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Control by Code of Energy Usage in Building Systems

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Abstract

Space heating, air-conditioning and refrigeration accounts for over 30% of the total energy use in the U.S. ASHRAE Standard 90P, ENERGY CONSERVATION IN NEW BUILDING DESIGN, sets forth requirements for the design of all types of new buildings, covering their exterior envelopes and selection of their HVAC, service water heating, electrical distribution and illuminating systems and equipment for efficient use of energy. This paper reviews the current status, content, and implications of the proposed energy standard and reports some experience with its use.

1. INTRODUCTION

Americans use over 72 quadrillion Btu's of energy each year. Heating, air conditioning, and refrigeration for residential and commercial consumers in this country use about 26.7% of this energy. This includes approximately 18% for space heating, 4% for water heating, 2.2% for refrigeration and 2.5% for air conditioning. This is exclusive of the energy utilized in industrial heating, cooling, and refrigeration requirements. While it is true that the American people use more energy than any other nation, it is also true that this is what makes the United States the most industrialized and prosperous country in the world. Unfortunately, a large amount of the energy is wasted. The National Bureau of Standards estimates that approximately 40% of the energy used for heating is wasted while energy requirements for cooling can be reduced 30% with little sacrifice to comfort. Energy conservation must become a part of construction technology. There should be an energy standard which will eliminate the wasting of our precious energy resources, but which is workable, allows for creative engineering and has adequate technical review in its creation.

In 1973, the National Conference of States on Building Codes and Standards (NCSBCS), the organization of state building code officials, requested from the National Bureau of Standards (NBS) guidelines on energy conservation which could be incorporated into the various state building codes. In turn, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) was requested by NBS to sponsor the standard on an interim basis and later as a standard of the American National Standards Institute (ANSI) through its consensus procedures.

NCSBCS was wise to seek informed answers to the problem which confronted it as a result of the energy crisis. Too often, in the past, professional and technical organizations have not been asked to be involved or even consulted. There have been and are proposed many standards governing heating and air conditioning which are either being prepared or being proposed with good intentions, but with far less than a full understanding of the full impact of these. Proposals such as shutting down all air conditioning systems whenever the ambient outside temperature is below 75°F show lack of understanding of the technology involved, since they ignore the efficiency and comfort of the building occupants.

In February 1974, NBS presented its finished document[1] to ASHRAE in an effort to obtain broad-based, professional support and endorsement. Such was not forthcoming; however, ASHRAE did accept the responsibility of either re-writing the NBS proposal or providing an alternative standard which ASHRAE membership would support. In late June, Proposed Standard 90P[2] was submitted to public review. The review was quite extensive[3-6] The result has occasioned major revision of 90P and its re-issuance for another round of public inspection. The current version of the proposed ASHRAE Standard 90P, ENERGY CONSERVATION IN NEW BUILDING DESIGN, sets forth requirements for the design of all types of new buildings, covering their exterior envelopes and selection of their HVAC, service water heating, electrical distribution and illuminating systems and equipment for efficient use of energy.

ASHRAE has not been the only source for suggested energy standards or legislation[7,8]. National focus however, appears to reside with the ASHRAE effort. In 1973 only two states had passed legislation regulating energy in construction. Today, however, 38 states have ongoing activity related to energy conservation for buildings. At the present time seven states are considering their own energy document for implementation within their state. However, they indicated that if the ASHRAE document becomes available soon, they could consider changing from a state-developed document to the ASHRAE document. The remaining states have stated that they will wait for the ASHRAE energy standard if it is forthcoming within a reasonable length of time. It will not be long until all 50 states have legislation regulating energy in the construction field in new and existing buildings. It becomes extremely important that a national document be developed, adopted, and implemented to achieve a uniform approach to energy conservation.

2. PRESCRIPTIVE VERSUS PERFORMANCE CODES

If there is widespread realization of an energy problem, why the delay in executing a standard? One reason is the existence of two conflicting theories on how one conserves energy.

One group advocates a prescriptive type of code under which all building components influencing energy consumption would be individually specified. For example: "Glass areas shall constitute no more than xx% of outside wall areas." Prescriptive codes have advantages. They are familiar to designers, specifiers and building inspectors. They provide a go-and-no-go gauge on which even relatively inexperienced men can base approvals. However, prescriptive codes have serious drawbacks and could have a negative impact on the industry and on growth within the industry. A typical example would be a requirement for a specific thickness of insulation, which would eliminate the economic advantages of developing more effective insulating materials.

The second group favors an overall energy consumption budget for buildings expressed in Btu/sq.ft. of floor area/yr. Obviously, no single budget figure would be applicable to all types of buildings. These budgets would vary according to geographic area and conditions of occupancy and use. This group argues that the prescriptive approach to this particular problem rests on a dangerous assumption, to wit: "Maximum energy conservation will result from proper specification of each component." But, this group argues, when the HVAC, mechanical, lighting systems and the building shell, each with its own set of governing criteria, are considered to be unrelated, trade-offs between those segments would be disallowed. Without such trade-offs, maximum reduction of energy consumption may be impossible to achieve.

A discussion of as complicated a subject as trade-offs between one building system (e.g. lighting) and another (e.g. the building shell) is apt to be cloudy unless it is illustrated with specific examples.

Considering the U value of glass versus the U value of insulated masonry walls, would not the total energy consumption of the building have necessarily been lower if the glass area had been reduced? A study of energy consumption in 13 prestigious Chicago buildings, published in the September, 1974 issue of ARCHITECTURE PLUS, provides some clue to the answer.

These buildings average an annual energy usage of 264,000 Btu/sq.ft./yr. The highest energy user was found to be an older concrete building with clear glass area less than 50% of wall area, using 330,000 Btu/sq.ft./yr. The lowest energy user was the IBM Building, with reflective glass area more than 75% of wall area, using 141,000 Btu/sq.ft./yr.

The facts cast doubt on the simplistic solution of arbitrarily restricting glass area. Energy budget design quantifies and evaluates both mechanical and non-mechanical building systems in terms of their impact on overall annual fuel consumption. The energy budget provides design freedom in the case of new buildings, operating energy levels for upgrading and renovation of existing buildings, and automatic provision for the incorporation of new technologies and energy sources without necessitating standards revision.

The objection most often raised to adopting standards or legislation which include energy budgets, is a lack of hard data establishing realistic consumption levels. If the national objective is to have buildings of the future consume xx% less energy than existing buildings, proponents of the energy budget approach urge that the logical way to proceed is to find out from what base figure the reduction is to be made. There have been spot checks on energy consumption in existing buildings, but what is needed is a meaningful national data bank on a great number of buildings by location, type, and conditions of occupancy and use. The center for Building Technology, National Bureau of Standards, is now working toward that objective at the behest of the Federal Energy Administration. If it is decided that, in new buildings, a reduction in energy consumption of xx% is both attainable and dictated by the energy situation, an annual overall energy budget for each new building may be derived from such a data bank. The proponents of energy budget codes feel that each team of architects and engineers should be permitted to design within the limits of their assigned budget in any way their ingenuity and capability suggests. The national objective of energy conservation will have been served.

ASHRAE Standard 90-P, in its present form, attempts to mediate both approaches. The concluding chapters allow the designer some flexibility in an otherwise restrictive standard. The code would require all new residential, commercial, and institutional buildings to conform to the numerical values specified, for the structure and the mechanical systems, unless the designer has some better ideas. He will be permitted to deviate from the standards if he can show that the annual energy consumption will be no greater than if he had followed the standards. To prove this he must draw up a full-year energy usage analysis for the structure which conforms to the standard, and another analysis for his proposed deviations.

The second major reason for delay in establishing the standard, and probably the most troublesome difference of opinion to face ASHRAE, has been the "source energy" question. ASHRAE in developing 90P side-steps the issue on the grounds that the best expertice in the power generation field exists outside ASHRAE and that the source energy problem is thus best addressed by others. The standard "takes into account energy losses and efficiencies connected with new buildings *within the boundary of a contiguous area* under one ownership. It does not take into consideration the energy used in the extraction, processing and delivery to the building site of the basic fuels or secondary forms of energy." Hence, the current version of Standard 90 limits the subject of energy conservation to the "building line"; that is, it treats all energy sources without reference to the energy required to deliver them to the building.

3. CURRENT STATUS OF ASHRAE STANDARD 90

ASHRAE Standard 90-75 consisting of the following eleven sections was approved by the society's board of directors on August 11, 1975 and is now an official ASHRAE Standard:

1.0 PURPOSE
2.0 SCOPE
3.0 DEFINITIONS
4.0 EXTERIOR ENVELOPE
5.0 HVAC SYSTEMS
6.0 HVAC EQUIPMENT
7.0 SERVICE WATER HEATING
8.0 ELECTRICAL DISTRIBUTION SYSTEMS
9.0 LIGHTING POWER BUDGET DETERMINATION PROCEDURE
10.0 ENERGY REQUIREMENTS FOR BUILDING DESIGNS BASED ON SYSTEMS ANALYSIS
11.0 REQUIREMENTS FOR BUILDING UTILIZING SOLAR, WIND OR NON-DEPLETING ENERGY SOURCES

However, responding to pressure from groups condemning the building line approach, a special ASHRAE Presidential Committee was appointed to deal with the source energy question. This committee has recommended the addition of a twelfth section on source energy, informally called "RUF-RIF." The purpose of Section 12, ANNUAL FUEL AND ENERGY RESOURCE DETERMINATION, is "to provide a method for reporting the calculated annual burden that a proposed building would place on available fuel and energy resources." The major contents of this proposed section are: (1) a requirement that a report be made on the impact of the building on the nation's energy sources, (2) a table of Resource Utilization Factors (RUF) which gives losses and energy burdens involved in processing, transporting, converting and delivering various forms of energy to a building, and (3) the concept of Resource Impact Factors (RIF) to account for the relative desirability of using one fuel or energy resource over another in a particular location. ASHRAE would not provide RIF numbers. Section 12 was published in the July issue of the ASHRAE Journal for open review and will probably not be finalized until sometime in 1976.

There are no enforcement provisions in ASHRAE Standard 90-75. This document contains a codified list of design recommendations which can be adopted by state and local building authorities, and enforcement would be at those levels, where it is incorporated into law.

4. EXAMPLE OF EFFECT OF STANDARD 90 ON RESIDENTIAL ENERGY REQUIREMENTS

In order to roughly assess the degree of change in building construction and energy usage for compliance with the requirements of 90P, load and energy calculations consistent with ASHRAE procedures and using the AXCESS Energy Analysis Program were made on a relatively typical residence (patterned after an actual house). Details of the basic residential structure are given as Figure 1.

Excerpts from the applicable sections of Standard 90P are as follows:

4.2.3 For estimating heat loss or gain through the exterior envelope of the building the following design temperatures shall apply:

	Indoor	Outdoor
Winter	70F	97½%
Summer	80F	2½%

4.3.1.1 Equation 1 shall be used to determine acceptable combinations of wall, window and door areas, and thermal properties to meet the requirements of Table 1 ...

Equation 1

$$U_o = \frac{U_{wall} A_{wall} + U_{window} A_{window} + U_{door} A_{door}}{A_o}$$

Table 1

ONE, TWO AND MULTI-FAMILY RESIDENTIAL LOW RISE

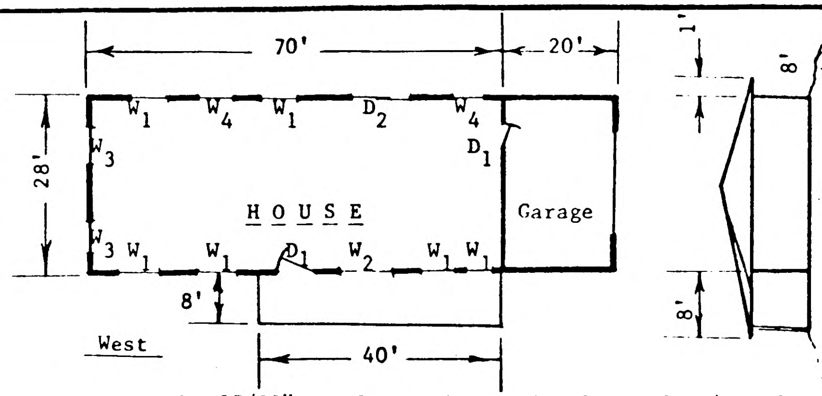
Heating Degree Days	Max.-U_o-Walls Btu/hr ft^2 F
⋮	⋮
5000	0.23
⋮	⋮

4.3.2 The thermal transmittance value for the roof/ceiling shall not exceed a value of $U_o = 0.05$ Btu/hr ft^2 F.

5.3.2.4 Infiltration

Unless specifically calculated otherwise, heating and cooling design load

BASIC PLAN:



Wall Construction: Face Brick, 25/32" insulating board sheathing, 2 x 4 studs on 16" centers, 3/8" gypsum board interior.

Ceiling: 2 x 6 ceiling joists, 16" oc, no flooring above, 3/8" gypsum board ceiling.

Roof: Asphalt shingles on solid wood sheathing, 2 x 6 rafters, no insulation between rafters, no ceiling applied to rafters, 1:4 pitch, 1 ft overhang on eaves, no overhang on gables.

Full basement: Heated, 10" concrete walls, all below grade, 4" concrete floor over 4" gravel.

One fireplace in living room on first floor.

Garage: Attached but unheated.

Windows: W_1 - 3' x 5' single glazed, double hung wood sash, weather stripped with stormwindow
W_2 - 10' x 5 1/2' picture window, double glazed, 1/2" air space
W_3 - 5' x 3' wood sash casement, double glazed, 1/2" air space
W_4 - 3' x 3' wood sash casement, double glazed, 1/2" air space

Doors: D_1 - 3'0" x 6'8", 1 3/4" solid with glass storm door
D_2 - Sliding patio glass door, two section, each 3' x 6'8", double glazed, 1/2" air space, aluminum frame

FIGURE 1 - BASIC PLAN FOR RESIDENTIAL TEST BUILDING

determinations for the entire structure shall include infiltration at the rate of no more than 0.7 air changes per hour for one and two-family dwellings..

5.4.2 Humidity Control

If an HVAC system is equipped with a means for adding moisture, to maintain specific selected relative humidities in spaces or zones, an automatic, space-humidity control device shall be provided. This device shall be capable of being set to prevent new energy from being used to produce space relative humidity above 20 percent RH.

In relation to the basic residential structure of Figure 1, the 90P requirements for insulation would correspond to approximately 7 inches of glass-fiber ceiling insulation but only 1/3 inch glass-fiber wall insulation due to the use of double glazed or storm windows and insulating sheathing.

The results of the load analysis are shown in Table 1 and indicate that compliance with 90P would result in considerable decrease in both furnace and air-conditioner *size* from that required for a poorly insulated residence. On the other hand, the results also show that with readily available and relatively inexpensive insulation (R = 11 for walls and R = 11 or 23 for ceilings) it is possible to better the 90P requirements.

The results shown in Table II are more significant as they reflect the *energy requirements* of the residential heating and cooling systems. Again, there is considerable savings when complying with 90P over a poorly insulated structure and yet it is very possible to do even better with standard materials on the market. Energy usage for a residence constructed in accordance with 90P would be cut almost in half for heating and by one-third for cooling compared with an uninsulated and non-weatherstripped structure. Heating and cooling energy requirements could be cut additional 17% and 5%, respectively, if nominal "full" insulation

TABLE I - EFFECT OF CONSTRUCTION ON RESIDENTIAL DESIGN LOADS		
CONSTRUCTION	H E A T I N G Design Load, Btuh	C O O L I N G Design Load, Btuh
ASHRAE Standard 90P (Base)	42,000	34,000
0 Ceiling Insulation 0 Wall Insulation 1.5 AC/hr Infiltration	88,000	59,000
0 Ceiling Insulation 0 Wall Insulation 0.7 AC/hr Infiltration	72,000	52,000
0 Ceiling Insulation 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	60,000	48,000
2" Ceiling Insulation (R=7) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	43,000	36,000
4" Ceiling Insulation (R=11) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	41,000	34,000
7" Ceiling Insulation (R=23) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	37,000	31,000
DESIGN CONDITIONS Location: St. Louis, Mo. Outdoor: WINTER; 8°F db (97½% value) SUMMER; 95°F db, 78 F wb (2½% values) Indoor: WINTER; 70°F db, 20% relative humidity SUMMER; 78°F db, 65% relative humidity		

were used in the walls.

ASHRAE Standard 90 "does *not* incorporate specific procedures for the *operation,* maintenance and use of buildings." Thus, although the system is designed for indoor temperatures of 70°F in winter and 78°F in summer, the thermostat could still be set at other values. Since the outdoor design values (97½% and 2½%) are equalled or exceeded only 129 hours during the year, a system sized in accordance with 90P would be able to maintain 75°F an estimated 90+% of the time. Table III presents a comparison of the fuel requirements for heating for thermostat settings of 70°F and 75°F. For the insulated cases shown, the averate savings in fuel is about 2½% for each degree the thermostat is lowered. Table IV gives the effects of thermostat settings of 78°F and 75°F on the cooling energy requirements. For an insulated residence, the average energy savings for cooling is about 5 percent for each degree increase in thermostat setting.

5. CONCLUSIONS

In the time span of a few years, the majority of states will probably have energy conservation laws relating to building construction. It is imperative that this legislation be based on more than just good intentions. What is needed is an energy

TABLE II - EFFECT OF CONSTRUCTION ON RESIDENTIAL ENERGY REQUIREMENTS				
CONSTRUCTION	HEATING		COOLING	
	Gallons	% Change	Kw-hrs	% Change
ASHRAE Standard 90P (Base)	759	0	5424	0
0 Ceiling Insulation 0 Wall Insulation 1.5 AC/hr Infiltration	1487	+96	7232	+33
0 Ceiling Insulation 0 Wall Insulation 0.7 AC/hr Infiltration	1203	+58	7071	+30
0 Ceiling Insulation 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	1010	+33	6617	+22
2" Ceiling Insulation (R=7) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	747	-2	5566	+3
4" Ceiling Insulation (R=11) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	687	-9	5342	-2
7" Ceiling Insulation (R=23) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	628	-17	5126	-5

OPERATING CONDITIONS
Location: St. Louis, Mo.
Year: 1971 Hourly Weather Data
Indoor: WINTER; 70°F db, 20% rh
SUMMER; 78°F db
CAC-continuous fan operation

HEATING
#2 Fuel Oil: 139,000 Btu/gallon
80% seasonal efficiency

COOLING
EER=6.84 Btuh/watt
(exc. main blower)

standard which will eliminate the wasting of our precious energy resources, but which is workable and allows for creative engineering and architecture. ASHRAE Standard 90 does provide a set of criteria consistent with available technology and materials which will result in substantial energy savings without being unduly restrictive.

6. POSTSCRIPT

On October 20, 1975, after the above paper was presented, ASHRAE Standard 90-75 was officially released. Two changes over the 90P contents which affect the results shown in this paper are: (1) Indoor winter design conditions are now 72°F db and 30 percent maximum relative humidity; and (2) an infiltration limit of 0.7 AC/hr is not specifically required.

7. REFERENCES

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TABLE III - EFFECT OF THERMOSTAT SETTING ON ENERGY REQUIREMENTS (HEATING)

INDOOR TEMPERATURE / CONSTRUCTION	70°F		75°F	
	Gallons	% Change	Gallons	% Change
ASHRAE Standard 90P (Base)	759	0	873	+15
4" Ceiling Insulation (R=11) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	687	-9	786	+4
7" Ceiling Insulation (R=23) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	628	-17	715	-6

OPERATING CONDITIONS
Location: St. Louis, Mo.
Year: 1971 Hourly Weather Data
CAC-continuous fan operation

HEATING
#2 Fuel Oil: 139,000 Btu/gallon
80% seasonal efficiency

TABLE IV - EFFECT OF THERMOSTAT SETTING ON ENERGY REQUIREMENTS (COOLING)

INDOOR TEMPERATURE / CONSTRUCTION	78 F		75 F	
	Kw-hrs	% Change	Kw-hrs	% Change
ASHRAE Standard 90P (Base)	5424	0	6472	+19
4" Ceiling Insulation (R=11) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	5342	-2	6279	+16
7" Ceiling Insulation (R=23) 3½" Wall Insulation (R=11) 0.7 AC/hr Infiltration	5126	-5	5981	+10

OPERATING CONDITIONS
Location: St. Louis, Mo.
Year: 1971 Hourly Weather Data
CAC-continuous fan operation

COOLING
EER=6.84 Btuh/watt
(exc. main blower)

8. BIOGRAPHIES

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