THE IMPLEMENTATION AND EFFECTIVENESS OF AIR INFILTRATION STANDARDS IN BUILDINGS

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THE ROLE OF AIR INFILTRATION IN ENERGY CONSERVATION

JOHN P. MILLHONE

Director, Office of Building Energy Research and Development
U.S. Department of Energy
Room GF-231, 1000 Independence Ave., S.W.
Washington, D.C. 20585

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1. INTRODUCTION

The importance of the subject you will be discussing during the next few days can be dramatized by the kind of mathematics that gets attention here in Reno.

The United States spends about $500 billion dollars on energy. Buildings consume about 36% of this energy. Of this share, roughly half is used to heat and cool buildings. And one-third of this energy is used to condition infiltration and ventilation air. As a result, a reduction of infiltration and ventilation rates by a mere 1% would reduce annual U.S. energy costs by about 300 million dollars.

We're playing for high stakes here.

In my remarks, I'll describe how we're trying to save this energy. Infiltration and ventilation activities are an important part of the comprehensive energy conservation research policy of the U.S. Department of Energy. The starting point for this policy is an analysis of how energy is used in the nation's buildings. This begins with an examination of the buildings themselves.

2. U.S. BUILDING ENERGY USE

The United States has more than 81 million occupied residential buildings; 69% owner-occupied, 31% occupied by renters. Single-family residences constitute 69% of these residences; multi-family, 25%; and mobile homes, 6%.

The U.S. commercial building sector makes up 44.6 billion square feet of floor space. This is divided among different building types, the major ones being: office, 18.4%; retail, 17.2%; warehouse, 13.6%; education, 13.1%; and assembly, 11.3%.

We then consider how these buildings use energy. The residential sector uses 16 quads; the commercial sector, 10 quads (1 quad equals 10^{15} Btu). The primary uses in the residential sector are: space heating (47.7%), water heating (14.4%), and refrigerators and freezers (13.2%). The primary uses in the commercial sector are: space heating (44%), lighting (22.5%), air conditioning (21.1%), and water heating (10.1%).

This shows us where the Btu's are. But it's also useful to look at what has been happening to this energy consumption. Here, there's good news and there's bad news. Let's dispense with the

bad news first. Although progress has been made, the U.S. energy use is higher per capita than that of other IEA countries and we have a great deal more to do to use our energy efficiently.

The good news is that the United States has made enormous progress in controlling its once ravenous appetite for energy. Last year we used 45 fewer quads of energy than we would have if the pre-1972 trends had continued. A portion of this amount --19 quads--is due to a lower gross national product. The larger amount--26 quads--is due to energy conservation, defined as an increased level of energy efficiency. Twenty-six quads is a staggering amount--as much oil as all the other IEA nations use in a year...or as much as the power generated by 870 1000MW electrical plants.

The energy consumption in residential and commercial buildings contributed to this record. This energy use remained fairly stable during the past decade. It started the decade at 24.1 quads, rose slowly to peak at 26.1 quads in 1978, and has since declined to 25.5 quads in 1983. If it had continued at its pre-1972 trend, it would have passed 42 quads.

During this period, there have been some interesting shifts in the sources of energy. Natural gas use changed little. Petroleum use declined rapidly, almost by one-half. Electricity use increased significantly, rising from less than 50% to more than 60% of the energy used in buildings. (This is measuring electricity in terms of the Btu's of the generating fuels.)

The past trends are interesting, but it also is important to try to peer into the energy uses in the future. The energy end-use projections show some shifts by the year 2000.

Table 1 Energy End-Use Projections*
Residential and Commercial Buildings

	Residential Percentage		Commercial Percentage	
	1983	2000	1983	2000
Space Heating	45.0	41.3	39.8	34.7
Space Cooling	7.0	12.7	20.9	32.5
Lighting	7.5	5.7	27.4	20.2
Water Heating	14.2	17.0	2.0	2.7
Other	26.3	23.3	9.9	9.8
	100%	100%	100%	100%

* Year 2000 projections from Energy End-Use Model, Oak Ridge National Laboratory

The end-use projections show that space heating and cooling--the uses affected by infiltration and ventilation--are expected to be even more important in the year 2000 than they are today. Their share of residential energy use will increase from 52% to 54%. Their share of commercial energy use will increase even more,

from 60.7% to 67.2%. The reason for these increases is the increased energy use for space cooling, which is expected to more than offset a decline in the energy required for space heating.

I'm afraid that the numbers have been coming about as fast as they do at the green felt tables that some of us visited last night, but they make an important point. The R&D that you do on the infiltration and ventilation of buildings is extremely important to your countries and ours and they will be even more important in the future.

Next I would like to turn to DOE's strategy for conducting this research.

3. U.S. POLICY APPROACH

The clearest and most comprehensive statement of the U.S. conservation policy is contained in the latest National Energy Policy Plan submitted to Congress by DOE. Energy conservation is singled out for special emphasis in this latest plan, reflecting the personal interest of Secretary Donald P. Hodel.

The plan identifies three areas of energy programs and actions that are particularly important: conservation, research and development, and energy security.

The goal of the U.S. policy is to foster an adequate supply of energy at reasonable costs. Implicit in this goal is a balanced and mixed energy resource system--one which relies upon a number of energy resources, including fossil fuels, solar and other renewables, and energy conservation.

"Energy conservation," the policy states, "ought to be viewed by policymakers, producers, and consumers as a significantly important energy resource. That is, energy conservation should be seen as a set of actions that individuals and businesses can take that are cost-effective alternatives to new supply development. Energy conservation actions are often cheaper and easier to undertake, and they often make good business sense. It need not be viewed as an altruistic activity or as a sacrifice."[1]

Expanding on this theme, the policy states: "Conservation has shown itself to be a unique, economic, and highly flexible energy resource applicable to all energy technologies and fuel types. It is not limited by geography or indigenous natural resources, and it may offer significant environmental advantages. No other energy resource can be tailored to individual needs or employed in increments as effectively as conservation, and each additional increment results in immediate energy savings, thus promptly reducing costs and offering return on capital investment. In short, conservation actions in response to changing market incentives have a degree of flexibility unequaled by any other

energy resource option, and they will continue to be an important component of our energy resource choices made by consumers and businesses."

In the conservation area, the broad objectives of this national plan are put in place through the "Energy Conservation Multi-Year Plan, FY 1986-FY 1990." The plan assesses the R&D needs in each of the end-use sectors: buildings, transportation, industry, and systems research--a cross-cutting sector that includes energy storage, electric energy systems and basic energy conversion and utilization technologies.

In the plan, first priority is given to implementing the statutory responsibilities contained in U.S. laws. These include the development of guidelines and standards for the energy-efficiency of new residential and commercial buildings. The standards are to be voluntary for the private sector and mandatory for new Federal buildings.

The plan then then disaggregates each of the end use sectors into specific research areas. The building sector includes 38 research technologies. Examples are wall systems, infiltration and ventilation, and condensing combustion systems. Then the relative priority of these research areas are ranked according to seven major criteria. These criteria are:

o Contribution to the energy-related objectives in the national plan;

o Contribution to maintaining or enhancing U.S. leadership in technology and international trade;

o Contribution to national defense;

o Other societal benefits, including economic, environmental, scientific, health and safety;

o Federal costs, and the degree of private-sector cost sharing;

o The degree of risk associated with the cost of project failure, as compared to the net present value of anticipated benefits; and, importantly,

o The appropriateness of Federal involvement.

Each of the 38 building technologies is given a score, based upon its perceived contribution to these objectives.

In this priority setting, infiltration and ventilation research is ranked 21st, which may appear inconsistent with the importance I attributed it earlier. The explanation is that infiltration and ventilation research is also intertwined into other research activities. For example, pollution characterization, mitigation and control is ranked 7th.

The first priority is given to commercial building systems integration, which involves an analysis of how energy-efficient components can be integrated to optimize their peformance in real buildings. A similar activity involving residential buildings is ranked 8th. Research on the retrofit of existing buildings is ranked 5th. Fenestration materials, components, systems and performance is ranked 12th. Performance simulation through computer models is ranked 16th. Home energy rating systems is ranked 18th. Advanced concepts for commercial building HVAC systems is ranked 26th. Diagnostics is ranked 27th. Energy management control systems is ranked 29th. Field monitoring and monitoring is ranked 30th. Construction quality is ranked 33rd. As you can see, all of these research activities depend heavily on infiltration and ventilation research. I believe this pattern is important and want to return to it in my concluding remarks, but first I want to tell you about DOE's current activities.

4. CURRENT DOE ACTIVITIES

The lead laboratory for infiltration, ventilation, and indoor air quality research for DOE is the Lawrence Berkeley Laboratory in Berkeley, California. Current research efforts at LBL include the development of measurement techniques and models for infiltration, air leakage, and ventilation in buildings. A companion effort is devoted to identifying important indoor pollutants and characterizing the dependence of indoor pollutant concentrations on building factors related to energy use. Specific examples of current research objectives include:

- Development of techniques to understand indoor radon concentrations and building entry mechanisms;
- Development of energy-efficient techniques to control excess pollutant concentrations in buildings;
- Design efforts for a national indoor air quality survey;
- Development of new methods for measuring whole-house air leakage;
- Development of a multizone infiltration model; and
- Determination of the energy effects of natural ventilation and comfort requirements.

The Department also supports work at the Brookhaven National Laboratory on Long Island, New York; at the National Bureau of Standards at Gaithersburg, Maryland; and at Princeton University at Princeton, New Jersey.

At Brookhaven, research is being funded to apply the use of perflurocarbon tracers (PFT) to perform multizone air flow measurements in both mechanically and naturally ventilated buildings. The concentrations measured using this relatively

inexpensive passive sampling technique allow the determination of both air infiltration and exfiltration rates from each building zone and the air exchange rates among zones.

At the National Bureau of Standards, DOE is funding the development of test methods for evaluating the movement of air into and within large commercial buildings. The objectives of this research include determinating ventilation efficiencies in commercial buildings and their impact on building energy costs and indoor air quality.

At Princeton, the DOE-funded research is devoted, in part, to studying the relationship between pressurization testing for air leakage and tracer gas measurements of infiltration and the accuracy of models based upon these measurements to predict retrofit energy savings in single- and multi-family residences. This work includes the development of a constant concentration tracer gas device to measure multizone natural ventilation, which will be used in multi-chamber experiments.

5. FUTURE DIRECTION OF DOE ACTIVITIES

As we look into the future, I anticipate a continuing major emphasis on infiltration and ventilation R&D, although there probably will be some changes in focus for the U.S. program. These changes include:

- The attention will be less on infiltration and ventilation, if those areas are interpreted narrowly, and more on closely related subjects such as "whole" building performance, distribution losses in heating, ventilation and air conditioning (HVAC) systems, indoor air quality, and air movement within buildings.

- There will be a shift of emphasis from air movement in single-family residences to air movement in multi-family high-rise and mid-rise apartments, and commercial buildings.

- There will be a shift of emphasis from how to save heating energy in cold climates to how to save cooling energy in warm climates, with implications for related infiltration and ventilation research.

- There will be more emphasis on the retrofit of existing buildings and less on the design and construction of new buildings. This will have implications on infiltration and ventilation research, although there will be continuing support for the development of guidelines and manuals for new building designs.

- The research will involve the use of multiple tracer gases to increase our understanding of more complex air movement questions, such as infiltration and interzone air movements under dynamic weather and HVAC operating conditions.

- Increased attention will be given to technology transfer, which will require that research results are interpreted into handbooks and guidelines that practicing architects and engineers can use in the design and operation of real buildings.

6. CONCLUSION

These future directions suggest we are entering into a new phase of building energy research activities. In the past, we have focused on the energy features of the components of buildings--walls, fenestration, roofs, HVAC systems. Because of its generic nature, much of the research on infiltration and ventilation has escaped this segmented approach. During the past 10 years, we have made great advances in understanding how building components perform, although much work remains to be done.

Now that this component work is well engaged, the next phase of research needs to focus on a range of integrative studies that will show how this new knowledge can be used to design, build, and operate energy-miserly buildings that offer healthy, productive, and attractive environments for their occupants. The challenge to you researchers in the infiltration and ventilation fields will be to recast your research plans into the priorities of this next phase of building research.

REFERENCES

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