** Though relatively minor in significance, each occupant adds heat to a house through metabolic processes. Combined with the waste heat from appliances and lighting, these internal gains can reduce heating requirements significantly, and in a very energy efficient house they may provide all the heat needed during much of the heating season.

- **Solar Gains –** Sunlight shining through the windows and glass doors or indirectly provided via solar collectors, is the other major energy input into houses. We can optimize a house design to make use of this free energy source during the winter and to keep it out during the summer (when it can add to cooling requirements).

Energy Flows Out

All of the energy that flows into a house eventually flows out. In the case of electricity, the energy is usually first converted into heat. (Incandescent light bulbs, for example, give off 90% of their input energy as heat, and only 10% as light. Eventually, even that light is converted into heat) How readily that heat leaks out of a house depends on how energy-efficient the house is.

Mechanisms of Heat Transfer

Heat moves from warm areas to cooler areas. This heat can be transferred by three mechanisms: conduction, convection and radiation.

- **Conduction:** is the movement of heat through a solid material. Conducted heat travels in any direction. Conduction moves the heat from a stove burner through a cooking pan and through its contests to warm it. The R-value of an insulating material is its resistance to conductive heat loss. (A more complete discussion of R-value is provided later in this section.) Insulation is installed in walls and ceilings to reduce the conductive heat loss from houses.

- **Convection:** is the movement of heat from one location to another in a fluid such as air or water by the movement of that fluid. Forced convection is at work in a warm-air heating system when heated air is pushed through ducts by a fan. Natural convection is at work in a hollow wall cavity when circulating air carries heat from the warmer side to the cooler side (see **Figure 2)**. As the air is warmed, it becomes less dense and rises, fueling this convective loop (heat does not rise, but hot air does).

  Infiltration and exfiltration of air through the building envelope (outer shell) transfers heat into or out of the building envelope by convection. In this case, the convection currents are from the weather, wind, drafts, and pressure differences on each side of the shell. During the winter months, we want to block the flow of warm air out and cold air in. During the summer months, we may want to block the flow of warm air into the building during the day, but we can also use convection to cool the house at night by opening windows and allowing the cool outdoor air to replace the warm indoor air. All of this heat transfer occurs by convection.

- **Radiation –** is the movement of heat from a warmer object (mass) to a cooler object or mass by the transfer of heat waves or radiation. Radiative heat transfer does not affect the air between the heat emitting and the heat absorbing objects. For example, a wood stove radiates heat throughout a room. Any object within direct reach of the heat waves fro the stove can absorb the radiant warmth.

  There are different forms of radiation with different energy levels. Light from any source, such as the sun or a lamp, has relatively short wavelengths. Heat radiation has relatively long wavelengths. Once light strikes an opaque surface, its energy is converted into heat energy. Simplified, the solar energy transmitted through windows provides passive solar heat. Recently new window technology (low emissivity glazing) has been developed which allows long wave light radiation to pass through windows, but reflects short wave heat radiation, thus improving the ability of buildings to use passive solar heat. From a heat gain point of view, the sun’s radiant energy is very important for both heating and cooling.

Factors Affecting Heat Loss

Building design and construction materials and methods affect heat transfer in buildings. Attention is focused on reducing heat loss during the heating season. **Heat loss is a function of five basic factors:**

1. **Surface Area –** Heat escaping from a house must pass through the building envelope. The greater the surface area of that envelope, the more heat can pass through. A boxier two story house has less surface area of envelop for a given floor area.

2. **Temperature Difference –** Heat always moves from areas of higher temperature to areas of lower temperature. The amount of temperature difference between the inside and the outside of a house will determine the rate at which the heat energy moves. A greater temperature difference results in more rapid heat loss. There is one reason why turning down a thermostat saves so much energy.

3. **Time –** Since energy movement occurs over time, time becomes a factor in the heat loss equation. It is possible to shorten the amount of time that a building is heated at a given temperature level, for example, by using a set back thermostat. This reduces the time that higher temperatures are maintained within the home, and reduces transfer.

4. **Thermal Resistance -** The thermal resistance of building materials is expressed as the R-value. The higher the value, the greater the resistance. All materials have some resistance to heat loss; bust most structural materials have relatively low R-values. Insulation materials have higher R-values and are designed specifically to reduce the rate of heat loss through the building shell.

5. **Air Leakage –** Air leakage, which is often referred to as infiltration, occurs in all homes. As outside air enters the home, it must be heated or cooled for comfort. In many homes, the rate of leakage accounts for 30% or more of the space-heating load. Leakage is a form of convective heat loss and depends on the size and location of leaks, wind speeds, temperature differences between indoor and outdoors, and the design of the house. As thermal resistance is increased through greater levels of insulation, conductive heat loss is reduced and heat loss due to air leakage becomes proportionally greater.

HEATING SYSTEM EFFICIENCY

There are many factors that influence the efficiency of heating systems. New boilers and furnaces are available with AFUE's (Annual Fuel Utilization Efficiency) in the range of 85% and higher, a significant improvement over the standard 80% units. The affects of distribution systems are demonstrated in the discussion of possible infiltration induced by forced air systems. Equipment over sizing will lead to excessive system cycling and inefficiencies.

Radiant slabs are increasingly popular distribution systems. They provide comfortable even heat distribution, but generally do not themselves lead to reduced heating costs. Radiant heat will provide comfort at lower temperature settings than systems that rely on heating air. However, unless the system is operated in a manner which uses this attribute operation costs will be about the same as for other distribution systems.

System layout and controls also influences energy efficiency. Multiple zones allow customizing heating patterns depending on the use of different areas of the building. Programmable thermostats allow the automatic use of lower temperature settings when occupancy patterns permit, such as at night when people are sleeping and when the building is unoccupied.

Individual room space heaters have become popular in energy efficient homes with open floor plans. Some of these units are quite efficient and they may eliminate the need for a chimney.

Sealed combustion is a desirable feature especially for its indoor air quality benefits. Sealed combustion units draw their combustion air supply directly from outside, and exhaust flue gases directly to the outside. This reduces the chances for flue gas to back draft into the building.

Ground Source Heat Pumps (GSHPs) are receiving much attention nationally and by Maine electric utilities. Heat pumps efficiently extract heat energy from one source and augment it to supply heat to another location. GSHPs use either water or tubing laid in the ground as the heat source. Because of high installation costs it is not clear whether or not these systems are cost effective in Maine.

WHAT’S AN R-VALUE, ANYWAY?

R-value is the resistance to conductive heat loss. Insulating materials have relatively high R-values, while many other building materials, such as concrete; aluminum and wood have much lower R-values. Even among insulation materials, there are significant differences in the R-value of the products.

While the R-value is the measure of resistance to heat flow, the inverse of R-value, called U-value is a measure of the number of BTUs that will flow through a square foot of the material for each degree Fahrenheit difference in temperature from one side to the other in an hour. (Btu/ft^2 F hr) This is the term used in most heat loss calculations. A wall system with a high R-value has a very low U-value because U=1/R. The lower the U-value, the less heat moves through the material.

The relationship between the R-value (or U-value) and heat loss is direct. A wall system that has twice the R-value (or half the U-value) will only allow half as much heat through. An R-22 wall (U=.045) is twice as energy efficient than an R-11 wall (U=.091). The R-22 wall will lose .045 Btus of heat per square foot of area for each degree Fahrenheit difference in temperature between the inside and outside, while the R-11 wall will lose .091 Btu/ft^2 F hr.

When considering what wall or ceiling system to design into an energy-efficient home, the R-value of that assembly is critically important. The R-values of different materials may be referenced in various tables available in construction and energy publications. R-values are presented either for a specific thickness of material or on a per inch basis. With plywood, it makes sense to look for an R-value figure for the specific thickness of plywood you are using (say ½” or 5/8”). With other materials, such as loose fill insulation and wood, it often makes more sense to use the per inch R-value number and multiply it by the thickness.

Tables that list U-values distinguish between *conductivity (k) and conductance* ©. Conductivity (k) is the U-value of a 1” thickness of material, while conductance © is the U-value of the thickness listed. Unlike R-values, with U-values you cannot find the overall U-value of a material by multiplying the per inch conductivity (k) by the thickness. Nor can you add U-values, as you can R-values. To determine the overall U-value of a building section or assembly, you must total the R-values of each component and then calculate the inverse of the overall R-value. To do that, you need to first calculate the inverse R-Value. Most tables stick with R-values, but keep the differences in mind if you find yourself using a table of conductivities (k-values) and conductances (C-values). Also, some manufacturer's specifications will list k or C-values instead of R-values.

WINDOWS

Windows have the unique quality that they can be both heat producers and losers. New technologies mean that windows have greatly improved window performance to the point where north-facing windows can at times produce solar heat gains even in the winter.

Windows transfer heat energy into a building by allowing light waves into the space, which are converted directly to heat when they strike any opaque surface. They lose energy by conduction, convection and radiation.

A window unit is characterized by three areas of heat loss: the frame, the edge band (approximately 2 inches wide) and the center of the glass. The relationship of these areas has been recognized by the National Fenestration Rating Council so that all new window units now have a label showing its unit U-value. This rating does not take into account solar heat gain or infiltration, but those concerns are being addressed.

Center of glass R-values have progressed to the point where R-10 is readily available. However, the edge and frame losses significantly lower overall unit R-values by 30 to 50%. Higher center of glass R-values have been achieved by applying "selective surface" coatings to the glass. These coatings allow light waves to pass through, but do not allow heat waves. By placing several layers of these selective materials in a window R-values can be greatly increased. These coatings do reduce solar heat gain somewhat, therefore some designers specify higher light transmitting glass to promote solar heat gains.

Another technique used to improve center of glass R-values is to inject an inert gas usually argon, sometimes krypton, between the glass layers. These heavier than air gases reduce convention heat transfer between interior and exterior panes.

Edge losses are being reduced by the use of new low conduction spacers between the panes of glass.

IV. MOISTURE CONTROL

Moisture is one of the most confusing and most difficult problems in homes. Houses are becoming tighter partly because of the desire to improve energy efficiency, and partly because of changes in building construction practices, such as the use of composition board sheathing. If care is not taken during the design and construction of a house, moisture can cause considerable problems. Moisture will reduce the insulating value of many types of insulation. Condensation on wall surfaces can promote mold and fungus growth. Severe moisture problems in wall and ceiling cavities can cause rotting and structural damage.

MOISTURE SOURCES AND MOVEMENT

Tow things must be considered when dealing with moisture. These are where the moisture originally comes from, i.e., how it gets into a house in the first place and then how it gets from the house into wall and ceiling cavities where it can cause damage. **The primary sources of moisture in a home are as follows:**

Bulk moisture is a relatively large quantity of water that finds its way into improperly sealed areas. It consists primarily of rain and snow falling on a house and groundwater or runoff. Leaky pipes in the house can also introduce bulk moisture. Gravity and wind are the primary forces at work in bringing bulk moisture into a house. (See **Figure 3**.)

Capillary moisture enters a house primarily by seeping (capillary action) through a floor or wall that is in direct contact with the ground. Capillary action sucks up water through microscopic spaces much like those of a sponge, concrete, or wood. Basement floor slabs and earthen crawl space floors are the most common locations where capillary moisture is introduced. As the moisture reaches the floor or wall surface it usually evaporates, so it is not readily noticeable. When a basement slab is built on damp ground and there is no moisture barrier under the slab, capillary moisture can be a significant source of moisture in the home. Capillary moisture can also migrate into a house through framing members in contact with concrete.

Another place where capillary is a common phenomenon is where boards lap tightly, such as with clapboard siding. When water strikes the siding by such sources as rain, splashing, or lawn watering, some water is sucked up between the boards.

*******CHART*******

Household Activities such as breathing, bathing, cooking, clothes washing and others introduce moisture to houses. In some cases, without proper ventilation, these activities can create high enough humidity levels to cause problems. Storage of firewood in a home can introduce hundreds of gallons of moisture to a house.

Building Materials and Furnishings contribute moisture to a house in two ways. When a house is first built, concrete, drywall compound, certain insulation materials and framing lumber can release large quantities of moisture into the house. Once these materials have stabilized, they will still absorb and release moisture on a cyclical basis. When indoor humidity is high, building materials and furnishings absorb moisture; when indoor humidity drops, they release moisture. Sometimes called seasonal storage, this absorption and release of moisture tends to reduce rather than contribute to moisture problems.

Table 1.

Daily Moisture Sources in a Typical House			
From the Occupants		**From the Building**	
Four occupants	1.3 gal.	Earthen-floor crawl space Without moisture barrier	10-13 gal.
Indoor clothes drying	.3 gal.	New construction – drying of Concrete, drywall, lumber (over first 11/2 yrs)	1-1.3 gal
Cooking (3 meals/day)	.26 gal.		
Dishwashing (3 meals/day)	.13 gal.	Seasonal storage (framing drywall, concrete, etc.)	2.1 gal.
Floor washing (100 sq. ft.)	.25 gal	Drying and burning firewood	1.3 gal

Keeping Bulk Moisture out of walls and Roofs

Bulk moisture can get into wall and roof assemblies from the outside by improper roof, wall, and window flashing, poor weatherization details, and poor quality or improper installation of roofing and siding materials. These problems can be avoided by following accepted construction practices, most of which are beyond the scope of this manual. Care should be used when installing plumbing to avoid leaks, and pipes should be installed where they cannot freeze.

In Maine, ice dams are responsible for causing water leakage into houses. Heat escaping through the roof can melt snow on the roof. When this water reaches the cold eaves, it freezes, creating a dam that backs up water behind it. Ice dams are less common in well-insulated homes, but they should be planned for nonetheless.

Reducing Bulk Moisture Movement Through Foundation Walls

Keeping water out of foundation walls requires several different strategies that are familiar to most building inspectors.

- The outside of the foundation wall should be sealed with a damp-proofing layer or a continuous waterproofing layer.

- Clean free draining material should be provided as backfill against the foundation wall. In very damp soils, a specialized drainage layer along the outside of the foundation may be necessary.

- Perimeter footing drains should be installed around the entire foundation. These should drain to daylight, a large drywell, or a sump with pump. Footing drains should be surrounded with clean stone and protected from silt with a filter fabric.

- A roof overhang or gutters with downspouts should be provided to keep rain dripping off the roof as far from the foundation wall as possible. Gutters should not be connected to a foundation drain, but separate drainage for gutters is recommended.

- The ground surface should slope away from the building at a minimum 5% grade (6” over 10’).

- Low permeability soil (high clay content) or a moisture barrier membrane may also be placed beneath the top layer of soil for several feet out from the house during backfilling.

Reducing Capillary Moisture Migration

The entry of moisture into a house by capillary action is more difficult to see, so it is often overlooked. This may be adequately prevented by:

- Sealing outside of foundation wall with damp-proofing coating.

- Backfilling with good drainage material.

- In wet soils, installing a specialized drainage mat on the outside of the foundation wall.

- Providing a 4” layer of clean uniform-size stone under a concrete floor slab.

- Separate siding laps slightly by use of round head nails or small wedges.

- Installing a polyethylene moisture barrier under a concrete floor slab. This also helps reduce radon migration. This should be protected by a 2” to 3” layer of sand or by rigid insulation. Sand also facilitates concrete curing.

- Installing a black polyethylene moisture barrier on top of the ground surface in crawl spaces and extending the concrete walls up to grade level or slightly above. This also helps to reduce radon migration. Use black plastic to prevent plants from growing beneath it. Stones or dry sand placed on top of the plastic will help to keep it in place.

- Using pressure-treated wood as a sill over concrete foundation walls and slab floors. Install an asphalt shingle or other capillary break under wood posts, pier foundations and structural beams inset into pockets in the foundation wall (See **Figure 4**).

- Minimizing water splashing onto sidewalls by having foundations extend a minimum of 8 inches above finished ground level and installing gutters.

- Use “vented rain screen” wall construction.

WATER VAPOR

Dealing with liquid water is relatively straightforward. Once water evaporates and becomes vapor, its behavior and control become more complex. Water vapor (as a gas) causes no problems in a building. A problem occurs when conditions allow water vapor to condense (return to a liquid state). **To better understand problems with water vapor and condensation, the following review is provided.**

Relative Humidity, Dew Point and Condensation

All air contains some water vapor. The amount of water vapor a volume of air can hold depends on air temperature. Warm air can hold more water vapor than cold air. When a volume of air is saturated, it cannot hold any more water vapor. At 70ºF, for example, a cubic foot of air can hold .00118 pounds of water vapor at saturation. Relative humidity expresses the amount of water vapor in a volume of air relative to the total amount that air could hold at a specific temperature – the percent saturation at a given temperature. If a cubic foot of air at 70ºF is at 40% relative humidity, it holds 40% of the water vapor it could hold at saturation (.0018 lb X .40 = .00047 lb).

******CHART********

When this same air is cooled, the amount of water vapor it can hold decreases and its relative humidity increases. When the cubic foot of 70ºF air at 40% relative humidity is cooled to 50%F, its relative humidity increases to 80% (the actual amount of water vapor in that air remains the same). When the air is cooled further to 43ºF, it reaches its saturation point, or 100% relative humidity. This is called the *dew point* temperature. When the air is cooled further, water begins to condense out in liquid form.

This vapor science impacts a building's energy efficiency. During the winter, it is much cooler outside the house than inside. If warm air containing water vapor is able to move through the wall cavity toward the outside, it will cool down. Depending on the initial relative humidity of the air and the outside temperature, the dew point may be reached inside the wall cavity (See **Figure 5**). When moisture condenses it will happen on solid surfaces, such as glass fibers, sheathing, etc. Moisture condensing in the insulation will reduce its insulation ability and potentially cause rotting of framing members.

How Water Vapor Gets Into Wall and Ceiling Cavities

Water vapor can get into wall cavities in two primary ways: by diffusing through materials that are permeable to water vapor, and by air flowing into or through the wall.

Diffusion

Water vapor is a gas and this enables it to pass through many materials that seem to be solid. The ability of a material to allow water vapor to pass through is its *permeability* and is measured by a *perm rating*. *Perm ratings* of different materials are listed in **Table 2.** Materials with high perm ratings allow water vapor to move through relatively easily, while materials with low perm ratings retard water vapor diffusion. In general, **materials with perm ratings below 1.0 are considered vapor retarders or vapor barriers.**

Water vapor will diffuse through a high permeability material when there is a vapor pressure driving force. Vapor pressure is dependent upon the difference in relative humidity and temperature from one side of a wall to another. The vapor pressure driving force is generally toward the inside of the wall assembly. In winter, it comes from the indoors. In the summer, if the outdoor air is very humid and air conditioning is being used indoors, it can come from the outdoors. Refer to **Figure 6.**

AIR LEAKAGE

Ten years ago, diffusion was thought to be the primary means of moisture migration into wall and ceiling cavities. Tremendous emphasis was put on vapor barriers as a way to retard this water vapor diffusion. **Today we know that air leakage is actually a far more significant path for moisture migration into wall and ceiling cavities.** Studies have shown that as much 100 times the moisture moves into the building shell by air movement as it does by diffusion. A 10’ by 10’ wall section consisting of painted drywall (no vapor barrier) will allow, in a heating season, about 2/3 of a pint of water diffuse through it in a typical New England climate, while in a ½” hole in the same wall can transmit as much as 50 pints of water per season via air leakage. See **Figure 7.**

Table 2.

Perm Ratings of Common Materials

Type	Material	Perm Rating
Masonry	Concrete block (8”)	2.4
	Brick masonry (4”)	0.8
Exterior Wall Materials	Plywood (exterior)	0.7
	Pine (tongue-and-groove)	4.5
	Clapboards	5.4+
Interior Wall Materials	Gypsum drywall (1/2”)	40.0
	Plywood (interior)	1.9
Insulation	Extruded polystyrene (1”)	1.2
	Expanded polystyrene (1”)	2.0 - 5.8
	Unfaced batt insulation	30.0
	Urethane foam 1” (unfaced)	1.5
Vapor Retarders	Polyethylene (4-mil)	0.08
	Cross-laminated polyethylene (4-mil)*	0.08
	Polyethylene (6-mil)*	0.06
	Reinforced Aluminum foil (1-mil)*	0.0
	Foil facing on batt insulation	0.5
	Kraft facing on batt insulation	1.0
	Foil facing on rigid insulation*	0.0
Paints and Wallpaper	Latex primer-sealer	6.3
	“Vapor retarder” paint	0.45
	Primer plus one coat flat oil paint on plaster	1.6 – 3.0
	Enamel paint on smooth plaster	0.5 – 1.5
	Standard wallpaper	20.0
	Vinyl wallpaper	1.0
Papers and Housewraps	15-lb building felt	5.6
	Air barrier (Tyvek®, Typar®, etc.)	10-40

*When properly sealed, these materials can serve as both the air barrier and vapor barrier according to ENERGY CRAFTED HOME specifications.

Strategies to reduce moisture migration into wall and ceiling cavities and to get rid of any moisture that does get into the cavities are described below:

- **Install a polyethylene vapor barrier on the winter warm side of the wall and ceiling system, usually between the framing and drywall.** The vapor barrier can be installed up to one-third of the way into the insulated wall system, which sometimes makes sense in double 2 X 4 wall systems. The vapor barrier does not have to be painstakingly sealed if other building shell assemblies (drywall, framing, band joists, sill plate, etc.) are made tight, providing an air barrier. If the vapor barrier is well sealed during installation (edges of overlaps taped or caulked and penetration/tears sealed), this layer can also serve as the air barrier i.e., a single layer can serve both functions. When a single layer is used to stop both airflow and vapor diffusion it is referred to as an air/vapor barrier.

- Or, install foil-faced rigid foam insulation on the inside of the wall and ceiling framing. By properly sealing the joints and edges with vapor barrier tape and/or non-hardening sealant, this foil facing serves as both vapor diffusion retarder and air barrier

- If possible, design the wall and ceiling systems so that the innermost layers are the least permeable to moisture and the outer layers are progressively more permeable. There is some controversy about where to apply foam sheathing on walls, however, most experts recommend that it is better placed on the inside of the wall system than on the outside. Then gaps should be left between sheets of exterior plywood sheathing to allow trapped moisture to escape.

- Recommendations follow for **techniques to reduce air leakage through the building envelope. There should be at least one airtight barrier somewhere in the wall system. This air barrier can be anywhere in the wall, but the vapor barrier must be toward the winter warm side.**

- Provide adequate attic ventilation to get rid of any moisture that may get into the attic or sloped ceiling insulation.

- **Homeowners should keep the relative humidity levels of living space during the winter months between 40-50%.** From a health standpoint, humidity needs could range up to 60%, but this is beyond the limit a building can tolerate. A good compromise is 50%.

Venting Unwanted Moisture

Proper ventilation of roofs is usually recommended to carry away any moisture that may condense in the insulation. Equally important, roof ventilation usually plays an important role in preventing ice dam formation, and is recommended to reduce roof-sheathing temperatures thus prolonging shingle life. There is some current research, based on the physical principles of moisture movement and condensation, which suggests that venting may not be necessary to remove condensation in all roof designs. Roofs over cathedral ceilings and built-up roofs are examples of such designs. This is, however, new research and is not yet widely accepted.

Effective ventilation requires both inlet and outlet vents. The inlet vents should be at the bottom of the roof and the outlet vents at the top so that the natural buoyancy of heated air provides the driving force for the ventilation. Typical ventilation configurations for the most common roof designs are shown in **Figure 8.** Ventilation is most effective when there is a full ridge along the peak of the roof, as in gable and gambrel roofs. The inlet vents are provided as continuous soffit vents in the eaves, and a continuous ridge vent provides the outlet, as shown in **Figure 9.**
*********2 CHARTS**********

Gable-end vents can be used as the outlet vents in place of ridge vents, or as both inlet and outlet vents. Though not as effective as continuous soffit and ridge vents, gable end vents with continuous soffit (inlet) vents are usually satisfactory. Gable-end vents are least effective when used by themselves to provide both inlet and outlet ventilation.

Proper ventilation of mansard and hip roofs is more difficult because there is not a continuous ridge running the full length of the roof. Cupolas and/or roof ventilators must be used as outlet vents at or near the peak of the roof.

Shed roofs that abut walls can be vented using specially designed venting products made for that purpose.

Inlet and outlet vent areas should be roughly the same. A general rule of thumb for the area required is one square foot of combined inlet and outlet vent (net free vent area) for every 300 ft² of ceiling area to be vented when a vapor barrier is installed. For example, if ridge and soffit vents are used in combination for a house with a 1000 ft² unheated attic, a total net free vent area of 3 1/3 ft² should be provided (1 2/3ft² each for the soffit and ridge vent areas). With insulated cathedral ceilings, the area to be vented will be greater by 10% to 50%, depending upon the roof pitch.

These rules of them refer to the net free vent area, which takes into account the area taken up by louvers and/or screening (see **Table3).** With 1/8" screening, for example, you need an actual vent area that is 1¼ times as large as the required net free vent area. With 1/8" screening and louvers, the actual vent area needed is 2.25 times as large as required net free vent area.

Table 3.

Net Free Vent Area	
Vent Opening Size Vent Screening	**Actual Opening Area Required To Provide 1 ft² of Net Free Vent Area (ft²)**
¼" Screen	**1.0**
¼" Screen w/louvers	**2.0**
1/8" Screen	**1.25**
1/8 Screen w/louvers	**2.25**
1/16th Screen	**2.0**
1/16th Screening w/louvers	**3.0**

To provide 3-1/3 ft² of net free vent area for the 1,000 ft² attic described above using louvered gable-end vents with 1/8" screening, you would need 3-1/3' x 2-1/4', or 7-1/2 ft² of total vent area. You could provide this with a rectangle vent at each end that is at least 3-3/4 ft² in total area (for example, a 2' x 2' vent).

With manufactured soffit and ridge vents, check the manufacturer's specifications to determine the net free vent area per linear foot. Two-inch wide pre-formed aluminum soffit vent strips typically provide 9 in² to 12 in² of net free vent area per foot of length. Ridge vents can provide as much as 18 in² of net free vent area per foot of length. With both soffit and ridge vents on a gable roof, you will typically get 27 in² to 30 in² of net free vent per foot of ridge. In a 28' x 36' house, with 36' of soffit ridge vents, the total net free vent area is calculated as follows:

> 36 ft x 30 in²/ft = 1,080 in², or 7-1/2 ft², which is adequate ventilation for either an unheated attic or an insulated cathedral ceiling.

If using screened disc vents in the soffits, be sure that an adequate inlet vent area is obtained. A 2" diameter hole with 1/8" screening provides only 2 ½ in² of net free vent area. Spacing these discs every 6" along the soffit provides 5 in² of net free vent area per running foot of soffit. This may meet the ventilation requirements, but the areas required should be calculated to make sure. Manufacturer's specifications for venting capacities should be consulted for the use of specialized vents, such as roof ventilators and turbine vents.

Insulating and venting cathedral or cathedralized ceilings poses several challenges. (Cathedralized ceilings is a term coined to describe attic spaces where the insulation is placed against the roof, rather than on the floor/ceiling.) Recent research studies indicate that traditional approaches to insulating and ventilating cathedral and cathedralized ceilings may need some modification.

In vented cathedral with fiberglass batts installed or fluffed to touch the roof sheathing, air leaks from inside the heated space increase sheathing moisture content to as much as 30%. Common features that provide air leakage pathways include most vented or unvented air space is maintained between the insulation and the sheathing, moisture levels equalize at non-detrimental levels. Additionally, these air leaks are known to contribute to ice dams.

This research leads to the conclusion that ventilation is not always necessary to prevent moisture damage to roof sheathing over cathedral ceilings. However, ventilating roof spaces to prevent ice dams is beneficial where practical. This warm roof concept shows promise for preventing moisture build-up above and below roof windows, and at roof hips and valleys where providing ventilation is quite difficult, at best. In those difficult to ventilate situations we must rely on adequate insulation levels and airtight interior surfaces to retard ice dams.

Roof ventilation may not be required in all roofs. If rigid foam insulation is installed in a built-up fashion between decking and roof sheathing, or if stress skin panels are used as the roofing, or if foam is sprayed directly on to the underside of the roof sheathing, there will be almost no air movement through the roof system and, therefore, little opportunity for water vapor to migrate and condense. In these situations, some builders and stress skin manufacturers recommend no ventilation (also called hot roof). Other experts and most shingle manufacturers, however, recommend venting these roofs. In fact, shingle warranties may be voided if the roof is not vented. Foam-core stress skin panel construction is becoming more common, particularly with timber frame buildings; whether these roofs should be ventilated is likely to be a subject of debate for some time.

Crawl-Space Ventilation

The need for crawl space ventilation is another subject of debate in the building industry today. Most experts and building codes recommend that crawl spaces be vented during the summer months to allow water vapor to escape. If a moisture barrier is used on the ground, one 8 x 16” vent is required for each 350 ft^2 of the floor area, according to this theory, with a minimum of four vents. Without a moisture barrier, the vent area should be at least twice that. Screened vents should be open during the summer months and closed in the winter.

There is growing concern about this recommended procedure, however. Some building scientists now recommend that crawl spaces and unheated basements, where a vapor barrier is used, **not** be vented during the summer. These experts argue that little moisture penetrates the moisture barrier on the ground and opening vents during the summer introduces more moisture than it gets rid of because the outside air has a high relative humidity. Because surfaces in the crawl space or unheated basement are generally cool, condensation can occur.

IV. AIR TIGHTNESS

AIR LEAKAGE CONTROL

The way to avoid heat loss and moisture transfer due to air flow is to eliminate uncontrolled air exchange (air leakage) by sealing potential air leakage points during construction and provide controlled air exchange instead, using a mechanical ventilation system.

When the air leakage is from the outside in, we call it infiltration. When it is from the inside out, we call it exfiltration. Either way it contributes to heat loss, but exfiltration may lead to moisture problems as moisture in warm air condenses on cold surfaces in walls and ceiling cavities. Infiltration and exfiltration are always in balance, with the same amount of air flowing into the house as flows out.

Significance of Air Leakage

In most older houses, a great deal of air moves in and out through the envelope: typically one-half to three house volumes of air each hour! And on the harshest winter days, with high wind conditions or frigid temperatures, it can get a lot worse. The greatest infiltration occurs at the worst time, adding more to the load at coldest conditions. All that incoming air has to be heated to room temperature. It takes .018 Btus of heat to raise the temperature of one cubic foot of air one degree Fahrenheit in an hour (Btu/ft^3 F hr). In an 1,800 ft^2 house with a volume of 13, 500 ft^3, one complete air change in an hour would, therefore, result in heat loss of 243 Btu/F hr (13,500 ft^3 x .018 Btu/ft^3 F hr). If it is 10 F outside and 70 F inside, it will take 14, 580 Btu/hr just to heat the incoming air (243 Btu/F hr x 60 F). That is in addition to the conductive heat loss through the walls and ceiling. If the same house had an air exchange rate of two complete volumes of air each hour, the heat loss due to air leakage would be 29, 000 Btu/hr under those conditions.

In a well-insulated home today, air leakage usually accounts for 35% to 40% of the total heating load – but it can be as high as 80% in some situations, especially when oversized, non-sealed-combustion equipment is used.

Not only does air leakage have a big impact on heating loads and energy bills, but it can also dramatically affect comfort. A draft-free home is more comfortable than a drafty one, in fact, homeowners, may be comfortable at a lower average air temperature if the house is free of drafts. **Figure 10** shows the common leakage areas in a house.

********CHART***********

Air leakage also has a big impact on humidity levels in houses, which affects both comfort and occupant health. During the winter months, the outside air is very dry. With high air leakage, a lot of that dry outside air is continually brought into the house and the indoor humidity remains very low. There are various health problems associated with low humidity, including numerous allergies and respiratory infections. There are equally serious problems with high humidity. Experts say that the ideal humidity level in a house (for health reasons) is between 40% and 60% relative humidity (although for the "health" (condensation control) of the building, humidity levels should be kept below 50%). In very leaky Maine houses, relative humidity levels are often as low as 20% in the winter.

Finally, air leakage is the primary culprit in moisture problems in wall and ceiling cavities. Moisture gets into wall and ceiling cavities as warm air passes from the inside to the outside. As previously discussed, condensation can occur in the wall or ceiling cavity as the temperature of the air moving through drops.

Measuring Air Leakage

Air leakage is measured in air changes per hour (ACH). This is the number of times each hour that the entire house volume of air is exchanged with outside air. It is an average value. If the entire house has an air exchange rate of .5 ACH, some rooms may have only one quarter ACH, while a front hallway may exchange its air every ten minutes.

Air leakage rates can be measured with a blower door. With a blower door test, a sophisticated fan is set up in a door of the house, as shown in **Figure 11**. The fan either pressurizes or depressurizes the house and the rate of airflow through the blower door required to maintain a specific pressure differential in the house (usually 50 pascals) is measured. The air leakage rate can be expressed in several ways. Some prefer to use the air exchange rate at 50 pascals (the number of air changes per hour at that pressure differential). Another measurement is the effective leakage area – the equivalent hole that would exist if all the cracks were added up, in square inches or square feet. The latter measurement can be expressed as a leakage ratio – the effective leakage area divided by the shell area of the house. Very energy efficient houses might be expected to have a leakage ratio at 4 Pa of no more than 1 in^2 per 100 ft^2 of shell area. Call the Energy Conservation Division for a list of energy audit contractors who provide blower door testing services.

********CHART**********

Factors Affecting Air Leakage

Air leakage in homes is influenced by two major factors: holes in the building envelope (intentional and unintentional) and the pressure difference, or driving force of airflow, across the envelope. Common holes or leakage areas in a house and how to seal them are addressed later in this chapter. But first, let's look at the factors influencing the pressure difference across the building envelope.

There are four factors controlling the pressure difference across the building envelope in all houses: wind, the stack effect, unbalanced ventilation, and combustion appliances. Additionally, recent research has discovered that in houses with forced air distribution systems (heating or air-conditioning) duct layout, duct leakage, and interior doors position far outweigh the other factors.

Wind will increase the pressure on the upwind side of a house, driving air into the house through any holes in the building envelope, as shown in **Figure 12.1**. On the downwind side, wind decreases pressure on the envelope, pulling air out of the house. The magnitude of this effect depends on the strength of the wind. You can reduce the effect of wind through proper siting of a house and landscaping.

Stack or chimney effect influences the pressure difference across the building envelope as warm air rises to the top of a room. This warmer, more buoyant air wants to escape out through the envelope at the top of the wall, while the negative pressure at the bottom of the exterior wall wants to pull outside air into the house, as shown in **Figure 12.2**. In two story houses with unimpeded airflow between floors or in rooms with tall cathedral ceilings, this stack effect can be quite significant. Because of the stack effect, proper air sealing around chimneys, and all plumbing, electrical, and duct penetrations through the ceiling vapor retarder is very important.

Unbalanced Ventilation occurs when exhaust fans are operated without an inlet fan or fans for supply of make-up air. It is known as *exhaust-only ventilation*. Bathroom exhaust fans, kitchen exhaust fans, and dryers are the most common examples of exhaust only fans in houses (see **Figure 12.3**). Using exhaust only fans will pull air out of the house, creating negative pressure.

In a 1,500 ft^2 house, for example, a 50 cubic-foot per minute (cfm) bathroom exhaust fan can increase the entry of outside air by 50%. Exhaust fans in downvented kitchen ranges can be as large as 400 cfm, which can dramatically increase filtration in a house. To equalize the pressure, air is sucked in through cracks, gaps and other infiltration sources. This infiltration that supplies make-up air for these intermittently used exhaust fans will continue to affect the energy efficiency and health of the house even when the fans are not in use. In a 1500 ft^2 house, for example, a 50 cubic foot per minute (cfm) bathroom exhaust fan can increase the entry of outside air by 50%. Some extremely powerful exhaust fans, such as those used in downdraft kitchen ranges (requiring up to 400 cfm) may require more make-up air by causing a chimney down draft. Use of a balanced ventilation system will reduce air infiltration.

Combustion, whether in a wood stove, fireplace, gas water heater, or fossil-fuel-fired boiler or furnace requires oxygen. Air flows through the combustion changer and oxygen from the air supports the combustion. The rest of the air passes through the combustion chamber and up the chimney or flue. If the combustion appliance draws air directly from the room, as in the case with most wood stoves and fireplaces for example, negative pressure will be created in the house as the air passes through the combustion appliances and up the chimney. (**Figure 12.4**). A typical airtight wood stove draws about 20 cfm, while an open furnace draws about 400 cfm. It is advisable to specify that all combustion boilers, furnaces, hot water heaters be sealed combustion units that is that they have provisions for an outside air supply built into them. Wood stoves may need to be supplied with outside combustion air ducts, and all fireplaces should have a ducted combustion air supply.

Duct Leakage and Layout affect airflow. To function properly, the supply airflow must continually be in balance with the return airflow. Poorly designed and/or installed systems will lead to unbalanced air flow which leads to increased energy use, may cause health an safety problems, and may contribute to moisture damage to the building. Supply ducts that are installed outside the conditioned space, **or that are connected by airflow to the outside,** suck air into the building through other holes. This results in higher energy costs and possible moisture problems with air conditioning. Return ducts that are out of balance (restricted in some way, ie., too small or blocked) cause pressurization of the conditioned space leading to exfiltration allowing potential moisture problems with heating systems and increased energy costs. Leaky returns in unbalanced systems will depressurize the space they are in and suck in air from that space resulting in possible health problems and increased energy costs. Some studies have found leaking duct systems reduced effective heating system efficiency by an average of about 50% with a high of 80%.

********CHART*********

There are some general rules to achieve an airtight, balanced duct system:

- All supply registers must have clear access to the return register
- All ducts should be located within the conditioned space.
- The conditioned space should be airtight.
- Ducts located outside of the conditioned space should be air tight and well insulated. Duct sealing should be completed with mastics or mastic and fiberglass mesh. Duct tape is inadequate.
- Duct boots at registers should be sealed to prevent leaks into the building cavities.
- Generally, building cavities should not be used as ducts, rather airtight ducts that fit into the cavities should be installed.
- Air handler plenums should be sealed.

Door Position also affects the function of duct systems. In addition to having the entire system in balance, each individual room must be in balance. Closing interior doors triples infiltration rates in houses with a central air return. Closed rooms are pressurized, leading to exfiltration from those rooms, while the open rooms are depressurized, leading to infiltration. Solutions include:

- Installing returns in every room.

- Installing transfer grills in doors or walls connecting the potentially closed rooms to the space containing the return register.

- Undercutting doors usually does not supply enough pressure relief.

Increasingly there are reports of poor indoor air quality leading to illness of building occupants, sometimes even death. One contributor to these problems is uncontrolled pressure difference in buildings caused by exhaust air systems (for example clothes dryers, downdraft ranges, and whole house vacuums) and possibly forced air distribution system imbalances. Depressurization of basements can cause infiltration of soil gases such as water vapor and radon, can cause back drafting, spillage, and even flame roll out from appliances that utilize air for combustion. In worst cases, these conditions can be implicated in house fires and carbon monoxide poisonings. Often problems are not caused by one exhaust appliance, but by combinations of them operating at the same time.

It is important to realize that only small pressure differences are very significant. A chimney draft may have a pressure of 5Pa (pascals) for a natural gas heater, or 3 Pa for a fireplace with a smoldering fire. (250 pascals = 1 inch of water) Measured results in some houses have found depressurization potential of up to 20 pascals. Measurement of pressure differences involves the use of blower doors and manometers. This is a skill that is little known in Maine.

Common Leakage Areas in Houses and How to Avoid Them

An air retarder system is needed to control envelope air leakage. The materials used to make this retarder system should have the following characteristics:

- The materials should be healthful and safe.

- They must be impermeable to air flow.

- They must be able to withstand the pressures placed on them by air and weight of other materials resting on them.

- The system must be continuous.

- The system must be durable and maintainable.

Often we find polyethylene has evolved into a combination vapor retarder/air retarder material. There are other alternatives, including:

- Housewraps (Tyvek, Typar, Barricade, etc.)

- Sheathings (foam insulation board, plywood, sheetrock)

- Dense pack blown fiber insulation.

These materials do not alone constitute a system. They need to be made continuous around intersect of different building components. Slight cracks can greatly reduce their effectiveness. Sealants, tapes and fillers are used to complete the retarder system. See **appendix** for illustrations of air retarder system.

VII. STANDARDS APPLICABLE TO COMMERCIAL AND INSTITUTIONAL CONSTRUCTION

Compliance with State energy efficiency standards is mandatory for new construction of all commercial and institutional buildings. "New Construction" includes the construction of new additions to existing buildings. For building expansion, the standards are applicable to the newly added space only, and the energy efficiency of the existing space cannot be used to cover (be applied to) the requirements of the new space. Exempted from this requirement are industrial buildings that house manufacturing operations. The law adopts the United States Office of Management and Budget Standard Industrial Codes 20 through 39 to define specifically which manufacturing operations are exempt. The standard industrial classification is a statistical classification used by the U.S. Government in preparing economic statistics.

Any person who constructs a building (on speculation), with the intention of selling or renting it, must accept responsibility to ensure that the standards are met. The purchaser or tenant of the new building must install equipment which meets the standards.

Maine adopts current ASHRAE 90 Standards as part of its requirement for commercial and institutional buildings. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society (IES) through a combined effort developed **the current ASHRAE/IES 90.1-1989 standard "Energy Efficient Design of New Buildings Except Low Rise Residential Buildings".**

ASHRAE is an international professional engineering association. One of its most notable functions is to set minimum quality standards for the design, installation, and operation of equipment and systems which use energy. Among the more than 100 standards they have issued, is the 90 Standard for energy efficiency in buildings. The energy efficiency design requirements of ASHRAE 90.1 are the result of applying the principles and materials research compiled in the ASHRAE *Handbook of Fundamentals.* ASHRAE 90 provides the basis for all energy efficiency standards adopted in the United States.

The requirements of the ASHRAE 90 standard apply to the building envelope, the distribution of energy, as well as the systems and equipment for auxiliaries, heating, ventilation, air-conditioning, service water heating, lighting, and energy management. The standard is applicable to all new buildings or portions of buildings that provide facilities or shelter for human occupancy and use energy for the purpose of providing human comfort. Exceptions to this standard include single and multi family residential buildings of three or fewer stories above grade. The standard is **not** applicable to:

a) areas of buildings intended primarily for manufacturing
b) buildings, or separately enclosed identifiable areas having a combination of dedicated space heating, service water heating, ventilation, air conditioning or lighting systems whose combined peak load is less than 3.5 Btu/(h ft^2) of gross floor area.

c) Buildings of fewer than 100 ft^2 of gross floor area.

Maine standards also require ventilation systems designed to provide outdoor air ventilation rates in accordance with ASHRAE Standard 62-1989, "Ventilation for Acceptable Indoor Air Quality."

Maine Standards for commercial and institutional buildings are summarized below in **Table 4.**

Table 4.

·All New Construction & Additions (including speculative and rental) ·ASHRAE 90.1 – 1989 Plus ·ASHRAE 62 – 1989	·Exempt: Industrial buildings (manufacturing)

There are three methods for determining conformance with the building envelope design criteria. These are:

1) the building energy cost budget method;
2) the system performance compliance method, and
3) the prescriptive criteria compliance method.

The Building Energy Cost Budget Method provides the greatest degree of design flexibility. The designer is allowed to incorporate state-of-the-art energy conservation, passive solar, daylighting techniques and construction materials, as well as, consider "off peak" electrical demand benefits. Off-peak benefits cannot be incorporated into either of the other two compliance methods.

To use this method, the designer first calculates an Energy Cost Budget for a prototype or reference building which he has designed. The building energy use is then simulated using a sophisticated computer program, such as "DOE-2". Energy Cost Budgets are then calculated for alternative building designs which have the same gross area, number of floors, form, orientation, occupancy, and use as the prototype building design. Any design with a calculated Energy Cost Budget that is equal to or lower than that of the original building meets the standard's criteria.

The Systems Performance Compliance Method uses a personal computer based program which allows selection from a wide variety of building envelope related criteria. Criteria selected would include gross wall area, window area, a shading coefficient for the glazing systems, visible light transmission of the glass, overall U-value (heat transmission rate) of the envelope, heat capacity and insulation location, internal power loads for lights and equipment, and automatic lighting controls for areas within15 feet of the exterior walls. Then, based upon weather data stored in the program for the city selected, the program calculates if the energy design of the envelope is in compliance with the thermal performance guidelines established in the computer data base. The cities of Portland, Bangor and Caribou are the Maine reference locations available. Refer to the Zone Map located on page 80 for the most compatible climatic zone.

The Prescriptive Criteria Compliance Method is a quick, simple method of determining compliance by using one of a series of 30 tables called Alternative Component Packages (ACP) which represent different climatic areas (Portland, Bangor, and Caribou in Maine). The designer performs a few simple calculations and selects some design parameters, such as internal power loads from lights and equipment, shading coefficients for the glazing system, overall fenestration (window) U-value, ad visible light transmission. These values are then compared to the ACP table selected to determine compliance.

Predictive energy efficiency can be quite complex to analyze, even for small commercial buildings. Unlike residences, commercial building energy use is often dominated by cooling, lighting or refrigeration loads. These loads are usually generated by activities taking place inside the building, rather than by outside climatic conditions as is typical for heating loads.

The complexity of the energy loads in commercial buildings makes it particularly difficult for a building inspector to determine compliance simply on the basis of performing a plan review and conducting a few on-site inspections. Some architects may feel comfortable performing calculations to determine building envelope efficiency, but **generally a professional engineer will be called upon to ascertain compliance with the ASHRAE/IES 90.1 standard. The Energy Conservation Division will accept the specific certification of a registered architect or professional engineer that a building design meets the ASHRAE/IES-90.1 criteria.**

While it is impossible to provide advanced approval for certain envelope design, ECD can provide a building inspector an idea of the minimum insulation and fenestration levels that might be expected to meet the minimum criteria. It is important to remember that energy use in many small commercial or institutional buildings may, like a residence, be dominated by external loads (cold outdoor temperatures), and therefore it would be beneficial in these cases for the minimum envelope requirements to be exceeded.

Code enforcement officers should be aware that Maine requires that the owner or the owner’s legal representative certify that the new commercial space meets the energy standards before the permanent electrical service can be installed. The certification form is distributed and collected by the electric utility and sent on to the Energy Conservation Division. While this provision requires no action of the CEO, it might be considerate to let permit applicants know that this certificate requirement exists.

VII. STANDARDS APPLICABLE TO RESIDENTIAL CONSTRUCTION

The applicability of the mandatory residential standards is a somewhat confusing matter due to the fact that there are several different layers of requirements for different kinds of construction or funding sources. Refer to **Table 5** to help clarify the requirements as we go along.

Conformance to the energy efficiency standards is mandatory for any new conditioned space in a residential building constructed after January 1, 1989. This includes modular homes, but provides an exception for owner built and occupied single-family residences, and for log homes. The exemption for owner built single-family residences allows the owner to hire a person to supervise the construction of the residence or to hire a general contractor to supervise the construction. Essentially, this means that for single family residences, only those that are built on speculation or intended to become rental property are required to comply with the standards, and "custom built" residences are exempt.

All new conditioned space in multi family residences must comply with the standards, regardless of who is doing the construction. A multi-family building is a building with more than one dwelling unit. Additionally, even if no new conditioned space is being added, multi-family buildings with 3 or more dwelling units must comply with the standards when they are substantially renovated, that is, when the costs of renovation are to exceed 75% of the assessed value of the building prior to the renovation. A conditional waiver to the renovation requirements may be granted by the Energy Conservation Division for reasons of extreme economic hardship, or conflict with historic preservation requirements. **Multi-family residences that are constructed, remodeled or renovated using any federal, state, county or municipal funds for whole or partial funding are prohibited from installing electric heat as a primary heating system.** A waiver provision is provided for buildings designed to meet super-insulation conditions specified in the law (to be reviewed later).

"New conditioned space" is a very inclusive term. It means space within a building that is either heated or cooled. Thus, all newly constructed residences, new additions to existing residences, or conversions from unconditioned to conditioned space within residences that were built after January 1, 1989 (such as when finishing off an attic or shed room, or when converting a non-residential building to a residential building) are required to conform to the standards.

All residences, except electrically heated subsidized multi-family residences which have been granted a waiver, must meet the same envelope insulation requirements. There are two ways to demonstrate compliance with the envelope requirement:

1) installing the specified minimum levels of insulation, or

2) calculating that the energy performance of a proposed design that does not meet the minimum insulation levels will be equal to or better than if that design had met the minimum insulation levels (further explanations to follow).

The prescribed minimum insulation levels for residences are listed in Tables 6.1, 6.2, and 6.3.

The performance compliance alternative allows for greater design flexibility. This approach allows a designer to increase insulation levels in one section of a building to offset the affect of lowered insulation levels in another section. For example, it might be more cost effective to install R-30 insulation in a cathedral ceiling and to insulate the walls to higher than R-19. This is permissible as long as the estimated heat loss, using calculations based upon accepted engineering principles (as found in the ASHRAE Handbook of Fundamentals), is equal to or less than the estimated heat loss that would occur if the building were built with R-38 ceiling insulation and R-19 wall insulation. See the **appendix** for an example of a computer analysis showing such an example.

In addition to the envelope insulation requirements, any new construction or substantial renovation of a conditioned space in a multi family residence with 3 or more dwelling units must also conform to the applicable provisions of the ASHRAE-90 standard that do not conflict with Maine's envelope standard. ASHRAE 90 has requirements for heating, ventilating and air conditioning systems and equipment, service water heating, energy distribution systems, electric power, lighting, auxiliary systems and equipment, and energy management. ASHRAE 90 also requires that adequate fresh ventilation air be provided in accordance with ASHRAE 62-1989. (See **Table 7** for examples of these requirements.) Due to ASHRAE procedures for performing a periodic review of their standards, there are now two ASHRAE 90 standards. ASHRAE 90.2-1983, Energy Efficient Design for New Low Rise Residential Buildings (those with three or fewer stories above grade), and ASHRAE 90.1-1989, which is applicable to high-rise residential buildings, as well as the previously mentioned commercial and institutional buildings.

Table 6.1

Minimum Insulation Levels Required by Maine Energy Standards

Building Component	Description	R-Value*
Ceilings	All ceilings that face outdoor or unheated spaces, Including cathedral or sloped ceilings. See special Definitions and conditions for ceiling insulation below.	R-38
Walls	All walls which face outdoors or unheated spaces, Including insulated knee walls in heated attics. Band Joists at wall perimeters must be insulated to the Same level.	R-19
Windows	All window units, including glass in patio doors. The Unit R-value is an area weighted average of the R-values of the frame material, the edge of the glass And the center of the glass.	R-2
Floors over Unheated spaces	Floors over crawl spaces, floors over unheated basements, overhanging floors, garages.	R-19
Slab-on-grade Floors	There are two options for insulating slabs in slab-on-grade construction: either a) around the perimeter From the top of the slab to the design frost line; or b) Around the perimeter to the thickness of the slab and Horizontally beneath the slab for a distance equivalent To the design of the frost line. See zone map of Maine On page 4 and the design frost depths that apply. (Table 4)	R-10
Foundation walls That enclose below-Grade heated space	The insulation must extend from the top of the foundation to the design frost line.	R-10

*The specified R-value refers to the rated R-value of the insulation only, not taking into account reductions in the system R-value due to framing members, and not including the added system R-value for other building components (sheathing, siding, drywall, etc.) and air films.

Performance Based Compliance Alternative – an alternative method of complying is available, see Appendix F for details.

Tables 6.2 and 6.3

Batt Insulation Requirements for Sloped Ceilings		
Nominal rafter depth In inches		**Batt insulation thickness permitted, plus additional required R-value to be placed at the Underside face of the rafter**
12 inches (2X12 rafter)		12-inch batt (R-38 typical)
10 inches (2X10 rafter)		9 ½ -inch batt (R-30 typical), plus additional R-8
8 inches (2X8 rafter)		8-inch batt (R-25 typical), plus additional R-13
6 inches (2X6 rafter)		6 ¼ -inch batt (R-19 typical), plus additional R-19
4 inches (2X4 rafter)		3 ½ - inch batt (R-11 typical), plus additional R-27,
	or	3 5/8 inch batt (R-13 typical), plus additional R-25

Blown Fibrous Insulation Requirements For Sloped Ceilings	
Nominal rafter depth In inches	**Rafter cavity to be filled, plus additional R-value to be placed on the underside of rafters**
12 inches (2X12 rafter)	Fill available space
10 inches (2X10 rafter)	Fill available space, plus additional R-8
8 inches (2X8 rafter)	Fill available space, plus additional R-13
6 inches (2x6 rafter)	Fill available space, plus additional R-19
4 inches (2X4 rafter)	Fill available space, plus additional R-27

Table 7.

TYPICAL ASHRAE 90.2-1993 REQUIREMENTS
FOR LOW RISE MULTI FAMILY BUILDINGS

THESE ARE JUST GUIDELINES. SPECIFIC CRITERIA MAY VARY

Heating, Ventilating and Air-Conditioning Systems and Equipment:

· The heating system will be sized using procedures described in the 1989 ASHRAE Handbook of Fundamentals, or other specified acceptable methods such as Manual J.

· Winter outside design temperature will be the 97.5% values listed in the 1989 ASHRAE Handbook of Fundamentals.

· Winter inside design temperature will be 70F

Air Distribution Systems:

· Ducts shall be sized and designed in accordance with 1989 ASHRAE Handbook of Fundamentals and the Air Conditioning Contractors of America Manual D.

· Ducts shall be constructed, installed and sealed in accordance with acceptable industry standards issued by the Sheet Metal and Air Conditioning Contractors National Association, and the North American Insulation Manufacturers Association.

· Systems shall provide a means for balancing air flows.

· Ducts and plenums located in unconditioned spaces shall be insulated. Heating ducts do not need to be insulated when installed in basements with insulated walls.

Hydronic Distribution Systems:

· Pipe sizing and design in accordance with the Hydronic Institute;s I-B-R Installation Guide for Hydronic Heating Systems or the 1989 ASHRAE Handbook of Fundamentals.

· Pipes located in unconditioned spaces shall be insulated.

Table 7. (Continued)

Ventilation:

· Ventilation for acceptable indoor air quality shall be in accordance with ASHRAE 62-1989.

· Combustion air shall be supplied when infiltration rate is inadequate.

· Kitchen and bathroom exhaust shall be installed.

· Fireplaces shall have a tight damper, firebox doors, and an outside combustion air source within the firebox.

HVAC Equipment:

· Warm air furnaces shall have a minimum AFUE of 78%

· Boilers shall have a minimum AFUE of 80%

Controls:

• Each zone shall have a thermostat capable of being set from 55 F to 85 F with a means of manual or automatic setback.

· Each mechanical ventilation system shall have an assessable switch.

· Automatic devices to supply moisture to the air shall have a humistat to shut off the moisture supply when the relative humidity reaches 30%.

Service Water heating:

· Residential water heaters shall meet the Department of Energy minimum efficiency levels.

· Shower flow rates shall be 3.0 gallons per minute maximum.

· Water heaters without integral heat traps that have vertical pipe risers shall be installed with heat traps on both inlet and outlets.

As previously mentioned, subsidized multi-family residences are prohibited from installing a primary electric heating system when being newly constructed, renovated, or remodeled. A waiver to this prohibition may be sought from the Commissioner of the Department of Economic and Community Development. The waiver will be granted only if the proposed construction will meet the super-insulation standards prescribed in the law and the rule adopted by the ECD/DECD under that law. A copy of the rule can be found in the **appendix.**

The standards required to obtain a waiver are summarized below:

Insulation:

Ceiling	R-57
Walls	R-38
Floors over unheated space	R-25
Slab-on-grade floors	R-15
Foundations	R-19
Window units	R-2.5

Doors must be insulated or have a storm door;

Infiltration controls must be installed, as prescribed by rule;

A ventilation system must be installed, as prescribed by rule;

Or, the building must meet a performance equivalent:

If the calculated annual energy consumption of a building having the same infiltration controls and ventilation system, but having different insulation levels, is not greater than that of a similar building constructed in accordance with the prescribed insulation levels, it will then meet the requirements.

MODEL ENERGY CODES

The US Department of Energy, in compliance with the 1992 Energy Policy Act, has reviewed the 1993 CABO Model Energy Code and determined that its use will save energy in a cost effective manner. This determination has no direct impact on most new houses in Maine, however, federally funded or backed loans will require conformance with this code. Maine's residential code does not meet the MEC standards in several aspects.

There are several ways to determine compliance with the MEC. The National Homebuilders Association and the National Mineral Insulation Manufacturers Association have both created booklets on meeting the code. Perhaps the easiest approaches are those issued by the Pacific Northwest Laboratory for DOE. MECheck is an easy to use PC software program, and there is also available a printed matrix of alternatives that meet the standard.

So far, compliance can be certified by the builder, so once again CEO’s need only be aware of this requirement.

IX. ENFORCEMENT AND ADMINISTRATION OF THE STANDARDS

The Energy Conservation Division of the Department of Economic and Community Development is responsible for the administration and enforcement of the energy efficiency standards. Administration duties include publishing and disseminating information about the standards, promulgating rules and regulations associated wit the standards, and developing goals for presentation to the legislature which seek to improve the standards and their implementation.

Enforcement, or more accurately the lack of enforcement, continues to be an issue. The ECD, in October 1991, was granted clear authority to review plans prior to construction and conduct on site inspections to verify compliance. The authority is truly limited in that, the only way to achieve conformance is to persuade a person to meet the requirements under the potential threat that there will be a **civil court action which could result in a fine of up to 5% of the value of the construction.** Many of the traditional tools of the building inspector are not available to ECD. For example, the ECD has been granted no budget for enforcement, nor is it authorized to charge permit fees to support an inspection program, issue stop work orders, or force current work in progress to be brought into compliance.

Municipalities and local CEOs have few, if any, specific responsibilities for enforcement of the energy standards. Municipalities may adopt an energy standards ordinance, as long as, it is no less stringent than the State requirements. Where a municipal ordinance is being considered, it is probably best to directly reference the Maine Standards. **Regardless of whether a municipal code is adopted, the CEO is likely to become involved with the Standards in cases where their municipality provides a subsidy for a multi-family residence.** The municipality would then be responsible to obtain certification, from the owner of the proposed building, that it complies with the prohibition against installing electric heat. At the very least, CEOs are encouraged to be aware of the requirements and act as a link in the education chain to help raise the awareness of developers, designers, builders and property owners.

Code enforcement officers should be aware that Maine requires that a contract be signed for all home construction work in excess of $1400.00. It is required that the contract state whether or not the work will conform to the State energy standards. There are also specific contract requirements for insulation installation. Refer to the **appendix** for a copy of the laws regarding these contracts.

The energy standards are intended to place conditions on those aspects of the building which affect its energy efficiency. In other words, they are not intended to conflict with other codes, such as those which regulate life safety, electrical installation, or plumbing. In fact, energy efficiency building practices and requirements of other codes often compliment and augment each other.

There is a potential for conflict with the energy provisions of the widely adopted BOCA and CABO structural and mechanical codes. The State's requirements take precedence over locally adopted less stringent codes. To avoid confusion, **it is suggested that local ordinances either specifically adopt the State standards in place of those found in national codes such as BOCA, or at least avoid adoption of the energy chapters (Article 31 in BOCA, and Part VII in CABO).**

There are also conflicts between the 1990 BOCA Mechanical Code and the Maine Energy Standards. Specifically, BOCA Articles 16 (Ventilation Air) and 19 (Energy Conservation) are based on old ASHRAE standards (ASHRAE 90-A-1980 and ASHRAE 62-81), whereas Maine requires compliance with the most current ASHRAE standards (ASHRAE/IES 90.1-1989 and ASHRAE 62-1989).

Unfortunately, there does not appear to be a simple, straightforward way to alleviate this situation. BOCA is considering adoption of the Model Energy Code (MEC) which is based on the ASHRAE standards, but the outcome is uncertain. Even if BOCA does adopt the MEC, conflicts would remain unless they were to directly adopt ASHRAE/IES 90.1. This situation is further complicated by the fact that the BOCA Mechanical Code applies to construction in and of all buildings, whereas, Maine standards adopt only the ASHRAE standards which apply to commercial and institutional buildings (ASHRAE/IES 90.1). Additionally, as long as BOCA maintains a policy of annually reviewing and adopting changes, their codes will always lag behind the adoption of any standards they reference. These conflicts affect only the energy efficiency features of the equipment and systems and do not affect installation requirements. Energy efficiency features are such things as equipment fuel use, zoning requirements, the volume of fresh air required, and the amount of energy that is used to run HVAC distribution systems.

It seems that the best course of action is for the CEO to be aware of the potential for conflict and be able to inform designers that they must comply with the State Standards for energy efficiency and with the BOCA codes for installation specifications and installation.

CEOs are encouraged to seek help from the Energy Conservation Division, whether by notifying the ECD of possible violations, or by asking questions about the application of the law.

X. APPENDIX

COMMON PROBLEM HOUSE DESIGN

This section is intended to alert you to some frequently found problem areas. Using the suggestions presented in this manual will help minimize problems.

Cape – New cape style houses frequently have air leaks in the area behind the knee walls. These leaks often allow air exchange between the floor/ceiling joists separating the first and second floors. Shed dormers are frequently under-insulated leading to ice dam formation. Old capes often have no plates capping the tops of interior walls, so airflow is unimpeded from the cellar to the attic.

Gambrel – The overhang of the second floor is frequently not insulated or sealed against air infiltration. In addition to causing a cold floor at the overhang, cold air is distributed throughout the house by the floor joist cavities. Infiltration also enters the exterior wall supported by the overhang.

Split-level – Roof and abutting wall intersections allow air interchange between cold-vented attic spaces and uninsulated walls, reducing effective R-values.

Steel Studs

Steel studs have been common in commercial construction for decades, and are increasingly being used in residential construction. Some of the reasons for this increased popularity include: limited supply of good quality lumber, high lumber prices, no twisting creates straight walls, and the potential to use recycled steel. Steel studs pose several energy related problems. The principle problem is caused by the high conductivity of the steel leading to a 30% to 50% reduction in the R-value of walls using only in-fill insulation. Additionally, improperly sized and loose fitting insulation reduces fire resistance as much as 40%. Loose fitting insulation is generally due to installing insulation made for wood stud walls.

Laboratory tests suggest that the most commonly available and effective solution is o install at least R-5 extrude polystyrene insulation sheathing in addition o the in-fill insulation. Field infrared thermographs suggest that foam insulation may not be working so well.

Another proposed, but apparently much less effective suggestion, is to install horizontal hat channels to reduce the contact of the interior or exterior sheathing with the studs.

Hat channels do have the potential to reduce the appearance of “ghost marks” which highlight each stud due to the attraction of dust particles to cold interior surfaces.

Steel studs “c” sections must be filled with insulation to minimize air movement within the wall cavity. Wide insulation is specifically manufactured for use with steel studs.

COMMON LEAKAGE AREAS IN HOUSES: HOW TO AVOID THEM

1. Build a vestibule or air lock entry on the primary entry door. This allows the exterior door to be closed before the door to the house is opened to cut down on wind.

2. Install high-quality, pre-hung, factory-weather-stripped windows.

3. Install high-quality, pre-hung, factory-weather-stripped entry doors. Metal and fiberglass doors are preferred over wood doors, because of insulating value and stability. But a well-built wood door with high quality weather-stripping works fairly well.

4. Use only airtight recessed lights in insulated ceilings.

5. for access to an unheated attic (if necessary), install a weather-stripped, well-insulated attic hatch. Preferably, access can be placed on the outside of the house.

6. Try not to locate tub on outside wall. However, if the bathtub is to be installed along an exterior wall, be sure that air and vapor retarder systems are installed behind the tub. Insulate before installing.

7. During window and door installation, carefully seal around jambs with low expanding foam sealant.

8. Install a sill sealer, gasket, and/or caulk between the sill and foundation and from sill to the plate.

9. Install a continuous vapor retarder toward the inside of all exterior walls and insulated ceilings. If this vapor retarder is well sealed at all edges, joints and overlaps, it will also serve as an air retarder as well; otherwise, a separate air retarder should be included in the wall and ceiling assemblies.

10. During framing, caulk the plates to the subfloor as wall sections are tilted into place.

11. If installing a chimney, seal stack penetrations through insulated floors, walls and ceilings.

12. Provide tight-fitting insulating covers for through-the-wall air conditioners and air conditioning sleeves.

13. Provide back draft dampers on all ventilation ducts passing through the envelope except on heat recovery ventilators (air to air heat exchangers), and on combustion air inlets for fireplaces and wood stoves.

14. Seal cracks around all pipes, vent stacks, wires, boxes, and conduits penetrating the exterior walls and ceilings.

15. Minimize the placement of electrical outlets on exterior walls (within code guidelines), and carefully seal those receptacles to the air retarder, or be sure that a good air retarder is provided elsewhere in the wall assembly.

16. Install only sealed-combustion heating and water heating equipment.

17. If ducting for the heating system passes through unheated space, fully insulate the ducts (to high R-value) and seal the joints between duct sections.

18. when using joist spaces or wall cavities for return air ducts, care must be taken to seal and insulate same. Outside walls should not be used in this manner.

19. Install kitchen and bathroom exhaust fans with back draft or automatic dampers to limit air leakage. To reduce back drafting, condensation, and convective heat loss, local exhaust should be ducted down before passing through the building shell.

20. Ideally in energy-efficient homes, fireplaces are not recommended because of their inherent inefficiency and the heat loss associated with them. However, if a fireplace is to be installed, do the following:

    a. Install a tight-fitting damper at the top of masonry fireplace flue.
    b. Install high-quality, tight closing glass doors on the front of the fireplace.
    c. Install a combustion air inlet duct directly to the fireplace.
    d. Seal chimney and flue penetrations through insulated ceilings and roofs in accordance with local fire codes.
    e. Build chimney with its entire mass within the house envelope up to the ceiling/roof penetration.

MATERIALS USED TO CONTROL AIR LEAKAGE

Building a tight house that will remain tight necessitates using high-quality materials and installing them properly. In addition to the discussion below, refer to **Table 6** for a list of common sealing materials and their properties.

Table 6

Common Caulking Materials

Generic Product	Cost	Useful Life	Joint Movement	Comments
Oil-based Caulk	Low	3-5 yrs	Very poor – 1%	Poor adhesion to wet surfaces. Considerable shrinkage. Generally not recommended.
Butyl Rubber Caulk	Low to Medium	3-10 yrs	Fair 5-10%	Good adhesion to masonry and metal: poor to wet surfaces. May be stringy during application. Long curing time before paintable.
Acrylic Latex Caulk	Low to Medium	3-10 yrs	Poor – 2%	Use only for interior applications on joints between similar materials. Easy to use; cleans up with water; paintable.
Siliconized Acrylic Latex Caulk	Medium	10-20 yrs	Fair up to 10%	Silicone greatly improves product over standard acrylic latex. Easy clean up & painting; minimal shrinkage. Considerable variation between brands relative to % silicone.
Silicone Caulk	High	20-50+ yrs	Highest – 50%	Excellent flexibility. Good adhesion to most materials. Effective over very wide temp. range. Easy application. Most are not paintable. May not bond well to all woods.
One-part Polyurethane Caulk (Sikaflex)	High	20-30 yrs.	Good – 25%	Excellent adhesion to most surfaces. Very good performance. Paintable. Clean up may be difficult. Used by professionals for yrs; has become widely available only recently.
Ethylene Copolymer (Geocel)	Medium	>20yrs	Good – 25%	Good adhesion to most materials; good flexibility; paintable. Good general-purpose caulk.
Polyurethane Foam Sealant	Medium	10-20 yrs	Poor	Good for filling large cracks but does not move well. Not recommended outdoors.
Acoustic Sealant	Medium	20-30 yrs	Good	Not paintable, non-shrinking. For unexposed joints Only. (Sound control & sealing ?/V barrier)
Silicon Firestop	Very High	?	Excellent 20-60%	Two part sealant that expands by chemical reaction to form compression seal in crack. Fire rated for applications such as party wall sealing. Applied as liquid, so needs backer material.

Caulks

To function properly in sealing between two surfaces, a caulk must be able to expand and contract with the seasonal movement of the materials. (Wood, for example, expands in the summer months and shrinks in the winter.) Some products maintain much greater flexibility over time than others. High-quality silicone and polyurethane caulks, for example, will maintain excellent flexibility – greater than 25% expansion and contraction in joints – for more than twenty years, while oil based caulks when new allow only about 1% joint movement, and they dry out and lose all flexibility after just a few years.

When you are comparing caulks at a building supply center, it may be difficult to distinguish one type of caulk from another by their labels. If you cannot determine what type of caulk it is, read the label and look for properties you want, such as a long lifetime, a guarantee of quality, paintability, ability to bond to the substrates you will be using, etc. Price is often a good indicator of quality – the better, longer lasting caulks cost more. When you apply caulk, remember the proper bonding of any caulk depends on the surface it is being applied against. Surfaces should be structurally sound and free of dust, grease and moisture. Caulks are limited in their ability to seal gaps wider than 3/16" without additional measures.

Expanding Foam Sealants

Introduced in the past fifteen years, one-part foam sealants have greatly simplified the sealing of windows, doors, wiring penetrations and any large gaps during construction. These sealants are available in cans or larger canisters. Specialized application guns are available from some manufacturers for use with the larger cans. Both low expanding and high expanding foam sealants are available. In general, the low expanding types are preferable for all but the largest holes. If not experienced with high expanding foam sealant application, then use of low expanding foam sealant around windows and doors is especially important, because the high expanding sealants can swell the jambs, making window and door operation difficult. Extra large doors, sliders, windows, etc. can be braced to prevent bowing of jamb when foam is applied through the rough opening. Limit foam to one bead between R.O. and jamb to prevent these problems. High expanding foam sealants are more common than low expanding types, and the high expanding foam may be the only type available at local building supply stores.

One-part and two-part sealants are very different. Two-part foam sealants expand and cure more quickly than one-part foams. As a result, these can be used in spray insulation applications where a larger area must be insulated. Examine the literature on the foam sealant carefully. If unavailable as a stock item at building supply stores, low expanding foams can generally be ordered by the store or purchased directly from the manufacturer. All foam sealants are polyurethane. While all foam sealants originally contained CFCs, many are now available that use less damaging HCFCs or hydrocarbons.

Gaskets and Backer Rod

High quality EPDM, closed-cell, or polymer-saturated open-cell foam gaskets should be used under sill plates. Foam backer rods (round cross-section) can be used for sealing deep cracks or providing a backing for caulk in deep cracks. (See **Figure 13**). Open-cell foam gaskets can be used for sealing between exterior wall sections, plates and subfloor.

Figure 13

Adhesives

Adhesives used for bonding plywood subfloors to joists will help to some degree with air leakage control. Some builders also use adhesives in place of caulking or gaskets under wall bottom plates. Adhesives can be used to seal thresholds to subfloors.

Vapor Barrier

A vapor barrier, generally a 6-mil layer of polyethylene or stronger, should always be installed on the interior (winter warm) side of wall or ceiling insulation. The best vapor barriers are reinforced, cross-laminated polyethylene, but these are more expensive than standard polyethylene. If using standard polyethylene, buy only virgin 6-mil or thicker. If the vapor barrier is continuous and well sealed with tape or non-hardening sealant at all edges, joints and overlaps, it will also serve as an air barrier. If not, a separate air barrier should be provided elsewhere in the wall or ceiling cavity.

Exterior Air Barrier

An exterior air barrier or weather barrier (e.g. Tyvek®, Typar®) is quite different from an air/vapor barrier. It is commonly installed on the outside of the sheathing before siding is installed, and it is designed to block wind and rain, but allow water vapor to pass through. The weather barrier should be taped to window and door openings for maximum effectiveness. With clad windows, also tape over flanges with contractor’s tape. With wood windows, apply a bead of caulk to seal window to weather barrier. Also, tape top and bottom edges of weather barrier and all seams with quality contractor’s tape.

SPECIAL CONCERNS WITH STRESS-SKIN CONSTRUCTION

Air leakage and moisture migration through panel joints can be a big problem with stress-skin panel constructions. While the foam-core panels themselves are very airtight, joints between panels are often very leaky. A typical double plywood “spline” joint and airflow paths through it are shown in **Figure 14**. For this reason, special air-sealing practices are required when stress skin panels are used.

COMPUTER ANALYSIS OF PREDICTIVE ENERGY PERFORMANCE OF 2-HOUSE DESIGNS
This shows how the flexibility of standards works to achieve a design similar to that sought while meeting performance requirements.

On of the goals of this proposed revision is to allow some design flexibility in the methods chosen to insulate a building. It is sometimes desirable to compare the predicted energy performance of a building that does not meet the prescriptive standards found in Sec. 5. 10 MRSA § 1415-C with one of similar design which does meet those standards. If the proposed building meets or exceeds the performance of the "base" building, then it would meet the standard under this proposal. I have enclosed and summarized a real example of how this would be useful.

The analysis is of an already built multi-family residence in Brunswick. This building qualified for the CMP "Good Cents Home Program", but did not meet Maine's prescriptive standards. The 1st floor walls were insulated to R-26, and the sloped ceiling was insulated to R-30. By adjusting insulation levels in those two sections to walls at R-19, and sloped ceiling at R-38 the building now meets our standard, and the builder finds that it can be constructed within his budget. Unfortunately, energy consumption and total annual heating costs are increased. Heat loss through the walls is increased by 1467 Btu/h, resulting in a net loss of 1149 Btu/h. This translates to an increase of $78 per year for heating. By permitting a performance-based analysis, the original building would have met our standard and greater energy savings would have been achieved.

03/20/1989
Design # 0985700035

Central Maine Power Company
Good Cents Home Program

Prepared for:	Theberge Birchmeadow Unit A I1 Brunswick, ME 04011	Date:	6/24/1988
		District: Brunswick	
Prepared by:	Andrew W. Wellen		Design # 0985100035

Design Conditions	Indoor Temperature	Outdoor Temperature	Heating Degree Days
	70	-10	7300

03/20/1989
Design # 0985100035

HEAT LOSS ANALYSIS (AS DESIGNED)

Surface Description	Area Sq. Ft.	Proposed Insulation	BTUH Loss	% Loss
Walls:				
First Floor	1,120	R-19	4,942	16.6
Second Floor	343	R-19	1,514	5.1
Total:	1,463		6,456	21.6
Doors:				
To Garage	17	R-14	101	0.3
Entry	20	R-14	114	0.4
Storage	16	R-9	148	0.5
Total:	54		363	1.2
Ceilings:				
2^{nd} Fl Flat	312	R-38	659	2.2
2^{nd} Fl Slope	546	R-38	1,156	3.9
First Ell	180	R-54	266	0.9
First Floor	420	R-30	1,133	3.8
Total:	1,458		3,215	10.8
Floors:				
First Floor	1,312	R-10	4,566	15.3
Second Floor	768	R-0	0	0.0
Total:	2,080		4,566	15.3

3/20/1989
Design # 0985100035

Windows:

Living Room	31	R-3.3	767	2.6
First Other	20	R-3.3	503	1.7
Bath First	21	R-3.3	511	1.7
Ell	10	R-3.3	255	0.9
Ell Other	20	R-3.3	503	1.7
Kitchen	8	R-3.3	213	0.7
Prado	40	R-3.3	969	3.2
Roof Window	16	R-2.7	500	1.7
Roof Other	12	R-2.7	368	1.2
Total:	182		4,592	15.4
Air Exchange Loss			10,667	35.7

Zone Description	Vol. Cu.ft.	Btuh Loss
First floor	10,496	22,404
Second Floor	4,320	7,454
Total:	14, 816	29,862

BTUH PER SQ. FT. HEAT LOSS * 14.4/

This value is computed using a floor area of 2,080 sq. ft. and a total design heat loss of 29,862 Btuh.

CONGRATULATIONS! THE DESIGN SPECIFICATIONS FOR YOUR HOME QUALIFY UNDER THE GOOD CENTS STANDARDS.

***By building a good cents home you can realize up to a 40% savings in heating costs compared to the typical home being built in Maine.

STANDARDS PRESCRIBED FOR SUBSIDIZED MULTI-FAMILY RESIDENCES

1. **Summary**

These regulations define terms and prescribe conservation techniques to be used to achieve compliance with Section 1415 G of the Energy Efficiency Building Performance Standards Act, 10 MRSA Chapter 214, Sections1410-1420.

2. **Definitions**

A. **Addition:** "Addition" means new space (construction) which is attached to an existing building.

B. **Assessed value:** "Assessed value," means the value of the building set for property tax purposes prior to the renovation.

C. **Ceiling:** "Ceiling" means the overhead section of a room, including over the tops of walls enclosing that room. Ceilings may have any slope from horizontal up to, but not including vertical.

D. **Electric space heating equipment:** "Electric space heating equipment" means any heating system which derives more than 50% of its heat energy input from electricity and has a Heating Seasonal Performance Factor (HSPF) in compliance with ASHRAE 90.1.

E. **Heat energy input:** "Heat energy input" means energy supplied to produce heat, exclusive of energy supplied to transport and distribute the heat produced.

F. **Insulation:** "Insulation" means material primarily used to slow down heat flow, and is limited to materials defined as insulation by the Federal Trade Commission in 16 CFR Chapter 1 (1-1-88 Edition), Part 460 – "Labeling and Advertising of Home Insulation."

G. **Minimum unit R-**Value: "Minimum unit R-value" means the R-value of the overall window unit. The overall R-value is area weighted average of the R-values for the window frame, the edge of the glass, and the center of the glass, as defined and prescribed in the most current AHSRAE Handbook of Fundamentals.

H. **Owner:** "Owner" includes any person who will be, or has become the legal owner of property constructed, renovated, or remodeled wit the use in whole or in part using public funds, guarantees or bond proceeds for whole or partial funding.

I. **Positive Heat Supply:** "Positive heat supply" means heat deliberately supplied to a space by design, such as, but not limited to, a supply register, a radiator, or a heating element.

J. **Public Funds, Guarantees, or Bond Proceeds:** "Public funds, guarantees, or bond proceeds" means any funds provided to a person by any federal, state, county, or municipal governmental or quasi-governmental agency to be used to reduce the costs of constructing, renovating, or remodeling multi-family residential buildings as defined in Section 1415.G.1. This includes, but is not necessarily limited to: grants, interest subsidies, funds from the repayment of previously provided public funds, and donations of land or services. The phrase shall hereafter be called “public funds”.

K. **R-value**: “R-value” is an indication of the amount of resistance to heat flow. R-values stated in labels, fact sheets, ads, or other promotional material must be established by tests which meet the requirements of the Federal Trade Commission as contained in 16 CFR Chapter 1 (1-188 Edition) part 460 – “Labeling and Advertising of Home Insulation.” R-values for unlabeled products shall be those found in the most current ASHRAE Handbook of Fundamentals, Chapter 23 – Design Heat Transmission Coefficients.

R-values may be rounded to the nearest 1/10th for tested R-values of less than 10, and to the nearest whole number for R-values of 10 or more.

L. **Shall be insulated to**: “Shall by insulated to” means that insulation rated at the prescribed R-value shall be installed.

M. **Single Family Residence:** “Single family residence: means a detached residential building intended to be occupied by one family in a single unit.

N. **Subsidized Housing:** “Subsidized housing” means a residence which is constructed, renovated, or remodeled with the use of any public funds, guarantees, or bond proceeds as defined above.

O. **Thermal Transmittance (U or U-value):** The coefficient of heat transmission (air to air). It is the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films. The U-value applies to combinations of different materials used in series along the heat flow path, single material that comprise a building section, cavity air spaces and surface air films on both sides of a building element. It is expressed in units of **Btu/degrees F X Ft^2 X Hr.**

P. **Unheated Space:** “Unheated space,” means a space which is neither a conditioned space nor has any provisions for providing a positive heat supply.

Q. **Vapor Retarder:** “Vapor retarder” means a material installed to retard water vapor diffusion into building component assemblies. The retarder is designed to have a maximum permeance rating of 1.0 as defined in the most current ASHRAE Handbook of Fundamentals. The terms “vapor barrier” and “air/vapor barrier” are often used interchangeably with the term “vapor retarder”.

R. **Wall:** “Wall” means a vertical element of a building used to primarily to enclose or separate spaces.

S. **Wind wash:** “Wind wash,” means the uncontrolled wind driven movement of air through installed building insulation.

3. MANDATORY COMPLIANCE

A. Multiple Occupancy

When a building contains more than one type of occupancy, such as, but not limited to, residential and commercial, then each portion of the building shall conform to the requirements for the type of occupancy contained therein. Areas of a building shared by more than one type of occupant shall meet the more stringent requirements.

B. **Transition Provision**

This standard shall take effect January 1, 1992. Projects demonstrating substantial activity and contract commitments before this date which have received either 1.) A building permit, or 2.) a plumbing permit, shall not be required to comply with section 1415G.

Multi-phase projects must comply with this section for phases of the project where construction has not started by January 1, 1992, or where construction has not been continuous.

C. **Additions**

Additions to subsidized multi-family residences must meet the minimum standards that apply to all residential buildings, unless a waiver is granted, in which case the addition must meet standards specified in Section 1415 – G.

Additions are a form of new construction. Additions that are to be built under the waiver provisions must meet the standards for new construction. Only the addition must comply with the waiver conditions, and characteristics of the existing building may not be considered in performing any energy analysis of the addition used to demonstrate compliance with Section 1415-G.

D. Appurtenant Structures

Structures appurtenant to subsidized multi-family residences, such as, but not limited to, recreation buildings, dining halls, and offices, must comply with the provisions of this section of law.

4. ACCEPTED PRACTICES

A. Frost Line

For determining compliance with this section of the Standards, the design frost line shall be those listed in Table 1 for each zone as found on the Zone Map.

Table 1

Design frost line for conforming to the
Requirements of Maine's
<u>Energy Efficiency Building Performance Standards</u>
When installing insulation on foundations
Or slab-on-grade floors

Zone	Design Frost Line in Feet Below Grade
1	4 feet
2	5 feet
3	6 feet

B. Ceiling Insulation

Ceiling insulation shall be installed in a manner which maintains the minimum depth of insulation needed to achieve the minimum specified R-value. The measurement shall be taken at the outside edge of the exterior wall framing.

C. Maintenance of R-value

The following measures shall be installed to maintain the integrity of the R-value of the installed insulation.

1. **Wind Wash –** A barrier must be provided at the following locations to mitigate wind wash;
   a. the exterior edge of attic insulation; and
   b. cantilevered floors and bay windows, including corners with adjoining vertical walls above and below.

2. **Vapor Retarders –** A continuous vapor retarder shall be installed on all walls and ceilings which face outdoors or unheated spaces. The retarder shall be installed at or near the warm (interior) side of the insulation, but in no case may be placed more than 1/3 of the R-value into the insulation.

   A vapor retarder shall be installed under all slabs. The retarder may be covered by a thin layer of sand to protect it from damage during the construction of the slab.

   A vapor retarder shall be installed on top of all dirt crawl space floors. The edges of the retarder shall be wrapped up onto the foundation walls a minimum of 6 inches, and sealed and mechanically fastened to the foundation.

5. INFILTRATION

A) A continuous air leakage (infiltration) barrier shall be installed over the inside face of framing in ceilings which face an outdoor or unheated space, and over either the inside or outside face of framing in walls which face an outdoor or unheated space. The ceiling and wall barriers must be sealed to each other.

Gaps between the rough and finish frames around windows and doors, joints between walls and foundations, all penetrations through the infiltration barrier, such as but not limited to, those for plumbing electrical conduits, wires or boxes, and ducts, shall be sealed with permanent tape, caulk, sealant, or gaskets.

All walls, ceilings, and floors that separate different dwelling units shall be sealed against air movement from one unit to another. Air infiltration barrier material shall be continuous. All penetrations through the air infiltration barrier, separating dwelling units shall be sealed with permanent tape, caulk, sealant, or gaskets.

All air ducts shall be sealed in accordance with the duct construction standards of the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

6. VENTILATION

A. Each dwelling unit shall have balanced mechanical ventilation designed to provide outside air in conformance with ASHRAE 62-1989, "Ventilation for Acceptable Indoor Air Quality". Fresh air is not to be supplied to dwelling unit from community rooms. Balancing of the system shall be certified by testing completed by a technician certified by the Air Balancing Institute.

B. Common Rooms, located in any building having to comply with this standard, shall have balanced mechanical ventilation designed to provide outside air in conformance with ASHRAE 62-1989.

C. This ventilation requirement is not to be construed to prohibit central ventilation systems, it is only intended to require that fresh air be supplied and stale air exhausted for each dwelling unit independently of ventilation rates in other units, and for the building as a whole.

D. An operations manual for the ventilation system(s) will be provided to the building manager. An operations manual for the ventilation system located in the individual dwelling unit shall provide an overview of how the ventilation system functions to assure indoor air quality, operation instructions for any controls located in the dwelling unit, the name of the person to call for service (may be different for tenants than for managers), a schedule for any regular maintenance to be performed by the tenant or manager.

7. PERFORMANCE COMPLIANCE ALTERNATIVE

A. **Scope -** This section establishes criteria for the design of buildings in terms of the building's annual energy usage.

B. **Analysis Criteria**

1) Compliance with this section will require an analysis of the annual energy usage of the proposed building design and a comparison of such usage with the annual energy usage of a standard building design.

2) The proposed building design will be deemed to meet the requirements of Section if the annual energy usage of the proposed building design is not greater than the annual energy usage of a standard building design. The standard design shall be based on the criteria for specified by Section 1415-G and this rule for insulation levels, infiltration controls, and ventilation.

3) The standard building design shall be substantially identical to the proposed building design in the following respects:

a) Function and design requirements;
b) Size, shape, geometry, and orientation;
c) Operating schedule, temperature, humidity, ventilation and footcandles;
d) Internal heat gains from occupants and equipment;
e) Energy source for each energy end-use; and
f) Equipment and system type.

C. **Analysis Procedure**

1) The energy usage of the standard building design and the proposed building design shall be determined through the use of identical energy analysis procedures.

a) The energy usage shall be expressed as total Btu usage per year per square foot of conditioned floor area for both the proposed building design and the standard building design.
b) The energy usage from various energy sources shall be converted to Btu per year per square foot of conditioned floor area for the purpose of comparing the annual energy usage.

2) The analysis procedure shall account for the operation of the building and its systems through a full year operating period.

3) The analysis of the annual energy usage of the standard building design and the proposed building design shall be based on the same outdoor weather conditions including temperatures, solar radiation, wind, and humidity of typical days in the year representing seasonal variation.

D. Documentation

The analysis of the annual energy usage of the proposed building design and the standard building design shall be prepared by a licensed professional. The analysis shall provide technical data on the proposed building design, the standard building design, and the data used to verify that the requirements of this Standard are met.

CERTIFICATION OF COMPLIANCE

A. Information

An information package about the requirements of Section 1415-G shall be prepared by the Energy Conservation Division. The packet shall contain a description of the requirements for subsidized multi-family residences, instructions on how to apply for a waiver, and a certificate for the owner to complete and sign, certifying compliance with the requirements. This packet shall be distributed to known grantors of public funds which may potentially be used for multi family residences.

The grantor shall provide the owner for the proposed construction, renovation, or remodeling project with the information package about requirements of Section 1415-G, including all of the information contained in the packet prepared by the ECD.

B. Certification Notice to DECD

Prior to providing or agreeing to provide a subsidy, the grantor shall require that the owner provide either: 1) signed certification that the primary heating system will not be electric, or 2) an approved waiver from the Commissioner of DECD. No subsidy shall be granted without either 1 or 2.

If the owner certifies that there will be no primary electric heat, the grantor shall forward the original signed certification to the ECD at the time of pre-construction approval to provide the public funds. The building owner, and the grantor shall each retain a copy of the certification.

C. Waiver

If the owner chooses to install an electric primary heating system, he/she shall complete a waiver application and submit it to the Energy Conservation Division for review. Within 5 business days of receipt of the initial application, the ECD shall review the application to assure that all of the required information has been completed. If more information is required, the owner will be notified that he must provide additional information.

Within 30 days of receipt of a completed application the Commissioner of DECD shall issue a written approval or denial of the waiver request. Approval or denial shall be based solely on whether or not the proposed design meets the energy efficiency requirements specified by law. A waiver approval shall be dated, numbered, and signed by the Commissioner of DECD.

F. Inspection

The person constructing a building project that has received a waiver must notify the ECD by calling 626-6000 when the following construction stages have been completed so that the building may be inspected prior to continuing with construction that will make the work inaccessible. Inspections shall occur prior to backfilling the foundation; after insulation and vapor retarder have been installed and prior to covering them with interior finish materials; after the ventilation system is installed. If the ECD does not inspect within 2 full working days, then the work may be covered.

LAW GOVERNING INSULATION CONTRACTORS, TITLE 10 CHAPTER 219 § 1481-1484

1481 Definitions

As used in this chapter, unless the context otherwise indicates, the following words shall have the following meanings:

1. **Insulation**. "Insulation" means any material, including but not limited to mineral wool, cellulose fibre, vermiculite and perlite, and foams to reduce heat flow between the interior and exterior surfaces of a building.

2. **Person.** "Person" means an individual, a copartnership, corporation or any other legal entity.

3. **Residence or Residential.** "Residence" or "residential" shall mean any existing dwelling structure with 3 or less living units whether leased or owner occupied. Except as provided in the subsection, buildings used for commercial or business purposes shall not be subject to the provisions of this chapter.

4. **Resistance factor.** "Resistance factor" shall have the same meaning as "thermal resistance", as defined in the ASHRAE Handbook of Fundamentals.

1482. Residential insulation contract

No person shall install insulation in any existing residence for compensation without providing the owner or lessee in advance with a written contract which shall include, but not be limited to, the following provisions which shall be clearly and conspicuously disclosed in the contract:

1. **Resistance factor.** The resistance factor of the insulation per inch and the thickness in inches to be installed;

2. **Type of insulation.** The type of insulation to be installed;

3. **Area covered.** An estimate of the square footage of area to be covered;

4. **Degree of flammability.** The degree of flammability of the insulation;

5. **Method of installation.** The method of installation to be used;

6. **Type of ventilation.** The type of ventilation to be installed. If no ventilation is to be installed, the contract shall so state;

7. **Guarantee against settling.** Whether the installed insulation is guaranteed against settling and, if so, for how long and to what degree; if not, the contract shall so state;

8. **Type of vapor barrier.** The type of vapor barrier to be installed. If no vapor barrier is to be installed, the contract shall so state;

9. **Areas to be insulated.** The areas of the dwelling to be insulated.

10. **Changes required.** Any construction, reconstruction or structural changes required to install the insulation.

11. **Work following insulation.** Any restoration, finishing or cleanup work to be performed following the installation of insulation.

12. **Provisions of warranties.** The provisions of all warranties.

13. **Names.** The name, business address and owner of the firm providing the goods and services provided herein; and;

14. **Use of urea formaldehyde insulation.** If urea formaldehyde insulation is to be installed, the following information:

    A. A warning that urea formaldehyde may cause the occupants to experience harmful side effects, including respiratory problems, dizziness, nausea, eye and throat irritations and cancer;

    B. Disclosure that allergic symptoms may develop anywhere from a few days to more than 6 months after installation; and

    C. Disclosure whether the contractor will take corrective action if an allergic reaction develops.

1483. Civil forfeiture; Unfair Trade Practices Act Violation

Any person who fails to provide the owner or tenant with an insulation contract, containing at least the minimum information required by section 1482, prior to this installation of insulation into an existing residence shall be deemed to have committed a civil violation for which a forfeiture of not less than $200 for the first offense and not less than $500 for each subsequent offense shall be adjudged. In addition to the civil penalty provided in this section, any violation of this chapter shall constitute a violation of the Unfair Trade Practices Act in Title 5, Chapter 10.

1484. Exemption

This chapter shall not apply to any person who provides to the owner or the lessee of a residence the labor or material for installing insulation in that residence if that person is not primarily engaged in the business of installing insulation and if that person does not advertise, solicit or hold himself out as one who installs insulation. For the purpose of this section, the term “not primarily engaged in the business of installing insulation” means having gross receipts for the installation of insulation which do not exceed either $2,500 for all labor or $4,500 for all materials in any one calendar year.

LAW GOVERNING HOME CONSTRUCTION CONTRACTS, TITLE 10, CHAPTER 219-A, § 1486-1490

1486. Definitions

As used in this chapter, unless the context otherwise indicates, the following terms have the following meanings.

1. Change orders. "Change orders," means a written amendment to the home construction contract which becomes part of and in conformance with the existing contract.
2. Down payment. "Down payment' means all payments to a home construction contractor prior to or contemporaneous with the execution of the home construction contract.
3. Materials. "Materials" means all supplies which are used to construct, alter or repair a residence.
4. Home construction contract. "Home construction contract" means a contract to build, remodel or repair a residence, including not only structural work, but also electrical, plumbing, and heating work; carpeting; window replacement; and other nonstructural work.
5. Residence. "Residence" means a dwelling structure with three or less living units and garage. Buildings used for commercial or business purposes are not subject to this chapter.

1487. Home Construction Contracts

Any home construction contract for more than $1,400 in materials or labor must be in writing and must be signed by both the home construction contractor and the homeowner or lessee. Both the contractor and the homeowner or lessee shall receive a copy of the executed contract prior to any work performance. This basic contract must contain the entire agreement between the homeowner or lessee and the home construction contractor and must contain at least the following parts.

1. Names of the parties. The name, address and phone number of both the home construction contractor and the homeowner or lessee.
2. Location. The location of the property upon which the construction work is to be done;
3. Work dates. Both the estimated date of commencement of work and the estimated date when the work will be substantially completed.
4. Contract price. The total contract price, including all costs to be incurred in the proper performance of the work, or, if the work is priced according to a "cost-plus" formula, the agree-upon price and an estimate of the cost of labor and materials.
5. Payment. The method of payment, with the initial down payment being limited to no more than one third of the total contract price;
6. Description of the work. A general description of the work and materials to be used;
7. Warranty. A warranty statement which reads:

In addition to any additional warranties agreed to by the parties, the contractor warrants that the work will be free from faulty materials; constructed according to the standards of the building code applicable for this location; constructed in a skillful manner and fit for habitation. The warranty rights and remedies set forth in the Maine Uniform Commercial Code apply to this contract;

8. Resolution of disputes. A statement allowing the parties the option to adopt one of three methods of resolving contract disputes. At a minimum, this statement must provide the following information:

   If a dispute arises concerning the provisions of this contract or the performance by the parties, then the parties agree to settle this dispute by jointly paying for one of the following (check one only):

   (1) Binding arbitration as regulated by the Maine Uniform Arbitration Act, with the parties agreeing to accept as final the arbitrator's decision (_____);
   (2) Nonbinding arbitration, with the parties free to not accept the arbitrator's decision and to seek satisfaction through other means, including a lawsuit (_____);
   (3) Mediation, with the parties agreeing to enter into good faith negotiations through a neutral mediator in order to attempt to resolve their differences (_____);

9. Change orders. A change order statement which reads:
   Any alteration or deviation from the above contractual specifications that involve extra cost will be executed only upon the parties entering into a written change order;

10. Door-to-door sales. If the contract is being used for sales regulated by the consumer solicitation sales law, Title 32, Chapter 69, subchapter V or the home solicitation sales law, Title 9-A, Part 5, a description o f the consumer's rights to avoid the contract, as set forth in these laws.; and

11. Residential insulation. If the construction includes installation of insulation in an existing residence, any disclosures required by Chapter 219, Insulation Contractors.

12. Energy Standards. A statement by the contractor that Chapter 214 establishes minimum energy efficiency building standards for new residential construction, and whether the new building or an addition to an existing building will meet or exceed those standards.

1488. Change orders.

Each change order to a home construction contract must be in writing and becomes a part of and is in conformance with the existing contract. All work shall be performed under the same terms and conditions as specified in the original contract unless otherwise stipulated. The change order must detail all changes to the original contract that result in a revision of the contract price. The previous contract price must be stated and the revised price shall also be stated. Both parties must sign the change order.

1489. Exemption

Parties to a home construction contract may exempt themselves from the requirements of this chapter only if the contractor specifically informs the homeowner or lessee of his rights under this chapter and the parties then mutually agree to a contract or change order that does not contain the parts set forth in sections 1487 and 1488.

1490. Penalties

1. Violation. Any violation of this chapter shall constitute prima facie evidence of a violation of the Unfair Trade Practices Act, Title 5, Chapter 10.

2. Civil penalty. Each violation of this chapter constitutes a civil violation for which a forfeiture or not less than $100 or more than $1000 may be adjusted. No action may be brought for a civil violation under this subsection more than two years after the date of the occurrence of the violation. No home construction contractor may be held liable for a civil violation under this subsection if the contractor shows by a preponderance of the evidence that the violation was unintentional and a bona fide error, notwithstanding the maintenance of procedures reasonably adopted to avoid any such error.

GLOSSARY OF TERMS

Air barrier: Or house wrap. A thin plastic film that blocks wind but allows water vapor to pass through. Generally installed between exterior sheathing and siding.

Air changes per Hour (ACH): Measurement of infiltration. The number of times an hour that the entire house volume of air is replaced with outside air.

Air inlet vents: Small vents through the building envelope to provide replacement air. Generally used in conjunction with exhaust vents.

Airtight Drywall Approach (ADA): A method of construction for moisture control that places less reliance on a vapor barrier and more on the tightness of the inside wall.

Air-to-air heat exchanger: Device for bringing & partially preheating fresh outdoor air as indoor air is exhausted. Fan-operated. Both through-the-wall and whole-house units are available.

Back-drafting: Potentially dangerous situation in which combustion gases (from furnace, boiler, gas water heater, fireplace, etc.) exhaust into the house instead of up the chimney. Caused by negative pressure in the house – usually as a result of exhaust-only fans operating in a tight house.

Backer rod: Foam “rope” that is used for sealing around wall penetrations, sealing between framing members and as a backing for caulk in deep cracks.

Blower door testing: Method of measuring air infiltration by depressurizing the house with a large fan and instrumentation set into an exterior door opening.

Cantilevered truss: Roof truss that overhangs the walls so that a greater thickness of insulation can be installed at the eaves.

Catalytic combustor: Device built into some wood stoves to increase combustion efficiency.

Compact fluorescent lamp: High-efficiency fluorescent lamp that is about the same size as incandescent light bulbs. Some include integral ballasts and can be screwed into standard light bulb sockets.

Condensation: Change of state from gas to liquid. Occurs with water vapor as an air mass is cooled down.

Condensing furnace or boiler: High efficiency heating system that extracts heat out of water vapor that would otherwise escape up the chimney.

Conductive heat loss: The transfer of heat energy from one material to another by the motion of adjacent atoms and molecules.

Convective heat loss: The transfer of heat energy from one location to another by the motion of fluids that carry the heat.

Dampproofing: Exterior foundation treatment to reduce the likelihood of moisture seeping through the wall into the basement. *Waterproofing* provides more complete protection, but is usually not required.

Dew point: The temperature at which a volume of air reaches 100% relative humidity and water vapor begins condensing.

Diffuse: The process by which water vapor and other gases can move through a solid. The rate of diffusion is determined by the material’s permeability or perm rating.

Drainage mat: A porous mat installed against the outside of the foundation wall to drain groundwater and runoff away from the wall surface and down to footing drains.

Energy Guide Labels: Labels on most new appliances providing information on yearly energy costs. Useful for comparing appliances.

Expanding foam sealant: A polyurethane foam that is applied from a can or canister. Used for sealing around windows, doors and wall penetrations.

Flame retention burner: A relatively new type of burner commonly used in oil boilers and furnaces today. By more effectively mixing air and oil droplets, a heating system with a flame retention burner requires less air flow and, therefore, loses less heat up the chimney.

Foam gaskets: Foam strips or rolls used to seal between framing members (under wall plates, for example), behind drywall, etc. Especially important with ADA construction.

Heat loss coefficient: A measurement of a building’s heat loss expressed in btu/°F hr. This number can be used for sizing heating systems and determining annual heating requirements.

Heating degree-day: A unit that represents a 1°F deviation from a fixed reference point (usually 65°) in the mean daily outdoor temperature. If the average outside temperature is 45°, 20-degree-days would be tallied for that day (65°-45°). By adding up degree-days, monthly and annual degree-day totals can be obtained.

Heating design temperature: The lowest expected temperature for use in sizing heating systems, based on average weather conditions.

High-Intensity Discharge (HID) lamps: High efficiency light source, including high pressure sodium, low-pressure sodium and metal halide lamps.

Hot roof: An insulated roof without an air space under the roof sheathing. Generally not recommended.

I-Joist: A manufactured laminated-wood joist that has greater strength than standard lumber. Available in greater widths and lengths. Sometimes used as rafters when high insulation levels are required.

Indirect water heater: A storage-type water heater that uses heat from a standard boiler. Much less expensive to operate than tankless coil water heater.

Magnetic declination: The difference between true north (or south) and magnetic north (or south). For solar siting, true directions should be used. If using a compass, you need to correct for the magnetic declination.

Net free vent area: Actual ventilation area provided by a screened or louvered vent accounting for air blockage by screening and louvers.

Passive solar: A building design to collect, store and distribute solar energy without fans and pumps.

Permeability: Ability of a material to allow water vapor to diffuse through it.

Perm rating: Measurement of a material's ability to transmit water vapor.

Pulse combustion: Combustion system used in some gas furnaces and boilers to achieve very high efficiency.

Rafter Plate: Plate installed on top of ceiling joists to raise rafter tails above the wall plate and thereby allow thicker insulation at the eaves.

Raised heel truss: A roof truss design that allows full thickness ceiling insulation at the eaves.

R-value: Measurement of a material's ability to block heat flow. Inverse of U-value (U=1/R).

Relative humidity: The amount of water vapor in a volume of air relative to the total it could hold at that temperature, expressed as a percentage.

Re-set control: Also called modulating aquastat. Control to regulate boiler temperature relative to outside temperature. When it is not as cold out, lower-temperature water can be circulated through hot water radiators.

Sealed combustion: Heating or water heating appliance in which combustion is totally sealed off from the house air (fresh air is supplied directly to the appliance), eliminating back drafting concerns.

Sill sealer: Foam gasket or insulation material for sealing between sill and foundation wall.

Saturated foam sill sealer: Foam gasket impregnated with non-hardening sealant to provide highest quality sill sealer.

Splines: Wood or plywood strips for joining stress skin panels.

Stress skin panels: Building panels for enclosing timber frame buildings or building "frameless" houses. Laminated system with exterior sheathing, insulation and inner wall surface.

Standpipe: Pipe set into the crushed stone before a slab is poured. Usually capped for later use in ventilating radon if a problem shows up.

Sun Angle: Angle of the sun above horizontal as it moves across the sky. Used in designing solar heating systems.

Suntempering: Simple passive solar design utilizing moderate areas of south facing glass. There are no special measures taken to store and distribute solar heat.

Tankless coil: Inefficient type of water heater operating off a boiler. As hot water is used, the boiler must fire to heat it. Particularly wasteful in the summer.

Tapered insulation: Foundation insulation strategy where full-thickness insulation is used over the upper part of the wall, and thinner insulation is used below.

Timber frame construction: Construction technique in which large timbers are used to provide structural strength in a building.

Thermal mass: Masonry or other material for storing heat in passive solar heating system.

U-value: Measurement of the heat conduction through a building component in Btu/°F hr. Inverse of R-value.

Vented rain screen: Air space provided by strapping between sheathing and sliding to allow for ventilation. Sometimes used in wall section above shed roof.

Vapor barrier: Thin film – usually polyurethane or foil – for blocking the movement of water vapor. Installed on inner (warm) side of insulation. Also called air/vapor barrier, recognizing its role in blocking air flow as well.

Vent spacer: Baffle material for ensuring an air space under the roof sheathing. Used primarily in insulated cathedral ceilings.

Water table trim: Trim used at the bottom of a wall to shed water out over protruding foundation insulation.

Wet-spray cellulose: Relatively new type of insulation that is sprayed into open wall cavities, somewhat higher R-value than fiberglass and better at sealing around wires, etc.

Zones: Separately controlled distribution lines from a central heating system. Each controlled by its own thermostat.

X. ENERGY STANDARDS REFERENCES

ORGANIZATIONS

ASHRAE	The American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329; phone: (404) 636-8400.
BOCA	The Building Code Officials & Code Administration International, Inc., 4051 Flossmoor Rd., Country Club Hills, IL, 60478-5795; phone: (708)799-2300.
CABO	The Council of American Building Officials, 5203 Leesburg Pike, Falls Church, VA, 22041.
DOE	The United States Department of Energy, Washington, DC, 20545
ECD	The Energy Conservation Division, Department of Economic and Community Development, State House Station 53, Augusta, ME 04333, phone: (207)624-6000
GAMA	The Gas Appliance Manufacturers Association, Inc., P.O. Box 9245, Arlington, VA 22209.
IES	The Illuminating Engineering Society, 345 East 47th Street, New York, NY 10017
SMACNA	The Sheet Metal and Air Conditioning Contractors National Association, Inc., 8224 Old Courthouse Road, Tysons Corner, Vienna, VA, 22180

PUBLICATIONS

ASHRAE 55-1981 – The ASHRAE Standard for Thermal Environmental Conditions for Human Occupancy.

ASHRAE 62-1989 – The ASHRAE Standard for Ventilation for Acceptable Indoor Air Quality.

ASHRAE 90A-1980 – The ASHRAE Standard for Energy Conservation in new Building Design. This standard is applicable to low-rise residential buildings only. Any references to other types of new building design have been superseded by ASHRAE 90.1 – 1989.

ASHRAE/IES 90.1-1989 – The ASHRAE Standard for Energy Efficient Design of New Buildings, Except new Low-Rise Residential Buildings.

ASHRAE 1989 Handbook – Fundamentals – This volume covers that basic principles and data for the entire technology of the HVAC industry, including theories, engineering concepts, and basic materials data.

BOCA National Building Code/1990 – Article 31 Energy Conservation.

BOCA National Mechanical Code/1990 – Article 16 Ventilation Air, Article 19 Energy Conservation

DOE – Building Foundation Design Handbook, a comprehensive survey of energy efficiency for all types of residential foundations.

GAMA Directory – Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment. Tested Efficiency ratings for gas and oil heating equipment, and gas, oil, and electric water heating equipment.

Model Energy Code, published by CABO with participation by BOCA, ICBO, SBCCI, and NCSBCS.

Standard Industrial Classification Manual, published by the Executive Office of the President, Office of Management and Budget.

XI. INDEX

This material has been printed by the Maine State Planning Office for the Municipal Code Enforcement Officer Training & Certification Program under appropriation number 010 07B 2901 012.