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A Review of ASHRAE Standard 100: Energy Conservation in Existing Buildings

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A REVIEW OF ASHRAE STANDARD 100
ENERGY CONSERVATION IN EXISTING BUILDINGS

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Abstract

The ASHRAE 100 Series of Standards, Energy Conservation in Existing Buildings, has been through two open reviews and is presently being edited prior to publication. The draft standards are discussed in this paper and compared with ASHRAE Standard 90, Energy Conservation in New Building Design.

1. INTRODUCTION

In 1975, following two years of work and review, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), working with the Illuminating Society of North America (IES), published Standard 90-1975, Energy Conservation in New Building Design. This was the first comprehensive energy standard and has become the basis for several model energy codes and many state energy codes. It has also been adopted as a Standard of the American National Standards Institute (ANSI).

Presently ASHRAE Standard 100, Energy Conservation in Existing Buildings is being readied for issuance. Like Standard 90, it has been several years in the making and has undergone two open reviews. Because of its comprehensiveness, it will address virtually all types of structures in which energy is consumed (or more properly, degraded). Because existing buildings greatly outnumber new ones, Standard 100 could affect many more buildings than Standard 90.

2. THE 100 SERIES OF STANDARDS

Work on Standard 90 showed the difficulty in addressing all types of buildings in a single standard. Therefore, Standard 100 actually comprises six separate documents, designated as Standards 100.1 through 100.6. The categories are as follows:

100.1 Low Rise Residential
100.2 High Rise Residential
100.3 Commercial
100.4 Industrial
100.5 Institutional
100.6 Public Assembly

A look at the definitions of the categories in the Standards will make the distinctions clearer:

"Low Rise Residential buildings shall include all detached single-family and two-family dwellings including those with not more than five lodgers or boarders outside the family unit per family. Included also are mobile homes, triplexes, fourplexes, rowhouses, and other multiple-family dwellings not more than three stories in height exclusive of basement having complete kitchen and bath

facilities for each dwelling unit. Included also are all buildings that can be reasonably interpreted as being of this type, even if they are not specifically named in this Standard"

"High Rise Residential buildings shall include all multiple-family dwellings having more than three stories, exclusive of basements, and having complete kitchen and bath facilities for each dwelling unit, and having no more than five lodgers or boarders outside the family unit per family. Included, among others, are apartment buildings, condominiums, medium rise garden apartments, etc., where non-transient occupancy exists."

"Commercial buildings shall include all hotel and motel buildings, lodging houses, boarding houses and dormitory buildings arranged for the shelter and sleeping accommodations of one or more individuals excepting those classified as Institutional, Low Rise Residential or High Rise Residential. Complete kitchen and bath facilities may exist if the lodging is for vacational or other transient purposes as compared to residential purposes. Also included are all structures used for display and sales purposes involving stocks of goods, wares or merchandise incidental to such purposes and accessible to the public, including, among others, retail stores, shops, salesrooms and markets. It shall also include all structures used for the transaction of business, for rendering of professional services, or for other services that include stocks of goods, wares or merchandise in limited quantities incidental to office use or sample purposes including among others, offices, banks, civil administration activities (such as post offices and courthouses), radio and TV studios and stations, motor fuel service stations and similar establishments. Also included are assembly halls, restaurants, fast food concessions and cocktail and snack bars designed to contain less than fifty persons at capacity."

"Industrial buildings shall include all structures in which occupants and/or machines are engaged in fabricating, assembling or processing of products or materials, including, among others, factories, assembly plants, industrial laboratories, and all others used for industrial and manufacturing purposes. Also included are structures designed to house, among others, the production and distribution of electric, gas or steam power, telephone exchanges, rolling mills, and foundries. Also included are structures for the storage and warehousing of all materials and products not usually available for retail sale and requiring energy for environmental control."

"Institutional buildings shall include all structures used as church schools, schools, colleges, and for similar educational purposes. Also included are all research institutes and the testing and research laboratories incidental to their use and for educational purposes. Also included are all structures harboring people suffering limitations because of health or age for care or treatment including, among others, day nurseries, hospitals, sanitariums, clinics, infirmaries, orphanages, and homes for the aged and infirm. Also included are structures in which people are detained for penal or correctional purposes or in which the liberty of the occupants is restricted including, among others, jails, prisons, reformatories, and mental health institutions. Also included are structures used for prosecuting public or civic services and activities of an emergency nature including, among others, fire houses and police stations. Also included are museums, art galleries, libraries, and similar buildings."

"Public Assembly buildings shall include all buildings which are designed to be used as places of assembly for more than

fifty persons. Included are all churches, theatres, and other buildings used primarily for theatrical performances and exhibitions. Also included are structures used as dance halls, night clubs, and for similar purposes including those with food service. Also included are structures in which persons assemble for amusement, entertainment or recreation, and incidental motion picture, dramatic, theatrical or educational presentations, lectures or other events for similar purpose occur, including, among others, exhibition halls, lecture halls, restaurants, and recreational centers, fieldhouses, coliseums, and passenger terminals."

The Standards address in detail the issue of buildings with different sections falling under different Standards or one area being under several different Standards.

Excluded from the Standards are buildings with peak design rate of energy use of 1 w/ft^2 or less. Also excluded are buildings of designated historical value.

The target level of performance for all the 100 Standards is set by Standard 90; that is, the intent of Standards 100 is that the overall level of energy consumption for an existing building be not greater than for a new building of similar size, orientation, location and function which complies with the applicable provisions of Standard 90. Because Standards 100 are for existing buildings, they contain operating and maintenance provisions not in Standard 90, which is a design standard only.

3. REVIEW OF STANDARD 90

Since Standard 90 is referenced so many times in Standards 100, a brief review of it is appropriate. Following Sections 1-3, Purpose, Scope and Definitions, Sections 4 through 9 contain prescriptive standards on building components and systems. These first 9 sections have been separated from the following three and have just been updated and issued as ANSI/ASHRAE/IES 90A-1980. Sections 10 and 11 cover alternate compliance procedures. These are now ASHRAE/IES 90B-1975. Finally, Section 12, which addresses source energy, is now ASHRAE 90C-1977.

Section 4 of Standard 90 addresses the exterior envelope. Walls (including windows) are covered in two different manners, one for residential (called Type A) buildings, one for non-residential (called Type B) buildings. Type A specifies wall, floor and roof U values appropriate to the heating climate. Type B buildings are subject to separate heating and cooling criteria for wall, floor and roof performance and must meet the more stringent of the criteria.

The concept of overall thermal transfer value (OTTV) is used in this section to evaluate the effectiveness of walls in reducing cooling load. While the heating criteria simply require area weighted U values for walls and roofs with windows and skylights and for floors, the OTTV includes solar gains through walls and windows, along with appropriate structural lags. Unlike U values which have conductance units (BTU/hr ft^2 °F), OTTVs are energy rates (BTU/hr ft^2).

Section 4 also sets criteria for air leakage around windows and doors.

Section 5 deals with heating, ventilating and air-conditioning (HVAC) systems. Outdoor and indoor design conditions are specified and ventilation rates are referenced to ASHRAE/ANSI Standard 62-1973, Natural and Mechanical Ventilation. Other subjects within Section 5 include zoning, control setback and shutoff, systems with simultaneous heating and cooling, economizer cycle, shutoff of ventilation, transport energy, energy recovery, insulation of pipes and ducts, duct construction and balancing. Especially important provisions within the subsection on systems with simultaneous heating and cooling are that recovered energy may be used for reheat, but that if "new" energy is to be used, it is to be minimized in a reheat system by resetting the supply temperature from the zone requiring the coolest air. In a double duct or multizone

system, cold and hot decks are to be reset from the zones requiring the coolest and hottest air, respectively.

Section 6 is devoted to HVAC equipment and sets minimum performance ratings for heating and cooling equipment.

Section 7 covers Service Water Heating, dealing with standby and operating losses, measures to reduce consumption of hot water and swimming pool heaters.

Section 8, Energy Distribution Systems, calls for energy efficient design and also contains as Section 8.3:

> "In any multifamily dwelling the Energy Distribution System shall be designed so as to encourage tenant responsibility for energy conservation. Such system designs shall recognize the limitations imposed by state-of-art technologies."

The implication is to encourage submetering if practical.

Section 9 is the Lighting Power Budget Determination Procedure. The lighting designer is encouraged to provide sufficient lighting for the tasks at hand while keeping down the power required. Concepts such as localized lighting, high efficiency sources and fixtures, room reflectance, controls and limits on exterior lighting are covered.

Section 10, Energy Requirements for Building Design on Systems Analysis, outlines a performance compliance procedure in which the building being tested is compared with a building of equivalent size, function and energy-source which does comply with Sections 4-9. Computer analysis is implied but not mandated.

Section 11, Requirements for Buildings Utilizing Solar, Geothermal, Wind or Other Non-Depleting Energy Sources, states that energy derived from so-called non-depleting energy sources is excluded from the total energy chargable to a proposed alternative design. Thus a building which didn't comply with Sections 4-9 or even with Section 10 in terms of overall energy usage could be brought into compliance if sufficient amounts of the overall energy were derived from non-depletable sources. Structures under 20,000 square feet can be exempted from a full-year energy calculation if a professional engineer certifies that "the average annual input of such non-depletable sources, or the extent of such nocturnal cooling can reasonably be expected to meet the demands imposed by the proposed alternative design." Also "other commercial, institutional and industrial structures that derive over 50 percent of their annual thermal requirements (heating, cooling, service water heating) or over 30 percent of their annual total energy requirements from non-depletable sources shall be exempted from the necessity of comparing the proposed design to a standard design which follows the provisions of Sections 4 through 9. Documentation, provided by a registered engineer, verifying the percentage of annual energy use derived from such non-depletable sources shall be required..."

Section 12, Annual Fuel and Energy Resource Determination, attempts to address the source energy needed to serve the building. The most obvious application of this section addresses the fact that 2.5 to 3 units of source energy at a power plant are needed to produce 1 unit of electrical energy at the building boundary.

4. COMPLIANCE WITH STANDARDS 100

It is possible to satisfy the design requirements of any of the 100 Standards by compliance with Sections 4-9 of Standard 90; however, because the 100 Standards apply to existing buildings, operating and maintenance provisions also apply for all except 100.1, Low Rise Residential. Alternative design compliance methods for different Standards include demonstration of energy-use equivalence with a similar Standard 90 compliant structure; use of non-depletable energy sources for a significant portion of the requirement for the building; and a certification by a professional engineer that all economically feasible design modifications have been made.

There are detail differences between the Standards. In this section, the important provisions of each will be explored.

Standard 100.1 Low Rise Residential. Compliance is shown with this Standard when the existing performance either meets or exceeds the requirements of Standard 90 or when each of the energy conserving modifications in the Standard which results in an annual saving of 15% or more of the cost of the modification has been accomplished. Costs include design fees, labor and material costs and contractor overhead and profit. Sections 5-10 of this Standard parallel Sections 4-9 of Standard 90, with specific recommendations in each appropriate to residences and to existing buildings (that is, addressing common design and construction defects and also recommending operation and maintenance procedures). Appendices include energy management procedures for lighting and a lighting check list, citations from the literature on retrofitting, and listings of materials and products for retrofitting, of caulks and sealants, of appropriate standards, and finally a bibliography.

Standard 100.2 High Rise Residential. Compliance procedures are called out in considerably more detail than in 100.1. Again if the building complies with Sections 4-9 of Standard 90 or 5-10 of 100.2 and also meets the applicable operating and maintenance provisions of 100.2, it is in compliance. Alternatively if each economically justified change to bring the building into compliance as above is implemented, along with the operating and maintenance procedures, it complies. Yet another method calls for performing an energy audit, mathematically modeling the existing facility using information gained from the audit, and demonstrating that the calculated annual energy use is lower than that for a similar but hypothetical building which conforms with the minimum provisions of Sections 5-10 of 100.2. For a building which is modeled but does not show lower usage than the conforming hypothetical building, improvements are modeled until lower energy is demonstrated. Non-depletable energy sources can be used to bring a building into compliance. All the above are additionally subject to the operating and maintenance procedures of 100.2.

Economic justification for retrofit measures is tied to an estimate of annual savings of 10% or more of the installed cost (maximum 10 year payback), unless the building has a "demonstrated" life less than 10 years, in which case the maximum payback is half the estimated life.

In Standard 100.2, Sections 5-10 are similar to Sections 4-9 of Standard 90. In addition, Standard 100.2 has an operation and maintenance section, Appendix I, which covers check lists for the following:

1.0 Exterior Envelope
- 1.1 Personnel and service entrances
- 1.2 Air leakage and natural ventilation
- 1.3 Solar shading

2.0 HVAC Systems
- 2.1 Fans
- 2.2 Pumps
- 2.3 Motors
- 2.4 Air Handling Equipment
- 2.5 Refrigerant Circuit and Controls
- 2.6 Refrigerant Compressor
- 2.7 Air Cooled Condenser
- 2.8 Evaporative Condenser
- 2.9 Water-Cooled Condenser
- 2.10 Cooling Towers/Closed Circuit Coolers
- 2.11 Water Chiller Evaporator
- 2.12 Absorption Equipment
- 2.13 Self-Contained Units
- 2.14 Boilers
- 2.15 Boilers (Coal Fired)
- 2.16 Boilers (Electric)
- 2.17 Make-Up Air and Unit Heaters
- 2.18 Radiators, Convectors, Baseboard, and Finned-Tube Units
- 2.19 Electric Heating
- 2.20 Hot and Chilled Water Piping
- 2.21 Steam Piping System
- 2.22 Pneumatic Controls Air Compressor
- 2.23 Control Adjustment

3.0 HVAC Equipment
- 3.1 Air and Water Balancing
- 3.2 Separate Service Hot Water Supply System
- 3.3 Separate Supply and Exhaust Systems for Special Purposes
- 3.4 Equipment Insulation
- 3.5 Combustion and Refrigeration Equipment

4.0 Service Water Heating
- 4.1 Shut Down
- 4.2 Lines/Valves
- 4.3 Insulation
- 4.4 Burners
- 4.5 Heating Elements
- 4.6 Controls
- 4.7 System Condition

5.0 Electrical Distribution System

Standard 100.3 Commercial. Compliance procedures stated in 100.3 are virtually identical to those in 100.2:

(1) Comply with Sections 4-9 of Standard 90 directly or after retrofit, or

(2) perform an energy audit, mathematically model the building and compare with a mathematical model of a similar building which complies with Sections 4-9 of Standard 90. Lower usage before or after retrofit gives compliance, or

(3) use non-depletable or waste energy as in Section 11 of Standard 90.

All of the above require, in addition, meeting the operating and maintenance provisions of 100.3.

One unexplained provision for a building in (2) which does not comply is to "make significant change or changes in building use, operating schedule, etc." and recalculate usage.

The economic justification provision allows disregarding any modification with an annual saving less than 10% of the installed cost (maximum 10 year payback). Buildings with a "demonstrated" life less than 2 years are automatically exempt. For buildings with a "demonstrated" life, N, between 2 and 10 years, the payback is (1.2N-2) years.

Sections 5-10 of Standard 100.3 again parallel 4-9 of Standard 90. The sections are quite detailed and contain the operating and maintenance provisions as well as design requirements.

Standard 100.4 Industrial. This Standard is primarily directed at the envelope, HVAC and lighting systems, like the other Standards 100. This Standard does not address the energy used in manufacturing processes except to recommend that an audit be made of each process. Compliance is achieved in much the same manner as with 100.2 and 100.3, although the draft contains no economic justification criteria. One HVAC system recommendation not mentioned in 100.1-100.3 is to consider encouraging temperature stratification in cooling situations and to circulate to eliminate stratification in heating situations. Operating and maintenance procedures are incorporated into the various sections.

Standard 100.5 Institutional. Compliance procedures are similar to those of the other Standards. Sections 5-10 directly parallel 4-9 of Standard 90 but are more detailed and contain operating and maintenance provisions. Compliance can be achieved by one of the following methods:

(1) Satisfy Sections 4-9 of Standard 90 or 5-10 of 100.5, before or after retrofit, or

(2) perform an energy audit, mathematically model the building and compare it with a mathematical model of a similar compliant building; lower consumption before or after retrofit or after using non-depletable energy sources will comply, or

(3) follow the procedure of (2) but do only those retrofit items which will give "combined" annual savings of at least 20% of the "combined" installed cost (5 year payback). For buildings with "demonstrated" lives less than 10 years, the payback period should be less than half the remaining life.

Standard 100.6 Public Assembly. Compliance procedures are essentally the same as those of Standard 100.5 except that the economic justification is based on an annual savings of 25% of the installed cost (4 year payback) or a payback period of half the remaining life of a building with less than a 10 year life.

5. CONCLUSION

Even though the authors have stated "this Standard is not intended nor should it be construed to represent the most effective utilization of energy with the most economic method", the Standards should increase awareness of the energy management opportunities in existing buildings and should provide an impetus to energy code development.

6. BIOGRAPHY

Albert W. Black, III, is a Senior Engineer with Charles J. R. McClure and Associates, St. Louis, and is President of Mechanical Engineering Data Services, Inc. (MEDSI), a subsidiary of McClure and Associates. He received a BSME from Washington University in 1957, a MSE from Princeton University in 1959, and a Ph.D. from the University of Minnesota in 1966. He was Assistant Professor of Mechanical Engineering at Washington University from 1965 to 1970 and Associate Professor of Engineering Science at Parks College of St. Louis University from 1970 to 1974. He is a Professional Engineer registered in Missouri and Iowa.