A TRAINING PROGRAM FOR ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION VOLUME II

**ENERGY CONSERVATION TECHNOLOGY
FOR THE BUILDING INSPECTOR**

DECEMBER 1977

**ENERGY CONSERVATION TECHNOLOGY
SERIES 100**

**Prepared For The
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ENERGY CONSERVATION IN NEW-
BUILDING CONSTRUCTION,
VOLUME II.**

**ENERGY CONSERVATION TECHNOLOGY:
FOR THE BUILDING INSPECTOR**

44 ENERGY CONSERVATION TECHNOLOGY SERIES 100

DEVELOPED BY

**BUILDING OFFICIALS & CODE ADMINISTRATORS INTERNATIONAL, INC.
INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS
SOUTHERN BUILDING CODE CONGRESS INTERNATIONAL, INC.
NATIONAL ACADEMY OF CODE ADMINISTRATION**

FOR

NATIONAL CONFERENCE OF STATES ON BUILDING CODES AND STANDARDS, INC.

DECEMBER 1977

**PREPARED FOR THE
DEPARTMENT OF ENERGY**

WORK PERFORMED UNDER CONTRACT No. E(04-3)1230

ECT COURSES

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Plan Examiners 300

IV ENERGY CONSERVATION TECHNOLOGY -
ADVANCED COURSE FOR PLAN EXAMINERS
300 Introduction to Energy
Conservation
301 Energy Fundamentals
302 Model Energy Code
303 Model Energy Code Application

COURSES

VOLUME I ENERGY CONSERVATION TECHNOLOGY - MANAGEMENT AND ENERGY CONSERVATION

SERIES 000

Intended Audience: Appointed and elected administrators of state and local governments.

Course Descriptions:

ECT-000. Management and Energy Conservation. Designed to acquaint public administrators at the policy making level with the meaning and implications for government of legislation relative to energy conservation standards for buildings, to underscore the need for training for employees responsible for implementing the new Model Energy Conservation Technology educational program now available. Optimization of agency resources and development of ability to handle technical demands will be considered as will the new technical skills required.

VOLUME II - ENERGY CONSERVATION TECHNOLOGY FOR THE BUILDING INSPECTOR

SERIES 100

Intended Audience: Personnel engaged in the inspection of buildings for compliance with approved plans.

Course Descriptions:

ECT-100. Introduction to Energy Conservation. Review of the energy situation, nationally and worldwide, establishing the importance of energy conservation in building construction. Discussion of recent research and trends. Illustrated with examples of buildings designed with energy conservation in mind.

ECT-101. Energy Fundamentals. Review of Energy Terminology and applications including heat transfer and insulation terms and practices involved in building so as to conserve energy.

ECT-102. Model Energy Conservation Code. An analysis of the Model Energy Conservation Code's requirements covering its administrative, plan review and inspection provisions and their impact on building construction.

ECT-103. Model Energy Conservation Code Application. Application of the Model Energy Conservation Code to achieve the building standards and inspection standards anticipated in ECT-102. Product recognition (labeling and approvals) and installation requirements will be included. The application of the Code's requirements to building, mechanical, plumbing and electrical inspections will be identified. The administrative, plan review and enforcement factors involved in achieving the code requirements also will be covered. Plan review is to include accepted practices for achieving the code requirements. The course will include practical examples of how these concepts can be applied to on-the-job situations.

VOLUME III - ENERGY CONSERVATION TECHNOLOGY FOR PLAN EXAMINERS AND CODE ADMINISTRATORS

SERIES 200

Intended Audience: Personnel involved in the review of plans or inspection of conventional residential buildings and small commercial and industrial buildings.

Course Description:

ECT-200. Introduction to Energy Conservation. Review of the energy situation, nationally and worldwide, establishing the importance of energy conservation in building construction. Discussion of recent research and trends. Illustrated with examples of buildings designed with energy conservation in mind.

ECT-201. Energy Fundamentals. Introduction and application of energy terminology and formulas including basic principles of heat flow in building construction.

ECT-202. Model Energy Conservation Code. An analysis of the Model Energy Conservation Code's administrative, plan review and inspection provisions and their impact on building construction.

ECT-203. Model Energy Code Application. Application to the Model Energy Conservation Code provisions and requirements to accomplish its energy conservation objectives. Product recognition (labeling and approvals), installation requirements and review of sample plans that illustrate principles and practices involved in designing energy conserving buildings will be included. The building, mechanical, plumbing and electrical inspections involved in applying the Code's requirements also will be identified. Incorporation of the code's administrative, plan review, inspection and enforcement provisions in the regular operations of the code administration agency will be discussed. Plan review will cover design provisions and accepted practices that meet the energy conservation requirements set forth in the Code.

VOLUME IV - ENERGY CONSERVATION TECHNOLOGY - ADVANCED COURSE FOR PLAN EXAMINERS

SERIES 300

Intended Audience: Personnel involved in review of plans or inspection of all buildings including those incorporating complex systems.

Course Description:

ECT-300. Introduction to Energy Conservation. Review of the energy situation, nationally and worldwide, establishing the importance of energy conservation in building construction. Discussion of recent research trends. Illustrated by examples of buildings designed with energy conservation in mind.

ECT-301. Energy Fundamentals. College level review of thermo-environmental energy principles that relate to energy conservation including energy terminology and formulas.

ECT-302. Model Energy Conservation Code. An analysis of the Model Energy Conservation Code's requirements covering its administrative, plan review and inspection provisions and their impact on building construction. Emphasis will be placed on systems analysis, design provisions and accepted practices.

ECT-303. Model Energy Conservation Code Application. Application of the Model Energy Conservation Code to the plan review process and in the design of energy conserving buildings. Information will be provided relative to performance and innovative design approaches and to product acceptance systems. The effect of this code upon the regular administrative, plan review, inspection and enforcement activities of the code administration agency will be indicated.

INTRODUCTION

One of the major goals set forth in the contract between the United States Department of Energy and the National Conference of States on Building Codes and Standards, Inc. (NCSBCS), together with the major model code groups, concerning the development of a Model Code for Energy Conservation in New Building Construction was filling the recognized need to provide uniform training in the implementation and enforcement of this code by the building officials.

It is recognized that the field of energy conservation was an area not previously entered into by code officials. Further, it was recognized that those presently serving their states and communities as well as those who would necessarily become involved in the future would be at differing levels at the curve of understanding the subject.

It was also determined that a specific introduction into the subject of energy conservation as would be encountered in applying codes and standards was needed for those in a policy-making position in the various states. The rationale for an orderly and coherent adoptive process for a uniform method of energy conservation enforcement appeared the most positive method to quickly assure that a start would be made on energy conservation methods in buildings.

A successive series of training manuals was developed by the Building Officials & Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), Southern Building Code Congress International, Inc. (SBCC), the National Academy of Code Administration (NACA), and the National Conference of States on Building Codes and Standards, Inc., for the United States Department of Energy, using personnel who were both well acquainted with the topic and who were currently involved in the continuing educational process for code officials. The results are presented in four volumes, each of which is oriented toward a specific audience and their need-to-know. The training program is entitled:

A TRAINING PROGRAM FOR ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION

VOLUME I - ENERGY CONSERVATION TECHNOLOGY - MANAGEMENT AND ENERGY CONSERVATION (ECT Series 000)

This training manual is both an introduction to the need for energy conservation in buildings and a definition of the need for and the role of the enforcement of official for energy conservation.

VOLUME II - ENERGY CONSERVATION TECHNOLOGY FOR THE BUILDING INSPECTOR
(ECT Series 100)

This training manual contains the basic information necessary to acquaint the field building inspector with the concepts of energy conservation in buildings and instructs him in the basic techniques of field inspection of energy compliance.

VOLUME III - ENERGY CONSERVATION TECHNOLOGY FOR PLAN EXAMINERS AND CODE ADMINISTRATORS (ECT Series 200)

This manual contains a more in-depth training in the review techniques and concepts required by the plan examiners and code officials in administering the code for conventional construction.

VOLUME IV - ENERGY CONSERVATION TECHNOLOGY - ADVANCED COURSE FOR PLAN EXAMINERS (ECT Series 300)

This manual contains training material that will be needed by plan examiners in the building departments involved in major or complex structures who are thoroughly familiar with the conventional principles and application of energy conservation requirements in building construction, but who will be faced with the responsibility of reviewing and approving involved complex technical alternative solutions to the problem of conserving energy in buildings.

These training modules are prepared on the basis of the assumed level of comprehension of the student. It is entirely possible that they may be used individually or in toto, depending upon the level of the student.

Comments and recommendations by instructors and participants are invited to assure that the revisions of these training materials which will be undertaken on a periodic basis are responsive to the needs of state and local building officials.

COMMENTS TO THE INSTRUCTOR

The following document is a model of the type of materials best suited to the training of a building inspector on the effects of, examples of and code requirements for energy conservation in new buildings.

It is important to note that these materials are intended to provide a basis for a comprehensive training program and can be revised, expanded and updated as necessary to achieve any desired level of instruction. An outline of the recommended time elements required to present the materials is given herein, with suggestions for possible areas of expansion or additional subjects which might be covered.

It is recommended that this manual, with the exception of the problem solutions in ECT-103, be provided to each student as a student manual. In addition, it is recommended that a copy of ASHRAE 90-75¹, the NAHB Insulation Manual² and the Model Code for Energy Conservation in New Building Construction³ be provided. Additional reference materials may also be desired, if additional subjects are covered, such as the thermal mass effect of masonry and concrete structures. It is not recommended that the ASHRAE Handbook of Fundamentals⁴ be required for these training sessions.

The course is divided into four categories with the following general scope and recommended time elements. The recommended times are based on the materials contained in this manual only. If additional material is added, times should be increased accordingly.

CHAPTER I

ECT-100 INTRODUCTION TO ENERGY CONSERVATION

Recommended Class Time: 1 Hour

Intended to give a brief overview of the current energy situation of the nation in order to establish a basis and a need for energy conservation.

CHAPTER II

ECT-101 ENERGY FUNDAMENTALS

Recommended Class Time: 5 Hours

Objective of this session is twofold. First, to define and explain the key terms associated with heat transfer, thermal transmission, and units of measurement. Second, to show how the thermal trans-

mission (U) of an assembly can be calculated.

The main focus of attention regarding terminology is on those terms dealing with the building envelope, and U and R values of materials and assemblies. A sample calculation of the U value of a wall is given and a sample calculation of the combining of elements for an overall (U_o) value is given.

CHAPTER III

ECT-102 THE ENERGY CODE

Recommended Class Time: 4 Hours

Objective here is to outline and briefly explain the Model Code. Emphasis is placed on the Code format, the three paths of compliance and a detailed explanation of what is regulated in the code. It is recommended that wherever possible, quick examples of how the code requirements affect inspection techniques are suggested.

CHAPTER IV

ECT-103 MODEL ENERGY CODE APPLICATIONS

Recommended Class Time: 8 Hours

This category also has two primary objectives. One is to detail the inspection techniques required to insure the field work is conducted according to the approved plans and the other is to examine a sample residential building to determine if the building complies with the code.

The inspection techniques aspect can best be accomplished with the use of visual aids. A series of slides of actual construction showing good and bad practices is recommended. Additional items which may be of interest to students are a film of "The Arkansas Story"⁵, a comprehensive study of a residence designed specifically with energy conservation in mind. Also materials dealing with case studies of other buildings available through the General Services Administration (GSA) may prove useful, however, this is recommended as having secondary importance to the building inspector.

The practical examples are of primary importance to the overall training. Although they deal with things not normally within the scope of work of a building inspector, they provide him with a basic knowledge of how the building performs thermally and the importance of each and every material in the building envelope to code compliance. Three case studies of a building and their solutions have

been provided for different degree day areas. Only one should be used within the recommended time allotted. The case study used should closely represent the degree day locations of the students' jurisdictions and the prevailing method of construction used. All three case studies result in one or more of the assemblies meeting the required U_o value and one or more exceeding the U_o value. This was done in order to demonstrate the trade-off aspect of the code and provides for the calculation of the overall U_t value for the entire building. If alterations or revisions to the problems are considered, they should be done in such a manner that the same results described above are achieved.

The forms that are included in Figures 103-1 through 4 likewise are intended to be model documents. As a generality, the use and explanation of mathematical formulae are foreign to most building inspectors, so an attempt was made to develop a tool which would simplify the calculation process.

In general, most code enforcement officials have had little or no previous training in energy conservation concepts or fundamentals. The method of presentation of the material, the amount of detail sought, and use of visual aids should be judged by the instructor based on the level of education and the relative extent of knowledge of the audience.

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CHAPTER I

INTRODUCTION TO ENERGY CONSERVATION

(ECT-100)

DEFINITIONS

Energy is usually defined as the capacity for the performance of work. Work, in turn, is defined as the product of a force times the distance over which the force has acted. Energy then is the capability of a substance or body to do measureable work.

Energy, as commonly known, exists in the form of chemical, gravitational, electrical, nuclear, heat, and mass. Transformation of one form to another is constantly taking place naturally and by the direction of man. Trees absorb the energy from the sun and by the process of photosynthesis convert this electromagnetic energy into chemical energy causing the tree to grow, a natural form of energy conversion.

HISTORY

Man has contrived many transformations of energy in his attempts to relieve himself of the work formerly done by hand. The storage of water behind the wall of a dam created the potential for doing work on a water wheel which in turn was connected to a mechanical device for grinding grain. In today's world the hydroelectric dam installation transforms the gravitational energy of water into mechanical energy in a large turbine which in turn is connected to an electrical generator thereby transforming mechanical energy into electrical energy.

The modern steam power plant transforms the chemical energy stored in the fossil fuels, coal, oil, gas and wood, into heat energy which is added to water to generate steam. The steam is fed to a steam turbine thereby transforming the heat energy into mechanical energy which in turn is transformed into electrical energy by an alternator connected to the turbine.

A great deal of research and development work is being performed in the area of the nuclear fuels and nuclear reactors. In both the pressurized water reactor and the boiling water reactors the heat energy released by the fission process is utilized in the conversion of water to steam which, either indirectly or directly, is fed to a turbine where it is transformed into mechanical and then electrical energy by a turbo-alternator.

Many sources of energy are now being explored for possible utilization

as means of heat and power for the purpose of meeting the present day needs. There is renewed interest in the wind, tides, sun and fusion as non-depletable sources of energy, all of which possibly will be used to develop power in the future.

CONSERVATION

The United States has always enjoyed a high standard of living. It is interesting to note that this country stands above all others with its high gross national product and correlated high energy consumption, whereas, those countries with low gross national products also are low energy consumers. Most of the European countries, Russia and New Zealand, consume less than half the energy per capita than the United States. The Soviet Union increased its average consumption each year beginning with 1945 to 1965 by 14 percent, while Japan has a growth rate greater than the United States.

The developing countries of the third world are aspiring for the energy consuming benefits enjoyed by the remainder of the world. This will not be difficult to do now that the United States is exporting billions of dollars each year because of the increasing cost of oil imports.

What impact does all of this have upon the family living in the United States?

Given below is a table of the domestic reserves of oil, natural gas and coal with the estimated years remaining at the current use rates as published in the report of the Commerce Technical Advisory Board Recommendations for a National Energy Program.⁶

TABLE 100-1

DOMESTIC RESERVES OF OIL, NATURAL GAS AND COAL

	<u>OIL</u>	<u>GAS</u>	<u>COAL</u>
Proven Recoverable with Current Tech- nology and Economics	40(a)	250(b)	434(c)
Years Remaining at Current Use Rates	7 years	11 years	700 years
Total Proven Reserves	300(a)	500(b)	1600(c)
Years Remaining at Current Use Rates	50 years	22 years	2600 years
Ultimately Discover- able Reserves	600(a)	900(b)	3207(c)
Years Remaining at Current Use Rates	100 years	40 years	5200 years
(a) Billion Barrels; (b) Trillion Cubic Feet; (c) Billion Tons			

Obviously, the preceding table points up the necessity for action on all fronts to conserve the remaining resources available to the nation. It also points up the urgency for further discovery of new energy reserves, and the development of those possible sources, such as, fusion, solar and fission, which have as yet not reached their full potential.

Figure 100-1 dramatically illustrates domestic production in terms of Quadrillion Btu (1×10^{15} Btu's) and the projected needs through 1985 as extrapolated by the Citizen's Advisory Committee on Environmental Quality.⁷

FIGURE 100-18

The logical conclusion that may be drawn from the above is the fact that as the Gross National Product of the various countries of the world increases, so will the need for energy. Associated with growth of the Gross National Product is the population growth of the world. At the present time the population of the world is doubling about every 35 years, which means that in the year 2000 there will be approximately seven billion persons populating the earth.

Combine this population growth with the aspirations of all the people of the earth for higher standards of living with the corresponding increases in the Gross National Product, and one begins to be overwhelmed by the future demands for energy.

"The implications of projecting historical energy trends for the future of our natural resources are no less dramatic. The earth's resources of oil, gas, coal and uranium are finite. Resource experts project the U.S. resources of gas and oil will be largely depleted within the next few decades. Foreign fossil fuel resources may provide a temporary respite for the United States, but as other nations strive for our standard of living, we cannot expect to indefinitely command a disproportionate share of these foreign reserves. U.S. coal reserves, although large, face difficult environmental problems that inhibit their exploitation. Reserves of our fissionable material are only slightly larger than our fossil reserves, unless we can assume the timely success of the nuclear breeder reactor program."⁹

The percent of imports is shown above the dotted line which marks the limit of domestic production. Clearly, this percentage is increasing at such an alarming rate that unless new domestic sources are found, and unless this need is curtailed by the initiation of extreme conservation measures, the United States will become almost as dependent on imports as many of the foreign countries.

APPLICATION

This brief review of the energy situation as it appears today emphasizes the need for the previously mentioned conservation measures.

For the building inspector, the concern lies with conservation measures employed in both residential and commercial buildings, both new and those rehabilitated. With the building of new homes, office buildings, shopping centers, and department stores, there is a growing market for energy both in the building and operation of structures. Many of the cities in the United States are being redeveloped with new buildings which will consume much more energy than those they are replacing. Shopping centers and department stores are using improved lighting,

elevators, escalators, snow melting heating coils and other energy consuming devices which increase the demand upon the energy resources either directly or indirectly.

Although heating systems have always been considered essential in a larger portion of the United States, cooling systems are being installed in nearly all new and rehabilitated construction, thereby escalating the demand for additional energy. Most new residences are not acceptable for sale unless they provide the so-called modern conveniences to which the American public has become accustomed.

It has been estimated that approximately 25 percent of the total energy supplied in the United States is used in commercial and residential buildings, with half being used for residential purposes and the other half being utilized in hotels, stores and office buildings.

Because the construction and operation of a building is not considered as a total system, the economics of construction and operations are considered as separate entities. The larger percentage of construction and development is performed as a commercial investment thereby entailing procedures which may not guarantee the best construction from an energy point of view. The most building for the least money, unfortunately, is the criterion for operation. Let the owner worry about the operating cost is the philosophy.

The building inspector must therefore be aware of those construction details and practices which, because of these policies, unnecessarily waste much of the provided energy.

What are some of the areas of which the inspector should be especially cognizant? To begin with, there is the siting of the structure. Very often, especially in urban developments where land costs are high and sites are limited, little can be done about the orientation of a structure. However, with the recent trend of commercial establishments relocating in suburban areas many possibilities exist for proper orientation of various components of a structure. Proper siting may utilize the solar effects and reduce infiltration with a consequent benefit to the owner and the nation.

The use of materials and structural methods which will conserve both heat loss and heat gain of a building is most effective.

"A study of homes in Atlanta, New York and Minneapolis with floor area of 1800 square feet concluded that most homes were greatly under insulated. Even the new (F.H.A.) standards established in 1971, although an improvement, do not yet achieve optimum insulation conditions. Table 17-5 lists the old and new standards together with the optimum considered for a house in New York."10

TABLE 17-5
COMPARISON OF INSULATION REQUIREMENTS AND MONETARY AND ENERGY SAVINGS
FOR A NEW YORK RESIDENCE

<u>Insulation Specification</u>	<u>Unrevised MPS*</u>		<u>Revised MPS*</u>		<u>Economic Optimum</u>	
	<u>Gas</u>	<u>Elec.</u>	<u>Gas</u>	<u>Elec.</u>	<u>Gas</u>	<u>Elec.</u>
wall insulation thickness (")	0	1-7/8	1-7/8	1-7/8	3-1/2	3-1/2
ceiling insulation thickness(")	1-7/8	1-7/8	3-1/2	3-1/2	3-1/2	6
floor insulation	No	No	Yes	Yes	Yes	Yes
storm windows	No	No	No	No	Yes	Yes
monetary savings(5/yr)	0	0	28	75	32	155
reduction of energy consumption(%)	0	0	29	19	49	47

*Minimum property standards (MPS) for one and two living units.

Storm doors and storm windows are exceedingly effective in reducing the infiltration into and out of buildings. Installation and closing of dampers in fireplace flues is an effective method of reducing the heat loss from indoor space. Proper caulking and weatherstripping of all openings in windows and doors will reduce the energy loss in a most meaningful way.

The proper selection of heating and cooling equipment is of vital importance in this overall picture of energy conservation. Furnaces are not always operated at peak conditions or at the level of highest efficiency. Therefore, care should be exercised in order that for the prevailing weather conditions furnaces which operate at the highest efficiency over the greater time period are selected.

Cooling units also vary in their consumption of energy for the cooling accomplished. Some consume more energy than others for the same cooling effect. Care should be exercised in the selection of the most efficient units. The units should also be installed properly in order that they too operate at the most efficient level for the greater part of the cooling season.

Proper maintenance of all equipment is absolutely necessary if cost of operation is to be kept at the minimum. Filters in both heating and cooling units should be replaceable or removable for regular periodic replacement or cleaning. Insulation of pipes and ducts should be replaced when damaged and all leaks in pipes, flues or other appurtenances should be repaired in order to prevent the leakage of energy.

Windows, doors and skylights should be operable in order that they be opened during periods when the mechanical cooling is not necessary. There are many occasions, particularly during the spring, summer and fall seasons when windows may be opened in lieu of using artificial cooling. Unfortunately, many of the commercial buildings are designed with windows which do not permit opening; consequently, the cooling and ventilating needs are met by means of energy consuming mechanical devices.

Careful consideration of the ventilation requirements of a building is one aspect of the building codes that should be examined in light of energy conservation. In many instances, the over sizing of ventilating ducts and fans emphasizes unnecessary energy waste.

Excess light is still another area in which care should be exercised. In many instances, excess lighting is installed for purposes of esthetics or advertising, particularly in commercial installations. Not enough circuits are installed with the proper switching which will permit adequate illumination of an area, yet conserve on the power consumed for this purpose. Provisions should be made in the architectural design for natural lighting when possible. In all instances, provisions should be made for natural lighting, ventilation and cooling when possible, as there is no substitute for free energy.

RESEARCH

Until additional sources of the depletable fuels are discovered and developed, the United States must concentrate its research efforts on harnessing those unlimited sources of energy which to date have been subjected to superficial research and development.

The fusion process offers the possibility of increasing the energy source of nuclear fuel to approximately a thousand years through the use of the breeder reactor. Although much work has been done in this area, further development of the breeder reactor is necessary before it can become a dependable source of power.

Solar energy which offers a source of energy that could meet the future needs of the United States for an infinite period of time has just begun to be explored with the seriousness the present crisis demands. Research and development is taking place in many institutions aimed at solving many of the associated problems. Obviously, problems of location, variation of intensity due to cloudiness, fog and day and night orientation all have to be solved if significant amounts of energy are to be realized from this source.

Geothermal heat is now being utilized in isolated instances. The earth's interior is a well known source of heat which could last for many, many years. Experimentation to determine the possibility of seismic effects, waste heat to the surrounding environment and waste water contaminated with minerals is taking place. Exploration for new wells is being carried on. However, this is an extremely expensive process requiring drilling many thousands of feet to reach the steam producing rock. Much of the exploration to date has taken place in the western parts of the United States. Whether geothermal energy is non-depletable is yet to be determined; however, it is a source of energy that could be used to supplement other sources thereby reducing the demand for imports.

Finally, water and wind power are areas in which increasing interest is being demonstrated. Tidal action and additional hydroelectric generation will, no doubt, play an increasing role in the energy needs of this country. To date, the initial cost of developing sites would not justify this type of investment, especially by private enterprise; however, with the increasing cost of other energy sources, renewed interest in tidal power development is beginning to surface. It is questionable as to whether the development of sites with extreme tidal ranges has reached the "economically feasible stage". This is yet to be determined.

Many federal agencies are sponsoring research at all of these frontiers and, like all other challenges this country has faced in the past, there is a prevailing climate of optimism that the energy crisis also will be surmounted.

CHAPTER II

ENERGY FUNDAMENTALS

(ECT-101)

TERMS

Terms defined in this section include energy, temperature, BTU, heat transfer, conduction, convection, radiation, degree day, thermal resistance (R), thermal transmission(U).

ENERGY

Energy is the capacity for doing work. It can be expressed in terms of mechanical, kinetic, molecular, chemical and other forms depending upon the system. Energy usually is converted from one form to another when it is put to practical use. Combustion is an excellent example of the chemical energy in a substance being transformed into heat energy through the change of the molecular structure of the substance when it combines with oxygen. This process is known as an exothermic process because heat is released as a result of this transformation.

In the automobile cylinder the heat is released due to the rapid burning of the gasoline causing the gases in the cylinder to expand because of the great temperature increase thereby creating a pressure that pushes against the piston. In this instance the chemical energy has been transformed to heat energy which in turn is transformed to mechanical energy.

Customarily, the terms associated with units of energy are the kilowatt-hour (kWh) or the British Thermal Unit (BTU). The type of energy we are primarily concerned with is heat energy. The transfer of heat from a building in winter and to a building in summer creates the need for energy consumption for space heating and cooling. Work in the form of heat energy is required to heat and cool a building to offset the heat transfer.

BTU

The British Thermal Unit (BTU) is a measure of the quantity or amount of heat energy. The BTU is usually defined as the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

This is a general definition which will not have a great deal of meaning in its application hereafter. The emphasis on the definition is only to show that there is a standard origin by which we can measure the quantity of heat energy. It is also necessary to think of the BTU in terms of time in order to apply and measure heat energy in buildings. The common unit of time is the hour making the term, then,

Btu per hour. A common designation of this unit is Btu/hour or just Btuh. You will become familiar with this term as it is used to size heating and air conditioning equipment and to measure the heat loss and heat gain of a building.

TEMPERATURE

Temperature is a measure of the intensity of heat, not the quantity or amount of heat that is present. This is often a misconception by many. Temperature is measured on the Fahrenheit scale with 32°F and 212°F being the freezing and boiling points of water, respectively.

One basic law of thermodynamics that should be remembered is that heat always flows from a higher temperature to a lower temperature. This tells us that heat will either flow into or out of a building depending on whether the temperature inside is lesser or greater than the temperature outside. If there is no temperature difference, there will be no heat flow. This situation, however, seldom occurs for long periods of time. Depending on geographical latitudes, in the winter the outside temperature is lower than the indoor temperature which indicates a heat flow out of the building, thereby requiring a positive heat supply to maintain comfortable indoor temperatures. This flow of heat is called heat transfer.

HEAT TRANSFER

The movement of heat through the openings and surfaces of a building is known as heat transfer. It is usually assumed to be at a constant rate, or steady state, and is based upon predetermined temperature differences. If the heat is transferred from the interior of a building to its exterior then it is known as a heat loss.

If the direction of flow is in the opposite direction; i.e., from the exterior to the interior, then it is known as heat gain.

The designs of heating and cooling systems are based upon the calculated heat loss and heat gain, therefore, certain factors are assumed or determined before these calculations can be made. The greater the heat loss from a building, the larger the heating source must be in order to maintain a constant temperature within the building.

The total heat loss is made up of two losses, namely, the transmission loss and the infiltration loss. The transmission loss is the heat that is conducted through the surfaces of the space. The infiltration loss is the heat that is necessary to heat the air which leaks into a building through the cracks and openings in the enclosure. Cracks between the window sash, window frames, doors, door frames and other openings permit a surprisingly large amount of heat to escape from the enclosure because of the air leaking into the structure.

Heat is transferred by three methods, namely:

Conduction
Convection
Radiation

Conduction is the flow of heat directly through a solid material. The measure of how good a conductor a material is can be determined by the rapidity with which the movement of heat through the material occurs. This may also be used to measure the insulation characteristics of a material. The faster the flow of heat, the better a conductor the material. Such a material with high conductance would be considered a poor insulator. A material which does not conduct heat rapidly is said to have a high resistance and would be considered a good insulator. By building the walls and roofs of a building of materials having known conductive characteristics, the heat flow rate for the building can be controlled.

Example: What would the heat loss(Q) through a wall with an area of 1000 ft²(A) and a thermal transmission (U) of .242 be if the outdoor and indoor design temperatures(T) were 0°F and 72°F, respectively?

Solution:

$$\begin{aligned} Q &= U \times A \times TD \\ &= .242 \frac{\text{Btu}}{\text{hr. ft}^2\text{°F}} \times 1000 \text{ ft}^2 \times (72\text{°F} - 0\text{°F}) \\ &= 17,424 \frac{\text{Btu}}{\text{hr.}} \end{aligned}$$

Convection is derived from the word convey which obviously means to carry. When heat is transferred by the process of convection it has been transported or moved from one place to another by being carried by a fluid. Usually, the fluid is either air or water because they are inexpensive and readily available. When air is heated in a furnace and then conveyed through the duct work to the various rooms in the building, then the heat is being transferred from the furnace by convection. Most cooling systems utilize the convection process to move heat from one place to another in a building. Another example of heat transfer by convection is the infiltration of cold air in the winter into a building through cracks around doors and windows.

Radiation is an important heat transfer process when cooling is being considered. Radiant energy is heat energy which is transferred by electromagnetic waves similar to those which transfer

light and television signals. These waves are known as infrared or heat waves and have a prescribed wave length range. The higher the temperature of a body the greater is the amount of heat energy emitted by the body. The Sun, of course, is the one body that transfers all of its heat energy by means of radiation process. The earth receives a small part of this radiation. From this source comes all of earth's energy potential except for nuclear and fusion energy. In fact, if it were not for the Sun, nothing would be able to survive on the earth.

As beneficial as the Sun is to the earth, it can also create problems when attempts are made to keep buildings at a comfortable temperature. In many latitudes of the United States, particularly in the summertime when the Sun is above the equator, it becomes necessary to mechanically cool buildings in order to maintain comfortable living and working environments, all because of the heat energy radiated to the building walls, windows and roof by the Sun.

These three methods of heat transfer are the processes that occur which create the need to heat and cool buildings. As was pointed out earlier, the amount of heat that is transferred varies with the temperature difference between the outside and inside conditions. By knowing the trend in outdoor temperature conditions of specific locations, one can estimate the heating requirements that a building will have. This is known as the Degree Day Method.

DEGREE DAYS

Degree days are measured from 65°F downward on the temperature scale and are counted from the average temperature for each 24 hour period. There are as many degree days for a 24 hour period as there are Fahrenheit degrees difference between the average temperature and 65°F. For example, if today's average temperature was 60°F there would be 5 heating degree days for the day. This type of data is continually being recorded and degree day values for an entire year are available. Typical annual degree day values can range from 500 in Southern California to 10,000 in Northern Minnesota. This indicates the relative heating requirements in that area with an annual value of 500 are minimal, as the average daily temperature very seldom falls below 65°F. The opposite is true of a climate experiencing 10,000 heating degree days. Heating degree days are also the basis for the Model Code requirements for the thermal performance of the building envelope.

THERMAL TRANSMISSION

Heat flow through elements of the building envelope (walls, roof, floors, doors, windows, etc.) depends on three factors:

1. Area: The larger the area of the element, the more heat it will conduct. A 400 foot square wall will conduct twice as much as a 200 foot square wall.
2. Temperature Difference: The greater the difference is, the more heat flow will occur in the element. For example, if the

temperature difference between inside and outside temperature is increased from 30° to 60°F, the flow of heat through the element will double.

3. Material Properties: The material and thickness of building envelope elements are spoken of in terms of four factors; conductivity, conductance, resistance and overall coefficient of heat transfer.
 - a. Conductivity: The ability of various materials to conduct heat. The good conductors are metals. The poorer conductors, such as wood, asbestos, gases, cork and felt, are called insulators. How well a substance transmits heat by conduction is a physical property of the particular material called thermal conductivity. The symbol for thermal conductivity is "k".
 - b. Thermal conductivity: Is defined as the amount of heat (Btu's) that passes through a homogeneous material 1 inch thick and 1 foot square in area, in an hour's time, with a temperature difference of 1°F between the outer and inner surfaces. Values "k" are expressed in (Btu's-inch/hr-°F-ft²). The lower a material's "k", the higher its insulating value.
 - c. Conductance: Conductance is similar to conductivity except that it is a measure of the rate of heat flow for the actual thickness of a material or an air space (either more or less than 1 inch), 1 foot square in area, at a temperature difference of 1°F. If conductivity (k) of a material is known, the conductance (C) can be determined as follows:

$$C = \frac{k}{x}$$

Where x = thickness. The lower the C, the higher the insulating value.

4. Resistance: Resistance is a measure of a material's ability to retard heat flow rather than promote it. Resistance generally is referred to as a thermal resistance and is usually symbolized by "R". A number to the R indicates the ability of one specific material, or a specific group of materials to resist heat flow. Resistance (R) is a numerical reciprocal of conductance (C), thus:
An example for conductance is when:

$$C = 0.10, \text{ then } R = \frac{1}{0.10} = 10 \text{ hr ft}^2/\text{Btu}$$

The higher the R number, the higher the insulating value.

5. Overall Coefficient of Heat Transfer: The overall coefficient of heat transfer refers to the value of all the materials in a building in series materials, air spaces, and surface air films. The overall coefficient of heat transfer generally is spoken of as "U value" and is expressed in terms of Btuh per ft² of area per °F temperature difference.
The overall coefficient of heat transfer is the reciprocal of the

total resistance which equals the sum of separate resistances.
Thus:

$$U = \frac{1}{R_T}$$

$$\text{Where } R_T = R_1 + R_2 + R_3 \text{ --- } + R_n$$

The lower the U value, the higher the insulating value.

R values of various different materials are normally determined by physical testing. The most common standard tests are ASTM C177, Thermal Conductivity by the Guarded Hot Plate Method, and ASTM C236, Thermal Conductivity by the Guarded Hot Box Method. Once a material has been tested, it is safe to assume that all materials of the same composition will have the same R value. For this reason, the ASHRAE Handbook of Fundamentals⁴ lists a number of various materials and their respective C and R values. The NAHB Insulation Manual² also contains similar information. Tables 103-1 are an excerpt from the ASHRAE Handbook of Fundamentals giving values of various materials, air spaces, and surface films.

CALCULATING U_o VALUES

The Model Code regulates, among other things, the thermal performance of the shell of a building by setting maximum U_o values for walls, roofs, floors over unheated spaces, etc. Therefore, it is necessary for code officials to become aware of how these values are determined. This is also beneficial for the building inspector since it will give him a good feeling for the effect of what happens when materials are substituted in the field. When a certain assembly is called for on the plans and a different sheathing material, for example, is substituted, the assembly may still have the required strength characteristics but it may not have the required thermal properties.

We will discuss two aspects of calculating U_o values. The first will be a given cross-section of materials. As we discussed earlier, however, most assemblies are made up of various different sub-assemblies. The second aspect will be combining the effects of different materials to determine the overall U_o value.

CALCULATING A U VALUE

Consider the section view of a wood frame wall assembly. In most cases, walls in residential construction consist of four distinct assemblies of materials, sometimes more. They are:

1. The portion of the wall that includes the wood framing member.
2. The portion of the wall that includes the cavity space.
3. The portion of the wall containing windows.
4. The portion of the wall containing doors.

Another common element that might add a fifth item would be a wall that

is 1/2 brick veneer. This constitutes a different assembly of materials having different thermal transmission properties. Each different assembly must be separately calculated then combined to determine the overall U_0 value for the wall.

General Procedure:

- Obtain or prepare a sketch of the assembly identifying each material of the assembly and dimensions to indicate the sizes (areas) of the assembly.
- Determine the R values of each material. This can be obtained from test reports or by referring to Tables such as shown in Tables 103-1.
- For each different assembly, add the R values of each material, including surface film R values.
- Using the relationship $U = 1/R$ calculate the U value of that portion of the assembly by dividing $1/R$.

$$U = 1/R_t \text{ where;}$$

$$R_t = R_1 + R_2 + R_3 + \dots$$

- Indicate the area of the assembly (in square feet). This will be used when combining the effects of all the different materials in the assembly.

Example #1

$$U_W = 1/R_W = 1/7.51 = .1333$$

Example #2

$$U_W = 1/R_W = 1/10.01 = .099$$

Example #3

COMBINING U VALUES

Since the code regulates the overall U_o value of a wall, roof and floor assembly, it is necessary to determine the combined effects of the U values of all different sub-assemblies. A sub-assembly can be defined as that cross-section of a wall, floor or roof having a given thermal transmission property expressed as a U value. Four and sometimes five common sub-assemblies occurring in almost every wood frame wall construction were mentioned previously. In order to combine the effects and determine the overall U_o , we must know the U value and the area (in square feet) of each sub-assembly. Then using the relationship:

$$U_o \times A_o = (U_1 \times A_1) + (U_2 \times A_2) + (U_3 \times A_3) + \dots$$

we can determine the U_o value. The relationship is taken from the basic heat loss formula:

$$Q = U \times A \times TD$$

and can be thought of as "the whole is equal to the sum of its parts", the whole being $U_o \times A_o$. The U values and areas of the sub-assemblies are determined as discussed above and the overall area, A_o , of the assembly can be determined from the plans. To solve the equation for U_o the equation is transposed as follows:

$$U_o = \frac{(U_1 \times A_1) + (U_2 \times A_2) + (U_3 \times A_3) + \dots}{A_o}$$

Example: Given a wall section having U values and areas of sub-assemblies as follows, determine the overall U_o of the wall.

U framing = .133	A framing = 110 ft ²
U cavity = .099	A cavity = 625 ft ²
U windows = .62	A windows = 225 ft ²
U doors = .49	A doors = 40 ft ²

Solution:

$$\begin{aligned} 1. A_o &= A_f + A_c + A_w + A_d \\ &= 110 + 625 + 225 + 40 \\ &= 1000 \text{ ft}^2 \end{aligned}$$

$$\begin{aligned}
 2. \quad U_o &= \frac{(U_f \times A_f) + (U_c \times A_c) + (U_w \times A_w) + (U_d \times A_d)}{A_o} \\
 &= \frac{(.133 \times 110) + (.099 \times 625) + (.62 \times 225) + (.49 \times 40)}{1000} \\
 &= \frac{14.63 + 61.88 + 139.5 + 19.6}{1000} \\
 &= \frac{235.61}{1000} \\
 U_o &= .24
 \end{aligned}$$

This value would then be compared with the maximum U_o value permitted by the code for the appropriate Degree Day location. If the actual U_o were greater than the code requirement, the wall would not comply. Again, the higher the U value, the poorer an insulator and the greater the heat loss would be.

This same method for combining the effects of sub-assemblies to determine the overall U_o value of a wall, or roof, etc., can be used to determine the overall U value of an entire building. In this case, the sub-assemblies to be combined would be the overall wall, roof and floor assemblies. This aspect will be discussed later in explaining one of the paths of compliance permitted by the Code.

ADDITIONAL DEFINITIONS

There are several other terms which should be studied. They include:

Building Envelope. The elements of a building which enclose conditioned spaces through which thermal energy may be transferred to or from the exterior.

Building Inspector. The duly appointed and authorized member of the enforcement department who will be responsible for inspection of construction for compliance with the Energy Code.

Energy Code(Code). Refers to the Model Code for Energy Conservation in New Buildings. May be referred to as the Model Code or the Code.

Degree Day, Heating. A unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. For any one day, when the mean temperature is

less than 65F, there exist as many Degree Days as there are Fahrenheit degrees difference in temperature between the mean temperature for the day and 65F.

Energy Efficiency Ratio (EER). The ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions.

Enforcement Official. The duly appointed official responsible for the administration and enforcement of the Model Code.

Gross Floor Area. The sum of areas of the several floors of the building, including basements, cellars, mezzanine and intermediate floored tiers and penthouses of headroom height, measured from the exterior faces of exterior walls or from the centerline of walls separating buildings.

- Covered walkways, open roofed-over areas, porches and similar spaces shall be excluded.

- The gross floor area does not include such features as pipe trenches, exterior terraces or steps, chimneys, room overhang, etc.

Gross Wall Area. The vertical projection of the exterior wall area bounding interior space which is conditioned by an energy using system; includes opaque wall, window and door areas.

- The gross area of exterior walls consists of all opaque wall areas, including foundation walls above grade, between floor spandrels, peripheral edges of floors, window areas including sash, and door areas, where such surfaces are exposed to outdoor air and enclose a heated or mechanically cooled space, including interstitial areas between two such spaces.

Heated Space. Space, within a building, which is provided with a positive heat supply to maintain air temperature of 50F or higher.

HVAC System. A system that provides either collectively or individually the processes of comfort heating, ventilating, and/or air conditioning within or associated with a building.

Infiltration. The uncontrolled inward air leakage through cracks and interstices in any building element and around windows and doors of a building, caused by the pressure effects of wind and/or the effect of differences in the indoor and outdoor air density.

Non-Depletable Energy Sources. Sources of energy (excluding minerals) derived from incoming solar radiation including photosynthetic pro-

cesses; from phenomena resulting therefrom including wind, waves and tides, lake or pond thermal differences; and energy derived from the internal heat of the earth, including nocturnal thermal exchanges.

Opaque Areas. All exposed areas of a building envelope, which enclose conditioned space, except openings for windows, skylights, doors and building service systems.

Overall Thermal Transfer Value (OTTV). An overall coefficient of heat gain expressed in units of Btu per hour per square foot.

Roof Assembly. A roof assembly shall be considered as all components of the roof/ceiling envelope through which heat flows, thereby creating a building transmission heat loss or gain, where such assembly is exposed to outdoor air and encloses a heated or mechanically cooled space.

The gross area of a roof assembly consists of the total interior surface of such assembly, including skylights, exposed to the heated or mechanically cooled space.

When return air ceiling plenums are employed, the roof/ceiling assembly shall:

1. For thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly; and,
2. For gross area purposes, be based upon the interior face of the upper plenum surface.

Thermal Transmittance (U). Overall coefficient of heat transmission (air to air) expressed in units of Btu per hour per square foot per degree F. It is the time rate of heat flow. The U value applies to combinations of different materials used in series along the heat flow path, single materials that comprise a building section, cavity air spaces, and surface air films on both sides of a building element.

Thermal Transmittance (U_o). Overall (average) heat transmission of a gross area of the exterior building envelope, expressed in units of Btu per hour per square foot per degree F.

The U_o value applies to the combined effect of the time rate of heat flows through the various parallel paths, such as windows, doors, and opaque construction areas, comprising the gross area of one or more exterior building components, such as walls, floors, or roof/ceilings.

Zone. A space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

CHAPTER III
THE ENERGY CODE
(ECT-102)

The inspector's responsibility involves the enforcement of the Model Code. In order to develop an understanding of the Code, this chapter will be devoted to the Code and we will proceed through the Code discussing items of interest and importance to the field inspector.

The Table of Contents of the Code indicates that the Code is divided into six sections:

SECTION 1. ADMINISTRATION AND ENFORCEMENT

SECTION 2. DEFINITIONS

SECTION 3. DESIGN CONDITIONS

SECTION 4. BUILDING DESIGN BY SYSTEMS ANALYSIS AND BUILDINGS
UTILIZING NON-DEPLETABLE ENERGY SOURCES

SECTION 5. COMPONENT DESIGN

SECTION 6. BUILDING DESIGN BY ACCEPTABLE PRACTICE

The Administration and Enforcement Section obviously provides the legal and administrative provisions necessary in a code. The Definition Section likewise is self-explanatory. The Design Conditions Section establishes the minimum design conditions, such as indoor and outdoor design temperatures.

Section 4, 5 and 6 are alternate design methods a building designer may use in designing a building for conformance with the Code. In other words, compliance means a designer need only comply with one of the three sections.

The Model Code is modeled after ASHRAE 90-75 and puts that standard into code language and format. ASHRAE 90-75 was developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

We will now proceed through the Code, section by section. Those items important to the field inspector will receive the most emphasis.

SECTION 1 - ADMINISTRATION AND ENFORCEMENT

The Code applies to only new buildings designed primarily for human occupancy. It is extremely important to understand that the Code does not apply retroactively to existing buildings. Certain new buildings are excluded from compliance with the Code:

1. Buildings with a peak design rate of energy usage of 3.4 BTU/hr./sq. ft. of floor area or less. To utilize this exception, the designer must submit adequate information justifying the exception to the Enforcement Official. A type of building this might apply to could be an unheated warehouse with a small heated office.
2. Buildings which are neither heated nor cooled.

Existing Buildings

The application of the Code to existing buildings shall be made to the new construction only as follows:

1. When an addition to an existing building is made, the new addition, only, must comply with the Code.
2. A historic structure is exempt from the Code provided it has been preserved because of historic, architectural or public policy.
3. Any change in the occupancy of a structure which would require an increase in depletable fuel or electrical energy will be permitted only when the structure is made to comply with the Code.

The Code also requires for existing buildings, as it does for new structures, that any new materials or equipment installed after the Code becomes effective shall be identified in order to show compliance with the Code. If any materials, method of construction, design, or insulating materials are used other than those specifically prescribed in the Code, they must be approved by the Enforcement Official, not the building inspector, unless this authority has been officially assigned.

The Code specifically allows the use of alternate materials and methods of construction provided they have been approved by the Enforcement Official.

Complete maintenance information necessary for efficient operation of the equipment must be furnished with the equipment. Required routine maintenance actions shall be stated and incorporated in the form of a clearly legible label accessible to the inspector at all times after installation.

The inspector will have available to him a set of approved plans and specifications which have been submitted to and approved by the Enforcement Official. These plans will show in detail all the information necessary for complete and adequate performance of the duties of the inspector. This data will include information about the exterior envelope materials and assembly, U values of the respective elements and R values of all insulating materials.

In addition to the above, information pertaining to the size and type of equipment and their controls will be available for inspection.

All construction work requiring a permit will be subject to inspection. Under no conditions may work be performed on the structure beyond the point indicated by each successive inspection without written authorization of the enforcement official. The enforcement official may require reinspection as deemed necessary.

The number and types of inspections required are a local determination and should be integrated into existing inspection procedures.

When the enforcement official is satisfied that the buildings are completed and meet the requirements of the Code after a final inspection the buildings may be released for occupancy.

SECTION 2 - DEFINITIONS

Section 2 consists of the definition of words and terms used in the Code. Since many of the words and terms used in the section are familiar to the building inspector, the definitions highlighted in this manual will be those that are unique to the enforcement of the energy code.

Accessible. (As applied to equipment.) Admitting close approach, not guarded by locked doors, elevation or other effective means. (See Readily Accessible.)

Air Conditioning. The process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet requirements of the conditioned space.

Air Transport Factor. The ratio of the rate of useful sensible heat removal from the conditioned space to the energy input to the supply and return fan motor(s), expressed in consistent units and under the designated operating conditions.

Automatic. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as for example, a change in current strength, pressure, temperature or mechanical configuration.

Boiler Capacity. The rate of heat output in Btu/h (W) measured at the boiler outlet at the design inlet, outlet, and rated input.

Building Envelope. The elements of a building which enclose conditioned spaces through which thermal energy may be transferred to or from the exterior.

Building Project. A building or group of buildings, including on-site energy conversion or electric-generating facilities, which utilize a single submittal for a construction permit or are within the boundary of a contiguous area under one ownership.

Coefficient of Beam Utilization (CBU). The ratio of the luminous flux (lumens) reaching a specified area directly from a floodlight or projector to the total beam luminous flux.

Coefficient of Performance (COP) - Cooling. The ratio of the rate of net heat removal to the rate of total energy input, expressed in consistent units and under designated rating conditions.

Coefficient of Performance (COP) - Heat pump, Heating. The ratio of the rate of net heat output to the rate of total energy input, expressed in consistent units and under designated rating conditions.

Coefficient of Utilization (CU). The ratio of the luminous flux (lumens) from a luminaire received on the work plane to the lumens emitted by the luminaire's lamps alone.

Color Rendition. General expression for the effect of a light source on the color. Appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.

Comfort Envelope. The area on a psychrometric chart enclosing all those conditions described in Std RS-1 of the Code as being comfortable.

Conditioned Floor Area. The horizontal projection of that portion of interior space which is contained within exterior walls and which is conditioned directly or indirectly by an energy-using system.

Efficiency, Overall System. The ratio of useful energy (at the point of use) to the thermal energy input for a designated time period, expressed in percent.

Energy. The capacity for doing work; taking a number of forms which may be transformed from one into another, such as thermal (heat), mechanical (work), electrical, and chemical; in customary units, measured in kilo-watt-hours (kWh) or British thermal units (Btu).

Energy Recovered. (See Recovered Energy.)

Equivalent Sphere Illumination (ESI). The level of sphere illumination which would produce task visibility equivalent to that produced by a specific lighting environment.

Exterior Envelope. (See Building Envelope.)

Floodlighting. A lighting system designated to light an area using projector-type luminaires usually capable of being pointed in any direction.

Fuel. A substance which may be burned to give heat or generate electricity; a nuclear substance used to generate electricity. The potential heat energy that is stored in fuels was received from the sun.

Gross Floor Area. The sum of areas of the several floors of the building, including basements, cellars, mezzanine and intermediate floored tiers and penthouses, measured from the exterior faces of exterior walls or from the center line of walls separating building.

- Covered walkways, open roofed-over areas, porches and similar spaces shall be excluded.

- The gross floor area does not include such features as pipe trenches, exterior terraces or steps, chimneys, roof overhangs, etc.

It is important to note that the measurements are from exterior face to exterior face.

Gross Wall Area. The vertical projection of the exterior wall area bounding interior space which is conditioned by an energy-using system; includes opaque wall, window and door areas.

In calculating the gross wall area, measurements shall be made from exterior face to exterior face for the horizontal measurement.

Heat. The form of energy that is transferred by virtue of a temperature difference.

Heated Space. Space, within a building, which is provided with a positive heat supply to maintain air temperature of 50F or higher.

Humidistat. An instrument which measures changes in humidity and controls a device(s) for maintaining a desired humidity.

HVAC. Heating, ventilating and air conditioning.

HVAC System. A system that provides either collectively or individually the process of comfort heating, ventilating, and/or air conditioning within or associated with a building.

Illumination. The density of the luminous flux incident on a surface; it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.

Infiltration. The uncontrolled inward air leakage through cracks and interstices in any building element and around windows and doors of a building, caused by the pressure effects of wind and/or the effect of differences in the indoor and outdoor air density.

Light Loss Factor (LLF). A factor used in calculating the level of illumination after a given period of time and under given conditions. It takes into account temperature and voltage variations, dirt accumulation on luminaire and room surfaces, lamp depreciation, maintenance procedures, and atmospheric conditions.

Luminaire. A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

Manual. Capable of being operated by personal intervention (adjective). (See Automatic.)

Non-Depletable Energy Sources. Sources of energy (excluding minerals) derived from incoming solar radiation including photosynthetic processes; from phenomena resulting therefrom including wind, waves, and tides, lake or pond thermal differences; and energy derived from the internal heat of the earth, including nocturnal thermal exchanges.

Opaque Areas. All exposed areas of a building envelope which enclose conditioned space, except openings for windows, skylights, doors and building service systems.

Outside Air. Air taken from the outdoors and, therefore, not previously circulated through the system.

Packaged Terminal Air Conditioner. A factory-selected combination of heating and cooling components, assemblies or sections, intended to serve a room or zone.

Positive Heat Supply. Heat supplied to a space by design or by heat losses occurring from energy-consuming systems or components associated with that space.

Power. In connection with machines, power is the time rate of doing work. In connection with the transmission of energy of all types, power refers to the rate at which energy is transmitted; in customary units, it is measured in watts(W) or British thermal units per hour (Btu/h).

Readily Accessible. Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over, to remove obstacles or to resort to portable ladders, chairs, etc. (See Accessible.)

Recovered Energy. Energy utilized which would otherwise be wasted from an energy utilization system.

Reflectance. The ratio of the light reflected by a surface to the light falling upon it.

Reheat. The application of sensible heat to supply air that has been previously cooled below the temperature of the conditioned space by either mechanical refrigeration or the introduction of outdoor air to provide cooling.

Reset. Adjustment of the set point of a control instrument to a higher or lower value automatically or manually to conserve energy.

Residential Building. Living units of one story, two stories or other low rise, single- and multi-family dwellings, not exceeding three stories above grade.

Utilizing this definition for purposes of the Model Code, a building 4 or more stories in height containing dwelling units is not classified as a residential building.

Room Air Conditioner. An encased assembly designed as a unit primarily for mounting in a window or through a wall, or as a console. It is designed primarily to provide free delivery of conditioned air to an enclosed space, room or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air, and may also include means for ventilating and heating.

Room Cavity Ratio (RCR). A number related to room dimensions used in average illumination calculations.

Sequence. A consecutive series of operations.

Service Systems. All energy-using systems in a building that are operated to provide services for the occupants or processes housed therein,

including HVAC, service water heating, illumination, transportation, cooking or food preparation, laundering or similar functions.

Service Water Heating. Supply of hot water for domestic or commercial purposes other than comfort heating.

Service Water Heating Demand. The maximum design rate of energy withdrawal from a service water heating system in a designated period of time (usually an hour or a day).

Shading Coefficient (SC).

$$SC = \frac{\text{Solar Heat Gain of Fenestration (West Elev. at 4P.M., 9/21)}}{\text{Solar Heat Gain Unshaded DSB (West Elev. at 4P.M., 9/21)}}$$

where

DS means double strength

B means grade class

Solar Energy Source. Source of thermal, chemical or electrical energy derived directly from conversion of incident solar radiation.

System. A combination of equipment and/or controls, accessories, inter-connecting means, and terminal elements by which energy is transformed so as to perform a specific function, such as HVAC, service water heating or illumination.

Terminal Element. The means by which the transformed energy from a system is finally delivered; i.e., registers, diffusers, lighting fixtures, faucets, etc.

Thermal Transmittance (U). Overall coefficient of heat transmission (air to air) expressed in units of Btu per hour per square foot per degree F. It is the time rate of heat flow. The U value applies to combinations of different materials used in series along the heat flow path, single materials that comprise a building section, cavity air spaces, and surface air films on both sides of a building element.

Thermal transmittance actually refers to heat loss. It is the number of Btu's per hour which will be lost by a square foot of surface area per degree F difference between inside and outside design temperatures.

Thermostat. An instrument which measures change in temperature and controls device(s) maintaining a desired temperature.

Thermal Transmittance (U_o). Overall (average) heat transmission of a gross area of the exterior building envelope, expressed in units of Btu per hour per square foot per degree F.

The U_o value applies to the combined effects of the time rate of heat flows through the various parallel paths, such as windows, doors, and opaque construction areas, comprising the gross area of one or more exterior building components, such as walls, floors or roof/ceiling.

The U_o value takes into account the fact that an envelope element such as an exterior wall is made up of doors, windows and opaque wall sections, each having a different U value. These separate U values can be combined into an overall average U_o value.

Unitary Cooling and Heating Equipment. One or more factory-made assemblies which normally include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function as well. Where such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

Unitary Heat Pump. One or more factory-made assemblies which normally include an indoor conditioning coil, compressor(s) and outdoor coil or refrigerant-to-water heat exchanger, including means to provide both heating and cooling functions. It is designed to provide the functions of air-circulating, air cleaning, cooling and heating with controlled temperature, and dehumidifying, and may optionally include the function of humidifying. When such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

Veiling Reflections. Regular reflections superimposed upon diffuse reflections from an object that partially or totally obscure the details to be seen by reducing the contrast. This sometimes is called reflected glare.

Ventilation Air. That portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space. (See Std RS-3 and Section 5 of the Code.)

Work Plane. The plane at which work usually is done and at which the illumination is specified and measured. Unless otherwise indicated, this is assumed to be a horizontal plane 30 inches above the floor.

Zone. A space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

SECTION 3 - DESIGN CONDITIONS

Section 3 of the Code establishes the minimum design parameters for the thermal design of the exterior envelope of buildings for HVAC equipment. Any building designed to be both heated and cooled must meet the more stringent of the heating or cooling requirements specified in the Code.

The table in Section 302.0 sets forth:

1. Winter design temperature.
2. Summer design dry-bulb temperature.
3. Summer design wet-bulb temperature.
4. Degree days heating.
5. Degrees north latitude.

In the Code, no values are specified in this table. These design values are unique to each specific geographic location. Once this table is filled in for a specific location, the Code applies to that location only. The values in the table are determined by using tables similar to Tables 101-1 and 101-2. These specific tables were obtained from the NAHB Insulation Manual and the ASHRAE Handbook of Fundamentals, although they are also available from other sources.

The outdoor design temperatures shall be selected from the columns of 97 1/2 percent values for winter and 2 1/2 percent values for summer. As an example, let's use Billings, Montana. From the Tables:

Winter design temperature	-10°F
Summer design dry-bulb temperature	91°F
Summer design wet-bulb temperature	66°F
Degree days heating	7000
Degrees north latitude	45°-50'

The 97 1/2 percent winter design temperature means that 97 1/2 percent of the time the temperature will be warmer than -10°F. Conversely, the temperature will only be below -10°F 2 1/2 percent of the time. The same reasoning applies to the summer design temperatures.

The indoor design temperatures are 72°F for heating and 78°F for cooling. The question may arise as to whether the 72°F should be adjusted downward to 68°F or 66°F to account for local or state laws. This may be done; however, the use of 72°F in design calculations is conservative since we ultimately are dealing with temperature differences between the inside and outside.

For the Billings, Montana example, the difference would be:

$$\Delta t = 72^{\circ} - (-10^{\circ}) = 82^{\circ} \text{ for } 72^{\circ} \text{ inside}$$

$$\Delta t = 68^{\circ} - (-10^{\circ}) = 78^{\circ} \text{ for } 68^{\circ} \text{ inside}$$

This results in very little change in the design and probably is not worth worrying about.

The indoor relative humidity for heating shall not exceed 30 percent. For cooling, the actual design relative humidity shall be selected to provide for minimum total HVAC system energy use.

The provisions of Section 3 will generally be taken into account during the plan review process and generally will not be the responsibility of the field inspector. Familiarity with these design provisions is important in understanding the Code and the field inspection activities.

SECTION 4 - BUILDING DESIGN BY SYSTEMS ANALYSIS AND BUILDINGS UTILIZING NON-DEPLETABLE ENERGY SOURCES

This section of the Code is one which will seldom, if ever, be used by the field inspector. As discussed previously, a designer may use Section 4, 5, or 6 in designing the energy conservation systems of a building. Section 4 is referred to as the systems design approach. It allows for the design of buildings in terms of the total annual energy use, including all of the systems necessary for the proper functioning of the structure.

Section 4 permits an energy analysis to be submitted in which the total annual energy consumption does not exceed that obtained from that of a "standard building" which is based on the design procedure as outlined in Section 5 and 6.

The purpose of Section 4 is to allow for flexibility in architectural design and machine components; however, it still limits the energy requirements to those figures which would be arrived at if standard architectural procedures and machine components were adhered to.

The "standard design" means a building of similar design utilizing the same energy source and having a total equal floor area. The indoor and outdoor design temperatures, and the design humidity as spelled out in Section 3 of the Code shall be maintained for the energy consumption calculations. The two designs; i.e., the systems design and the "standard design" shall both be expressed in terms of the total energy input to the structures as Btu per gross building square foot per year.

CLIMATIC CONDITIONS FOR THE UNITED STATES*

Col. 1 State and Station	Col. 2 Latitude ^b	Col. 3 Longitude ^c	Col. 4 Elevation ^d Feet	Winter ^a			Summer ^a			Col. 7 Mean Daily Range	Col. 8			
				Col. 5		Col. 6			Col. 9					
				Design	Dry-Bulb 92% 97.5%	Mean Dry-Bulb and Coincident Wet-Bulb 1% 2.5% 5%	Mean Range	Design	Wet-Bulb 1% 2.5% 5%					
Mankato	44	1	94	0	785	-17	-12	91/72	88/72	85/70	24	77	75	73
Minneapolis/ St Paul AP	44	5	93	1	822	-16	-12	92/75	89/73	86/71	22	77	75	73
Rochester AP	44	0	92	3	1297	-17	-12	90/74	87/72	84/71	24	77	75	73
St Cloud AP (S)	45	4	94	1	1034	-15	-11	91/74	88/72	85/70	24	76	74	72
Virginia	47	3	92	3	1435	-25	-21	85/69	83/68	80/66	23	71	70	68
Willmar	45	1	95	0	1133	-15	-11	91/74	88/72	85/71	24	76	74	72
Winona	44	1	91	4	652	-14	-10	91/75	88/73	85/72	24	77	75	74
MISSISSIPPI														
Biloxi														
Keesler AFB	30	2	89	0	25	28	31	94/79	92/79	90/78	16	82	81	80
Clarksdale	34	1	90	3	178	14	19	96/77	94/77	92/76	21	80	79	78
Columbus AFB	33	4	88	3	224	15	20	95/77	93/77	91/76	22	80	79	78
Greenville AFB	33	3	91	1	139	15	20	95/77	93/77	91/76	21	80	79	78
Greenwood	33	3	90	1	128	15	20	95/77	93/77	91/76	21	80	79	78
Hattiesburg	31	2	89	2	200	24	27	96/78	94/77	92/77	21	81	80	79
Jackson AP	32	2	90	1	330	21	25	97/76	95/76	93/76	21	79	78	78
Laurel	31	4	89	1	264	24	27	96/78	94/77	92/77	21	81	80	79
McComb AP	31	2	90	3	458	21	26	96/77	94/76	92/76	18	80	79	78
Meridian AP	32	2	88	5	294	19	23	97/77	95/76	93/76	22	80	79	78
Natchez	31	4	91	3	168	23	27	96/78	94/78	92/77	21	81	80	79
Tupelo	34	2	88	4	289	14	19	96/77	94/77	92/76	22	80	79	78
Vicksburg CO	32	2	91	0	234	22	26	97/78	95/78	93/77	21	81	80	79
MISSOURI														
Cape Girardeau	37	1	89	3	330	8	13	96/76	95/75	92/75	21	79	78	77
Columbia AP (S)	39	0	92	2	778	-1	4	97/74	94/74	91/73	22	78	77	76
Farmington AP	37	5	90	3	928	3	8	96/76	93/75	90/74	22	78	77	75
Hannibal	39	4	91	2	489	-2	3	96/76	93/76	90/76	22	80	78	77
Jefferson City	38	4	92	1	640	2	7	98/75	95/74	92/74	23	78	77	76
Joplin AP	37	1	94	3	982	6	10	100/73	97/73	94/73	24	78	77	76
Kansas City AP	39	1	94	4	742	2	6	99/75	96/74	93/74	20	78	77	76
Kirksville AP	40	1	92	4	966	-5	0	96/74	93/74	90/73	24	78	77	76
Mexico	39	1	92	0	775	-1	4	97/74	94/74	91/73	22	78	77	76
Moberly	39	3	92	3	850	-2	3	97/74	94/74	91/73	23	78	77	76
Poplar Bluff	36	5	90	3	322	11	16	98/78	95/76	92/76	22	81	79	78
Rolla	38	0	91	5	1202	3	9	94/77	91/75	89/74	22	78	77	76
St Joseph AP	39	5	95	0	809	-3	2	96/77	93/76	91/76	23	81	79	77
St Louis AP	38	5	90	2	335	2	6	97/75	94/75	91/74	21	78	77	76
St Louis CO	38	4	90	2	465	3	8	98/75	94/75	91/74	18	78	77	76
Sedalia														
Whiteman AFB	38	4	93	3	838	-1	4	95/76	92/76	90/75	22	79	78	76
Sikeston	36	5	89	3	318	9	15	98/77	95/76	92/75	21	80	78	77
Springfield AP	37	1	93	2	1265	3	9	96/73	93/74	91/74	23	78	77	75
MONTANA														
Billings AP	45	5	108	3	3567	-15	-10	94/64	91/64	88/63	31	67	66	64
Bozeman	45	5	111	0	4856	-20	-14	90/61	87/60	84/59	32	63	62	60
Butte AP	46	0	112	3	5526	-24	-17	86/58	83/56	80/56	35	60	58	57
Cut Bank AP	48	4	112	2	3838	-25	-20	81/61	83/61	82/60	35	64	62	61
Glengow AP (S)	48	1	106	4	2277	-22	-18	92/64	89/63	85/62	29	68	66	64
Glendive	47	1	104	4	2076	-18	-13	95/66	92/64	89/62	29	69	67	65
Great Falls AP (S)	47	3	111	2	3664	-21	-15	91/60	88/60	85/59	28	64	62	60
Havre	48	3	109	4	2488	-18	-11	94/65	90/64	87/63	33	68	66	65
Helena AP	46	4	112	0	3893	-21	-16	91/60	88/60	85/59	32	64	62	61
Kalispell AP	48	2	114	2	2965	-14	-7	91/62	87/61	84/60	34	65	63	62
Lewiston AP	47	0	109	3	4132	-22	-16	90/62	87/61	83/60	30	65	63	62
Livingston AP	45	4	110	3	4653	-20	-14	90/61	87/60	84/59	32	63	62	60
Miles City AP	46	3	105	5	2629	-20	-15	98/66	95/66	92/65	30	70	68	67
Missoula AP	46	5	114	1	3200	-13	-6	92/62	88/61	85/60	36	65	63	62
NEBRASKA														
Beatrice	40	2	96	5	1235	-5	-2	99/75	95/74	92/74	24	78	77	76
Chadron AP	42	5	103	0	3300	-8	-3	97/66	94/65	91/65	30	71	69	68
Columbus	41	3	97	2	1442	-6	-2	98/74	95/73	92/73	25	77	76	75
Fremont	41	3	96	3	1203	-6	-2	98/75	95/74	92/74	22	78	77	76

Table 101-1

Location	Winter Design Conditions				Summer Design Conditions				
	ASHRAE Winter Design Temp. (°F.)	Operating Cost Estimating Data			ASHRAE Summer Design Temp. & Range	Heat Gain Value Table	Operating Cost Estimating Data		
		Winter Degree Days	Estimated Cost of Gas For Heating (\$/Therm)	Heating Index			Summer Cooling Hours Over 80° F.	Estimated Cost Of Electricity For Cooling (\$/Kwhr)	Cooling Index
MISS. (cont'd.)									
Picayune		1600	0.1345	215	93M	3	2050	0.0111	332
Vicksburg	23	2000	0.1087	217	97M	3	1600	0.0114	265
MISSOURI									
Cape Girardeau	8	4200	0.1238	520	98M	5	1300	0.0183	347
Columbia	2	5000	0.0866	433	97M	3	1050	0.0180	275
Hannibal	-1	5400	0.0983	531	96M	3	850	0.0164	204
Jefferson City	2	4800	0.1182	567	97M	3	1100	0.0228	366
Joplin	7	4000	0.0928	371	97M	3	1050	0.0203	311
Kansas City	4	4800	0.0901	433	100M	5	1100	0.0222	356
St. Joseph	-1	5400	0.0928	501	97M	3	1150	0.0234	392
St. Louis	4	5000	0.1241	621	98M	5	1150	0.0214	359
Sedalia	4	5000	0.1038	519	97M	3	1100	0.0219	352
Springfield	5	5000	0.0955	478	97M	3	950	0.0160	222
MONTANA									
Billings	-10	7000	0.1103	772	94H	2	500	0.0140	102
Butte	-24	9800	0.1110	1088	86H	1	200	0.0140	41
Great Falls	-20	7800	0.1110	866	91H	1	300	0.0140	61
Helena	-17	8200	0.1110	910	90H	1	250	0.0140	51
Missoula	-7	8700	0.1110	910	92H	1	300	0.0140	61
NEBRASKA									
Columbus	-7	6600	0.1365	901	98M	5	850	0.0160	198
Grand Island	-6	6600	0.1024	676	98H	4	850	0.0163	202
Hastings	-3	6200	0.0833	517	98H	4	850	0.0150	186
Lincoln	-4	5800	0.1206	699	100M	5	1000	0.0150	219
Norfolk	-11	7000	0.1088	761	97H	2	800	0.0164	192
North Platte	6	(66M)	0.1024	676	97H	2	700	0.0150	153
Omaha	-5	6600	0.0924	610	97M	3	900	0.0150	197
Scottsbluff	-8	6600	0.0879	580	96H	2	850	0.0158	196
NEVADA									
Elko	-13	7400	0.1997	1478	94H	2	650	0.0180	171
Las Vegas	23	2800	0.1578	442	100H	4	2350	0.0078	266
Reno	2	6400	0.1725	1104	95H	2	650	0.0142	135
NLW HAMPSHIRE									
Concord	-11	7400	0.2180	1613	91H	1	400	0.0210	122
Dover		7200	0.2339	1684	88M	1	300	0.0214	93
Keene	-12	7400	0.2145	1587	90M	1	500	0.0211	154
Lancaster		7800	0.2066	1612	89M	1	400	0.0212	124
Manchester	-5	7200	0.2250	1620	92M	1	500	0.0211	154
Nashua		7000	0.2009	1406	92M	1	500	0.0211	154
Portsmouth	-2	7200	0.2339	1684	88M	1	300	0.0214	93
NEW JERSEY									
Atlantic City	14	4800	0.1810	869	91M	1	450	0.0203	133
Bernardsville		5400	0.2084	1125	94M	3	600	0.0204	178
Camden		4600	0.2088	960	94M	3	700	0.0190	194
Cape May		4800	0.1929	926	91M	1	450	0.0203	133
Clinton		5200	0.2264	1177	91M	1	550	0.0204	164
Edison		5000	0.2072	1036	93M	3	600	0.0191	167
Flemington		5200	0.2264	1177	91M	1	550	0.0204	164
Lakewood		5400	0.1952	1054	93M	3	600	0.0219	192
Morristown		5600	0.2083	1166	91M	1	650	0.0219	208

Table 101-2

If the system design results in an increase in energy consumption from one source and a decrease from another energy source the energy consumption for each source shall be converted to similar units and combined in order that a comparison may be made with the total energy consumption of the "standard design".

The calculations for the heating and cooling load of the two designs must be in such detail as to allow for evaluation of the effect on the design of changes in design parameters as delineated in the Code that could affect the total annual energy consumption.

Not only should the calculations detail the above parameters, they should allow also for variation in systems design, climatic factors, operational characteristics and mechanical equipment. The annual year is based upon 8760 hours of operation and the energy consumption calculations should be based on this time element.

When Section 4 is applied, an energy analysis comparison report is required. This report must elaborate upon comparative data employed in the alternative design and the "standard design". It must provide a complete analysis of the data and the consequent energy consumption.

It also shall demonstrate that the analysis is consistent with standard engineering practices and procedures. There is one exception to this requirement for an analysis, namely, single family dwellings or commercial industrial structures of 5000 square feet or less floor area with a single point control. In such cases, a comparison of energy consumption between alternative designs is required.

Buildings utilizing solar, geothermal, wind or other non-depletable energy sources to meet all or part of its energy requirements must comply with the Section 4 of the Code, except that the non-depletable energy may be excluded from the total energy consumption calculations for the building.

The non-depletable energy must be derived from a specific collection, storage and distribution system. The solar energy passing through windows may be considered as part of the solar heat source provided the following applies:

1. The window areas are provided with shutter or other devices which when closed will reduce heat losses through these areas.
2. The window areas are shaded or otherwise protected from direct rays the periods when cooling is required.
3. This provision shall apply also to those buildings utilizing nocturnal cooling in lieu of energy consuming refrigeration processes.

Alternate designs submitted as a request for exception to the standard design criteria shall be accompanied by an energy analysis as specified in Section 402 of the Code.

The report should be comprehensive and provide sufficient data and detail to permit verification of the comparative analysis and show that the designs meet the criteria of all pertinent sections of the Code.

Supporting evidence of all non-depletable energy and reduction of energy requirements because of nocturnal cooling must be submitted as part of the report and identified as such.

Alternative designs for residential and commercial buildings of less than 20,000 square feet that derive a minimum of 30% of their annual energy requirements from non-depletable sources or from nocturnal cooling shall be exempt from the requirement of a full year energy analysis provided the 30% requirement can reasonably be met.

Other commercial or institutional buildings deriving 50% or more of their thermal requirements or 30% or more of their annual total energy requirements from non-depletable sources are exempt from comparing the design with the design of a "standard design".

Documentation of all energy sources must be submitted with the proposed energy design.

Although the building inspector is not necessarily concerned with the design aspect of the Code, his familiarity with Section 4 is required for a thorough understanding of the alternatives available to the designer.

SECTION 5 - COMPONENT DESIGN

This Section of the Code is of primary interest to the inspector because it involves the inspector with the requirements for building construction as it relates to thermal conservation. It requires all buildings which are heated or mechanically cooled to conform to the thermal requirements as outlined in the approved design and specifications of the building and as prescribed by the Code.

The following definitions are re-stated to avoid confusion in terminology:

1. The gross area of exterior walls consists of all opaque wall areas (including foundation walls, between floor spandrels, peripheral edges of floors, etc.), window areas (including sash), and door areas, where such surfaces are exposed to outdoor air and enclose

a heated and/or mechanically cooled space (including interstitial areas between two such spaces).

2. A roof assembly shall be considered as all components of the roof ceiling envelope through which heat flows, thereby creating a building transmission heat loss or gain, where such assembly is exposed to outdoor air and encloses a heated and/or mechanically cooled space.
3. The gross area of a roof assembly consists of the total interior surface of such assembly, including skylights exposed to the heated and/or mechanically cooled space.
4. Where return air ceiling plenums are employed, the roof ceiling assembly shall:
 - a. for thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly, and
 - b. for gross area purposes, be based upon the interior face of the upper plenum surface.

Flexibility in the U_o value for individual segments is permitted by the Code provided the heat gain and/or loss for the entire building envelope does not exceed the value calculated for the individual maximum U_o values. The value for one segment or wall of a building may be increased or decreased provided this difference is compensated for by a counter variation in the U_o value for another segment of the structure.

This provision is very important for the inspector to understand. If a designer uses this provision, different R and U values from those usually seen by the inspector will result. It will be beneficial for the plan reviewer to note on the permit and approved plans that this provision has been used.

Tables 5-1 and 5-2 of the Code specify the U_o (overall average thermal transmittance value) values for all elements of a building envelope. Table 5-1 is for residential buildings and Table 5-2 is for all other buildings.

Residential buildings are defined as residential buildings three stories or less in height. The residential buildings are further divided into A-1 and A-2 buildings.

Type A-1 - detached one- and two-family dwellings.

Type A-2 - all other residential buildings three stories or less in height.

The U_o values are determined by using the charts from ASHRAE 90-75 showing the degree days heating information. Once the U_o values in Tables 5-1 and 5-2 are determined, this Section is unique for a specific jurisdiction.

It should be noted that concrete slabs on grade utilize an R value, not a U_o value. The R value refers to the required R value of the insulation required to be placed around the perimeter of the slab floor. The insulation shall extend downward from the top of the slab for a minimum distance of 24 inches or downward to the bottom of the slab, then horizontally beneath the slab for a minimum total distance of 24 inches.

There is no requirement for the slab thickness. The slab thickness shall be that required by the local building code.

Certain exemptions are made for geographical areas having less than 500 heating degree days. In this case:

1. There is no maximum U_o if the building is heated only.
2. The maximum U_o values for walls shall be 0.30 if the building is to be mechanically cooled when built, or if provision is made for the future addition of mechanical cooling.

Roof ceiling assemblies in which the finished interior surface is essentially the underside of the roof deck, such as a wooden cathedral ceiling, may utilize a maximum U_o value of 0.08.

The U_o value for the roof ceiling of residential buildings is not obtained from a chart but is directly rated to the degree day value. When the degree day heating is greater than 8000, the U_o value is 0.04. The U_o is 0.05 for degree day heating of less than 8000.

Non-residential buildings which are mechanically cooled must have an OTTV (Overall Average Thermal Transfer Value) not exceeding the value given in Table 5-2.

The air leakage section of the Code applies to all heated or mechanically cooled buildings. All openings that exist in a building which may permit infiltration of air into or out of the building must be sealed with a caulking compound, gasket or weather stripping. Openings around windows and doors must be carefully inspected.

All exterior doors and windows must be designed to limit air leakage into or out of the building as limited by Table 5-3 of the Code. Such doors and windows must be tested and will be labeled showing compliance

with the Code provisions. Site built windows and doors need not be labeled but must be constructed to minimize leakage.

Equation 1 is used to calculate the U_o value (overall average U value) for a building envelope element. For example, an exterior wall may have windows, doors and opaque wall sections each having a different U value. Equation 1 is used to combine these various U values to the U_o (overall average U value). Equation 2 is used to calculate the OTTV value for non-residential buildings.

Building Mechanical Systems

This section of the Code pertains to procedures to be used in calculating the heating and cooling loads, design requirements, equipment, component performance and control requirements. It also details requirements for insulating HVAC and for duct construction. Some construction, such as hospitals, laboratories and others as determined by the enforcement official, may be exempt from these requirements.

All calculations of design loads must be done according to accepted engineering practice and be within the parameters outlined in Section 3 of the Code. Infiltration calculations fall within this category.

Many of the larger buildings with dense occupancy rates have created the problem of simultaneous heating and cooling; i.e., the heating plant operates at reduced capacity when much of the heat loss is made up by people, lights and the sun shining on the building and through the windows. In fact, so much heat may be picked up from these sources, the extra may be redistributed to those areas where needed to reduce the new energy load.

In the core of the building the heating load may become so great that cooling is necessary in order to maintain the proper comfort level. This recovered heat energy or cooling effect may be redistributed to other areas of the structure provided the new energy required to distribute it, usually fan energy, is not greater than that which is distributed.

New energy may be used also to prevent the humidity level from rising above 60 percent or to prevent actual condensation of moisture upon walls and windows.

Although the designer of the highly complex dual duct and multi-zone systems will be responsible for the proper numbers, type and location of controls, nevertheless the inspector is responsible for assuring compliance with these requirements.

Those systems employing reheating or recooling of less than 5000 ft./min. or 20% of the total air supply, whichever is less, will not be subject to the temperature control requirement which minimizes the energy required for heating or cooling the supply air.

When concurrent heating or cooling systems are used to maintain the comfort temperature in a space, the new energy they require must be minimized by operating the zone units on a sequential basis, and by limiting the heat supplied to only that amount necessary to offset the heat loss due to transmission, infiltration and ventilation.

The Code advocates all energy recovery systems which demonstrate a positive energy balance.

In evaluating the performance of HVAC equipment the inspector may use the data supplied by the equipment manufacturer or that information which has been approved and recognized for this purpose under a national procedure.

Unitary heat pumps which have a completely electric energy supply must show a coefficient of performance for heating which is not less than the values given in Table 5-4.

$$\text{COP} = \frac{(\text{Net Heat}) \text{ output}}{(\text{Total Energy}) \text{ input}}$$

Supplementary heaters are excluded from the above calculations. When these devices are used to augment the heat pump they shall operate only after the heat pump has reached its maximum output. However, they are permitted to be used during transient periods as spelled out in the Code. The thermostat shall be of such a type, namely, two stage, which controls the supplementary heater on the second stage so as to permit it to operate only a supplementary source of heat.

Supplementary heating may be obtained from electric resistor type of heaters or from combustion type heaters.

When combustion heating equipment is used in HVAC systems, all oil and gas units must show a minimum combustion efficiency of 75% at rated output. The Code defines the losses that may be deducted from 100% in order to arrive at the efficiency of the unit.

Each mechanical ventilation system must be equipped so as to be completely shut off and also be equipped with some means of reducing the amount of air supplied or exhausted from the space.

All electrically operated cooling unitary systems must show a

coefficient of performance not less than the values listed in Table 5-5 of the Code. This provision does not apply to open case refrigeration units as found in food stores.

The Coefficient of Performance for Cooling is defined as ratio of the rate of net heat removal to the rate of total energy input.

$$\text{COP} = \frac{\text{Heat air in} - \text{Heat air out}}{(\text{Total Energy}) \text{ input}}$$

Applied HVAC - System Components which are electrically operated must show coefficients of performance of not less than those values listed in Table 5-6. The COP is defined as the rate of net heat removal as compared to the rate of total energy input.

$$\text{COP} = \frac{\text{Heat in} - \text{Heat out}}{(\text{Total Energy}) \text{ input}}$$

This same equipment, if operated by a heat source instead of an electrical source, must show a COP not less than that given in Table 5-7. These requirements apply to absorption equipment, engine and turbine driven equipment.

The air transport factor, which is a measure of the amount of sensible heat removed as compared to the Btu/h input to the fans used to remove the sensible heat, must not be less than 4.0. In other words, each Btu supplied to the fans used in the system must remove 4 times as much sensible heat, for all air HVAC systems.

The inspector must determine that sufficient dampers and other means are provided to insure complete balancing of the total system, be it air or water.

Cooling with outdoor air is recommended when 100 percent of the fan capacity can be used and its use will result in lower usage of new energy. This system should be activated automatically. Exceptions to the economizer cycle are allowed by the Code and are so listed.

At least one thermostat shall be used on all systems for the regulation of space temperature as follows:

For heating only - 55 to 75°F
For cooling only - 70 to 85°F
For heating and cooling - 55 to 85°F.

The inspector should check to see that it is adjusted for a 10°F temperature range between full heating and full cooling.

Where the system is provided with a device for adding moisture for purposes of controlling the humidity, a humidistat must be installed. The humidistat must be of a type which would limit energy input for relative humidities above 30 percent when moisture is added and below 60 percent when moisture is reduced.

When a one- or two-family residence is zoned by utilizing separate HVAC systems, each of the systems must be controlled by its own thermostat. To further control the heating or cooling of each zone, manually or automatically controlled dampers, valves or other controls must be provided. These controls should be capable of completely closing off the input or partially restricting the input to each of the zones or floors of the building. Basements and garages may be excluded from the heating or cooling requirement.

The above regulations apply also to apartment or other multi-family buildings. Each apartment or family unit must be considered separately and will have its thermostat and controls.

All unheated spaces of the building must meet the piping requirements of part C of this Section of the Code.

For all other types of buildings a separate thermostat must be provided for each separate HVAC system. As a minimum, each floor may be considered as a separate zone, however, in those buildings where the transmission losses are being offset by a perimeter system the entire side of the building having uniform exposure may be zoned as a separate unit. Additional dampers, valves or other controls must be provided to completely or partially restrict heating or cooling to each zone.

In all dwelling units (one, two and multi-family units) the installed thermostats must be capable of reducing the energy required for heating or cooling during those periods of reduced needs by means of a manual or automatic switch or clock.

In all other buildings each HVAC system shall be equipped with a readily accessible means of shutting off or reducing the energy input during those periods of reduced needs. The devices used for this purpose may be manual or automatic.

All duct systems must be insulated unless:

1. The temperature difference between the air in the duct and the surrounding air is 25°F or less.
2. The supply or return air ducts are installed in basements or cellars or unventilated crawl spaces with insulated walls in one- and two-family dwellings.

3. The heat gain or loss of the ducts without insulation will not increase the energy requirements of the building.
4. The ducts are located within the HVAC equipment.
5. They are exhaust ducts.

The R value of the duct insulation is determined by using the equation:

$$R = \frac{T_1 - T_2}{15}$$

where T_1 is the temperature of the air in the duct, and T_2 is the surrounding air temperature.

Example:

$$\text{If } T_1 - T_2 = 90^\circ$$

$$R = \frac{90}{15} = 6$$

The duct must then be insulated with material having an R value of 6 or greater.

The construction of ducts must conform to the reference standards in the Code.

All high-pressure and medium-pressure ducts must be leak tested as required by national standards.

When low pressure supply ducts are located outside the conditioned space, all transverse joints must be sealed with mastic or mastic plus tape. Pressure sensitive tape may be used on fibrous glass ductwork.

All dampers must be designed so as to completely close to minimize leakage through the damper.

All piping carrying hot water must be insulated unless:

1. It is installed within the HVAC equipment.
2. The water temperature is between 55°F and 120°F.
3. The heat gain or loss of the piping without insulation does not increase the energy requirements of the building.

4. The piping is installed in basements or cellars or in unventilated crawl spaces with insulated walls in one- and two-family dwellings.

If insulation is required for the piping, the minimum thickness is specified in Table 5-8 for insulation having an R value between 4.0 and 4.6 per inch of thickness. If an insulation material is used having an R greater than 4.6, the minimum thickness needed can be determined as follows:

$$\text{minimum thickness} = \frac{4.6 \times \text{Table 5-8 thickness}}{\text{Actual R value of material used}}$$

If an insulation material is used having an R less than 4.0, the minimum thickness needed can be determined as follows:

$$\text{minimum thickness} = \frac{4.0 \times \text{Table 5-8 thickness}}{\text{Actual R value of material used}}$$

The code, for the most part, prescribes the design criteria for service water heaters. The inspector will be required to check the heater name plates and data sheet to see that the heaters conform to these criteria. Unfired hot water storage tanks must be insulated so as to limit the heat loss to a maximum of 15 Btu/h per square foot of external tank surface area. In determining the heat loss the ambient temperature shall be taken no higher than 65°F.

Service water heaters must be equipped with an automatic temperature device which will permit adjustment through the acceptable temperature range. In addition, it must have a separate switch or valve which will permit the shutting down of the heater by turning off the energy supply to all heating units.

All swimming pools must limit the water temperature to 80°F or less unless they are used for therapeutic purposes. Uncovered and unenclosed pools using electrical or depletable energy sources must have controls which will automatically cut off the energy supply when the outdoor temperature drops below 60°F.

Hot water service systems utilizing pumps for circulation purposes must have provisions for automatically or manually cutting off the pump when the system is not in operation.

Insulation must be provided on all recirculating systems when the heat loss exceeds 25 Btu/h per square foot of external pipe surface for piping laid above ground and 35 Btu/h per square foot for piping laid below ground. This heat loss shall be based on an ambient temperature of 65°F.

Showers used for other than safety reasons must be equipped with flow control devices which limit the total flow to a maximum of 3 gpm per showerhead.

Lavatories in restrooms of public facilities shall:

1. Be equipped with outlet devices which limit the flow of hot water to a maximum of 0.5 gpm.
2. Be equipped with devices which limit the outlet temperature to a maximum of 110°F.
3. Be equipped with self-closing valves that limit delivery to a maximum of 0.25 gallons of hot water.

The electrical equipment installed in a building must be designed to minimize electrical energy loss. Equipment rated greater than 1000 watts and lighting equipment rated greater than 15 watts with an inductive reactance load component shall be designed to limit the power factor to 85 percent or more. A power factor of less than 85 percent shall be corrected to at least 90 percent under rated load conditions. Power factor corrective devices must be so wired into the circuit as to have the balancing device in the circuit when the device is switched on unless this presents an unsafe condition.

The maximum voltage drop of a circuit shall not exceed 3 percent in branch circuits and feeders, for a total of 5 percent to the farthest outlet, under design load conditions.

Sufficient switching circuits must be provided in order that maximum utilization may be made of natural lighting. In all multi-family dwellings, each dwelling unit must be wired for separate metering of electrical consumption.

The Code provides for the use of a lighting power budget to determine the upper limit of the power to be available to provide lighting. The Code describes the method of calculation and sets the illumination levels for various uses and activities.

SECTION 6 - BUILDING DESIGN BY ACCEPTABLE PRACTICE

Section 6 is titled Building Design by Acceptable Practice and is referred to as the accepted practice section. As described earlier, Section 1 of the Model Code requires buildings to be designed to comply with the requirements of either Section 4, 5 or 6. Section 6 uses charts and tables and thus simplifies the checking or designing of a building envelope.

Since charts and tables are used, a certain degree of conservativeness is inherent in the section. The use of the accepted practice provisions can be compared to using span tables in a building code. Such use is acceptable within defined parameters.

Section 6 is applicable to:

1. Buildings less than 5,000 square feet in gross floor area and 3 stories or less in height.
2. Residential buildings that are heated and/or mechanically cooled.
3. Other buildings that are heated only.

For walls, Charts 6-A and 6-B of the Code are used along with Table 6-1A. The maximum allowable U_o value for the walls must be determined from Tables 5-1 and 5-2 in Section 5 of the Model Code.

Let's assume that we selected a value for U_o of 0.25 from Table 5-1. In the plan checking operation, we would then determine the type of wall section used and the R value of the insulation. Assume it is a wood stud wall with R-11 batt insulation.

Going to Table 6-1A, we find that wall section as the first one shown. An R-11 insulation gives us a U_w of 0.09. Thus U_w takes into account both the wood framed section of the wall and the cavity (insulated) area.

Since we have single glazed openings, we then go to Chart 6-A. To use this chart, we must determine the percentage of windows in the exterior walls. Assume that the plans we are checking have 15% windows. Find 15% along the bottom of the chart and go vertically until the 0.09 (U_w) diagonal line is intersected. Then go horizontally to the left side of the chart and read the U_o value. The 0.09 is half way between the 0.08 and 0.10 lines. The U_o value is 0.245, therefore, the wall section is acceptable. The use of this section does not require extensive calculations and is quite simple. Chart 6-B is used if you have double glazed openings.

Table 6-2 and 6-3 are used for roof-ceilings and for floors over unheated spaces. The U_o values for these elements are determined from Tables 5-1 and 5-2 and picked directly from Tables 6-2 and 6-3.

The remaining portions of Section 6 are identical to provisions of Section 5 which were discussed previously.

CHAPTER 4

MODEL ENERGY CODE APPLICATIONS

(ECT-103)

MODEL CODE TESTING

Now that we have briefly reviewed the Model Code, it is important to understand the effect the Code has on construction and energy consumption. The Model Code testing was accomplished by testing ASHRAE 90-75, on which the Model Code is based. One study of particular interest was performed by Arthur D. Little, Inc. (ADL)¹¹

The purpose of the Arthur D. Little study was to analyze the various energy, economic and institutional impacts that might occur following adoption and usage of ASHRAE 90-75. Impact on the construction industry in general and on energy consumption, initial cost, and operating costs of projects was determined on the basis of impact on each of five types of buildings in four geographic and different climatic areas, as shown Table 102-1.

TABLE 102-1¹²

REPRESENTATIVE LOCATIONS SELECTED FOR COMPUTER ANALYSIS OF
PROTOTYPICAL BUILDINGS

	Weighted Average Annual Heating Degree Days	Location Selected			
		City	Degree Days	Summer Design Conditions	
				<u>db</u>	<u>wb</u>
Northeast	5,470	New York (Airport)	5,219	87°	76°
North Central	6,345	Omaha	6,612	94°	78°
South	2,795	Atlanta	2,961	92°	77°
West	3,515	Albuquerque	4,348	94°	56°

The five building types investigated were:

- Single family detached dwelling
- Low-rise apartment building

- Office building
- Retail store
- School building

Thus, there were 30 prototypical buildings considered.

In each geographic location two sets of calculations were made:

- one for a conventional building, and
- one for the same building constructed to ASHRAE 90-75 standards.

The conventional building was one that was constructed in accordance with normal construction utilized in 1973 in that specific geographic area.

Why were 1973 construction practices used? It was prior to the major concern with energy conservation and energy shortages which resulted in many construction practice changes. Even at that time, however, many energy conservation measures were being taken and are reflected in the study. The four geographic locations are shown in Table 102-1.

The unweighted average reduction in annual energy consumption relative to 1973 construction and operational practices across the four locations were:

Single family dwelling	11.3%
Low-rise apartment building	42.7%
Office building	59.7%
Retail store	40.1%
School building	48.1%

The application of ASHRAE 90-75 brought about the following physical differences in the conventional versus the ASHRAE 90-75 modified buildings:

Exterior Glass - The glass area (percent fenestration) was reduced in approximately two thirds of the buildings. Reductions were as much as 30%, but in most cases were less than 20%.

Exterior Wall - Decreases in glass area were balanced by increases in opaque wall areas.

Insulation - Additional insulation requirements for residential construction varied from 90 to 300 pounds per unit. The commercial construction required even greater amounts of insulation.

Lighting - Reductions in lamps and lamp fixtures varied by building type and averaged 24% and 22%, respectively, for non-residential construction.

HVAC System Capacities - Reductions in heating were significant, averaging 42%, while reductions in cooling systems averaged 31%.

Charts 102-1 through 102-5 show the comparative energy consumption for each of the five building types in the four geographic areas.

Chart 102-1

*Electrical energy usage measured at building boundary, and does not include allowances for loss in efficiency due to its generation, transmission and distribution.

COMPARATIVE ANNUAL ENERGY CONSUMPTION, *SCHOOL BUILDINGS CONVENTIONAL VERSUS ASHRAE 90 MODIFIED PROTOTYPICAL SCHOOL BUILDINGS

*Electrical energy usage measured at building boundary, and does not include allowances for loss in efficiency due to its generation, transmission and distribution.

COMPARATIVE ANNUAL ENERGY CONSUMPTION,* CONVENTIONAL VERSUS
ASHRAE 90 MODIFIED PROTOTYPICAL RETAIL STORES

Chart 102-2

Chart 102-3

*Electrical energy usage measured at building boundary, and does not include allowances for loss in efficiency due to its generation, transmission and distribution.

COMPARATIVE ANNUAL ENERGY CONSUMPTION, *CONVENTIONAL VERSUS
ASHRAE 90 MODIFIED PROTOTYPICAL OFFICE BUILDINGS

Chart 102-4

*Electrical energy usage measured at building boundary, and does not include allowances for loss in efficiency due to its generation, transmission and distribution.

COMPARATIVE ANNUAL ENERGY CONSUMPTION,*CONVENTIONAL VERSUS
ASHRAE 90 MODIFIED PROTOTYPICAL LOW-RISE MULTI-FAMILY APARTMENT BUILDINGS

Chart 102-5

*Electrical energy usage measured at building boundary, and does not include allowances for loss in efficiency due to its generation, transmission and distribution.

COMPARATIVE ANNUAL ENERGY CONSUMPTION, *CONVENTIONAL VERSUS
ASHRAE 90 MODIFIED PROTOTYPICAL SINGLE FAMILY RESIDENCES

PART I - MATERIALS IDENTIFICATION AND FIELD INSPECTION

I. THERMAL INSULATION OF THE BUILDING ENVELOPE

Substances which are poor conductors of heat are called insulators. In general, a material is a good insulator if it is porous and if its molecular structure is irregular. Since gases are the best insulators, any solid material which contains pockets of air is a good insulator. Cork, sawdust, shredded bark, and certain manufactured materials such as mineral wool, pressed cane fiberboard and cellulose are excellent insulators.

By retarding heat flow, insulation, when properly installed, may serve to:

1. Conserve energy by reducing heat loss or gain through building envelope, piping, ducts and equipment.
2. Control surface temperature of equipment for personnel protection and comfort.
3. Prevent water vapor transmission.
4. Reduce temperature fluctuations within an enclosure when heating or cooling is not needed or available.

A. Insulating Materials

Commonly used insulating materials include:

Mineral Wool: Mineral wool usually consists of the spun fibers of rock, slag, or glass. They are inorganic, noncombustible, rot-proof, and vermin-proof.

Cellulose: Cellulose insulation usually consists of macerated paper or wood fibers, usually chemically-treated to make it water-repellent and fire retardant.

Aluminum Foil: Aluminum foil resists heat flow only through reflection. Air spaces must be used in conjunction with reflective foil and the foil must face the air space in order to give credit to the foil for additional resistance.

Plastics: Plastic insulation usually comes as a foamed material either in the form of a rigid board or for foaming in place.

B. Insulation Identification

The insulation materials available are manufactured in a variety of forms for different applications, as follows:

Batts and Blankets: Batts and blankets usually consist of mineral wool either in a long roll (blanket) or cut to specified lengths (batt). They are used mostly for walls, roof, ceiling, and floors over unheated areas.

Batts and blankets have the R value on the package, or on the vapor barrier. Note the difference in stated R values caused by the placement of the material in floor, wall or roof.

Blown: Blown insulation, applied by means of a high pressure hose, is loose cellulose or modulated mineral wool. It is the only type insulation that can be added to existing walls and is frequently used for roof and ceiling insulation.

Loose fill insulation must be blown into the walls, floors and ceilings so that the proper density (lbs. per sq.in.) is obtained. Insulation should be blown into each wall cavity at both top and bottom so that all spaces will be filled and variations in density will be minimized. Variations in insulation density will affect the effectiveness of the material. It is important to note that the label lists both the thickness of material and the coverage per bag. It is important that this be obtained.

Reflective: Reflective insulation is composed of one or more sheets of aluminum foil. When more than one sheet is used, the air between sheets provides some insulation in addition to that provided through reflection. Application is limited primarily to floors over crawl spaces where humidity or moisture is a problem.

Batt/Blanket and Reflective: Batts and blankets may be obtained with an aluminum foil attached to one or both sides, thus adding reflective thermal resistance to regular batts and blanket insulating qualities.

Rigid: Rigid insulation consists of boards, sheets and slabs cut to specific lengths. They are usually composed of cellulose fiber polystyrene, urethane, mineral wool, cork, or cellular glass. Rigid insulation is used primarily for wall sheathing and for insulating the edges of a concrete slab floor.

Foam: Foam insulation usually is composed of urethane which is applied in a manner similar to that used for sprayed insulation and for similar applications. Care should be taken that foam plastics are installed in accordance with the building code regulations on foam plastics.

Sprayed: Sprayed insulation generally is the same as blown except that a binder such as asphalt is added so that the material sticks to whatever surface it is sprayed onto. It often is used for insulation on masonry walls.

Insulation is specified on the basis of its performance in reducing heat transfer (R-value), not by insulation thickness in inches. Insulation materials vary in their ability to restrict heat transfer, depending on the type of insulation material, its fiber or cell structure, density, moisture content, and other physical characteristics, and by the protection provided by enclosing liners, and the method and care of application.

C. Common Insulation Locations

In homes and apartments insulation can be applied effectively as follows:

1. Exterior walls.
2. Ceiling with cold spaces above and dormer ceilings. The attic access panel can be insulated by stapling the edges of a piece of blanket insulation to its top. Use of adhesive backed foam tape on the bottom side around the edge of the attic access panel is a convenient method of weatherstripping that opening.
3. Knee walls when attic space is finished as living quarters.
4. Between collar beams, leaving open space above for ventilation.
5. Around the perimeter of a slab-on-grade when required.
6. Floors above vented crawl spaces. When a crawl space is used as a plenum, insulation is applied to crawl space walls instead of the floor above.
7. Floors over an unheated or an open space such as over a garage or a porch, and the cantilevered portion of a floor.
8. Basement walls when below-grade is finished for living purposes.

Sill sealer (insulation) between sill and foundation provides an effective wind infiltration barrier.

9. In back of band or header joists.

D. Other Locations for Insulation

There are special locations in apartment buildings where thermal insulation may be effective. Walls of unheated stairwells common to living units; floors of living units over boiler or other heat-producing mechanical equipment rooms; floors of conditioned spaces over unheated entrances or halls, and even, in some cases, walls of living units adjacent to incinerator and elevator shafts.

Thermal insulation is used frequently in apartments for acoustical purposes as well.

Most buildings also will benefit from insulation being applied to ducts and pipe runs, primarily to reduce the impact of ambient temperature on the temperature of the treated air or water being moved. Analyses of temperature change, heat loss or heat gain, and other factors affecting the economics of thermal insulation are seldom made for residential installations, but are essential for large commercial and industrial projects.

Ducts within buildings may be of sheet metal, or fibrous glass which provides combined air barrier, thermal insulation, and sound absorption. Ducts for embedding in or below floor slabs may be of compressed fiber, asbestos cement, ceramic tile, or other rigid materials.

Duct insulations include semi-rigid boards and flexible-blanket types, composed of organic and inorganic materials in fibrous, cellular, or bonded particle forms. Insulations for exterior surface application may have attached vapor barriers or facings, or vapor barriers may be separately applied.

Large pipes may be insulated with curved or flat segmental, or cylindrical half-, third-, or quarter-sections of insulation, particularly where removal for frequent servicing of the pipe is necessary. Fittings (valves, tees, elbows, etc.) are insulated with preformed fitting insulation, fabricated fitting insulation, or individual pieces cut from sectional straight pipe insulation, or insulating cements. Fitting insulation should be consistent with the pipe insulation.

Pipe insulation finish indoors will be governed generally by location. The simplest finish is a laminate of kraft paper, glass fiber reinforcing, and a vapor seal membrane. For maximum fire safety, unusual exposure conditions, or appearance, factory or separately applied metal jackets may be used.

Finish outdoors must primarily protect the insulation from the weather, chemical exposure, mechanical abuse, and appearance as additional considerations.

E. Installation

For insulation to be effective, it is critical that it be installed correctly. There are numerous publications now available which indicate precisely how certain forms of insulation should be applied to specific areas of buildings to achieve maximum benefit. Proper insulation installation practices are shown in Appendix A.

F. Notes on Installation

In many cases, a vapor barrier is used to protect the insulation from moisture damage due to water condensation in winter.

A vapor barrier usually consists of a thin sheet of plastic or some other material which prevents passage of moisture to those forms of insulation which are susceptible to moisture damage. The vapor barrier should cover the insulation on the inside or the warm surface side of the insulated wall, ceiling, etc., so that moisture contained in the inside air does not reach the insulation. Effectiveness of the vapor barrier will be greatly reduced if openings, even though very small, exist in the barrier. Many forms of insulation are available with a factory applied vapor barrier.

Irregular areas must be given careful attention when any insulation is installed. At the top and bottom of wall cavities (areas between the studs), blanket-type insulation should be sealed by stapling and/or taping to the floor and ceiling plates. Insulating material should be carefully fitted around all piping, wiring, and other projections. The proper thickness should be maintained throughout the walls, ceiling, and floors.

G. Typical Insulation Problems

Particular areas tend to be overlooked by the insulation installer and may also be difficult for the inspector to see. These include:

Walls:

Wall between living space and an unheated garage or storage room, dormer walls, and the portion of wall above the ceiling or an adjacent section of a split level home.

- Behind bath tubs and prefabricated showers, the fixtures may prevent inspection of the wall behind them.
- Behind electrical boxes and pipes.
- Behind and under stairways.
- In plywood shear walls.
- Spaces around openings between jambs and framing.

Floors:

In this case, the insulation is exposed to the weather since it is installed before the floor sheathing is in place and is unprotected from rain and dampness. It is difficult to inspect the supports (wires or staples) for the floor insulation without crawling under the building.

H. Building Envelope - Other Considerations

Windows and Doors: Windows and doors in exterior walls (other than required fire windows and doors) must be caulked, weatherstripped, or gasketed to reduce air infiltration.

Air leakage through the joints in windows and doors is controlled during manufacture. Inspection for labels or certifications relative to infiltration may be difficult because labels may fall off during transport and construction, or may be removed by the contractor during final clean up.

For non-residential occupancies, all doors are regulated. For residential occupancies, only sliding glass doors are regulated.

I. Inspection Points

Ceilings: Full coverage over top plates is necessary, but soffit vents should not be blocked.

Fastening and Workmanship: Under floors - wires holding batts in or insulation falls away from the floor.

Walls: Emphasis on quick installation may result in dependence on friction fit rather than proper stapling. Some products are intended to be installed with a friction fit, but others are designed to be stapled, and must be.

Attics: Eave vents in attics must be protected by baffles to prevent blocking of the vent with insulation material.

Pipes and Penetrations: Uninsulated pipes may provide a significant gap in the exterior envelope insulation of the building.

Penetrations through walls, if not carefully sealed, may permit unacceptable amounts of air infiltration.

II. OTHER SYSTEMS

A. MECHANICAL SYSTEMS:

HVAC Equipment:

Fuel Burning (gas and oil) - The code gives the requirements to which HVAC equipment must be built. The label on the gas furnace, or on the oil burner and furnace, will contain either the statement that the combustion efficiency is at least 75% or will give input BTU's and output BTU's. Combustion efficiency can be found simply by this formula -

$$\frac{\text{Output (BTU)}}{\text{Input (BTU)}} \times 100 = 75\% \text{ or more}$$

Electrically Operated HVAC Equipment - See Section 503.4(b) and Table 5-4 (heating) and Table 5-5 (cooling) of the Code.

In the case of electrically operated units you cannot determine the Coefficient of Performance in the field without special equipment. Therefore the information must appear on the label of the equipment. The tables referred to above give the precise numbers which must be reached.

Air Delivery - Field installed equipment must be checked for conformance with approved plans. Any unitary system that has the fan as a part of the unit, with the unit labeled in accordance with the requirements above, will be satisfactory.

Temperature Control (Code Section 503.8) - In plain language, any modern thermostat designed for use with the equipment being installed will meet the requirements.

Hot Water Heaters (Code Section 504.2) - As of this date, labels on domestic hot water heaters in retail outlets do not contain any of the information required in part (a). However, any of the automatic storage tank hot water heaters that are labeled by accepted inspection agencies exceed these requirements. The labels to be found are American Gas Association (AGA) for gas or Underwriters Laboratories, Inc. (UL) for electric. All hot water heaters must now be automatic.

III. CODE INTERACTION

Conflicts with other regulations, and with desirable design practice, may occur as a result of the Energy Conservation Code.

Of special concern are ventilation and fire problems.

A. Ventilation

Restriction of air infiltration may result in inadequate ventilation, especially for supply to, and exhaust from, combustion processes. There may be no requirements for exhaust equipment for gas ranges because of a tacit assumption that air infiltration around windows and doors will provide sufficient ventilation to permit safe operation of such equipment. Such may not be the case where labeled windows are used. While exhaust and ventilation equipment could be required in new construction it could be much more difficult to require addition of such equipment in retrofit projects which may involve little more than window replacement and may not even require a building permit.

B. Fire

Fire problems resulting from insulation requirements may be due to high flame spread of materials or to the heat retaining properties of the insulation itself.

Flame spread problems, as well as fire propagation problems, may result from the materials used, particularly in board type insulation. It is incorrect to assume that the location of insulation makes this unimportant, because a significant number of fires originate in electrical wiring located within walls. Materials used in rigid insulation may cause unacceptable generation of smoke and toxic gases. Such factors are compounded by the location of insulation because any concealed space presents special detection and extinguishment problems.

Further fire problems are caused by the insulation function per se, because the increased retention of heat accelerates the combustion process within the building, resulting in a probable reduction in time during which escape is possible. Unless this factor is compensated for, improved insulation will probably cause increases in fire deaths.

IV. FIELD INSPECTION

Inspection of insulation and mechanical systems for code conformance is not difficult. It is necessary that exact information relative to products be included on the plans.

Products must then be examined to determine that they are those specified.

The inspector will check for required labels on windows and insulation materials.

Ducts and piping will be inspected for required insulation and sealing.

The inspector will check for thermostats and water conserving shower heads as required.

In public facilities, hot water faucets are required to be of a water conserving type.

Controls for lights should permit selective use. Frequently, energy can be saved if lights can be turned off during the hours when an area receives ample natural light. Also during the time when janitorial crews are working, light is needed only in areas actually being cleaned. If control locations make it necessary to illuminate an entire building or floor at a time, much energy is wasted.

V. PLAN REQUIREMENTS

When application is made for a building permit, two sets of plans and specifications will be submitted to the Enforcement Official. These plans and specifications are required to provide adequate description of the building's energy conservation equipment, such as --

- Component materials of exterior envelope
- U Values of respective elements (except insulation)
- R Values of insulating materials
- Size and type of apparatus and equipment
- Equipment and system controls
- Any other data required to demonstrate conformance with requirements.

PART II - PRACTICAL APPLICATIONS; EXAMPLES

Considerable discussion has heretofore been devoted to the definition of terms as they relate to the thermal performance of a building; the process by which the thermal transmission values can be calculated; and the requirements of the Model Code and their effect on the inspection process.

"Thermal Performance" is the key word that is being stressed in the Model Code and in this course material. The Code is a performance oriented document and above all permits the use of any system of construction that performs in the manner established as the minimum performance level. In order to demonstrate the compliance process of the thermal performance of a building, the following practical exercise is offered. This exercise should demonstrate the following objectives:

1. How to analyze a given building for code compliance;
2. Show the flexibility (hence, performance) of how a building may comply with the code; and
3. Provide a useful tool for making the compliance process as easy as possible.

The tool here is somewhat of a plan review form which aids in keeping the data used in calculations in a neat and orderly fashion in order to reduce confusion and possible error. These sheets, shown in Figure 103-1 are one of many possible methods which can be used to make the analysis easier. It is certainly not the only method possible, but is helpful in keeping the data in a logical format in as little space as necessary. Above all, the user should keep in mind that forms can be altered to suit his needs as long as the basis of the calculations remains intact.

The basis of the calculations lies in two mathematical formulae. One, which has been discussed in detail, is the calculation method for a U value; that is, adding the R values of the materials and taking the reciprocal to determine the U value. These equations look like this:

$$R_t = R_1 + R_2 + R_3 + \dots$$

$$1/R_t = U$$

The second equation used as a basis for tables is the equation previously discussed for combining the different U values of sub-assemblies that exist in any wall, floor or roof-ceiling assembly.

This equation looks like this:

$$U_o = \frac{U_1A_1 + U_2A_2 + U_3A_3 + \dots}{A_o}$$

To derive the different portions of the tables requires only the setting up of spaces on the sheet for data as necessary to complete the above equations. To determine individual compliance of the various envelope elements (walls, roof-ceiling, floors), there are two charts, each corresponding to one of the equations above.

The first, reproduced below, deals with calculations of the U values for the two different assemblies of the blank envelope element, namely, the portion containing the framing member and the portion containing the cavity. The R value of each material is entered and totaled. The final space will contain the reciprocal of the R_t value which is the U value of the sub-assembly. It should be noted that there may be more spaces than values and that some may be left blank. For example, under the column for framing there will be no value for "insulation" or "air space" since there is a 2" x X" framing member where the cavity would normally occur. It should also be noted that if another calculation is necessary for additional sub-assemblies, such as a wall that is 1/2 brick veneer, a third column could be added. Throughout the sheets there are also entry spaces designated as "other" should there be a need.

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R_t = TOTAL LINES 1-10		
12 $U = 1/R$ TOTAL		

The second sheet, reproduced below, corresponds to the second equation for combining the U values of sub-assemblies to determine the overall U_o value.

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS WALL				
14 WINDOW				
15 DOOR				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE WALL	2)			
19 FRAMING	3)		5)	
20 CAVITY	4)		6)	
21 U_o = TOTAL LINES 14, 15, 16, 17, 19, 20				

The first column is the entry for the area (square feet) of the sub-assemblies. The area of the blank envelope element that contains a framing is relatively constant for a given stud or rafter space. Therefore, the framing area ratios shown may be used. These represent the percentage of blank envelope element that is framing member. (Read carefully the notes corresponding to the tables!) The gross area (A_o) is the total area of exterior assembly including all sub-assemblies.

The second column is the gross area ratio. This is the ratio of the area of the sub-assembly to the gross area.

The third column contains entries for the calculated U values of the sub-assemblies. You will note that the U values to be entered for the cavity and framing portion are the same as calculated in the previous chart. The U values for doors and windows (skylights) are a straight entry with no previous calculation since most materials such as those from the Handbook of Fundamentals give the U values rather than R values, hence no calculation is necessary.

The last column is the product of multiplying the gross area ratio (column 2) by the U value (column 3). The overall U_o value for the entire assembly is then determined by adding the values in the last column.

This relationship can be proven to be valid by manipulating the basic equation:

$$U_o = \frac{U_1 \times A_1 + U_2 \times A_2 + U_3 \times A_3 + \dots}{A_o}$$

This equation can also be written as follows; and this then shows the steps that were just described in the table.

$$U_o = U_1 \times \frac{(A_1)}{(A_o)} + U_2 \times \frac{(A_2)}{(A_o)} + U_3 \times \frac{(A_3)}{(A_o)} + \dots$$

where $\frac{A_1}{A_o}$, $\frac{A_2}{A_o}$ and $\frac{A_3}{A_o}$ are the gross area ratios in column 2;

where U_1 , U_2 and U_3 are the U values in column 3;

where $U_1 (A_1/A_o)$, etc. are the product of columns 2 and 3 shown in column 4; and where the entire equation is the sum of the values in column 4.

The same basic approach is taken for figuring walls (first page) and for figuring roof-ceiling and floors (second page). The third page contains two charts for combining the U_o values of each envelope assembly to determine and compare an overall U_t value for the building should it be necessary to calculate one. (Reference is made to the trade-off aspect permitted by the code discussed earlier). The third page also contains a simplified method for determining compliance with the cooling requirements for walls. In the types of buildings we are concentrating on (small residential) this calculation does not come into play.

INSTRUCTIONS

Instructions on the use of the tables are included in Figure 103-1.

U₀ CALCULATIONS FOR WALLS

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS WALL				
14 WINDOW				
15 DOOR				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE WALL 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

THESE FOOTNOTES APPLICABLE TO ALL PAGES

- 1) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area. For example, the ratio of line 19 - FRAMING = $\frac{\text{Framing Area} - \text{line 19}}{\text{Gross Area} - \text{line 13}}$
- 2) Line 18 OPAQUE AREA, equals line 13 AREA minus 14, 15, 16, and 17 AREA.
- 3) FRAMING AREA equals line 18 AREA times appropriate FRAMING RATIO TABLE A.
- 4) CAVITY AREA equals line 18 minus line 19 AREA.
- 5) Line 12 U VALUE for FRAMING.
- 6) Line 12 U VALUE for CAVITY.
- 7) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area.
- 8) The U VALUES obtained from Table 5-1 or 5-2.
- 9) This U VALUE is the value indicated on line 21 page 1.
- 10) This U VALUE is the value indicated on line 21 page 2 for floors.
- 11) This U VALUE is the value indicated on line 21 page 2 for ceiling-roof.
- 12) U x Ratio Allowed total must be greater than U x Ratio Actual Total.
- 13) TABLE A RATIO.
- 14) TABLE B RATIO.

U₀ CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS FLOOR				
14 OTHER (Specify)				
15 OTHER (Specify)				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE FLOOR 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS ROOF-CEIL.				
14 SKYLIGHT				
15 ROOF SCUPPER				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE ROOF-CEIL. 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

Figure 103-1

COMBINING COMPONENTS

U ACTUAL ≤ U ALLOWED

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO	ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL					22 WALL			9)	
23 FLOOR					23 FLOOR			10)	
24 CEILING- ROOF					24 CEILING- ROOF			11)	
25 TOTAL		U _T ALLOWED =			25 TOTAL		U _T ACTUAL =		

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

Figure 103-1

WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY	WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
1 AIR FILM OUTSIDE			13 GROSS WALL				
2 OUTER SURFACE			14 WINDOW				
3 OUTER SHEATHING			15 DOOR				
4 FRAMING			16 OTHER (Specify)				
5 CAVITY a) INSULATION			17 OTHER (Specify)				
6 b) AIR SPACE			18 OPAQUE WALL	2)			
7 INSIDE SURFACE			19 FRAMING	3)	13)	5)	
8 AIR FILM INSIDE			20 CAVITY	4)	14)	6)	
9 OTHER a)			21 U _c = TOTAL LINES 19, 20				
10 (Specify) b)							
11 R _T = TOTAL LINES 1-10							
12 U = 1/R TOTAL							

Figure 103-1

**CALCULATING COMPONENT THERMAL TRANSMISSION
VALUES (U_0) HEATING**

- STEP 1. Determine the individual R values in series in the section and list them in the appropriate blanks lines 1-10. Note entries required for both cavity and framing sections.
- STEP 2. Total lines 1-10 and enter results line 11.
- STEP 3. Take the reciprocal of line 11. This is the Thermal Transmission Coefficient and the value should be entered on line 12.
- STEP 4. Determine the GROSS AREA of the component line 13.
- STEP 5. Determine the areas of the component that are composed of different materials lines 14-20. See footnote 3 and 4.
- STEP 6. Determine GROSS AREA RATIO - see footnote 1. Enter values lines 14-17, 19 and 20.
- STEP 7. Enter thermal coefficients U values for various component areas, lines 14-17, 19 and 20. See footnote 5 and 6.
- STEP 8. Multiply GROSS AREA RATIO by their respective Thermal Coefficient Values (U_0). Lines 14-17, 19 and 20.
- STEP 9. Total lines 14-17, 19 and 20. This is the overall Thermal Transmission value of the component.

**CALCULATING BUILDING ENVELOPE EQUIVALENT
THERMAL TRANSMISSION COEFFICIENT**

- STEP 1. Enter the GROSS AREAS of the components (wall, roofing, ceiling, and floors) lines 22-24.
- STEP 2. Add the individual areas, lines 22-24.
- STEP 3. Determine GROSS AREA RATIO - See footnote 7. Enter lines 22-24.
- STEP 4. Enter thermal coefficients for various components. See footnotes 8, 9, 10, 11.
- STEP 5. Multiply GROSS AREA RATIO by the respective Thermal Coefficient value (U_0). Lines 22-24.
- STEP 6. Add the U x Ratio values of the components.
- STEP 7. Compare U x Ratio value allowed with U x Ratio value actual. See footnote 12.

Figure 103-1

**CALCULATING THERMAL TRANSMISSION COEFFICIENTS
U VALUES: COOLING WALLS ONLY**

- STEP 1. Repeat steps 1-5 Heating.
- STEP 2. Determine OPAQUE AREA RATIO - See footnote 13, 14, enter these values, lines 19 and 20.
- STEP 3. Enter Thermal Transmission Coefficient values for framing and cavity - see footnote 5 and 6.
- STEP 4. Multiply OPAQUE AREA RATIO by the respective Thermal Transmission value, lines 19 and 20.
- STEP 5. Add the U x Ratio values, lines 19 and 20. This value is the Thermal Transmission value for the opaque wall and is used in calculating the OIV.

SUMMARY

The basic procedure for analyzing a building for compliance with Section 5 of the Code can be summarized as follows:

Procedure

1. Determine the location of the building and the annual heating degree day value for the location.
2. Analyze the wall components.
 - a. Determine the blank wall section and establish the R values of individual materials (From Tables 103-1), including air film resistances. (Two calculations are necessary to account for the portion of the blank wall that consists of framing members and the portion containing cavity space.)
 - b. Add the R values and take the reciprocal to determine the U value ($U = 1/R$).
 - c. Determine the U or R values as appropriate for the doors and windows.
 - d. Calculate the gross wall area, the window area and the door area.
 - e. Determine the blank or opaque wall area. (Gross wall area minus the sum of the door and window areas.)
 - f. Determine the framing area by multiplying the opaque wall area by the appropriate framing ratio.
 - g. Determine the gross area ratios of the different assemblies of materials. These represent the ratio of window area to gross area, framing area to gross area, cavity area to gross area, etc.
 - h. Multiply the U values of the different assemblies by their respective gross area ratios.
 - i. The overall U_o value for the wall is the sum total of the U values times the area ratios of each different assembly of materials.
3. Analyze the floor and roof-ceiling components.
 - a. The same procedure is followed as for walls. As with walls,

care must be taken to separately calculate the U values for each section of the roof that comprises a different assembly of materials (e.g., framing, cavity, skylight, etc.)

4. Determine from the Code reference the maximum U_o for walls, floors and roof for the appropriate degree day value.
5. Determine individual code compliance of the walls, floor and roof.
 - a. If the actual U_o of an element is less than the maximum U_o permitted by the Code, the assembly complies.
 - b. If all elements comply individually, the entire building complies and the analysis is complete.
 - c. If all elements do not comply individually, we know the entire building does not comply and the design must be revised by the permit applicant.
 - d. If one or more elements comply with the Code and one or more elements do not comply, we must combine the effects of all the elements and determine an overall U_t for the entire building. The Code permits an assembly, such as a wall, to have a higher U_o value than permitted for walls as long as another assembly such as a roof, has a U_o value sufficiently less than the maximum permitted for roofs such that the overall building will not have a greater heat loss than it would if the building had met all of the specified maximum U_o values. This can be established according to the following steps.
6. Determine the maximum U_t for the building that would be permitted by the Code.
 - a. Indicate the gross wall, roof and floor areas of the actual building. (Previously calculated.) Add these areas to determine the overall gross area of the building envelope.
 - b. Determine the area ratios of the floor, wall and roof assemblies by dividing the gross area of each assembly by the gross area of the building envelope.
 - c. Multiply these ratios by the U_o value permitted by the Code for each assembly.
 - d. Add the U_o permitted times area ratio values. The sum total is the maximum U_t for that building permitted by the Code.
7. Determine the actual U_t for the building as proposed.

- a. Steps 6.a and 6.b above are the same. Since we are comparing the same building as proposed versus meeting the maximum Code requirements, the wall, roof and floor areas are the same and the area ratios are the same.
- b. Continue with steps 6.c and 6.d above but inserting the actual U_o values previously calculated for the wall, roof and floor assemblies instead of the maximum U_o value permitted by the Code. This results in an actual U_t for the proposed building.
- c. If the actual U_t is less than the maximum U_t permitted, the entire building complies with the Code. If the actual U_t is greater than the maximum, this indicates that the building will permit a greater heat loss than the same building would if it met all the maximum U_o values prescribed by the Code.

The following are problems and solutions of a small residential building for various degree day locations in the United States. Determine whether the building is in compliance with the Model Code.

Problem 1. 1 story residential building, located in Gainesville, Florida.

Given: Plan Sheet A.

Problem 2. 1 story residential building, located in San Francisco, California.

Given: Plan Sheet B.

Problem 3. 1 story residential building, located in Worcester, Massachusetts.

Given: Plan Sheet C.

FLOOR PLAN

900 SQ. FT.

SECTION

NOTES

1. ALL WINDOWS ARE SINGLE GLAZING
2. ALL DOORS ARE 1" SOLID WOOD W/O STORM DOORS.

FRONT ELEVATION

EXAMPLE PROBLEM - RESIDENTIAL
MODEL ENERGY CONSERVATION CODE
LOCATION: GAINESVILLE, FLORIDA
(1000 D.D.)

U₀ CALCULATIONS FOR WALLS

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS WALL				
14 WINDOW				
15 DOOR				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE WALL	2)			
19 FRAMING	3)		5)	
20 CAVITY	4)		6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

THESE FOOTNOTES APPLICABLE TO ALL PAGES

- 1) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area. For example, the ratio of line 19 -

$$\text{FRAMING} = \frac{\text{Framing Area} - \text{line 19}}{\text{Gross Area} - \text{line 13}}$$

- 2) Line 18 OPAQUE AREA, equals line 13 AREA minus 14, 15, 16, and 17 AREA.
- 3) FRAMING AREA equals line 18 AREA times appropriate FRAMING RATIO TABLE A.
- 4) CAVITY AREA equals line 18 minus line 19 AREA.
- 5) Line 12 U VALUE for FRAMING.
- 6) Line 12 U VALUE for CAVITY.
- 7) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area.
- 8) The U VALUES obtained from Table 5-1 or 5-2.
- 9) This U VALUE is the value indicated on line 21 page 1.
- 10) This U VALUE is the value indicated on line 21 page 2 for floors.
- 11) This U VALUE is the value indicated on line 21 page 2 for ceiling-roof.
- 12) U x Ratio Allowed total must be greater than U x Ratio Actual Total.
- 13) TABLE A RATIO.
- 14) TABLE B RATIO.

U_0 CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R_T = TOTAL LINES 1-10		
12 U = $1/R$ TOTAL		

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	$U \times$ RATIO
13 GROSS FLOOR				
14 OTHER (Specify)				
15 OTHER (Specify)				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE FLOOR 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U_0 = TOTAL LINES 14, 15, 16, 17, 19, 20				

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9) OTHER a)		
10 (Specify) b)		
11 R_T = TOTAL LINES 1-10		
12 U = $1/R$ TOTAL		

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	$U \times$ RATIO
13 GROSS ROOF-CEIL.				
14 SKYLIGHT				
15 ROOF SCUPPER				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE ROOF-CEIL. 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U_0 = TOTAL LINES 14, 15, 16, 17, 19, 20				

COMBINING COMPONENTS

$$U \text{ ACTUAL} \leq U \text{ ALLOWED}$$

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO	ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL					22 WALL			9)	
23 FLOOR					23 FLOOR			10)	
24 CEILING- ROOF					24 CEILING- ROOF			11)	
25 TOTAL		$U_T \text{ ALLOWED} =$			25 TOTAL		$U_T \text{ ACTUAL} =$		

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

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WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY	WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
1 AIR FILM OUTSIDE			13 GROSS WALL				
2 OUTER SURFACE			14 WINDOW				
3 OUTER SHEATHING			15 DOOR				
4 FRAMING			16 OTHER (Specify)				
5 CAVITY a) INSULATION			17 OTHER (Specify)				
6 b) AIR SPACE			18 OPAQUE WALL	2)			
7 INSIDE SURFACE			19 FRAMING	3)	13)	5)	
8 AIR FILM INSIDE			20 CAVITY	4)	14)	6)	
9 OTHER a)			21 $U_o = \text{TOTAL LINES 19, 20}$				
10 (Specify) b)							
11 $R_T = \text{TOTAL LINES 1-10}$							
12 $U = 1/R \text{ TOTAL}$

FLOOR PLAN

900 SQ. FT.

SECTION

NOTES

1. ALL WINDOWS ARE DOUBLE GLAZING W/1/4" AIR SPACE.
2. ALL DOORS ARE 1 1/2" SOLID WOOD W/O STORM DOORS.

FRONT ELEVATION

EXAMPLE PROBLEM - RESIDENTIAL
MODEL ENERGY CONSERVATION CODE
LOCATION: SAN FRANCISCO, CALIF.
(3000 D.D.)

U₀ CALCULATIONS FOR WALLS

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	U x RATIO
13 GROSS WALL				
14 WINDOW				
15 DOOR				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE WALL 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

THESE FOOTNOTES APPLICABLE TO ALL PAGES

- 1) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area. For example, the ratio of line 19 - FRAMING = $\frac{\text{Framing Area} - \text{line 19}}{\text{Gross Area} - \text{line 13}}$
- 2) Line 18 OPAQUE AREA, equals line 13 AREA minus 14, 15, 16, and 17 AREA.
- 3) FRAMING AREA equals line 18 AREA times appropriate FRAMING RATIO TABLE A.
- 4) CAVITY AREA equals line 18 minus line 19 AREA.
- 5) Line 12 U VALUE for FRAMING.
- 6) Line 12 U VALUE for CAVITY.
- 7) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area.
- 8) The U VALUES obtained from Table 5-1 or 5-2.
- 9) This U VALUE is the value indicated on line 21 page 1.
- 10) This U VALUE is the value indicated on line 21 page 2 for floors.
- 11) This U VALUE is the value indicated on line 21 page 2 for ceiling-roof.
- 12) U x Ratio Allowed total must be greater than U x Ratio Actual Total.
- 13) TABLE A RATIO.
- 14) TABLE B RATIO.

U₀ CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS FLOOR				
14 OTHER (Specify)				
15 OTHER (Specify)				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE FLOOR 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9) OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS ROOF-CEIL.				
14 SKYLIGHT				
15 ROOF SCUPPER				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE ROOF-CEIL. 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

COMBINING COMPONENTS

$$U \text{ ACTUAL} \leq U \text{ ALLOWED}$$

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO	ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL					22 WALL			9)	
23 FLOOR					23 FLOOR			10)	
24 CEILING- ROOF					24 CEILING- ROOF			11)	
25 TOTAL		$U_T \text{ ALLOWED} =$			25 TOTAL		$U_T \text{ ACTUAL} =$		

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

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WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY	WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
1 AIR FILM OUTSIDE			13 GROSS WALL				
2 OUTER SURFACE			14 WINDOW				
3 OUTER SHEATHING			15 DOOR				
4 FRAMING			16 OTHER (Specify)				
5 CAVITY a) INSULATION			17 OTHER (Specify)				
6 b) AIR SPACE			18 OPAQUE WALL	2)			
7 INSIDE SURFACE			19 FRAMING	3)	13)	5)	
8 AIR FILM INSIDE			20 CAVITY	4)	14)	6)	
9 OTHER a)			21 $U_o = \text{TOTAL LINES 19, 20}$				
10 (Specify) b)							
11 $R_T = \text{TOTAL LINES 1-10}$							
12 $U = 1/R \text{ TOTAL}$

FLOOR PLAN

900 SQ. FT.

NOTES

1. ALL WINDOWS ARE TRIPLE GLAZING w/ 1/2" AIR SPACE.
2. ALL DOORS ARE 1" SOLID WOOD w/o STORM DOORS.

FRONT ELEVATION

EXAMPLE PROBLEM - RESIDENTIAL
MODEL ENERGY CONSERVATION CODE
LOCATION: WORCHESTER, MASS.
(7200 D.D.)

U₀ CALCULATIONS FOR WALLS

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS WALL				
14 WINDOW				
15 DOOR				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE WALL 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

THESE FOOTNOTES APPLICABLE TO ALL PAGES

1) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area. For example, the ratio of line 19 -

$$\text{FRAMING} = \frac{\text{Framing Area} - \text{line 19}}{\text{Gross Area} - \text{line 13}}$$

2) Line 18 OPAQUE AREA, equals line 13 AREA minus 14, 15, 16, and 17 AREA.

3) FRAMING AREA equals line 18 AREA times appropriate FRAMING RATIO TABLE A.

4) CAVITY AREA equals line 18 minus line 19 AREA.

5) Line 12 U VALUE for FRAMING.

6) Line 12 U VALUE for CAVITY.

7) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area.

8) The U VALUES obtained from Table 5-1 or 5-2.

9) This U VALUE is the value indicated on line 21 page 1.

10) This U VALUE is the value indicated on line 21 page 2 for floors.

11) This U VALUE is the value indicated on line 21 page 2 for ceiling-roof.

12) U x Ratio Allowed total must be greater than U x Ratio Actual Total.

13) TABLE A RATIO.

14) TABLE B RATIO.

U₀ CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS FLOOR				
14 OTHER (Specify)				
15 OTHER (Specify)				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE FLOOR 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R _T = TOTAL LINES 1-10		
12 U = 1/R TOTAL		

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS ROOF-CEIL.				
14 SKYLIGHT				
15 ROOF SCUPPER				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE ROOF-CEIL. 2)				
19 FRAMING 3)			5)	
20 CAVITY 4)			6)	
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				

COMBINING COMPONENTS

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO
22 WALL				
23 FLOOR				
24 CEILING- ROOF				
25 TOTAL		U_T ALLOWED =		

U ACTUAL $\leq$ U ALLOWED

ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL			9)	
23 FLOOR			10)	
24 CEILING- ROOF			11)	
25 TOTAL		U_T ACTUAL =		

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

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WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE		
2 OUTER SURFACE		
3 OUTER SHEATHING		
4 FRAMING		
5 CAVITY a) INSULATION		
6 b) AIR SPACE		
7 INSIDE SURFACE		
8 AIR FILM INSIDE		
9 OTHER a)		
10 (Specify) b)		
11 R_T = TOTAL LINES 1-10		
12 U = $1/R$ TOTAL		

WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
13 GROSS WALL				
14 WINDOW				
15 DOOR				
16 OTHER (Specify)				
17 OTHER (Specify)				
18 OPAQUE WALL	2)			
19 FRAMING	3)	13)	5)	
20 CAVITY	4)	14)	6)	
21 U_o = TOTAL LINES 19, 20				

Table 103-14

Thermal Properties of Typical Building and Insulating Materials—(Design Values)*
 (For Industrial Insulation Design Values, see Table 3B). These constants are expressed in Btu per (hour) (square foot) (degree Fahrenheit temperature difference). Conductivities (*k*) are per inch thickness, and conductances (*C*) are for thickness or construction stated, not per inch thickness. All values are for a mean temperature of 75 F, except as noted by an asterisk (*) which have been reported at 45 F. The SI units for Resistance (last two columns) were calculated by taking the values from the two Resistance columns under Customary Unit, and multiplying by the factor 1/*k* (r/m.) and 1/*C* (R) for the appropriate conversion factor in Table 18.

Description	Density (lb./ft. ³)	Conduc- tivity (<i>k</i>)	Conduc- tance (<i>C</i>)	Customary Unit		Specific Heat, Btu/(lb) (deg F)	SI Unit	
				Resistance ^b (<i>R</i>)			Resistance ^b (<i>R</i>)	
				Per inch thickness (1/ <i>k</i>)	For thick- ness listed (1/ <i>C</i>)		(m·K) W	(m ² ·K) W
BUILDING BOARD								
Boards, Panels, Subflooring, Sheathing								
Woodboard Panel Products								
Asbestos-cement board	120	4.0	—	0.25	—	0.24	1.73	—
Asbestos-cement board	0.125 in. 120	—	33.00	—	0.03	—	—	0.003
Asbestos-cement board	0.25 in. 120	—	16.50	—	0.06	—	—	0.01
Gypsum or plaster board	0.375 in. 50	—	3.10	—	0.32	0.26	—	0.06
Gypsum or plaster board	0.5 in. 50	—	2.22	—	0.45	—	—	0.03
Gypsum or plaster board	0.625 in. 50	—	1.78	—	0.56	—	—	0.10
Plywood (Douglas Fir)	34	0.80	—	1.25	—	0.29	0.66	—
Plywood (Douglas Fir)	0.25 in. 34	—	3.20	—	0.31	—	—	0.03
Plywood (Douglas Fir)	0.375 in. 34	—	2.13	—	0.47	—	—	0.03
Plywood (Douglas Fir)	0.5 in. 34	—	1.60	—	0.62	—	—	0.11
Plywood (Douglas Fir)	0.625 in. 34	—	1.29	—	0.77	—	—	0.19

Table 103-1

Surface Conductances and Resistances for Air All conductance values expressed in Btu/(hr·ft ² ·F).						Coefficients of Transmission (U) for Slab Doors Btu per (hr·ft ² ·F)				
SECTION A. Surface Conductances and Resistances ^{a,b,d}						Winter		Summer		
Surface Emittance						Solid Wood, No Storm Door		Storm Door ^b		
Position of Surface	Direction of Heat Flow	Non-reflective ^c $\epsilon = 0.90$	Reflective $\epsilon = 0.20$	Reflective $\epsilon = 0.85$		Thickness ^a	Wood	Metal	No Storm Door	
1-in.		0.64	0.30	0.39	0.61					
1.25-in.		0.55	0.28	0.34	0.53					
1.5-in.		0.49	0.27	0.33	0.47					
2-in.		0.43	0.24	0.29	0.43					
						Steel Door ^{b,c}				
1.75 in.										
A ^c		0.59	—	—	0.58					
B ^d		0.19	—	—	0.19					
C ^e		0.47	—	—	0.46					
STILL AIR										
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32			
Sloping—45 deg	Upward	1.60	0.62	0.88	1.14	0.73	1.37			
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70			
Sloping—45 deg	Downward	1.32	0.76	0.60	1.67	0.45	2.22			
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55			
MOVING AIR										
(Any Position)										
15-mph Wind	Any	6.00	0.17							
(for winter)										
7.5-mph Wind	Any	4.00	0.25							
(for summer)										

Overall Coefficients of Heat Transmission (U-Factor) of Windows and Skylights, Btu/(ft ² ·deg F)					
PART A. Exterior ^a Vertical Panels					
Description	Winter ^a	Summer ^a	Winter ^a	Summer ^a	
Flat Glass ^b					
Single Glass	No Shade 1.10	No Shade 1.04	Indoor Shade ^{***} 0.83	Indoor Shade ^{***} 0.81	
Insulating Glass; Double ^c					
3/16-in. air space ^d	0.62	0.63	0.52	0.58	
1/4-in. air space ^d	0.58	0.61	0.48	0.53	
1/2-in. air space ^d	0.49	0.56			
1/2-in. air space, low emittance coating ^f			0.42	0.52	
$\epsilon=0.20$	0.32	0.38	0.30	0.37	
$\epsilon=0.40$	0.38	0.45	0.36	0.44	
$\epsilon=0.60$	0.43	0.51	0.38	0.48	
Insulating Glass; Triple ^c					
1/4-in. air space ^d	0.39	0.44	0.31	0.40	
1/2-in. air space ^d	0.31	0.39	0.26	0.36	
Storm Windows					
1-in. to 4-in. air spaces ^d	0.50	0.50	0.42	0.48	
Part B. Exterior ^a Horizontal Panels (Skylights)					
Description	Winter ^d	Summer ^d			
Flat Glass ^a					
Single Glass	1.23	0.83			
Insulating Glass; Double ^c					
3/16-in. air space ^d	0.70	0.57			
1/4-in. air space ^d	0.63	0.54			
1/2-in. air space ^d	0.59	0.49			
1/2-in. air space, low emittance coating ^f					
$\epsilon=0.20$	0.48	0.36			
$\epsilon=0.40$	0.52	0.42			
$\epsilon=0.60$	0.56	0.46			
Plastic Domes ^h					
Single Walled	1.15	0.80			
Double Walled	0.70	0.46			

Part C. Adjustment Factors for Various Window and Sliding Patio Door Types (Multiply U-Values in Parts A and B by These Factors)			
Description	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All Glass ^b	1.00	1.00	1.00
Wood Sash; 80% Glass	0.90	0.95	0.90
Wood Sash; 60% Glass	0.80	0.85	0.80
Metal Sash; 80% Glass	1.00	1.20 ^m	1.20 ^m
Sliding Patio Doors			
Wood Frame	0.95	1.00	—
Metal Frame	1.00	1.10 ^m	—

^a See Part C for adjustments for various windows and sliding patio doors.

^b Emissivity of uncoated glass surface = 0.84.

^c Double and triple refer to number of lights of glass.

^d 0.125-in. glass.

^e 0.25-in. glass.

^f Coating on either glass surface facing air space; all other glass surfaces uncoated.

^g Window design: 0.25-in. glass, 0.125-in. glass, 0.25-in. glass.

^h Refers to windows with negligible opaque areas.

ⁱ For heat flow up.

^j For heat flow down.

^k Based on area of opening, not total surface area.

^l Values will be less than these when metal sash and frame incorporate thermal breaks. In some thermal break designs U values will be equal to or less than those for the glass. Window manufacturers should be consulted for specific data.

^m 15 mph outdoor air velocity; 0 F outdoor air; 70 F inside air temp natural convection.

ⁿ 7.5 mph outdoor air velocity; 89 F outdoor air; 75 F inside air natural convection; solar radiation 248.3 Btu/hr·ft².

^o Values apply to tightly closed venetian and vertical blinds, draperies, and roller shades.

Table 103-1

Thermal Properties of Typical Building and Insulating Materials—(Design Values) ^a								
Description	Density (lb/ft ³)	Conduc- tivity (k)	Conduc- tance (C)	Customary Unit		Specific Heat, Btu/(lb (deg F)	SI Unit	
				Resistance ^b (R)			Resistance ^b (R)	(m·K) W
				Per inch thickness (1/k)	For thick- ness listed (1/C)			
Plywood or wood panels..... 0.75 in.	34	—	1.07	—	0.93	0.29		0.16
Vegetable Fiber Board								
Sheathing, regular density..... 0.5 in.	18	—	0.76	—	1.32	0.31		0.23
..... 0.78125 in.	18	—	0.49	—	2.06			0.36
Sheathing intermediate density..... 0.5 in.	22	—	0.82	—	1.22	0.31		0.21
Nail-base sheathing..... 0.5 in.	25	—	0.88	—	1.14	0.31		0.20
Shingle backer..... 0.375 in.	18	—	1.06	—	0.94	0.31		0.17
Shingle backer..... 0.3125 in.	18	—	1.28	—	0.78			0.14
Sound deadening board..... 0.5 in.	15	—	0.74	—	1.35	0.30		0.24
Tile and lay-in panels, plain or acoustic..... 0.5 in.	18	0.40	—	2.50	—	0.14	17.33	
..... 0.5 in.	18	—	0.80	—	1.25			0.22
..... 0.75 in.	18	—	0.53	—	1.89			0.33
Laminated paperboard.....	30	0.50	—	2.00	—	0.33	13.86	
Homogeneous board from recycled paper.....	30	0.50	—	2.00	—	0.28	13.86	
Hardboard								
Medium density.....	50	0.73	—	1.37	—	0.31	9.49	
High density, service temp. service underlay.....	55	0.82	—	1.22	—	0.32	8.46	
High density, std. tempered.....	63	1.00	—	1.00	—	0.32	6.93	
Particleboard								
Low density.....	37	0.54	—	1.85	—	0.31	12.82	
Medium density.....	50	0.94	—	1.06	—	0.31	7.35	
High density.....	62.5	1.18	—	0.85	—	0.31	5.89	
Underlayment..... 0.625 in.	40	—	1.22	—	0.82	0.29		0.14
Wood subfloor..... 0.75 in.	40	—	1.06	—	0.94	0.33		0.17
BUILDING MEMBRANE								
Vapor—permeable felt.....	—	—	16.70	—	0.06			0.01
Vapor—seal, 2 layers of mopped 15-lb felt.....	—	—	8.35	—	0.12			0.02
Vapor—seal, plastic film.....	—	—	—	—	Negl.			
FINISH FLOORING MATERIALS								
Carpet and fibrous pad.....	—	—	0.48	—	2.08	0.34		0.37
Carpet and rubber pad.....	—	—	0.81	—	1.23	0.33		0.22
Cork tile..... 0.125 in.	—	—	3.60	—	0.28	0.48		0.05
Terrazzo..... 1 in.	—	—	12.50	—	0.08	0.19		0.01
Tile—asphalt, linoleum, vinyl, rubber vinyl asbestos.....	—	—	20.00	—	0.05	0.30		0.01
ceramic.....	—	—	—	—	—	0.24		
Wood, hardwood finish..... 0.75 in.	—	—	1.47	—	0.68	0.19		0.12
INSULATING MATERIALS								
BLANKET AND BATT								
Mineral Fiber, fibrous form processed from rock, slag, or glass								
approx. 2-2.75 in.....	0.3-2.0	—	0.143	—	7 ^a	0.17-0.23		1.23
approx. 3-3.5 in.....	0.3-2.0	—	0.091	—	11 ^a			1.94
approx. 3.50-6.5.....	0.3-2.0	—	0.053	—	19 ^a			3.35
approx. 6-7 in.....	0.3-2.0	—	0.045	—	22 ^a			3.87
approx. 8.5 in.....	0.3-2.0	—	0.033	—	30 ^a			5.28
BOARD AND SLAB								
Cellular glass.....	8.5	0.38	—	2.63	—	0.24	18.23	
Glass fiber, organic bonded.....	4-9	0.25	—	4.00	—	0.23	27.72	
Expanded rubber (rigid).....	4.5	0.22	—	4.55	—	0.40	31.53	
Expanded polystyrene extruded								
Cut cell surface.....	1.8	0.25	—	4.00	—	0.29	27.72	
Smooth skin surface.....	2.2	0.20	—	5.00	—	0.29	34.65	
Expanded polystyrene extruded								
Smooth skin surface.....	3.5	0.19	—	5.26	—		36.45	
Expanded polystyrene, molded beads.....	1.0	0.28	—	3.57	—	0.29	34.74	
Expanded polyurethane ^c (R-11 exp.).....	1.5	0.16	—	6.25	—	0.38	43.82	
(Thickness 1 in. or greater).....	2.5	—	—	—	—	—	—	—

Table 103-1

Thermal Properties of Typical Building and Insulating Materials—(Design Values) ^a								
Description	Density (lb/ft ³)	Conduc- tivity (k)	Conduc- tance (C)	Customary Unit		Specific Heat, Btu/(lb (deg F)	SI Unit	
				Resistance ^b (R)			Resistance ^b (R)	
				Per inch thickness (1/k)	For thick- ness listed (1/C)		(m ² ·K) W	(m ³ ·K) W
Mineral fiber with resin binder	15	0.29	—	3.45	—	0.17	23.91	
Mineral fiberboard, wet felted								
Core or roof insulation	16-17	0.34	—	2.94	—		20.38	
Acoustical tile	18	0.35	—	2.86	—	0.19	19.82	
Acoustical tile	21	0.37	—	2.70	—		18.71	
Mineral fiberboard, wet molded								
Acoustical tiles	23	0.42	—	2.38	—	0.14	16.49	
Wood or cane fiberboard								
Acoustical tiles 0.5 in.	—	—	0.80	—	1.25	0.31		0.22
Acoustical tiles 0.75 in.	—	—	0.53	—	1.89			0.33
Interior finish (plank, tile)	15-	0.35	—	2.86	—	0.32	19.82	
Wood shredded (cemented in preformed slabs).	22	0.60	—	1.67	—	0.31	11.57	
LOOSE FILL								
Cellulosic insulation (milled paper or wood pulp)	2.3-3.2	0.27-0.32	—	3.13-3.70	—	0.33	21.69-25.64	
Sawdust or shavings	8.0-15.0	0.45	—	2.22	—	0.33	15.39	
Wood fiber, softwoods	2.0-3.5	0.30	—	3.33	—	0.33	23.08	
Perlite, expanded	5.0-8.0	0.37	—	2.70	—	0.26	18.71	
Mineral fiber (rock, slag or glass)								
approx. 3.75-5 in.	0.6-2.0	—	—	—	11	0.17		1.94
approx. 6.5-8.75 in.	0.6-2.0	—	—	—	19			3.35
approx. 7.5-10 in.	0.6-2.0	—	—	—	22			3.87
approx. 10.25-13.75 in.	0.6-2.0	—	—	—	30			5.28
Vermiculite, exfoliated	7.0-8.2	0.47	—	2.13	—	3.20	14.76	
	4.0-6.0	0.44	—	2.27	—		15.73	
ROOF INSULATION ^b								
Preformed, for use above deck								
Different roof insulations are available in different thicknesses to provide the design C values listed. ^b			0.72 to 0.12		1.39 to 8.33		— to —	0.24 to 1.47
Consult individual manufacturers for actual thickness of their material.								
MASONRY MATERIALS								
CONCRETES								
Cement mortar	116	5.0	—	0.20	—		1.39	
Gypsum-fiber concrete 87.5% gypsum, 12.5% wood chips	51	1.66	—	0.60	—	0.21	4.16	
Lightweight aggregates including ex- panded shale, clay or slate; expanded	120	5.2	—	0.19	—		1.32	
slag; cinders; pumice; vermiculite; also cellular concretes.	100	3.6	—	0.28	—		1.94	
	80	2.5	—	0.40	—		2.77	
	60	1.7	—	0.59	—		4.09	
	40	1.15	—	0.86	—		5.96	
	30	0.90	—	1.11	—		7.69	
	20	0.70	—	1.43	—		9.91	
Perlite, expanded	40	0.93	—	1.08	—		7.48	
	30	0.71	—	1.41	—		9.77	
	20	0.50	—	2.00	—	0.32	13.86	
Sand and gravel or stone aggregate (oven dried)	140	9.0	—	0.11	—	0.22	0.76	
Sand and gravel or stone aggregate (not dried)	140	12.0	—	0.08	—		0.55	
Strucco	116	5.0	—	0.20	—		1.39	
MASONRY UNITS								
Brick, common ¹	120	5.0	—	0.20	—	0.19	1.39	
Brick, face ¹	120	9.0	—	0.11	—		0.76	
Clay tile, hollow:								
1 cell deep 3 in.	—	—	1.25	—	0.80	0.21		0.14
1 cell deep 4 in.	—	—	0.90	—	1.11			0.20
2 cells deep 6 in.	—	—	0.66	—	1.52			0.27
2 cells deep 8 in.	—	—	0.54	—	1.85			0.33
2 cells deep 10 in.	—	—	0.45	—	2.22			0.39
3 cells deep 12 in.	—	—	0.40	—	2.50			0.44

Table 103-1

Thermal Properties of Typical Building and Insulating Materials—(Design Values)^a

Description	Density (lb/ft ³)	Conduc- tivity (k)	Conduc- tance (C)	Customary Unit		Specific Heat, Btu/(lb (deg F)	SI Unit	
				Resistance ^a (R)			Resistance ^a (R)	Resistance ^a (R)
				Per inch thickness (1/k)	For thick- ness listed (1/C)			
Concrete blocks, three oval core:								
Sand and gravel aggregate	4 in.	—	1.40	—	0.71	0.22		0.13
	8 in.	—	0.90	—	1.11			0.20
	12 in.	—	0.78	—	1.28			0.23
Cinder aggregate	3 in.	—	1.16	—	0.85	0.21		0.15
	4 in.	—	0.90	—	1.11			0.20
	8 in.	—	0.58	—	1.72			0.30
	12 in.	—	0.53	—	1.89			0.33
Lightweight aggregate	3 in.	—	0.79	—	1.27	0.21		0.22
(expanded shale, clay, slate	4 in.	—	0.67	—	1.50			0.26
or slag; pumice)	8 in.	—	0.50	—	2.00			0.35
	12 in.	—	0.44	—	2.27			0.40
Concrete blocks, rectangular core. ^{a)}								
Sand and gravel aggregate		—	0.96	—	1.04	0.22		0.18
2 core, 8 in. 36 lb. 1/2"		—	0.52	—	1.93	0.22		0.34
Same with filled cores ^{1/2"}								
Lightweight aggregate (expanded shale,								
clay, slate or slag, pumice):								
3 core, 6 in. 19 lb. 1/2"		—	0.61	—	1.63	0.21		0.29
Same with filled cores ^{1/2"}		—	0.33	—	2.99			0.53
2 core, 8 in. 24 lb. 1/2"		—	0.46	—	2.18			0.38
Same with filled cores ^{1/2"}		—	0.20	—	5.03			0.89
3 core, 12 in. 38 lb. 1/2"		—	0.40	—	2.48			0.44
Same with filled cores ^{1/2"}		—	0.17	—	5.82			1.02
Stone, lime or sand.		12.50	—	0.08	—	0.19	0.33	—
Gypsum partition tile:								
3 × 12 × 30 in. solid		—	0.79	—	1.26	0.19		0.22
3 × 12 × 30 in. 4-cell		—	0.74	—	1.33			0.24
4 × 12 × 30 in. 3-cell		—	0.60	—	1.67			0.29
METALS								
(See Chapter 37, Table 3)								
PLASTERING MATERIALS								
Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20	1.39	—
Sand aggregate 0.375 in.	—	—	13.3	—	0.08	0.20		0.01
Sand aggregate 0.75 in.	—	—	6.66	—	0.15	0.20		0.03
Gypsum plaster:								
Lightweight aggregate 0.5 in.	45	—	3.12	—	0.32			0.06
Lightweight aggregate 0.625 in.	45	—	2.67	—	0.39			0.07
Lightweight agg. on metal lath 0.75 in.	—	—	2.13	—	0.47			0.08
Perlite aggregate	45	1.5	—	0.67	—	0.32	4.64	—
Sand aggregate	105	5.6	—	0.18	—	0.20	1.25	—
Sand aggregate 0.5 in.	105	—	11.10	—	0.09			0.02
Sand aggregate 0.625 in.	105	—	9.10	—	0.11			0.02
Sand aggregate on metal lath 0.75 in.	—	—	7.70	—	0.13			0.02
Vermiculite aggregate	45	1.7	—	0.59	—		4.09	—
ROOFING								
Asbestos-cement shingles	120	—	4.76	—	0.21	0.24		0.04
Asphalt roll roofing	70	—	6.50	—	0.15	0.36		0.03
Asphalt shingles	70	—	2.27	—	0.44	0.30		0.08
Built-up roofing 0.375 in.	70	—	3.00	—	0.33	0.35		0.06
Slate 0.5 in.	—	—	20.00	—	0.05	0.30		0.01
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31		0.17
SIDING MATERIALS (ON FLAT SURFACE)								
Shingles								
Asbestos-cement	120	—	4.75	—	0.21			0.04
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31		0.15
Wood, double, 16 in., 12 in. exposure	—	—	0.84	—	1.19	0.28		0.21
Wood, plus insul. backer board, 0.3125 in.	—	—	0.71	—	1.40	0.31		0.25
Siding								
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24		0.04
Asphalt roll siding	—	—	6.50	—	0.15	0.35		0.03
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35		0.26
Wood, drop, 1 × 8 in.	—	—	1.27	—	0.79	0.28		0.14
Wood, bevel, 0.5 × 8 in., lapped	—	—	1.23	—	0.81	0.28		0.14
Wood, bevel, 0.75 × 10 in., lapped	—	—	0.95	—	1.05	0.28		0.18
Wood, plywood, 0.375 in., lapped	—	—	1.59	—	0.59	0.29		0.10
Wood, medium density siding, 0.4375 in.	40	1.49	—	0.67		0.28	4.63	—

Table 103-1

Thermal Properties of Typical Building and Insulating Materials—(Design Values)^a

Description	Customary Unit						SI Unit	
	Density (lb/ft ³)	Conduc- tivity (k)	Conduc- tance (C)	Resistance ^b (R)		Specific Heat, Btu/(lb (deg F)	Resistance ^b (R)	
				Per inch thickness (1/k)	For thick- ness listed (1/C)		(m·K)	(m ² ·K)
							W	W
Aluminum or Steel ^c , over sheathing	—	—	1.61	—	0.61	0.29	—	0.11
Hollow-backed	—	—	—	—	—	—	—	—
Insulating-board backed nominal 0.375 in.	—	—	0.53	—	1.82	0.32	—	0.12
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.95	—	—	0.12
Architectural glass	—	—	10.00	—	0.10	0.20	—	0.02
WOODS								
Maple, oak, and similar hardwoods	45	1.10	—	0.91	—	0.30	6.31	—
Fir, pine, and similar softwoods	32	0.80	—	1.25	—	0.33	8.66	—
Fir, pine, and similar softwoods	—	—	1.06	—	0.94	—	—	0.17
..... 0.75 in.	—	—	0.53	—	1.82	—	—	0.12
..... 1.5 in.	—	—	0.32	—	3.12	—	—	0.60
..... 2.5 in.	—	—	0.23	—	4.35	—	—	0.73

Notes for Table 3A

^aRepresentative values for dry materials were selected by ASHRAE TC4.4, Insulation and Moisture Barriers. They are intended as design (not specification) values for materials in normal use. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

^bResistance values are the reciprocal of C before rounding off C to two decimal places.

^cAlso see Insulating Materials, Board.

^dDoes not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an air space, see Tables 1 and 2 for the insulating value of air space for the appropriate effective emittance and temperature conditions of the space.

^eConductivity varies with fiber diameter. (See Chapter 20, Thermal Conductivity section, and Fig. 1) Insulation is produced by different densities; therefore, there is a wide variation in thickness for the same R-value among manufacturers. No effort should be made to relate any specific R-value to any specific thickness. Commercial thicknesses generally available range from 2 to 8.5.

^fValues are for aged board stock. For change in conductivity with age of expanded urethane, see Chapter 19, Factors Affecting Thermal Conductivity.

^gInsulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

^hThe U. S. Department of Commerce, *Simplified Practice Recommendation for Thermal Conductance Factors for Preformed Above-Deck Roof Insulation*, No. R 257-33, recognizes the specification of roof insulation on the basis of the C-values shown. Roof insulation is made in thicknesses to meet these values.

ⁱFace brick and common brick do not always have these specific densities. When density is different from that shown, there will be a change in thermal conductivity.

^jData on rectangular core concrete blocks differ from the above data on oval core blocks, due to core configuration, different mean temperatures, and possibly differences in unit weights. Weight data on the oval core blocks tested are not available.

^kWeights of units approximately 7.625 in. high and 15.75 in. long. These weights are given as a means of describing the blocks tested, but conductance values are all for 1 ft² of area.

^lVermiculite, perlite, or mineral wool insulation. Where insulation is used, vapor barriers or other precautions must be considered to keep insulation dry.

^mValues for metal siding applied over flat surfaces vary widely, depending on amount of ventilation of air space beneath the siding; whether air space is reflective or nonreflective; and on thickness, type, and application of insulating backing-board used. Values given are averages for use as design guides, and were obtained from several guarded hotbox tests (ASTM C236) or calibrated hotbox (BSS 77) on hollow-backed types and types made using backing-boards of wood fiber, foamed plastic, and glass fiber. Departures of 50% or more from the values given may occur.

Table 103-2⁴

THERMAL RESISTANCE (R) VALUES FOR AIR SPACES

POSITION OF AIR SPACE	DIRECTION OF HEAT FLOW	THICKNESS OF AIR SPACE			
		1/2"	3/4"	1½"	3½"
Horizontal	Up	0.84	0.87	0.89	0.93
45° Slope	Up	0.90	0.94	0.91	0.96
Vertical	Horizontal	0.91	1.01	1.02	1.01
Horizontal	Down	0.92	1.02	1.14	1.21
45° Slope	Down	0.92	1.02	1.09	1.05

Coefficients of Transmission (U) of Windows, Skylights, and Light Transmitting Partitions

These values are for heat transfer from air to air, Btu/(hr · ft² · F). To calculate total heat gain including solar transmission, see Chapter 28.

PART A—VERTICAL PANELS (EXTERIOR WINDOWS, SLIDING PATIO DOORS, AND PARTITIONS)— FLAT GLASS, GLASS BLOCK, AND PLASTIC SHEET				PART B—HORIZONTAL PANELS (SKYLIGHTS)— FLAT GLASS, GLASS BLOCK, AND PLASTIC DOMES			
Description	Exterior ^a			Description	Exterior ^a		
	Winter	Summer	Interior		Winter ^f	Summer ^g	Interior ^h
Flat Glass^b				Flat Glass^b			
single glass	1.10	1.04	0.73	single glass	1.23	0.83	0.96
insulating glass—double ^c				insulating glass—double ^c			
0.1875-in. air space ^d	0.62	0.65	0.51	0.1875-in. air space ^d	0.70	0.57	0.62
0.25-in. air space ^d	0.58	0.61	0.49	0.25-in. air space ^d	0.65	0.54	0.59
0.5-in. air space ^e	0.49	0.56	0.46	0.5-in. air space ^e	0.59	0.49	0.56
0.5-in. air space, low emittance coating ^f				0.5-in. air space, low emittance coating ^f			
e = 0.20	0.32	0.38	0.32	e = 0.20	0.48	0.36	0.39
e = 0.40	0.38	0.45	0.38	e = 0.40	0.52	0.42	0.45
e = 0.60	0.43	0.51	0.42	e = 0.60	0.56	0.46	0.50
insulating glass—triple ^c				Glass Block^b			
0.25-in. air spaces ^d	0.39	0.44	0.38	11 × 11 × 3 in. thick with cavity divider	0.53	0.35	0.44
0.5-in. air spaces ^e	0.31	0.39	0.30	12 × 12 × 4 in. thick with cavity divider	0.51	0.34	0.42
storm windows							
1-in. to 4-in. air space ^d	0.50	0.50	0.44				
Plastic Sheet				Plastic Domes^b			
single glazed				single-walled	1.15	0.80	—
0.125-in. thick	1.06	0.98	—	double-walled	0.70	0.46	—
0.25-in. thick	0.96	0.89	—				
0.5-in. thick	0.81	0.76	—				
insulating unit—double ^c							
0.25-in. air space ^d	0.55	0.56	—				
0.5-in. air space ^e	0.43	0.45	—				
Glass Block^b							
6 × 6 × 4 in. thick	0.60	0.57	0.46				
8 × 8 × 4 in. thick	0.56	0.54	0.44				
—with cavity divider	0.48	0.46	0.38				
12 × 12 × 4 in. thick	0.52	0.50	0.41				
—with cavity divider	0.44	0.42	0.36				
12 × 12 × 2 in. thick	0.60	0.57	0.46				

PART C—ADJUSTMENT FACTORS FOR VARIOUS WINDOW AND SLIDING PATIO DOOR TYPES (MULTIPLY U VALUES IN PARTS A AND B BY THESE FACTORS)

Description	Double or Triple Glass		
	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All Glass ⁱ	1.00	1.00	1.00
Wood Sash—80% Glass	0.90	0.95	0.90
Wood Sash—60% Glass	0.80	0.85	0.80
Metal Sash—80% Glass	1.00	1.20 ^m	1.20 ^m
Sliding Patio Doors			
Wood Frame	0.95	1.00	—
Metal Frame	1.00	1.10 ^m	—

^aSee Part C for adjustment for various window and sliding patio door types.

^bEmittance of uncoated glass surface = 0.84.

^cDouble and triple refer to the number of lights of glass.

^d0.125-in. glass.

^e0.25-in. glass.

^fCoating on either glass surface facing air space; all other glass surfaces uncoated.

^gWindow design: 0.25-in. glass—0.125-in. glass—0.25-in. glass.

^hDimensions are nominal.

ⁱFor heat flow up.

^jFor heat flow down.

^kBased on area of opening, not total surface area.

^lRefers to windows with negligible opaque area.

^mValues will be less than those when metal sash and frame incorporate thermal breaks. In some thermal break designs, U-values will be equal to or less than those for the glass. Window manufacturers should be consulted for specific data.

TABLE 103-34

Btu per (hr · ft ² · F)				
		Winter		Summer
Thickness ^a	Solid Wood, No Storm Door		Storm Door ^b	
	No Storm Door	Wood	Metal	No Storm Door
1-in.	0.64	0.30	0.39	0.61
1.25-in.	0.55	0.28	0.34	0.53
1.5-in.	0.49	0.27	0.33	0.47
2-in.	0.43	0.24	0.29	0.42
Steel Door ^{b,c}				
1.75 in.				
A ^c	0.59	—	—	0.58
B ^d	0.19	—	—	0.18
C ^e	0.47	—	—	0.46

^aNominal thickness.

^bValues for wood storm doors are for approximately 50% glass; for metal storm door values apply for any percent of glass.

^cA = Mineral fiber core (2 lb/ft³).

^dB = Solid urethane foam core with thermal break.

^eC = Solid polystyrene core with thermal break.

Coefficients of Transmission (U) for Slab Doors

TABLE 103-4⁴

All conductance values expressed in Btu/(hr·ft²·F).

A surface cannot take credit for both an air space resistance value and a surface resistance value. No credit for an air space value can be taken for any surface facing an air space of less than 0.5 in.

SECTION A. Surface Conductances and Resistances ^{a,b,d}						SECTION B. Reflectivity and Emittance Values of Various Surfaces ^c and Effective Emittances of Air Spaces						
		Surface Emittance						Effective Emittance E of Air Space				
Position of Surface	Direction of Heat Flow	Non-reflective $\epsilon = 0.90$	Reflective $\epsilon = 0.30$		Reflective $\epsilon = 0.05$		Surface	Reflectivity in Percent	Average Emittance ϵ	One surface emittance ϵ ; the other 0.90	Both surfaces emittances ϵ	
			k_1	R	k_1	R						k_2
STILL AIR												
Horizontal	Upward	1.63	0.61	0.91	1.70	0.76	1.32	Aluminum foil, bright	92 to 97	0.05	0.05	0.03
Sloping—45 deg	Upward	1.60	0.62	0.88	1.14	0.73	1.37	Aluminum sheet	80 to 95	0.12	0.12	0.06
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70	Aluminum coated paper, polished	75 to 84	0.20	0.20	0.11
Sloping—45 deg	Downward	1.32	0.76	0.60	1.67	0.45	2.22	Steel, galvanized, bright	70 to 80	0.25	0.24	0.15
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55	Aluminum paint	30 to 70	0.50	0.47	0.35
MOVING AIR												
(Any Position)			k_1	R	k_2	R	k_2	R				
15-mph Wind	Any	6.00	0.17						Building materials: wood, paper, masonry, nonmetallic paints	5 to 15	0.90	0.82
(for winter)									Regular glass	5 to 15	0.84	0.77
7.5-mph Wind	Any	4.00	0.25									
(for summer)												

^aFor ventilated attics or spaces above ceilings under summer conditions (heat flow down) see Table 6.

^bConductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10 deg F and for surface temperature of 70 F.

^cSee also Chapter 2, Table 4.

^dSee Fig. 1 for additional data.

Surface Conductances and Resistances for Air

TABLE 103-5⁴

FOOTNOTES

1ASHRAE STANDARD 90-75: ENERGY CONSERVATION IN NEW BUILDING DESIGN.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017.

2NAHB INSULATION MANUAL. National Association of Home Builders, 15th & M Streets, N.W., Washington, D.C. 20005

3MODEL CODE FOR ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION. December, 1977. Department of Energy.

4ASHRAE HANDBOOK OF FUNDAMENTALS. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017. 1977.

5THE ARKANSAS STORY. Owens-Corning Fiberglas Corporation, Fiberglass Tower, Toledo, Ohio 43659.

6REPORT OF THE COMMERCE TECHNICAL ADVISORY BOARD. Panel on Project Independence Blueprint, U.S.A. Department of Commerce, 1975. p.69

7Report, CITIZEN ACTION GUIDE TO ENERGY CONSERVATION, Citizen's Advisory Committee on Environmental Quality, p.10.

8Ibid.

9REPORT OF THE TASK FORCE ON ENERGY OF THE SUBCOMMITTEE ON SCIENCE RESEARCH, AND DEVELOPMENT OF THE COMMITTEE ON SCIENCE AND ASTRONAUTICS, U.S. House of Representatives, Ninety-Second Congress, December, 1972, U.S. Government Printing Office, p.311.

10,11AN IMPACT ASSESSMENT OF ASHRAE STANDARD 90-75, "ENERGY CONSERVATION IN NEW BUILDING DESIGN", Report to Federal Energy Administration, December 1975, C-78309. Arthur D. Little, Inc.

12Ibid.

13Ibid.

14Ibid.

15Ibid.

16Ibid.

17Ibid.

APPENDIX A

1. Ceilings

There are three methods of installing blanket insulation in ceilings:

1. Stapling from below (Fig. 1a and 1b).
2. Installing unfaced (without a vapor barrier), pressure-fit blankets (Fig. 2).
3. Laying the insulation in from above when the ceiling finish material is in place.

Fig. 1a

Fig. 1b

Staple flanges to the ceiling joists as shown in Fig. 1a and 1b. Extend the insulation entirely across the top plate, keeping the blanket as close to the plate as possible. If necessary, stuff the gap between blanket and plate with loose insulation. When eave vents are used, the insulation should not block air movement from eave to space above insulation.

Wedge unfaced, pressure-fit blankets between ceiling joists (Fig. 2). Allow insulation to overlap the top plate of the exterior wall, but not enough to block eave ventilation. The insulation should touch the top of the plate to avoid heat loss and wind penetration beneath the insulation.

A separate vapor barrier is unnecessary under some conditions. For instance, if the ratio of total net free ventilating area to area of ceiling is 1/300 or more and half of that area is provided by ventilators located in the upper portion of the space to be ventilated (at least 3 feet above eave or cornice vents) and the balance of required ventilating area is provided by eave or cornice vents, no separate vapor barrier is necessary. This meets the requirements of the FHA Minimum Property Standards. See Page 19.

Fig. 2

2. Walls

Fig. 3a

Fig. 3b

Push blankets into stud spaces so they touch the sheathing or siding. Working from the top down, space staples about 8 inches apart, pulling down flanges to fit snugly against studs. Cut blanket ends to fit tight against top and bottom plates (Fig. 3a). As an alternate, cut blankets slightly overlapped and staple through the vapor barrier to the plates by compressing the insulation (Fig. 3b).

Fig. 4

When pressure-fit blankets without a vapor barrier are used, wedge them into place. Cover inside face of wall studs with a 2-mil-thick polyethylene vapor barrier (Fig. 4), stapled to top and bottom plates. Unroll the sheet across the entire wall area including window and door openings. Cut out openings later. Foil-backed gypsumboard may be used as a vapor barrier instead of polyethylene.

Fig. 5

Push insulation behind (cold side in winter) pipes, ducts, and electrical boxes (Fig. 5). As an alternate, the space may be packed with loose insulation or a piece of insulation of the proper size can be cut and fit into place.

Fig. 6

Stuff small spaces between rough framing and door and window heads, jambs, and sills with pieces of insulation (Fig. 6). Staple insulation vapor barrier paper or polyethylene to cover these small spaces.

Fig. 7a

Fig. 7b

Insulate non-standard-width stud or joist spaces by cutting the insulation and vapor barrier an inch or so wider than the space to be filled (Fig. 7a). Staple uncut flange as usual. Pull the vapor barrier on the cut side to the other stud, compressing the insulation behind it, and staple through vapor barrier to stud. (Fig. 7b). Unfaced blankets are cut slightly oversize and wedged into place.

3. Masonry Walls

Fig. 8a

Fig. 8b

Masonry walls may be insulated using either nominal 2 x 2 or 1 x 2 furring strips. Furring strips may be 16 or 24 inches o.c., depending on thickness and type of wall finish. Two kinds of insulation may be used. For 1 x 2 furring (Fig. 8a), masonry wall insulation nominally 1-inch-thick (about R-3) of the pressure-fit type is available without a vapor barrier. In this case, use a separate 2-mil polyethylene film or foil-backed gypsumboard for the vapor barrier. For 2 x 2 furring (Fig. 8b), R-7 insulation with vapor barrier may be used. When R-7 insulation is compressed to 1 3/4 inches (1 1/2 inches plus 1/4-inch of shim), its thermal resistance is reduced to about R-6. For the R-7 insulation with a vapor barrier, staple the blanket flange to the face of the furring strip (the 1-3/4-inch space is not adequate to recess the insulation and staple flanges to the side of the furring strip as recommended for walls). When the R-7 is used, furring strips can be 24 inches on center since the compressed insulation provides intermediate support for "thin" panelling.

Fig. 10a

Fig. 10b

If perimeter insulation is needed for slab-on-ground construction, install it as shown in Fig. 10a or Fig. 10b.

4. Dropped Soffits—Kitchen/Bath

Insulation of dropped soffits over kitchen cabinets, bathtubs, or showers may need special attention when they are exposed to the attic. If the dropped soffit is framed before ceiling finish material is applied, a "board" (plywood, hardboard, gypsumboard, etc.) needs to be installed over the cavity to support blown insulation. The dropped soffit area is no problem with blanket insulation or when blown attic insulation is used and the ceiling finish material extends over the cavity. When using blanket insulation, stuff it between trusses or rafters to extend over and span the dropped soffit cavity.

In apartments with back-to-back kitchens or baths, it is preferable to extend ceiling finish material over dropped soffits to the party wall to avoid acoustical short circuits.

4. Pipes and Wires

Pack insulation in the space around pipes and wires that pass through wall plates into attics and vented crawl spaces.

5. Recessed Light Fixtures

Install insulation around, not over, recessed light fixtures in roof/ceiling constructions to preclude excessive heat build up. Holes in such rough-in recess boxes provide a moisture vapor opening and no practical way is known to seal them. However, recessed light fixtures are widely used and moisture vapor problems traceable to these fixtures are virtually unknown. Nonetheless, it is suggested that when they are used in cathedral, flat, or mansard roof/ceilings in cold climates, particular attention be given to ventilating the space between roof and ceiling.

In apartment construction, the holes in these fixtures can create acoustical flanking paths through attics.

7. Floors and Crawl Spaces

Floors over crawl spaces may be insulated either by insulating the foundation walls if the crawl space is *unvented*, or if the crawl space is *vented* by placing insulation between the joists. The former method, as described below, is usually more economical.

Fig. 9a

Place the vapor barrier (polyethylene film) covering the crawl space ground against the wall (Fig. 9a), using occasional pieces of tape to hold it against the wall until the insulation has been put into place. If the inside surface of the crawl space wall is not over 21 inches high, use nominal 2-foot-wide blanket insulation, or if the wall is not over 12-13 inches high, use nominal 16-inch-wide insulation. Place one edge of insulation on top of foundation wall, taping it temporarily in place as needed. The remainder of the insulation should drape over and against the inside of the wall. Insulation is held permanently in place by the sill plate or header joist if no sill plate is used. If the bottom of the insulation stands away from the wall, use stones, bricks or blocks spaced as needed to hold it against the wall. The vapor barrier on the insulation should face inward (the warm side in winter). In this method of installation, the insulation also serves as a sill sealer.

Walls of *unvented* crawl spaces also may be insulated by fastening rigid insulation board to the inside face of the wall extending from ground to top of wall. Follow manufacturer's instructions for method and type of adhesive or fasteners.

Floors over *vented* crawl spaces (Fig. 9b) can be insulated by installing insulation between the joists and holding it in place by:

1. Using heavy-gage wires pointed at both ends and made especially for this purpose. Bow the wires and wedge them under insulation and between joists.
2. Lacing wire back and forth between nails placed in bottom of joists.
3. Nailing chicken wire to bottom of joists.

In all cases, the vapor barrier side of the insulation should face the floor above—that is, be adjacent to the warm side in winter. Polyethylene may be used as a vapor barrier to cover the ground. If it is desired to protect the insulation from the weather, such as may be the case in open crawl spaces, nail standard, interior grade softwood plywood, nail-base insulation board, or similar covering to the bottom of floor joists.

Fig. 9b

Fig. 9c

floor insulation
(alternate methods)

Fig. 9d

Fig. 9e

vapor barrier side

In basement and *unvented* crawl space constructions, sill sealer insulation may be used if necessary to prevent air infiltration between sill and foundation or between header joist and foundation. The sill sealer is merely unrolled on top of foundation wall and temporarily taped in place as necessary (Fig. 9c).

Wedge or staple short pieces of blanket insulation behind band or header joists (Fig. 9c and 9d). As an alternative, when using insulation at the bottom of joists, the header joist may be insulated by "folding" the end of the blanket up 90 degrees and pushing it against the header (Fig. 9e).

Headers in cantilevered floor construction (Fig. 9e) can be insulated as mentioned above. Insulate soffits below cantilevered floors by cutting blanket to fit and wedging it in place, vapor barrier facing up. As an alternate, these headers and soffits can be insulated by folding the end of the blanket against the header, as shown in the righthand section of Fig. 9c.

SOLUTION TO PROBLEMS

U₀ CALCULATIONS FOR WALLS

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.17	.17
2 OUTER SURFACE	1.46	1.46
3 OUTER SHEATHING	.62	.62
4 FRAMING	4.35	
5 CAVITY a) INSULATION		7.00
6 b) AIR SPACE		-
7 INSIDE SURFACE	.45	.45
8 AIR FILM INSIDE	.68	.68
9 OTHER a)	-	-
10 (Specify) b)	-	-
11 R _T = TOTAL LINES 1-10	7.73	10.38
12 U = 1/R TOTAL	.129	.096

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS WALL	960			
14 WINDOW	225	.234	1.13	.264
15 DOOR	40	.042	.64	.027
16 OTHER (Specify)	-	-	-	-
17 OTHER (Specify)	-	-	-	-
18 OPAQUE WALL	2) 695			
19 FRAMING	3) 105	.109	5) .129	.014
20 CAVITY	4) 590	.615	6) .096	.059
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.364

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

THESE FOOTNOTES APPLICABLE TO ALL PAGES

- 1) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area. For example, the ratio of line 19 -

$$\text{FRAMING} = \frac{\text{Framing Area} - \text{line 19}}{\text{Gross Area} - \text{line 13}}$$

- 2) Line 18 OPAQUE AREA, equals line 13 AREA minus 14, 15, 16, and 17 AREA.
- 3) FRAMING AREA equals line 18 AREA times appropriate FRAMING RATIO TABLE A.
- 4) CAVITY AREA equals line 18 minus line 19 AREA.
- 5) Line 12 U VALUE for FRAMING.
- 6) Line 12 U VALUE for CAVITY.
- 7) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area.
- 8) The U VALUES obtained from Table 5-1 or 5-2.
- 9) This U VALUE is the value indicated on line 21 page 1.
- 10) This U VALUE is the value indicated on line 21 page 2 for floors.
- 11) This U VALUE is the value indicated on line 21 page 2 for ceiling-roof.
- 12) U x Ratio Allowed total must be greater than U x Ratio Actual Total.
- 13) TABLE A RATIO.
- 14) TABLE B RATIO.

U₀ CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.92	.92
2 OUTER SURFACE	—	—
3 OUTER SHEATHING	1.25	1.25
4 FRAMING	11.88	—
5 CAVITY a) INSULATION	—	—
6 b) AIR SPACE	—	—
7 INSIDE SURFACE	2.08	2.08
8 AIR FILM INSIDE	.92	.92
9 OTHER a)	—	—
10 (Specify) b)	—	—
11 R _T = TOTAL LINES 1-10	17.05	5.17
12 U = 1/R TOTAL	.059	.193

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS FLOOR	900	—	—	—
14 OTHER (Specify)	—	—	—	—
15 OTHER (Specify)	—	—	—	—
16 OTHER (Specify)	—	—	—	—
17 OTHER (Specify)	—	—	—	—
18 OPAQUE FLOOR	2) 900	—	—	—
19 FRAMING	3) 90	.10	5) .059	.006
20 CAVITY	4) 810	.90	6) .193	.174
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.180

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.61	.61
2 OUTER SURFACE	—	—
3 OUTER SHEATHING	—	—
4 FRAMING	9.38	—
5 CAVITY a) INSULATION	—	15.00
6 b) AIR SPACE	—	—
7 INSIDE SURFACE	.45	.45
8 AIR FILM INSIDE	.61	.61
9) OTHER a)	—	—
10 (Specify) b)	—	—
11 R _T = TOTAL LINES 1-10	11.05	16.67
12 U = 1/R TOTAL	.090	.060

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS ROOF-CEIL.	900	—	—	—
14 SKYLIGHT	—	—	—	—
15 ROOF SCUPPER	—	—	—	—
16 OTHER (Specify)	—	—	—	—
17 OTHER (Specify)	—	—	—	—
18 OPAQUE ROOF-CEIL.	2) 900	—	—	—
19 FRAMING	3) 90	.10	5) .090	.009
20 CAVITY	4) 810	.90	6) .060	.054
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.063

COMBINING COMPONENTS

$$U \text{ ACTUAL} \leq U \text{ ALLOWED}$$

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO	ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL	960	.348	.29	.101	22 WALL	960	.348	.364 ₉₎	.127
23 FLOOR	900	.326	.32	.104	23 FLOOR	900	.326	.180 ₁₀₎	.059
24 CEILING- ROOF	900	.326	.05	.016	24 CEILING- ROOF	900	.326	.063 ₁₁₎	.021
25 TOTAL	2760	$U_T \text{ ALLOWED} =$		.221	25 TOTAL	2760	$U_T \text{ ACTUAL} =$		.207

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

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WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY	WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
1 AIR FILM OUTSIDE			13 GROSS WALL				
2 OUTER SURFACE			14 WINDOW				
3 OUTER SHEATHING			15 DOOR				
4 FRAMING			16 OTHER (Specify)				
5 CAVITY a) INSULATION			17 OTHER (Specify)				
6 b) AIR SPACE			18 OPAQUE WALL	2)			
7 INSIDE SURFACE			19 FRAMING	3)	13)	5)	
8 AIR FILM INSIDE			20 CAVITY	4)	14)	6)	
9 OTHER a)			21 $U_o = \text{TOTAL LINES 19, 20}$				
10 (Specify) b)							
11 $R_T = \text{TOTAL LINES 1-10}$							
12 $U = 1/R \text{ TOTAL}$							

U₀ CALCULATIONS FOR WALLS

WALLS HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.17	.17
2 OUTER SURFACE	1.46	1.46
3 OUTER SHEATHING	.62	.62
4 FRAMING	4.35	
5 CAVITY a) INSULATION		7.00
6 b) AIR SPACE		-
7 INSIDE SURFACE	.45	.45
8 AIR FILM INSIDE	.68	.68
9 OTHER a)	-	-
10 (Specify) b)	-	-
11 R _T = TOTAL LINES 1-10	7.73	10.38
12 U = 1/R TOTAL	.129	.096

WALLS HEATING	AREA s.f.	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS WALL	960			
14 WINDOW	225	.234	.65	.152
15 DOOR	40	.042	.49	.021
16 OTHER (Specify)	-	-	-	-
17 OTHER (Specify)	-	-	-	-
18 OPAQUE WALL	2) 695			
19 FRAMING	3) 105	.109	5) .129	.014
20 CAVITY	4) 590	.615	6) .096	.059
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.246

PROBLEM 2

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

THESE FOOTNOTES APPLICABLE TO ALL PAGES

- 1) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area. For example, the ratio of line 19 -

$$\text{FRAMING} = \frac{\text{Framing Area} - \text{line 19}}{\text{Gross Area} - \text{line 13}}$$

- 2) Line 18 OPAQUE AREA, equals line 13 AREA minus 14, 15, 16, and 17 AREA.
- 3) FRAMING AREA equals line 18 AREA times appropriate FRAMING RATIO TABLE A.
- 4) CAVITY AREA equals line 18 minus line 19 AREA.
- 5) Line 12 U VALUE for FRAMING.
- 6) Line 12 U VALUE for CAVITY.
- 7) GROSS AREA RATIO equals ratio of individual areas to gross area. This ratio may be obtained by dividing each individual line area by the gross area.
- 8) The U VALUES obtained from Table 5-1 or 5-2.
- 9) This U VALUE is the value indicated on line 21 page 1.
- 10) This U VALUE is the value indicated on line 21 page 2 for floors.
- 11) This U VALUE is the value indicated on line 21 page 2 for ceiling-roof.
- 12) U x Ratio Allowed total must be greater than U x Ratio Actual Total.
- 13) TABLE A RATIO.
- 14) TABLE B RATIO.

U₀ CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.92	.92
2 OUTER SURFACE	—	—
3 OUTER SHEATHING	1.25	1.25
4 FRAMING	11.88	—
5 CAVITY a) INSULATION	—	—
6 b) AIR SPACE	—	—
7 INSIDE SURFACE	2.08	2.08
8 AIR FILM INSIDE	.92	.92
9 OTHER a)	—	—
10 (Specify) b)	—	—
11 R _T = TOTAL LINES 1-10	17.05	5.17
12 U = 1/R TOTAL	.059	.193

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS FLOOR	900	—	—	—
14 OTHER (Specify)	—	—	—	—
15 OTHER (Specify)	—	—	—	—
16 OTHER (Specify)	—	—	—	—
17 OTHER (Specify)	—	—	—	—
18 OPAQUE FLOOR	2) 900	—	—	—
19 FRAMING	3) 90	.10	5) .059	.006
20 CAVITY	4) 810	.90	6) .173	.174
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.180

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.61	.61
2 OUTER SURFACE	—	—
3 OUTER SHEATHING	—	—
4 FRAMING	9.38	—
5 CAVITY a) INSULATION	—	15.00
6 b) AIR SPACE	—	—
7 INSIDE SURFACE	.45	.45
8 AIR FILM INSIDE	.61	.61
9 OTHER a)	—	—
10 (Specify) b)	—	—
11 R _T = TOTAL LINES 1-10	11.05	16.67
12 U = 1/R TOTAL	.090	.060

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS ROOF-CEIL.	900	—	—	—
14 SKYLIGHT	—	—	—	—
15 ROOF SCUPPER	—	—	—	—
16 OTHER (Specify)	—	—	—	—
17 OTHER (Specify)	—	—	—	—
18 OPAQUE ROOF-CEIL.	2) 900	—	—	—
19 FRAMING	3) 90	.10	5) .090	.009
20 CAVITY	4) 810	.90	6) .060	.054
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.063

COMBINING COMPONENTS

U ACTUAL $\leq$ U ALLOWED

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO	ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL	960	.348	.26	.091	22 WALL	960	.348	.2469)	.086
23 FLOOR	900	.326	.18	.059	23 FLOOR	900	.326	.18 10)	.059
24 CEILING- ROOF	900	.326	.05	.016	24 CEILING- ROOF	900	.326	.06311)	.021
25 TOTAL	2760	U_T ALLOWED =		.166	25 TOTAL	2760	U_T ACTUAL =		.166

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

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WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY	WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
1 AIR FILM OUTSIDE			13 GROSS WALL				
2 OUTER SURFACE			14 WINDOW				
3 OUTER SHEATHING			15 DOOR				
4 FRAMING			16 OTHER (Specify)				
5 CAVITY a) INSULATION			17 OTHER (Specify)				
6 b) AIR SPACE			18 OPAQUE WALL	2)			
7 INSIDE SURFACE			19 FRAMING	3)	13)	5)	
8 AIR FILM INSIDE			20 CAVITY	4)	14)	6)	
9 OTHER a)			21 U_o = TOTAL LINES 19, 20				
10 (Specify) b)							
11 R_T = TOTAL LINES 1-10							
12 U = 1/R TOTAL							

U₀ CALCULATIONS FOR FLOORS AND ROOF-CEILING

FLOOR HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.92	.92
2 OUTER SURFACE	—	—
3 OUTER SHEATHING	.62	.62
4 FRAMING	11.88	
5 CAVITY a) INSULATION		19.00
6 b) AIR SPACE		—
7 INSIDE SURFACE	2.08	2.08
8 AIR FILM INSIDE	.92	.92
9 OTHER a)	—	—
10 (Specify) b)	—	—
11 R _T = TOTAL LINES 1-10	16.42	23.54
12 U = 1/R TOTAL	.061	.042

FLOOR HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS FLOOR	900			
14 OTHER (Specify)	—	—	—	—
15 OTHER (Specify)	—	—	—	—
16 OTHER (Specify)	—	—	—	—
17 OTHER (Specify)	—	—	—	—
18 OPAQUE FLOOR	2) 900			
19 FRAMING	3) 90	.10	5) .061	.006
20 CAVITY	4) 810	.90	6) .042	.038
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.044

JOIST OR RAFTER SPACING	12"	16"	24"
RATIO	0.13	0.10	0.06

TABLE A - JOIST OR RAFTER FRAMING RATIO

ROOF - CEILING HEATING	R VALUES FRAMING	R VALUES CAVITY
1 AIR FILM OUTSIDE	.17	.17
2 OUTER SURFACE	—	—
3 OUTER SHEATHING	—	—
4 FRAMING	9.38	
5 CAVITY a) INSULATION		19.00
6 b) AIR SPACE		—
7 INSIDE SURFACE	.45	.45
8 AIR FILM INSIDE	.61	.61
9) OTHER a)	—	—
10 (Specify) b)	—	—
11 R _T = TOTAL LINES 1-10	10.61	20.23
12 U = 1/R TOTAL	.094	.049

ROOF - CEILING HEATING	AREA (s.f.)	GROSS AREA RATIO 1)	U VALUE	UxRATIO
13 GROSS ROOF-CEIL.	900			
14 SKYLIGHT	—	—	—	—
15 ROOF SCUPPER	—	—	—	—
16 OTHER (Specify)	—	—	—	—
17 OTHER (Specify)	—	—	—	—
18 OPAQUE ROOF-CEIL.	2) 900			
19 FRAMING	3) 90	.10	5) .094	.009
20 CAVITY	4) 810	.90	6) .049	.044
21 U ₀ = TOTAL LINES 14, 15, 16, 17, 19, 20				.053

COMBINING COMPONENTS

U ACTUAL ≤ U ALLOWED

ALLOWED	AREA	GROSS AREA RATIO 7)	U VALUE ALLOWED 8)	UxRATIO	ACTUAL	AREA	GROSS AREA RATIO 7)	U VALUE ACTUAL 8)	UxRATIO
22 WALL	960	.348	.20	.070	22 WALL	960	.348	.168 ⁹⁾	.058
23 FLOOR	900	.326	.08	.026	23 FLOOR	900	.326	.044 ¹⁰⁾	.014
24 CEILING- ROOF	900	.326	.05	.016	24 CEILING- ROOF	900	.326	.053 ¹¹⁾	.017
25 TOTAL	2760	U _T ALLOWED =		.112	25 TOTAL	2760	U _T ACTUAL =		.089

TABLE A - STUD FRAMING RATIO

STUD SPACING	12"	16"	24"
RATIO	0.17	0.15	0.10

TABLE B - CAVITY RATIO

STUD SPACING	12"	16"	24"
RATIO	.83	.85	.90

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WALLS COOLING	R VALUES FRAMING	R VALUES CAVITY	WALLS COOLING	AREA (s.f.)	OPAQUE 1) AREA RATIO	U VALUE	UxRATIO
1 AIR FILM OUTSIDE			13 GROSS WALL				
2 OUTER SURFACE			14 WINDOW				
3 OUTER SHEATHING			15 DOOR				
4 FRAMING			16 OTHER (Specify)				
5 CAVITY a) INSULATION			17 OTHER (Specify)				
6 b) AIR SPACE			18 OPAQUE WALL	2)			
7 INSIDE SURFACE			19 FRAMING	3)	13)	5)	
8 AIR FILM INSIDE			20 CAVITY	4)	14)	6)	
9 OTHER a)			21 U ₀ = TOTAL LINES 19, 20				
10 (Specify) b)							
11 R _T = TOTAL LINES 1-10							
12 U = 1/R TOTAL							