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U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Research and Innovation in the Building Regulatory Process

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Research and Innovation in the Building Regulatory Process

Proceedings of the Second
NBS/NCSBCS Joint Conference

Held in Bozeman, Montana on
September 20, 1977, in conjunction
with the Tenth Annual Meeting of the
National Conference of States on Building
Codes and Standards, Inc. (NCSBCS)

Patrick W. Cooke, Editor

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PREFACE

The building regulatory process in the United States is an extremely important extension of public policy since it is the prime vehicle for regulating safety and health in and around buildings. This process of regulating building construction and occupancy, however, is as diverse and dispersed as the industrial enterprise it is authorized to regulate in the public interest.

In order to stimulate a sustained effort in establishing the basis for a more systematic understanding of the building regulatory process and to further identify the relationship between regulation and technical innovation, the National Conference of States on Building Codes and Standards Inc. (NCSBCS) and the National Bureau of Standards collaborated in the joint sponsorship of this second national conference on research and innovation in the building regulatory process. The Conference was held on September 20, 1977, in conjunction with the Tenth Annual Meeting of NCSBCS in Bozeman, Montana. The first such Conference was conducted in 1976 in Providence, Rhode Island, and was reported on in NBS Special Publication 473*. The results of that event were well received by both the building community and the research community.

This document contains the twenty five papers presented at the various technical sessions held during the second national conference on research and innovation in the building regulatory process. The program for the conduct of the Conference corresponds to the Table of Contents of these Proceedings. It is hoped that occasions of this type will continue to inform and assist understanding and decision making in the regulatory area.

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*NBS Special Publication 473, "Research and Innovation in the Building Regulatory Process," available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Order No. SN003-003-01775-2, Price $6.00.

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NCSBCS Delegates

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Mr. John Wenning (Wisconsin)

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the National Academy of Code Administration)
Mr. Charles T. Mahaffey

Special recognition and appreciation are extended to Ms. Rita Whalen and Mrs. Mary Chaney of NBS for successfully coordinating the publication of these Proceedings.

CONTENTS

SI Conversion Units

The following list of selected conversion factors for the most frequently used quantities in building design and construction may be used.

	INTERNATIONAL [SI] UNIT	CUSTOMARY UNIT	APPROXIMATE OR EXACT CONVERSION*
LENGTH	meter (m)	foot (ft)	1 ft = 0.3048 m*
	millimeter (mm)	inch (in)	1 in = 25.4 mm*
AREA	square meter (m^2)	square yard (yd^2)	1 yd^2 = 0.8361 m^2
		square foot (ft^2)	1 ft^2 = 0.092 90 m^2
	square millimeter (mm^2)	square inch (in^2)	1 in^2 = 645.2 mm^2
VOLUME	cubic meter (m^3)	cubic yard (yd^3)	1 yd^3 = 0.7646 m^3
		cubic foot (ft^3)	1 ft^3 = 0.028 37 m^3
	cubic millimeter (mm^3)	cubic inch (in^3)	1 in^3 = 16 390 mm^3
CAPACITY	liter (L)	gallon (gal)	1 gal = 3.785 L
VELOCITY, SPEED	meter per second (m/s)	foot per second (ft/s)	1 ft/s = 0.3048 m/s*
	kilometer per hour (km/h)	mile per hour (mile/h or m.p.h.)	1 mile/h = 1.609 km/h
ACCELERATION	meter per second squared (m/s^2)	foot per second squared (ft/s^2)	1 ft/s^2 = 0.3048 m/s^2*
MASS	metric ton (t)	ton [2000 lb]	1 ton = 0.9702 t
	kilogram (kg)	pound (lb)	1 lb = 0.4536 kg
	gram (g)	ounce (oz)	1 oz = 28.35 g
DENSITY	metric ton per cubic meter (t/m^3)	ton per cubic yard (ton/yd^3)	1 ton/yd^3 = 1.187 t/m^3
	kilogram per cubic meter (kg/m^3)	pound per cubic foot (lb/ft^3)	1 lb/ft^3 = 16.02 kg/m^3
FORCE	kilonewton (kN)	ton-force (tonf)	1 tonf = 8.896 kN
		kip [1000 lbf]	1 kip = 4.448 kN
	newton (N)	pound-force (lbf)	1 lbf = 4.448 N
MOMENT OF FORCE, TORQUE	kilonewton meter (kN·m)	ton-force foot (tonf·ft)	1 tonf·ft = 2.712 kN·m
	newton meter (N·m)	pound-force inch (lbf·in)	1 lbf·in = 0.1130 N·m
PRESSURE, STRESS	megapascal (MPa)	ton-force per square inch ($tonf/in^2$)	1 $tonf/in^2$ = 13.79 MPa
	kilopascal (kPa)	ton-force per square foot ($tonf/ft^2$)	1 $tonf/ft^2$ = 95.76 kPa
		pound-force per square inch (lbf/in^2)	1 lbf/in^2 = 6.895 kPa
	pascal (Pa)	pound-force per square foot (lbf/ft^2)	1 lbf/ft^2 = 47.88 Pa
WORK, ENERGY, QUANTITY OF HEAT	kilojoule (kJ)	British thermal unit (Btu)	1 Btu = 1.055 kJ
	joule (J)	foot pound-force (ft·lbf)	1 ft·lbf = 1.356 J
COEFFICIENT OF HEAT TRANSFER [U-Value]	watt per square meter kelvin [$W/(m^2·K)$]	Btu per square foot hour degree Fahrenheit ($Btu/ft^2·h·°F$)	1 $Btu/ft^2·h·°F$ = 5.678 $W/(m^2·K)$
THERMAL CONDUCTIVITY [k-Value]	watt per meter kelvin [W/(m·K)]	Btu per foot hour degree Fahrenheit (Btu/ft·h·°F)	1 Btu/ft·h·°F = 1.731 W/(m·K)

NOTES:

(1) The above conversion factors are shown to four significant digits, where appropriate. The asterisk (*) denotes an exact conversion.

(2) Unprefixed SI units are underlined. [The kilogram, although prefixed, is an SI base unit]

(3) A more comprehensive listing of conversion factors is contained in Appendix A of NBS Technical Note 938 (pages 32 - 35).

(4) Additional conversion factors are shown in ANSI Z210.1 - 1976, "American National Standard for Metric Practice;" ASTM E380 - 76, or IEEE Std 268 - 1976.

ABSTRACT

The Second NBS/NCSBCS Joint Conference on Research and Innovation in the Building Regulatory Process was held in Bozeman, Montana on September 20, 1977. The proceedings contain the 25 papers presented at the eight technical sessions. The technical sessions addressed the following issues:

- Implementation of Solar and Energy Conservation Building Standards
- Issues in Building Regulations
- Considerations in the Development of Energy Conservation Building Standards
- Developing New Approaches for Formulating Building Regulations
- State Experiences in the Development of Energy Conservation Building Standards
- The Expanding Role of the Building Official
- Application and Impact of Building Energy Conservation Standards
- Administration of Building Regulations

THE NATIONAL SOLAR HEATING AND COOLING INFORMATION CENTER: MEETING THE CODE OFFICIALS' INFORMATION NEEDS

by

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Under the provisions of the Solar Heating and Cooling Demonstration Act of 1974, a National Solar Heating and Cooling Center was established in 1976 by the Department of Housing and Urban Development, in cooperation with the Department of Energy. It is the express mission of the Center to gather information about the practical feasibility of solar heating and cooling systems in homes and buildings and to disseminate this information to the general public and to specialized technical or professional groups including building code officials.

Recent developments are accelerating code officials' need for solar information. Solar homes are being built in all geographic areas of the country. Architects, engineers, designers and contractors are gaining solar experience or showing an interest in solar. In addition, many State legislatures are taking direct or indirect action in the solar area which will affect building codes. Some States include general or specific solar considerations in State building codes. Others are making solar familiar by requiring life-cycle cost estimates of competing forms of energy, including solar, in new or substantially renovated State buildings.

Key Words: Building regulations; data collection; demonstration program; dissemination; information needs; residential construction; solar energy; space heating; technology.

Good morning. My name is Gerald Mara and I am the governmental affairs specialist of the National Solar Heating and Cooling Information Center. Let me begin this presentation by saying a few words about the Center. The National Center is operated by the Franklin Institute Research Laboratories in Philadelphia for the U.S. Department of Housing and Urban Development in cooperation with the Department of Energy. The Center was set up in 1976 as part of the National Program for the Solar Heating and Cooling of Buildings. It is the Center's job to gather information about the practical feasibility of solar heating and cooling systems in homes and buildings, and to disseminate this information to the general public and to specialized or professional groups.

All of the specialized groups we serve have some particular connection with the building process. These include builders/developers of large housing tracts, construction or installation professionals, lenders who provide construction or home mortgage financing, manufacturers of solar products and policy makers, including legislators and code officials. We believe that this latter group is of great importance and it is the Center's ability to meet their (your) information needs that I am going to discuss today.

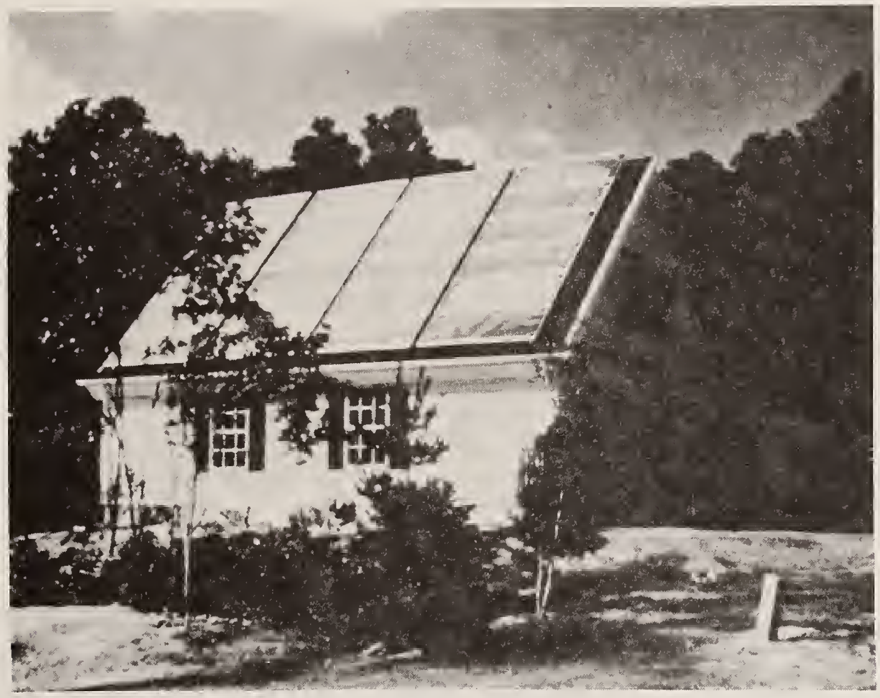
Before I say more about what the Center can provide to you, let me step back a bit and indicate briefly why code officials and other policy makers are finding it increasingly necessary to get information about solar energy.

The reason for their need is fairly simple - the increasing construction of solar homes in the United States. Now, when I say "solar home" in this context, I am referring chiefly to homes (or buildings) whose space and/or domestic water heat is provided more or less directly by solar energy. That is, I am not referring to the conversion of solar energy to electricity, but to the direct application of solar energy in buildings that is technically and economically feasible on a widespread scale today.

The application of solar technology for space and domestic water heating is certainly not new. Some domestic uses of solar have been utilized quite literally since the dawn of civilization. But, at least in this country, the use of solar energy for these purposes has certainly never been more widespread than it is today.

Today solar homes are being built in all geographic areas of the country. Let me show you some examples. These new homes with space and domestic water heating supplied by solar were built as a part of HUD's residential demonstration program. This next series of slides contains pictures of solar domestic hot water installations in northern climates. Most of these were solar retrofits or solar additions to existing buildings. (The pictures shown on page 3 illustrate typical installations of this type).

There are many reasons to believe that these structures constitute only the beginning of the use of solar in homes and buildings. The National Center estimates that right now there are between three and five thousand



"Examples of solar retrofits to existing buildings."

buildings in the U.S. with solar space and domestic water heating and there are many times that number with solar heated water only. As I mentioned earlier, the Center provides information to building professionals with solar interest and experience and this number is certainly growing rapidly. The fact is that most solar installations, particularly hot water retrofits, can be done by applying practices standard to existing building trades. It is getting easier to find a building professional who is willing and able to do a solar job.

Many State legislatures are also taking steps to encourage solar construction. Currently, 28 States offer some form of tax incentive, such as property or sales tax exemption or an income tax credit or deduction for a person who installs solar. What I have described to you is a series of private and public commitments to increasing the number of solar homes in this country.

Let us go back now to the slides of the solar homes you saw earlier. These structures had to comply with State or local building codes just like other kinds of conventional construction. Building code officials were asked to inspect these structures and to determine if they should be approved. Of course solar homes are not really that much different from conventional homes.

In many cases, particularly solar domestic hot water retrofits, solar will have relatively little impact on a home's overall design. Most of each solar home could probably be evaluated in the same way as conventionally heated buildings.

But did code officials have any difficulty in making judgments about the solar portion of these installations? Frankly, I do not know. If the HUD residential demonstration program is a yardstick, there seem to be very few problems surfacing in the evaluation of solar systems by State and local codes. But the fact is that few building codes contain any specifically solar provisions. Those few that do which we know of are in the so-called hurricane belt in the Gulf States and their provisions are designed mostly to ensure that collectors meet some sort of wind load requirement. What most building officials have to do now is apply certain existing provisions to solar components that are roughly analogous, for example skylights for active collectors.

This kind of procedure might get to be cumbersome as more solar homes are built. In addition, at least some of the State tax incentives I mentioned earlier provide that exemptible or creditable systems have to be approved by the State or local building department. So, I think it is obvious that code officials are going to need more information on solar applications.

That is where the Center comes in, at least in disseminating the information as it becomes available. Our job is to make sure that information that is available is provided to the appropriate user groups. Of course, the Center itself generates some information, including lists of State, local or municipal governmental actions that are important for solar. It also gathers information that is produced in other areas of the solar program (as well as through other means) and disseminates it as necessary.

Let me briefly mention some kinds of information being produced now which are of conceivable relevance to codes officials. Let us start with the demonstration projects I mentioned earlier. HUD and DOE currently administer a series of residential and non-residential solar demonstration projects, which are designed to furnish information on the technical performance of solar systems; solar's market appeal; and the relation of solar construction to existing building practices, including codes, zoning ordinances or obtaining home mortgage financing.

Gathering these data is essentially the job of the other participants in the program. The American Institute of Architects' Research Corporation and Dubin-Bloome Associates are currently evaluating technical data on the design and performance of the systems used.

The Real Estate Research Corporation is currently undertaking a series of surveys of those involved in the demonstration building process. These surveys also include gathering information from persons in the building process who chose not to become involved in solar construction, neither building, buying nor financing. The portion of these surveys relevant here is that which deals with codes officials' reactions to solar construction. Results from this portion of the survey research will help to indicate if and where problem areas exist in codes officials' evaluation of solar construction. Completed reports to date indicate relatively few problems encountered in the demonstration programs. Most of these seem due to codes officials' unfamiliarity with solar. But these problems have been found to be relatively easily solved.

Another series of products within the overall National Program for the Solar Heating and Cooling of Buildings are performance criteria for solar systems and minimum property standards for solar construction. Currently, these standards are being used to determine the acceptability of solar applications within the demonstration program. The Minimum Property Standards for solar space and domestic water heating systems can also be used now to determine eligibility for FHA mortgage guarantees.

In addition to using these standards <u>within</u> existing Federal programs, it is also thought that they can be of use in assisting the development of model codes that can be voluntarily adopted by existing codes' jurisdictions. The National Bureau of Standards (NBS) is cooperating closely with HUD and the Department of Energy to help develop some model solar codes.

Now there are the elements of the National Program which are probably of the most immediate relevance for codes officials. As I mentioned earlier, it is the Center's responsibility to ensure that this and similar information is disseminated to the appropriate audiences.

To accomplish this objective, the Center is engaged in two basic complementary activities, responding to the requests we receive and outreaching to important audiences or groups.

In the response mode, information is disseminated through the Center's telephone and mail operations. The telephone operation, a toll-free number set-up headquartered in Philadelphia, comprises seven incoming lines handled by about 20 information analysts. The lines are open five days a week, eleven hours a day. Currently, telephone inquiries number about 1,650 per week. Specific questions are answered either on the spot, or, if requiring research, through a special letter.

Everyone who calls the Center is sent a basic packet of information, data specific to the individual's request, and is placed on our mailing list, which now numbers about 140,000.

In addition to the general information package, the Center has available several specialized bibliographies and some specific information materials. We also have several engineers on hand to handle technical questions.

The other arm of the response mode is the mail operation, which handles written inquiries received at a central post office box number. This operation works in much the same manner as the telephone operation. Letter inquiries are currently coming in at a rate of about 1,700 per week.

The data base or source of information disseminated in the response mode is gathered and stored in several ways. It is gathered through some of the other parts of the program I mentioned and through research done by the staff at the Center.

As for storage, three major information files are currently on line in the Center's data bank. The Center has computerized listings of manufacturers of solar systems and components now numbering about 400; a file on public policy, listing approximately 600 pieces of governmental action, including the solar building codes provisions which currently exist; and a solar contacts file, composed of over 2,000 names of architects, builders, contractors, designers, engineers, installers and energy consultants. These individuals are either experienced or interested in solar energy systems for heating and cooling.

Each of these files is accessible in several ways. For instance, the file on governmental activity can be accessed through the governmental level involved, the kind of action (legislation or regulations), or the specific content of the action (tax incentive, solar access or building code).

In addition to this information from our own files, the Center has access to bibliographic data stored at ERDA/TIC; survey data at the National Bureau of Standards; and instrumented data from HUD and DOE demonstration projects stored at NASA. This data can be retrieved via terminals when required.

Several other areas of information are available at the Center in the form of manual look-up files. One of the major files in this category is the solar homes files, which contains pertinent information on over 1,500 solar homes which have been identified in the United States. While all of our information files are updated and expanded continuously, this file is expected to grow more rapidly. Information from this file is given out only when the home is available for public viewing. When the home is not open as such, only the builder's or architect's name is given out.

Other information files include an education file covering colleges, universities and institutions which offer courses in various aspects of solar energy. These include training courses for solar installers; a climatological file containing information on averaged solar radiation values, degree days, cloudy days and other climatic data; and demonstration project files with information on HUD and DOE financed homes and buildings. In this connection, the Center also disseminates information on how qualified groups may apply for the HUD and DOE grants.

To meet the needs of several professional groups, a file of information on testing, evaluation and standards for solar equipment and components is currently being established. It will contain data on organizations conducting testing, performing evaluations and developing standards, as well as information on approved testing/evaluation methods and adopted or recommended State, Federal and industry-wide standards. When model codes become available, the Center will maintain information on the applications they cover and where to obtain copies. The Center may even have copies to distribute as we do for other items such as the newest Intermediate Minimum Property Standards.

In addition, the Center has a speakers bureau with biographic information on about 275 knowledgeable individuals willing to address both lay and professional groups on the topic of solar energy.

In the outreach or market development mode, the Center functions to direct specific information gathered to those audiences it would benefit most in terms of the program's overall goal. This approach is aimed primarily at the building trade and professional categories... contractors, code officials, developers, architects, designers, planners, legislators, engineers, manufacturers, the financial community, and trade and professional associations.

The reason for directing the market development effort at these groups is to ensure that the professionals who will have to meet the demand for solar homes will have adequate information at their hands. The actual building of solar heated homes and buildings by these groups will generate an even greater interest and subsequent potential for the use of solar energy. After all, it serves no purpose to create an interest in the potential purchases, if there is nothing available on the market.

The means used in the market development approach include exhibits, specialized documents, films, slide presentations, speakers and educational packages. Some of these media currently exist and are in use, while others are in the planning or development stages.

To give you an idea of our present outreach effort, I will describe those media now in use. In constant use is a mobile solar display van, which travels throughout the country visiting large energy fairs, local groups such as schools and industrial plants, and shopping centers. Similar tools used are portable displays such as working models, backdrops, and simulation models; and large booths incorporating these models, which are sent staffed by the Center to various trade and professional conferences and exhibitions throughout the U.S.

Specialized documents are sometimes developed with a slant towards the group being addressed to accompany the exhibits.

While I have described what we are doing now, I would like to add a few words about our plans for the future. In addition to the speakers bureau used in the response mode, the Center is beginning to get involved in having its own staff arrange conferences, workshops and panel discussions within the framework of a larger conference. We have just recently completed the first of four regional solar conferences in Massachusetts, which we are co-sponsoring with the Massachusetts (State) Solar Action Office. One of the prime groups we address in these conferences are code officials.

The ultimate goal of the Center is to assist in bringing the targeted audiences of both the response and market development modes together. For example, we would like very much to bring about a dialogue between solar installers and codes officials. In this way, it is hoped the barriers which lie in the way of solar energy development can be abolished, and we, as a nation, can get on with the task of effectively utilizing the economically feasible and practical applications of solar energy to heat and cool our homes and buildings.

Thank you.

IMPLEMENTATION OF ENERGY CONSERVATION BUILDING STANDARDS

by

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Codes and Standards for Energy Conservation in Buildings are currently being written and adopted by States and model code organizations. These Standards are necessary as one of the means of buying the time required to develop alternate energy sources to continue our life style.

But codes and standards are only as effective as their implementation. Who will enforce them in new buildings and monitor them in existing buildings? The logical person for this immense task is the local building code enforcement officer, who in most cases has neither the training nor the background to deal with the terms and concepts involved. He must be upgraded if our nation is to gain time to become energy self-sufficient.

This paper deals with what the code enforcement officer has to know and how he can attain the required level of knowledge to competently enforce energy conservation standards.

Key Words: Buildings; building code official; education level; energy conservation; evaluations; upgrading, certification.

BACKGROUND

Many articles and papers have been written on the "Energy Crisis" and many solutions have been prepared. You are probably all familiar with the figures having heard them so often. The numbers may vary somewhat depending on the source but energy use in the United States is broken up into the following categories: Transportation 25.2%; Industrial 41.2%; Commercial 14.4%; Residential 19.2%. Commercial and residential building systems together consume over one-third of the energy used in the United States and over half of this (about 57%) is due to space heating and cooling. It has been estimated that energy conservation practices can probably save 15 to 25% in existing buildings and 35 to 50% in new construction over present rates. Because this is such a significant amount, it is important that steps be taken to assure these savings as soon as possible.

Energy conservation can be accomplished by designing energy saving new buildings and retrofitting old buildings. The design of new buildings is the province of the architect and engineer. To make certain the energy designs are effective, the conservation standards based on ASHRAE 90-75 must be followed. Retrofitting or remodeling is open to just about anyone from the student to the insulation salesman. While I am not aware of any standards for existing buildings, if we are to obtain all the advantages of energy saving possible by retrofitting, standards must be written. When these standards are written they will have to be implemented.

The thousands of cities across the country that have adopted building codes also have Building Code Enforcement Officers who are presently charged with evaluating new construction as well as upgrading and monitoring existing construction. I believe the local code enforcement officer to be the person to implement the Energy Conservation Standards for Buildings. He is also the logical person from whom the building owner can request information or obtain advice about energy conservation measures.

EDUCATION LEVEL REQUIRED

To be effective, the code officers must be competent to answer questions, make evaluations, and approve drawings and specifications. Energy consumption for heating, cooling, illumination, etc. is based on a series of abstract ideas. It is not measured like footings and wall thicknesses with a carpenter's rule. It cannot be read like ratings on a ventilating fan. You cannot see a BTU of heat. The code officer will be dealing with terms such as U-value, R, degree day, overall thermal transfer values, temperature differences, and many others that are probably not familiar to him.

If the code enforcement officer is to implement energy standards, he must become a para-professional by taking courses to upgrade his knowledge of buildings in this area. Such courses are presently being given by universities, model code groups, and government bodies. In Pennsylvania, courses sponsored jointly by the Pennsylvania State University and the Pennsylvania Department of Community Affairs are being offered to local officials at various locations throughout the State. The current courses are to acquaint the code officials with the terms and calculations used in designing and evaluating heat loss in buildings. Future courses are needed to cover other areas of energy use such as air-conditioning, illumination, water heating, and electrical distribution. These are the areas covered by ASHRAE Standard 90-75 which is the general guide for local energy standards. With proper background and knowledge, the requirements can be converted into inches of insulation, size of heating and cooling equipment, number and type of luminaires, etc. If the enforcement officer knows what U and R mean, he can compare the building values to required minimum R and maximum U values. These are specification standards in that they deal with specific maximums and minimums. This is the type of standard that is easiest to implement, for less background knowledge is required. The building code official can be rapidly equipped to handle this kind of number matching if no evaluation is involved.

But how does he handle performance standards? ASHRAE 90-75 and other standards, including BOCA Basic Energy Conservation Code, allow a system analysis approach to building design. This means the design can deviate from the specific design criteria of maximum and minimum values if the designer can demonstrate that the annual energy consumption will not be greater than it would be if he had followed the specific criteria. They also allow a credit for use of non-depleting energy sources such as wind, solar, and geo-thermal. How does the code official handle this? Does he accept the designer's figures, without checking, and approve the project?

How does the code officer handle calculations that are not covered in text book examples or that vary from the examples? Should he be able to calculate the U-value of a well-ventilated roof assembly? Should he know that insulation can cause problems with water vapor and condensation and requires vapor barriers or vapor retarders? How much should he know about permeability of construction materials?

Just how much technical knowledge should the building official have? In addition to being able to answer questions like those just stated, should he also be able to give advice to homeowners? I think he is the person to do this. Literature today is full of suggestions on how to save energy. But the homeowner needs someone to clarify the half-statements and make recommendations on which of the many methods are most practical or economical. The code enforcement officer should know what types of insulation are available, their relative effectiveness, and which one is best for use in a particular location. When the magazine articles say that air and wood are good insulators, he should know, that compared to fiberglass and polystyrene, they are actually poor insulators. If double insulating glass is recommended, the building official should have enough background in materials to warn the homeowner that inexpensive insulating glass may be poor quality, with putty and vinyl tape seal which will probably allow moist air to leak in between the glass panes and cause fogging and streaking.

EVALUATING ENERGY STATEMENTS

One catch-phrase is "insulate the attic to R30." This is the equivalent of about nine inches of fiberglass. This is fine for new buildings when the other areas of the building have equivalent R values, such as R19 for walls and floors. But what about existing buildings with little or no insulation? Is R30 in the attic the most efficient and economical application? Given the same type of construction throughout a typical one story ranch house loses over half its heat through the roof because there is more roof surface than wall surface. But the same floor area divided into two floors can reduce the proportions to 30% roof area and 70% wall area. Here the wall becomes more critical and the more effective location to insulate. Also, if only one part of the building is insulated, the other parts of the building become a larger percentage of the total remaining heat loss. Insulating the ceiling to R19 is easy and fairly economical. Increasing the insulation over 50% to R30 does not give the same economic return because you are now reducing a much smaller percentage of the total loss. For example, suppose the ceiling loss is 40% of the total. Insulating to R19 and adding no other insulation to the building could reduce this percentage to about 12% of the new total heat loss. Even doubling the ceiling insulation to R38 could do no more than cut the remaining ceiling loss in half, so increased insulation always has diminishing return unless the loss of all areas is reduced equally. A much more effective and profitable treatment is to insulate another high loss area; after the ceiling is about R19. Insulating the walls would be most effective as this is a large percentage of the building envelope but this is both difficult and expensive. Additional money would be better spent insulating the glass areas and reducing infiltration. This means storm windows, weatherstripping, and caulking. Storm windows will cut the loss through single glass about 50%.

The person who implements the code should be able to evaluate this kind of information rather than using the various rules of thumb blindly. This means a working knowledge of heat loss and heat gain theory. Acquiring this knowledge does not require a deep background in physics and math. It only requires an interest in the subject and an opportunity to learn. If the opportunity is presented through courses and the interest is sparked by requirements that the code official update himself, he can soon become expert enough to effectively implement the energy standards.

CERTIFICATION

In most cases, the present building official has neither the training nor the desire to evaluate a set of plans for energy requirements.

One reason for this lack of interest is that no one is requiring him to enforce legislation, for it does not exist in most areas. So the first step, if we are to reduce energy consumption in buildings, is to legislate standards for both new and existing buildings. The second step, then, is to upgrade the code officer so he has the knowledge and ability to evaluate buildings, answer requests and make decisions.

But merely offering courses is not enough. Penn State University has been offering courses to building officials for over six years and we estimate we are reaching less than 25% of the building officials in the State. If the local code official is to become qualified, he must be required to attend courses and be tested to monitor his learning. Required attendance does not guarantee learning, but it can if the code enforcement officers are to be certified and must attain a certain level of education. States must set up standards for certification and see that the local building officials meet these standards. If a barber needs a license to cut hair, the qualifications of a building code officer should certainly be certified.

CONCLUSION

If the local code enforcement officer is not qualified, who else can handle the job? State or Federal inspectors? They will also have to be trained and there are very few in relation to the number of buildings in this country. Architects and engineers? Their fees will discourage building owners from requesting their services except in the case of large and complex buildings. A possible solution is to hire an energy conservation specialist. Very few exist and their background and salary is at a much higher level than required for energy standards implementation. Why create a new bureaucracy when there are thousands of building code officials who are already familiar with construction and building code requirements? The only logical person to implement energy conservation building standards for most existing and new construction, if the standards are to be effective and truly save energy, is a well informed, conscientious code official, who has gained his knowledge through upgrading courses.

Specifically, this is how Energy Conservation Building Standards can be implemented:

1. Adopt building codes in communities and municipalities where none exist. When codes are adopted, code enforcement officers must be appointed.

2. Work to have Energy Conservation Standards for both new and existing buildings adopted if none exist. This can be on a State level or a model code which contains energy standards can be adopted locally. Only about one-half of the 2400 municipalities in Pennsylvania have building codes, or put another way, about one-third of the population of the State is not covered by any form of building code. Many States are probably in no better situation.

3. Require that code enforcement officials be certified to a certain level of expertise. Some states already have certification programs.

4. Attend seminars on the use and interpretation of Energy Standards. If no seminars exist in local areas, attend model code seminars or request the State government or State university to establish seminars. These seminars can be partially or fully funded by Federal or State monies.

5. Give advance notice of programs so municipalities can budget to send their code officers. Any costs not funded by Federal or State government should be financed by the municipality and the code officer should be given time off to attend programs.

6. Convince the persons responsible for sending code officers to seminars and workshops that upgrading is necessary and desirable. These people are generally borough, town and city managers, many of whom apparently see no need for this expense.

7. Suggest that the code enforcement officer take the initiative to:

   a. Obtain a copy of ASHRAE Standard 90-75.

   b. Read the Standard before attending seminars and list questions to be asked.

   c. Be sure to ask these questions if the seminar content does not cover them.

   d. Send for other energy booklets - build up a library.

   e. Keep current on new developments and products, such as water flow restrictors for shower heads and new fluorescent lamps that provide 97% the light output of existing 40 watt lamps but only use 35 watts of electrical power.

   f. Scan popular magazines for information and possible misinformation. Know what they suggest before the homeowner asks about it.

   g. Ask professionals - architects, engineers and energy specialists.

   h. Contact University extension offices and industry specialists as possible information sources.

Conservation will not solve our energy problems, but adoption of codes and standards for Energy Conservation in Buildings, and the effective implementation of these codes by the local building code official can help this nation gain time to become energy self-sufficient.

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A PROPOSAL FOR THE IMPLEMENTATION OF ENERGY CONSERVATION BUILDING STANDARDS AND CODES

by

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This paper deals with the mechanics of application, monitoring, and enforcement of State adopted energy conservation standards. It will be presumed that the administrative or legislative process has mandated an energy code for the respective State.

The issues to be examined are: (1) the complexity of the energy standard and its appropriateness for the (a) climatic factors of the respective State and (b) general level and magnitude of building construction within the State; (2) the process of educating and informing the various design professional groups who will integrate the code requirements into new and existing structures, on both an initial and continuing education basis; (3) the process of training and educating the enforcing agency's personnel and the factors to consider in first choosing the appropriate State agency; (4) the necessity for prescriptive and performance components of the code itself and enforcement implications; and (5) the impact of energy standards on (a) architectural design flexibility and (b) building costs, including "tradeoff" possibilities.

Key Words: Built environment; education and training; energy conservation; enforcement; legislation; promulgation; regulation; standards.

INTRODUCTION

Virtually everyone in this country is directly affected by the police power of the Constitution which, among other results, has led to the enactment of laws to protect the public and general welfare. Zoning laws, health, safety, housing, building, and fire codes are all examples.[1]

The innumerable forms of regulation stemming from Constitutional police power authority have all attempted to affect the quality of life with emphasis on the built environment. While the ostensible mainstay of this collection of governmental rule-making has been public benefit, the United States is now forced to take yet another step in the regulatory process, but this time, not to affect the quality of life, but to insure its very survival as we presently know it. The necessity for energy conservation is upon us, but not yet with us. This latter comment refers to the collective inability of this country to meaningfully and voluntarily confront what most people still believe is a non-existent crisis.[2]

Many States, however, have prepared or are preparing energy legislation and Federal regulation has already established minimum energy standards for Federal projects. The wisdom of such action may be characterized by some as further bureaucratic intervention. Architects and engineers in particular are less than elated over the prospect of another "code." However, the need for action is now no longer seriously questioned by those who are even moderately enlightened on the subject.[3] The task now is one of putting the regulatory language into effect, the subject to which this paper is addressed.

THE ENFORCEMENT PROCESS

While beginning at this point takes for granted that some body of rules concerning energy conservation has been put into effect at the State level, there can be little taken for granted as to the anticipated similarity which the energy codes of the several States will ultimately have.

Climatic differences alone will account for major dissimilarities, although after the winter just past, the people of Portland, Maine, and Atlanta, Georgia, are probably wondering just how much their respective climatological conditions really differ. The major division will separate those States which are users of energy for cooling from those States requiring energy for heating. Many States, of course, are substantial users of both and their task of implementation will not be made easier as a result.

Given, then, the differences that will evolve from State to State, the following observations are offered to code administrators and entities having responsibility for putting the code to work.

Initially, the selection of first echelon code enforcement personnel, or code specialists, must be a task carefully undertaken. Unlike the experienced carpenter or plumber who could readily adapt to the role of building inspector, or the fireman who could be groomed for the position of fire marshal lieutenant, the energy enforcement specialist must be technically competent in a manner unprecedented for code enforcement personnel. This requirement is necessitated by: (a) the technical nature of the subject matter and the permutations of computations that could derive from a proposed design for new buildings, and (b) the undeniable fact that flexibility and open-mindedness must characterize the relationship of design professional and enforcement specialist in solving energy problems, particularly where aesthetics and design discretion are involved.

Clearly, a code requirement is a law which requires compliance. As any lawyer will profess, however, there is the letter of the law and there is the spirit of the law. Sometimes strict adherence to the former will defeat the latter. If a code requires a limitation on the glass fenestration area of a given structure, it may be that the architect through orientation and manipulation of interior spaces and materials may well be able to affect a greater reduction in overall Btu loss and stay well within the building's energy budget, than would have been the outcome of following a rigid formula governing apparent building envelope.[4]

In as much as energy conservation in buildings has moved so rapidly into the forefront, great care should also be exercised in the strict enforcement of methods and materials codes.

A somewhat dramatic statement, vis-a-vis typically encountered code language, is made in the Model Code for Energy Conservation in New Building Construction, Interim Code,[5] section 102(b), subtitled "Alternate Materials - Method of Construction, Design or Insulating Systems." Paraphrased, that statement gives the enforcement specialist wide latitude in determining how energy conservation performance standards are met. This language underscores the necessity for competent, well qualified enforcement personnel and code administrators.

A word of caution to code enforcement administrators and supervisors is appropriate here. There is often a fine line between what is discretionary and what is arbitrary. Various doctrines of immunity have long protected municipalities and their employees from indiscriminate and reactionary decision making. The law has usually said that the "ballot box" is the solution to those problems. In this era of job security and protection in the public sector, this is an out-moded defense to that change. Most architects will attest that a fire marshal whose pronouncements are at best unpredictable and at worst mercurial is not only a source of consternation and frustration, but is sometimes a destructive and counter productive element in the process of making a building project feasible. This lack of predictability, and even worse, last minute change in requirements, can wreck a proposed project, degrade the client's estimate of the architect or engineer, and cause the expenditure of funds from which nothing results. Because the fire marshal is always cloaked in the robe of protector, a very emotionally charged situation can result if and when he feels it necessary to defend himself from a charge of capricious or arbitrary behavior.

While this example may seem to overstate the point, its purpose is to illustrate the power and authority inherent in the code enforcement official, particularly if the applicable code contains language such as that in section 102(b) of the Interim Code.

TRAINING ENFORCEMENT PERSONNEL

After the selection process, the next phase involves the "energy" education of those selected. For most State entities charged with the responsibility of energy management, whether they be the office of the state fire marshal, the office or department of energy, or some other, this matter of educating enforcement personnel will entail plowing new ground. Few, if any, of the selected enforcement personnel will have technical experience allowing them to immediately function in a competent manner. Depending on the particular energy code adopted, there may or may not be training programs and laboratories available in package form from the proponent of that code.[6] In some instances, programs on a national level may be available to instruct a nucleus of personnel who would then return to their home States and become instructors for others.[7] The point is, the instructional process prior to and concurrent with the implementation of the code is a crucial factor. With this in mind, there is at least one other approach to the education process worth examining.

Because both users and overseers of the code will be initially unfamiliar with the requirements of any energy code, there will exist a unique opportunity for simultaneous involvement of both groups in the educational process.[8] It is the opinion of this writer that great benefit can result from instructional sessions wherein architects, engineers, code administrators, and enforcement personnel are all participants, all discussing problems together, and all expressing their own points of view. The catalyst for this symposium of sorts will probably be the State energy entity, or at least the entity charged with enforcement, where there is a division. The sponsoring or coordinating body could, however, be the State professional societies for architects and engineers, the State colleges of architecture or engineering, if present, the continuing education components of any of those groups, or the enforcing agency itself. Those groups in the former catagories will probably be better suited to organize and coordinate these sessions, which may be offered as a series or as a single program repeated each year.

CONTINUING EDUCATION

The need for continuing education in the field of energy code enforcement is of special importance. It is a subject which the enforcement entity must evaluate on a regular basis to insure that: (a) design professionals are afforded the opportunity to become knowledgeable and proficient in using the code. This information should be imparted in a manner consistent with State developed policy for administering the code, as well as the requirements of the code itself; (b) users of the code are constantly informed of inevitable changes, adjustments, and "fine tuning" of the code, as it is put into practice; (c) elements of the code having ramifications concerning design latitude and material usage, especially from the architect's point of view, are thoroughly discussed and completely understood; and (d) there is an ongoing discussion of the cost factors associated with implementation of the code, such that embarrassing and sometimes fatal (to the continuation of the project) mistakes in cost estimating are avoided. As a final element of the initial and continuing education process, both enforcement personnel and design professionals must be afforded opportunities to actually inspect proper field installation procedures where new or different techniques are called for under the code. Classroom instruction will do much to ensure proper use of the code. The nexus between architect or engineer and contractor on the job site, however, remains crucial. Even the best set of drawings and specifications requires some interpretation. Selection, installation and placement of energy conserving materials and components will certainly follow suite, requiring some degree of on-site review, and, to use the term in standard American Institute of Architects (AIA) documents, "contract administration" by the design professional.

In the area of continuing education, and again because of the "newness" of an energy code, the necessity for a single informational State resource center seems imperative. Certainly design professionals will have cause to use this source often. Whether for preliminary discussion of a project in the mill or for requesting the performance criteria of materials under consideration, the need for information and the ability to discuss problems or proposals with an arm of the enforcing agency is clear. Under this same heading, the informational needs of builders, subcontractors, material suppliers and home owners should also be considered.

PUBLIC INFORMATION

The significance of the enforcing agency's role as a source of information for those in the construction process will increase with time. Indeed, it will be the enforcing agency which will of necessity have contact with and knowledge of every innovative and alternative energy device and system put into operation. Section four of the Interim Code refers to buildings in this category as utilizing non-depletable energy sources.

For purposes of cross-fertilization, it will be almost incumbent upon the enforcing agency to establish some means of recording and disseminating the means, methods, materials and data concerning non-depletable utilization. It is not unrealistic to expect some measure of speculation and experimentation in this area, and where this is so, the history of those systems must be given special documentation such that subsequent designs can benefit from the successful precedents. This information will also be of assistance in adjusting the language of the code to accommodate new solutions.

Certainly, material suppliers in the energy conservation business will be advertising the virtues of their wares, especially in the field of alternative energy equipment utilization. Design professionals will be bombarded with all measure of Madison Avenue's best, some good, some not. It will, in all probability, remain the responsibility of the State energy code enforcement entity to accumulate and make available objective data concerning the particular geographical adaptation and actual efficiency of all systems utilized within the State, under the jurisdiction of the code. Also, while not normally part of a code enforcement agency's responsibility, but certainly having precedent in the efforts of agricultural extension offices, the State energy office should include careful cost documentation as part of the collection of data.[9]

If what is being suggested appears as a metaphorical bureaucratic balloon slowly increasing in size and authority, consider the following. In the preliminary description of the Kentucky Energy Department and its mandate, the statement is made that "...this department is in comparison extremely small in its requirements for personnel, space, and budget. Furthermore, it has every intention of remaining that way, utilizing the resources and capabilities of other state governmental agencies to fulfill its charge." Thus, as will always be the case, the responsibilities are enormous while the fiscal means become more illusive, even with the assistance of Federal funding. None of this, of course, detracts from the overall importance of energy conservation, which as stated earlier, boils down to a simple matter of survival of our way of life as we would hope it to be.

MISSION SUMMARY

The final point to be made has to do with a rather subjective topic, that of attitude and spirit as they relate to solving the national problem of dwindling fuel resources. The energy office of each State will have, in this writer's opinion, still another very important responsibility toward the people it serves. As with the tourist commission and office of economic development, which can be found in one form or another in every State, the energy office will have to adopt a public relations plan second to none. To date, most efforts in this area have been rather superficial and something obviously less than convincing. Many studies have been undertaken, however, at the Federal level, and it is on this basis that the State energy offices must build to achieve results. Architects and engineers will need little convincing and in many instances will serve as envoys in assisting the energy department to spread the word. Beyond this, however, every staff member of the energy office must be led to develop a sense of urgency and an attitude of concern and informed enthusiasm that is a constant reminder to the public of the seriousness of the business at hand. All this may at first sound slightly stilted. Considering the mission, however, and considering the great need to redirect public opinion on the subject, is there any other choice?

In closing, there is this final footnote. A first grader went to his school's library and asked the librarian for information about caterpillars. The librarian responded by loading the youngster's arms with books on the subject until he could not see where he was going. After a moment of troubled silence the remark was heard, "I didn't want to know that much about catepillars!" So it is in the field of energy conservation. If the same question is asked today concerning information on energy, there had best be a boxcar handy to carry the load.

For those who are looking for a place to start, and for those administrators wanting to recommend short readings to their staff and enforcement personnel as the seeds for encouraging a broad and informed overview of the subject, consider the following. Richard L. Crowther's book, Sun Earth[10] and The Energy Primer[11] by the Portola Institute are two fairly basic source books for what is going on in the field of energy conservation and for what is anticipated in the years ahead. Obviously, there are thousands of other publications available. These two, however, will provide a good first step in understanding the magnitude of the task at hand and will offer some interesting and stimulating suggestions of where we might go from here.

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8. States with community college systems should consider using those facilities to stage workshops to reach code enforcement personnel in rural areas. Architects and engineers could be retained to coordinate and instruct after they themselves have undergone training sponsored by the state energy agency. In some instances, the community college may be able to offer code courses as part of its curriculum. There may be difficulty in finding competent instructors, however, and reliance on design professionals who are using the code may be necessary in instructing code enforcement personnel. While this may appear to be the cart leading the horse, it none-the-less is a workable system for getting architects, engineers and code enforcement personnel together with syllabus guidance and overall planning and coordination remaining with the state energy agency.

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RESEARCH ON NATURAL AND MAN-MADE HAZARDS: IMPACTS ON BUILDING REGULATIONS

by

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A crucial problem facing the building regulatory system in the United States today is the question of how the results of current technical engineering and scientific research into different natural and man-made hazards that are dealt with by building regulations are to be specifically reflected or incorporated into codes or standards. Ad hoc responses of the building regulatory system to pressures from different research groups, albeit well-meaning pressures, to incorporate research findings with respect to specific hazards, may lead to piecemeal implementation in which there is no underlying logic which attempts to bring about a fundamentally consistent method of dealing with all of the different hazards involved.

This paper speculates in an argumentative way on the role of the building regulatory system with respect to new research and the emergence of increasingly sophisticated scientific methods of analysis. The paper addresses possible bases on which code structures could be developed with the view of treating all hazard-related measures consistently. Some conceptual difficulties are noted along with more pragmatic concerns. In particular the point is addressed that if regulations become more sophisticated in response to more increasingly sophisticated scientific or engineering methods of analysis, then the possibilities for innovation and creative approaches to reducing hazards are increased, but at the same time the technical expertise of all those charged with enforcing the code must also be increased. Therein lies a basic conflict.

A very fundamental issue raised is that the role of the law on which building regulations are based and what it can or should be in relation to the scientific methods embodied in new research is unclear. It is hypothesized that many of the dilemmas currently facing the building regulatory system in regard to new research can be resolved only by considerations involving a greatly extended socio-political context.

Key Words: Building design; building regulatory system; decision processes; hazards-related phenomena; innovations; research findings; scientific methods; socio-political system; technical expertise.

One of the more interesting trends in construction that began in the 17th and 18th centuries is the often slow but inexorable emergence of the application of the scientific method to the design of buildings to render them safe from natural and man-made hazards. A relevant example is the field of structural engineering that developed in a relatively unhurried and orderly way. More recently, however, there has been a literal explosion of scientific information potentially applicable to the design of all, rather than selected, aspects of buildings. There has been a very large amount of work done by the scientific community, for example, in connection with the study of fire as a physiochemical phenomenon. While the obvious hope is that this basic research will yield new techniques for reducing fire hazards in buildings, the exact role or position of the building regulatory system vis-a-vis this research is still far from clear. One reason for this is simply that the historical balance that has existed between the building regulatory system and the methods of science and engineering has been upset by the great influx of new scientific knowledge and a new balance has not yet been achieved. In the past, a useful consequence of the originally slow gestation period that was present for both the methods of science and engineering and the simultaneously emerging law-based building regulatory system (which was responding to similar goals in building design but in a more historically traditional way) is that an easy and often supportive and interactive relationship existed between the two fields. It is obvious that some of the early model codes of this century, for example, were largely based on codifying the results of then-current scientifically-oriented or technical inquiries made with the intent of trying to find ways of reducing property and life loss. As such one role of codes was that of a force for change and innovation in building practices. More generally, however, early building bylaws also included traditional empirical measures deemed to be necessary for the collective good.

More recently, the influx of new scientific methods that are potentially applicable to building design has created something on the order of a crisis in the building regulatory field. There is no doubt that the rate of development of new research knowledge will continue to increase. The massive natural hazards program currently sponsored by the National Science Foundation, for example, will undoubtedly accelerate such new work. All remnants of traditional empirical measures found in building regulations will be challenged. Refusal of the building regulatory system to immediately incorporate new research findings into codes and standards will immediately cause some to brand the system as counter-innovative and constraining -- a sad state of affairs for a system whose roots lay in fostering innovative and rational building practices rather than the converse.

While the potential long-run benefits of new research are self-evident, implementation of this new research into building regulations must be done with care. Ad hoc responses of the building regulatory system to pressures from different research groups, albeit well-meaning pressures, to incorporate research findings with respect to specific hazards may lead to piecemeal implementations in which there is no underlying logic which attempts to bring about a fundamentally consistent method of dealing with all of the different hazards involved. It has been reported, for example, that the value implicitly placed on a human life by current codes is different for provisions related to fire and those related to earthquakes as evaluated by a cost/benefit analysis (3). The levels of protection afforded are appreciably different. Whether or not the levels of safety afforded should be exactly the same is worthy of debate. The fact that they are unconsciously different is untenable -- at least from the viewpoint of the scientific community.

This paper speculates on what form the results of current research on hazards should take for implementation into building regulations from two points of view. The first point of view is how to develop an ideal form such that a uniform philosophy for dealing with all hazards in a consistent way is possible so that a parity of relative importance is maintained. What additional research is needed to effect this type of approach is also considered.

The second point of view addresses the different question of how to deal with the fact that if a more internally consistent code basis were developed that could incorporate on-going technical research, then a probable consequence is that the professional technical expertise and sophistication of all the individuals dealing with the code would necessarily have to be simultaneously increased for such an approach to be possible at a practical level. A related point concerns the vast number of buildings built without the aid of professionals at all, but which still must be controlled by the regulatory system. These factors present unquestionable difficulties with regard to implementing code approaches having the necessary sophistication to be useful to implementing research-based methodologies.

Another fundamental point develops from inquiring into developing a fully consistent method of dealing with all natural and man-made hazards in buildings and some of the more pragmatic difficulties of implementing such an approach. This is that the real dilemma involved in the research and building regulations confrontation is actually one of a far more fundamental nature dealing with the lack of clarity of the law on which building regulations must be based with respect to building design methodologies having their foundations in the scientific disciplines.

It is suggested that the issue of how best to implement research findings into building regulations is ultimately a political question and it is in this arena that the issue would be most fruitfully discussed.

The paper is speculative in nature and deliberately intended to be argumentative with the intent of engendering useful debate on the issues involved.

Background

There are a large number of domains in which research is being conducted that may potentially have implications for the building regulatory system. Research in areas sponsored by the disaster and natural hazards program of the National Science Foundation are obvious examples. As a way of understanding the issues involved in the implementation into building regulations of research of this type, it is useful to focus the discussion in this paper on one of the most important hazards, fire, and to a lesser degree on earthquakes. As will be seen, there are common issues involved in the implementation of any scientifically oriented research, and the precise hazard discussed is only of secondary importance. Fire was selected because it represents a hazard about which there has been a flurry of recent research but which can be said to represent an emerging rather than a flourishing research discipline. It is particularly useful to look at fire since the massive research funding provided by the National Science Foundation has recently been largely terminated. Although some fire studies are still underway, termination of the program has obviously curtailed research efforts in this domain. A lot of work has been completed, however, and it is of interest to speculate on the consequence of this work vis-a-vis the building regulatory system.

Earthquake studies, by contrast, are currently receiving enormous funding. A further contrast in that such studies are largely rooted in the traditional methods of structural engineering, which is a fairly sophisticated and developed profession as compared to that of fire engineering. To be sure, however, many of the topics of concern in earthquake studies are on the fringes of the traditional body of knowledge extant in the profession and are delving into less objectively based domains. As will be discussed, this last point is of no small importance vis-a-vis the building regulatory system.

The following will briefly highlight some of the relevant research work in the two hazard fields as a way of setting the context for subsequent discussions on the role of the building regulatory system in relation to this work.

Fire Hazards; Recent Research

While our knowledge of the phenomenon of fire in buildings is not as empirically based as it once was, there is little doubt that practitioners dealing with fire control in buildings are forced to rely on analytical tools that are considerably less sophisticated than comparable tools used in other professions. Numerous examples could be cited to illustrate this point. Perhaps the most salient is the current inability of fire engineers to analytically predict the course or effect of a fire and its related phenomena, e.g., spread of toxic gases or smoke, in any particular building space that has been completely defined in terms of its geometry and materials and where there is an assumed point of ignition. The progress of a fire cannot be adequately predicted for these circumstances involving only a building shell. The more realistic case of a situation involving "random" elements such as odd pieces of furniture or scattered clothing is even further beyond current analytical capabilities.

To the average fire engineer plying his traditional craft, the absence of such analytical capabilities is probably not startling, nor perhaps are such capabilities even viewed as nececessary to make building safe. To members of other disciplines in the scientific community, however, the lack of such capabilities is often regarded as appalling. The perceived issue is usually not so much one of whether or not the particular activity described is of value or not as a necessary building design tool, but that the state-of-the-art in an area apparently susceptible to scientific methodologies is so retarded as to not have applied such methodologies. It is invariably implicitly assumed that science-based methodologies would prove useful as building design tools. Such is the confidence of the scientific discipline.

That the state-of-the-art is as it is, however, should not be surprising for some very good reasons. One is that fire is a very complex physical and chemical phenomenon not readily susceptible to rational analysis. Until the recent financial backing provided by various private and public agencies, there was simply insufficient incentive for members of the scientific community to study fire in buildings and to provide the necessary theoretical understanding of the phenomenon necessary for more sophisticated engineering approaches to be developed.

Now that there has been a spate of sponsored research in the area, however, it is of interest to assess briefly the new state-of-the-art. In general, types of recent research can be classified into two very broad categories: basic and applied. The first concerns basic scientific research into fire as a physical and chemical phenomenon. The long-range goal of this research is generally to establish a better understanding of the factors that control the ignition and growth of fires. The emphasis of this type of research is on gaining a theoretical understanding of fire as a process without regard to whether the fire occurs in buildings or in some other context. Thus, the findings will contribute to an understanding of fire in buildings but are not necessarily directly applicable in an obvious way to their practical design. The second category of research is based upon our current understanding of the theoretical aspects of fire and is consciously oriented toward achieving results that can be applied directly to the design of buildings for fire safety. Efforts in this second category generally fall into one of two types: studies that are directed toward improving the general level of fire technology and that are thus broadly applicable, and studies that are geared toward reaching the fire hazard in specific situations.

With respect to basic research, a review of most research studies either recently completed or underway reveals that most of the research is still currently in a stage of infancy, particularly those dealing with understanding fire as a physical and chemical phenomenon. Enormous strides have been made by the scientific community in this respect, but most studies were built on a dearth of prior research and largely represent fundamental efforts.

The subjects addressed by basic research studies are fairly wide-ranging. Studies have been made, for example, of heat transfer by convection and radiation. These phenomena are of basic importance since the rate of fire spread in an enclosure such as a room is a function of the heating, by the fire itself, of nearby but still uninvolved fuel elements. Failure to recognize radiative and convective influences would make it impossible to predict accurately the path of a fire in a given situation. Other studies on the pyrolysis process are important in describing the ease of ignition of materials. Studies of the basic mechanisms by which water or other agents put out fires are of obvious value. Exactly why a wind blowing over a match may extinguish a flame, for example, may seem to be a simple question to answer, but to the scientist seeking to precisely describe the principles involved, the answer is surprisingly difficult to provide.

Studies on the behavior of combustion products are resulting in computer simulations of the way these gases are distributed over time in an enclosure. Other types of computer models are being developed as well.

A traditional method of science has always been experimentation. Experimental studies seeking to develop or provide generalizable theoretical constructs include exploring ways of accurately modeling on a small scale a complete fire history for any governing set of variables. Pressure and atmospheric modeling techniques, for example, are being developed. Related studies include correlating experimental data for model tests with those of full-scale tests of simulated bedrooms. Modeling techniques of this type are potentially enormously valuable. Modeling techniques, for example, are commonly used in many other highly sophisticated engineering disciplines, e.g., the aerospace industry, to great advantage. There is every reason to believe that they would be of similar value with respect to fire engineering.

Supplementing work on fire as a phenomenon are basic studies considering the bio-medical consequences of fire on building occupants. Human sensitivity to fire and fire-related phenomena are surprisingly uncharted.

Studies of the type outlined above are paving the way for a complete theoretical understanding of how a fire ignites and progresses in a building and its effects on occupants, but it is evident that this understanding is far from fully developed. There is still a long way to go before dealing with fire hazards in buildings really achieves the level of an engineering discipline of a stature and assurance comparable to that of disciplines dealing with other hazards, e.g., the structural engineering profession. A continued gestation period is needed. The important point is, however, that the theoretical bases for engineering are currently being laid and that, if given encouragement and the opportunity to apply findings, fire engineering could indeed develop into a sophisticated profession.

Fire Control Approaches Suggested By Research

Before looking at what stance the building regulatory mechanism should take in relation to the type of work briefly described above, it is useful to simply speculate on the potential type of future code provisions that the research seems to inherently suggest. With respect to fire, much of the research mentioned--including numerical analyses and modeling studies in both full and reduced scale-point to the general possibility of computing the progress and consequences of a fire started at any assumed spot in a room whose geometry and contents have been specified. Perhaps eventually this could be done for a complete dwelling unit. This is, of course, more than a slightly optimistic view when one looks in more detail at the analytical difficulties involved in relation to the research results achieved thus far. Still the potential analytical capability mentioned is not an unreasonable aspiration.

It might, however, be questioned as to whether meeting this aspiration is really necessary to ensure the fire-safe design of buildings. Could not, for example, many of the current design problems be corrected by paying more attention to devising more thoughtful tests for material behaviors under fire conditions? Frequently used measures such as "Flame Spread Ratings" have, of course, been under wide attack as of dubious value by some researchers. While testing improvements would undoubtedly yield some benefits, it is evident that no matter how much attention is paid to material characteristics, a basic difficulty still underlies the successful application and use of ratings of individual materials as a way of reducing overall building hazards. The flaw is an obvious one known to most fire engineers and is most simply explained by what is now a classic example. It is amazingly difficult to start and sustain a fire with one log regardless of its material susceptibility to fire as measured by a criterion such as a Flame Spread Rating. However, with the addition of a second or third log placed in close proximity to the first, a fire once ignited can be sustained and made to grow rapidly. This phenomenon can be described primarily in terms of radiative feedback. A single-valued descriptor of the flammability for any given material does not adequately describe its actual flammability when it is placed adjacent to itself or other substances. It may well be possible to assign a meaningful flammability index or rating to a system of several logs, but this index would have to depend as much on the characteristics of the system, including its geometry, as on the characteristics of each specific element within the system. This dependency of the fire sensitivity characteristics of the assembly on the nature of the relations between elements as well as the geometry and material characteristics of the elements themselves, is the fundamental reason that tends to justify and give credence to the aspiration initially described of attempting to devise a full, analytical capability for predicting the behavior of a fire in a given context.

Assuming that such analytical capabilities did exist, the type of code provisions immediately suggested are those that make use of allowable rating systems to establish acceptable levels of fire hazard for whole functional units such as particular rooms or entire dwellings. Rating scales of this type would have to depend on the geometric characteristics of the spaces and the specific characteristics of the materials used and would, therefore, be based on the susceptibility of the system as a whole to fire. This method is potentially far superior to the assignment of single-value descriptors to individual materials without accounting for the geometry of material placement and is a realistic way of potentially controlling fire hazards in buildings.

The precise nature of an allowable rating system applying to whole functional units can only be guessed at. Ideally, it would still be a single-valued descriptor, but of necessity the descriptor would probably have to be composed of a weighted combination of several more specific indicators such as ease of ignition, rate of spread of flame, smoke, and toxic gases. Closer study might indicate, however, that any single-valued descriptor based on several specific indicators would be meaningless and would have to be replaced by a series of individual allowable ratings for controlling specific phenomena in a functional unit. Associated with the rating method used might be time criteria governing the periods for maintaining the integrity and safety of different kinds of occupancies during fires.

An advantage of the use of overall ratings for functional units is that the exact ratings could be made to depend upon the occupancy involved and the degree to which human safety is a concern. In buildings where human safety is not an overly critical issue, for instance in warehouses, the ratings could be tuned to be responsive primarily to property protection. In cases where life protection is of paramount importance, for example, in housing, a rating system primarily responsive to life safety could be used with implicit measures, such as rate of smoke or toxic gas-spread especially emphasized. The latter could even respond to different occupancy groups within housing. Distinctions could be made for dwelling units housing the elderly and those housing large family groups. As mentioned, different variables among these ratings might reflect the importance assigned to controlling specific phenomena, such as time to flashover, ease of ignition, and the rates of spread of flame, smoke and toxic gases.

Attention could be given to the possibility of linking requirements with the degree to which building contents could be controlled. Rightly or wrongly, many buildings constructed in accordance with current codes have been characterized as well-fabricated incinerators able to withstand a burnout of highly flammable contents. While there are obvious difficulties in controlling building contents, the linking of requirements with contents may be possible in certain types of residences such as dormitories where many of the furnishings are built-in.

It is evident that if a system of the type outlined could indeed by implemented, the opportunities for creative innovation in design would be enormously improved. Traditional measures such as height and area limits which dramatically affect building design (see ref. 5), for example, would no longer be needed since the goals they were intended to accomplish would be implicit in the more sophisticated system. If such measures were tied into occupancy types, then the regulatory mechanism could truly be said to be "responsive."

The above discussion is at once as serious and well intentioned as the author can muster but is also ever so slightly on the tongue and cheek side as well, with the intent of the latter to bring into focus two of the salient problems facing the building regulatory mechanism--that of setting reasonable criteria and that of establishing the limits to the extent of the context considered. On what basis would be exact numerical values of ratings for functional units be established and what is the degree of scientific reliability of the criteria employed? Should the criteria be based on considerations related to an extended context or a more limited one, i.e., should criteria be related to "housing" or "housing for low-income families." A more extended system of the type described would, of course, be the joy of academics throughout the land because it has the guise of scientific credibility, but at the same time begins pushing into less objective grounds. Implementation of the idea of linking criteria with occupancy types and doing things such as varying the relative weights of measures--from ease of ignition or rate of toxic gas spread to whether the building is occupied by elderly or low-income families--would require massive amounts of research into domains that simply cannot be said to have the almost brutal credibility of those associated with the so-called "hard sciences." It is interesting to note, however, that as the frontier is pushed in the softer direction, more opportunities appear to open up for truly creative and responsive design.

It could even be argued, for example, that emphasizing hard science criteria at the expense of less objective measures may well be detrimental to fulfilling the mission of the building regulatory mechanism in assuring the safety of building occupants by virtue of misdirected priorities and resource allocations. It is undoubtedly true that insufficient attention has been placed on subjective considerations in life safety during fires. It is evident, for example, that people under duress in fire conditions resort to the familiar routes of escape or those that seem innately reasonable, no matter what "exit" signs may say. There is good reason to believe that buildings could be so architecturally designed as to communicate innately appropriate rather than inappropriate senses of proper evacuation routes and thereby be more effective in protecting the safety of occupants than all of the prespecified code mechanisms put together. This is, of course, an extreme position and one which would, no doubt, have to be tempered when faced with the realities of building design.

Reflections of the above type, of course, are nothing but anathemas to officials in the building regulatory mechanism charged with assuring the safety of building occupants while at the same time being responsible for creating documents that have the force of law and which should seem, therefore, to have as much objectivity as possible. It may well be desirable to set a limit on the type of research findings that should be included in code documents having the force of law with other types transformed into standards or guidelines.

Earthquake Hazards

In contrast to the research on fire briefly described above which has been built on a dearth of prior research, recent work on earthquake hazards has been able to begin at a much more developed level. The basic analytical capability, for example, of taking a given structural configuration of physical elements of specified material properties and being able to *a priori* predict the behavior of the system reasonably well with respect to an applied set of loads has existed for a long time. This existing capability is surprisingly analogous to that now only aspired to by fire engineers of computing the progress of a fire through a given configuration of physical elements. To be sure, however, the dynamic phenomenna is buildings that are associated with earthquake movements are highly complex, and there exist a whole host of questions that remain to be answered before our theoretical understanding of earthquake hazards can be said to be complete. Quantitative input data describing possible ground movements, for example, are surprisingly sparse, and our knowledge of site and structure interactions or of the exact role and behavior of non-structural building elements is similarly on the vague side--at least when viewed in terms of quantitative predictability.

If significant, unsolved problems didn't yet exist, then the massive recent funding for earthquake research would indeed be curious (albeit a significant portion of this funding is not directed towards technical studies). Still, by and large, the knowledge level and technical expertise in the area that is already currently available is on a far more sophisticated plane than is our technical expertise in other domains related to building performance.

An interesting aspect of the fact that current earthquake hazard research is starting off on a relatively high plane of development is that many studies are pushing the frontiers of technical research into domains that are considerably more value-laden and subjective than ever before. Obvious examples are those studies that are taking cost/benefit approaches or those dealing with risk-balancing techniques. It is into domains such as these that the logic of much research leads as it seeks to find rational bases on which to make decisions or evaluate alternatives. Despite the fact that many of these studies are done by credible scientists or engineers, the measures used are often far less susceptible to traditional methods of scientific vertification than are those encountered in classical structural research firmly based on well established principles of mechanics.

BASIS FOR TREATING HAZARD PHENOMENA CONSISTENTLY

Background

While incorporating some of the suggested provisions made in relation to fire may make sense with respect to controlling that hazard, they may not make equivalent sense with respect to a general code philosophy directed towards taking a consistent attitude to general hazard control in buildings. It is reasonable to think that there should be some consistent method of dealing with suggestions stemming from different hazard (e.g., fire, earthquake) study areas, since they are addressing the same general goal of reducing risks to building occupants due to natural or man-made hazards.

The problem, however, is one of answering the question of the basis on which provisions dealing with different hazards can be logically compared. The natural phenomena associated with fire, for example, are very different from those associated with earthquakes. It follows, therefore, that the only way a consistent basis can be established is not to deal directly with measures related primarily to the phenomena themselves, but to deal with measures related to the effects of the phenomena on the occupants of a building, the activities therein, or the physical property itself. Many investigators have, of course, realized this principle, and have either developed tools to address the issue or have borrowed them from other disciplines. It is of interest to review in general terms the basic approaches developed thus far or that have been proposed. It is suggested that provisions such as those previously described related to fire can be used, but that the bases underlying any numerical criteria used must be found on more general grounds.

Current Approaches

For purposes of this brief discussion it is useful to simplisticly divide the relevant approaches suggested thus far into three general categories: (1) cost/benefit analysis, (2) death or injury-risk analyses, and (3) multiattribute decision theory.

Cost/benefit analysis is, of course, a commonly-used tool for reducing certain types of problems to common bases. In such studies all losses are expressed monetarily. The losses can be either direct property losses or less tangible fatality, injury or societal costs. Application of this general approach to assessing the economic impact of building codes has been convincingly demonstrated in a most-welcome, recent paper by McConnaughey (4). While cost/ benefit models are most useful for studying economic impacts, they have also been used for selecting alternative ways of allocating resources with the intent of minimizing human suffering.

Whether or not analyses that are basically economic in nature should be applied as a basis for developing criteria for building code provisions intended to assure the force of law is an interesting point of conjecture. Proponents of the method of course point out that not taking an economic orientation is unrealistic; others argue that this point should be debated more.

On a more pragmatic plane, it is important to note that from the viewpoint of hazard evaluations, applications of cost/benefit approaches necessarily require placing a value on human life. While such a notion may seem shocking to the uninitiated, the act of placing monetary values on human life is commonly done in many connections affecting our daily lives (e.g., insurance matters). Of interest herein, however, is not the morality of the question, but rather that such measures must be value-laden and dependent upon a host of variables to the extent that they cannot be said to have the credibility of hard-science measures. Used correctly as aids in the decision-making process, however, such models can still be of enormous value.

Interesting approaches which deal exclusively with the risk of death of injury and not at all with monetary values or economic impacts have also been developed. Starr (6) has evaluated risk of deaths from various causes. Risks are classified into those associated with voluntary activities or involuntary activities. In the first case an individual is knowingly exposing himself to a risk and naturally adjusts his exposure to the risk accordingly. Involuntary risks are those to which an individual is exposed by an external source. Clearly the type of risks associated with hazards in buildings are of the latter type. Interestingly enough, Starr estimated that an individual is on the order of 1000 times more willing to accept voluntary as opposed to involuntary risks. Wiggins and Moran have suggested, for example, that risks on the order of 10^{-7} fatalities/person exposed/year might be used as a basis for earthquake design requirements (9). Like cost/ benefit analyses, however, such measures are extremely value-laden and involve subjective assessments.

Various combination approaches can be taken which deal simultaneously with risk of death and monetary evaluations. These multiattribute approaches deal with problems in terms of characteristics considered most relevant. However, the two models previously discussed represent clearer approaches and are more useful as discussion vehicles for clarifying issues, although a multi-attribute approach might well prove most attractive in the long run.

Either a cost/benefit or risk of death analysis could be used as the basis for establishing building code provisions related to natural and man-made hazards in buildings. It is perfectly possible, for example, to imagine a code system stemming from a cost/benefit type of approach whose provisions were based on criteria related to the value of a human life. Criteria would be established such that the stringency of all provisions governing hazard-related phenomena, no matter what hazard was considered, places the same value on a human life. The important point is that such a criterion could provide the necessary common ground for establishing criteria for diverse hazards such as earthquakes and fires.

Alternatively, a risk of death approach could be used (based on the involuntary exposure category) that basically accomplished the same goal, except that the criteria used would be expressed in risk terms rather than monetary values. Provisions could be adjusted such that the same death risk was present with respect to all hazards. Since the mission of a building code is to ensure the safety of building occupants, the notion of going to death risk criteria and not to criteria involving economic implications certainly has great conceptual appeal.

It should be noted that while the basic criteria might be of the type described above, specific provisions could still be more explicitly related to the hazard phenomenon of concern. It is just that their stringency would be determined on the more basic criteria discussed.

What level these basic criteria should assume (e.g., what is an appropriate numerical risk level or value of life) is a topic of inquiry beyond the scope of this paper--other than to note that there is no reason why a parity should not be established with other criteria explicitly stated or implicitly present in other systems affecting the public. That there should be differences in risk levels present in public buildings and public transportation systems, for example, is not really explicable. On the other hand, while a grand risk-balancing approach certainly has conceptual appeal, it is interesting to note that it is unclear exactly why risk from different hazards should be balanced and code provisions designed accordingly, other than that it does not seem sensible not to balance them. This interesting point should be pursued in depth if a risk approach is to be adopted. Not all researchers believe that these more commonly discussed methods described above (benefit/cost or risk of death analysis), are the most appropriate techniques to use in setting public policy. De Neufville, for example, notes that such analyses may lead to incorrect and unacceptable recommendations (1). His argument is based on data demonstrating that the public's evaluation of any protection against hazard damages is both a highly non-linear function of its level and the level of other benefits and varies among different elements of society. He proposes an alternative criterion when approximate evaluations are appropriate and when a more complete assessment of the values used by a different interest group is required. It thus appears that there yet exists conceptual difficulties in formulating a consistent basis for evaluating the effects of different hazards. Coupled with the conceptual difficulties noted are more pragmatic concerns. McConnaughey has noted the incredible effort it takes simply to evaluate, using a cost/benefit approach, a few limited provisions (4).

Full scale implementation of any of the approaches described is really a rather grandiose aspiration at the moment. The question addressed, however, is not one of how to immediately implement such approaches, but whether or not aspirations of the type described are reasonable as a consistent code basis. Whether or not codes of the next century should have such bases is really the issue at hand. If so, then we can begin slowly working in this direction. If not, then we had best establish another direction or the floundering will only get worse. A critical issue for debate from the building regulatory viewpoint seems to be the objective credibility of the measures and criteria suggested thus far. A fundamental difficulty seems to be that the frontiers of technical research are encountering far less sure ground than that covered before. While the efforts to cope with this situation are admirable, the difficulty nonetheless remains.

IMPLICATIONS FOR THE BUILDING REGULATORY MECHANISM

Background

It is obvious that the building regulatory mechanism has quite a task in front of itself with respect to how to (indeed, if it should at all) rationally incorporate recommendations or procedures stemming from the type of research briefly described. It is almost invariably true that any researcher would like to see manifestations of his or her work appearing in documents such as building codes. The reasons for this are self-evident with the good intentions and convictions of the research as to the need and potential value of such incorporations playing a major role. The pressures brought to bear on the building regulatory mechanism to respond in some way are often enormous. After all, it is often supposed, are not devices such as codes merely artificial constraints placed in the way of innovation? While this latter point has been dealt with quite well by others, e.g., Ventre (8), the pressure for change nevertheless remains--as well it should. No building code can remain static and hope to continuously fulfill its original mission as a force for positive change of building practices for the benefit of society.

There is good reason to believe, however, that there should be some element of conservatism in how the building regulatory system responds in that changes made assume the force of law. Assigning to the building regulatory system the role of a vast, experimental laboratory is an interesting, but more than slightly unsettling idea. There are far too many examples in the history of science and technology where many has used the power of these tools to effect certain results only to find that other unanticipated, and perhaps undesirable, consequences have also resulted.

From the building regulatory viewpoint, the issue of change is not whether responsive change is undesirable, for few in the system other than special interest groups would argue this, but rather what assurances exist or can be developed that any changes made will indeed contribute to the collective good of the very society that legislated their existence. A far more pragmatic consideration is that the building regulatory mechanism is huge and complex. Instead of buzzing about, it moves necessarily in slow and ponderous steps. The consequence is that once major changes are made, they are incredibly difficult to rechange. A related point is that once minor changes with respect to certain phenomena are made, it is often very difficult to effect more major changes with respect to the <u>same</u> phenomena within any sort of reasonably short time period. For example, it is evident that this very point is one of the principal issue underlying the late controversy of whether or not the so-called "corner test" should be used as a basis for establishing flammability ratings for materials and replace existing tests. Some researchers maintained that the corner test was far better than existing methods. Others who were concerned felt that while the test was perhaps slightly better, it was still of intrinsically dubious theoretical value, and that direct adoption as a standard test would only impede the eventual adoption of more meaningful approaches. Pragmatic though it may be, the point is a serious one.

Parity Level Considerations

A fundamental concern underlying the example cited above is that of the danger of piecemeal approaches to implementation of research findings in which changes not made in accordance with a carefully thought-out set of guidelines reflecting a logically consistent code philosophy are apt to prove more counterproductive in the long run, despite their immediate innovative quality.

On a more general level, it is evident that the same danger of piecemeal approaches exists with respect to the simultaneous incorporation of research results dealing with the many different hazards currently being studied. As the brief state-of-the-art review presented earlier indicates, the levels of development of engineering expertise with respect to fire and earthquake hazards are remarkably different. It will be some time before a parity of development is reached. This difference in levels poses a very great problem for the building regulatory mechanism, since it is evident that on the one hand there is the pressure for change in areas that can be changed, while on the other the dangers of a piecemeal approach exist. It is not suggested, however, that the building regulatory mechanism sit idle because of a perceived danger. It may well be that wholesale changes could be made with respect to how some hazards are treated with the intent of setting up a model for how to treat other hazards when their levels of technical sophistication achieves a parity. That this is a valid approach, however, remains to be demonstrated in a thoroughly convincing way. The whole question of whether interim modifications become models for change or, less desirably, obstacles to future development is one which needs more thought than has been given to it and is suggested as a prime research topic.

In any event, it is evident that eventually a parity of technical expertise with respect to different hazards can be achieved and that it is desirable to begin setting up a code structure that will allow for a consistent treatment of different hazards. It is suggested that an immediately useful and beneficial role that the government or private funding agencies could play vis-a-vis supporting innovation in the building regulatory field is that of sponsoring research such that parities of comparable technical expertise are developed with respect to different hazards.

Confidence Level Concerns

A fundamental point of concern for the building regulatory mechanism undoubtedly lies with some of the problems addressed earlier. In particular the problems of establishing on what basis criteria are set for consistent methods for treating different hazard phenomena and for setting limits to the extent of the context considered in formulating criteria. The basic problem is that, as approaches become more sophisticated and the context of concern is extended, there is strong reason to believe that the possibilities for innovative design are increased, while at the same time there is a tendency for the measures that are involved to become more subjectively and less objectively based with a decrease in confidence in the measures resulting as a consequence. Suggestions have already been made with respect to how these problems might be treated. It is evident, however, that the conceptual difficulties present are of no small magnitude, and the most appropriate stance that the building regulatory mechanism could or should take is decidely unclear. It is evident that the building regulatory mechanism could potentially act more decisively and with greater confidence if some of the conceptual difficulties in the criteria suggested by scientific researchers were more uniformly convincing. Alternatively it should suggest its own. Whether the building regulatory mechanism would act, however, is another story. To use concerns of the type noted above for total inaction would perhaps be seeking an excuse for inaction rather than believing in the issues involved.

The Nonappropriateness Problem

Implicit in the discussion thus far has been the tacit assumption that once research results are available to pave the way for more theoretical understandings of different hazard phenomena, such understandings can be immediately applied to the building field in a practical way. This assumption, is, of course, questionable on a number of grounds. One of these is simply the issue of exactly who would make sophisticated analyses of the type described, e.g., rating the fire hazard for a whole functional unit in numerical terms. It is not unreasonable to believe that for large special projects, teams of individuals having the necessary specialized knowledge could indeed be assembled. The real difficulty lies not with major uniquely designed projects, but with more run-of-the-mill minor building projects. Most privately developed single-family detached housing and multi-family low-rise housing in this country, for example, is normally built without the aid of professional architects and engineers.

For buildings such as single-family detached housing, codes using provisions of the more sophisticated type described which would involve features such as allowable ratings for rooms would probably work very poorly. The question of who would analyze the dwelling unit of concern and establish the actual ratings to compare with those promulgated in regulations looms very large. It is more than doubtful that the average contractor could perform such an activity, or, for that matter, the average building inspector or city code official charged with enforcing the promulgated regulations. The latter can check on an individual basis whether a particular material is acceptable, for example, but if the question of acceptability were linked to the actual use and relative placement or positioning of the material in a given situation, it is evident that personnel relatively untrained in engineering would not be equipped to handle such questions. Professional engineers having extensive theoretical training in fire hazards could, of course, be required to approve or assess plans. It is clear, however, that requiring such involvement would add more to the difficulties already present in getting a new house underway. There would also be new costs for additional services, probably comparable to the one or two percent of total costs associate with the fees of comparable professional structural and mechanical engineers. A further complication might be additional time delays.

The basic difficulty that underlies this discussion is that, as a regulation becomes more sophisticated, the possibilities for innovation and creative approaches to fire safety are increased. As the level of sophistication increases, however, so must the expertise of the people who actually implement the regulations.

Whether professionals should be involved in all building designs is an often fought question and the crux of the matter. Of interest herein is that building regulations are ultimately promulgated by society itself for the purposes of protecting the collective good of society. If it can be demonstrated that the larger collective good of society is best served by not accepting the important but restricted values that a science or engineering based approach offers, then society, of course, can choose the option not to require professional involvement. It is possible, for example, that the increased costs associated with professional involvement would be sufficient to make the aspiration of assuring decent housing for all low-income families even bleaker than it currently is. With respect to some building types, it is, therefore, possible that professional involvement might not best contribute to the larger collective good of society. Obviously, there are trade-offs involved, notably the possibility of decreased risks to occupants through the involvement of professionals, that need to be assessed before this critical question can be resolved.

If a nonrequired involvement of professionals for the design of some building types is deemed to best serve the collective good of society, then the dilemma facing the building regulatory mechanism is obviously enormous. It needs to at once address two fundamentally different types of groups involved in building which radically differ in not only their values vis-a-vis building, but in their specific design approaches as well.

The conflict discussed above is true with respect to other hazards than fire. It is entirely too fundamental for there to be any easy solution for the building regulatory mechanism to pursue. A possible option that has been repeatedly advanced and repeatedly not caught on as a viable approach, with good reason, is that of a code structure in which a dual format is used. The obvious intent is usually to provide simultaneously the type of provisions that are most appropriate to the user. In the frequent arguments about the relative merits of performance versus specification provisions, for example, it is usually suggested that performance measures be allowed as an alternative to specification type provisions. Many building officials and others have argued, however, that such a format is not only confusing, but also redundant, since model codes are already largely performance oriented. Still, given the dilemma involved, it may make some sense to revive discussion about the dual format notion but with a different twist. Instead of the intent of a dual format notion being to escape the application of specification provisions, the idea would be to do so with the intent of encouraging them for those that wish to use them. It is suggested that a more strongly specification type approach for certain building types, albeit a streamlined one, than is currently present in model codes might well prove a desirable option not only to a great many builders who pursue their trades without the alliance of professional architects and engineers but to society at large whose best interests are often best served by expediting building. By a similar token, the provisions that are intended to expedite application of the scientific method by trained professionals should be made as abstract as necessary to best serve the perceived needs of such groups. The problem of cumbersomeness and workability still exists, but the different twist suggested may prove beneficial in the long run.

BASIC RELATIONSHIPS

Looked at in a fairly abstract way, it is evident that many of the problems and conflicts described above stem from the fact that the building regulatory mechanism is a manifestation of a socio-political system, while the roots of scientific methods ostensibly lie elsewhere. The word "obstensibly" is deliberately used since the point about the roots of science lying elsewhere is utlimately a point of interesting conjecture. Of interest at the moment, however, is that if science ever deliberately chose to regulate itself, or found such a necessity imposed upon it, it is certainly doubtful if it would choose a vehicle having the characteristics of the building regulatory mechanism. Now that some of the more conceptual aspirations and pragmatic difficulties of applying scientific methods to building design have been addressed, it is useful to speculate more abstractly about the relation of scientifically oriented building design methods to the foundations of the building regulatory system--the law.

An extremely interesting argument very relevant to the issue discussed in this paper has been advanced by Ferguson (2) who has maintained that the methods of law are not adapted to technological information in the sense that the two systems are basically different. Law, he argues, is arbitrary and precise and regulates real situations, things and entities, whereas technology deals with universal abstracts and relations.

While the thesis mentioned above could be argued, and will be, it is of interest to temporarily expand the thesis slightly to clarify some of the issues involved. A common feature of all building design activities based on the scientific or rigorous engineering methodologies is that they invariably deal with the act of positioning physical elements and formulating associated interrelationships with the objective of imparting a desired performance attribute to the total system. The consequent result is that a different answer is provided for each situation depending on the context involved. The structural engineer performs such activities, albeit less abstractly conceived, as a matter of course, as do more sophisticated fire engineers. Therefore, since the law is based on a body of precedents established by real situations it is peculiarly unsuited to dealing with methodologies which produce design solutions not based on any analogous precedents at all, but on an understanding of physical phenomena. By a similar token, the law is uniquely suited to specification-type provisions which are, of course, firmly based on real precedents.

If the conclusion is drawn, however, that the law is not potentially capable of coping with changing approaches and new methods, an error is made in underestimating the flexibility of the legal system. A good example of how the legal system has already responded to innovative changes in methodologies is the rise of tort law in the 19th century, which was conspicuously linked with the rise of industrialism. The notion of tort law is of interest here for a number of reasons. With respect to building, a builder has obligations placed on him by society over and above those explicit in the realm of contractual liability. Society, through the legal system, places the obligation not to injure others on all of its members. This obligation is of a civil nature. A breach of this obligation may give rise to an action in damages by the injured party. That action lies in tort. While it is difficult to express briefly the role of tort law, one of its primary functions is to distribute the losses that arise through human activities. While having some punitive aspects, its principal function is to establish whether an individual who suffers a loss can shift that loss to the individual whose conduct or activities have substantially caused that loss to occur. Tort law has, for example, long been the legal basis for losses incident to construction procedures.

Also of interest are those principles of law that deal more directly with faulty design. In the manufacturer's liability field, many situations involving injuries due to faulty product design have been moved by the court to tort (7). In those cases where faulty theoretical design (not workmanship) has involved deaths, the situation is even more vague. This is not to say that opinions do not exist or that actions have not been taken, only that the principles are not as settled as in other areas.

The more the relation of the law and activities stemming from application of the scientific method is looked into, the more it is evident that a far from clear and precisely definable relationship exists. Since buidling codes have their basis in the law, there are undoubtedly implications of this unclear relationshp--most of which have yet to be explored. One consequence, however, is obvious. It is evident that the problems involved can never be easily resolved without addressing the problem of the relation of the law to the scientific method in more fundamental terms and coming to grips with the issue at this level. The idea that a group of building code officials and scientific researchers, neither of whom are usually particularly well versed in legal issues, would be capable of resolving any conflicting perceived missions without involving a larger context of concern is unrealistic. The confrontations would simply take place in a context beyond their control and which preordains a certain measure of irreconcilability. It is evident that strategies for attaining implementation of research must be developed in relation to a much larger context and, consequently, involve participants other than just code officials and scientific researchers. Obviously this is a suggestion for what might well be a potentially fruitful area of general research which is currently relatively unexplored.

Looked at in what is perhaps a naively simple way, for example, the result of a more extended inquiry taking place in a larger context might well indicate that the only type of relationship that could exist in which the scientific method could be exercised in a totally unfettered way, thereby potentially opening up opportunities for innovation, is one which does not include any sort of building regulatory system of the type we currently have at all. Rather the mechanism by which society might choose to protect itself from hazards might be one in which the law enters in only if losses (including death and injuries) are incurred that were thought to be actionable, in which case the issue involved would be decided in court. This prospect is either intriguing or frightening, or perhaps both, depending on the perspective assumed. The implications of such an approach, however, are literally too enormous to be explored in a brief paper. It might well be, however, an option to consider as a viable approach to be taken to prevention in the future--the distant future to be sure. Planning strategies for the next century, however, is useful both in its own terms and as a way of clarifying issues for more immediate action.

SUMMARY AND CONCLUSIONS

For those seeking immediate solutions to pressing problems, this has undoubtedly not been a very optimistic paper. A primary hypothesis underlying this paper is that the possibilities for true innovation in many aspects of building design are possible only if the scientific method can be employed in an unfettered way. Over and over again, however, the point was raised that many fundamental problems exist in the incorporation of new research into code documents. The extent of these problems is such as to suggest that the real unsolved research problems of relevance to the building community lie not so much with uncertainties in the theoretical body of knowledge that is existent, but simply in what to do with the findings already available or which will soon become available.

To summarize a few salient points raised in the paper as a prelude to some final suggestions, it was noted that the one thing common to methodologies of potential usefulness in building design that have been suggested by research in different hazards is that all deal with the positioning and relationships of building elements to one another in addition to dealing with the physical characteritics of the elements themselves. This was found true with respect to both earthquake and fire hazards. This same notion also characterizes other applications of the scientific method to building design as well. Unless some sort of generalized way of coping with operations involving the positioning and relating of building elements in building regulations on a consistent basis can be developed, it is doubtful if there will ever be anything but an uneasy situation existing between the building regulatory mechanism and research groups. The best strategy for accomplishing this end currently seems to be the adoption of measures that are based on the effects of a phenomenon such as an earthquake hazard on the occupants of a building, the activities therein and/or the physical property itself, rather than dealing with measures related directly to the phenomenon itself. It is evident that the type of bases suggested thus far, e.g., risk measures, are necessarily fairly abstract and tend to lean more to the subjective rather than objective side than is perhaps defensible for incorporation into code documents that are of necessity attempting to specify goals against which the attributes of a physical system can be confidently measured. Even if the measures form only the basis of possible provisions rather than the actual provisions themselves, the question of confidence and subjectivity still arises. Perhaps middle ground measures can be determined, but the nature of such measures is currently unclear.

The conceptual difficulties involved in developing consistent measures for all hazard related provisions almost pall, however, in comparison with the questions of implementation. In the first place, it is evident that the levels of technical development in different hazard research areas is very different, although their final aspiration levels may be similar. The difficult question, therefore, exists of whether or not to surge ahead in some of the more developed areas--with the implicit dangers of a piecemeal approach--or to await (but not necessarily idly) until all hazard-related methodologies are at comparable levels of development, and then attempt to establish a code basis that is consistently applicable to all methodologies. There are obviously relative advantages and disadvantages to both approaches.

It is suggested that a highly beneficial contribution that could be made by governments or private funding agencies with the intent of supporting innovation in building regulations as to sponsor research designed to bring about a parity in the levels of technical expertise present with respect to all building hazards instead of concentrating on selected hazards.

A more pragmatic implementation question is the fact that, as the technical sophistication of codes increase in response to increasingly sophisticated design methodologies, the sophistication of those also increase. This conflict cannot be easily resolved. The related point that not all code controlled buildings necessarily involve professional engineers in their design, nor should they, is also relevant. A dual format code structure was tentatively suggested.

A point of obvious struggle that tends to underlie some of the problems outlined above is that the building regulatory system is a manifestation of a socio-political decision rather than that of a scientific discipline.

Promulgating, maintaining and enforcing building codes are governmental and hence political acts. Not recognizing this elementary principle is an error made surprisingly often by individuals in both the building code field and scientific research domains. The error can be disastrous, since it is only by recognizing this elenemtal principle and following the lines of inquiry suggested by it that there is hope that a more supportive relationship between building control mechanisms and scientific methodologies can ever be developed.

Since building codes are political acts, they are also ultimately societal acts. It is fundamental that society has the option of pursuing approaches to its own well-being other than those we now have or which are suggested by interest groups. It could be maintained, for example, that the rush to impose the values of the scientific community on the buliding code and hence society is not necessarily any better in terms of the larger collective societal good than are values imposed by special interest groups such as trade unions. Perhaps the strongest position that the scientific community has in this respect is not necessarily one of the logic of their methods, but simply that it appears that their methods are a surer way of contributing to the collective good in the domains of health and safety than are the methods of other biased interest groups. That this is true, however, is not always as convincingly demonstrated as it should be. Too often changes are suggested that are apparently based only on the firm conviction that science must be right and nothing else. An obligation exists not only on the part of building code officials to demonstrate that changes made are in the service of the collective good, but with the proponents of change as well.

In any event society does have the right to choose its own course in how it wishes to protect itself from building hazards even if the methods chosen are radically different from those we either now have or that are suggested by the scientific community. A role that remains surprisingly unexplored for both the leaders of the building regulatory mechanism and the larger research community (not necessarily just the scientific community) should be to suggest, monitor and evaluate all of the options available to society in a much more extended socio-political context than is currently considered, so that society can indeed make informed choices about its own course of action.

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RESPONSE TO BUILDING INNOVATION BY BUILDING CODES AND REGULATIONS

by

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The major U.S. building codes are updated intermittently (e.g., MPS issues updates as they are processed, BOCA issues supplements annually, etc.). The States and other regulatory bodies which adopt these codes do so sometime after the updates are issued. The result is that there is a considerable time span for the process of: recognition of the need for a code change; adoption of the code change; revision of the code; adoption of the revision by regulatory bodies; and implementation of the revision.

Innovations in the building industry, however, are constantly occurring, and there is frequently no allowance in the language of codes or in their interpretation for items not specifically identified.

The position of the author is that building codes and regulatory agencies must be more responsive to innovative materials and methods in order to foster, rather than hinder, improvements and efficiencies in the building process.

Key Words: Building codes; code changes; incentives; innovations; log homes; minimum property standards; model code agencies; regulations.

INTRODUCTION

The major U. S. building codes are updated intermittently (e.g., MPS issues updates as they are processed, BOCA issues supplements annually, etc.). The states and other regulatory bodies which adopt these codes do so some time after the updates are issued. The result is that there is a considerable time span for the process of: recognition of the need for a code change; adoption of the code change; revision of the code; adoption of the revision by regulatory bodies; and implementation of the revision.

Innovations in the building industry, however, are constantly occurring; and there is frequently no allowance in the language of codes or in their interpretation, for items not specifically identified.

THE POSITION OF THE AUTHOR IS THAT BUILDING CODES AND REGULATORY AGENCIES MUST BE MORE RESPONSIVE TO INNOVATIVE MATERIALS AND METHODS IN ORDER TO FOSTER, RATHER THAN HINDER, IMPROVEMENTS AND EFFICIENCIES IN THE BUILDING PROCESS.

The following four case studies are cited as examples where innovations in the building process have been both fostered and hindered.

CASE STUDY 1: F.H.A. MINIMUM PROPERTY STANDARDS

1. Background

A mid-West manufacturer of mobile homes and modular homes in early 1977 submitted a group of its homes to the F.H.A. for Structural Engineering Bulletin suitability.

The applicable standard was the HUD Minimum Property Standards for One and Two Family Dwellings, 1973 Edition with supplements.

2. The Innovation

The home manufacturer had developed a technique whereby drywall ceilings were glued to the underside of ceiling trusses rather than being nailed or stapled in the conventional way.

The drywall was laid face down on a horizontal jig and the assembly of roof trusses was placed on top of the drywall sheets. A jet of liquid urethane was squirted at the intersection of the drywall surface and the truss-bottom-chord's face perpendicular to it. Within a few seconds the urethane foamed up and formed a rigid weld fillet which firmly held the drywall to the trees. Figure 1 indicates this detail.

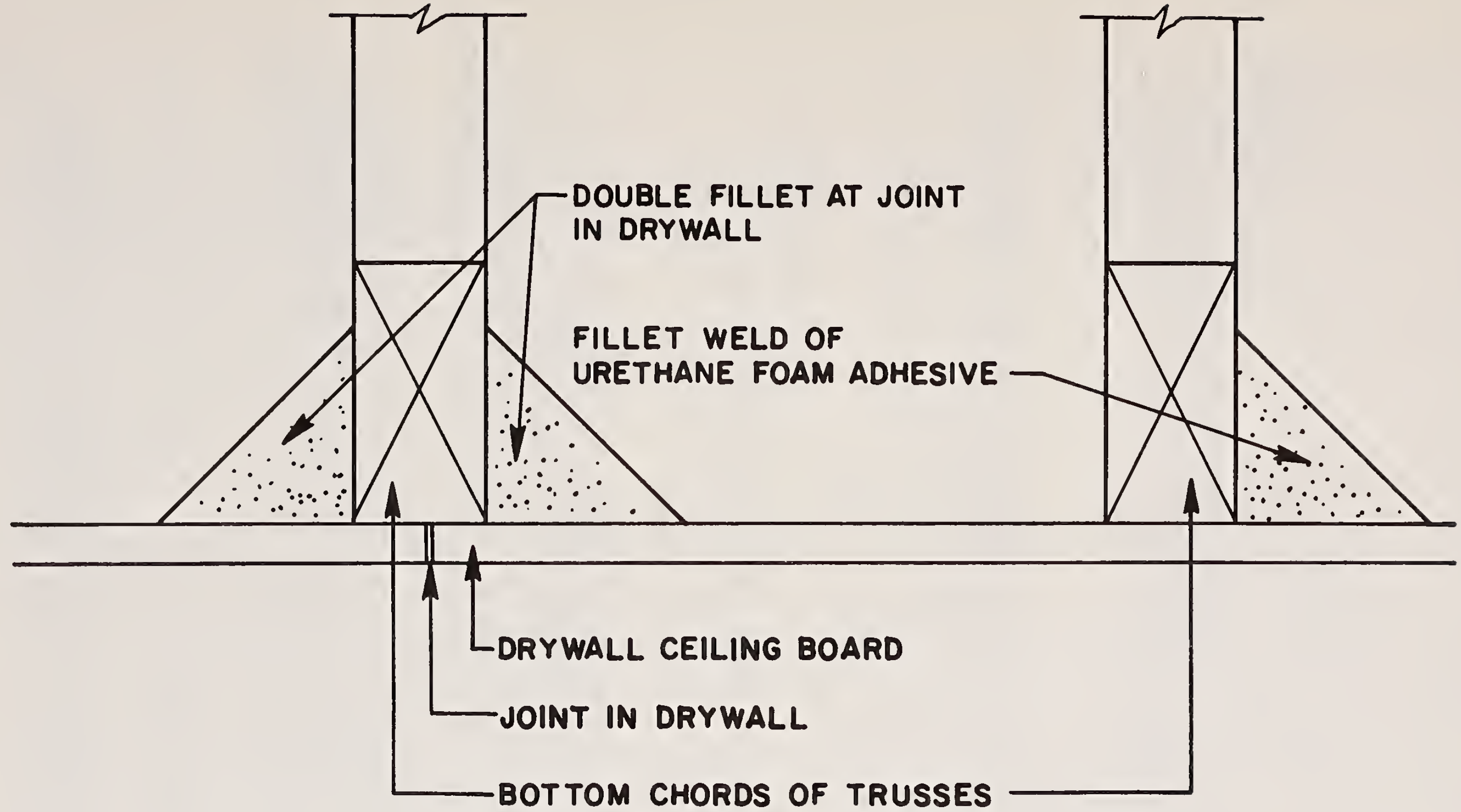


Figure 1: Detail of connection of roof truss to drywall ceiling using urethane foam

By this technique spackle-and-tape operations were greatly reduced, fastener penetration of drywall was eliminated, there were significant savings in time, materials and labor, and the integrity of the ceiling surface was maintained.

3. The Code

The Code did not specifically allow the use of adhesives in ceiling applications, although the Code does state that "These standards are intended to encourage the use of new or innovative technologies, methods or materials. ... Alternatives, nonconventional or innovative methods and materials shall demonstrate, however, equivalent quality to these standards in structural soundness, durability, economy of maintenance or operation and usability."

4. The Justification

The home manufacturer undertook extensive tests on the process and additionally arranged for outside agencies to undertake tests, including the following:

a. Underwriters Laboratories, Inc.:

1. Shear Resistance Tests for Ceiling Boards, UL1296

2. Aging and Temperature Cycle Tests on Foam.

b. Pittsburgh Testing Laboratory:

1. Shear Resistance Tests for Ceiling Boards, UL1296.

The structural tests met all requirements; the aging tests were still in process at time of writing but had retained an average of 94% of original strength in all tests, with the lowest reading being at 81% of original strength in the 20-year equivalency test.

These properties were adequate for the technique to be accepted for use in mobile homes under HUD/FHA Mobile Home Construction and Safety Standards and it was argued that although these differed substantially from the MPS, it was an indication of acceptance of the technique.

5. Rejection of Technique

The Architecture and Engineering Division of FHA rejected the technique and stated that conformance to the MPS was required, adding that:

"If you wish to use a new method of attachment for such a widely used product as drywall, we suggest that you secure: (1) acceptance of the method by industry and by the model codes, and (2) inclusion of the method in the American National Standards Institute (ANSI) Specification A 97.1. We will then be in position to consider the suitability of the method for use under HUD/FHA housing programs."

6. Conclusions

It is not clear whether the FHA action was in keeping with the code intent to "encourage the use of innovative methods," nor is it clear if the FHA instruction to secure acceptance by other bodies was a valid requirement to determine equivalency to MPS standards.

It does seem, however, that the home manufacturer did exhaust many if not all avenues of actual materials testing procedures and that it might have been incumbent upon FHA to:

a. Accept these test results as proof of equivalency to MPS standards, or

b. Suggest alternate or additional tests which would prove equivalency.

Suggesting acceptance by other agencies as a basis for consideration for acceptance by FHA appears to be more of a hindrance than a help to the innovative technique.

CASE STUDY 2: UNIFORM BUILDING CODE/ CORPS OF ENGINEERS STANDARDS

1. Background

In 1973 the U. S. Army Corps of Engineers administered the procurement of housing under the U. S. Air Force Industrialized Construction Program. The procurement included the delivery of relocatable modular dormitory buildings to house 1,188 men at Air Force bases in Delaware, Virginia and Florida.

The modular dormitory units, similar to motel units, were produced by a manufacturer in upstate New York. The modules were built with a frame of light-gage steel studs, joists and rafters, to which plywood and drywall sheathing were glued and fastened.

The applicable standard was a performance specification issued by the Corps of Engineers, which included references to the Uniform Building Code, 1970 Edition, as well as to publications of the American Institute of Steel Construction.

Figure 2: Air Force housing module. Sidewalls have sheathing only on inner face of steel studs.

Figure 3: Structural testing of 8 ft. x 8 ft. sample of load-bearing sidewall.

2. <u>The Innovation</u>

The manufacturer had determined, based on advice from architectural/engineering consultants, that the walls of his modules were remarkably strong due to steel studs with sheathing both sides and due to doubling up of walls as modules were placed side by side.

The manufacturer decided to eliminate the outer skin of sheathing from each of the side walls, such that the steel studs had sheathing of 5/8" drywall on one side only. Tests and calculations by the manufacturer verified that this technique maintained the structural integrity of the units.

This technique resulted in savings of approximately 240,000 sq.ft. of plywood sheathing. Due to the Value Engineering clause of the contract, both the manufacturer and the Air Force stood to benefit from the innovation.

3. <u>The Code</u>

Neither the specifications nor any of the referenced codes or publications dealt with the use of light-gage steel studs which had sheathing other than on both sides. Related literature, journals and text books were researched but there was no basis on which the Corps could approve the structural analysis presented by the manufacturer and his consultants.

4. <u>The Justification</u>

The Corps agreed to a testing program in which 8 ft. x 8 ft. sections of wall were subjected to shear/racking and aerial loading tests. Figure 3 shows the test sample under load.

The tests were completed in a timely manner, according to applicable ASTM procedures and witnessed by the Corps.

5. <u>Acceptance of Technique</u>

Despite the lack of precedent or reference, the Corps approved the procedure without interrupting the construction schedule.

6. <u>Conclusions</u>

Here was an instance of a highly structured organization, with extremely complex codes, standards and procedures, the U. S. Army, moving with due speed to evaluate and approve an innovative building technique which resulted in tangible benefits to both the manufacturer and the Government.

This procedure clearly fostered improvement and efficiency in the building process.

CASE STUDY 3: BOCA BASIC BUILDING CODE

1. Background

A number of East Coast States have adopted the BOCA Basic Building Code as a statewide standard to which all factory produced homes must comply. Compliance is usually monitored by inspection of components and procedures inside the manufactorers' facilities by independent third party inspection agencies. The intent is that all aspects of the house not able to be inspected on the site due to their being hidden from view are inspected at the plant after installation but prior to being hidden.

Conventional construction in these same States sometimes falls within different code jurisdictions, depending on the statutes in force in the local town or county. In any event, all conventional construction is theoretically inspectable at the site and none of the independent inspection agency requirements apply.

This case study focuses on a hybrid situation, a manufacturer who precuts components in a factory after which they are assembled on-site, and who maintains that everything is inspectable at the site.

2. The Innovation

The manufacturer produces precut post and beam components which are assembled on site. To this structural frame are attached pre-assembled panels consisting of sheathing on both sides of a core of urethane foam, see Figure 4. The panels are not load bearing except for their own weight and for local loads; they contain no electrical, plumbing or other services or inserts. The panels do provide the wall insulation and the interior and exterior finish.

3. The Problem

It appears that in some BOCA code jurisdictions, building officials are considering whether they should impose a requirement on the manufacturer to undergo independent third party inspection of his panel production.

Their argument is that the insulation is factory installed and not able to be inspected on site.

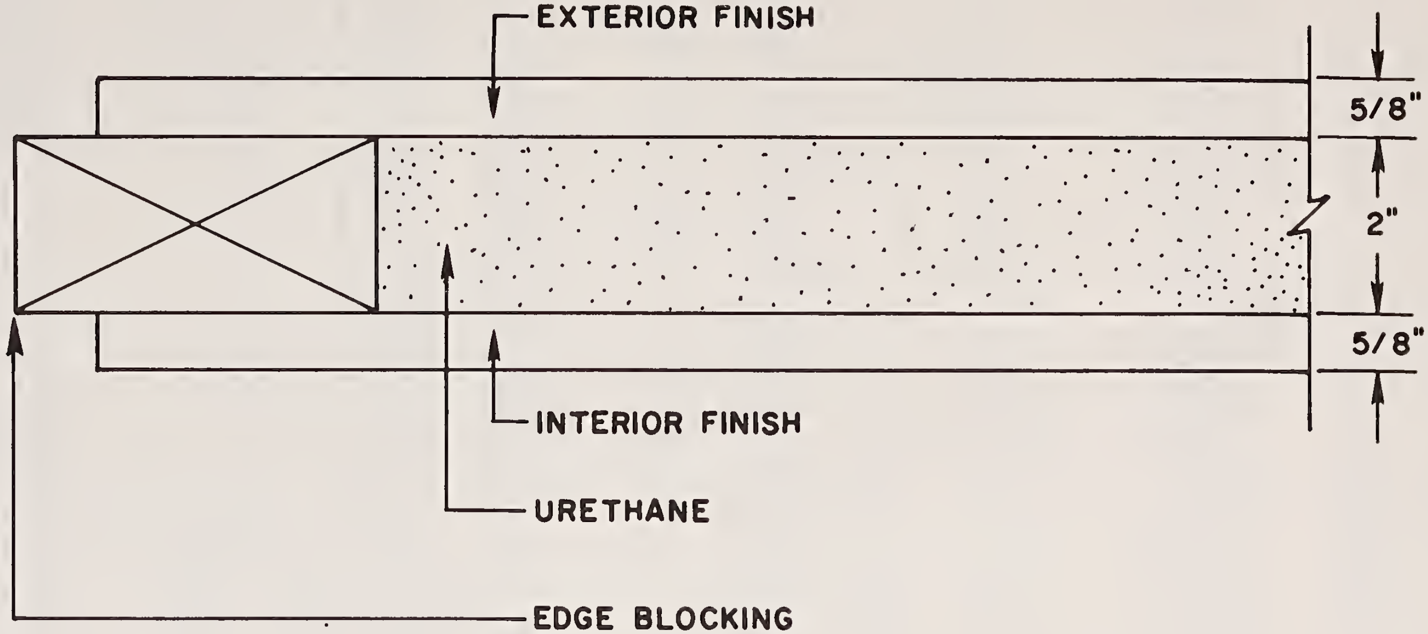


Figure 4: Section through foam core wall panel

The manufacturer argues that his panel is a pre-cut non-load bearing panel and, like an insulated entrance door, should be allowed to come to the site without undergoing an inspection program. The manufacturer has undertaken structural and heat loss tests of his panel and has received BOCA approval for it as a component.

The matter is still not resolved. However, if forced to incorporate a third party inspection program into his operations, the manufacturer will probably abandon his process and laminate one skin of his panel onto the core at the site, thus exposing the insulation to view.

4. Conclusion

In this case the enforcement agency rather than the code itself, is at the center of the dilemma. The manufacturers' situation falls into a grey area and it is not clear as to whether he is or is not hiding components from the on-site building inspector's view.

Whatever the outcome, it is hoped that the enforcement agency will find a way to approve the manufacturers' system such as to assist in the incorporation of innovative techniques.

CASE STUDY 4: CODE ASPECTS OF LOG HOME CONSTRUCTION

1. Background

Log homes were introduced to the United States in 1638 and have been an inherent backdrop to the development of this country's history.

In recent years, there has been a resurgence of activity in the construction of log homes. Many of these are produced by factory pre-cut techniques and the most advanced engineering and production methods.

Despite its place in history, this construction technique has recently encountered problem areas with a number of building codes and standards.

2. The Problem

The major problem has been in the area of energy insulation. Many energy insulation standards have been promulgated in the past two years, some of them prescriptive but most performance oriented, such as the highly effective ASHRAE 90-75.

The New York State Public Service Commission, for example, issued its Energy Insulation Standards to become effective April 1, 1977. These included a requirement for a maximum wall U-value of .07 (or R = 14.29), but allowed for compensatory insulation such that any deficiency in the wall could be compensated for by insulation in excess of the minimum in other house components, such as roof, floor and openings.

None of the eight producers of log homes whose wall insulation values we have analyzed (see Tables 1 and 2) meet the P.S.C. requirement; all have to compensate in other areas, resulting in very heavily insulated roofs, floors, etc.

The Farmers Home Administration on March 21, 1977, issued its proposed rules on Insulation Standards. These were prescriptive standards calling for maximum wall U-values of .05 (or R = 20), which no log home producer could meet with current construction techniques.

Yet in actual energy usage, tabulations and energy loss tests, log homes perform far better than the calculations say they should, generally by a factor of some 25 percent.

This wide discrepancy between calculated and actual heat losses has long been acknowledged by engineers, but not fully identified; nor qualified, and never fully considered, in building codes.

Even the most thorough building codes only list partial requirements:

a. Heat conductance by virtue of U-values.

b. Convection losses through infiltration.

But there are other, important criteria whereby heat is lost or not lost in homes, and specifically in log homes.

a. There is a mass factor inherent in solid logs. This factor reduces heat loss due to the bulk of the material and is evident in brick, stone and concrete walls.

b. Log walls have surface shape and texture which absorb and re-radiate heat from both the sun and from internal heat sources. This "heat retention" or "resistivity" quality is clearly evident when you touch a log wall on a winter night, but is not presently qualified in any codes or standards.

c. Solid wood walls do not contain any insulation other than their own, highly effective, insulative values. Therefore, there is no possibility of breakdown of insulation performance due to moisture penetration, dust saturation, material settling, non-filling of insulatable space, or other construction defects.

TABLE 1

CALCULATION FOR THERMAL CONDUCTIVITY AND RESISTANCE / INCH FOR VARIOUS WOOD SPECIES:

NOTE:
STD TEXT, ASHRAE HANDBOOK OF FUNDAMENTALS, 1972, TABLE 3, "PROPERTIES OF SOLIDS" (INCLUDING THERMAL CONDUCTIVITY OF WOOD) p 570-572, DRAWS ITS DATA FROM F.P.L.'s WOOD HANDBOOK (FOOTNOTE Z, P. 571)

USING AS PRIMARY REFERENCE, THEN:
FOREST PRODUCTS LABORATORIES, WOOD HANDBOOK, U.S.D.A. HANDBOOK No 72, 1975 EDITION:

CALCULATE THERMAL CONDUCTIVITY (K) ACCORDING TO THE EQUATION: (p. 3-19)

$$K = S(1.39 + 0.028\,M) + 0.165 = \text{BTU} \cdot \text{IN} / \text{HR} \cdot {}^\circ\text{F} \cdot \text{SF}$$

WHERE K = THERMAL CONDUCTIVITY OF SPECIFIC WOOD SPECIES
S = SPECIFIC GRAVITY OF WOOD SPECIES
M = MOISTURE CONTENT IN PERCENT

MOISTURE CONTENT FOR NORTHERN STATES (INTERIOR USE) $M = .08$ (p. 14-5); FOR EXTERIOR USE, ACCORDING TO STATE OF OHIO SPECIFICATION, $M = .16$; OTHER STATES, $M = .12$. IN WINTER, HOWEVER, EXTERIOR WOOD MOISTURE CONTENT RETURNS TO APPROXIMATELY 8%. IN THE FOLLOWING CALCULATIONS, VALUES FOR SPECIFIC GRAVITY ARE TAKEN FROM TABLE 4-7, p. 4-24. VALUES IN TABLE 4-2, p. 4-13 HAVE ALSO BEEN REVIEWED.

A. EASTERN WHITE PINE:
- $M = 8.0$ (INTERIOR)
  $S = .335$
  $K = .335(1.39 + 0.028(8.0)) + 0.165 = 0.706$
  $R_1 = 1/K = 1.417$ / INCH
- $M = 16.0$ (EXTERIOR)
  $S = .345$
  $K = .345(1.39 + 0.028(16.0)) + 0.165 = 0.799$
  $R_1 = 1/K = 1.251$ / INCH

B RED PINE & SPRUCE PINE
- $M = 8.0$ (INTERIOR)
  $S = .41$
  $K = .41(1.39 + 0.028(8.0)) + 0.165 = 0.827$
  $R_1 = 1/K = 1.210$ / INCH
- $M = 16$ (EXTERIOR)
  $S = .44(1.39 + 0.028(16.)) + 0.165 = 0.974$
  $R_1 = 1/K = 1.027$ / INCH

C. LODGEPOLE PINE, PONDEROSA PINE

- M = 8.0
  S = .39
  K = .39(1.39 + .028(8.0)) + .165 = .794
  R_1 = 1/K = 1.259/INCH
- M = 16.0
  S = .44
  K = .44(1.39 + .028(16.0)) + .165 = .974
  R_1 = 1/K = 1.027 /INCH

D SOUTHERN PINES: AVERAGE
(LOBOLLY, LONGLEAF, SHORTLEAF, SLASH, VIRGINIA, POND)

- M = 8.0
  S = .47
  K = .47(1.39 + .028(8.0)) + .165 = .924
  R_1 = 1.083/INCH
- M = 16.0
  S = .53
  K = .53(1.39 + .028(16.0)) + .165 = 1.139
  R_1 = 1/K = 0.878 /INCH

E. ATLANTIC WHITE CEDAR:

- M = 8.0
  S = .315
  K = .315(1.39 + .028(8.0)) + .165 = .673
  R_1 = 1.485/INCH
- M = 16.0
  S = .325
  K = .325(1.39 + .028(16.0)) + .165 = .762
  R_1 = 1.312/INCH

F. EASTERN RED CEDAR:

- M = 8.0
  S = .45
  K = .45(1.39 + .028(8.0)) + .165 = .891
  R_1 = 1.122 /INCH
- M = 16.0
  S = .48
  K = .48(1.39 + .028(16.0)) + .165 = 1.047
  R_1 = 0.955 /INCH

G NORTHERN WHITE CEDAR

- M = 8.0
  S = .30
  K = .30(1.39 + .028(8.0)) + .165 = .649
  R_1 = 1.540/INCH
- M = 16.0
  S = .32
  K = .32(1.39 + .028(16)) + .165 = .753
  R_1 = 1.328 /INCH

H. SPRUCE

- M = 8.0

  S = .34

  $K = .34(1.39 + 0.028(8.0)) + 0.165 = 0.714$

  $R_1 = 1/K = 1.401$

- M = 16.0 (EXTERIOR)

  S = .35

  $K = .35(1.39 + 0.028(16.0)) + 0.165 = 0.808$

  $R_1 = 1/K = 1.237$

I. HEMLOCK

- M = 8.0

  S = .41

  $K = .41(1.39 + 0.028(8.0)) + 0.165 = 0.827$

  $R_1 = 1/K = 1.209$

- M = 16.0 (EXTERIOR)

  S = .42

  $K = .42(1.39 + 0.028(16.0)) + 0.165 = 0.937$

  $R_1 = 1/K = 1.067$

TABLE 2

LOG MANUFACTURER WALL DETAILS:

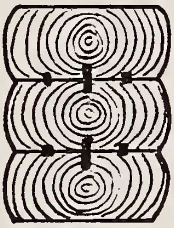
A. VERMONT LOG BUILDINGS, INC.

MINIMUM AVERAGE
WALL THICKNESS = 7.4"

(EASTERN WHITE PINE)

AT M = 8
R_1 = 1.417 /INCH
R_{TOTAL} = 11.34 ANS.
(PLUS AIR FILM)*
AT M = 16
R_1 = 1.251 /INCH
R_{TOTAL} = 10.11 ANS.
(PLUS AIR FILM)*

B. NEW ENGLAND LOG HOMES, INC.

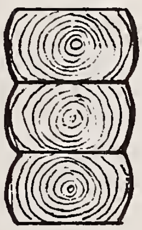


AVE. THICKNESS = 9.69"

(RED PINE)

AT M = 8
R_1 = 1.210 /INCH
R_{TOTAL} = 12.57 ANS.
(PLUS AIR FILM)*
AT M = 16
R_1 = 1.027 /INCH
R_{TOTAL} = 10.80 ANS.
(PLUS AIR FILM)*

C. AUTHENTIC HOMES CORP.



MIN AVERAGE
THICKNESS = 7.61"

(LODGEPOLE PINE)

AT M = 8
R_1 = 1.259 /INCH
R_{TOTAL} = 10.43 ANS.
(PLUS AIR FILM)*
AT M = 16
R_1 = 1.027 /INCH
R_{TOTAL} = 8.67 ANS.
(PLUS AIR FILM)*

* AIR FILM VALUES USED IN CALCULATION:
INTERIOR SURFACE: R = 0.68
EXTERIOR SURFACE: R = 0.17

D. ALTA INDUSTRIES, LTD.

MIN AVERAGE THICKNESS = 4.75"

(EASTERN WHITE PINE)

AT M = 8
R_1 = 1.417 /INCH
R_{TOTAL} = 7.58
(PLUS AIR FILM)
AT M = 16
R_1 = 1.251
R_{TOTAL} = 6.79
(PLUS AIR FILM)

E NORTHEASTERN LOG HOMES

AVERAGE THICKNESS = 5.27"

(EASTERN WHITE PINE)

AT M = 8
R_1 = 1.417 /INCH
R_{TOTAL} = 8.32
(PLUS AIR FILM)
AT M = 16
R_1 = 1.251 /INCH
R_{TOTAL} = 7.44
(PLUS AIR FILM)

d. Solid log walls make use of surface and baseboard electric and utility raceways and outlets. So, there are no electric outlets, junction boxes, etc., which penetrate the wall. These penetrations have been responsible for about 20% of the heat loss due to infiltration which itself is responsible for 25-40% of all heat loss in framed homes.

e. Most calculations assume that the outdoor temperature, -20°F or whatever it is, is constant during the whole day. This, of course, is not so. Moreover, the interior need for heat fluctuates widely over a 24-hour period.

   The resulting temperature gradient between interior and exterior is a totally different picture from the one suggested by constant U-value requirements.

   In other words, it might be that a home needs a wall factor of:

   R - 16 for 1 hour a day
   R - 10 for 8 hours a day, and
   R - 4 for 15 hours a day.

   And we suggest that the optimum value should be the goal, not the maximum value.

f. And a number of unanswered, unresolved phenomena, none of which are identified in insulation standards in most building codes.

3. Conclusion

In this instance it appears incumbent upon the Log Home industry to develop a program to research, develop and gain approval for evaluation procedures to more accurately ascertain the true thermal performance of log homes. Ultimately it will be the code promulgating agencies' position to approve these procedures and it is hoped that this "re-innovative" building technique will not be hindered by such approvals.

CONCLUSIONS

Building code agencies and their personnel can be responsive to innovations in building but are frequently not so.

I believe that a key reason is that there are no incentives for an agency inspector or engineer to stick his neck out by approving an innovative technique. Nobody was ever fired for rejecting an application for approval of a new product "subject to receipt of additional data." One can always find an additional item to require.

The degree to which innovations are evaluated is becoming more complex and the thorough evaluation of new techniques is usually fully justified. And indications are that things are not too bad after all. New products and techniques <u>are</u> being approved even if they are not being approved as quickly as some people would like.

In a world economy based on finite resources, innovation is not optional. It is imperative. Building codes and regulatory agencies must be highly responsive to such innovations in order to play their part in the improvement of the building process.

A CONSULTING ENGINEER'S VIEW OF BUILDING CODE PROCESS FROM CONCEPTION TO ADOPTION

by

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The author has been attending the meetings of the model code groups for the past several years. During that time period, he has observed the process, noted the changes that are taking place in the process, identified forces responsible for the changes, analyzed the problems and has formulated possible areas to refine, streamline and be more efficient in the building code promulgation process.

The paper will present the building code process from the standpoint of the designers and engineers who must work with its provisions. The paper will show a significant trend in the past few years that is complicating the process. This includes more code changes, more complex code changes, expansion of the codes into more areas of control, and attempts to keep pace with the plethora of new products, devices and designs flooding the building materials market.

Key Words: Building codes, due process; legislation; model codes; promulgation; regulatory process; standards development.

INTRODUCTION

Laws and Regulations have become as American as apple pie. As this country's standard of living has increased, so has the amount and complexity of rules and regulations. The building code regulatory process is part of this evolution. It has not been that many years since building code provisions necessary to assure public safety and welfare were a succinct set of prescriptive rules that were easily formulated and understood. But that is ancient history and we are concerned with today and tomorrow.

The times are changing and the model building code groups must adapt to avoid obsolescence or outside legislative regulation. One indication of this is the proposed Senate Bill 825 which is entitled the "Voluntary Standards and Accreditation Act." If passed, the federal government will be directly involved in the supervision of voluntary standards development through the Federal Trade Commission and a new agency, the National Standards Management Board. The current privilege of promulgating concensus model codes would be tightly controlled by Washington.

This paper discusses three basic topics. First, the present model building code promulgating process has not adapted itself to cope with the changing technical and sociological atmosphere in which it operates. Second, the process as currently operating does not adequately represent due process, or public exposure. Third, possible alterations to the code process will be presented which could help to alleviate the problems discussed. While not totally encompassing or collectively exhaustive, these procedural changes are indicative of the possible changes that could be implemented.

These three topics will be from my point of view as a consulting engineer specializing in fire safety and building code related subjects assisting architects and engineers on building design and construction. Because of our business, we are active participants in the building code promulgating and regulatory process and have observed changes taking place and their consequent effects.

THE CODES ARE EXPANDING

Prior to addressing any issue, it is necessary to identify the magnitude of the situation. Based on the number of printed words, Figure 1 graphically depicts the growth in the Uniform Building Code since 1970.

Also based on the number of words, the 1977 supplement to the UBC (which covers a one year period) is 76% the size of the 1975 Accumulative supplement (which covered 2 years).

On the average, the 1977 changes are 52% more than either the 1974 or 1975 changes. Therefore, not only are the codes getting larger, the number of approved changes each year is expanding.

GROWTH IN THE UNIFORM BUILDING CODE

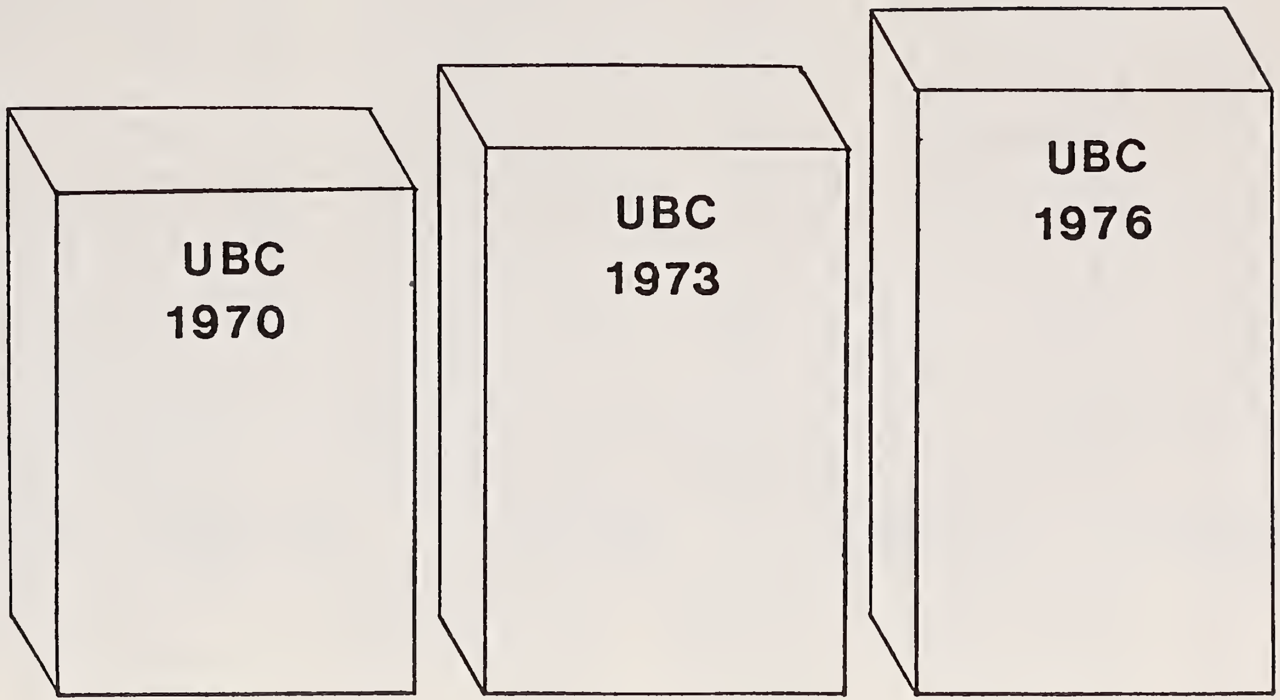

FIGURE 1

Obviously, not all changes submitted for consideration are approved. The number of changes submitted to the BOCA Basic Building Code for each of the past 6 years is shown in Figure 2. The number of changes in this short period has tripled.

The Standard Building Code of the SBCC in 1976 had 214 changes submitted compared to 250 in 1977. This is a 20% increase in one year.

In each of the three model building code groups, the committees charged with making recommendations for approval, disapproval or further study must analyze each change and hold open hearings to discuss each and every submission. With more changes being submitted each year, the committee members must devote more time to this voluntary effort or each item must receive less attention. In all likelihood, some or each has occurred; but with continuing increased workloads, it is likely that less attention will be given to each item. This is undesirable.

Of the 1977 submissions to BOCA, there are 11 different submissions to Section 431, 13 to Section 616, 14 to Section 1202 and 14 to Section 2102. In addition to considering each, the various proposals need correlation to remove duplication, compatibility, and preferred wording. This translates into either more time or less attention to detail.

The 1977 submissions to BOCA contain 50 new items for inclusion into the Basic Code, while there are only 27 items for deletion without substitution; almost a two to one ratio. This shows a widening in the scope of building codes. Examples of totally new items introduced into the model building codes since 1973 include provisions for high-rise buildings, foamed plastic insulation, energy use, handicapped access and egress and historic buildings. It should be obvious that the task of creating, reviewing and modifying a building code is becoming more time consuming, more complicated and more difficult.

RECENT CHANGES IN THE PROCESS

How have the model code groups handled the additional and more complicated work load? One method that has been utilized by BOCA and ICBO is the "consent calendar." By this method, once an item has been recommended for approval, disapproval or further study by the main code changes committee, the item is not debatable at the annual meeting unless specifically challenged in writing by a specified date. This frees time at the annual meeting for discussion of items that individuals or groups feel is of extreme importance, and need additional consideration before action is formalized. This process helps to expedite the proceedings at the annual meeting, but does not alleviate the committees or subcommittees work load.

Committees and subcommittees have been experiencing the work expansion that we have discussed. This has forced more meetings into

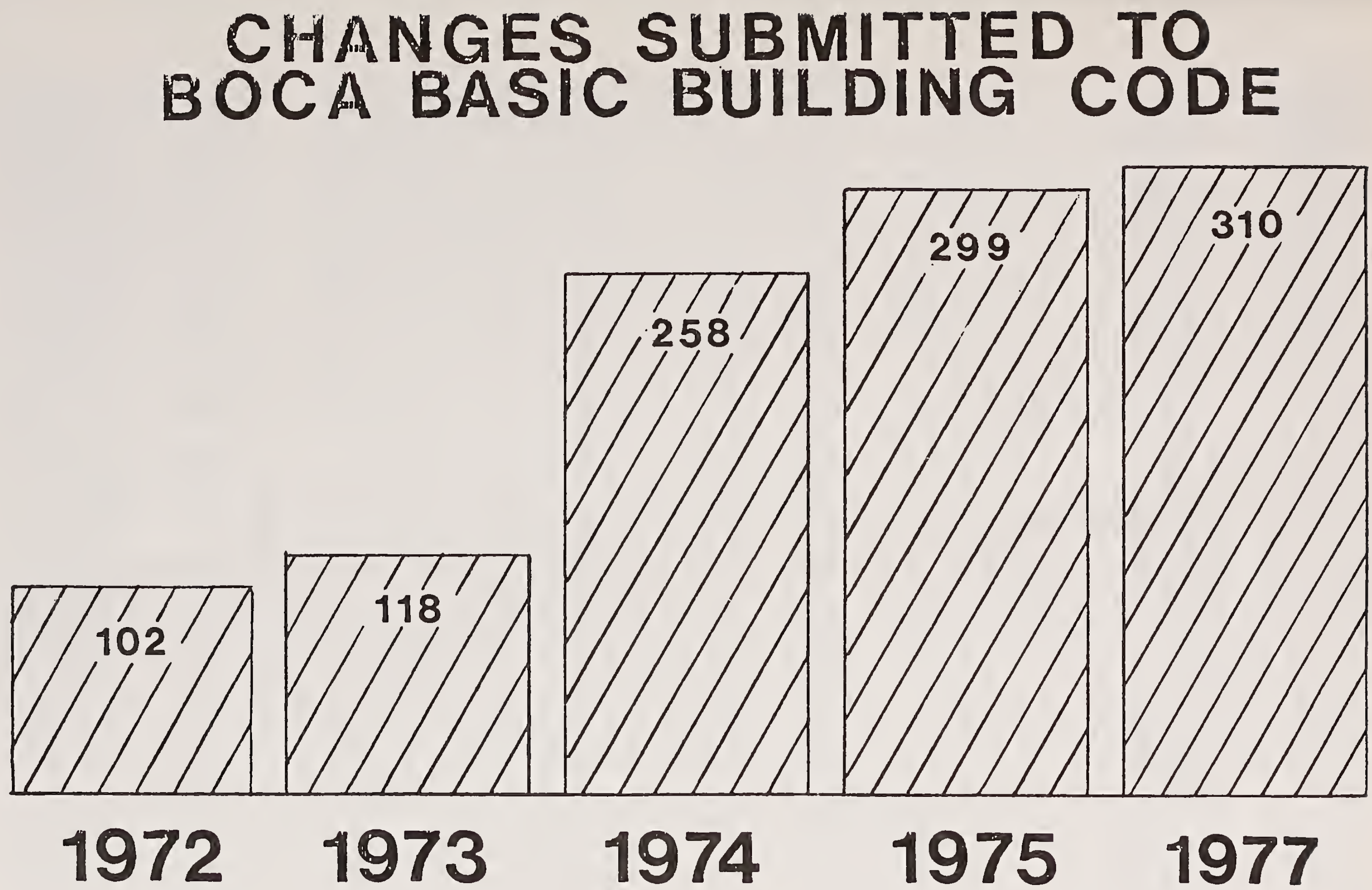
CHANGES SUBMITTED TO
BOCA BASIC BUILDING CODE
102
118
258
299
310
1972
1973
1974
1975
1977

FIGURE 2

longer duration and into evenings. The devotion of more and more time to the code process has an upper limit. The costs of attending more and longer meetings can become an unbearable expense. These expenses do not only include the costs of transportation, lodging and meals; but also the cost of time, which is the most precious.

Since proposed code changes are multiplying and expanding in both breadth and depth, additional ad hoc and subcommittees are being formed to handle the added burden. This entails even more meetings and results in more time and expense to the members and other attendees.

WEAKNESSES IN THE SYSTEM

Thus far, we have addressed only the external forces that have complicated and compromised the model building code promulgation process. As a regular participant at model code group meetings, I have observed many internal forces that have contributed to the present situation.

In all of the meetings, agenda items are discussed in the order in which they would appear in the code. With human nature what it is, early items receive a considerable degree of discussion and items from the later chapters are often rushed through without adequate discussion and consideration. Every chapter and section of a building code is important and each submission needs due process, public exposure and deliberation.

Another human foible is the "more is better syndrome." It works like this; if one additional exit is good, two is undoubtedly better. The problem with this philosophy is that it ignores the harsh reality that the designer and owner must recognize--that extras cost more money and this cost must be evaluated based on the utility or need of the item. There have been many code officials who have told me that economics do not count and that the code is written to safeguard the public. This is only partially true. The code is written to insure public safety by establishing minimum performance or specification as stated in each of the model code documents. The codes are not directed towards prescribing or establishing the ultimate. With building costs escalating ever upward, the code making groups must consider all proposed changes from a cost-benefit standpoint and only approve those changes that are really necessary to insure an acceptable level of safety. The code making process should not isolate itself in a vacuum while ignoring the impact on the design and construction industry. The codes are prepared to regulate building construction and should always recognize the impact of any code provision.

With the building codes becoming more complex and detailed, it is desirable to have groups and individuals with expertise on all specific issues participate in the process. The entire procedure has become too elaborate for generalists. It is impossible for any single individual to be fully informed on every topic that is part of the code. However, the committees do not always appear to be formed from their expertise on the subject. Often, committee members are forced to make a decision on items they really cannot fully analyze. It is cumbersome to educate the committee members in order to present a proposed code change. This slows down the process and leads to decisions based on limited subject knowledge.

At present, the only voting members of the model building code groups are building officials. Fire officials are normally excluded from voting; and trade associations, designers, architects, engineers and manufacturers have a voice but no vote. By their respective constitutions, the code groups only represent a concensus of building code officials. Also, each jurisdiction is entitled to one vote and all votes bear equal weight. Therefore, the State of Indiana's vote in ICBO has no more impact than the vote of Kalamazoo, Michigan, or Livermore, California, even though population, number of building permits or value of construction is different by several orders of magnitude. The philosophy of 1 man--1 vote is not followed.

Another situation is the "haves and have nots." The larger and more affluent companies and trade associations can afford the time and expense to devote to the building code making process. Others cannot afford the investment. Consequently, those that can afford the effort are regularly heard and listened to, while the small guy does not have the same opportunity.

It is desirable for trade associations and manufacturers to be present and represented at the code meetings. However, there is a problem. The individuals who represent industry are there for the benefit of their firms or affiliated companies and, therefore, represent vested interests. These representatives are quite knowledgeable to their field, but since they attend the meetings for specific purposes; they obviously present the more favorable view of their employers. It becomes necessary for the committee members to review the data submitted by all parties in the proper perspective. Unless both sides of an issue are properly presented, this can be a difficult task. Industry and trade associations are beginning to realize that their effectiveness is enhanced by a completely objective presentation of the facts. This is partially due to the influences of legal decisions in the area of product liability. While objective presentation approaches the norm, there are still several interests that persist in presenting arguments based on unsupported, distorted or emotional information or on data taken out of context.

POSSIBLE GOVERNMENT REGULATION

Senate Bill 825 makes several contentions. The first is that government must protect the public. This implies that the current model building code system does not. To rebut this argument, it must be shown that the current voluntary code making process, as one of its principle purposes, provides this service. This can only be effectively demonstrated by showing how all aspects of society that are affected by codes and standards, have been included in the decision making process and that the final product--the code or standard--has evolved through democratic due process with the proper checks and balances.

Another allegation is that the system fails to develop needed standards. The model code groups must prove that once a need is identified, the mechanisms are provided to develop the necessary regulatory provisions in a streamlined manner.

The bill also contends that the process includes adverse effects on competition. This can only be refuted by proving that meaningful participation by all affected parties is actively recruited and welcomed in the code groups.

The "findings of fact" in the bill question the due process of the code groups. This issue not only addresses the ability to be listened to, but also that adequate time and thought is given, and that the decisions are made by a representative jury. This indicates that committee membership and voting rights must not be vested exclusively in the enforcing agencies.

The bill states that the code process "can be a means for widespread consumer deception." The best counter-argument is once again to demonstrate the active and meaningful participation of all affected interests.

It is also contended that the "code process poses grave economic hardships for small business concerns." This is a tough one to defend against for any privately funded organization, especially considering the necessity to maintain due process. In essence, the bill is saying that government is the only vehicle available to protect small businesses. To protect small businesses, code making must be streamlined to permit any size firm the opportunity to be equally represented at the decision making levels.

There are other arguments presented in SB 825, but they directly relate to the points that I have enumerated. This legislation did not originate in a vacuum. It was created for many of the reasons that have already been discussed. The prognosis is clear; unless the code making bodies start initiating changes, the government may take over the entire process for the purported purpose of providing protection to the public.

POSSIBLE CHANGES

The need for change has been expressed from the standpoint of internal and external influences to the model code groups as well as the eminent threat of government intervention. The final segment of this treatise will be to identify some possible ways change could be introduced.

The voting procedure could be changed. Instead of a single vote per jurisdiction, the voting by code officials could be based on population, square footage of buildings or some other more equitable base. Voting could be set up for approval or disapproval or an action by the various committees without the ability to amend. Committee membership could be comprised of code officials, fire officials, manufacturers, architects, engineers, consumer groups or other interested representatives; some subcommittees are now. In this manner, committees could be comprised of individuals with specific expertise in the scope of work covered by each committee. Additional committees would have to be formed and some mechanism would have to be provided to appoint committee members. The appointments could also be subject to an approval vote of the code officials. Due to the cost of attending meetings, the voting could be conducted by mail. With the proposed change in the weight of each vote and the difficulties in tabulation, this would be a necessity. The disadvantage would be the inability of some of the members to discuss each committee recommendation in an open forum. Since supporting documentation would have to be provided to each voting member and other interested parties, increased printing and postage costs to the code groups would result.

Another streamlining method would be to place a time limit by which a committee must take affirmative action on a subject. Assuming a two year limit, the committee must recommend approval, approval as revised or disapproval within two years after submission. A recommendation of further study could not be made beyond two years. The problem with this proposal would be the tendency to have a committee recommend disapproval of an item having merit simply because time is expiring. Close control on committee membership, agendas and meeting dates could help alleviate this. In conjunction with this proposal, the committees would discuss proposed changes based on the date of submission and not based on the section of the code. This would need to be tempered when similar changes or related changes are proposed at later dates. The responsibility for the coordination of the agenda items would be by the staff of the code groups.

To insure that the agenda is fully covered in a scheduled meeting time, time limits for arguments could be established. As an example, the proponent of a change could be allotted 10 minutes for presentation with each opponent given 5 minutes. The proponent may then be given 5 minutes for rebuttal. Not more than one individual from any group or jurisdiction could speak on the same item. While time limits of this nature are constraining, they could be instrumental in guaranteeing each submission a respectable hearing.

To limit the expenses involved in attending the various code meetings, "committee weeks" could be scheduled where several committees could meet during the same week. Unrelated committees could meet simultaneously while related committees could meet back to back. By judicious scheduling and preprinted agendas, individuals could attend those portions at each committee that have specific interest. Meeting locations should be as centralized as possible and arranged to provide maximum exposure, not just to be convenient for a single or group of committee members. This would require increased coordination by the staff of the building code groups in scheduling meetings.

There is significant duplication of effort between BOCA, ICBO and SBCC. Efforts have been initiated to consolidate the three groups through the establishment of CABO and BCMC, but increased effort is desirable. As an ultimate goal, the work done in developing three different codes could be combined to establish a single concensus model building code. This could possibly be done by dividing the issues. As an example, ICBO could be given full responsibility for fire suppression and alarm, BOCA could take exiting and SBCC could have full charge of fire resistivity. Through this approach, the duplication of effort could be eliminated and a single nationwide building code could be promulgated without government intervention.

CONCLUSIONS

The pattern is very clear:

- The codes are expanding in breadth and depth.
- The number of proposed changes each year is growing.
- Building design and construction technology is becoming more sophisticated.
- The Federal government is concerned about the objectivity and representative nature of the current system.

The model building code groups have not streamlined their procedures to keep pace with the rapidly changing environment. By their structure, they have excluded many segments of society that should be included in the code process. In other words, there has not been adequate "public exposure." The procedural regulations and qualifications for voting can be challenged as not representing "due process."

These problems are being scrutinized by consumer advocate groups, private individuals and the federal government.

The system that was devised several years ago has become cumbersome and may be non-responsive to the needs of the late 1970's, unless the model building code groups develop change from the inside, it may be forced from the outside.

STANDARDS/CODES FOR ENERGY CONSERVATION IN LIGHTING DESIGN

by

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There is a general agreement on the need to eliminate unnecessary energy use in providing artificial illumination for buildings. However, there is widespread disagreement on the procedure that should be promulgated to achieve that need. This paper suggests a method to evaluate building standards/codes and compares three procedures developed to achieve energy efficient lighting systems. The procedures compared are (1) a standard developed by the Illuminating Engineering Society and published as Section 9 of ASHRAE Standard 90-75; (2) a guideline published by the General Services Administration; and (3) a code being developed by a State building code commission.

Key Words: Artificial illumination; buildings; criteria; energy conservation; energy consumption; environmental design; lighting levels; standards.

There is a general agreement on the need to eliminate unnecessary energy usage in providing artificial illumination for buildings. However, there is widespread disagreement on the procedure* that should be promulgated to achieve that need. This paper suggests a method to evaluate lighting standards/codes and compares three procedures developed to achieve energy efficient lighting systems. The procedures compared are (1) a standard developed by the Illuminating Engineering Society and published as Section 9 of ASHRAE Standard 90-75; (2) a guideline published by the General Services Administration; and (3) a code being developed by a State building code commission.

During the past year most governmental units having regulatory control over building construction have directed their attention to the use of energy in buildings. In many cases they have enacted, or are considering legislation that would result in the reduction of energy use in existing buildings and/or control the design of new buildings so that the potential for energy conservation will be greater.[1] This paper will examine procedures that have been developed to achieve a reduction in the energy used for providing artificial lighting in buildings. In conducting this evaluation, first, a set of criteria will be proposed; secondly, the alternative procedures will be identified; third, the procedures will be examined by the criteria; and finally, a summary and conclusion will be presented. The validity of the comparisons is dependent on the comprehensiveness of the evaluation criteria. Therefore, special attention must be given to the instrument that is suggested for use in the evaluation, for if this instrument is valid, we will have taken a giant step toward selecting the appropriate procedure.

EVALUATION CRITERIA

In establishing a method for evaluation of a procedure, the first test would be to check the universality of the method, i.e., the substratum on which it is built must provide a commonality for evaluating any procedure. It is proposed that the appropriate method would begin with the three rudimentary criteria: effectiveness, propriety, and applicability.

Evaluating the <u>effectiveness</u> of a procedure would determine how successful it will be in achieving the stated objectives. There is no attempt here to determine the validity or comprehensiveness of the objectives. For example, the procedures examined address only the subject of energy consumption and do not relate to the use of resources. The criteria is presented for evaluating a procedure--not the political, moralistic, or technical factors from which it evolved. Further subdivision of effectiveness would include the components energy and power as evaluation criteria.

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* The documents that may be examined are often given different technical names such as standards, guidelines or codes. The term "procedure" will be used in a generic sense to include all of these documents.

A test of the propriety of a procedure would examine how well it addresses the psycho-physiological needs of people. This converts to the basic criteria for examing any environmental design, i.e., does the design address the image, activity, and technology requirements of the environment?

The applicability of a procedure is a most important criteria. If it can be implemented with fairness and consistency without generating significantly negative implications for any of the major members of the building community then, and only then, can an optimistic prognosis be made for the success of the procedure.

Effectiveness

Energy: The energy consumption in buildings begins with the energy consumed in the production of the components that are used to construct the building. Research conducted by Hannon, et al[(2)] has, for example, indicated that the energy embodied in a standard steel system floor bay is 292,723 Btu/SF[(3)], whereas the energy embodied in a reinforced concrete system floor bay is 172,021 Btu/SF[(4)]. Although data on all components is not yet available, a standard should encourage optimum energy embodiment in components.

The basic definition of energy in effect stipulates that to achieve reduced energy consumed in lighting conditions must be imposed to control the time of operation. Available control systems may be classified as manual, semi-automatic, or automatic. Manual control systems are totally dependent on human behavior for operation and are thus unreliable as energy conserving techniques. At the other extreme, automatic controls are usually preprogrammed based on predicted operational sequences and depending on the sophistication of the system, may or may not maximize energy reduction. Semi-automatic control systems usually require manual initiation of the operation which can be terminated either manually or automatically. A semi-automatic control system in a room would require that an occupant turn on the lights, and would permit the occupant to extinguish the lights upon leaving, but would automatically extinguish the lights should they inadvertently continue to operate. Thus, for a procedure to be effective in energy reduction, it must require minimum energy consumption by a lighting system which can be assured only by the inclusion of semi-automatic, or a very sophisticated automatic control system.

Power: A procedure that restricts the power demand would limit the energy consumption that could occur. In any operation the energy use would be limited by the power rating of the connected load. This has the effect of not only establishing a maximum energy use for continuous operation, but also limits the demand at any point in time.

As the use of a space changes, the lighting requirements also change. In a classroom for drafting instruction the possible visual activities may require 30, 70, or 100 footcandle of illumination.[(5)] Therefore, an effective procedure provides for reduced power demand with activity change.

Propriety

Image: Determining if a procedure is proper involves evaluating subjective as well as objective requirements. Although increased energy conservation might be achieved if no accommodations were made to enhance the image of a space, there are situations where this policy would seem over restrictive. When justified, lighting should be designed to accommodate the needs of architectural form achievement and color rendition requirement.

Activity: Buildings are conceived, designed, and constructed to provide an environment for achieving stated goals. These goals, with few exceptions, can be classified in terms of their visual requirement. Thus, it can be concluded that a properly designed lighting system will accommodate the varying visual acquity of users, the relationship between quality of light and activity achievement, the requirements for public health and safety, and the needs for security of property.

Technology: Often situations arise where the most energy efficient item or design is not desirable under the extenuating circumstances. For example, where difficulty of lamp replacement justifies long life, or where lighting needs are minimal such that a small source is desirable, or where the heat of light impacts the heating or cooling system, or where ambient conditions are extreme. A proper lighting system design should acknowledge constraints of methods and materials, and properly interact with other building systems.

Applicability

Implementation: To be conducive to fair and consistent enforcement, a regulation must be written in understandable language that can be understood and interpreted with a high degree of predictability. This statement would seem to limit regulation to the prescriptive type of instrument. However, the intricacies of performance-oriented instruments may be mastered if the need for education is recognized and proper training conducted.

Implications: The building community consists of a highly diverse group of participants, including manufacturers, distributors, designers, contractors, regulatory agencies, unions, owners, users, and many others. For maximum effect, a procedure would encourage innovation and research by these participants and should not significantly increase the life cycle cost of constructing, owning and operating a building.

EFFECTIVENESS	Energy	encourages optimum energy intensity of components
		requires minimum energy consumption by lighting system
	Power	restricts power demand
		provides for reduced power demand with activity change
PROPRIETY	Image	accommodates architectural form achievement
		accommodates color rendition requirements
	Activity	accommodates relationship between quality of light and activity achievement
		accommodates relationship between quantity of light and activity achievement
		accomodates varying visual acuity of users
		accommodates requirements for public health, safety and welfare
		accommodates need for security of property
	Technology	acknowledges constraints of methods and materials
		acknowledges interaction with other building systems
APPLICABILITY	Implementation	inducive to fair and consistent enforcement
	Implications	encourages research and innovation
		increases life cycle cost

PROCEDURES

This author has made no attempt to collect all the procedures that have been developed but has selected prototypes representing the different basic techniques. The procedures selected are:

ASHRAE Standard 90-75, "Energy Conservation in New Building Design." Section 9[6], this document was developed by the Illuminating Engineering Society who also published the lighting standard in a separate document "IES Recommended Lighting Power Budget Determination Procedure EMS-1."[7] (Subsequently referred to as "Procedure EMS-1.") (See Appendix 1.)

General Services Administration "Energy Conservation Guidelines for Existing Office Buildings." Prepared by the GSA staff in cooperation with the AIA Research Corporation and selected professionals.[8] (Subsequently referred to as "Procedure GSA.") These guidelines were chosen, even though they specifically apply to existing buildings, because they are more comprehensive than earlier GSA guidelines. (See Appendix 2.)

State Lighting Code: a procedure being developed by a State building commission. This code has not been enacted; thus it would be inappropriate to identify the State. (Subsequently referred to as "Procedure S.")

PROCEDURES EXAMINATION

Energy

Procedure EMS-1: no attempt is made to regulate energy embodiment in components; minimal requirements are included for manual switching (Section 8.5); proper lighting controls are suggested (Section 9.2.2); suggestion for circuiting, switching, or dimming includes the provisions for reduction of lighting to 50 percent level, turning off all lighting when space is empty, and manually or automatically dimming for daylight utilization (Section 9.52).

Procedure GSA: no attempt is made to regulate energy embodiment in components; separate, convenient switching and switching to utilize daylighting is suggested (paragraph C-7); circuiting for 5 watts per sq. ft. suggested (paragraph C-11); need for adequate circuiting and proper controls, including automatic controls, detailed (paragraphs G-1, 2).

Procedure S: no attempt is made to regulate energy embodiment in components; each enclosed area required to have separate switching; areas over 500 sq. ft. must have 50 percent lighting level control; switching to utilize daylighting required; switches must be readily accessible; task lighting to include switches at each location.

Power

Procedure EMS-1: Maximum allowable power budget (limit) for building is determined according to visual activity in various spaces (Section 9.2): Lighting design is completely independent of budgeting procedure; achieving varied power levels for varying tasks responsibility of designer; designer encouraged to design for less power than limit allows (Section 9.2.2).

Procedure GSA: a power goal of 2.3 watts per sq. ft. of net rentable space is set; multiple lamp luminaires with integral switches suggested for varying need (paragraph G.1.c).

Procedure S: maximum of 3 watts per sq. ft. set for spaces with critical visual activity; 1 watt per sq. ft. for spaces with no visual activity; .5 watts per sq. ft. for corridors, etc.; portable lights, suggested for increased visual needs, are not included in power limit.

Image

Procedure EMS-1: power for highlighting added to budget (Section 9.3.4.2.b); lamp of lower efficacy may be used where color rendition is important (Section 9.3.2.1).

Procedure GSA: no allowance is made for image achievement.

Procedure S: no allowance is made for image achievement.

Activity

Procedure EMS-1: designer charged with responsibility to provide effective visual environment (Section 9.2); budget determination includes varying quantity of light for activity achievement (Section 9.3.1); budget determination stimulates luminaire coefficient of utilization based on need for quality lighting (Section 9.3.2.2); health, safety, and welfare needs are responsibility of designer (Section 9.2); budget determination allows for exterior security lighting (Section 9.4).

Procedure GSA: suggested quantity of light is determined by using a visual difficulty rating which is given for several tasks, multipled by hours per day task is to be performed, adjustment factor included for defective eyesight (Paragraph D.2); quality lighting is recommended and instructions given for achieving ESI (Equivalent Sphere Illumination) (Paragraph D.1); no specific allowance made for lighting for health and safety, and no exterior security recommendation made (Paragraph H.1).

Procedure S: higher watts per sq. ft. budget is allowed for areas of greater visual needs, actual achievement is designer's responsibility; no reference made to health and safety, or security of property; however, budget allowance is given for each linear foot of building exterior.

Technology

Procedure EMS-1: budget allowance made for installations not permitting source of highest efficacy (Section 9.3.2.1); surface reflectances and light loss factor specified for budget purposes but exceptions are allowed (Sections 9.3.3 and 9.3.4.3); designer encouraged to interact with other energy needs (Section 9.2.2); designer encouraged to use lamps of higher efficacy and more efficient luminaires (Section 9.2.2); inefficiency of lighting smaller rooms compensated for in budget procedure.

Procedure GSA: suggestions made for achieving good design but no specific variance for technology limitation (Section C); interaction with other systems encouraged (Paragraph C-9).

Procedure S: no acknowledgement of technological constraints or need to interact with other systems.

Implementation

Procedure EMS-1: Budget prepared based on planned, or intended, activities in space, list of specific activities and number of work stations must be determined before budget preparation; budget requires calculations for each space; many variables possible, designers and enforcers will need familiarization or training.

Procedure GSA: Power limit of 2.3 watts per sq. ft. rentable space, only criterion for compliance.

Procedure S: area of each individual space must be determined and general activity to be performed in that space; budget based on area and watts per sq. ft.

Implications

Procedure EMS-1: Requires designers to follow IES guidelines more closely; eliminates temptation to misuse recommendations[9]; need for detailed study of visual activities in building should result in earlier involvement of lighting designer which could result in more innovative designs; use of generic lamp efficacies, and luminaire coefficients of utilization, in calculations procedures encourages selecting sources and luminaires of higher quality for installation, which should encourage research and innovation by manufacturers. Design will result in a reduction in lamps[10] and luminaires[11]; slightly higher design costs[12]; more involved installation with some reduction in total construction cost[13]; long term benefits to owner and user; and will require careful scrutiny by enforcement agency.

Procedure GSA: budget can easily be prepared without involvement of lighting designer; no incentive offered for innovation in manufacture or design; author has no information on cost implication but estimates it would average out to be same as for EMS-1, easy to enforce.

Procedure S: budget can be prepared without involvement of lighting designer; no incentive offered for innovation in manufacture or design; author has no information on cost implications; easy to enforce.

SUMMATION AND CONCLUSION

Effectiveness

The EMS-1 procedure has the greatest potential for energy conservation, but the effectiveness is dependent on how the designer administers, and the regulator audits, the budget calculations. The GSA procedure rewards efficient space design as the budget is based on net rentable space and power for lighting other spaces must be gleaned from this power maximum. Both the GSA and S procedures are prescriptive and offer little incentive or challenge to reduce power load below specified amount. (See Appendix 3.)

Propriety

Herein lies the significant difference in the procedures. The EMS-1 power budget is derived from criteria of high propriety for a specific space, whereas the GSA and S procedures have pre established power limit that does not relate to a specific space or space utilization. All three procedures rely on the designer to achieve proper lighting.

Applicability

The EMS-1 procedure will be difficult to implement at the plan inspection stage with consistency and fairness unless proper training is achieved. The GSA and S procedure can be easily implemented at the plan inspection stage. All three procedures are equally easy to check for construction compliance.

Design costs will increase slightly where the EMS-1 procedure is chosen; other implications are dependent on how the building community responds. The regulator will serve a critical roll if a designer chooses to circumvent the intent of the EMS-1 procedure.

A word of caution on reducing lighting levels--allowing for the impact on heating and cooling systems and using a rate of $.03 per kWh --a fifty footcandle increase in lighting level can be achieved for less than $.13 per sq. ft. per year. Assuming a 200 sq. ft. office, this amounts to $26.00 or .13 percent of the wage of a $20,000 per year employee. A productivity test conducted by the Illuminating Engineering Research Institute showed a 3 percent rise in productivity (higher rise recorded under many circumstances) when lighting was increased from 50 to 100 footcandles. This indicates that if the additional 50 footcandle of lighting were needed 4 percent of the time, it would be economically justified.[14]

The EMS-1 procedure offers a challenge that the building community should not only accept but should support with vigor. It is the only procedure available that approaches the problem in a professional manner enabling the competent energy conscious members of the building community to excell. Granted there will be a period of adoption but the instrument is designed to achieve the right results for the right reasons.

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APPENDIX 1

EMS-1 PROCEDURE

The lighting power budget, as determined by the EMS-1 procedure, is the sum of the lighting power requirements computed for all interior spaces and exterior areas in accordance with the following:

Power limit determination: The power requirements for a specific space is computed by summing the watts allowable for task lighting, general lighting, non-critical lighting, and special lighting. Special lighting is included at actual watts but the others are calculated by the following equation:

$$W \text{ (watts)} = \frac{A \text{ (area)} \times FC \text{ (footcandle)}}{LE \text{ (lamp efficacy)} \times CU \text{ (luminaire coefficient utilization)} \times LLF \text{ (light loss factor)}}$$

Area: An allowance of 50 square feet is made for each work station where a task is performed, the remaining area in the space, up to an amount equal to the total task area is classified as general lighting and any area still remaining is considered non-critical.

Footcandle: For the most critical task performed at each work station an illumination level as recommended by the IES Handbook will be allowed. The general lighting shall be one-third of the weighted task illumination but no less than 20 footcandles. The non-critical lighting shall be one-third of the general lighting but no less than 10 footcandles.

Lamp Efficacy: The value for lamp efficacy shall be chosen from the following: 55 lumen per watt where moderated color rendition is appropriate; 40 lm/W for good color; and 25 lm/W if high color rendition is appropriate.

Coefficient of Utilization: The coefficient of utilization (CU) is in effect the ratio of the lumen received on the workplane to the total lamp lumen. It is affected by three variables: First, the geometry of the room as expressed by the room cavity ratio (RCR); second, the reflectances of the room's ceiling, wall and floor--which in the budget procedure are given as 80%, 50%, and 20%; and third, the efficiency of the luminaire.

The RCR is calculated by the equation: $RCR = 5 \text{ hrc} \frac{L + W}{L \times W}$ where hrc is the distance from the luminaire to the workplane, and L and W are the length and width of the room.

The luminaire selected for use in the computations shall be of one of the generic types as listed in the Illuminating Engineering Society Lighting Handbook, 5th Edition, but the luminaire must pass one of the following tests.

Under the specified condition of reflectances of 80% (ceiling), 50% (walls), 20% (floor), and for a room cavity ratio of one, the coefficient of utilization must be at least .55 for a space where the illumination is specified as equivalent sphere illumination (ESI) and the visual comfort probability (VCP) is required to be high; .63 for a space where VCP is a requirement but ESI is not; or .70 where neither VCP or ESI are design requirements (see example 1).

Once the luminare has passed the test, the CU value shall be extrapolated for the RCR of the specific room for which the power limit is being computed.

Light Loss Factor (LLF): A measure of the depreciation of the illumination over time, given as a set value of .70 for the budget procedure.

Example: The following computations for two office areas are given to illustrate the application of the procedure.

Budget parameters:

Reflectances of 80, 50, 20, and a light loss factor of .70.
Coefficient of Utilization from accompanying table.
Room A: a small office L=15, W=10, hrc=6.5.
Room B: an open office L=100, W=100, hrc=10.
Task area is 50% of total area.

Room A $\quad RCR = 5 \times 6.5 \times \frac{25}{1500} = 5.4$

Room B $\quad RCR = 5 \times 10 \times \frac{200}{10000} = 1$

Room A $\quad$ CU= .41 for an RCR=5.4.

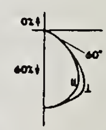
Room B $\quad$ CU= .65 for an RCR=1.

Room A $\quad$ Task area 75 sq. ft. recommended task illumination 50 fc, moderate color

For tasks $W = \frac{75 \times 50}{55 \times .41 \times .7} =$ 238 watts

For general $W = \frac{75 \times 20}{55 \times .41 \times .7} =$ 95 watts

(Budget) Power limit for room 333 watts
2.22 watts per square foot.

Typical Luminaire	Typical Distribution and Per Cent Lamp Lumens: Maint. Cat.	Maximum S/MH Guide[d]	ρcc[a] → 80 / ρw[b] → 50 / RCR[c] ↓	ρfc = 20
	V	1.4/1.2	0	.71
			1	.65
			2	.59
			3	.53
			4	.48
			5	.43
			6	.39
			7	.36
			8	.32
			9	.29
Fluorescent unit with flat prismatic lens, 4 lamp 2' wide—multiply by 1.10 for 2 lamp			10	.26

Room B   Task area 5000 sq. ft recommended task illumination 50 fc, moderate color

For tasks $W = \frac{5000 \times 50}{55 \times .65 \times .70} =$ 9990 watts

General $W = \frac{5000 \times 20}{55 \times .65 \times .70} =$ 3996 watts

(Budget) power limit for space   13986 watts

1.4 watts per square foot

APPENDIX 2

GSA PROCEDURE

Although the GSA power limit is a prescriptive 2.3 watts per square foot, it does make design recommendations. Of special interest is the recommended method for determining illumination levels of office tasks.

The method is based on the visual difficulty rating listed below.

Visual Difficulty Rating (R) of Tasks

	Task Description	Visual Difficulty Rating (R)
1.	Large Black Object on White Background	1
2.	Book or Magazine, Printed Matter, 8-Point and Larger	2
3.	Typed Original	2
4.	Ink Writing (Script)	3
5.	Newspaper Text	4
6.	Shorthand Notes, Ink	4
7.	Handwriting (Script) in No. 2 Pencil	5
8.	Shorthand Notes, No. 3 Pencil	6
9.	"Washed-Out" Copy from Copying Machine	7
10.	Bookkeeping	8
11.	Drafting	8
12.	Telephone Directory	12
13.	Typed Carbon, Fifth Copy	15

The values from this table are multiplied by the hours of performance per day, and if the worker is over 50 years of age, by a factor of 1.5. This visual difficulty factor is used to enter the following table to determine the necessary illumination.

Recommended Illumination Levels for Office Tasks

Task or Area	Visual Difficulty (VDF)	Design Level (FC)	Average Level Range (FC)
Service of Public Areas	-	15	12-18
Circulation Areas within Office Space, but not at Work Stations	-	30	24-36
Normal Office Work, Reading, Writing, etc.	1-39	50	40-60
Office Work, Prolonged, Visually Difficult or Critical in Nature	40-59	75	60-90
Office Work, Prolonged, Visually Difficult and Critical in Nature	60 & Up	100	80-120

Example:

Task	Hours	Visual Difficulty Rating	Visual Difficulty Factor
Read Newspaper	1	4	4
Typed Originals	2	2	4
Ink Writing	1	3	3
Washout Copy	2	7	14
Shorthand Notes	2	6	12
Total	8		37

For worker under 50 — 50fc
For worker over 50 — 75fc

APPENDIX 3

PROCEDURES COMPARISON

watts per square foot (EMS-1, task area 50% of total, moderate color)

Procedure	Room	Task Illumination		
		50 fc	75 fc	100 fc
EMS-1	A	2.22	3.16	4.2
	B	1.4	2.0	2.7
GSA	A or B	2.3	2.3	2.3
S	A or B	3	3	3

Room A 15 x 10 x 9 small office

Room B 100 x 100 x 12.5 open office

THE NEED FOR A MORE EXPLICIT DEFINITION IN BUILDING REGULATIONS OF THE INTERNAL THERMAL ENVIRONMENT IN BUILDINGS*

by

Dean R. Heerwagen[1], Ashley F. Emery[2], Charles J. Kippenhan[2], and Gordon B. Varey[3]

A survey of several widely-accepted or newly-proposed building codes or standards has been conducted to determine (1) what guidelines for establishing occupant thermal comfort currently exist, and (2) whether these guidelines may inhibit the achievement of energy conservation in building operation. This review has shown that the present requirements pertaining to thermal comfort afford non-optimal conditions, from the points of view of both the provision of thermal comfort and the achievement of energy conservation. In this essay, the authors have cited results from three groups of researchers who have provided definitive work on human thermal comfort. It is suggested that such results be used in writing future building regulations and that energy conservation will result from their inclusions. Additionally, the authors have also suggested that future regulations require the use of several innovative devices or strategies (for building operation or control) and these are discussed.

A thermal simulation computer program UWENSOL is described and its application is displayed as a means of accurately predicting both heating and cooling loads and thermal conditions within buildings during their design.

Key Words: Building performance simulation; building regulations; computer applications; energy conservation; thermal comfort; thermal performance of buildings.

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INTRODUCTION

In the Institute for Environmental Studies at the University of Washington, an interdisciplinary team of architects, engineers, and atmospheric scientists has been organized. This group is currently seeking to develop design guidelines for buildings, which will result in the conservation of energy during the life of the buildings. Throughout this study, we have recognized that energy is used in buildings to provide a comfortable environment for occupants to live and work. The provision of comfort has been taken as a fundamental issue; to offer conditions which of themselves produce appreciable occupant discomfort will likley reduce the ability of the building occupant to perform desired or required activities, whether in a home or work situation. Thus, our goal for this research is to identify means by which energy consumption can be reduced without adversely affecting the occupant's well-being.

In this essay we will describe our considerations and preliminary conclusions about four issues central to this goal: (1) the identification of a comfort envelope that is as broadly-defined as to be still acceptable by the building occupants; (2) the consideration of practices which can be used to overcome potentially uncomfortable environmental conditions; (3) the suggestion of innovative devices and strategies that can improve current methods for attaining comfort; and (4) the description and use of a computer tool by which building performance can be simulated accurately during the designing of the building (to permit determination of whether comfort conditions would exist). We will document these considerations and conclusions, initially, by reference to the various applicable building regulations and standards on the subject of thermal comfort and to definitive research on conditions for achieving occupant thermal comfort and, subsequently, by describing a series of calculations performed through the use of our thermal simulation computer program.

A REVIEW OF THERMAL COMFORT GUIDELINES PROVIDED BY EXISTING (AND PROPOSED) BUILDING CODES AND PROFESSIONAL STANDARDS

When our research group began to evaluate the series of building concepts that we anticipated could provide substantial conservation opportunities, we carefully reviewed the appropriate building codes and industry standards for required thermal comfort provisions in buildings. Guidelines were sought about the four primary variables that determine the character of the internal building environment: (1) ambient air temperature, (2) mean radiant temperature, (3) relative air velocity, and (4) relative humidity. We found that the codes and standards which govern how buildings are to be constructed are largely imprecise and that generally little recognition has been given to insuring occupant thermal comfort. In this section, we will summarize the results of our review of the several codes and standards, and in the next section we shall cite and describe research conducted by numbers of experimenters, which offer rigorously-based guidelines for insuring occupant thermal comfort.

To digress momentarily on the function of building regulations: building regulations -- whether promulgated as codes or as standards -- have been used in the United States to guarantee the well-being and safety of the building occupant. Such regulations protect the occupant against faulty design and construction by providing "...minimum standards to safeguard life or limb, health, property, and public welfare..."[1] of the occupants and those who live or work around the regulated buildings. But, rather than simply setting "minimum standards," it can be argued that future regulations should include statements which will cause the achievement of markedly improved building thermal performances. We do not wish to require absolute efficiencies (e.g., such as by prescribing minimum U-values for the building envelope); rather, we would wish that regulations subsequent to existing codes and standards be upgraded to reflect improved knowledge and professional competencies. To illustrate this argument, we note that the already well known ASHRAE Standard 90-75[(1)] has established guidelines for buildings which, when issued, exceeded all then-current codes in many respects. But, as we will argue below, if the indoor temperatures specified in this Standard had been altered to those comfort conditions that were known from research that had been conducted and verified some years before the issuance of the Standard, then appreciably better building performance would be achievable.

For architects and engineers who are designing buildings to be constructed in the State of Washington, the primary set of regulations that must be satisfied for all buildings occupied by human beings is the Uniform Building Code, issued by the International Conference of Building Officials[(2)]. This Code directly stipulates a heating requirement only for residential units (i.e., single and multiple-unit private housing and all public units such as hotels and motels). The requirement reads that "every dwelling unit and guest room shall be provided with heating facilities capable of maintaining a room temperature of 70°F at a point three feet above the floor in all habitable rooms."[2] Ventilation rates are given for all occupied building types, but permissible velocities are noted only for air movement directly from the supply registers. For buildings used for non-residential occupancies, air temperatures are not specified. In the index to this Code, the reader is referred to the Uniform Mechanical Code which is also published by the International Conference of Building Officials[(3)]. The Mechanical Code, however, does not list requirements for occupant thermal comfort and instead is concerned primarily with the construction and operation of the various heating, ventilating, and air conditioning equipment commonly used in buildings.

For further information regarding minimum or recommended internal building conditions (i.e., those including ambient air and mean radiant temperatures, relative humidity, and relative air velocity),

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[1]Section 102, Uniform Building Code, 1976 Edition. Page 23.

[2]Section 1311, Uniform Building Code, 1976 Edition. Page 91.

the building designer might consult the three ASHRAE Standards which address themselves, directly or otherwise, to the internal building environment: (1) Standard 55-74, "Thermal Environmental Conditions for Human Occupancy;" (4) (2) Standard 62-73, "Standards for Natural and Mechanical Ventilation;" (5) and (3) Standard 90-75, "Energy Conservation in New Building Design." (1)

Of these three documents, the first Standard (55-74) is by far the most comprehensive of the three in providing direction for establishing occupant thermal comfort. This Standard defines a "comfort envelope" in which it is said that at least 80% of the normally-clothed North American men and women will be thermally comfortable while pursuing sedentary or similarly light work activities indoors.[3] This comfort envelope (Figure 1) is based on two variables: (1) adjusted dry-bulb temperature and (2) water vapor pressure. The specific statements in the Standard which describe these variables and which define the comfort evelope are given below:

(Section 3.1) When the dry-bulb temperature equals the mean radiant temperature (MRT), the dry-bulb temperature equals the adjusted dry-bulb temperature (ADBT), as defined by the following equation:

$$ADBT = 1/2\ (DBT + MRT)$$

When the mean radiant temperature is different from the dry-bulb temperature, a compensation is made as noted in the following item below. The comfort envelope is defined as a quadrangle with the following corner coordinates: ADBT = 71.5 and 77.6°F at 14 mm Hg vapor pressure and ADBT = 72.6 and 79.7°F at 5 mm Hg vapor pressure.

(Section 3.3) When the mean radiant temperature in the occupied zone differs from the dry-bulb temperature, the dry-bulb temperature shall be reduced by one degree (F) for each degree mean radiant temperature elevation above the air temperature and vice versa.

(Section 3.2) The water vapor pressure in the occupied zone shall be at or between 5.0 and 14.0 mm Hg. These conditions correspond approximately to 20 and 65% relative humidity.

(Section 3.4) The air velocity in the occupied zone shall be 70 feet/minute or less at any time.

Of the other two ASHRAE Standards responsible for defining internal building conditions, the Standard 90-75 closely follows the contents of Standard 55-74 in defining permissible dry-bulb

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[3] Section 2.1, ASHRAE Standard 55-74, "Thermal Environmental Conditions for Occupancy." Page 3.

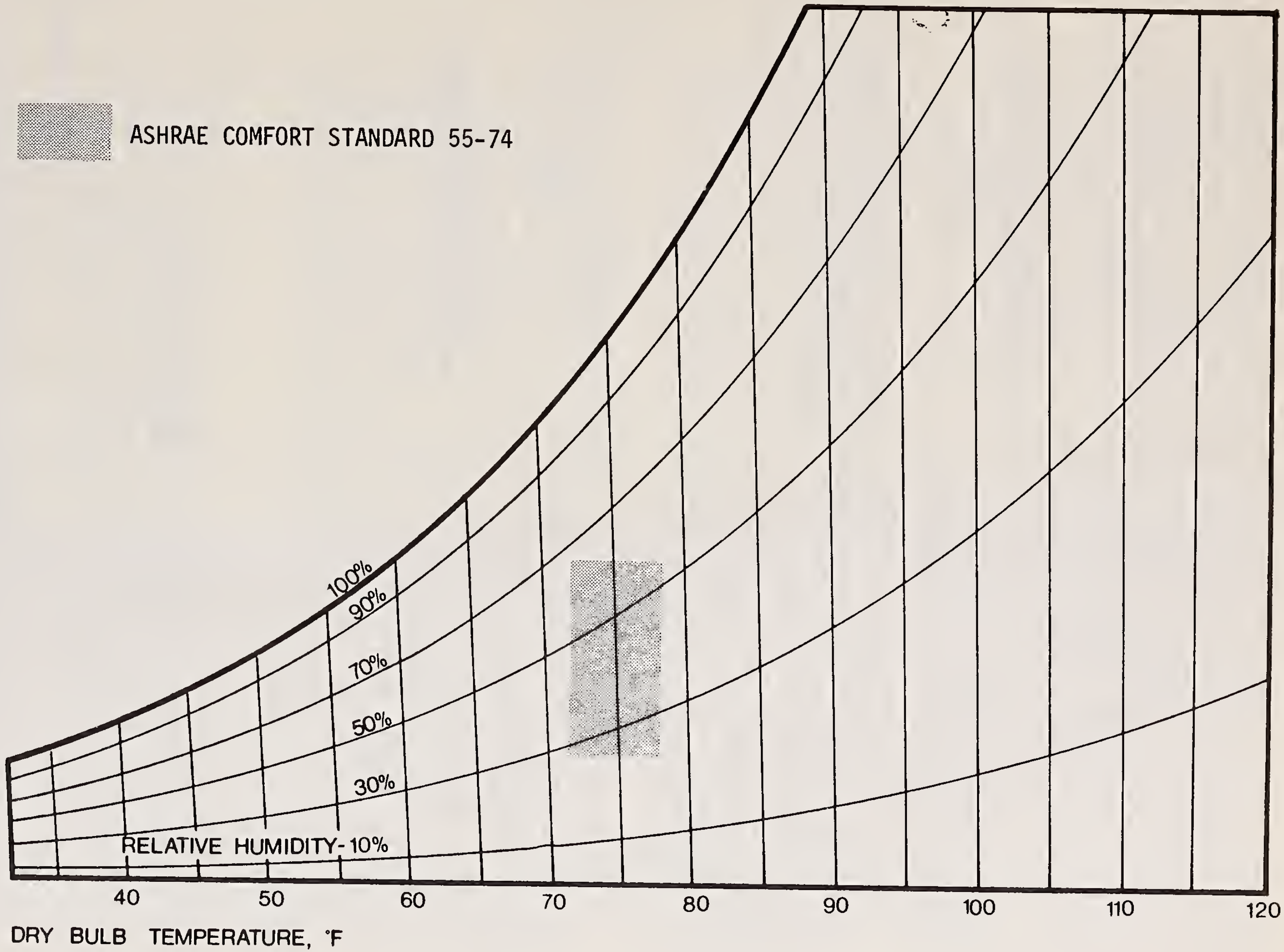

FIGURE 1: The Comfort Envelope (derived from ASHRAE Standard 55-74 [4])

temperature and relative humidity. This Standard (90-75) states that all building and systems calculations shall be based on interior dry-bulb temperature of 72°F for the winter and 78°F for the summer. Relative humidity levels are limited to a maximum of 30% where humidification is required during winter mechanical equipment operation. Summer humidity levels are fixed according to those boundaries set by the comfort envelope defined in Standard 55-74. No specific requirements are noted for the other two environmental variables (i.e., mean radiant temperature and relative air velocity). The third Standard (62-73) provides minimum and recommended guidelines for natural and mechanical ventilation. Its primary function is to furnish suggested ventilation rates and permissible contaminant contents in the supply air. There is no specific mention of recommended internal thermal design conditions.

Lastly, the foresighted Washington State building designer might consider two additional sources of regulative guidelines: (1) the proposed "Energy Conservation Standards for Non-residential Buildings" currently under review by the State of California[6]; and (2) the preliminary draft of the "Model Code for Energy Conservation in New Building Construction"[7], which is being developed jointly by (a) Building Officials and Code Administrators International, Inc. (BOCA), (b) International Conference of Building Officials (ICBO), and (c) Southern Building Code Congress International, Inc. (SBCC).

Both of these model codes, for instance, are being reviewed by the City of Seattle Energy Office as bases for the inclusion of energy standards in the City building code (which is, in turn, based on the Uniform Building Code). Each of these model codes has been written using the ASHRAE Standard 90-75 as a basis, and each has sought to alter the technical content of the parent Standard as little as possible. The California proposal differs from the ASHRAE Standard only where 70°F is suggested as an indoor design temperature. In an apparent conceptual inconsistency, it is suggested that the HVAC equipment be designed to recognize the comfort envelope established by ASHRAE Standard 55-74. The model code being developed by the three primary national code-writing organizations specifically states its reliance on the Standard 55-74 for a definition of a thermal comfort envelope.

To summarize our findings from this review of applicable building codes and standards, the legally-binding building regulation for designers in the Pacific Northwest is the Uniform Building Code. As we have noted, its tenet for establishing occupant thermal comfort applies only to residential buildings and then the regulation requires that heating be provided that is capable of maintaining an air temperature of 70°F. Of the three standards and the two proposed code amendments, all but the ASHRAE Standard 62-73 cite the comfort envelope initially described in ASHRAE Standard 55-74 as the basis for defining thermal comfort. With the likely passage of the proposed model code that has been jointly developed by the three most widely-accepted regulating bodies, this comfort envelope will become the new definition for comfort conditions.

LESSONS FROM RECENT RESEARCH ON HUMAN THERMAL COMFORT

It is our contention that the comfort envelope defined in the ASHRAE Standard 55-74 is too conservative. The various research findings described below substantiate our belief that a larger envelope can, in fact, be used to define conditions with which the building occupant will be comfortable. Results in Section IV will demonstrate that the definition of such a larger comfort zone will offer marked energy conservation opportunities.

First, let us point out that the temperature criteria for thermal comfort rose steadily between 1900 and 1960. When Nevins[(8)] in 1961 surveyed temperature requirements developed over that 60-year period, he found that a temperature range of 65 to 70°F (DBT) was acceptable in 1900, but that by 1960, the temperature range that was recommended for human comfort was 75 to 78°F (DBT) -- both ranges being given for 40% relative humidity. The reasons for this steady increase are probably several: the reduction in the weight of clothing (and thus, to a marked extent, in its ability to insulate), the ease with which heating could be achieved (with the ready availability of fossil fuels), changes in living habits, and changes in the way buildings have been built. Whatever the precise reason, it is important to recognize that a person's feeling of comfort is directly related to the individual's ability to respond to the various environmental conditions that impinge on his/her physiological state. Besides the primary environmental factors of the ambient air and mean radiant temperatures, the relative humidity of the air, and the relative air velocity moving about the person, two additional personal variables also have a direct and marked effect on the comfort level of the building occupant: (1) the activity level of the occupant (or, the metabolic rate of internal heat production), and (2) the thermal resistance of the occupant's clothing (as described in terms of clo[4]). Nearly all of the recent research on human comfort has recognized these six factors as those which determine the nature of the individual's physiological response to the building environment.

During the last fifty years, there has been a succession of indices, equations, and envelopes or zones developed -- numbering at least a dozen -- for predicting thermal comfort. These have been described in the literature by such authors as Newburg[(9)], Hill _et al_[(10)], and Givoni[(11)]. Beginning with Houghton and Yaglou's work [for example, 12] in the 1920's and continuing through to the early 1960's, most of the efforts spent on characterizing human comfort were organized around the development of a series of thermal indices, which could be used to predict physiological responses to varying

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[4]A _clo_ is "the amount of insulation necessary to maintain comfort and a mean skin temperature of 90°F in a room at 70°F with air movement not over 10 feet/minute, humidity not over 50%, with a metabolism of 50 Calories/square meter/hour." From Newburgh, L. H. (editor) _Physiology of Heat Regulation and the Science of Clothing_. New York: Hafner Publishing Company, 1968. Page 442. Numerically, 1 clo = 0.18°C/cal-sq. meter-hour.

environmental conditions. Some of these indices were rationally derived from research, whereas others result from empiricism. As Givoni has demonstrated by comparing the several indices, they differ most frequently in at least four significant respects: (1) the specific environmental and personal factors and physiological responses that are addressed, (2) the manners in which these factors and responses are weighted for relative importance and how or whether the factors and responses are interdependent, (3) the range of environmental conditions in which these indices are applicable, and (4) the forms in which the various indices are expressed.[5] Generally, the results of using these indices were less satisfactory than might be wished and reliance upon them as descriptors or predictors of comfort conditions has declined. Instead, during the last fifteen years, the development of such indices has given way to the establishment of thermal comfort envelopes (such as the one on which the ASHRAE Standard 55-74[(4)] is based). Three major research efforts have been undertaken during this period and specific recommendations about comfort conditions have been advanced from each. The initial work was begun by Nevins and his colleagues at Kansas State University in the 1960's. Through collaboration with Nevins and his associates and from much additional independent work, two other groups have also made important contributions to this study area. Specifically, one group has been led by Gagge at the Pierce Foundation Laboratory in New Haven, and the other has been directed by Fanger at the Technical University of Denmark. In the following paragraphs, we will briefly describe these important researches and summarize their results.

The work by Nevins and his colleagues[(13)] was begun in 1963. Initially, they sought to identify a comfort zone based on dry-bulb temperature and relative humidity scales by noting how test subjects evaluated specific thermal environmental conditions when the ambient air temperature and relative humidity were varied. The subjects were asked to describe the various environmental conditions in terms of a seven-point rating scale, ranging from "cold" to "hot" with "comfortable" at the median point. As such, the evaluations by the test subjects were based more precisely on their thermal sensation capabilities than on the more general issue of thermal comfort. Subsequent research, as reported by Rohles[(14)], then led to the development of a "Modal Comfort Envelope."

In the research conducted at Kansas State University, 720 subjects (equally divided by sex) were tested in the experiments that led to the first paper noted above, and a total of 1600 -- the first 720 subjects plus an additional 880 -- were examined and later reported about in the second paper. Using the data that were collected from the first set of observations, a "Baseline Comfort Chart" was drawn (see Figure 2 for a reproduction of this Chart). Following the additional testing, the Modal Comfort Chart was derived (see Figure 3). The first Chart contains three lines -- on what is

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[5]See Givoni, B. Man, Climate and Architecture, Second Edition. London: Applied Science Publishers, Ltd., 1976. Chapter 5, pp. 75-102.

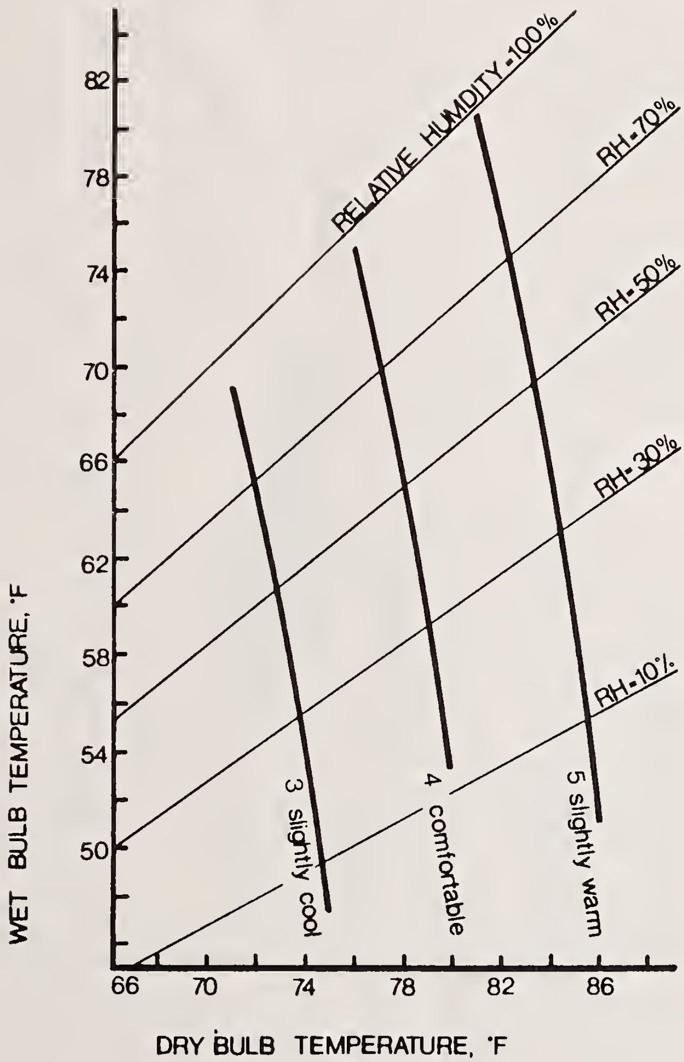

FIGURE 2: The Baseline Comfort Chart
(from Nevins et al [13], page 289)

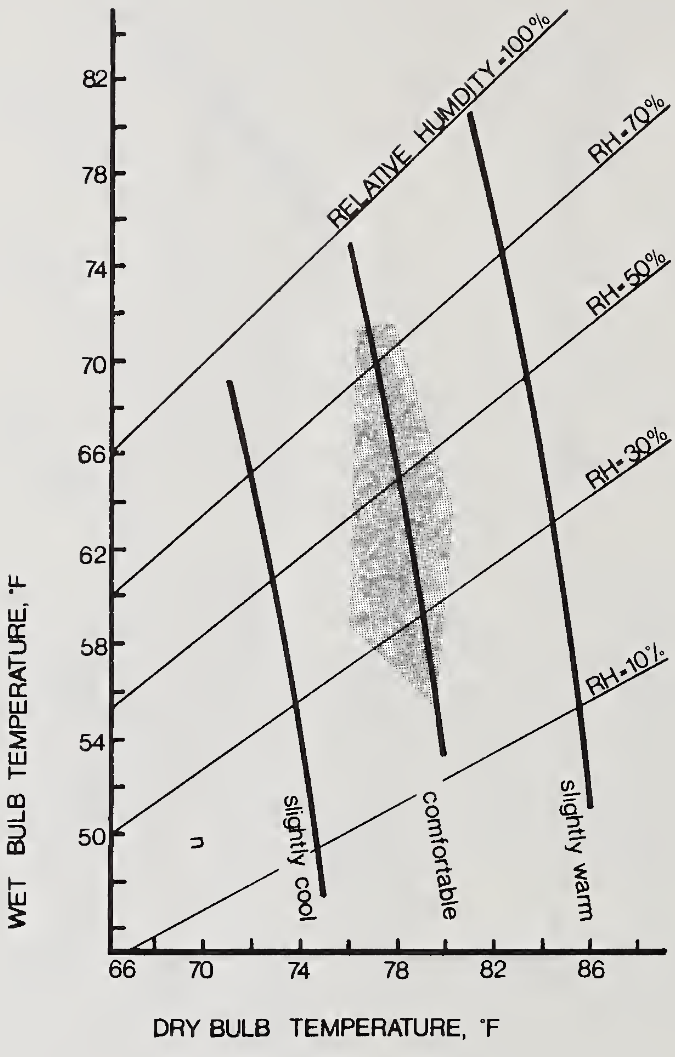

FIGURE 3: The Modal Comfort Envelope (from Rohles [14])

essentially a modified Psychrometric Chart -- noting, respectively, conditions of being "slightly cool," "comfortable," and "slightly warm." The Modal Comfort Chart is drawn with an envelope overlaid on these three lines, with the envelope signifying the zone in which the test subjects were comfortable.

The second major comfort work group is the one led by Fanger at the Technical University of Denmark. This work has been summarized in his book Thermal Comfort[15]. He began his work by seeking to relate the several environmental and personal factors that influence the maintenance of comfort with the several mechanisms by which heat is lost or gained by the human body. From the resultant relationships describing these heat exchange mechanisms, Fanger has been able to derive a comphrehensive equation which allows the calculation of whether an individual will be comfortable when exposed to a specific set of environmental conditions and for particular metabolic (activity) rates and clothing insulation levels. Following the derivation of this Comfort Equation, Fanger then compiled a group of nomographs in which combinations of the several environmental and personal factors are compared; these nomographs have thus been set forth as "comfort diagrams." His intention was that such diagrams could be used in general practice without the iterative solution of the extended and quite complex Comfort Equation.

Following his derivation of the Comfort Envelope, Fanger set about relating the use of this Equation to the evaluation of specific room climates. Using a rating scale similar to the one established by Nevins and his colleagues, he developed the concept of a "Predicted Mean Vote." From data supplied by Nevins et al[13] and McNall et al[16] for sedentary and active subjects, respectively, Fanger found that the predicted mean vote (PMV) was indeed a function of the six environmental and personal factors to which the test subjects were exposed. Thus, an equation in which the PMV could be predicted evolved and has been summarized in his book Thermal Comfort[15]. This equation, relating the PMV with the six variables and, necessarily, with the several heat exchange mechanisms, permits one to determine the likelihood that an individual will feel comfortable or not when exposed to a given set of conditions (for the results of a set of sample calculations for an individual wearing clothing rated at 0.60 clo, see Figure 4). The other valuable concept developed by Fanger is the "Predicted Percentage of Dissatisfied" people that will be uncomfortable when they experience some set of environmental and personal conditions. The "predicted percentage of dissatisfied" (PPD) is directly related to the PMV for any set of conditions and an equation describing the relationship has been developed by Hill et al[10].

In general, the great value of Fanger's work is that it allows calculation, by digital computer, of whether the occupants of some space will be comfortable when exposed to any set of environmental conditions while clothed in a particular fashion and pursuing a specific activity. As such, this calculation device can be used as a design aid to evaluate any building space prior to its construction. Hill et al[10] have pointed out that, if there is a difficulty with Fanger's PMV and PPD ratings, it is that the predicted lines of

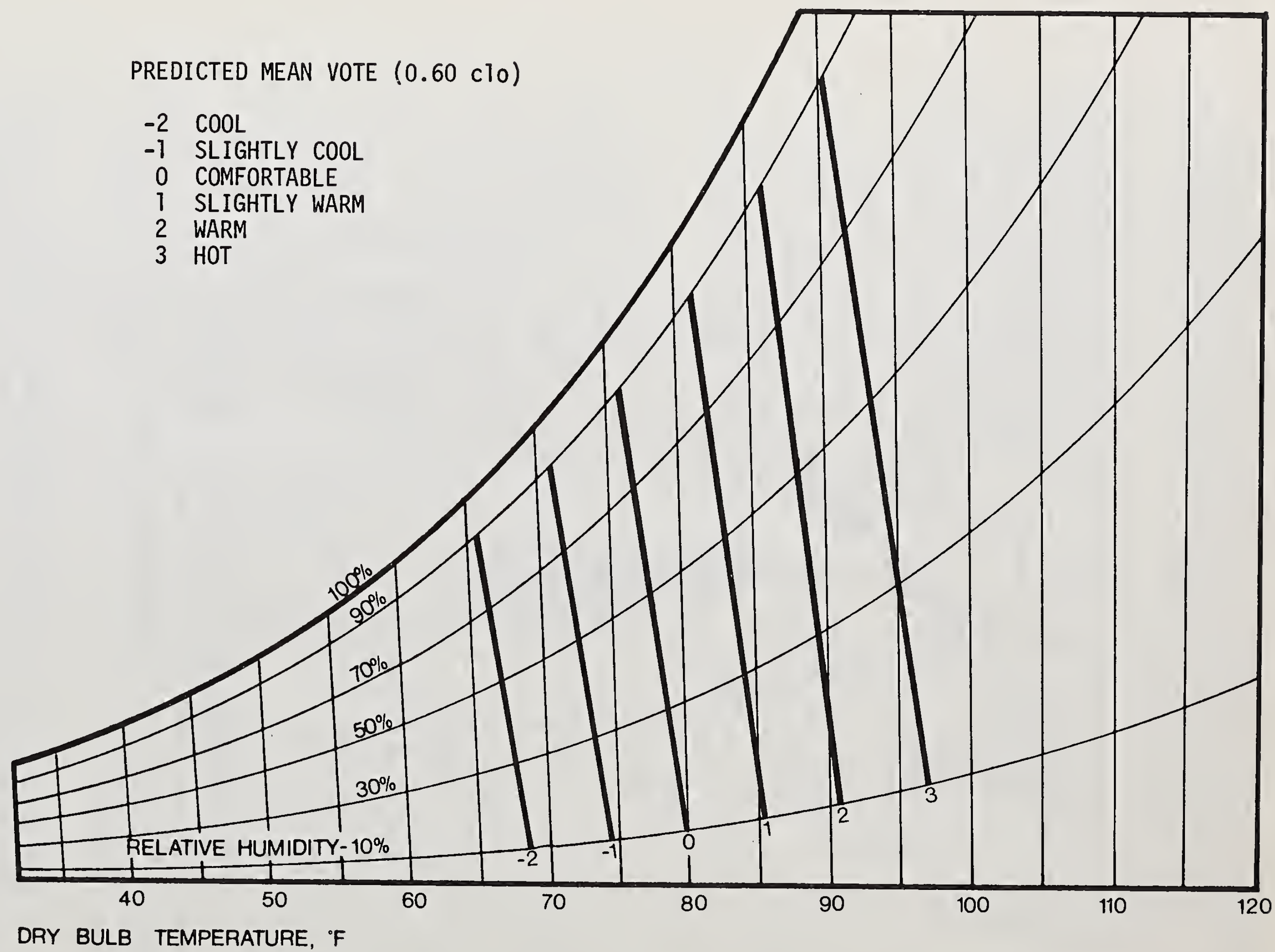

FIGURE 4: Lines of Predicted Mean Vote for an individual wearing a clothing ensemble rated at 0.60 clo (adapted from Hill et al [10])

relatively small and larger discomfort do not quite match those results found by Nevins, Rohles, and their colleagues who established their comfort guidelines from observations of a large sample of test subjects. Whereas the predicted ratings determined from the Fanger equations and the observed ratings from the test subjects gathered by Nevins, Rohles and their associates do differ in the zones of greater discomfort, the results of the two researches agree closely in the area of what is indeed comfortable.

The third major research effort towards establishing a definitive description of a thermal comfort zone is the work that has been in progress for the last decade at the John B. Pierce Foundation Laboratory in New Haven. Much of this group's primary work surrounds the development and application of a new version of the old thermal index "Effective Temperature" (ET), originally derived by Houghton and Yaglou[12] in the 1920's. The "New Effective Temperature" (designated ET*)[17] is based -- similar to Fanger's Comfort Equation -- on each of the human being's various heat exchange mecahnisms (it could be argued that the ET* scale may be more accurate than the Comfort Equation for conditions just out of the immediate comfort range because the ET* scale includes the exchange effects due to vasoregulation). In Figure 5, lines of the New Effective Temperature scale have been drawn on a Psychrometric Chart. An interpretation noting the significances of the various ET* ratings is presented in Table 1.

The ET* scale is essentially an analytic device that can be used to ascertain the likelihood of thermal comfort being achieved when the various environmental conditions are known and the clothing worn by the particular occupants and their specific activities (and, thus, their metabolic rates of heat production) have been established. As with Fanger's Comfort Equation, the New Effective Temperature scale recognizes the essential importance of the insulative value of clothing and of the activity rate as means of offsetting environmental conditions when one or more of these latter variables proves insufficient for meeting thermal comfort needs.

For our purposes here, the development of this New Effective Temperature scale is perhaps of less direct importance -- except as a means of verifying the results of a later study that is particularly noteworthy -- than this later study. In conjunction with their work on this new comfort scale and in assocation with Nevins, a recent study[18] was performed for the Federal Energy Administration which bears directly on the subject of this paper. In 1974, the FEA established building operating temperature guidelines for winter and summer conditions which differed from those presented in the ASHRAE Standard 55-74. The specific temperatures set by the FEA were 68-70°F for winter operation and 78-80°F for summer operation (with a proposed 80-82°F to be examined for later promulgation, pending further study). For the summer, humidity control was also to be avoided in the operation of the FEA buildings. The Pierce Foundation Laboratory team was asked to determine if these new standards were reasonable and what observations these researchers might make about the acceptability of these guidelines. The results of this investigation have been summarized in a report prepared by Gagge and Nevins[18].

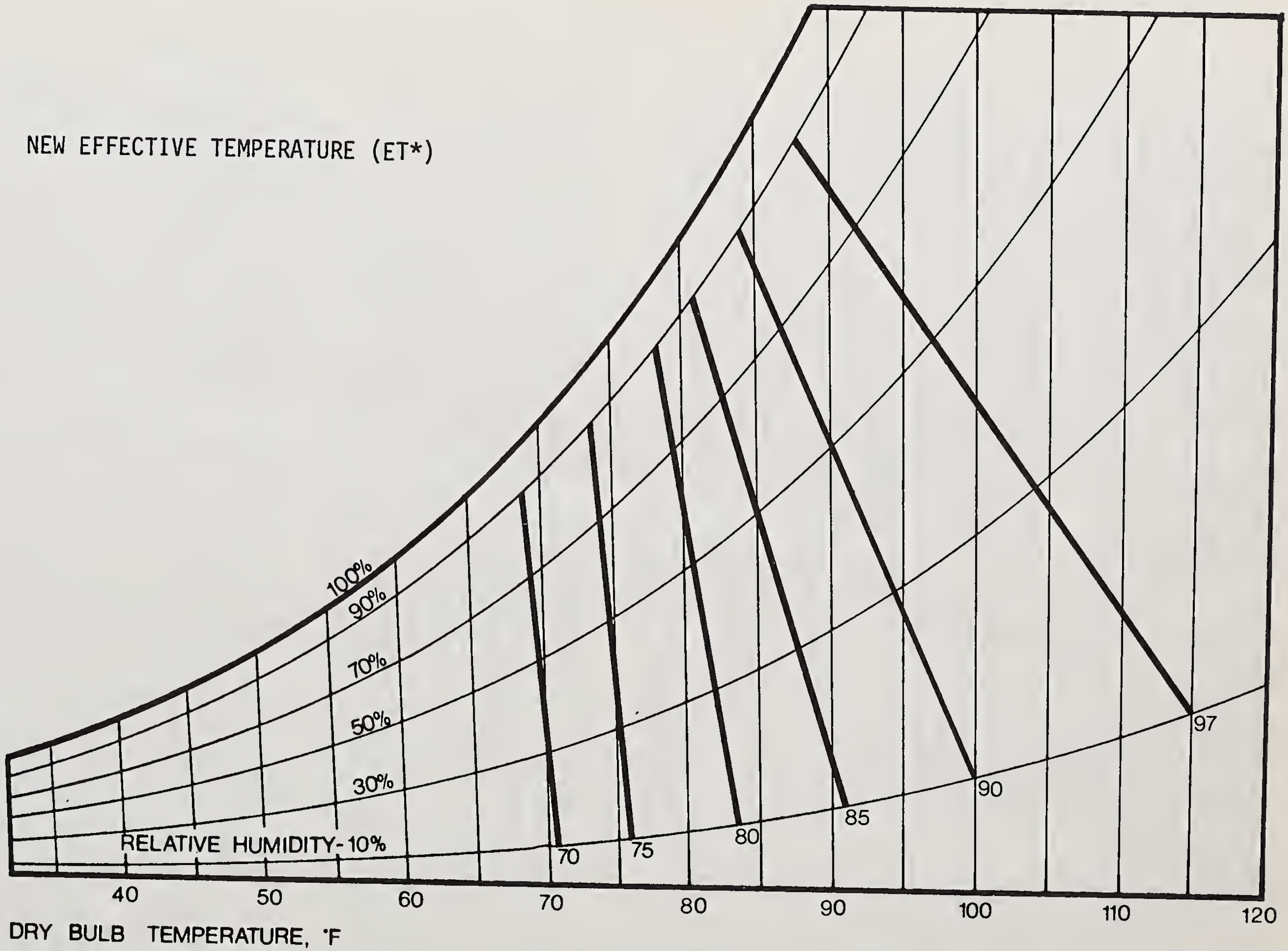

FIGURE 5: Lines of the New Effective Temperature (ET*) Scale (adapted from Hill et al [10])

HUMAN RESPONSE TO THERMAL ENVIRONMENT
(For sedentary, clothed subjects)

NEW T_{eff} SCALE °F	SENSATION: Temperature	SENSATION: Comfort	PHYSIOLOGY
110	Limited tolerance		Body heating
			Failure of regulation
	Very hot	Uncomfortable	Increasing stress caused by sweating and blood flow
100			
	Hot		
90	Warm	Slightly Uncomfortable	
	Slightly Warm		Normal regulation by sweating and vascular change
80			
	Neutral	Comfortable	Regulation by vascular change
70	Slightly Cool		
	Cool	Slightly uncomfortable	Increasing dry heat loss; Urge for more clothing or exercise (behavioral regulation)
60			
	Cold		
	Very cold	Uncomfortable	Vasoconstriction in hands and feet; shivering
50			
40			

(at 50% rh)

TABLE 1: A listing of responses of sedentary, clothed subjects to environmental conditions that are described by the New Effective Temperature (ET*) Scale (From Hardy [18]).

Whereas the thermal conditions set forth by the ASHRAE Standard 55-74 were re-validated as optimal for comfort, the authors noted that -- using the acceptability criterion (i.e., that 80% of those who are subjected to particular set of thermal conditions must be comfortable) -- variations from the ASHRAE Standard were acceptable. First, an upper limit on the temperature was placed at 78-80°F with relative humidities up to 70% with the proviso that lighter clothing be worn (ensembles rated at 0.4 clo or less). An ever higher temperature range, specifically 80-82°F, can be made acceptable if one or more of the following conditions were met: (1) the thermal resistance of clothing ensembles is maintained at 0.3 to 0.4 clo; (2) the relative air velocity is increased to the 50 to 100 fpm range, and/or (3) the relative humidity is maintained at 40% or less. Second, the temperature range of 68-70°F was found to be acceptable (to 80% of more of the test subject) if the clothing ensembles worn by the subjects had thermal resistance rating of 0.8 to 1.2 clo. Additionally, temperature in the 66-68°F range were also found to be acceptable if the temperature resistance of the clothing was maintained at the 0.8 to 1.2 clo level -- and it was evenly distributed over the body -- and drafts around the neck and extremities were avoided. The researchers observed that at both ends of the temperature range there are sex-dependent differences in the reaction to these extremes. Men appear to have a greater thermal sensitivity at the upper region of the range, whereas women, particularly those younger in age, seem to be more sensitive at the lower range. Both sensitivities appear to be overcome by relying on the aids noted above. Lastly, a primary conclusion was that "except for the ill and those in hospitals, there appears to be no serious health hazard for properly clothed individuals when exposed to temperatures in the range of 68 to 80°F."[6]

To summarize the researches noted in this section, there is considerable evidence to support that: (1) future building regulations should be based on a temperature range of 68 to 80°F (or possibly even 66 to 82°F); (2) such regulations should also describe required variable ranges for the relative humidity and the relative air velocity permitted in occupied space interiors (if not for the mean radiant temperature also), and (3) the thermal comfort guidelines set forth in the ASHRAE Standard 55-74 are too conservative. It should be noted that more research has been done examining the results of thermal comfort conditions at the upper end of the temperature range listed above. But the recent work by Gagge, Nevins, and their colleagues at the Pierce Foundation Laboratory has established evidence for means of providing comfort at the lower end of the range as well. It is extremely important to remember that the achievement of thermal comfort is dependent on the insulative value of the occupant's clothing and the form of activity being pursued by the occupant, as well as on the four environmental factors of ambient air and mean radiant temperatures, relative humidity, and relative air velocity. We would in no manner wish to see future building

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[6]Gagge, A. P. and Nevins, R. G. "Effects of Energy Conservation Guidelines on Comfort, Acceptability, and Health " [see 19]. Page 5.

regulations cite particular types of dress as mandatory (even if it were legal). Rather our interest is in emphasizing that intelligent choices of clothing by building occupants can establish comfort at the lower and upper ends of the 68 to 80°F or 66 to 82°F ranges.

Lastly, two additional issues that recent researchers have not addressed with sufficient intensity yet and which are of importance in developing comprehensive building regulations are: (1) nearly all the measurements of comfort have been done for subjects who were sedentary (passive) or were doing light office work; further work is required on acceptable thermal comfort ranges for building occupants pursuing the many more active tasks that frequently occur in buildings; and (2) each of the three major research efforts has identified thermal conditions which were described as "slightly warm" or "slightly cool" for some set of conditions; a question could then arise about whether exposure to such conditions has any effect on one's work or living task performance, and if not, could the acceptable range not be pushed out a little farther (say, between 65 and 85°F)?

III. A DISCUSSION CONCERNING APPLICATIONS OF INNOVATIVE SPACE CONDITIONING DEVICES AND STRATEGIES

In most buildings, several means are present which affect the degree of thermal comfort experienced by the building occupant. The heating, ventilating, and air conditioning system is, of course, largely responsible for conditioning the building either by adding or removing heat energy. But other sources of heat energy are or may also be present and these influence the maintenance of thermal comfort conditions: lighting fixtures, process equipment associated with the use of the building, incident solar radiation, and the body heat from the occupants themselves. Thus, the operation of the HVAC system in maintaining occupant comfort is dependent upon inputs from these sources and heat losses through the building envelope. How well or quickly the HVAC system responds to meeting the occupants' needs when such inputs or losses exist necessarily determines the quality and efficiency of the performance of the system. Noting this qualification about the character of the response of a HVAC system, we have identified a number of devices and use strategies whose adoptions will likely improve the operation of such systems, as well as aiding the achievement of thermal comfort. We would, therefore, advocate recognition of these innovations in future building regulations.

An Advocacy for the Development and Use of Improved Control Systems for Heating, Ventilating, and Air Conditioning Equipment

In an effort to improve the performance of buildings, both by insuring occupant thermal comfort and by conserving energy, we would suggest that future building regulations contain clauses which designate the devices by which mechanical systems in buildings are controlled. Here we will note four specific approaches that are commercially available or which will soon be available. Each of these will lead to reduced energy consumption in buildings without infringing on occupant thermal comfort. It is indeed possible that, for at least two of these approaches (namely, the second and fourth suggestions below), the likelihood of providing comfort may be improved.

The first of these approaches concerns the use of a dead-band thermostatic control on HVAC equipment, in place of the common single-temperature thermostat. For many mechanical systems with three- or four-pipe hot and chilled-water conditioning, a one-temperature thermostat controls the operation of the system. When the air temperature exceeds the set temperature (usually by no more than 1/2°F), cooling will begin. Alternately, when the air temperature falls below the set temperature (again, by the 1/2°F margin), heating of the air will occur. Clearly, such precise temperature control is rarely needed. Instead what should be required is the use of dead-band thermostatic control where heating or cooling occurs only when the air temperature, for instance, falls below 68°F or rises above 80°F, respectively. From the results of the comfort studies discussed in Section II, it should be clear that any single-temperature maintenance is unnecessary for establishing occupant comfort.

A second innovation whose use we advocate would be the application of true enthalpy-based control systems. We would suggest that rather than relying on individual thermostatic and humidistatic sensors separately measuring the building environment and determining the operation of the various HVAC systems components, controls should be employed where enthalpy of the air is the determining variable. Microprocessing circuitry is available for similar control functions in other industries and could be modified to meet this control need. Such microprocessors would permit the determination of the air enthalpy employing the continuous measurements of the temperature and relative humidity. Thus, enthalpy would control the mechanical system and the use of these controls would minimize reliance on a single combination of one temperature and one humidity as bases for establishing comfort. With a true enthalpy-based control device, the operation of the conditioning equipment could occur in response to varying temperatures and humidities as long as the enthalpy remained within a prescribed range (e.g., between 25 and 30 Btu/pound of dry air and temperature limits of 68 and 80°F).

Two other control devices that are presently in use but which should be more widely employed are (1) time-clock operation of HVAC equipment, and (2) the establishment of additional zones of control in buildings (rather than relying on a small number of control zones). The first of these two devices simply provides the system with a clock that either shuts down or sets back the heating system when the building occupants are not present or when the residents are asleep. Time-clock controls can also be employed for cooling systems for situations when the applicable buildings are not occupied (e.g., offices, schools, or laboratories). The other control method noted in this paragraph is one where, instead of using a one- or two-zone control system for large spaces or for a grouped series of smaller spaces with variable needs, smaller zones with the appropriate sensors, controls, and temperature management devices are established. Thus, reduction of meeting extreme conditions universally throughout a building can be accomplished.

Frequently, the application of such devices as these will have higher associated installation costs than would less dynamic controls. But, just as frequently, if life-cycle cost analyses are performed against the projected life of the building, it will be shown that appreciable savings can be realized. Also, the use of devices such as these will likely provide more thermally comfortable buildings. An additional trade-off that must be considered is the economic balance between the control system components and the air-moving, heat transfer equipment. If better controls diminish the need for heating or cooling equipment by more effectively utilizing this latter equipment, then more precise controls will be justified. Another more subtle savings may also occur by permitting the operation of the heating or cooling equipment closer to the design capacity through the employment of better control systems. To be avoided is the situation where large-capacity heating or cooling equipment is established to compensate for a lesser quality control system.

Construction of Buildings Which Respond Slowly to Changes in Environmental Conditions

A number of books and papers have recently been published in the American building literature (for example, 20 and 21) calling for the renewed construction of heavy or massive buildings in place of the now commonly-built lightweight, thin-envelope architecture. We would support the renewal of such an architectural style because the use of massive envelopes causes those buildings to respond more slowly to changes in environmental conditions (e.g., external temperature changes, intense solar irradiation, etc.). The use of massive buildings necessarily provides better assurance of maintaining occupant thermal comfort without the total reliance on HVAC systems. On the other hand, lightweight buildings respond quickly to environmental changes, and to insure occupant comfort, more dynamic mechanical systems are required. How quickly buildings themselves or their HVAC equipment should respond to gradual, or even dramatic, changes in conditions has not been well-established. If a thermal comfort range such as one of those discussed above is accepted, then the building and its attendant HVAC system can respond more slowly than if a single temperature is required for comfort. Alternately, when a massive building is permitted to cool down by using a temperature setback or by shutting the system off and then applying a warm-up period when occupancy is about to be resumed, appreciable energy can be saved in contrast to the situation where the building is maintained at a constant temperature level throughout the same period. We believe that too much emphasis has recently been placed on achieving short response times for buildings and that reliance on devices necessary to provide these quick responses is frequently energy-wasteful. Rather, we would strongly support the alternate construction and operation of massive buildings with mechanical systems of smaller capacities as an optimal means of achieving occupant thermal comfort.

An alternate situation that should be noted is the employment of a limited-capacity system to overcome a potentially uncomfortable condition. The practice of nocturnally cooling a building -- even with an HVAC system of limited capacity -- is beneficial because the external air is a virtually infinite heat sink. Thus, a building can be cooled down during the night and, if it has appreciable mass, its time delay for reaching its maximum internal temperature will be sufficient to minimize the need for refrigeration during a hot day. But, if you attempt in the morning to heat up a building which has cooled off overnight, with a system of limited capacity, the response time for the building to warm up will be lengthened. Thus, the response time for a building when it is exposed to moderate to large changes in environmental conditions can be dependent on the capacity of the HVAC system, as well as on the character of the building envelope.

Guidelines about the Operation of Buildings

A last noteworthy issue concerning the performances of buildings is that many building owners have recently begun to complain that the behaviors of their buildings are different than were predicted by the various designers. Upon review of the records of the performance, however, it is found that the reason for the discrepancy is due to the fact that buildings are being operated differently than the designers had intended. Either controls are overriden manually or the schedule of use is different from the program data given the designer or a building is not well maintained or any number of other difficulties arise and have not been adequately overcome. We do not wish to regulate the operation of buildings, nor do we expect that it is legally feasible (short of imposing fuel rationing). Rather, we want to note that such difficulties do occur and that perhaps building designers should attempt to anticipate them and to try to prevent their happenings.

IV. THE USE OF A THERMAL SIMULATION COMPUTER PROGRAM FOR PREDICTING THE THERMAL BEHAVIOR OF BUILDINGS

Until recently, the designers of buildings had no means to simulate accurately the thermal performance of their proposed design schemes. Calculation methods did exist which permitted the determination of the steady-state response of buildings to various heat sources and sinks within and outside the buildings. But these calculations did not reveal the time-dependent effects of the resultant heat fluxes. Transient-state calculations could be performed for the prediction of short-time responses, but these methods -- requiring numerous iterations -- were exceedingly complex and tedious. Now, however, with the beginning of the development of computer programs which will simulate accurately the thermal performance of a building, the designer is able to determine the behavior of the building or its parts when either is exposed to varying heat gain and loss conditions. Thus, the thermal performance of a building can be predetermined and the results of these simulations can be used as the basis for making design decisions which can improve the energy consumption requirements during the subsequent operation of the completed building. In addition to seeking to improve the performance of the building, the use of a thermal simulation computer program permits the designer to determine whether thermal comfort conditions will be present when the building is subjected to the several heat sources and sinks over time. Such a program can also calculate the amount of heating or cooling that will be required for offsetting heat fluxes, whose effects could cause occupant discomfort if not overcome.

We are currently developing and using a digital computation program, with which we are examining the thermal behavior of a number of building conditions. Our development of this program (called UWENSOL) has arisen from a research study in which we are seeking to identify and evaluate various energy-conserving techniques for a series of buildings projected for subsequent construction. In July 1976, our research team commenced work on this study at the request of the Washington State Legislature and the State Government's Department of Social and Health Services. The administration of this Department charged our team to: (1) choose two specific buildings within the range of projects that were anticipated for construction starts, and determine suitable energy-conserving guidelines for the future design and construction of these buildings; (2) following the establishment of such guidelines, serve as participants, with the architects and engineers, in the design phase of these buildings; and (3) after occupancy, test and evaluate the performance of the buildings to determine how well the various means for conserving energy were functioning.

The primary goals of the research team while participating in this study, have been to improve the technique of energy-efficient architectural design by the maximal use of passive means of energy control, to pursue appropriate trade-off analyses to foster the optimization of the use of such passive devices, and to integrate the passive devices with traditional and innovative active mechanical systems. Thus, our intentions are to reduce both peak and average consumptions of energy. To conduct the systematic evaluation of these devices, members of the study team have developed the digital computation program UWENSOL[22] which permits precise characterization of energy flows throughout buildings. This program is essentially a set of interconnected numerical algorithms, which in its entirety provides a comprehensive thermal simulation of any building subjected to common heat gain and loss sources.*

The implementation of the program UWENSOL requires three basic sets of information: (1) a careful description of the building form, including its geometry and the composition of the building envelope (i.e., surface areas and an indication of the materials employed in the envelope); (2) an hour-by-hour schedule of the occupant's presence and their employment of various devices that cause the flow of energy (e.g., lights, process equipment, primary and supplemental heating and cooling systems, etc); and (3) a detailed hourly listing of weather data (e.g., solar radiation and positioning, cloud cover presence, the various temperatures, wind speed, and humidity, etc.) Once these data sets are provided, it is possible to calculate -- over time and for various rooms -- heating and cooling loads for equipment sizing, the room air temperature, the temperatures at the surfaces of each room, the mean radiant temperatures in the room, and the humidity and enthalphy of the room air.

The use of the program UWENSOL thus provides the research team with a highly accurate means of simulating building thermal performance in response to changing (or transient) internal and environmental conditions. In the remainder of this Section, we will describe a series of calculations that indicate the usefulness of this program as a design tool. We will also demonstrate how this tool can be employed to evaluate design schemes both for predictions about whether comfort will be present and about energy consumption.

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*The basic mechanism for the calculational algorithm of UWENSOL is the finite difference solution of the various energy equations used to describe heat transfer throughout buildings. The use of the finite difference method is in contrast to the response factor method employed by the National Bureau of Standards and ASHRAE. We have carefully tested the two methods against each other and have shown that they give closely comparable results. Our preference for UWENSOL is based on its need for reduced core space and its use-time and on the relative ease with which pre-processing and post-processing routines can be written for the subsequent use of this program by architects and engineers. It has been our continuing intention throughout the duration of this study to develop a computational tool that can be relatively easily employed by designers as a means of testing and evaluating their design decisions.

Reduction of Energy Consumption by Using a Broader Comfort Envelope

At present, in our research study we are examining the operation of a 300-bed mental health care facility that is projected for construction in Steilacoom, Washington (as part of the Western Washington State Hospital). The living and primary care areas are anticipated to be built as a series of 25-bed modules. From programmatic data that we have assembled, we have developed a prototypical building plan for one of these modules (for plans of one of these modules and of the multiple arrangement of six of these modules together, see Figures 6 and 7). From this basic module, we have been carefully studying the thermal performance of two of the specific spaces when information such as that noted above (i.e., data about the physical forms, schedules of use, and microclimatology) is supplied. The two spaces being studied are a double-occupancy bedroom (a series of which are shown in Figure 6) and a day or common room (shown in Figure 8). For detailed description of these building parts and their schedule of use, please see Appendix A. An axonometric cut-away showing the placement of the dayroom appears in Figure 8.

To demonstrate that energy consumption can be reduced by employing a more broadly-defined comfort envelope, we have calculated the heating requirements for these two spaces under four sets of envelope boundaries: (1) ambient air temperature varying between 72 and 78°F (following the ASHRAE Standard 55-74); (2) air temperature varying between 68 and 80°F; (3) air temperature varying between 66 and 82°F; and (4) air temperature varying between 68 and 80°F, when the occupants are present and awake, then having the air temperature set back to 60°F either when the occupants are present and asleep or when the room is unoccupied for extended periods of time (i.e., longer than two hours). The first of these two spaces tested was the double-occupancy bedroom in which the residents are presumed to be present nearly continuously througout the 24-hour day and awake from 6 AM to 11 PM. For this situation, the results of the first three envelope boundary conditions are presented in Figure 9. It can be seen that the second and third conditions use progressively less energy than the first. A separate analysis shows that the fourth condition provides results that are similar to the second for the period when the occupants are awake, but when the occupants are asleep and the heating system has been turned down to 60°F, there is an appreciable reduction in the amount of energy consumed for permitting the temperature to float in the range between 68 and 60°F. Comparing the total amounts of thermal energy required to maintain this room at the levels set in each of the four conditions, we can see that: (1) the amounts of energy required for the first three boundary conditions decrease, one from the next as the temperature required is reduced (see Figure 9); and (2) the amount of energy required in the fourth case -- the one in which the heating system is set back at night -- is appreciably less than the second envelope condition (the constant 68°F temperature) and close to the amount required for the third condition (where the temperature was held at 66°F). For a summation of these amounts, see Table 2. We have found that in our simulations of this room when we are employing the temperature setback condition it is necessary to pre-warm the room by turning on the heating system one

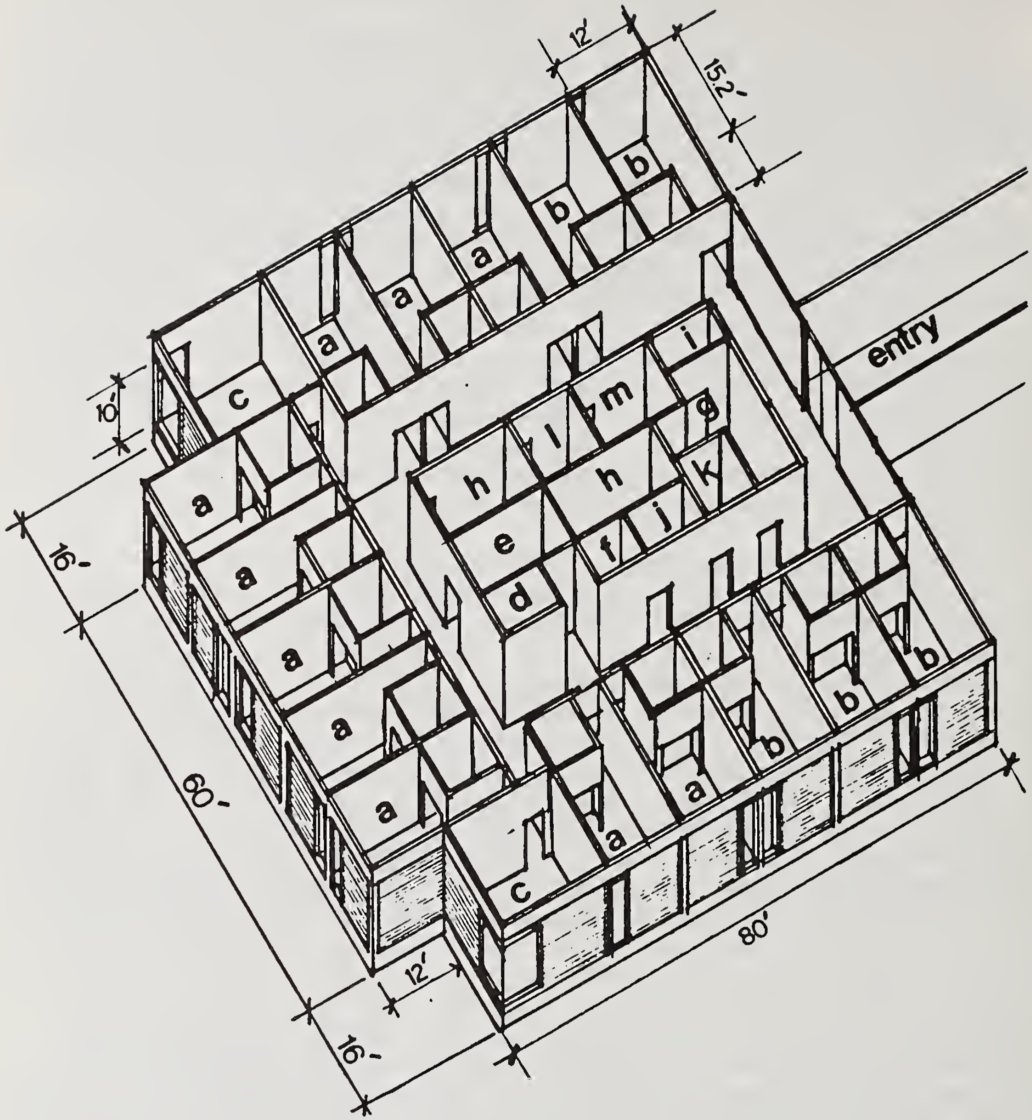
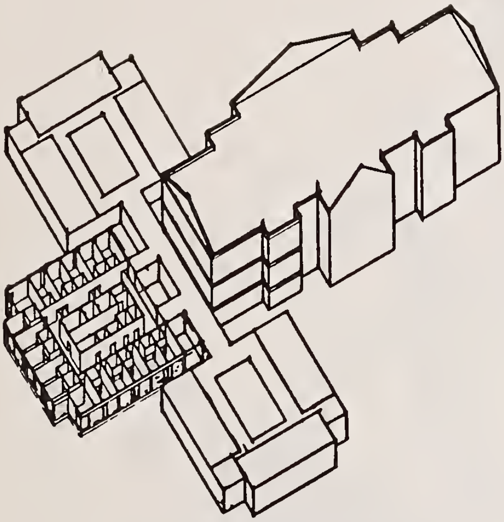
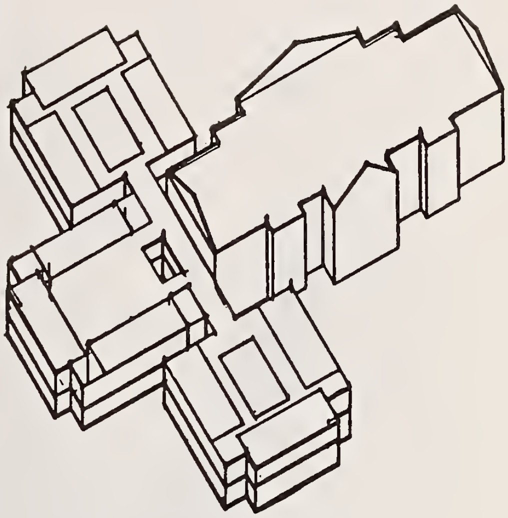


FIGURE 6: A 25-bed living module for the hypothetical health facility (letter keys appear on the following page).



One storey arrangement



Two storey arrangement

FIGURE 7: A summary of space requirements for a 25-bed living module (as shown in Figure 6) of the hypothetical health facility.

Letter key:

a.	10 two-bed rooms with toilet and shower	2750	sq.ft.
b.	5 private rooms with toilet and shower	1375	
c.	day area (or areas)	500	
d.	central toilet room	90	
e.	central bath and shower	120	
f.	linen	50	
g.	nurses station	200	
h.	treatment room	150	
i.	medication room	60	
j.	soiled utility	75	
k.	clean utility and pantry	75	
l.	consultation office	100	
m.	small conference room	120	
n.	storage room	100	
	Total assigned space for module:	5765	sq.ft.
	Total assigned space for six such modules:	34590	sq.ft.
	Circulation and mechanical space for six units:	15480	sq.ft.
	GRAND TOTAL	50000	sq.ft.

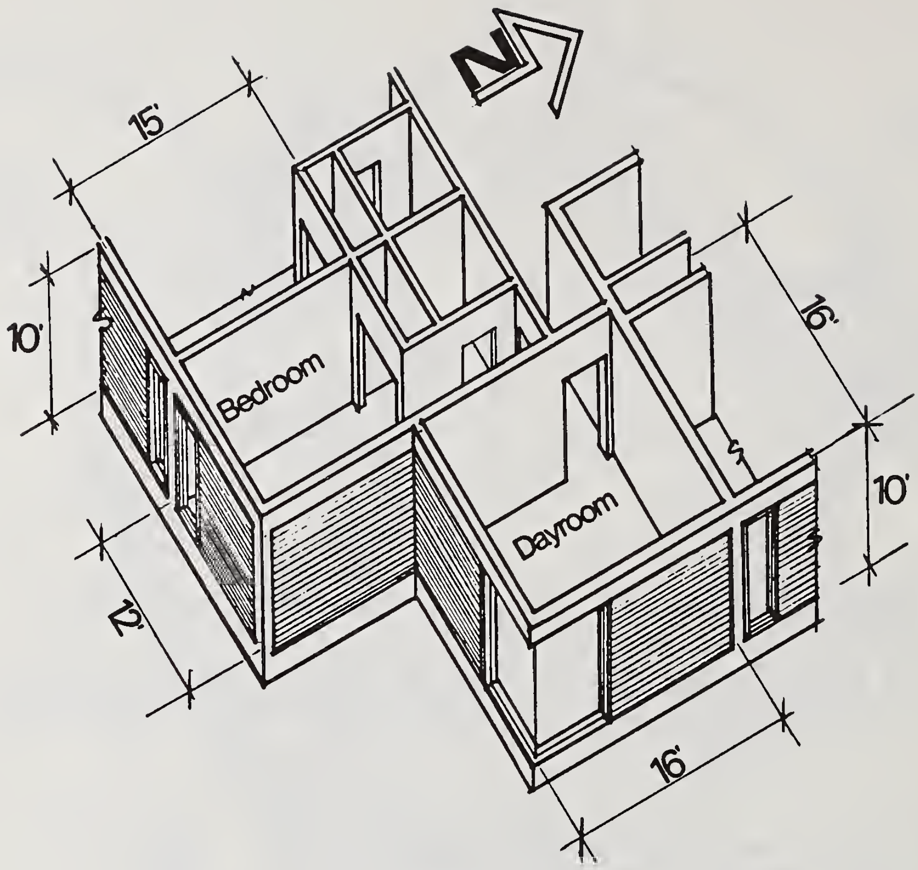


FIGURE 8: An axonometric cut-away of a cornder of the 25-bed living module showing a dayroom and a bedroom.

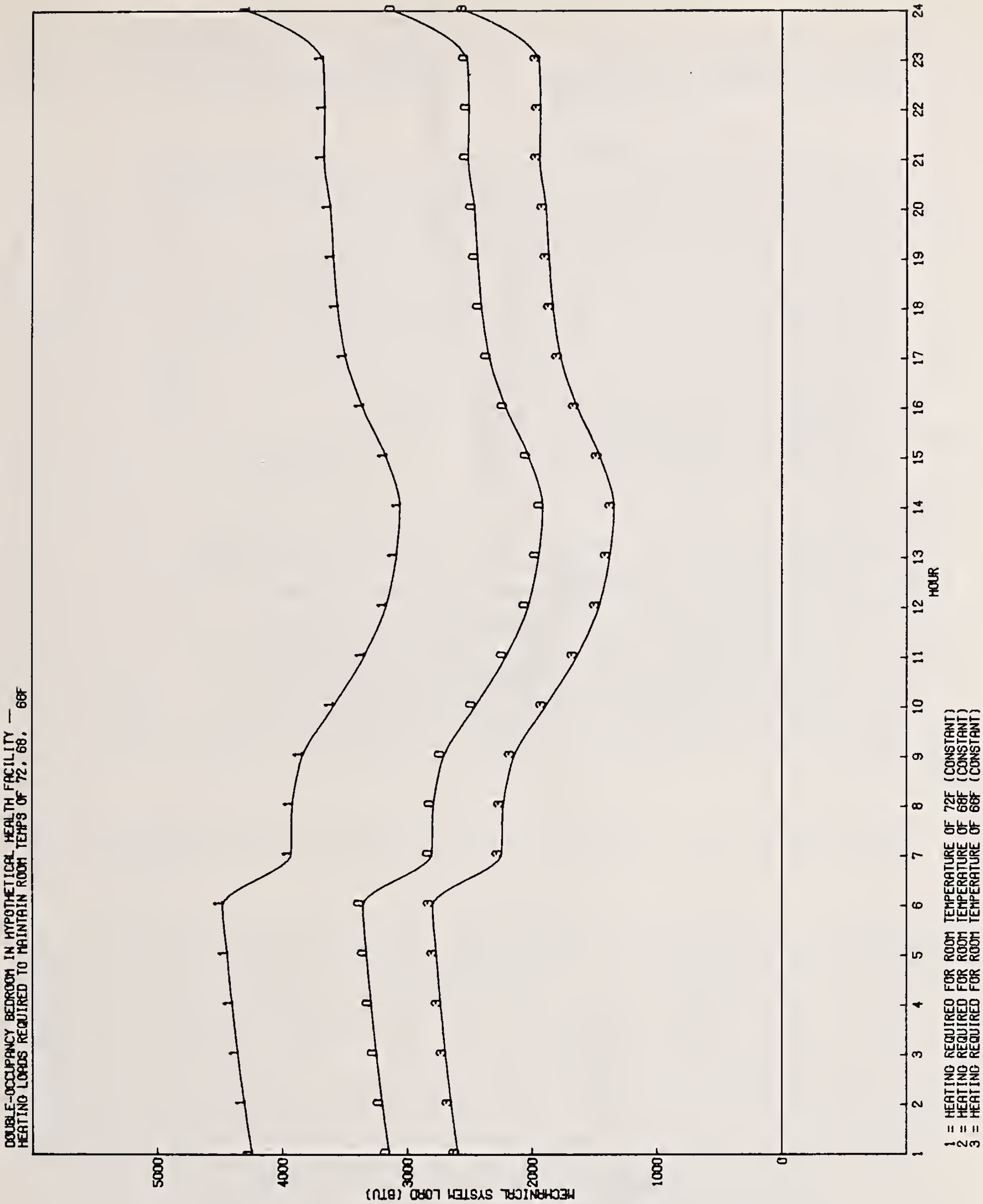


FIGURE 9: Hour-by-hour heating loads for the double-occupancy room

Internal Thermal Conditions	Heating Loads Required To Maintain The Specified Thermal Conditions *
1. Constant Room Temperature Minimum of 72 °F	90,236 BTU/day
2. Constant Room Temperature Minimum of 68 °F	62,995
3. Constant Room Temperature Minimum of 66 °F	49,425
4. Constant Room Temperature of 68 °F from 5 AM to 11 PM with a Temperature Setback to 60 °F from 11 PM to 5 AM	56,663

* Results of a series of thermal simulations performed using the computer program UWENSOL in conjunction with the weather data shown in Figure 12 and the room description for the Double-Occupancy Bedroom, as shown in Figure 6 and listed in Appendix A.

TABLE 2: Heating Equipment Loads for a 24-hour day for four thermal comfort envelope conditions (for the double-occupancy bedroom, as shown in Figure 6).

hour before the occupants arise in the morning. This simulated time of pre-warming follows actual practice in which building operators, who employ system setback periods, switch on their heating systems an hour to two hours before the residents get up.

For the second of the two building situations -- the dayroom -- whose thermal behavior was simulated, the results of the comparisons of energy consumption for the four operational conditions were similar to those observed during the first set of comparisons for the bedroom. Here again the amounts of energy required for the first three temperature limits decrease with the reduction of the minimum temperature permitted (see Figure 10). The analysis of the fourth boundary condition -- that for which a temperature setback is employed during extended periods of non-occupancy (such as from 10 PM to 8 AM) -- indicates a marked energy savings over the comparable situation where the temperature is fixed at a constant level over the 24-hour day (specifically, at 68°F). For short periods of non-occupancy (such as from 12 Noon to 1 PM and 6 PM to 7 PM when the occupants were elsewhere taking their meals) the HVAC system would not be set back. The sudden rises for the required heating loads (at 12 Noon and 6 PM) reflect that, when the occupants are away from the room and the lights are switched off, two significant heat sources are missing and that the heating system load will thus be greater if the system is to keep the room air temperature at a constant level. The continuous modeling of this room over a period of several days allows the designer to identify the effects of such short-term influences on the thermal behavior of the room and to determine with greater assurance what HVAC system capacities are required for maintenance of comfort.

<u>Use of the Mean Radiant Temperature as a Means of Providing Occupant Thermal Comfort</u>

It may be recalled from the discussions in Sections I and II that one of the environmental factors requiring control to insure thermal comfort was the mean radiant temperature -- or, more precisely, the balance of the radiant exchanges between the occupant(s) and the building enclosure. Control of this variable is specified in the ASHRAE Standard 55-74[(4)]. However, the Standard only states how to measure for and thus calculate this quantity, presumably after a building has been completed. Until recently, there was no accurate method of predicting the mean radiant temperature in a building enclosure during the designing of the building.

But with the development of a transient-state computation program such as UWENSOL, it is now possible to predict with accuracy, during the design phase, what the mean radiant temperatures will be within the building spaces. To illustrate this capability, we have determined the mean radiant temperature for a standing occupant located in the middle of the double-occupancy bedroom. In this demonstration we have varied the amount of glazing in the south-facing or exterior wall, having areas equal to 15%, 50%, and 85% of this south wall glazed with single-thickness, 1/8" double-strength clear window glass. The room air temperature is maintained as a constant

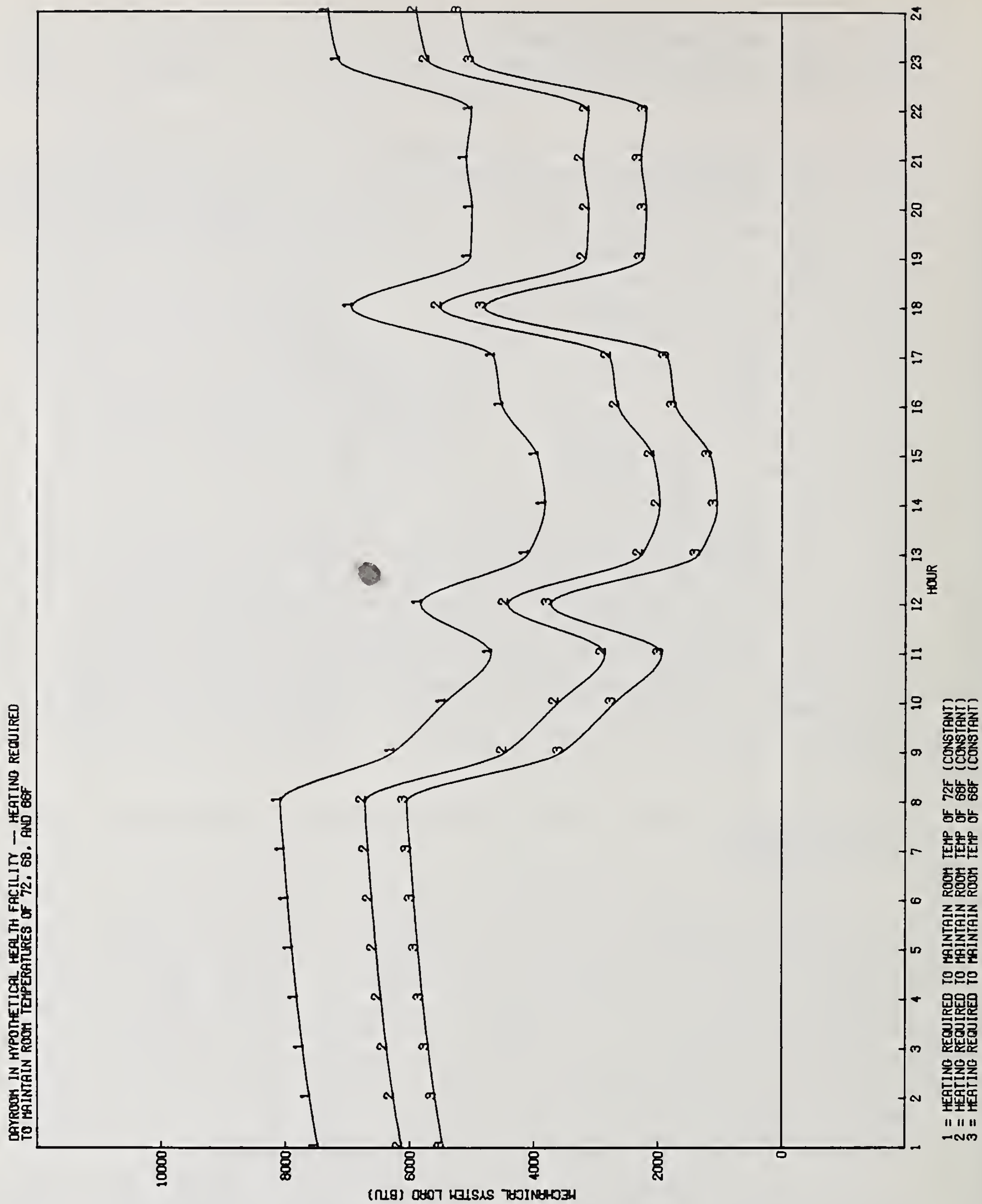


FIGURE 10: Hour-by-hour heating loads for the dayroom

68°F (dry-bulb temperature). As the reader may see from Figure 11, the mean radiant temperatures over the same 24-hour period for which the heating loads were calculated vary between about 64.2 and 66.3°F for the three amounts of areas of glazing. If the recommendation of ASHRAE Standard 55-74 is to be followed specifically, that for each 1°F the mean radiant temperature is below the designated termal comfort level (here, 68°F) the ambient air temperature should be increased 1°F to compensate -- then the air temperature for this bedroom should be maintained at about 71°F. For the designer confronting the condition of a too low mean radiant temperature and wishing to provide thermal comfort, the individual might follow this one or either of two alternatives for improving the MRT levels: (1) as noted in the sentence above, raise the air temperature in the room accordingly; (2) include in the design supplementary radiational heating sources, such as radiant panels or architectural radiation; or (3) improve the performance of the surfaces causing radiational cooling by either adding insulation or mass to retard the flow of heat outward or, such as in the case of glazing, reduce the size of window panels or employ double or triple thickness window assemblies.

The importance of being able to predict with accuracy the mean radiant temperatures at various locations within a building enclosure generally is founded on the attendant comfort problems associated with the presence of radiational heating or cooling surfaces. The problems posed by having large glazed areas in office buildings or schools can be avoided if designers are able to simulate the thermal behaviors of their design schemes during the designing of these buildings and to judge the consequences of their design decisions. Thus, no longer should there be situations where the ambient air temperature in a space on a winter or summer day is well within comfort boundaries but the effect of radiational heating or cooling makes the occupants uncomfortable.

Specification of Permissible External Design Conditions (Temperature, Humidity, Wind Speed)

Lastly, attention should also be given to the setting of reasonable external design conditions for use by designers when they plan and subsequently evaluate their schemes. For instance, the ASHRAE Standard 90-75[1] suggests that the external temperatures used for building envelope and mechanical system design parameters be those designated as the 97 1/2% and 2 1/2% conditions for winter and summer, respectively. We do not wish to debate whether these temperature guidelines are optimal or not: it might encourage the designing of more efficient buildings, without adversely affecting occupant thermal comfort, if instead the guidelines were set at 95% and 5%. Rather, we do wish to emphasize that the conditions offered by the ASHRAE Standard are for use while performing steadystate analyses. Still another set of choices can be made when a dynamic (transient-state) analysis is employed to compute the heating or cooling load requirements. One method which our group has applied is to select a sequence of days -- from a taped record of weather data -- during which extreme values (both maxima and minima) of dry-bulb temperatures

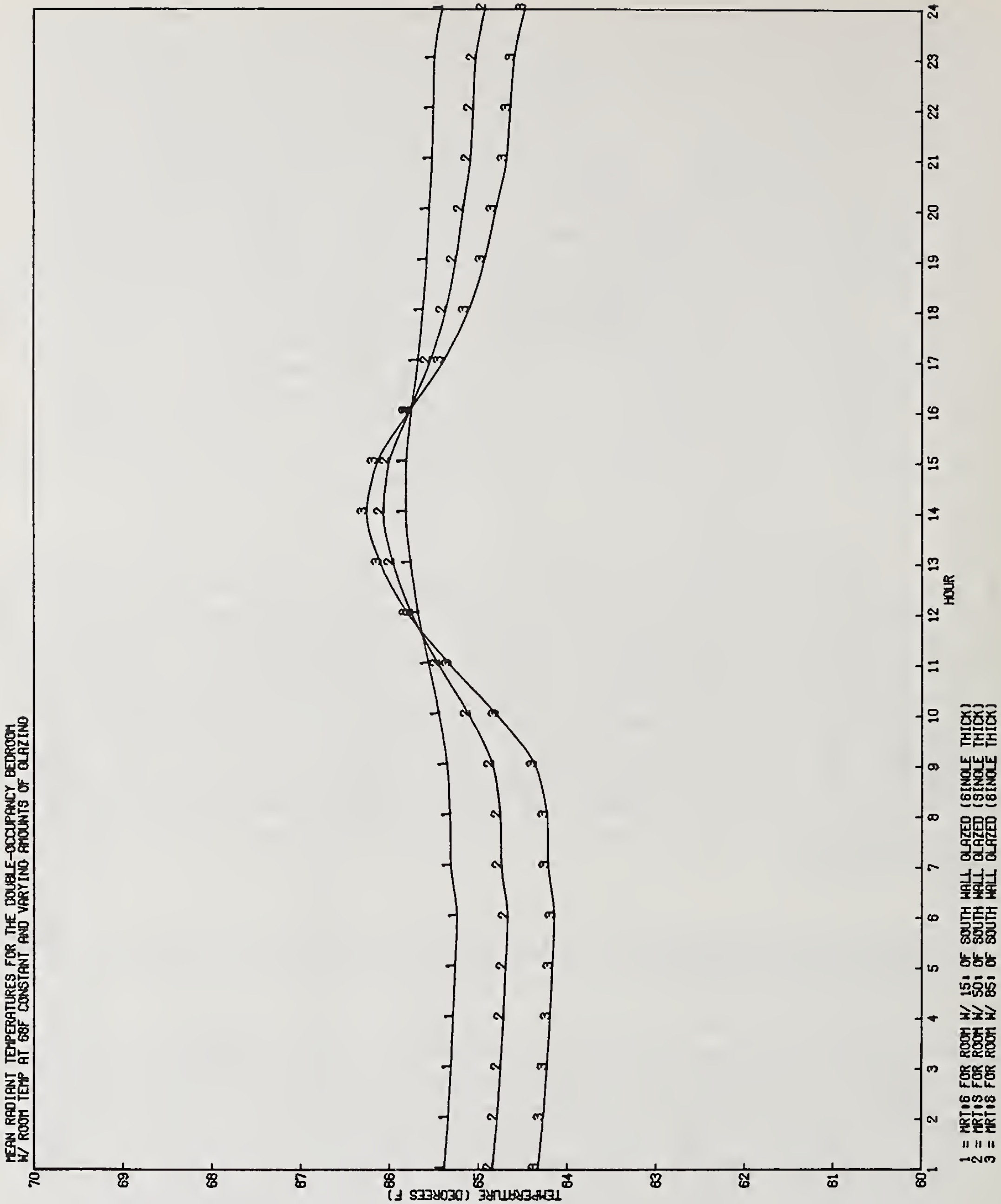


FIGURE 11: Mean-radiant temperatures calculated for an occupant standing in the middle of the double-occupancy bedroom with room air temperature constant at 68°F and with varying amounts of glazing

occurred. That is, we select conditions where extreme highs for summer and extreme lows for winter were recorded and where also the rates of temperature change were extreme. Then comparisons of the computed heating or cooling loans, given these weather conditions, are made using the UWENSOL program to perform a transient-state analysis. The results of these comparisons have invariably shown that the loads found using this dynamic analysis are less than those found by using the steady-state analysis based on the weather conditions recommended by the ASHRAE Standard 90-75 (which, in fact, were not extreme conditions). Our procedure also provides not only the peak heating or cooling load but also an average load over the period of days considered. The building may then be re-examined designating this average load as the HVAC system capacity and the solution re-computed to determine the resulting temperature excursions from optimum. From such re-calculations the degree of thermal comfort may be established. On the basis of this type of calulation the designer can more finely design both the building and the mechanical system.

CONCLUSION

In this essay, we have reviewed a number of building codes and standards with regard to the stated requirements or recommendations for establishing occupant thermal comfort. We have noted that the conditions set forth in the ASHRAE Standard 55-74 have generally been employed as the basis for writing comfort guidelines in the few standards and proposed model codes that do treat this subject. To provide a better definition of thermal comfort conditions, findings from studies on occupant thermal comfort which have been performed in the United States and Denmark are described. The results of these studies, which demonstrate very good agreement, indicate that the comfort guidelines suggested in the ASHRAE Standard are conservative. Alternate temperature guidelines have been noted here and we have briefly indicated that adoption of such guidelines would result in the conservation of energy. A number of innovative control devices and strategies for the operation of HVAC systems have been listed; employment of these devices and strategies are likely to improve the operating efficiency of buildings. We have also introduced a thermal simulation computer program, UWENSOL, which we have developed. Applications of this program have been discussed and means for improving the energy-efficient building and mechanical system designing by using this program have been displayed.

ACKNOWLEDGEMENT

We would like to express our gratitude to James Bedrick for his assistance in the performance of the computer work and to Phillip Schmidt for his careful preparation of the graphic materials. As was noted in the Introduction to this essay, we are four members of a twelve-person study team; other members of this group have aided us immeasurably in a number of ways. We are grateful for their assistance also.

APPENDIX A

Detailed Information About the Two Study Spaces

For each room, to test its performance under varying conditions, we first describe the room, employing the schematic program and plans (which we had developed earlier in our research study): the surfaces of the room must be noted in terms of areas and compass orientations; the presence and placement of glazing and other openings in these surfaces need to be listed; and the choices of materials used in the surfaces will be identified in terms of their respective placements in the walls, roof, and floor and their properties (e.g., absorptivity, conductivity, emissivity, specific heat, and density). Once these data are compiled, a schedule for the use of the space must be derived, including the occupant frequency, density, and metabolic rate; the lighting density and when the lighting is on or off; the amounts of ventilation and infiltration; and the interior design temperature and humidity. Additionally, information about the microclimatology surrounding the building must be noted, particularly the solar radiation intensities, wind velocities, and external temperatures and humidities. After all of this information has been assembled, calculations can be performed to determine the amount of heating or cooling that will be required to maintain the space within the thermal comfort range.

<u>Description of the Double-Occupancy Bedroom</u>

1. Physical Presence

   A. For the floor plan for this room, see Figure 6.

   B. Interior dimensions = 12' wide (east-west dimension) x 10' high x 23' deep (north-south dimension); note that the bathroom has been lumped with the bedroom and the two spaces are considered as one room for this analysis.

      1. The south-facing plane is the exterior wall and contains single-pane glazing of an area that is 15% of this wall (as studied using the UWENSOL program).
      2. The top plane of this room serves as both the ceiling and the roof and, as the roof, it is exposed to the sky.
      3. The door to the bedroom (from the corridor) is located in the north-facing plane.
      4. The east and west-facing planes are interior walls separating this bedroom from adjoining bedrooms on either side.
      5. The floor is a slab-on-grade.

C. The materials and their respective thickness are, for this model:

1. Floor: 4" concrete slab (140 lbs./cubic foot); the vinyl asbestos tile is present but has not been considered because of its quite low resistance to heat transfer.
2. South wall: (a) the window area is glazed with 1/8" double-strength, clear window glass; whether the glass is operable is not directly considered; and (b) the opaque area is composed of 4" face brick (placed on the exterior), 1" polystyrene insulation, and 8" concrete block (120 lbs./cubic foot).
3. East and west walls and the portion of the north wall that does not include the door: each of these consists of 1/2" gypsum plaster (50 lbs./cubic foot), 8" concrete block (120 lbs./cubic foot), and 1/2" gypsum plaster.
4. Door: 6'8" x 3' solid-core wood door.
5. The ceiling/roof plane consists of, from the inside to the outside: acoustic tile, 4" of lightweight (perlite) concrete (40 lbs./cubic foot), and built-up roofing.

II. Schedule of Use

A. Occupancy: Two adults will be present, for this model, continuously throughout the 24-hour period studied. The metabolic rate is fixed at 400 Btu/hr/occupant.

B. Lighting: The lighting level in the room has been set at 1.5 watts/square foot of floor area as a constant artificial illuminating intensity. This is equal to, for the bedroom floor area of 182 square feet, 931 Btu/hour. The artificial illumination is presumed to be switched "on" continuously from 6 AM to 11 PM. For this model, opportunities afforded by natural illumination were not included as a means of meeting lighting needs.

C. Ventilation Rate: The ventilation air is provided continuously and is based on the guideline of 10 cubic feet of supply/minute/occupant. Thus, there is a constant supply of 20 CFM. One-half of this supply is fresh air taken from outside of the building. The overall temperature of the supply air is 74°F.

D. Infiltration Rate: Infiltration is expected to occur at about 1/2 air change/hour or about 15 cubic feet/minute. This rate is based on the expectation that the glazing is either not operable or is partially operable with a careful application of weatherstripping.

E. Other measures: The ground temperature underneath the slab has been set at 60°F to recognize that the ground underneath such a slab would gradually be warmed by the heat that is transferred through the slab over time.

III. Weather Data

A graph of the diurnal temperature cycle and the solar insolation for the reference day appears as Figure 12. The solar insolation is a sum of the direct solar radiation, the diffuse radiation from the sky hemisphere, and the reflected radiation from the ground and surrounding objects (e.g., buildings, vegetations, etc.) The reference day is the second day of a winter sequence of measurements taken for a four-day period at the McChord Air Force Base in 1961. These data are representative of wintertime weather conditions in the Puget Sound area.

Description of the Dayroom

I. Physical Presence

A. For the floor plan for this room, see Figure 8.

B. Interior dimensions = 16' wide x 16' deep x 10' high.

1. Both the south- and west-facing planes are exterior walls and contain single-pane glazing with areas equal to 30% of each of these walls (as studied using the UWENSOL program). The total glazing area is presumed to be equally distributed between these two exterior walls.
2. The top plane of this room serves as the ceiling-roof and its top is exposed to the sky. A flat roof is used.
3. The door to the dayroom (from the corridor) is located in the east wall.
4. The north and east planes are interior walls separating this dayroom from adjoining bedrooms on either side. This dayroom is deployed as a corner room of the living module.
5. The floor is slab-on-grade.

C. The materials and their respective thicknesses are, for this model, entirely similar to those identified for the Double-Occupancy Bedroom.

II. Schedule of Use

A. Occupancy: Ten (10) adults will be present, for these calculations, during the following hours -- 8 AM to 12 Noon; 1 PM to 6 PM; and 7 PM to 10 PM. The metabolic rate for these adults is fixed at 400 Btu/hour/occupant.

B. Lighting: The lighting level in the room has been set at 2.0 watts/square foot of floor area as a constant artificial illuminating intensity. The artificial illumination is presumed to be 1/2 on during the period when there is solar radiation (from 8 AM to 4 PM) and when the room is occupied

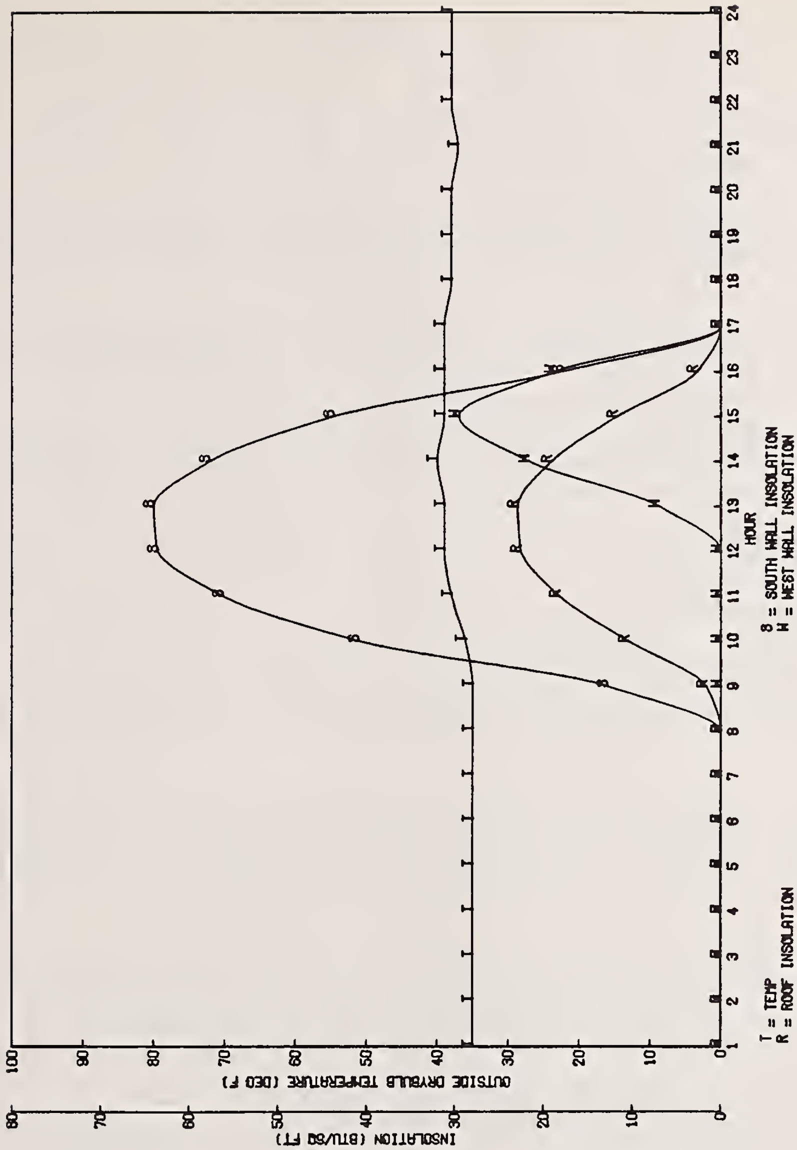


FIGURE 12: Outside air temperature and insolation incident on the external surfaces of the bedroom and dayroom

(as identified in 11.A. above). When there is no solar radiation, the lights are said to be operating at 100% of capacity. When the room is unoccupied (again, as identified above), then the lights are presumed to be off.

C. Ventilation Rate: The ventilation air is provided continuously throughout the 24-hour period at a rate of 150 cubic feet/minute. At least 66% of this supply is fresh air taken from outside of the building. The overall temperature of the supply air is set at 74°F.

D. Infiltration Rate: Because the building has an appreciable positive ventilation rate, the infiltration rate is presumed to be minimal and can be neglected.

E. The other measures noted for the calculations for the Double-Occupancy Bedroom are in effect for this room also.

III. Weather Data

The weather data noted above for the Double-Occupancy Bedroom are entirely identical for this Dayroom.

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IMPLEMENTATION OF ENERGY CONSERVATION BUILDING STANDARDS
THE VERIFICATION PROBLEM FOR HVAC SYSTEMS

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This paper outlines the parameters and procedures which should be considered in the preparation of energy conservation performance specifications and verification for building mechanical systems.

The trend toward implementation of energy conservation standards, particularly for commercial building, carries with it the question of how the building code official is to determine whether or not an energy conservation standard has been met. For prescriptive standards, e.g. insulation thickness requirements, this may be readily ascertainable. For performance standards for HVAC systems, this becomes a very significant problem for the code writer as well as the building code official.

It has been shown that significant energy savings may be achieved by careful balancing and optimization of building mechanical systems for new buildings or retrofit of existing inefficient systems. It is anticipated that code writers concerned with energy conservation standards may wish to address this important subject area in their codes.

Key Words: Balancing; building code official; code requirements; energy conservation; performance specifications; testing; verification.

INTRODUCTION

The historic role of testing and balancing of HVAC systems process has been to establish for the building owner whether or not HVAC contractual provisions have been satisfied. However, the technical expertise required in this traditional role, along with the requirements for proficiency and independence of the testing agency from other contractual interest in the HVAC system[1] is being called on by the architect-engineer and building owners to assess the effectiveness of energy conservation measures.

The trend toward implementation of energy conservation standards, particularly for commercial building, carries with it the question of how the building code official is to determine whether or not an energy conservation standard has been met. For some equipment and materials, this may be fairly straightforward, particularly as pertains to laboratory test certifications for furnaces and appliances and for materials with prescriptive standard specifications e.g., insulation thickness requirements.

However, in the area of performance standards involving heating, ventilating and air conditioning (HVAC) systems this can become a very significant problem. This paper outlines parameters and procedures which should be considered in the preparation and verification of energy conservation performance standards for building mechanical systems.

PERFORMANCE STANDARDS AND HVAC SYSTEMS

In considering the overall problem of energy conservation measures as they relate specifically to the HVAC systems in other than residential buildings, there are several considerations which deserve mention.

(1) There is a need to upgrade existing buildings and their systems to modify their energy consumption patterns to more acceptable levels. This, in general, will consist of modifying the building envelope in some manner to increase its energy efficiency and/or adjusting the mechanical system to provide optimum efficiency.

(2) For new construction, energy saving features may be incorporated into the design to include specific requirements regarding insulation, luminaire and solar heat build-up, and energy efficient HVAC systems. More and more, these requirements are being made a part of building codes through adoption of energy-related standards and model codes such as found in American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90-75,

"Energy Conservation in New Buildings," and the Building Officials and Code Administrators (BOCA), "Basic Energy Conservation Code/1977." The BOCA model code incorporates all applicable energy conservation requirements presently included in the BOCA "Basic Building, Mechanical, and Plumbing Codes" and incorporates the energy conservation requirements of ASHRAE 90-75. In addition, the Construction Research Council, representing institutional building owners, is addressing itself to specifications which will define requirements for performance and testing of HVAC systems.

(3) In the case of HVAC equipment and systems, the mere adjustment of an individual component may not, of itself, achieve a great deal. The "total" adjustment of the system can achieve major energy consumption improvements. This is based upon an understanding and appreciation of the prime definition of climate conditioning to be the process of treating air so as to control, simultaneously, the temperature, humidity, movement, cleanliness, and final distribution to meet the requirements of the space to be conditioned. While the individual air treatment processes contribute a specific element in producing human comfort, in practical applications, it is the composite effect of all of these processes, each related to and influencing the other, that produces the final desired conditions. If any element of the system is not functioning and performing as it should, the final result will be effected in terms of energy efficiency and overall system performance. The process for producing this coordinated function is referred to as HVAC system balancing. (It must be noted that there are definite engineering and physiological trade-offs involved in meeting requirements for the "people environment" as opposed to those representing the optimum energy efficiency of a system.)

All of which suggests the following:

(1) That energy performance of new buildings must ultimately be measured by some performance criteria which addresses the total system.

(2) That some datum is necessary against which to measure the effectiveness of changes to existing buildings.

ACHIEVING ENERGY EFFICIENCY FOR HVAC SYSTEMS

A well-tuned HVAC system, which like a properly tuned automobile, will use less energy to fulfill the purpose of design and at the same time cost less to operate. In the case of HVAC systems, a well-tuned system means a well-balanced system. Turning down thermostats or raising cooling thermostat settings will not make any appreciable difference in energy conservation except perhaps in small, package type residential systems. This argument is supported in part by Snell, Kusuda, and Didion's review of the general data from Project

Independence and other sources on energy use in the United States office buildings.[2] In one building site as an example, energy reductions related to system adjustment were essentially achieved by discipline in the use of lighting systems. For the same time period the energy consumption by fans and pumps, cooling, heating, and hot water was actually slightly higher, possibly as the result of reducing the heating provided by the luminaires. However, this same data suggests that major energy reductions are achievable if HVAC system performance is optimized for efficiency.

As pointed out by Liu, Hunt, and Powell,[3] the energy used for space heating and cooling, lighting, hot water heating, and mechanical ventilation constitutes a large portion (32 percent) of energy consumption in the United States. They note that it has been estimated that at least 10 to 20 percent and maybe as high as 40 to 50 percent of the energy used in buildings could be saved in the design and construction of new buildings. This could be achieved by performing a comprehensive thermal analysis of the building envelope, by a more careful evaluation of fresh air ventilation and lighting requirements, and by the utilization of efficient energy conversion equipment.

For existing buildings, implementation of HVAC energy conservation code requirements may impose special considerations. These are outlined elsewhere in this paper. However, there are a number of actions which may be undertaken voluntarily at the option of the owner or mandated by the code pending development of more definitive standards such as proposed in ASHRAE Standard 100.4P, "Energy Conservation in Existing Buildings -- Industrial." Among the energy improvement actions which are currently available under Associated Air Balance Council (AABC) procedures[4] and which may be applied at the option of the owner by the test and balance engineer working under the direction of a professional engineer are:

(1) Evaluation of the return air system for use of an economy cycle using outside air for cooling when the ambient temperature is between 40°F and 50°F.

(2) Measurement and evaluation of the water discharge temperature of the chiller and boiler to ascertain the feasibility of raising the chiller discharge temperature and lowering the boiler discharge temperature by a few degrees.

(3) Checking amperage demand of motors. If running overamped, they can possibly be adjusted downward by reducing fan speed by as little as 5 to 10 percent. In conjunction with the implementation of other energy conservation measures, it may even be possible to reduce fan motor size while still achieving desired performance.

(4) Heating and cooling coil surfaces should be inspected and cleaned thoroughly to prevent static pressure build up which produces extra fan loading and needless energy waste by the motor.

(5) Checking all pumps for proper head pressures and adjusting motor amperages to the most efficient settings.

(6) Checking the system for proper maintenance: inspect coolant for algae or slime which reduces heat transfer efficiency causing circulating pumps to work harder and wasting energy; clean strainers and check pipes for calcified deposits which reduce pumping efficiency.

(7) For systems containing several motors of the 10-50 horsepower class, evaluate and consider modification of the control system to provide step-starting to reduce peak power demands. If several chillers are used, consideration should be given to programming loan demand to give an optimum load to each chiller.

(8) Where natural gas fired boilers are used, pressure regulators should be tested to determine proper calibration. Fuel to air mixtures should be checked for most efficient combustion.

One point worth mentioning here is that some systems have never been properly tested, adjusted, and balanced. This, possibly, because it was felt that it was an unnecessary expenditure when the system was built and eliminated to save a few dollars on the initial cost of the building. It is on these buildings that the greater savings will be realized by applying good analysis procedures followed by expert test and balancing.

On other systems which have been balanced originally, it must be remembered that most were balanced before the energy crisis and at that time they may have been balanced to meet design criteria established by the plans and specifications for optimum performance and not optimum energy efficiency. To illustrate this point, many systems designs can be reevaluated to see where energy savings can be achieved through reduction of air volumes. It should be borne in mind that when heat generating systems are cut back or shut off to conserve energy, large reductions occur in the cooling demand which represents a major energy saving. Once cooling loads are reduced, air quantities can often be reduced. This, in turn, may require changes in air flow distribution patterns or redistribution of air to different zones. Damper settings may have to be adjusted to provide for the adjusted heat loads throughout the building.

MEASURING PERFORMANCE

Regardless of whether prescriptive or a performance specification is prepared, probably the major problem lies in determining whether the specification has been met. At the most elemental level, in dealing with a prescriptive specification the inspector's task is reasonably straightforward, e.g. measuring the inches of insulation, U factor, checking documentary of laboratory testing requirements for furnaces and other appliances. Unfortunately, this level of compliance determination suffers serious deficiencies with regard to evaluation of system performance or overall energy effectiveness of a given structure. It is even possible to conceive of the case whereby a building modification to improve energy efficiency would, in terms of the overall system, have a negative effect on the energy efficiency of the structure.

This question of determining the effectiveness (and compliance with code requirements) of an energy improvement measure is quite complex. It has been addressed by the Federal Energy Administration (FEA) in proposed rules and public hearings of Energy Audit Procedures.[5] In its testimony before the FEA at the public hearings in Washington, D.C. on the proposed rules, the Associated Air Balance Council made the following observations:

(a) There is a real need to protect the building owner or buyer from the overzealous supplier who may make energy performance claims which cannot be fully justified. The point being that, in general, neither the buyer/owner or the building code official may be in the position to evaluate the claim of the effectiveness of a given energy conservation technique as it applies to a given building. Some mechanism for qualified independent audit is required. (The proposed FEA approach is to develop a system to provide for an independent outside audit to establish compliance with performance criteria.)

(b) The FEA proposed rules tend to view proposed energy improvement techniques in isolation from the total system effects. AABC pointed out the serious pitfalls which await the unsuspecting as pertains to failing to consider the total HVAC system and not an isolated element or proposed improvement. We feel that element or subsystem optimization is potentially poor engineering and economic practice.

(c) The proposed rules do not include operating and maintenance costs in total purchase and installation cost in their life cycle cost calculations for energy effectiveness. While this may be difficult to relate to the building code official's area of interest, it does bring up the point that judging or approving an energy conservation measure solely on the basis of first cost is an extremely questionable procedure.

(d) In addressing the FEA recommendations of qualifications for certifiable energy auditors, the Associated Air Balance Council suggested that industry certifications such as those required for an AABC Test and Balance Engineer qualification be accepted by the FEA. This suggestion is consistent with the recommendation of the Building Research Advisory Board of the National Academy of Sciences[6] for test and balancing of HVAC systems:

"...The contract should specify that the adjusting, balancing, and testing services must be performed by an independent organization which in no way is affiliated with either the prime contractor, the installing mechanical equipment contractor, or manufacturing of equipment used in the environmental system, or the engineering firm responsible for the design of the system..."

"...contracts should stipulate that in order for a firm to qualify as an independent testing and balancing organization, it must either be a member of the Associated Air Balance Council or meet the criteria membership in the AABC..."

PE AND TBE RELATIONSHIPS

As can be gathered from the preceeding discussion, HVAC system performance measurement and corrective diagnosis represents a fairly sophisticated interdisciplinary activity involving building code officials, owners, the architect-engineer with his professional engineer (PE) staff specialists, and the test and balance engineer (TBE). In those cases where the Associated Air Balance Council certified TBE is also a PE and in a position to take on the PE responsibilities, the communication process is simplified. However, in general this may not be the case.

NEW CONSTRUCTION

Assuming that building energy code certification is required and presented, the code official should determine if the certification has been signed by an independent and qualified test and balance agency. If the certification was by such an agency, the building code official may accept the architect-engineer's certification. If the certification was not signed by an independent, qualified test and balance agency, the building code official should call for a certification signed by a TBE or equivalently qualified engineer. If the construction is presented for code approval without an energy code certification, the code official should require the A/E to obtain the HVAC energy certification. Alternately, the building code official may go directly to a TBE agency and request that the tests prescribed in the code are conducted.

EXISTING CONSTRUCTION

For existing buildings, the case may be complicated by either or both conditions where the energy code for new construction may not apply and where the original HVAC construction specifications are not available. Even if the construction specifications are available, changes to the building configuration, equipment, and usage may have rendered the original specification meaningless.

If the construction specifications are available (and relevant to current operating conditions) a TBE audit could be performed. This audit should then be placed in the hands of a mechanical system PE who would evaluate the HVAC system performance and direct any necessary modifications to bring the system up to code standards. Once this work is completed, the TBE should again be brought in to certify HVAC system performance.

If construction specifications are not available, the PE and TBE working together as a team should evaluate and document the mechanical system in situ. A TBE audit may be an integral part of this joint effort. The PE would prepare a HVAC system modification plan; the desired modifications completed by a mechanical contractor, followed by TBE certification of system performance.

ENERGY CONSERVATION CODES INVOLVING HVAC SYSTEMS

There appears to be an unquestioned need to improve code requirements for both new and existing construction as pertains to the energy conservation problem facing most if not all governmental levels. For residential construction and small commercial buildings, the trend may well be toward the prescriptive code or specification. For commercial buildings this refers to cooling - engineering considerations probably dictate a strong movement toward performance codes and specifications.

The problem is that although development of HVAC performance specifications is well advanced as the result of efforts of groups such as the Construction Research Council, the development of total building system energy performance specifications is very much in an embryonic state. Excellent work in this area is proceeding under the direction of the Center for Building Technology, National Bureau of Standards. Energy models for complete building systems are being investigated to determine the degree of interaction between subsystems and to develop the necessary mathematical relationships to define these interactions in terms of building design and performance.

The status of development of energy performance specifications for larger buildings notwithstanding, it appears that there is still a great deal which the code writer can do to deal with this problem at the local/municipal level. Assisting with this process is the self-interest of design professionals and building owners to develop energy efficient designs for both new and existing buildings. In most areas, the cost for energy is probably sufficient to serve this self-interest. However, the commercial real estate speculator may not perceive the needs of the ultimate building owner and could easily decide not to willingly seek out or demand an energy-efficient design (with its attendant added costs). Likewise, some owners of buildings with tenants may be tempted to pass on the costs of their building inefficiencies to their tenants. The code writer clearly needs tools to deal with these latter conditions, if only to serve the total interests of his jurisdication during energy restricted periods as were experienced in many parts of the United States during the winter of 1976-77. Fortunately, most codes have provisions for 3rd party certification and/or give the necessary authority to the building official to implement necessary action. This authority can be used to obtain field testing services. However, in general, it appears that the building official relies heavily on the plan checking phase supported by comprehensive data submitted by the designer.

For new construction, it is encouraging to note that community energy consumption norms are being developed. Most logically, this will be achieved through a study of energy consumption levels as they relate to specific building classifications. In conjunction with the local municipal building engineering staff and design professionals, design objectives can be agreed to, studied on a voluntary basis for some time period, and then finalized as local code requirements. It must be borne in mind that a properly balanced HVAC system, even without extensive building and equipment modifications, will produce substantial energy savings. This certainly should be given priority consideration for code adoption.

For an existing commercial building (with over 100 tons of air conditioning) consideration should be given to a phased-in requirement that the HVAC system be balanced for optimum energy efficiency which would meet nominal comfort standards. This requirement would establish an invaluable datum to assess the improvement in energy efficiency resulting from any other energy conservation measure applied to the building. Some of the steps in that procedure were outlined earlier in this paper. A requirement for subsequent audits may be considered following any major changes to the energy envelope.

SUMMARY

The state-of-the-art having reached the level which would allow codification of a definitive energy performance specification, there is now enough information available to allow the code writer, in conjunction with his engineering staff and local design professionals, to take the first step in substantially improving the energy efficiency of many larger buildings which may not be suited to prescriptive energy specifications.

One of the readily achievable payoff areas would be in improving the efficiency of mechanical systems for both new and existing structures. Much is achievable when the unique talents of the design engineer and test and balance engineer are brought together to address this problem.

We commend these thoughts and recommendations for your consideration.

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SYSTEMATIC ORGANIZATION OF STANDARDS AND CODES

by

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The ease and confidence with which a code or standard can be used depends on how well it is organized. A systematic method for organization of design standards and codes is described and illustrated with an example. The method provides checks on the uniqueness and completeness of the organization, where organization is taken to include both the scope and the arrangement of the provisions. The method promotes the use of technically valid provisions and improves the efficiency of standards generating activities. The illustrative example is the organization of a performance specification for the structure of residential buildings.

The method is based upon objective qualities of an organization. The key element of the method is the systematic classification of provisions. Each provision is related by its syntax and semantics to several classifiers. Requisite properties of uniqueness and completeness are achieved in the overall organization by requiring them in subsets of the classification and then building the overall organization in a systematic fashion.

Key Words: Building codes; classification; index; organization; outline; standards; systems engineering.

INTRODUCTION

A designer or regulator who refers to a code or standard must be able to find with ease and confidence the provisions he needs. Regulators are reluctant to accept new technology in codes and standards, in part, because they cannot be confident of finding the correct provisions. Designers are reluctant to use unfamiliar codes and standards, often because it is hard for them to find and to be sure they have found all the relevant provisions. The organization of provisions determines whether they can be efficiently and reliably found by the reader.

This article briefly describes an innovative method for outlining that provides a systematic and effective method for organizing standards or codes. An example reorganization of a set of provisions illustrates many important features of the method. Writers of provisions benefit by using the method because their task becomes more systematic, thereby possibly easier and more efficient. Designers or regulators benefit in the sense that they find it easier to locate pertinent provisions and they have assurance that the set of provisions is complete.

The procedures encourage a consistent treatment of and explicit decisions about scope and arrangement by the writer. An outline of classifiers (keywords) is constructed, then converted to an outline of provisions. Deciding upon what classifiers to use constitutes an analysis of scope, while deciding how to make an outline of the classifiers constitutes an analysis of the arrangement.

Provisions are classified according to their meaning (semantics) and structure (syntax). Explicit checks are made for completeness, clarity, and correctness in the set of provisions. The use of performance related classifiers assures that the reason for each provision is understood, even if it is not expressed in the final text. The outline assures that the set of provisions covers the scope, and provides an unambiguous location for each provision based on its subject matter so clear access is promoted.

BACKGROUND

Difficulty in finding relevant provisions is one of the problems that the format and expression of codes and standards can present to their readers. Errors also can arise from ambiguities and incompleteness in individual provisions and from missing or misinterpreting the relations between provisions. The <u>outlining method</u> is one part of a three part system for systematically analyzing and representing codes and standards in order to minimize these problems. The other two are: a <u>decision table</u> for dealing with the meaning of individual provisions and an <u>information network</u> for dealing with the precedence relations between provisions.

Decision tables and information networks were defined and their use was illustrated by Harris (1)* at the First NBS/NCSBCS Joint Conference in 1977. They can be briefly defined as follows:

1) The decision table is used to express the functional and logical relationships that establish the value for each data item that is defined in the document. A decision table is simply an orderly presentation of the reasoning controlling a set of decisions. It is easily analyzed to assure that the reasoning process will always lead to a unique result and that no possibility exists for encountering a situation not defined. Another advantage of decision tables is that they require an overall analysis of situations involving parallel thought processes whereas written text, and to some extent, flow charts both describe more of a sequential thought pattern.

2) The information network is used for reference to the other items of data that may be required in the evaluation of any data item. It gives a clear expression of the relations between provisions. Each data item is a point, or node, on the network. The nodes are connected to their ingredient nodes by branches that represent the flow of information through a set of provisions from the input data items to the terminal criteria. The ingredients of a node are defined as all those data items that may be required for direct evaluation of the node. For example, the allowable story area and the actual story area are ingredients to the provision that ". . . no floor shall have an area greater than the allowable area . . ."

Fenves and Wright (2) concisely describe the concepts and principles underlying the entire system, Harris et al (3) illustrate the use of each of the systems with and without computer aids, and Pollack (4) explains decision tables in detail. Work has been underway at the National Bureau of Standards (NBS) for about two years to improve the outlining method over that of reference 3. The example used in this report has served as one of several case studies in this effort. A full report describing this technique in more detail will be available from NBS in the near future.

BRIEF DESCRIPTION OF THE OUTLINING METHOD

The basic tools for locating provisions within a code or standard are the table of contents, headings printed within the text, the index, and internal cross references. The first three of these are lists of headings. A heading should relate meaningfully to the provisions beneath it so that the reader can find the provisions. The technique presented here for organization of standards accomplishes this by composing headings of one or more classifiers. The fourth tool, cross references, is an instruction from one point in the text to refer to another section, or heading. Cross references between related provisions are provided for in the information network system mentioned previously.

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*The numbers in parentheses refer to the citations listed in References.

The outlining method that organizes the headings is founded upon the proper relation of classifiers to provisions and to other classifiers. The relations occur at three levels: between individual classifiers and provisions, between individual classifiers within one class, and between different classes of classifiers. For example, the provision "the structural system shall safely support all loads expected during its service life" is related to the classifiers structural system, safety, and load. Each of these classifiers is related to similar classifiers, for example, safety is a member of a class of values such as durability, serviceability, and so on. In addition, there are relations between different classes for various reasons such as cause and effect or a need for finer distinction; for example, collapse is a member of a class of events that all cause the loss of some value in the class containing safety. Objective principles governing these relations have been derived from the following qualities desired in a final organization:

1. Qualities necessary for a good organization:

   Relevant: Each heading must be significantly relevant to its provisions; it must concisely express their scope.

   Meaningful: The intended readers must perceive the heading as being relevant.

   Unique: The headings must be distinct from one another to allow readers to access provisions unambiguously.

   Hierarchial: The headings at any level must be progressively ordered in a pattern significant to the reader and the headings must show a regular gradation in scope through the levels.

   Complete: The total set of headings must cover the entire scope of the set of provisions and nothing more.

2. Qualities desirable for a good organization:

   Minimal: The headings should be permuted so that the number of headings is the minimum for meaningful access.

   Even: The organization should divide the provisions so that depth (the number of levels in an organization) and breadth (the number of headings at one level) do not vary greatly from one part to another.

   Intelligible: The depth and breadth should not exceed the average span of immediate memory of the reader.

The relation between classifiers and provisions must provide relevant, meaningful headings. An analysis of the language of performance standards by Fenves, Rankin, and Tejuja (5) showed that performance type provisions have a small set of basic linguistic structures. In these structures, the subject of a provision typically names some physical entity while the predicate gives some desired characteristic; and frequently, the circumstance in which the characteristic is desired. Thus, it is relevant to class a provision by its physical entity and desired characteristic; for example, structural system and safety. The writers have extended this classification to cover all types of standards and provisions related to buildings. Examination of a large number of provisions in building regulations and study of several other systems of classification for building technology (6, 7) shows that the generic structure given in Table 1 is capable of encompassing a complete, relevant set of classifiers. The following are definitions and examples of some of the basic classes from the table:

THINGS - the objects, processes and events referred to in provisions.

Physical Entity - the systems, objects, parts, and materials that make up buildings, from bolts to structural systems, switches to electrical systems, and so on.

Human Entity - the agents of the construction process, such as designers, builders, and regulators, and the users of buildings.

Phenomenon - a response of a physical entity to the actions of its environment such as weathering, rotting, deflection, creep, cracking, etc. A particularly important subclass is termed LIMIT STATE which is defined as an event that causes the loss of a performance attribute either by the occurrence of the event (e.g., collapse) or by the magnitude of the response (e.g., excessive deflection).

Process - the activities involved in the design, construction, regulation, and use of buildings.

Environment - the circumstances in which physical entities exist such as exposure to wind, to corrosive attack, to imposed distortions, etc. This class, as well as several of the others, can serve two functions in provisions: to define the particular physical entity or process being addressed by the provision or to prescribe a desired characteristic.

QUALITIES - the characteristics of things referred to in provisions.

Physical Quality - size, weight, color, strength, location, time, etc. are among the many physical descriptors that can be used both to define entities or to mandate characteristics.

Social Quality - qualities, characteristics, or attributes of a thing that relate to human needs, aspirations, uses, and interactions. One subclass that is mandatory in performance standards and highly desirable in all standards is PERFORMANCE ATTRIBUTES which are the important qualities that are necessary to fulfill the needs of the building occupants, neighbors, owners, and society as a whole such as safety, functionality, durability, etc. Another common subclass is FUNCTION which is the intended use of a physical entity or process. There is a close relation between function, performance attribute, and environment; function generally having a strong influence on the latter two.

As a classification system for any particular code or standard is developed, many of the above classes will be used. As a minimum, one class of thing for subject and one class of quality for predicate will be necessary. Generally, many subclasses will be used to define the scope in the intricate fashion typical of today's codes and standards. The objective qualities of the organization, presented previously, become principles to guide the construction of the classification, as briefly explained in the following paragraphs.

First, the system must contain all classifiers relevant to each provision so that the index will be complete. Thus, any classification for a performance standard must contain a class of physical entities to serve as a subject, a class of performance attributes to serve as predicate for the performance requirements, and a class of limit states to serve as predicate for the performance criteria because of the basic structure of performance statements identified in reference 5. A classification of prescriptive criteria will typically be dominated by very detailed classes of physical entities for the subjects and physical qualities for the predicates. Note that from the set of all classifiers relevant to a provision, it appears to be possible to construct the provision by applying appropriate rules of syntax. Although these rules of syntax have only been identified for performance requirements and performance criteria as described by Fenves et al (5), and although the provision thus constructed might not be complete because numerical and Boolean values would not come from the classifiers, the concept does lend considerable rigor to the outlining method.

The individual classifiers must also be meaningful; that is, the intended readers of the provision must reliably associate the classifier with the provision to guarantee clear access to the correct provision. As classes of classifiers are formed, the members of the class must be mutually exclusive at any level to guarantee unique headings for unambiguous association of the provision to a heading, and they must be collectively exhaustive to guarantee completeness. The classifiers within a class and the relations between classes must be hierarchical in order to maintain the uniqueness and completeness as outlines are developed from the classifiers and to provide headings that are progressive and graded. The entire set of classifiers must be complete and unified. That is, all classifiers necessary to define the scope of the set of provisions must be present, and all classifiers present must be significant to the scope.

Once the classification is established, it is possible to develop outlines of classifiers by using a routine that develops a network from the various classes. It is possible to develop several different outlines from the same classification, and then select the one which appears best for the intended use. The routine, which can be executed using a computer, will not be discussed in this report but can be found in reference 3 and will be discussed further in a future NBS report. The rationale for selecting one outline over another is based on the desired qualities of minimal, even, and intelligible described previously.

CASE STUDY

The example used to illustrate the technique is taken from a draft set of provisions prepared for a model performance standard for innovative structures of residential building. Although no such standard has been promulgated, previous drafts for the same subject do exist at NBS to serve as a comparison for this example. The previous drafts have not been developed using the outlining technique illustrated here. The format selected for the example provisions is one used for several years at NBS for performance standards, known as Requirement - Criterion - Evaluation - Commentary or RCEC for short.

This format defines the acceptable kinds of provisions for a performance standard and imposes a hierarchy among them. Performance requirements are qualitative statements setting forth desired performance attributes for particular classes of physical entities. Performance criteria are more precise statements, frequently containing some measure of physical behavior, that are used to judge whether a related performance requirement is satisfied or not. Evaluations prescribe in greatly varying detail how to measure the quantities called for by a performance criterion. Commentary is used to explain the rationale and background behind criteria and evaluation procedures and is optional. The format requires that each performance requirement have one or more performance criteria and that each criterion have an evaluation procedure.

The first step in the case study was to establish those classifiers necessary to organize the set of performance requirements. Table 2 shows these classifiers and the outline for the requirements. The physical entities illustrate several important points for use of the method. First, the scope of the entire set of provisions is limited to the structure of residential buildings by the title so *building* stands alone at the most general level of physical entities. Furthermore, there are two subdivisions of buildings that are to be considered: *structural system* is obvious but *interior surfaces* are also included because the provisions will address the structural aspects of interior surfaces. Note that there are many parallel subdivisions of a building that are not included (heating system, lighting, etc., which do have structural features) but that *structural system* and *interior surfaces* are a complete expression of the scope for this set of provisions and thus establish the criterion for completeness that the organization must meet. Similarly, *floors* and *walls* are not the only possible interior surfaces of a building but others, such as ceilings, are consciously excluded at this stage because *floors* and *walls* are defined as a complete set. Also note that the terms satisfy the necessary principle of uniqueness, that is, *walls* and *floors* are distinct and unlikely to be confused.

The performance attributes, *safety* and *serviceability*, illustrate the richness in meaning that some classifiers possess. In the context of design regulations for building structures, *safety* is generally taken to mean life safety for occupants and neighbors of buildings. *Serviceability*, however, means more to a wider range of people. For occupants and neighbors, it means that the behavior of the structure should not impair the functionality of the building or cause discomfort to the occupants. For owners, it means that the structure should be maintainable and durable. Thus, although *safety* and *serviceability* are meaningful in the sense that the intended audience for the provisions understand them, they are not necessarily simple words.

The two environments listed show that arbitrary divisions are sometimes useful for purposes of arrangement as long as they still satisfy the requisite properties for classifiers. Note that this division between *force loads* and *other agents* was not originally perceived but was entered in one of the several iterations necessary to conduct the study.

The outline of classifiers is generated by successively appending classes together in a hierarchical fashion. The order is arbitrary to some extent, and several different outlines can be generated by using different orders. Each is equivalent in scope but different in arrangement; that is, each will have a place for each member of a set of provisions but the grouping and ordering will be different. The routine for generating the outline is simple enough for manual use on outlines of this size but requires a computer for record keeping on larger examples (3).

The right-hand column shows that three requirements have been identified from the outline and designated as R1, R2, and R3. The relation of the outline to the requirements illustrates several important points. The first requirement is associated with the three classifiers; *structural system*, *safety*, and *force loads*. Using the rules of syntax referred to previously (5), the performance requirement can be expressed as: "the structural system shall safely support all loads expected during its service like." The next entry, an X, shows that a requirement could have been written for the *safety* of *structural systems* under the action of *other agents* of the environment, but was not. At first glance this seems incomplete. However, the effect of *other agents*, such as heat, moisture, etc., on *safety* is not direct when compared to *force loads* and in fact is coupled to the presence of *force loads*. Because the effect of *other agents* on *safety* is of a different order, and because it is coupled to *force loads*, this effect is covered in the criteria related to requirement R1. Decisions about the organization, such as this one on completeness, are not necessarily easy or quick. Complex physical behavior or arbitrary limits on scope frequently require extended deliberation and compromise. The outlining technique calls attention to potential missing provisions, such as this, and requires explicit decisions by the writer.

Requirement R2 is written without considering the distinction between *force loads* and *other agents*. It is not necessary to specify the environment when writing requirements in many cases, and this is one. It will be shown that the two classes of environment are useful to group the criteria for R2 into two progressive sets, so their presence in the outline will be justified later. The next X shows that no requirement is associated with the classifiers *safety* and *interior surfaces*. This is because *interior surfaces* (a wall surface does not include the entire wall) are not considered to present any hazard to life in the structural sense of their behavior. Other kinds of hazards, such as toxicity, are possible but are outside the scope of these provisions because only limit states of a structural nature will be included. Once again, the outline has identified a potential missing provision and caused the writer to explicitly consider the impact of leaving it out.

Given that the only phenomena concerning *interior surfaces* to be considered by these provisions are those of a structural nature, one is realistically limited to considering *force loads*. Other problems of *serviceability*, such as paint adherence, are outside the scope, thus, the last X is shown in the outline.

Although the RCEC format specifies that the requirements give the overall structure, considerable freedom still exists in organizing the criteria, and the case study will carry on through the development of an outline for the criteria. Table 3 shows the additional classifiers necessary to organize the criteria. The first and most important class is the limit states. Each limit state is defined as some event that causes the loss of a performance attribute. In Table 3, each limit state is shown with the requirement(s) that it applies to, and in the case of those limit states applying to requirement R2, the particular environment that is relevant. Thus, the limit state *failure* is associated with both requirements R1 and R3, and the limit state *vibration* is associated with requirement R2 when *force loads* are considered.

The remaining classifiers relate to qualities and things used to further define the limit states and the measures of the limit states. Each subclass is developed for association with some limit state as shown. Thus, the class *drift loads* is developed for the limit state *drift,* the class *load occurrence* is developed for the limit state *failure,* the class *deflection duration* is developed for the classifier *flexible* which is part of a class that is developed for the limit state *deflection,* etc.

In general, these additional classes are necessary to define the scope in the detail necessary to write precise criteria. Frequently the same distinction can be obtained in alternate ways. For instance, it is necessary to separate grossly different modes of failure of structural systems because the performance measures used in the criteria are different. In this example, the separation was accomplished by considering the different levels of probability that a given load would occur: 1) those expected to occur once in the life of the structure, 2) those expected to occur many times in the life of a structure, and 3) those expected to occur in the life of only a very few structures. It would also be possible to separate the criteria by having a class of failure types: 1) conventional failure, 2) fatigue failures, and 3) exceptional failures, such as progressive collapse. The two ways of separating the criteria are nearly identical in that the same criteria end up being written. The class load occurrence was selected because it was felt that it was more relevant yet still meaningful.

Table 4 shows the outline of classifiers and the corresponding outline of provisions. The outline of classifiers was generated in the same fashion as the one for requirements. The provision outline is simply a condensation of the classifier outline with each heading corresponding to a requirement or a criterion. Note that in some instances sub-criteria are necessary to provide the proper hierarchy. The headings enclosed in parentheses indicate that the subject matter is covered concisely in one provision corresponding to the preceding heading. They are shown in Table 4 only to facilitate comparison with the classifier outline.

Table 5 shows the outline of the previous draft of this set of provisions compared to the present outline. First, note that the previous outline is not in the same format. There are 18 headings at the same level, roughly corresponding to criteria. There is no grouping of these criteria by performance requirement because no requirement is given, although the heading *strength and stiffness* is treated somewhat like a performance attribute. Next, note that several of the headings correspond to criterion C1.1. The evaluation procedure for that criterion is quite detailed in comparison to the others, and it is some of the subdivisions of that evaluation procedure that the extra headings in the old outline correspond to. There are some topics covered in the new provisions that were not in the old; such as resistance to exceptional loads, corrosion, and material property changes. One significant point to note about the ordering is that the old outline had parts of the evaluation procedure for new criterion C1.1 separated by relatively unrelated material, e.g., the provision for capacity of inserts and hangers is separated from other provisions for load capacity by provisions concerning deflections and drift. Another example of the same point is that provisions for horizontal and vertical deflection of members are separated by the provision for drift of a building.

CONCLUSION

An innovative method for outlining provisions for standards and codes is being developed at NBS. This article presents a partial description of the method illustrating it with one example. A more detailed description will soon be published by NBS. Although the only example cited is drawn from a draft performance standard, the method is equally applicable to prescriptive standards and the full range between. Application of the method provides explicit checks on completeness and clarity to the writer of the provisions and a more understandable and accessible organization for the reader. It also encourages decisions on scope to be made before studying arrangement, thus giving an efficient direction to committee deliberations when a new set of provisions is being formulated.

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Table 1

Basic Structure of the Classification

THING	QUALITY
ENTITY	PHYSICAL QUALITY
PHYSICAL ENTITY	
HUMAN ENTITY	SOCIAL QUALITY
ENERGY	
EVENT	
PHENOMENON	
PROCESS	
ENVIRONMENT	

Table 2

Classification for Requirements

CLASSIFIERS

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Physical Entity
      Building
           Structural System
           Interior Surfaces
                Floor
                Wall

Performance Attribute
      Safety
      Serviceability

Environment
      Force Loads
      Other Agents
```

```
OUTLINE OF                                  CORRESPONDING
CLASSIFIERS                                 REQUIREMENTS

Building
      Structure
           Safety
               Force Loads  - - - - - - R1
               Other Agents - - - - - - X
           Serviceability - - - - - - - R2
               Force Loads /*
               Other Agents /
      Interior Surfaces
           Safety - - - - - - - - - - - X
               Force Loads /
                    Floor /
                    Wall /
               Other Agents /
                    Floor /
                    Wall /
           Serviceability
               Force Loads  - - - - - - R3
                    Floor /
                    Wall /
               Other Agents - - - - - - X
                    Floor /
                    Wall /
```

---

* A / means that the scope of the requirement above will include this classifier.

Table 3

Classifiers for Criteria

CLASSIFIER	ASSOCIATED CLASSIFIER (REQUIREMENT)
LIMIT STATE	
Failure	R1, R3
Deflection	R2 + Force Loads
Drift	R2 + Force Loads
Vibration	R2 + Force Loads
Dimensional Change	R2 + Other Agents
Loss of Material	R2 + Other Agents
Material Change	R2 + Other Agents
TIME MEASURES	
Load Occurrence	Failure
Expected Maximum	
Repeated	
Exceptional	
Vibration Duration	Vibration
Transient	
Steady State	
Deflection Duration	Flexible (Deflection)
Short Term	
Long Term	
RESPONSE MEASURES	
Deflection Compatibility	Deflection
Flexible	
Brittle	
Transient Vibration Measure	Transient (Vibration)
Amplitude	
Damping	
Steady State Vibration Measure	Steady State (Vibration)
Acceleration	
Resonance	
ENVIRONMENT	
Drift Loads	Drift
Wind	
Earthquake	
PHYSICAL ENTITY	
Structural Parts	Dimensional Change
Member	
Joint	

Table 4

Outlines

CLASSIFIER OUTLINE	PROVISION OUTLINE
Building	
Structure	
Safety	
Force Loads	R1 Structural Safety
Failure	
Expected Maximum	C1.1 Resistance to Max. Load
Repeated	C1.2 Resistance to Rep. Load
Exceptional	C1.3 Resistance to Excep. Load
Serviceability	R2 Structural Serviceability
Force Loads	
Deflection	C2.1 Deflections Under Load
Flexible	
Short Term	(Short Term)
Long Term	(Long Term)
Brittle	(Brittle Materials)
Drift	C2.2 Lateral Drift
Wind	(Wind)
Earthquake	(Earthquake)
Vibration	C2.3 Vibration
Transient	
Amplitude	2.3.1 Trans. Vib. Amplitude
Damping	2.3.2 Trans. Vib. Damping
Steady State	2.3.3 Steady State Vib.
Acceleration	(Acceleration)
Resonance	(Resonance)
Other Agents	C2.4 Service Environment
Dimensional Changes	
Members	2.4.1 Dim. Changes in memb.
Joints	2.4.2 Joints
Loss of Material	2.4.3 Corrosion
Material Changes	2.4.4 Material Changes
Interior Surfaces	
Serviceability	R3 Serviceability of Floors and Walls
Force Load	
Failure	
Floor	C3.1 Floors
Wall	C3.2 Walls

Table 5

Comparison of Outlines

NEW

R1 Structural Safety
- C1.1 Resistance to Maximum Load
- C1.2 Resistance to Repeated Load
- C1.3 Resistance to Exceptional Load*

R2 Structural Serviceability
- C2.1 Deflections
- C2.2 Drift
- C2.3 Vibrations
  - Transient Vibration Amplitude†
  - Transient Vibration Damping†
  - Steady State Vibration†
- C2.4 Service Environment
  - Dimensional Changes in Structural Members
  - Joints*
  - Corrosion*
  - Material Changes*

R3 Serviceability of Floors and Walls
- C3.1 Floors
- C3.2 Walls

OLD

Structure - Strength and Stiffness
- Load Capacity
- Minimum Load Resistance
- Minimum Credible Strength
- Earthquake Loading
- Ductility Factor
- Load Capacity under Repeated Loading
- Loading Sustained for 24 Hours
- Effect of Creep and Residual Deflection on Load Capacity
- Vertical Deflections
- Drift
- Horizontal Deflections
- Vibrations
- Impact and Concentrated Loads on Floors
- Capacity of Inserts and Hangers
- Dimensional Changes in Structural Elements
- Horizontal Loads on Partitions
- Structure - Foundation Interaction
- Physical Simulation

---

*New Criterion
†New technical measure

CONSENSUS STANDARDS FORMULATION

by

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The charge has been made that the existence of standards inhibits innovation and consequently hampers technological advances. On the other hand, standards provide obvious benefits in consumer protection and economics through aggregation of markets. One possible remedy that has been advanced is provisions for accepting nonconforming products by exception. While such procedures would make introduction of new products easier, it would to a large extent destroy the fundamental purpose of a standard.

Another proposed remedy is to base all standards on performance requirements. While performance standards may be satisfactory in some cases, they are not a panacea that will easily solve all standards problems. Adequate definition of performance requirements and equally important acceptance requirements is a major problem. The pure performance standard opens the doors to unwanted features if it is not very carefully constructed.

The concept of standards is not wholly compatible with innovation, but standards provide sufficient benefit to warrant continued use. Their effectiveness depends upon procedures for formulation to make their purpose clear and identify their limitations.

Key Words: Economics; formulation; innovation; market aggregation; performance requirements; prescriptive standards; standards development.

CONSENSUS STANDARDS FORMULATION

The charge has been made that the use of standards inhibits innovation and consequently retards technological progress. On the other hand, standards provide obvious benefits in consumer protection and economy through aggregation of markets. By referring to a suitable standard, architects and engineers can save a great deal of effort in writing specifications. The intent of this paper is to examine this apparent dilemma and possibly provide some insight to considerations which should underlie procedures for foundation of standards.

Before attempting to establish requirements or procedures for standards formulation, it is necessary to obtain agreement on their function. Specifically, we must consider the questions, of when standards are appropriate and how they are to be used.

A common misconception of standards is that they certify that the requirements have been thoroughly evaluated from the standpoint of useful services. In fact, many standards are nothing more than an agreed-upon description of characteristics of an item. Therefore, standards, as they are now developed, cannot be used in lieu of engineering expertise. They only afford protection to the user who is technically competent. In considering standards formulation, it is necessary to resolve the responsibility of standards-writing groups to assure that an item covered by a standard will be satisfactory. There is no way for a standard to prevent misuse of a product and to this extent it is not feasible for a standards group to provide such assurance. On the other hand, it seems reasonable that a standard not be adopted if the product is unlikely to satisfy an obvious intended use. Between these two extremes is an area that requires careful definition.

Another misconception is that standards groups verify that items purporting to meet a standard actually do possess the proper characteristics. This would require a large investigation and testing effort and involve considerable expense which would ultimately be borne by the user. Is the additional protection which might be afforded the public worth the potential cost? Since standards cover everything from raw materials to complicated equipment, it may be possible that a single approach to standards formulation is not satisfactory for all categories of goods. A key element is the nature of the user and his ability to understand and interpret the function of the standard.

Standards are useful for widely used items for which there is a large market and a number of potential suppliers. If the item is not widely used and the potential market is small, a standard is not warranted. Standards serve two primary purposes. They permit specifiers to agree on a well-thought-out description of commonly-used articles. Thus, it is not necessary for each architect or engineer to constantly reinvent the wheel. Secondly, they permit suppliers to concentrate on products that will be widely accepted.

Economics possible through standardization have long been appreciated by American business. Lower production costs usually result from large volume and economics of scale due to market aggregation are a secondary benefit. Unfortunately, standardization always limits change and thus inhibits innovation. In a time when technology is changing at a very rapid pace, it is fitting that there is concern that standards will retard the utilization of beneficial developments. The formulation of standards should attempt to ameliorate this conflict to the extent possible.

One suggestion to make standards more responsive to innovation is to provide for acceptance of non-conforming items. The question is who would be responsible for acceptance. The function of evaluating nonconforming products and determining equivalency is very different from writing a standard for a well-known item. Standards writing groups would have to be reconstituted and resources to investigate provided. In addition to serving the purpose covered by the standard, non-conforming items may have additional characteristics which might be significant to the user. Only the user could determine the acceptability, for his purposes, of non-conforming items. Since the user must necessarily evaluate innovative products, it is difficult to see what service their inclusion under a standard would provide. The unwary standard user would be liable to experience difficulties in the form of unwanted surprises.

Establishing the scope of a standard to include all reasonably suitable products and still satisfy user desire for specificity is not easily accomplished. For example, there is an ASTM standard for plastic pipe. This is a relatively new product that is just becoming familiar to users. The present standard covers solid wall pipe which is the type for which there is user experience. Now it is proposed to include cellular pipe. This product apparently meets all the requirements stipulated in the standard but has no track record. Should it be included in the standard now or perhaps later? Should a new standard be developed for cellular plastic pipe? Questions of this nature are vital to the formulation of useful standards.

The second widely advocated aid to innovations is reliance on performance requirements rather than prescribed characteristics. The apparent simplicity of this idea is certainly appealing. In practice it is by no means easy to construct a performance specification which will prove satisfactory to the buyer and seller. It can sometimes be done but there are many pitfalls.

Prescriptive standards can deal adequately with well-known items. The products available on the market are familiar to users. Such characteristics as size, shape, weight, durability, and maintainability, are common knowledge although they may not be covered by the standard. A performance standard is essentially a black box approach. All essential characteristics must be covered in the description of performance or the user will be uncertain that the item will be.

An individual user may have difficulty determining all characteristics which are really important to him. A standards group will have additional difficulty because some requirements may be relevant to one user and not to another. There may be a tendency to incorporate only common requirements in the standard and thus leave many loose ends to be picked up by the individual specifier. This means that performance standards are likely to be more complex to construct and require greater digression in use.

In writing performance standards there may be a tendency to focus on the primary function and thereby inadvertently omit other characteristics important to many users. For example, a check valve is intended to prevent flow in the wrong direction. However, a performance standard limited to this function might prove unsatisfactory. Parts that are subject to excessive wear are obviously undesirable as is a housing that is easily damaged. Thus durability and handling characteristics must be included in the performance requirements. Some users might consider that maintainability should be included. Nobody wants a valve that would require such expensive tools to install, but that could easily be the result under a performance standard that is not very carefully drawn. Of course, it is not impossible to devise an adequate performance standard but certainly involves complexities not found in prescriptive standards.

It may be concluded that standardization and innovation are not wholly compatible goals. Standards have proven extremely useful to the specifer and must continue to be available. The task of making standards formulation procedures facilitate innovation is formidable and should be approached cautiously, and with the user in mind. The existing standards writing groups have proven to be viable because they fill a need. Some basic regulation may be appropriate in the public interest, but attempts to permit innovation by requiring set procedures and a specific format could be counter-productive. It would be most helpful to users, if a standard contained a brief statement as to how it was formulated and how it is intended to be used.

THE ROLE OF FIRE PREVENTION AND CONTROL ON BUILDING CONSTRUCTION AND REGULATIONS

by

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Fire prevention and control is an important feature of the modern building codes. Building set-back limits, structural design, and limitations on interior finish materials are among the building design parameters that reflect the public need for fire safety. Historically, codes have been developed to reduce mass urban fires and to limit property damage from the structural collapse of single building units. For example, a standard time-temperature curve has been developed and widely used (ASTM E119) for classification of building structural components in terms of a fire-time rating. More recently, there has developed an increased concern about life safety. Smoke and toxic gas produced by materials subjected to fire exposures are being evaluated and in some cases form part of a developing set of new regulations. The implementation of these new regulations poses a number of difficult problems to the local code regulatory and enforcement officials. An analysis is made of some of the alternative approaches which may be considered to aid the local building official in this important area of control.

Key Words: Building codes; control measures; fire codes; fire safety; governmental actions; life safety; regulation; risk assessment; societal goals.

INTRODUCTION

Fires have threatened life safety and inflicted losses to property throughout history. In the past, as now, governmental bodies have responded to these threats by developing fire service capabilities and restrictive building codes. Using these solutions effective governmental action has been implemented for many centuries.

In 80 B.C. Marcus Crassus organized a private fire brigade to protect his buildings in ancient Rome. These brigades were highly efficient and during his time fire losses were low. For political reasons after his death these brigades were disbanded and in 64 A.D. a major fire consumed Rome. At that time Rome had many of the general characteristics of a modern city being constructed of 6 to 7 story tenement buildings.

It is instructive to read the historian Tacitus' description of the rebuilt city a few years later:

"... with rows of streets according to measurement, with broad throughfares, with a restriction in heights of houses with open spaces, and the further addition of colonades, as a protection to the blocks of tenaments... The buildings themselves, to a certain height, were to be solidly constructed, without wooden beams, of stone, that material being impervious to fire, and to provide that the water which individuals... had appropriated might flow in greater abundance for the public use,... and everyone was to have in the open courtyard before their house equipment for stopping fires. Every building too, was to be enclosed by its own private wall, not one shared with others...".

Clearly the basic elements of a prescriptive city fire code were used. The elements consisted of fire resistive construction, set back limits, and material specifications. These elements were supported by an active and ready voluntary fire service. It is doubtful that the modern city administrator could improve much on the rebuilding of that ancient city.

Three key elements were involved in this process: (1) technical knowledge, (2) a public awareness of risk and its willingness to commit resources to minimize this risk, and (3) an effective governmental administration and enforcement policy. In time, as public awareness dimmed and governmental administration became ineffective, Rome again became the site of major urban fires. This cyclical process of major catastrophes followed by rebuilding and decay continued to the present century. Examples include the London fire in 1600, the New York fire of 1834, the San Francisco fire of 1858, the Chicago fire of 1888 and the Boston fire of 1906.

The fact that the incidence of major urban conflagrations has declined in recent times is most probably due to a combination of increased public awareness about fire (as a result of modern communication and educational systems) and, the development of new forms of governmental and private regulatory institutions.

Commencing in the latter part of the last century factory mutual insurance organizations were formed as a protective measure by factory owners to spread the adverse effects of an individual fire catastrophe over a wider financial base. A major output of the activities of these mutual organizations was the development of technical performance codes based on a "concensus" of technical experts. These efforts have developed into our present system of uniquely American consensus standards and codes. Effective administration of these codes was enforced by economic incentives, principally reduced insurance premiums, in the private sector as well as governmental regulations directed toward general public safety. In part because of the interests of the insurance agencies, the primary emphasis of these codes has been directed toward reducing property losses. Lesser emphasis has been placed on life safety.

For a number of reasons during the past decade there has been an increasing public awareness of hazards to life safety resulting from unwanted fires, particularly in one and two-family dwellings. Since legal responsibility for fire deaths in these occupancies has not resulted in monetary losses to the fire insurance underwriter, incentives which have effectively reduced property damage losses are not fully operative. Because of these factors there is an increasing political demand placed on public officials to develop and enforce fire codes and standards in which primary goals will be to reduce the number of home fire deaths. This is both a local and community and national problem area for governments. To perform this service it is apparent that new concepts and approaches must be developed which can complement our present system of concensus codes. One of the new approaches to this problem is the investigation of codes which is based on the level of risk the public is willing to accept in terms of the fire hazard.

LEVEL-OF-RISK FIRE CODES

The acceptable risk associated with a specific hazard varies both with respect to the type of hazard, and, the local community standards. Thus, a much higher factor of risk is generally acceptable for loss of life in a single family dwelling unit as compared to loss of life in an airplane crash. Similarly, arson is common in many urban ghetto areas and rare in most suburban neighborhoods.

One of the implications of a variable acceptable risk is that for the same hazard, (e.g. loss of life in a domestic fire) there may be different political pressures on government for control and regulations. These demands reflect the relative order of priorities of a specific community. In the United States the major underlying philosophy of the Fire Prevention and Control Act of 1974 is that control of hazards associated with fire is a problem of local government. State and local officials are expected to make their own decisions on the level of safety they want and determine how much cost is reasonable. However, it is impractical for each local political subdivision to perform the necessary research, development, and evaluation to produce its own individualized fire safety code. This poses a dilemma.

The current solution to this dilemma is for the local community to adopt one or more of the major model codes. At present there are at least 10 major model codes directed toward regulative fire safety in buildings and hundreds of voluntary technical standards. A major problem is that State and local officials lack an objective basis for comparing these model codes in terms of the safety provided and costs incurred.

One way to resolve this problem is to develop a single national concensus code. Either the prescriptive or performance codes could be utilized for this purpose. One major advantage of this approach would be a reduction of the problems incurred by manufacturers to produce and market on a national basis. Although a universal national code would reduce conflicts, it also limits the flexibility of local code groups to formulate requirements best suited to individual communities.

A second way to resolve the problem is to develop a form of fire code in which emphasis is given to providing the local official with an objective system for evaluating alternative solutions in terms of the acceptable levels of risk in the community but which also utilizes the benefits gained from the concensus standard system. Such a code would include a number of discrete elements. First, the risk associated with the hazard must be defined for the community. This requires a statistical data base either for the specific community or for a group of similar communities. Secondly, the acceptable level of risk must be specified. This requires a political insight into the sensitivity of the community with regard to the potential hazard. The sensitivity of the citizens of Southgate, Kentucky, toward interior finish and existing requirements in restaurants is currently very high after the recent Beverly Hills Supper Club fire. The code must be able to accommodate this selective sensitivity. A third desirable element is flexibility. The code should provide a mechanism where alternate solutions may be selected in order to have sufficient flexibility to allow new material and construction practices to be used on a national basis. Finally, to be effective any code must be administratively enforceable.

A hypothetical example of a level of risk code would be the development of building code criteria designed to reduce loss of fire fatalities in one and two-family dwelling units. Recognizing that individual fires in homes result in an estimated 8000 deaths per year an objective of a building code might be to reduce these by a "reasonable" number. Although limited reliable data is available, it would appear that the room of fire origin in fatal fires may, in many cases, be in a lower floor area. The reason for this fact is that smoke and heat rise from these lower areas often resulting in a threat to life safety on the upper floors. In other cases, the room of fire origin is the same as that in which the fire fatality occurs (e.g., a bedroom). The room of fire origin for one and two-family dwelling fatalities are summarized in Figure (1)*. It is noted that these data are obtained from national statistical averages which may or may not represent the average for a specific community. Figure (2) lists the compartment level of risk normalized to an arbitrary basis of 100. Assuming the statistical data is

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*Fire Protection Handbook, 14th Edition, p. 1-8 valid, the results indicate the areas in which most fatal fires originate are the basement, living room, and kitchen having values of 53.5, 22.5 and 16.7 LOR+, respectively.

This information can be used by the code official to determine the relative risk associated with living in a specific dwelling unit. For example, in Figure (3), a plan drawing is given for an individual home. Multiplying the number of rooms of each type in this home by their national average risk value the level of risk is determined. Without a basement the relative level of risk is associated with living in this home is 81.1 LOR. With a basement it becomes 134.6 LOR.

The next step in the process involves an assessment of desirable community goals in terms of the "allowable" level of risk that will be acceptable as a community standard. This assessment is essentially a political judgment. A possible community standard might be to not allow construction of new homes having a LOR greater than 75 based on national averages. This level of risk would act to reduce fire fatalities in the community as compared to a national norm. A second approach would be to establish a community-specific data base and use this base to provide similar guidance.

In order to more closely define the problem it is useful to determine the level of risk for individual compartment. Again since the data presented in Figure (1) is relative to a national statistical base for fires in one and two-family occupancy classes, the level of risk associated with individual areas of the home can be estimated from U.S. Census Bureau data. Once a community standard has been selected (e.g. 75 LOR) the code official can thus discuss with the builder various building options. Some of these options are listed in Figure (4), together with an itemization of other technical input that may be required to evaluate each option. Since the goal is to reduce the level of risk, judgment must be exercised regarding the effectiveness of each option when installed in the specific building. In this case, an efficiency of 100 percent effectiveness was assumed. In a practical code decision reference would be made to technical consensus values. Possible results for three contractor options are outlined in Figure (5). Installation of a sprinkler in the living room or area would reduce the LOR value to 55.6 for a non basement house. In this case, a possible alternative of the installation of a sprinkler in the den would not be acceptable since the den is not in direct communication to the stairwell leading to the second floor level. Similarly, installation of a fire detector in the stairwell would provide protection from most fires starting in the lower floor area. In this example, no substantial protection would be required for the den area and the additional placement of additional detectors in every bedroom occupied by a person who smokes would be recommended.

As indicated previously, one of the problems associated with this approach is the determination of the relative effectiveness of alternate fire suppression/fire warning systems. Before level of risk codes can be developed, much more technical

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+The unit LOR is defined as the level of risk associated with an average occupancy class relative to the assumed hazard.

information in this area will be needed. One point of concern is the fire control effectiveness of low rate of application water sprinklers. A second problem area involves the judgmental factors associated with "type of occupants" assumptions. For example, if non-ambulatory occupants are present the use of smoke or heat deteotors may be less satisfactory than sprinklers. Because of the range of technical sophistication that is needed to effectively solve these problems it is probable that some form of consensus group opinion may be required from technical experts in the field. However, it is believed that these problems are amenable to reasonable solutions.

The principle advantages of a level-of-risk type code outlined in the above example are: (1) specific solutions may be formulated for individual communities and buildings, (2) these solutions can be highly flexible in providing alternate solutions and alternate goals, and (3) cost effectiveness to achieve a prescribed level of risk. The major disadvantages are (1) a need for a community specific data base, and (2) a need to define community goals. It will be interesting to see how regulatory building codes in the future utilize these more formalized acceptable risk principles at national and local levels of government.

SUMMARY

The development and use of fire codes cannot be separated from other available community services such as fire suppression and public education. All are necessary components on a community program for fire safety. An effective fire code reduces the personnel and equipment requirements for fire service. An effective program of public fire education similarly is important to an effective fire code.

It is necessary to realize that fire codes are not simply a set of technical requirements. Rather, they involve a combination of technical, political, and administrative balances. What is important is that the general community believes that there is a clear and present danger and that the control measures taken are reasonable (i.e. cost effective, technically valid, and closely related to current community practices).

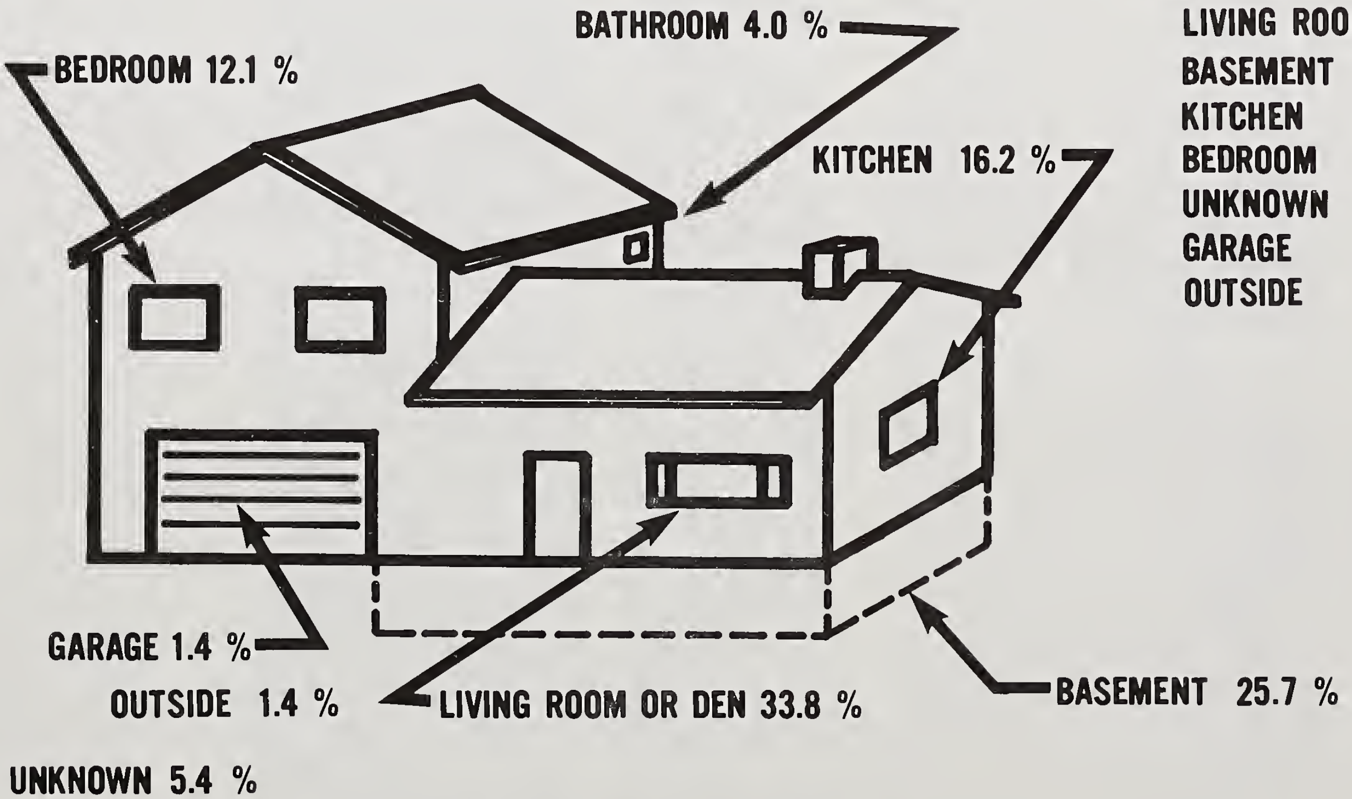
Technically, we have had the knowledge of how to implement an effective building code for at least two thousand years. Historically, this knowledge has been effectively used only periodically. Given a crisis caused by a major fire catastrophe, political and administration institutions are developed and implemented to reduce the probability of crisis reoccurrance. These rely on available technology for specific control measures and the absolute level of risk is less relevant than the visibility of the hazard. As the public awareness of the hazard recedes the enforcement becomes lax and a new cycle begins.

Building codes related to community fire safety are in a state of change. These changes reflect changing societal goals. In the recent past (i.e. the past 50 to 75 years) a major societal goal was to reduce mass conflagration in major urban areas. Our current building codes reflect these concerns. Recently there has been more emphasis on life safety. It is anticipated that more measures to reduce fire hazards which affect individual life safety will be incorporated into our building codes in the future.

Compared to our national net worth our losses are relatively low and the probability of a major urban conflagration is low. The major question is, "How can we do better with the political framework of our democratic nation?" particularly with regard to improving individual life safety in home fires. One answer to this question is a level-of-risk assessment. This new type of code provides a variety of technical solutions which can be adapted to the specific needs of individual local communities. In these codes the level-of-risk is estimated for alternate materials, equipment, and construction practices and then related to community priorities for specific occupancies. This new approach to the code regulatory problem provides a combination of technical, political, and administrative balances uniquely suited to the American form of democratic institutions.

FIRE ORIGINS FOR ONE- AND TWO-FAMILY DWELLING FATALITIES*

FATAL FIRE ORIGIN	
LIVING ROOM OR DEN	33.8%
BASEMENT	25.7%
KITCHEN	16.2%
BEDROOM	12.1%
UNKNOWN	5.4%
GARAGE	1.4%
OUTSIDE	1.4%



*REFERENCE FIRE PROTECTION HANDBOOK, 14TH EDITION PG 1-8

FIGURE (1). ROOM OF FIRE ORIGIN FOR ONE-AND TWO-FAMILY DWELLING FATALITIES

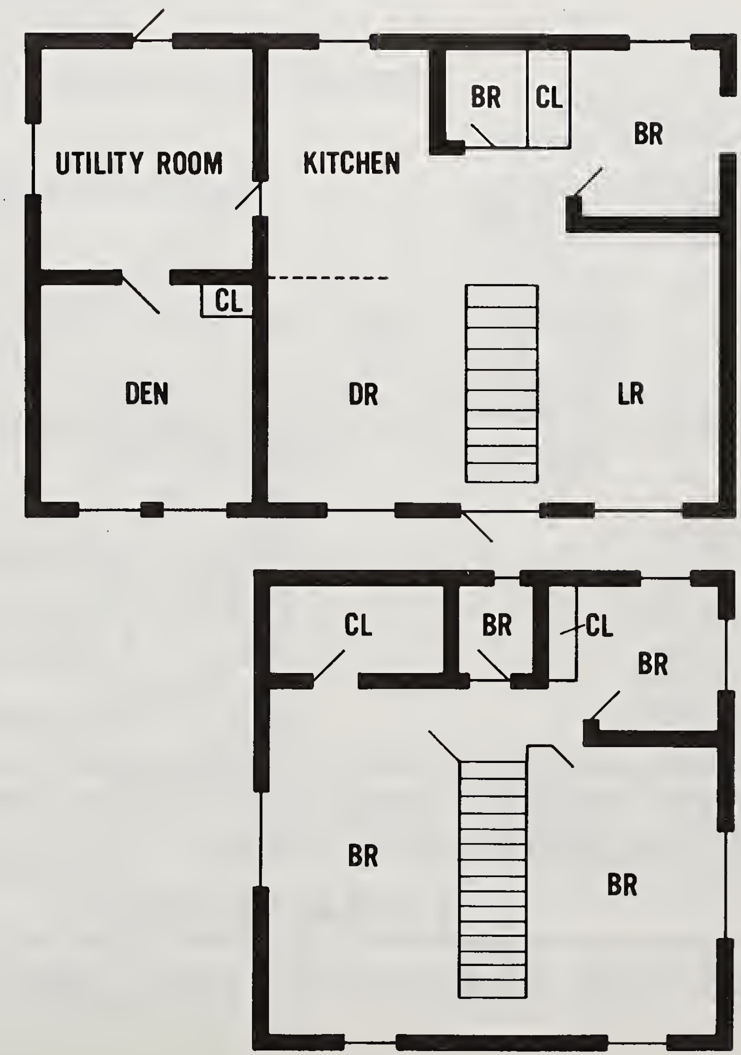
AVERAGE ONE- AND TWO-FAMILY DWELLING

COMPARTMENT	% FATAL FIRE ORIGIN	COMPARTMENTS PER DWELLING UNIT*	COMPARTMENT LEVEL OF RISK
BASEMENT	25.7	0.48	53.5
LIVING ROOM/DEN	33.8	1.5	22.5
KITCHEN	16.2	0.97	16.7
BEDROOM	12.1	2.5	4.84
UNKNOWN	5.4	–	–
BATHROOM	4.0	1.2	3.33
OUTSIDE	1.4	–	–
GARAGE	1.4	–	–
		TOTAL	100

*ANNUAL HOUSING SURVEY 1974 U.S. BUREAU OF CENSUS

FIGURE (2). AVERAGE LEVEL-OF-RISK FOR COMPARTMENTS IN ONE-AND TWO-FAMILY OCCUPANCIES

EXAMPLE – TYPICAL TWO-LEVEL DWELLING



	MULTIPLY	LOR
KITCHEN	(16.7) × 1	16.7
LIVING ROOM	(22.5) × 1	22.5
BEDROOM	(4.84) × 4	19.4
DINING ROOM	(UNK) × 0	0
DEN	(22.5) × 1	22.5
UTILITY	(UNK) × 0	0
BASEMENT	(53.5) × 1	53.5
CLOSETS	(UNK) × 0	0
	TOTAL	134.6

LEVEL OF RISK (NO BASEMENT) = 81.1

LEVEL OF RISK (BASEMENT) = 134.6

FIGURE (3). LEVEL-OF-RISK FOR COMPARTMENTS IN A TYPICAL FAMILY DWELLING

CONTRACTOR OPTIONS

(1) **SPRINKLER SYSTEM**

- LOCATION
- NUMBER REQUIRED
- RESPONSE RATE

(2) **FIRE DETECTORS**

- LOCATION
- NUMBER REQUIRED
- RESPONSE RATE

(3) **STRUCTURAL COMPARTMENTALIZATION**

- DOOR CLOSURES
- DOORS AT STAIRWELL
- EGRESS

(4) **MATERIAL CONTROLS**

- FINISH
- FURNITURE CONTROLS

FIGURE (4). FIRE SAFETY CONSTRUCTION OPTIONS

	LEVEL OF RISK	SPRINKLER	COMPARTMEN- TALIZATION	FIRE DETECTORS
KITCHEN	16.7	X	X	–
LIVING ROOM	22.5	X	X	–
BEDROOM (4)	19.4	X	X	–
DINING ROOM	–	–	–	–
DEN	22.5	X	X	–
UTILITY	–	–	–	–
BASEMENT	53.5	X	X	X
CLOSETS	–	–	–	–
STAIRWELL	–	–	–	X
TOTAL				
BASEMENT	134.6	58.6	58.6	22.5
NO BASEMENT	81.1	58.6	58.6	22.5
COMMUNITY STANDARD (75 LOR)	NO	YES	YES	YES

FIGURE (5). ESTIMATED REDUCTION IN LEVEL-OF-RISK IN A TYPICAL ONE FAMILY DWELLING COMPARED TO A COMMUNITY STANDARD

BUILDING REGULATION IN THE TWENTY-FIRST CENTURY

by

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Many research papers have been devoted to proposals dealing with innovation and rationalization in the building regulatory process.

This paper has two special features--it takes a broad and uninhibited look at the entire field of building controls, and it does so from an imaginary future date in September 2002, a quarter of a century after the Bozeman, Montana, conference. Instead of proposing changes, the paper takes a novel approach and discusses "retrospectively" the major changes that "have occurred" in the intervening 25 years. It thus provides food for thought without running into the gamut of reasons why changes cannot be made.

Key Words: Building regulations; innovation; international standards; metrication; performance standards; research; technological trends.

INTRODUCTION

The theme of this conference is "Research and Innovation in the Building Regulatory Process." This is a serious, appealing, and recurring theme. In my view, a luncheon speech should be related to that theme; however, it should relieve the seriousness of the technical sessions without sacrificing too much substance.

Any views expressed in this presentation are entirely my own and have not been censored by anyone. The ideas proposed have been developed as a result of many discussions with people knowledgeable on the subject of building control; the hypotheses are my own; and any mistakes made by me in the description of existing or former activities or organizations are also my own. In projecting the title of my presentation, I am guided by the realization that the twenty-first century, and the start of the second millennium are less than 23 years away. This point in time serves well to direct our thoughts to the future and to the need to formulate a series of objectives and related achievement targets for beneficial change.

Research and innovation are major arms of that "change." Research is the intellectual activity that projects proposals from the study and analysis of historical factors and trends. Innovation is the profound human capability to simplify, modify, improve, and originate within a reference framework of future expectations. While change is not always for the better, the pursuit of it is a keystone of human activity. It is probably the factor that sets the human being apart from other forms of life which have been content to remain in a static state. In recent times, change has become so rapid that the results have been demanding, distressing, and sometimes demoralizing for many people. My prognosis for the next quarter of a century is not promising - changes will continue to occur at a rapid rate and some people will withdraw rather than endeavor to keep pace. But, if change were to be harnessed by objectives to give it direction, we might cope more easily.

In building, and especially in the building regulatory process, many changes are proposed and pursued. If we gaze into the crystal ball we get an indication of additional changes. But it is for us to harness any such changes to the benefit of the community at-large, and to set markers in the channel of progress so that we can stay on course.

In postulating a "view of the past" from the year 2002, I am guided by a number of factors and trends. It would have been improbable in 1952, just 25 years or one generation ago, tc predict the technological evolution and trends of today - but not impossible. In "looking back" at events, we can compare their consequences with the expectations that we now hold and we may learn a great deal from such a comparison. One advantage of this approach is that any tendency to say "you should do" or "you should have done" is tempered to a much more palatable "you might do" or "you might have done." The proposed process is one of innovation, demanding a good deal of imagination and inventive ability.

TWENTY-FIVE YEARS FROM 1952 TO 1977

In order to put a perspective to my remarks I wish to go back to the Olympic year 1952. I have brought along a facsimile of pages one and two of the New York Times of 20 September 1952, to remind us of some of the events of 25 years ago. At that time it sold for five cents.

The year of 1952 was the time of escalation in the Korean conflict and of the presidential campaign of General Dwight D. Eisenhower. Even Richard Nixon made page one of the Times. It was before the advent of the transatlantic telephone cable, the use of transistors in communications and calculating devices, transcontinental jet travel (the commercial jet aircraft had not arrived), and large-scale data processing activities. Copying of data was slow and cumbersome; the XEROX machine was yet to be developed. Satellites and manned missions into space were still science fiction, as was the heart transplant.

In the generation since 1952, technology has advanced at an incredible pace, so much so that our time has become known as the "space age" or the "information age."

If we ask whether construction has moved equally fast, the answer is no. We have higher buildings, faster lifts, and more imaginative structures, but today's buildings are probably not too different from those of 1952. The advances have been in mechanical systems and services, which require a vast increase in energy supply to provide heating, cooling, air conditioning, and power for innumerable appliances - thus increasing our energy dependence.

Nowadays we are highly dependent upon the comfort we have created. We have shaped our buildings and they, in turn, have shaped us. In general building, the cost of the mechanical component has increased, as innovation in that area has excelled.

One significant building innovation in the past 25 years has been the mobile home; and only time will tell how permanent that innovation will be. I have been told that the mobile home has been a direct outcome of a loophole in statutory requirements, which deal differently with a habitat on wheels than with one firmly set into the ground.

In building codes generally, there has been an accelerating trend towards statewide requirements as the demands of the infused technology have required the removal of local barriers to economical production.

Thus, we have arrived in 1977 with a building scene that has seen rapid increases in the cost of new construction, as well as in the market price of pre-owned buildings. Our society has a vast investment in building assets, and the burden of maintenance and rehabilitation is growing rapidly. Retrofit to suit special needs (energy conservation, handicapped occupancies, fire-related requirements, etc.) is expensive and must be borne either individually or by the community.

To proceed into the twenty-first century, one might well ask some serious questions and do some serious thinking on research and innovation.

How can we best guide or direct (regulate) both new construction and rehabilitation?

How can the codes and standards system make a meaningful contribution to the challenges before us? How can it be improved?

Is the fragmentation of activities conducive to innovation, or is it counter-productive?

To answer these questions, we need to have a sense of purpose (goals or aims); objectives that are derived from the purpose; and strategies to achieve such objectives. We might ask: What is the purpose of the building regulatory process? What is the purpose of codes and standards? What is the objective of each section or item in each code and standard? Or what ought it be? Are our requirements and recommendations clear and concise, or do they represent a semi-technical, semi-legal nightmare? Where do we want to be 5 years from now, 10 years from now, and 25 years (one generation) from now?

All this is part of the traditional approach.

TWENTY-FIVE YEARS FROM 1977 TO 2002

While the present is seen by many as the extension of the past, it is also the threshold to the future. And, if we move to a hypothetical date in the future, we will be able to see the present in the perspective of the past.

I would like you to imagine that you are in the year 2002 - one generation, or 25 years from now. You are seated next to John Alexander, Coordinator of Codes Development at the National Codes and Standards Center, who is presiding over a video-link meeting of the National Committee on Code Reform. The meeting is due to commence in one-half an hour at 10:00 Central Standard Time. John Alexander is seated in front of the video-link console which has a triple function:

1. It provides instant access to the meeting by all committee members and all other interested parties. There is no secrecy; however, only committee members can discuss matters or present information. Meetings are held and video-recorded at a single and central point so that much more productive use is made of time since lengthy travel by committee members is avoided.

2. It allows for a video-tape transcript of proceedings so that what used to be minutes are instantly available. This places a much greater onus on the committee members to

properly prepare for the meeting. Any discussion of irrelevant matters and sidetracking of issues now becomes widely evident and is recorded. A coupled random access facility provides a video-record of all previous meetings, so that any reference to previous discussion or decisions can be factually substantiated. All resolutions are typed out on the video screen before being voted upon.

3. The video-console is linked to a general data storage facility of codes and standards information, so that a retrieval and visual display of any relevant technical data is accessible once the correct access code on the console is pressed. A secondary display unit is coupled to the video-console so that data searches may be carried out concurrently with the meeting. Each console also has a reprographic facility so that video-copies of any particular aspect can be made for closer examination.

Let us ask John Alexander to demonstrate the facility. We wish to compare existing requirements for site controls and fire protection (exit requirements) for data processing centers in various regions of the U. S., to ascertain whether there are any differences of a technical nature, and what their economic impact might be. The areas of interest are the Missouri basin (Missouri, Kansas, Nebraska, Iowa), the greater Washington, D. C. Metropolitan area (D. C., Maryland, Northern Virginia), and the Cincinnati region (Ohio, Northern Kentucky, Southeastern Indiana).

John Alexander selects various data codes from a coding index in front of him (building type, site control requirements, fire protection exit requirements). He then presses the code for Federated Model Code (FMC), as well as the code for each condition and each alternative location. (FMC is the Model Code prepared by the American National Model Codes Council.) As each set of requirements is shown on the video-screen, he activates the copy button to obtain a reprographic copy. It takes three minutes to assemble an up-to-date data file for ten localities. Where requirements are identical with the FMC, the printout simply states location, requirements, and FMC. Similarly, any reference standards can be accessed and reproduced instantly.

This data now can be used for decisions by the building client, the building designer, the building materials' producer, the building contractor, and the building official.

The information age has arrived in codes and standards, but it would not have been possible without the developments of the past 25 years.

Let us ask John Alexander to give us his views of some of the significant developments during the past 25 years in the time remaining before his meeting.

THE PERIOD FROM 1977 TO 1982

The first phase in development of the present state of building regulatory and standards practice occurred between 1977 and 1982. The highlights of that phase were in the development of programs leading to the adoption and administration of uniform comprehensive building codes and standards.

A. Greater Interest and Involvement in the Unification of Building Regulatory Requirements by State Governments

In the late 1970's, pressure increased from a number of sources for a review in the processes used to develop and implement building standards, building codes, and building regulations:

1. Industry, in general, expressed forceful views that the existing system of standards and building codes development was economically disadvantageous to the community. In a well documented campaign in which it was joined by professional and contractors' associations, it demonstrated that the same building processes and building elements were subject to as many as twenty differing requirements in various States, major cities, and localities.

   Recommendations were made to the National Institute of Building Sciences (NIBS), which had become operative in 1978, to set up a technical evaluation branch to recommend means of simplification and unification of criteria, standards, and technical provisions used by building regulatory jurisdictions and agencies, and to establish uniform test methods and evaluation techniques for building systems and products.

2. The Plastics Industry brought a constitutional challenge against several State governments and local government authorities, as well as two model codes, on the grounds of inhibition of interstate trade and commerce imposed by requirements restricting the application of plastics in building situations. The case was left in suspension, but a strong groundswell against arbitrary rejection of materials was evident.

3. The Federal sector, through authorizations by Congress and under powers given to various agencies, increased its efforts to establish national requirements in the building regulatory scene. Federal thrusts developed in the early 1970's in relation to mobile home requirements and considerations for the handicapped were followed by programs aimed at the development of uniform requirements for:

   a. Fire safety in buildings (fire protection, detection, and prevention)

b. Energy requirements for public and private buildings

- energy conservation related design
- application of alternative energy sources (solar, waste energy regeneration)
- energy efficient retrofit

c. High hazard environments

- earthquake protective design
- high wind design and retrofit
- flood control design and retrofit

d. Special occupancy requirements

- handicapped, sick, and infirm building occupants
- elderly building users
- buildings with a high percentage of child occupants (nurseries, schools, etc.)

The role of the National Conference of States on Building Codes and Standards (NCSBCS), expanded considerably when it entered into a contract with NIBS to set guidelines for the harmonization of regulatory processes, practices, and training of regulatory officials.

B. <u>The NIBS Performance Codes and Standards Task Force</u>

In the late 1970's, it became evident that problems in the building standards, codes, and regulations field were not so much "technical problems" as "resource allocation problems." To obtain a new basis for all definitive material relating to the building regulation process, the National Institute of Building Sciences (NIBS), formed a high-level full-time Performance Codes and Standards Task Force (PCSTF), to develop and promulgate nationally-recognized performance criteria, standards, and other provisions for the maintenance of life, safety, health, and public welfare suitable for nationwide adoption. The performance approach was selected over traditional prescriptive approaches to allow the widest practicable latitude for innovation in design and production, and cost stabilization due to the forces in a competitive marketplace. The Task Force developed a system of Objective Levels to define performance requirements and means of verification. These were as follows:

Level 1: <u>Fundamental Objectives</u>: setting out the "basic" principles in relation to any building complex or system, as well as the basis of a structured approach.

Level 2: Derived or Wide-Ranging Objectives: setting out the purpose of each major division of activity or subsystem in the form of objective statements delineating the functional performance expectations for various elements or service networks under specified environmental or other service conditions.

Level 3: Specific Objectives: setting out, in detail, the requirements (functions or properties) of specific building items, such as assemblies, components, or materials, as well as criteria for their installation and maintenance.

Specific objectives, to a large extent, are dependent upon the framework set down in Level 2. Since alternative solutions can be described in terms of their compliance, this level also comes closest to the traditional prescription approach.

Level 4: Objective Match: setting out uniform requirements for acceptable test methods and procedures to verify objectives fit. This Level also is complemented by a scheme of compliance certification.

Prior to the establishment of the Task Force, much of the effort was devoted to work at Levels 3 and 4, without the benefit of an overall objective system. The Task Force quickly dispelled doubts as to the validity of its work by using the "objective system" to test existing model codes and building standards. Many clauses in these documents had extremely obscure purposes, and in some cases no reasons could be advanced as to why they were included at all. It was recommended that in any codes and standards review, an objective statement be provided for each clause (showing the "why" or reason for the clause) to justify its inclusion.

The objective system was widely accepted and led to a general review of technical statements in codes and standards.

C. The United States Joins the Metric Building World

Conjointly with these developments, a great challenge to the building regulations and standards community occurred in the late Seventies and early-Eighties when the U. S. finally moved to become a metric community. National voluntary standards bodies, which had lost considerable international sales of publications when Canada, Australia, Britain, and 41 other predominantly English-speaking countries turned away from their customary measurement systems, had realized early on that metrication was more than just a nuisance requiring reprinting of documents in new units, dual stocking, and obsolescence of part of the standards inventory. They saw that it provided a unique opportunity for review and rationalization, for the elimination of duplication, for a nationwide updating of standards reference facilities, and for a reemergence of American technological "know-how" on the international scene.

Frantic activity ensued on all fronts to develop and issue rationalized metric building standards. Considerable support came from the Federal Government as directives had been issued that metric standards from voluntary national standards bodies should be adopted wherever available, and a metric standards development program was subsidized equally by the Government and industry.

Metrication in the model building codes area had an even greater impact. It further reduced the differences between technical requirements expressed in different codes. The Model Codes Standardization Council established a Coordinating Committee on Metric Construction Codes (CCMCC). This Committee was given a set of objectives similar to those espoused by the former Joint Committee on Building Codes. However, it added a general objective to preserve and establish a harmony of numerical values in metric model codes through the use of standardized procedures for conversion, rounding, and rationalization of values. At the same time, it was decided to introduce uniform fire-related requirements to head off a challenge from a proposed Federal Fire Code for Buildings.

At the legislative and enforcement levels, more States moved towards statewide uniform metric building and building service requirements. This was the result of two factors. Firstly, there were approaches from industry for uniform regional and statewide implementation dates for metric building regulations. Secondly, there were requests for statewide requirements by local authorities who were daunted by the prospect of having to "convert" individual building requirements and then to train people without the benefit of well-developed documents.

The metric conversion efforts continued well into the 1980's and provided a significant demonstration of the ability of the codes and standards community to achieve common objectives and to cooperate in harmony. The new communication channels developed as a result of metrication provided a most useful basis for subsequent cooperative efforts.

THE PERIOD FROM 1983 TO 1987

A Standard Format for Building Information

As an extension of the objective system developed by the Performance Codes and Standards Task Force (PCSTF), work commenced on the development and introduction of a "standard format" and general classification system for all building related data. This system would allow for an orderly structure of technical information in building regulations, building standards, test data, compliance certificates, technical instruction, specifications, and technical reference literature.

It quickly became apparent that the information and control process could be greatly simplified by a systematic approach to the presentation of information -- especially an approach that was designed to suit a data processing environment.

To simplify application, legal and administrative requirements dealing with purpose, scope, application, enforcement, appeal, and review were separated from technical requirements.

Many formats were examined for the presentation of technical requirements, but ultimately a system reflecting the concept of levels was introduced. Firstly, building codes were separated into four activity categories:

1. demolition and site preparation for new construction;

2. building design and construction, including all services;

3. building operations and maintenance; and,

4. building rehabilitation, renovation and retrofit.

For the new building design and construction code, the largest single activity category, the following technical subdivision was adopted:

a. Basic performance design for buildings and services systems:

   - relating to local factors (siting requirements, fire zone, flood zone)

   - relating to different environmental factors (seismic zone, wind zone, snow zone, thermal zone)

   - relating to building occupancies and their operational and functional needs.

b. Derived performance design in relation to:

   - structural factors

   - fire safety

   - accident safety

   - hygiene and environmental health

   - functional system performance

   - energy conservation.

c. Performance criteria and standards for building elements, products, materials, and services systems including fixtures and appliances; and their installation. The emphasis on mechanical, electrical, plumbing, communications or composite systems is at this level.

d. Test methods and certification requirements.

e. Accreditation, testing, and certification facilities.

The classes of occupancy agreed upon were related in matrix form to each requirement (clause or item) so that a tick against any one clause was adequate to show its applicability. Clauses relating to specific building occupancies (types) were thus clearly identified.

International Activity

As a result of metrication, the United States began to play a more prominent technical role at the international level. The U.S. made many proposals for international standards and technical guidelines through the work of the International Organization for Standardization (ISO), the United Nations - Economic Commission for Europe (UN-ECE) project on harmonization of building controls, and other activities.

THE PERIOD FROM 1988 TO 1992

The developmental work on an objective system and general format had been so successful that it led to the establishment of a National Construction Codes and Standards Center (NCCSC). This center had a number of technical operating divisions, which were jointly financed by industry and Federal/State governments, to develop, coordinate, and review technical standards under the broad overview of the National Institute of Building Sciences. In addition to the divisions, there were four offices in the Center which dealt with administration, education, legal interpretations, and communications (including publications).

This Center became the technical focus for many of the fragmented activities that previously had been carried out under varying auspices. Its essential purpose was to organize technical resources in such a way as to avoid duplication. Simultaneously, innovation in relation to building design and construction, materials and systems production, and installation procedures were encouraged by the development of a system of "innovation permits," for limited application of alternative technology in building situations. This system was under the monitoring overview of the National Conference of States on Building Codes and Standards.

With proper review and monitoring, the innovation permits provided a "field testing" system to supplement the more traditional laboratory-based testing approaches.

THE PERIOD FROM 1993 TO 1997

The trends of preceding activity had made building codes and standards far more uniform and easily comparable.

The remaining model code organizations had decided to pool their resources in a federation of model codes. This was done to preserve their valuable function of developing inputs into the building regulatory system in the face of increasing Federal and State government activity in relation to the unification of building requirements. This federation was called the American National Model Codes Council (ANMCC).

The Model Codes Council joined with the National Institute of Building Sciences (NIBS), the National Conference of States on Building Codes and Standards (NCSBCS), and the National Bureau of Standards (NBS) to establish a National Construction Codes Data Service (NCCDS) in association with the National Construction Codes and Standards Center. The National Construction Codes Data Service provided a comprehensive printout and readout service for any specific set or combination of code requirements. For a fee, an instant search and retrieval system became accessible to list or compare any local, regional, national, or North American requirements. Requirements were classified according to building use, building type, building product or process, or special requirement (hazardous environments, special occupancies or users, restricted uses, etc.).

By now the turbulent decades since 1977 had settled down into a system which was streamlined, widely understood, and utilized to expedite the "software" or paper-based processes in building activity.

THE PERIOD FROM 1998 TO 2002

At the turn of the century and the millennium, considerations turned outward. With the building codes and standards situation now relatively stable, the United States codes and standards community became involved in technology exchange programs with other nations. A major effort at both regional (North American) and international level was aimed at the harmonization of building requirements and standards, under the terms of an international "bimillennium project" sponsored by the United Nations. By the year 2000, the U.S. had returned to technological leadership in the building and building standards world.

CONCLUDING REMARKS

I have had a lot of fun developing this presentation. For those of you who regard it as a spoof, please look at it seriously; for those who regard it too seriously, please think of it, at least in part, as a spoof.

In this excursion into the future, the present has been shown as the past. What are we to learn from this lighthearted but nevertheless meaningful speculation?

The significant lesson is that in our increasingly complex society we cannot afford to drift from event to event if we wish to protect the aims of the community. We have to apply the human capacity for research and innovation in an imaginative and goal-oriented way and as the stepping stone for planning, coordination, and achievement.

The technical aspects are much easier to resolve than the political and human problems of giving change a meaningful dimension. Empires under attack will fight vigorously to preserve the status quo, before entering into programs intended to promote greater productivity.

But in order to be successful, we need a set of objectives - objectives that spell out the purpose of our activity, as well as making it possible to measure accomplishments against them.

The major objective of all parties in the construction community ought to be to devise and implement a simple, harmonious, intelligible, and easily accessible set of regulations, codes, and standards within the context of the regulatory system, but not necessarily demanding uniformity. We ought to set an overriding objective and that is to create and protect a built environment which makes it possible for man to function in this complex world. We need to be aware that as we shape our buildings and structures, so, in turn, they do shape us. Good buildings are one prerequisite for the maintenance of a healthy, vigorous, and happy community. Inadequate buildings, as sociologists tell us, can lead to serious consequences of distress, despondency, and damaging attrition.

In such an objective, building codes and standards are an important tool. In my view, they ought to form the most important basic reference in the construction community and in the general economy. And, they ought to be accepted equally by the paid public administrator, the technologist, and the businessman.

While it is probable that many of the existing codes and standards will be superseded or harmonized by the end of this century and some will disappear entirely, the local code administrator should not suffer. He or she will work more effectively with a system that is understood and accepted by all parties; that is more easily maintained, updated, and verified; and, that facilitates the educational process. NCSBCS, NIBS, and the model codes will survive and grow if they are attuned to the future as well as the past.

In my opinion, we must be forward looking to benefit future generations. We need a wide commitment to a set of objectives; the funding of non-partisan and multi-disciplinary research; enthusiastic leadership which introduces a sense of direction to our technological resources and skills; innovation and ingenuity; and, most importantly, the goodwill of all parties that are affected by new initiatives. The opportunities for accomplishment in the building regulatory field have never been greater - they just need to be grasped.

THE TEXAS APPROACH TO ENERGY CONSERVATION BUILDING STANDARDS

by

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In 1975 the State of Texas Legislature mandated that energy conservation standards be developed for new State Buildings. The legislation called for the development of performance criteria and for guidelines for energy efficient design for different classes of state owned or financed buildings. In complying with the requirements of the law, the State Building Commission sought to minimize any adverse impact of the new standards on the design process.

The State of Texas Building Energy Conservation Standard is divided into sections on the envelope, mechanical equipment, lighting, and service hot water. The standard is similar to ASHRAE 90-75 in the mechanical equipment and service hot water sections, but differs in the lighting and envelope sections. The lighting section specifies watts per square foot for most task areas with foot-candle designations for unusual areas. The building envelope section provides a new approach. It assures a minimal thermal performance of the shell by specifying an Energy Envelope Index which is a function of building size and location. The EEI calculations are similar to standard procedures for estimating loads (such as those published by ASHRAE) and is presented in the State Energy Conservation Manual. These procedures are summarized in this paper.

It is felt that the State of Texas procedure, while innovative, provides a flexible and workable standard acceptable to both the State and the design professionals and introduces a new approach toward performance standards.

Key Words: Alternatives; ASHRAE 90-75; building standards; energy conservation; performance standards.

INTRODUCTION

In 1975, the 64th Texas Legislature enacted the Energy Conservation in Buildings Act. The purpose of the Act was:

> to provide for the development of improved design, lighting, insulation, and architectural standards to promote efficient energy use in State buildings including buildings of state-supported institutions of higher education, to reduce wasteful or uneconomic consumption of energy by balancing the cost of energy procurement against the cost of energy conserving building practices to achieve the minimum lifetime cost for all new State buildings, including new buildings of state-supported institutions of higher education, measured by combined construction and operating costs, and to provide information to the public relating to energy saving uses, designs, construction methods, and techniques for all new and existing buildings.[1]

The Act required the following three specific items to be accomplished by the State Building Commission and the Governor's Energy Advisory Council to fulfill the purposes outlined in the law:

1. Energy Conservation Design Standards for all new State buildings.

2. Technical assistance to cities in the form of model energy conservation building codes.

3. Energy conservation manual for potential use by designers, builders, and contractors of residential and nonresidential buildings.

The staff of SBC and GEAC chose to enlist the aid and advice of an advisory committee selected from the professional design community and construction industry in the development and review of the standards for state buildings and the model codes for the cities. The staff and the majority of the model code advisory committee felt that the most efficacious solution to the model code requirement would be to use the draft of the NCSBCS model code as a basis and submit any necessary changes to NCSBCS and the national model code groups for consideration.

The staff was constrained by requirements to the Act to produce standards for state buildings that would:

> include both performance and procedural standards for maximum energy conservation allowed by the latest and most effective technology consistent with the requirement of public health and safety regulations and economic considerations.

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(1) Subdivision 35 of Article 1175, Revised Civil Statutes of Texas, 1925.

The standards shall be promulgated in terms of energy consumption allotments and shall take into consideration the various classes of building uses. Performance standards shall allow for design flexibility since only the total allotment of energy is prescribed.

Procedural standards shall be directed toward specific design and building practices that produce good thermal resistance and low air leakage and toward requiring practices in the design of mechanical and electrical systems which conserve energy. The procedural standards shall address, when applicable, the following items:

(1) insulation,

(2) lighting, according to the lighting necessary for the tasks for which each area is intended to be used,

(3) ventilation,

(4) the potential use of new systems for saving energy in ventilation, climate control, and other areas, and

(5) any other item which the State Building Commission deems appropriate.[2]

A NEW APPROACH

The staff had a legislative mandate to produce standards which had seemingly contradictory requirements in that both performance and procedural standards were required. However, the legislative intent was understood to be to minimize any adverse impact of the new standards on the design process. A compromise solution was sought whereby a new standard might be developed which would address the concerns of the specific group most impacted by each section of the standard.

ASHRAE 90-75 was recognized as a valuable energy conservation design standard, yet some did not consider it to be suited to all the requirements of the law. ASHRAE 90-75 was as vigorously opposed by many architects as it was supported by many engineers. The solution to this lack of consensus seemed to be to use 90-75 as the basis for those sections most directly affecting the engineers and develop a performance standard for the building shell which would reflect the energy efficiency of the design alternatives available to architects.

The State Design Standard which grew out of this compromise contains five (5) sections covering the following:

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(2) Subdivision 35 of Article 1175, Revised Civil Statutes of Texas, 1925.

1) building shell

2) mechanical systems

3) mechanical equipment

4) service water heating

5) lighting

The mechanical systems, mechanical equipment, and service water heating sections are very similar to ASHRAE 90-75 and were considered acceptable by the engineering professionals. The lighting section differs from 90-75. It provides for a lighting budget based on watts per square foot allowable for the different tasks within an area. The allowable power levels for different tasks have been compiled and listed in a tabular form. Additional requirements are made on switching and reduced levels of illumination for maintenance. Additional flexibility is provided since some task areas are designated in foot-candles with a maximum allowable of 3 watts per square foot, and exemptions are granted for special purpose areas like stage lighting. The lighting section is modeled after work done in California. It was chosen over the IES method due to the ease of checking compliance.

The most controversial and most innovative section of the standard is the section on the building shell. The development of this section grew out of the concern of the architectural profession and the requirement for a performance element in the Legislation. The remainder of this paper will be used to explain the methodology and application of this performance design standard.

PERFORMANCE STANDARD

The building shell section is based on compliance with what is called an Envelope Energy Index (EEI). The EEI is not intended to specify energy consumption, but to provide a comparative value for determining the relative energy efficiency of a building shell. The standard assures a minimal thermal performance of the shell by specifying an EEI as a function of building size and location. The standard EEI values were established using a prototypical building with square floor plan and a number of floors which tended to minimize the surface area of the building. The wall and roof U-value were taken from ASHRAE 90-75. It was also assumed that 30% of the wall area would be single glazed and have a shading coefficient of one-half. These assumptions do not prescribe the shape or amount of glazing in a building, they simply establish a target EEI value. The EEI has units of millions of BTU per year. There will be many combinations of building shape, orientation and materials which will meet the EEI values for the specified enclosed space.

Compliance with the standard may be determined by the architect during the preliminary design. In fact, the EEI method may be a very useful design tool in aiding the architect in the initial design phase. The EEI accounts for the influence of geometric factors, climatological variables associated with the location such as temperature and solar irradiation, and the effect of internal loads.

The EEI method employs standard procedures for calculating heating/cooling loads. However, in this procedure these loads are calculated on a daily, rather than hourly basis, and are correlated with daily average temperature. A number of studies have shown that the average dry bulb temperature provides the best single measure method for comparing envelope loads. It was felt multiple measure correlations would be too complex for practical application. The daily loads were utilized as they minimize the complexity of the calculation procedure. On a daily load basis, the mass or thermal capacitance, of the envelope has little effect, thus providing a significant simplification. The procedures for including solar and internal loads are also simplified. (The hourly design load for sizing equipment must be calculated separately as this procedure will not provide appropriate loads for that purpose.)

EEI CALCULATION

The thermal performance of any particular building envelope may be represented graphically as a function of BTU's transferred and daily average temperature as shown in Figure 1. The daily load curve will be a linear function of average daily temperature, therefore, the curve may be described by two points. Daily loads are calculated for two days, one for a summer day representative of average conditions in July, and one for a winter day representative of average conditions in January.

The daily loads are determined by using daily sums of the total equivalent temperature differences and solar heat gain factors described in the ASHRAE Handbook of Fundamentals 1972. In the present procedure, TETD and SHGF values must be corrected for percent possible sunshine, surface color coefficient, and an ambient dry bulb temperature profile different from that on which the Handbook tables are based. This must be done as daily envelope loads are to be compared on the basis of average conditions rather than peak load conditions. The correction procedure, however, is very simple and is outlined below:

Terms: Q_D = Daily load

ETD = Equivalent temperature difference ^oF

I_T = Total irradiation on a surface BTU/hr.

I_{DT} = Total daily irradiation on a surface BTU/day

A_p = Area of perimeter spaces

t_o = Outside air temperature ^oF

t_i = Inside air temperature ^oF

α/h = Color correction factor

%S = Percent possible sunshine

sc = Shading coefficient for windows (include both internal and external shading)

Load for Roof and Walls:

Equivalent temperature difference

$$ETD = t_o - t_i + \frac{\alpha}{h} (I_T) \%S$$

Daily sum $\Sigma ETD = (t_{oa} - t_i)\ 24 + \frac{\alpha}{h} (I_{DT}) \%S$

Daily load for wall or roof $Q_D = UA \quad (\Sigma ETD)$

Load for Windows:

Transmission $Q_T = U_g A_g (t_{oa} - t_i)\ 24$

Solar $Q_s = A_g I_{DT}\ (SC)\ (\%S)$

Daily load for glass $Q_{Dg} = Q_T + Q_S$

Internal Loads:

In this procedure, only the internal load in the perimeter zones will be assumed to interact with the building envelope. For calculation purposes, the perimeter zones will be assumed to be 15 feet deep.

Internal Loads:

Lights $Q_L = (\text{watts/ft.}^2)\ (3.413)\ A_p$ (hours of operation)

Equipment Q_E = (same form as lights)

People $Q_p = A_p/150$ (400 Btu/hr) (hours of occupancy)

This assumes an occupancy of one person per 150 square feet.

Total Daily Load $Q_{DT} = Q_D + Q_{Dg} + (Q_L + Q_E + Q_p)$

A series of graphs provide the index as a function of building size for each of 15 climatological areas of the State. Once an EEI has been established from the appropriate graph for a particular building size and location, a proposed building design may be checked for compliance. An architect may evaluate his building during the preliminary stages by calculating Q_{DT} for January and July and plotting the building load curve. A preliminary comparison is then made between the proposed building and standard by taking the January and July value from the appropriate graph for the same size building. Typically visual inspection will indicate if the proposed building is in compliance. If the building is close, compliance may be determined by establishing the proposed building load curve in equation form $Y = aX + b$. Simple substitution into the equation of the average monthly temperature for X will yield Q_{DT} for the other ten months. The summation of the Q_{DT} for each month multiplied by the number of days in each month provides an index value to compare with the EEI taken from an appropriate graph such as Figure 2. If the summation for 12 months is less than the EEI, the building complies; if it is greater, modifications of the building shell are required.

By plotting the end points of the standard building envelope load curve using graphs like Figures 3 and 4, the architect may establish a baseline for comparing design alternatives and visually inspect superior designs as shown on Figure 1. The Energy Conservation Manual has a standard data sheet shown as Figure 5 and a calculation form to provide ease of calculations as shown in Figures 6, 7, and 8. Additional calculation aids are provided in the Manual on thermal resistance of building materials and shading factor calculation aids.

CONCLUSIONS

The standard has been adopted for use in Texas on State buildings and is being tested for one year to allow for comment by professionals involved in State construction and to allow staff evaluation of enforcement difficulties. This approach toward energy conservation design standards is admittedly evolved from controversy and founded on compromise. Amendments and updating will be necessary but this standard provides a precedent for performance standards which can be quantitatively determined and satisfied before construction and provides little or no obstruction to the design and construction process.

Initial experience with using the EEI standards indicates most buildings comply without changes. Future changes in the indices are anticipated to encourage more efficient design.

CHART A-1-A

DETERMINING AVERAGE MONTHLY COOLING - HEATING VALUES

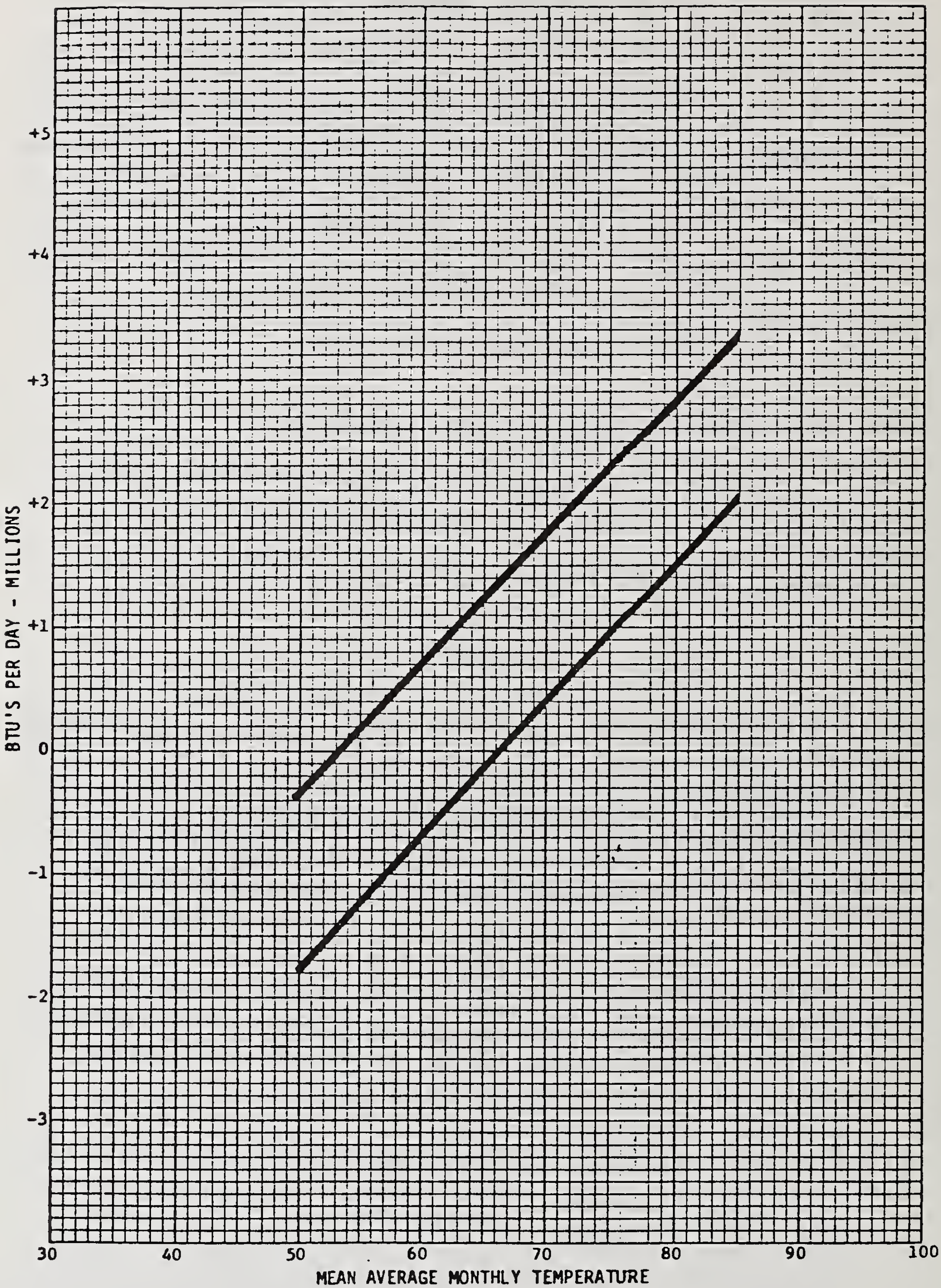


Figure 1

CHART A-4-B

ALLOWABLE EEI FOR BUILDINGS - AUSTIN

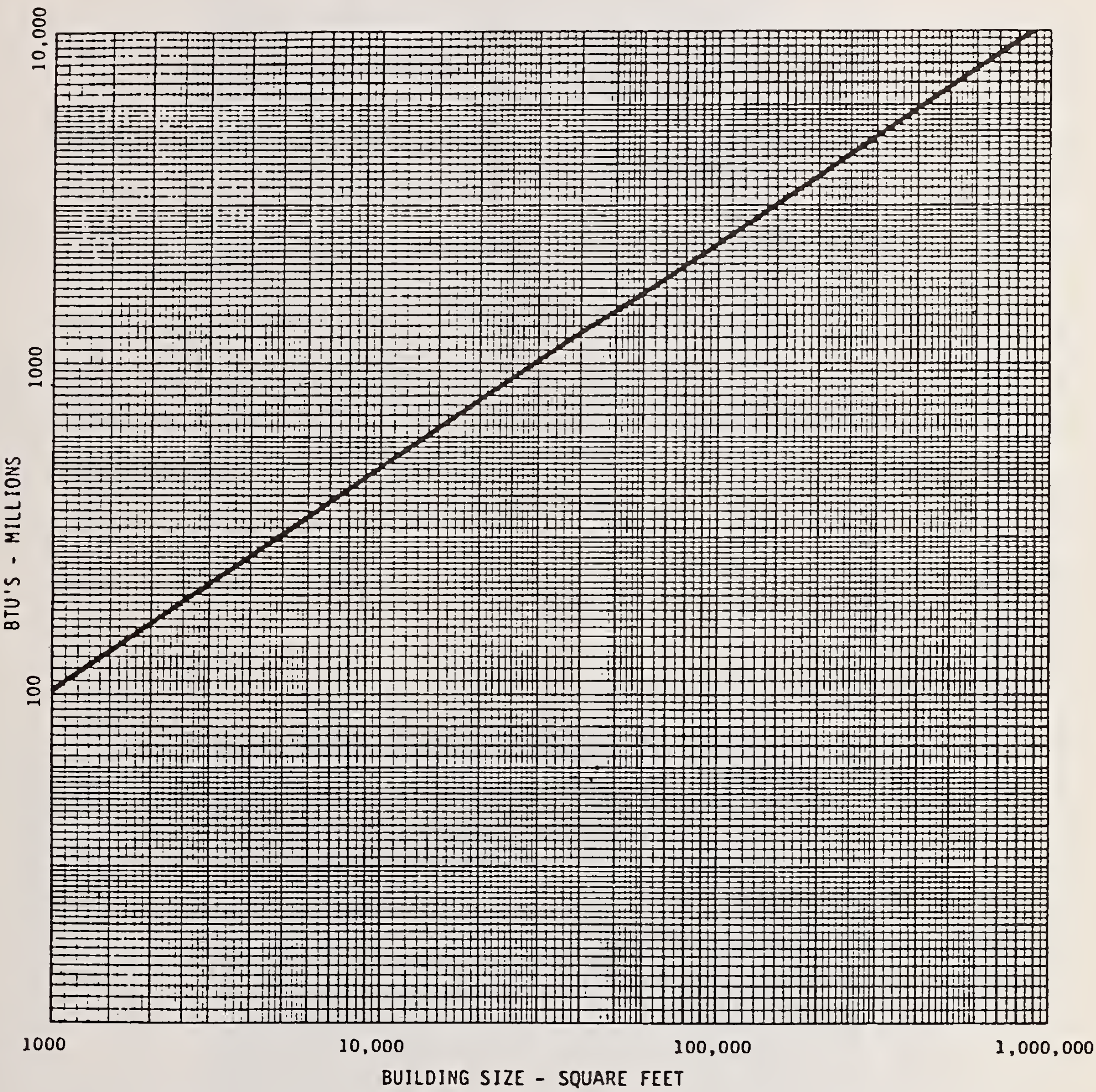


Figure 2

CHART A-2-B

JANUARY BTU VALUES FOR PROTOTYPICAL BUILDINGS - AUSTIN

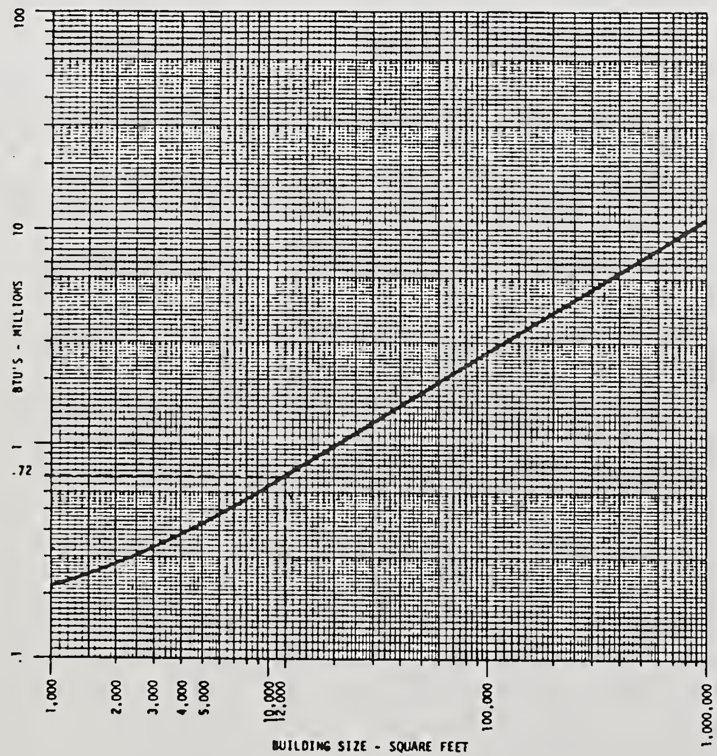


Figure 3

CHART A-3-B

JULY BTU VALUES FOR PROTOTYPICAL BUILDINGS - AUSTIN

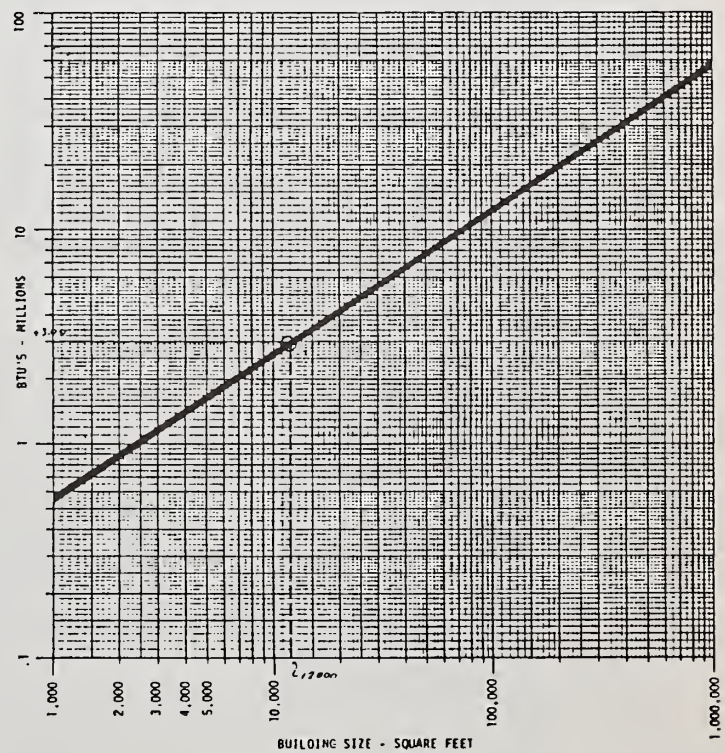


Figure 4

EXAMPLE

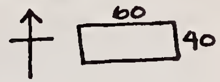
STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 1

PROJECT Texas Towers — PROJECT NAME A-2 Complex

LOCATION Austin — TYPE BUILDING Office

ARCHITECT T. Square & Assoc.



DATA INPUT FOR BUILDING ENERGY CALCULATIONS

A. BUILDING ENVELOPE

1. Gross Floor Area Sq. Ft. 12000 (5 FLOORS)
2. Perimeter Lin. Ft.[1] 200
3. Perimeter "F"[1] .25
4. Foundation Area Sq. Ft.[2] —
5. Foundation "U"[2] —
6. Roof Area Sq. Ft. 2400
7. Roof Structure "U" Value .1
8. Roof Color Coefficient 1
9. Skylight Area 0
10. Skylight "U" Value 0
11. Skylight Shading Coefficient 0

Item		Side 1	Side 2	Side 3	Side 4
12.	Net Wall Areas Type 1	2350	2275	2350	2275
13.	Type 1 Wall "U" Value	.10	.10	.10	.10
14.	Type 1 Wall Color Coef.	.7	.7	.7	.7
12A	Net Wall Areas Type 2				
13A	Type 2 Wall "U" Value				
14A	Type 2 Wall Color Coef.				
12B	Net Wall Areas Type 3				
13B	Type 3 Wall "U" Value				
14B	Type 3 Wall Color Coef.				
15.	Window Areas Type 1	1250	125	1250	125
16.	Window "U" Value Type 1	1.10	1.10	1.10	1.10
17.	Window Shading Coef. Type 1	.60	1	.60	1
15A	Window Areas Type 2				
16A	Window "U" Value Type 2				
17A	Window Shading Coef. Type 2				

[1] Fill in Items 2 & 3 for Slab or Grade Type Foundation.

[2] Fill in Items 4 & 5 for Pier and Beam Type Foundation.

[3] Orientation - Sides: 1 - N or NE; 2 - E or SE; 3 - S or SW; 4 - W or NW.

EXAMPLE

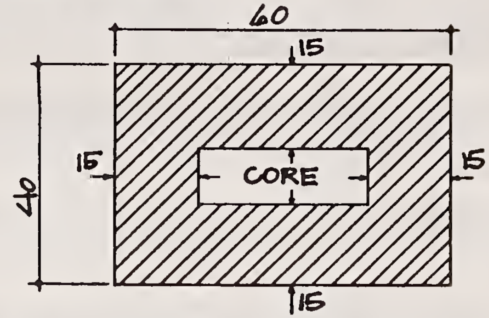
STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 2

Item		Side 1	Side 2	Side 3	Side 4
15B	Window Areas Type 3				
16B	Window "U" Value Type 3				
17B	Window Shading Coef. Type 3				
18.	Door Areas	42		42	

19. Door "U" 1.10
20. Lighting Level (Watts Per Sq. Ft.) 3
21. People Load (Sq. Ft./Person) 150
22. Miscellaneous Load (BTU Per Sq. Ft.) .70
23. Perimeter Area 10500*
24. Hours Lights On 10
25. Hours Building Occupied 8
26. Hours Miscellaneous Loads On 10

* Perimeter Area = (item 2 - 60) x 15 x number of floors.
This represents the influence of internal loads on the shell in a 15' perimeter zone of the building.



$$P = (60+40+60+40) = 200 \text{ LIN. FT.}$$

$$P_a = (200-60) \times 15 \times 5 = 10{,}500 \text{ SQ. FT.}$$

Figure 5

EXAMPLE

STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 3

100. Month - January

($t_o - t_i$)	x 24	= DEGREE HOURS/DAY
(49.7-75)	24	-607.2

101. Roof

(HORIZ. SOLAR x .35 x % SUN x COLOR COEF.[6] + ITEM 100)	x U[7]	x AREA[8] =	BTU/DAY
(137.5 x .35 x .46 x 1 - 607.2)	.1	2400	-92733.2

102. Skylights

(HORIZ. SOLAR x % SUN x SHADING COEF.[11] + ITEM 100)	x U[10]	x AREA[9] =	BTU/DAY
NONE			0

103. Wall Side 1 or 2

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 100)	x U[13]	x AREA[12] =	BTU/DAY
(159 x .35 x .46 x .7 - 607.2)	.1	2350	-138,481

104. Wall Side 3 or 4

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 100)	x U[13]	x AREA[12] =	BTU/DAY
(639.0 x .35 x .46 x .7 - 607.2)	.1	2275	-121754.5

105. Wall Side 5 or 6

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 100)	x U[13]	x AREA[12] =	BTU/DAY
(1672.0 x .35 x .46 x .7 - 607.2)	.1	2350	-98409.9

106. Wall Side 7 or 8

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 100)	x U[13]	x AREA[12] =	BTU/DAY
(639.0 x .35 x .46 x .7 - 607.2	.1	2275	-121754.5

107. Total Wall

103	+ 104	+ 105	+ 106	= BTU/DAY
-138481	-121754.5	-98409.9	-121754.5	-480399.9

108. Perimeter

PERIMETER[2]	x ITEM 100	x "F"[3]	= BTU/DAY
200	x (-607.2)	x .25	-30360

EXAMPLE

STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 4

109. Foundation

AREA[4]	x ITEM 100	x "U"[5]	= BTU/DAY
0			0

110. Windows Side 1

(U[16] x ITEM 100 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15]	= BTU/DAY
(1.10 x -607.2 + 159 x .46 x .60)	1250	-780045

111. Windows Side 2

(U[16] x ITEM 100 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15]	= BTU/DAY
(1.10 x -607.2 + 639.0 x .46 x 1)	125	-46747.5

112. Windows Side 3

(U[16] x ITEM 100 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15]	= BTU/DAY
(1.10 x -607.2 + 1672 x .46 x .60)	1250	-258060

113. Windows Side 4

(U[16] x ITEM 100 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[16]	= BTU/DAY
(1.10 x -607.2 + 639.0 x .46 x 1)	125	-46747.5

114. Total Windows

110	+ 111	+ 112	+ 113	= BTU/DAY
				-1,131,600

115. Total Shell Loads

101	+ 102	+ 107	+ 108	+ 109	+ 114	= BTU/DAY
-92733.2	-0	+480399.9	-30360	-0	-1131600	-1,735,093.10

Figure 6

EXAMPLE

STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 5

200. Month - July

$(t_o - t_i)$	x 24 =	DEGREE HOURS/DAY
(84.6-75)	24	230.4

201. Roof

(HORIZ. SOLAR x .35 x % SUN x COLOR COEF.[8] + ITEM 200)	x U[7]	x AREA[6] =	BTU/DAY
(2550x.35x.76 x 1 + 230.4)	.1	2400	+218088

202. Skylights

(HORIZ. SOLAR x % SUN x SHADING COEF.[11] + ITEM 200)	x U[10]	x AREA[9] =	BTU/DAY
NONE			0

203. Wall Side 1 or 2

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 200)	x U[13]	x AREA[12] =	BTU/DAY
(464x.35 x.76 x.7+230.4)	.1	2350	+74447.2

204. Wall Side 3 or 4

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 200)	x U[13]	x AREA[12] =	BTU/DAY
(1139x.35 x.76x.7+ 230.4)	.1	2275	+100664.6

205. Wall Side 5 or 6

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 200)	x U[13]	x AREA[12] =	BTU/DAY
(457x.35x.76x.7+230.4)	.1	2350	+74140.9

206. Wall Side 7 or 8

(WALL SOLAR x .35 x % SUN x COLOR COEF.[14] + ITEM 200)	x U[13]	x AREA[12] =	BTU/DAY
(1139x.35x.76x.7+230.4)	.1	2275	+100664.6

207. Total Wall

203 +	204 +	205 +	206 =	BTU/DAY
				+349917.3

208. Perimeter

PERIMETER[2]	x ITEM 200	x "F"[3] =	BTU/DAY
200	230.4	.25	+11520.0

EXAMPLE

STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 6

209. Foundation

AREA[4]	x ITEM 100	x "U"[5] =	BTU/DAY
0			0

210. Windows Side 1

(U[16] x ITEM 100 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15] =	BTU/DAY
(1.10x2304+464x.76x.60)	1250	+581280

211. Windows Side 2

(U[16] x ITEM 100 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15] =	BTU/DAY
(1.10x 2304+ 1139x.76 x 1.0)	125	+139885

212. Windows Side 3

(U[16] x ITEM 200 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15] =	BTU/DAY
(1.10x2304+457x.76x.60)	1250	+577290

213. Windows Side 4

(U[16] x ITEM 200 + WINDOW SOLAR x % SUN x SHADING COEF.[17])	x AREA[15] =	BTU/DAY
(1.10x2304 +1139x.76x1.0	125	+139885

214. Total Windows

210 +	211 +	212 +	213 =	BTU/DAY
				+1438340

215. Total Shell Loads

201 +	202 +	207 +	208 +	209 +	214 =	BTU/DAY
						+2017865.3

Figure 7

EXAMPLE

STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 7

300. Total Shell Loads (From 115 & 215)

MONTH	- HEATING	+ COOLING
JAN	-1,735,093.10	
FEB		
MAR		
APR		
MAY		
JUNE		
JULY		+2017865.3
AUG		
SEPT		
OCT		
NOV		
DEC		
TOTAL		

INTERNAL LOADS

400. People Load

ITEM 23	÷ SQ. FT./PERSON[21]	x 400	x NO. HOURS[25]	= BTU/DAY
10500	150	400	8	224,000

401. Lighting Load

ITEM 23	x WATTS/SQ. FT.[20]	x 3.413	x NO. HOURS[24]	= BTU/DAY
10500	3	3.413	10	1075095

402. Miscellaneous Load

ITEM 23	x MISC. LOAD/SQ. FT.[22]	x NO. HOURS[26]	= BTU/DAY
10500	.70	10	73500

403. Total Internal Load

400	+ 401	+ 402	= BTU/DAY
			1,372,595

EXAMPLE

STATE BUILDING COMMISSION
ENERGY CONSERVATION DIVISION

SHEET 8

404. Total Building Load Per Day (January)

115	+ 403	= BTU/DAY
-1735093.10	1,372,595	-362,497.6 *

*Enter in Chart A-1-A

405. Total Building Load Per Day (July)

215	+ 403	= BTU/DAY
2017865.3	1,372,595	3,390,460.3*

*Enter in Chart A-1-A

406. Total Building Load Per Month (January)

404	x DAYS IN MO.	= BTU/MO.
- 362,497.6	31	-11,237,425.6

407. Total Building Load Per Month (July)

405	x DAYS IN MO.	= BTU/MO.
+3,390460.3	31	+105,104,269.3

500. Total Yearly Summary (From 406 & 407)

MONTH	- HEATING	+ COOLING
JAN	-11,237,425.6	
FEB		
MAR		
APR		
MAY		
JUNE		
JULY		+105,104,269.3
AUG		
SEPT		
OCT		
NOV		
DEC		
TOTAL		

Figure 8

THE NEED TO IMPLEMENT ENERGY CONSERVATIVE INSULATION STANDARDS BASED ON AVERAGE ENERGY USE RATHER THAN PEAK ENERGY USE - THE NEW MEXICO EXPERIENCE

by

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Director of the Division of Energy Conservative Design
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Albuquerque, New Mexico

and

Larry W. Bickle, PH.D., M.E., President
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Albuquerque, New Mexico

All Federal insulating standards for residence walls, ceiling and glazing are based on steady state U-values which govern the heat transfer rate only under conditions of peak energy use. Even the Component Design section of ASHRAE Standard 90-75 considers only steady state U-values as the basis for their requirements at arriving at stipulated average heat transmission values. Theoretical studies on heat transfer through walls and glazing, and studies of actual energy use for heating for a group of approximately 20 residences of different insulation amounts, made by the authors for the New Mexico Energy Resources Board, indicate that while added insulation may reduce heat transfer during peak energy use periods there is no proof that insulating for peak energy use periods reduces the overall or average energy consumption during the heating season. Quite the contrary, we find that insulation for peak energy use may be counterproductive and result in a greater amount of energy used for the heating season than if one insulates for average energy use conditions.

Key Words: ASHRAE Standard; climatic conditions; energy conservation; glass area; heat transfer; insulation; standards; U-values.

All Federal insulating standards for residence walls, ceiling and glazing are based on steady state U-values which govern the heat transfer rate under conditions of peak energy use. Even the Component Design section of ASHRAE Standard 90-75 considers only steady state U-values as the basis for their requirements for stipulating average heat transmission values. Theoretical studies on heat transfer through walls and glazing and studies of actual energy use for heating for a group of 25 residences of different insulation amounts, made by the authors for the New Mexico Energy Resources Board, indicate that, while added insulation may reduce heat transfer during peak energy use periods, there is no proof that insulating for the peak energy use periods reduces the overall or average energy consumption during the heating season. Quite the contrary, we find that insulating for peak energy use, in some instances, may be counterproductive and result in a greater amount of energy used for the heating season than if one insulates for average energy use conditions.

The ASHRAE "Component Design" section and recent actions by the Federal Housing Administration of HUD in increasing insulation requirements and limiting glass areas, promulgate the conception that more and more insulation and less and less glass area will lead to energy conservation. In New Mexico we have not found this concept to have much validity for average energy consumption in heating and we are inclined to wonder whether the concept has much strength for even a majority of the continental United States.

If more and more insulation were categorically better, then why is there so little correlation between insulation quantities for walls and ceilings and average energy consumption for heating the twenty-five houses we studied in Albuquerque? See Figure 1. (A linear regression program to determine the "best fit" straight line for the data, produced an almost horizontal line, slope of -1.7° and only a -0.08 correlation coefficient; the combination of which is so weak that we omitted the line from Figure 1). Dr. Jay McGrew, President of Applied Science and Engineering, Littleton, Colorado, could find no correlation at all between ceiling insulation quantities and energy consumption in a study of over 30 houses in the Denver area. See Figure 2. Now in case you have already formed the opinion that this lack of correlation applies only where the sun shines profusely, then how does one account for the presentation made by Dr. Bonnie Haas Morrison to this same group last year? In a study of single family homes in randomly selected urban and rural areas of mid-Michigan the Standard Regression Coefficient for insulation in the walls versus amount of direct total energy consumed was only -0.096, and for ceiling insulation was only -0.161. The "Belief in the Energy Problem" was very nearly as strong a correlation as the wall insulation (see Figure 3).[1]

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[1] From: "Residential Energy Consumption: Socio-Physical Determinants of Energy Use in Single Family Dwellings," by Dr. Bonnie Haas Morrison, NBS Special Publication 473, June, 1977.

The State of New Mexico is one of the first to adopt Chapter 53 of the Uniform Building Code, which is based essentially on the ASHRAE Standard 90-75. However, it was considered that our climatic conditions of high percentages of sunshine and large diurnal temperature differences could significantly affect the way wall, roof and glazing components perform with respect to their steady state U-values. Chapter 10 of ASHRAE Standard 90-75 allows exceptions to the insulation requirements if there are supporting calculations to show equal or better performance. For homes and small projects, however, it is unlikely that the owner or builder can afford the cost of professional engineering analysis that would be required for each exception. Therefore, the State of New Mexico Energy Resources Board sponsored a research contract for the authors to investigate the actual performance of typical wall components and glazing components under New Mexico climatic conditions, for use by designers and builders of residences and small projects in lieu of the steady state U-value insulation requirements.

In order to perform the required theoretical calculations, we have developed a one-dimensional computer model that uses actual hour-by-hour weather data and "first principle" heat transfer relationships to compute heat transfer through walls and glazing. This program is described in more detail in Appendix A.

A significant aspect of the computer program is that it keeps track of the average heat flux at the inside surface of the wall over an extended time period (i.e., one or two weeks). This average heat flux is used with the average difference between inside and outside temperature to compute an "Effective U-Value" which is a measure of the average rather than the peak heat transfer characteristics of a wall or other surface. We think that this concept of an Effective U-value is an important contribution to understanding the problem of energy conservation in structures.

In order to develop insight into the influence of storage mass, color, orientation, diurnal temperature differences, etc.; the computer program was run for two different glazing types with three different inside treatments and for twenty-seven (27) wall types for the eleven (11) different climatic regions of New Mexico and the four (4) cardinal points of orientation (i.e., North, South, East, and West).

Although the work to date is not complete, the results so far show some interesting trends.

GLAZING

Our computer results indicate that even single glazing (with night time treatment of drawn dense drapes) can be a <u>net energy gainer</u> for South, East, and West orientations in the majority of New Mexico's climatic regions (to approximately 5300-degree days, heating). Single glazing, even for north windows without night time treatment, appears to perform much better on an average than the steady state U-value would indicate. See Figure 2 of Appendix A.

Our survey of houses in Albuquerque confirms the potential energy conservative aspects of glazing. In fact, the houses that we studied showed, that for glass areas between the ranges of 7.8% of the floor area and 16.3% of the floor areas, that the greater the glass area the less energy consumption for heating. See Figure 4. The Correlation Coefficient of -0.56 seems surprisingly strong in view of the facts that:

1. The houses had random orientation.
2. The majority of the houses had single glazing.
3. The houses had varying insulation quantities.
4. The effects of life style and furnace efficiencies on consumption must also be considered.

COLOR

The computer studies show that the Effective U-values for walls are a strong function of color (absorptivity), even for North orientations. See Figure 5.

In our housing survey, although the glass correlation was quite strong, an even stronger correlation was found in our study to exist between a color factor[1] for walls and roof and energy consumption. See Figure 5. The Slope of -0.41 and Correlation Factor of -0.674 is very strong considering all the variables of the houses. The negative slope and correlation factor indicates that the darker the color factor the less energy consumption.

Possible Net Energy Gainers

In addition to glazing, we have found that some wall types in certain circumstances appear to have the potential to be net energy gainers. Dark unfilled concrete block walls computed as energy gainer for two of our regions (see Figure 6) while log walls in dark colors computed to be energy gainers in several regions. (See Figure 7.)

---

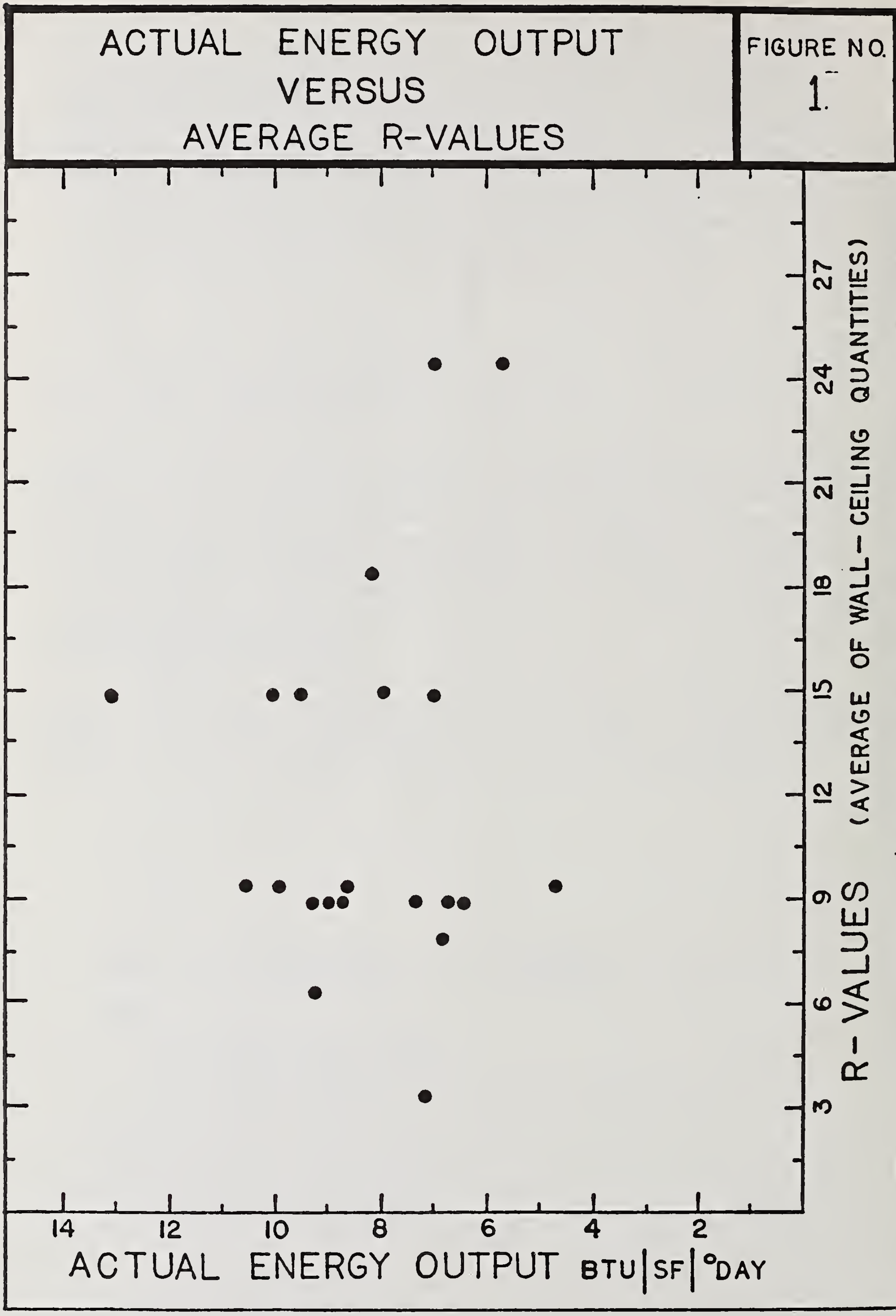
1 Color Factor = $\left[\frac{\text{Wall Area}}{\text{BTU/°Day}} \times a_1 + \frac{\text{Roof Area}}{\text{BTU/°Day}} \times a_2\right] \times 100$

Where:

a_1 = absorptivity of wall
a_2 = absorptivity of roof
BTU/°Day = average actual energy for heating in BTU per Degree Day

SUMMARY

Our work for New Mexico has been entirely devoted to the performance during the heating season since in this state evaporative coolers work so effectively while using less energy than most major household appliances. But even for the heating season our work is not yet completed. We have been funded by the New Mexico Energy Resources Board to conduct experimental heat transfer studies during this coming heating season and thus verify or (if necessary) modify our computer program. However, we think that our work to date is sufficient to cast serious doubts as to the wisdom of traditional thinking with regards to insulation and glazing policies. We are encouraged by the correlation using Effective U-Values that we have achieved between calculated average energy for heating and actual energy used for heating of the houses surveyed, as opposed to the correlation between steady-state U-value calculations and actual energy consumption. See Figures 8 and 9. Not only is the correlation stronger, but the slope of the correlation line for the Effective U-Value comparison is much closer to the desired correlation line. The better match of desired and "best fit" correlation lines appears to reflect the fact that the average estimated consumption of the houses, by the Effective U-Value method was only 6% lower than the actual consumption while the average of the estimates using steady-state U-values was 40% higher than the average actual consumption of the houses. The 6% low figure can, to an extent, be explained by differences in furnace efficiencies, life-style of occupants and quality of workmanship of the houses. But the 40% high figure is difficult to explain without questioning the applicability of steady-state U-Values to average energy consumption.


ACTUAL ENERGY OUTPUT
VERSUS
AVERAGE R-VALUES
FIGURE NO.
1
R-VALUES (AVERAGE OF WALL-CEILING QUANTITIES)
3
6
9
12
15
18
21
24
27
14
12
10
8
6
4
2
ACTUAL ENERGY OUTPUT BTU|SF|°DAY

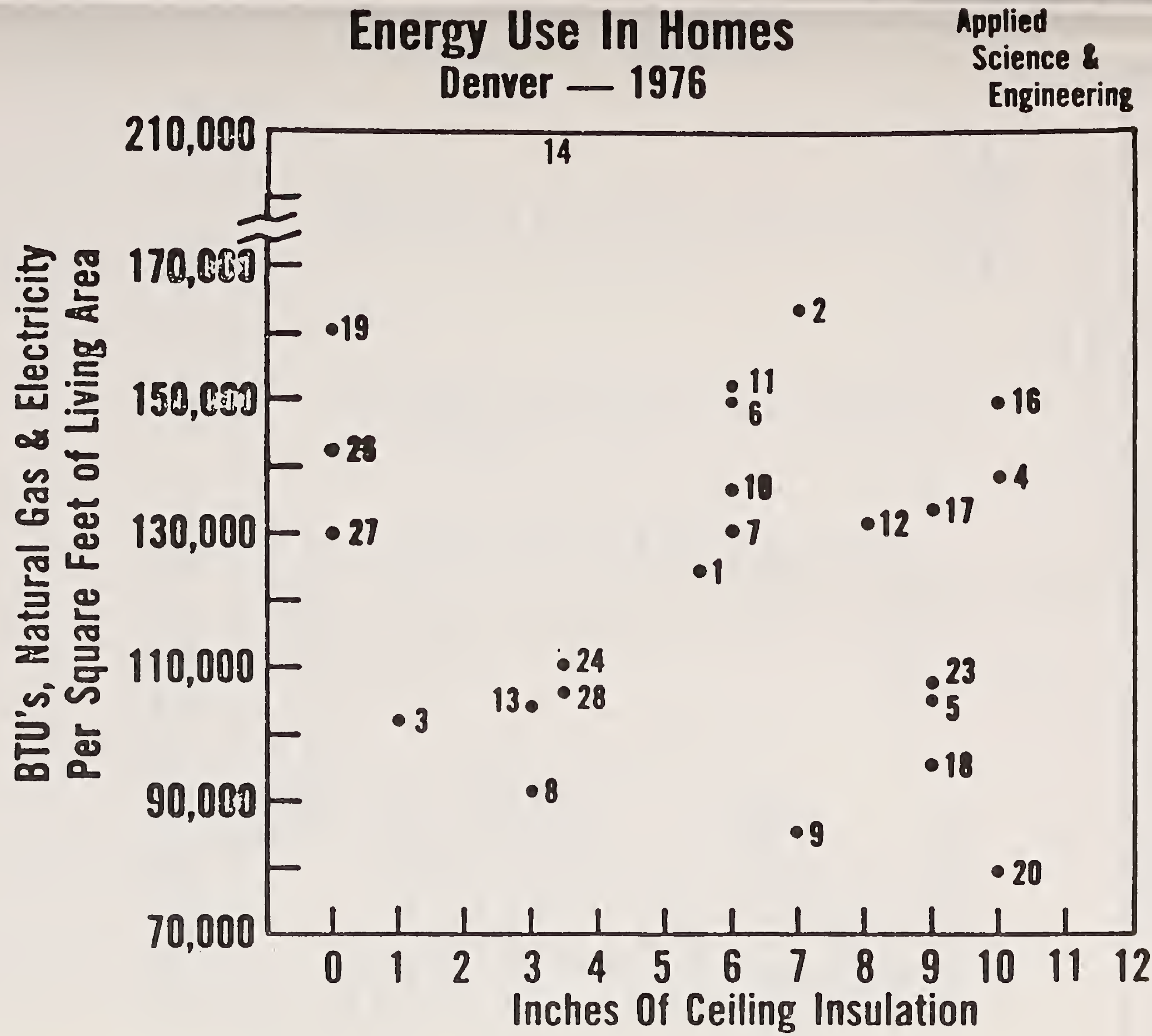

Energy Use In Homes
Denver — 1976
Applied Science & Engineering
BTU's, Natural Gas & Electricity Per Square Feet of Living Area
210,000
170,000
150,000
130,000
110,000
90,000
70,000
0 1 2 3 4 5 6 7 8 9 10 11 12
Inches Of Ceiling Insulation
14
19
28
27
3
13
24
28
8
11
6
10
7
1
2
9
12
17
23
5
18
16
4
20

FIGURE 2

Total Direct Energy Consumption

Table 2 — Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Seventeen Independent Variables on the Amount of Direct Total Energy Consumed in Single Family Detached Dwelling Units.

	Amount of Direct Total Energy Consumed		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Household size	.280	8.02	< .001
Major appliances	.211	3.19	< .01
Number of rooms	.173	1.30	= .25
Number of exterior doors	.168	2.38	< .05
Number of rooms heated	.165	1.71	< .25
Square feet	.081	.56	>> .25
Family gross income	.064	.35	>> .25
Number of floors	.055	.37	>> .25
Number of windows	.049	.24	>> .25
Insulation - floors	.027	.94	>> .25
Construction materials	.024	.73	>> .25
Family life cycle stage	.024	.58	>> .25
Number of rooms air cond.	-.007	.56	>> .25
Belief in energy problem	-.095	1.02	> .25
Insulation - walls	-.096	1.00	> .25
Location (rural/urban)	-.127	2.14	< .05
Insulation - ceiling	-.161	3.41	< .005
Overall F		4.38	< .0001

R = .696 df regression 17

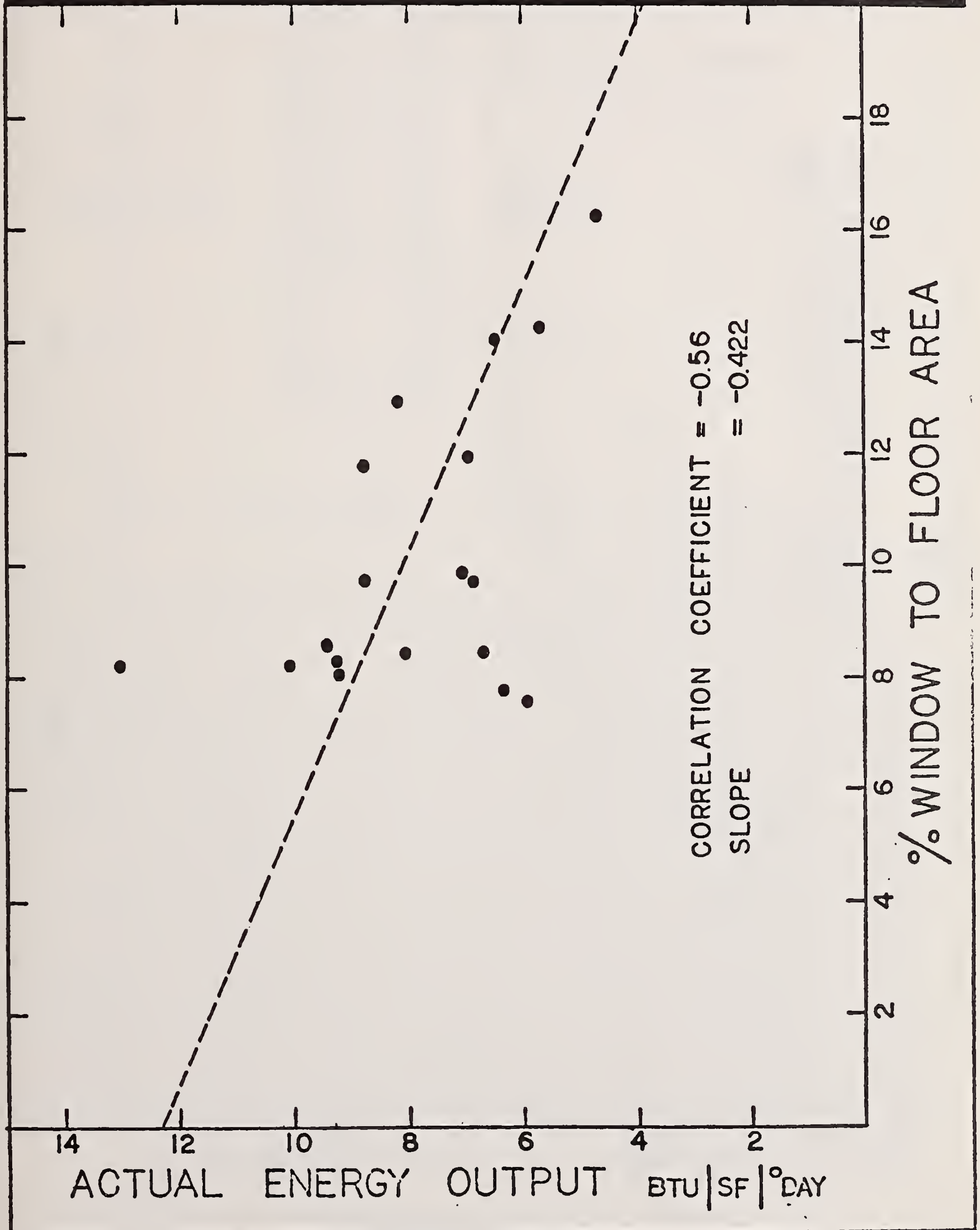
R^2 = .485 df residual 79

The interesting outcome of the stepwise regression was the total amount of variance explained (R^2 = .485) and the outcome ordering.

FIGURE 3

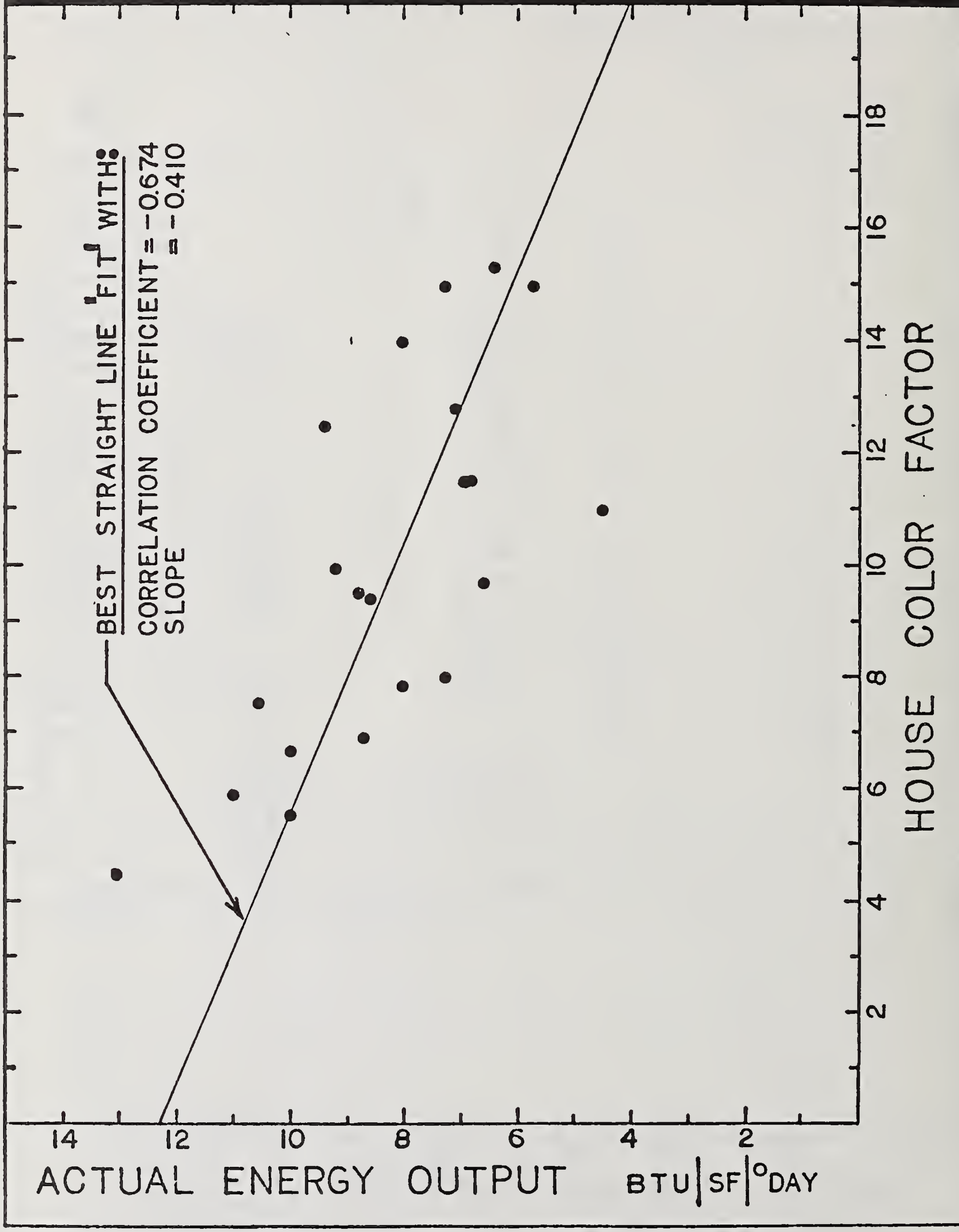
ACTUAL ENERGY OUTPUT VERSUS % WINDOW TO FLOOR AREA

FIGURE NO. 4

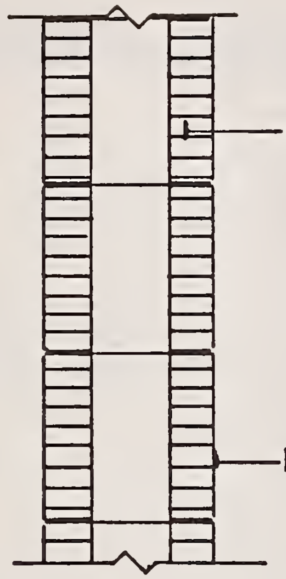


ACTUAL ENERGY OUTPUT
VERSUS
HOUSE COLOR FACTOR

FIGURE NO. 5



DECD UNM



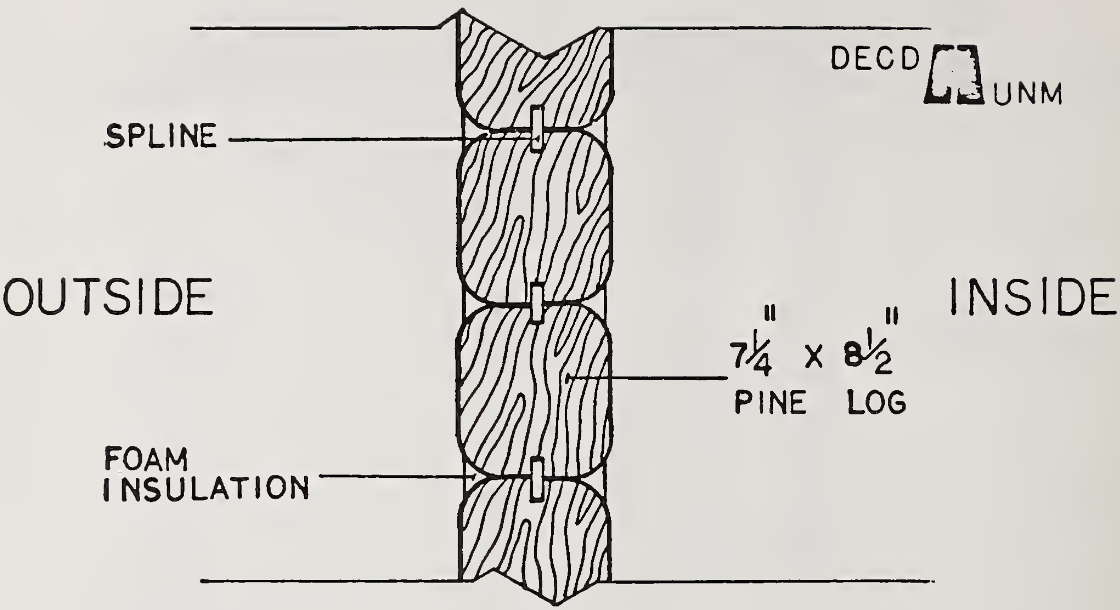
WALL TYPE 9: ASHRAE STEADY STATE U-VALUE 0.314 BTU/SF-HR-°F

EFFECTIVE "U"-VALUE (U_E): HEATING												
N.M. CLIMATIC REGION	WALL ORIENTATION											
	NORTH			EAST			SOUTH			WEST		
	*L	M	D	L	M	D	L	M	D	L	M	D
1	.290	.234	.175	.277	.202	.119	.264	.158	.052	.279	.201	.124
2	.275	.245	.214	.266	.223	.179	.255	.194	.133	.268	.226	.185
3	.272	.247	.223	.263	.226	.190	.252	.198	.145	.265	.231	.197
4	.270	.250	.232	.260	.226	.195	.246	.195	.143	.262	.233	.204
5	.270	.251	.232	.259	.225	.193	.245	.191	.137	.262	.232	.203
6	.270	.251	.232	.258	.222	.188	.243	.185	.125	.262	.230	.199
7	.272	.251	.231	.258	.219	.181	.241	.176	.109	.262	.228	.193
8	.274	.250	.227	.258	.212	.168	.238	.162	.083	.263	.222	.181
9	.278	.249	.221	.259	.204	.150	.236	.145	.049	.264	.215	.165
10	.284	.247	.210	.260	.190	.119	.232	.115	-008	.267	.203	.136
11	.284	.245	.201	.262	.181	.097	.231	.096	-047	.269	.194	.117

*WALL COLORS: L=LIGHT
M=MEDIUM
D=DARK

NOTE: ALL ENTRIES IN THE TABLE ARE PRECEDED BY "0". THAT IS: .122 = 0.122; -122 = -0.122

FIGURE 6



WALL TYPE 27 : ASHRAE STEADY STATE U-VALUE 0.099 BTU/SF-HR-°

EFFECTIVE "U"-VALUE (U_E): HEATING												
N.M. CLIMATIC REGION	WALL ORIENTATION											
	NORTH			EAST			SOUTH			WEST		
	*L	M	D	L	M	D	L	M	D	L	M	D
1	.089	.071	.052	.087	.066	.044	.085	.059	.035	.088	.067	.045
2	.091	.074	.058	.086	.063	.040	.080	.047	.015	.087	.065	.043
3	.091	.075	.060	.086	.062	.038	.078	.042	.008	.087	.064	.042
4	.092	.078	.063	.085	.060	.036	.074	.034	-005	.086	.063	.041
5	.093	.078	.064	.085	.059	.034	.073	.031	-010	.086	.062	.040
6	.093	.078	.064	.084	.057	.031	.071	.026	-019	.086	.061	.036
7	.093	.077	.062	.083	.053	.024	.069	.018	-032	.085	.058	.031
8	.094	.076	.057	.082	.047	.013	.065	.006	-053	.084	.052	.020
9	.095	.073	.051	.081	.038	-003	.061	-009	-079	.083	.045	.006
10	.096	.066	.037	.078	.023	-031	.055	-035	-126	.081	.031	-019
11	.097	.062	.028	.076	.013	-051	.050	-053	-157	.080	.022	-037

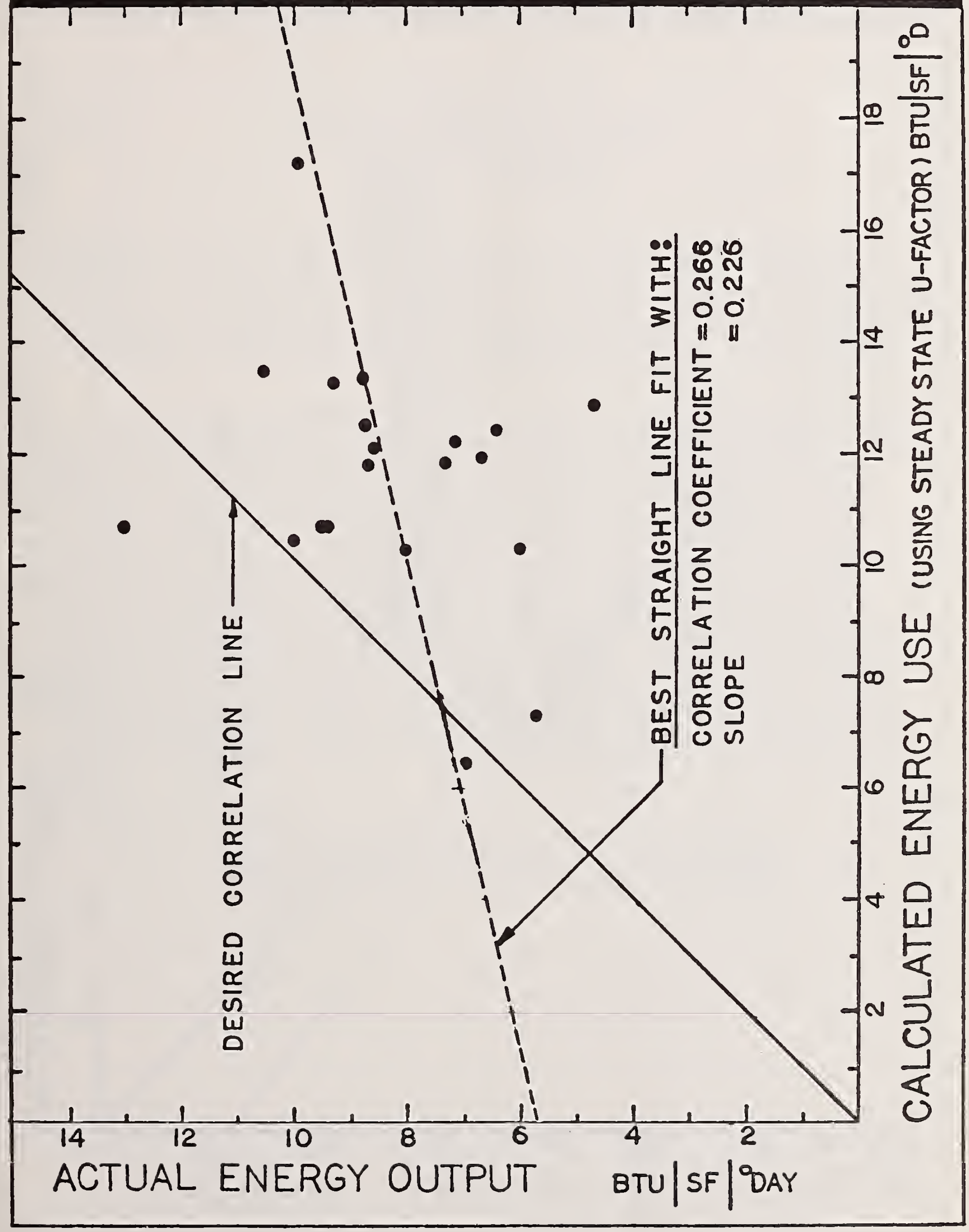
*WALL COLORS: L=LIGHT
M-MEDIUM
D=DARK

NOTE: ALL ENTRIES IN THIS TABLE ARE PRECEDED BY "0". THAT IS: .122 = 0.122; -122 = -0.122

FIGURE 7

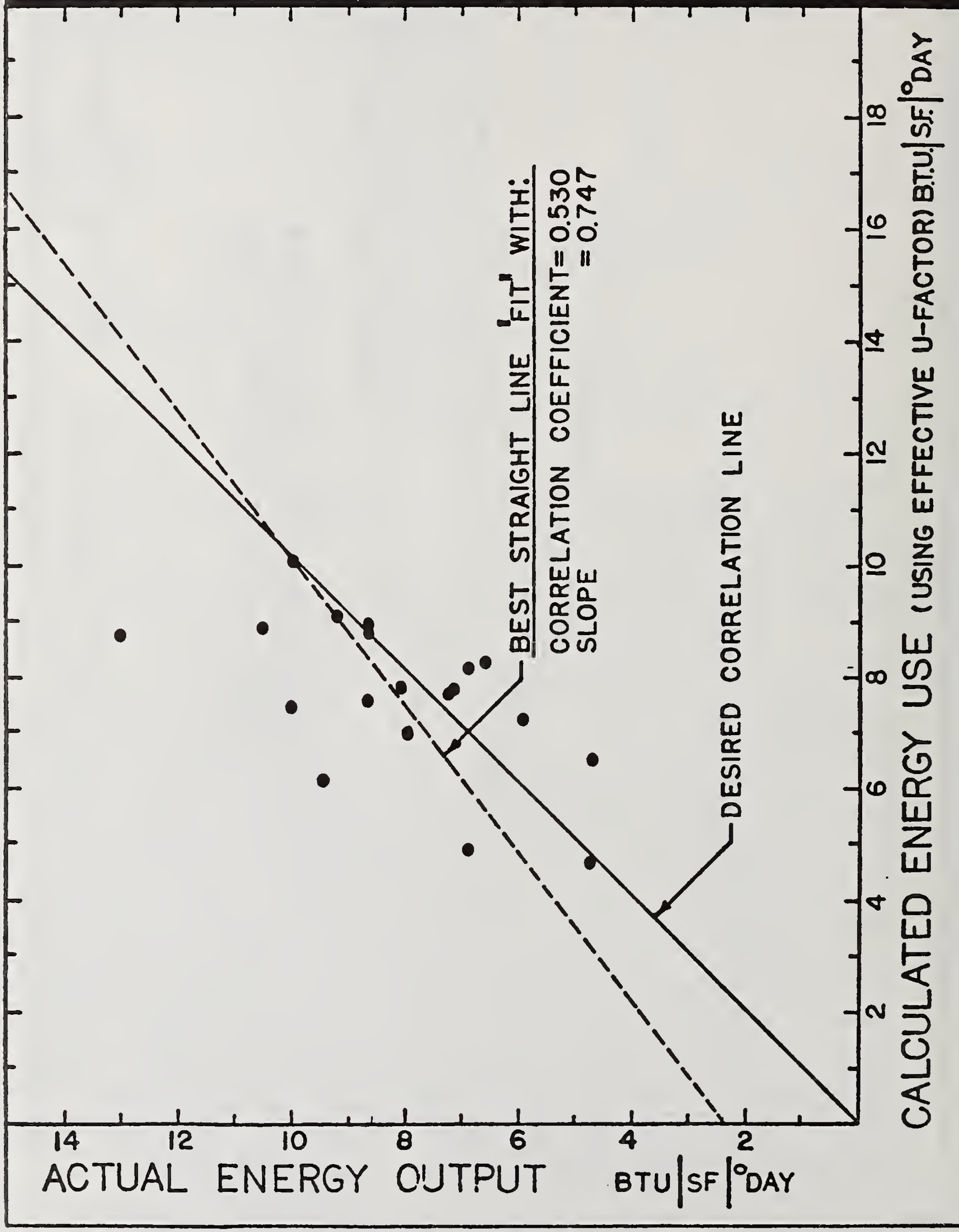
ACTUAL ENERGY OUTPUT VERSUS CALCULATED ENERGY USE

FIGURE NO. 8



ACTUAL ENERGY OUTPUT
VERSUS
CALCULATED ENERGY USE

FIGURE NO.
9



A STUDY OF THE EFFECT OF EXISTING ENERGY CONSERVATION REGULATIONS TO ASSIST IN THE SELECTION OF MORE COMPREHENSIVE ENERGY CONSERVATION STANDARDS

by

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The State of Wisconsin has had, since 1914, a statewide Administrative Building Code, administered and enforced by the Department of Industry, Labor and Human Relations (DILHR). This code regulates construction of all buildings except one- and two-family residences, farm buildings and temporary buildings. The rules contained in the code carry the stature of law.

An Energy Conservation Advisory Committee was appointed to DILHR by the Division Administrator, John Wenning, in December 1973, at the peak of the energy crisis. The committee made several recommendations, including lowering of inside temperatures and reducing the minimum ventilation from 7.5 c.f.m/person to 5 c.f.m/person. The committee also recommended a thermal performance standard which limited the heat loss through above-grade envelope areas to 13 Btu's per hour per square foot. These recommendations were incorporated into the Wisconsin Administrative Code in stages in 1974 and 1975. The thermal performance requirements generated strong opposition in the glass and masonry industries. These groups convinced a committee within the Wisconsin State Legislature to rescind the thermal performance section (May 1975) after five months of enforcement. The thermal performance requirements were reinstated in April 1976, when the full legislature did not act on the permanent suspension of the rules.

Key Words: ASHRAE Standards; building envelope; building regulations; data collection; energy budget; energy conservation; heat loss; thermal performance.

The State of Wisconsin has had, since 1914, a statewide building code. The Wisconsin Administrative Code is enforced by a centralized plan examination staff and a field inspection staff under the Department of Industry, Labor and Human Relations (DILHR). All public buildings and places of employment within the State are required by Wisconsin Statutes to comply with the Wisconsin Administrative Code.

Since January 1974, the State of Wisconsin recognized the energy shortage and steps were taken to reduce the amount of energy consumed in buildings. At that time, indoor design temperatures were reduced (offices and living areas were set up at 67°F., retail areas at 65°F.) and the ventilation air requirement was reduced to 5 cubic feet per minute (from 7.5 CFM) per person. On January 1, 1975 a further and more significant energy conserving requirement was added to the code. The thermal performance requirement limited heat loss (excluding infiltration and ventilation) in above grade gross walls and roofs facing heated interiors to not exceed 13 Btu's per hour per square foot of total building envelope.

The thermal performance rule generated much controversy from special interest groups (particularly the masonry and glazing industries) during its first few months of application. These groups were more concerned over possible decreases in sales than in energy conservation, and they pressured the Wisconsin State Legislature to repeal the rule. The rule was suspended by a Legislative Committee on May 29, 1975. However, the full Legislature failed to confirm the rule suspension and it went back into effect March 26, 1976. The rule has been in effect continuously since that time.

During the last several years, many energy conservation standards have been suggested or proposed. We have seen standards based on a budget approach (such as the State of Ohio's total connected energy load standard), a prescriptive approach (such as ASHRAE Standard 90-75) and performance standards (such as Wisconsin's Thermal Performance requirement). It has been thought that Wisconsin's thermal performance requirement has saved considerable energy in buildings, even though it deals only with conservation in the exterior envelope. In spite of the effectiveness of the current rules, the State of Wisconsin has considered adopting the more comprehensive energy standards listed above.

The method of conserving energy differed for all three standards, but all three contain provisions to limit the heat loss through the building envelope. (The total connected load approach sets a limit to the HVAC equipment output capacity plus the lighting load, which will tend to reduce the heat loss through the envelope. The concept is the less the connected load, the less energy consumed.) To evaluate the standards against each other is difficult, as the three do not cover the same areas. Because the thermal performance requirement covers only the envelope heat loss, this area will be covered in detail.

To compare the standards, energy related data was collected from building, heating, ventilating and air-conditioning plans that were submitted to DILHR for approval during the years 1973 and 1977. This approach was to illustrate energy consumption in buildings prior to the energy crisis (1973 plans) and the current year (1977 plans) of energy awareness. Because of the small number of high rise buildings built in any one time span, additional data for high rises was collected from as far back as 1964. The number of plans that were evaluated follows: 1973--542; 1977--154; and 28 high rise buildings. The information that was gathered was computerized and analyzed for comparisons of design philosophy between the years mentioned above, energy conservation measures added to the Wisconsin Administrative Building Code since 1973, and for comparisons of the present thermal performance requirement (13 Btu's per hour per square foot), the ASHRAE 90-75 Standard, and the Ohio total connected load concept.

In reviewing the total connected load budget, many questions of validity arose. By definition, the total connected load is "the total lighting load plus the total output capacity of all terminal heating units or the total building lighting load plus the total output capacity of all terminal air-conditioning units, whichever is greater." The capacity of the terminal units is to include output capacities of coils, the energy input to supply and return air fans, and the energy input to pumping equipment necessary for coil control. The connected load appears to be comprehensive; however, the following are to be excluded from the connected load: 1. Noncritical energy (recovered or renewable energy); 2. Energy for the operation of building emergency or standby equipment; 3. Energy used for purposes other than lighting, heating, ventilating or air-conditioning; 4. Energy required to make up air for kitchen exhaust, paint booths, dust collectors, industrial exhaust and similar installations; and 5. Energy for heating, ventilating or air-conditioning systems which are used exclusively for the purpose of overcoming process loads. The list of exclusions is extensive and can account for a sizeable percentage of a building's total energy use.

Item 3 above separates a building's energy use into two basic categories: 1. Energy related to control the building's environment, and 2. All other energy, including energy which can be attributed to the occupancy of the building (i.e., typewriters, computers, domestic water heaters, etc.). This non-environmental energy is excluded from the total connected load.

The 4th item above indicates that any energy expended to temper makeup air can be excluded from the total connected energy load. This severely limits this proposed code, as many buildings consume more energy in providing tempered makeup air than in any other area. In many areas, it may not be easy to separate the ventilation requirements from the heating specifications. Also, the Wisconsin Building Code allows situations where air may be transferred from one area to another, causing possible difficulties in determining whether to exclude the energy consumed in tempering the outside air.

In item 5 above, the process loads referred to have been exempted by item 3. Any additional energy consumed by a heating, ventilating or air-conditioning system to control the environment by offsetting the process loads is exempt by this item. This can provide an "energy loophole" of sizeable magnitude, as process loads can be several magnitudes larger than the building's construction loss. This item also poses problems for plan review, as a subjective decision will have to be made to determine the purpose of each heating unit. Heating and cooling units many times are used to offset many loads (construction, infiltration, ventilation as well as process loads), making it difficult to subdivide units by function.

The total connected load budget establishes an energy allotment figure for all occupancies. The total connected load, when divided by the total floor area, is not to exceed the adjusted allotment figure. The adjustments are for the building design, size and location. Specifically, these adjustments are for total floor area, number of levels, level height, and degree days for the building location. The following criteria was used in developing the adjustments: 1. Building area of 50,000 square feet; 2. Building height 14 feet, one story; 3. Square building configuration; 4. 10 percent of exterior walls in glass and doors; 5. Building transmission characteristics: a. roof = 0.10; b. net exterior walls = 0.10; c. windows = 0.56; d. slab edge = 45 Btu/linear foot; 6. $\Delta T = 80°F$. Adjustment equations (shown in Table 1) were developed by varying the above criteria in an attempt to encompass all building types. The allotment figures, adjustment criteria figures and corresponding equations were not conclusively shown to be presentative of actual building design and energy use. For example, as shown in Table 3, the average percentage of windows alone for the years 1973 and 1977 exceeds the 10 percent theoretical unit mentioned above.

The basic adjustment criteria are not representative of building design. The U-values appear to be the only item that is realistic; however, masonry walls would have to be well insulated to achieve a U-value of 0.10 Btu/h per sq. ft. per °F. The other items are not necessarily typical of building design, and attempting to apply one set of theoretical criteria to all buildings is unrealistic.

It is important to remember that the budget approach includes energy for heating and cooling equipment, ventilation fan loads and illumination. The total connected load figure is divided by the total floor area of the building and then adjusted by the above mentioned equations according to the building geometry. Therefore, all items comprising the total connected load are adjusted for floor area, number of stories, story height, and degree days. This approach is incorrect, as not all of the elements comprising the total connected load are functions of the adjustments. The lighting energy is a function of the occupancy and, therefore, the total floor area of a building (assuming that the lighting is designed on a task basis in footcandles); it is not dependent on story height, number of stories or degree days. In addition, the ventilation energy would not be a function of story height, number of stories, or total floor area. The lumping of various energy users together and then adjusting this figure results in adding an undetermined error to each calculation. Also, one of the original criteria for the allotment figures was a ΔT of 80°F. However, in the adjustments, degree days are used. This is confusing as there is no direct or easy correlation between annual degree days and the design temperature differential.

As indicated above, the budget approach has many drawbacks, but one of the most serious pertains to the mechanical systems. The basic concept of the budget is that the less the connected load, the less the energy used. However, this rarely applies to mechanical HVAC systems, in that the connected load is required to meet the needs on peak design days. Furthermore, the energy efficient system is designed to operate more efficiently at partial loads (which makeup 80-95 percent of the operating hours in each year) and frequently with relative inefficiency at full load. Thus, the energy efficient system can have a larger connected load than a much less efficient system. Since compliance with the allotment figure is dependent on the size of the mechanical system, this rule will encourage use of less efficient systems. Therefore, the total connected load budget actually restricts energy conservation. In addition, many buildings are designed to accommodate future additions. In many of those buildings, the heating system is sized for the future load as well as the existing load. Because the total connected load budget limits the output capacity of the HVAC equipment, this approach would not permit the use of oversized equipment. Instead, a separate HVAC system would have to be provided when the additions were built. Therefore, all the inefficiencies of the HVAC system would be doubled by a second system for these buildings.

In reviewing the computer program for all occupancies, compliance with the total connected load concept went from 46 percent (247 of 539) in 1973 to 66 percent (77 of 116) in 1977. (It has to be remembered that many of the buildings evaluated did not contain lighting data or plans. Therefore, the total connected loads for these buildings were calculated without a lighting load, which can account for 20 to 40 percent of a building's energy load.) This improvement in compliance can be due to many factors, including changes in design practice due to energy awareness (such as lower U-values in construction) and changes in code requirements (reductions in design temperatures and lower outside ventilation air quantities). For these two years, the summation of all heating equipment output capacities divided by the summation of the total heat losses (hereafter referred to as the heating overdesign factor) increased from 1.29 in 1973 to 1.81 in 1977. This increase would appear to contradict any energy saving philosophy, but actually this change is not unexpected. On closer inspection, the heating overdesign factor is controlled by many variables, as shown:

$$\text{Overdesign Factor} = \frac{\text{Total Heating Output Capacity}}{\text{Total Heat Loss}}$$

which breaks down into

$$\text{Overdesign Factor} = \frac{\text{Total Heating Output Capacity}}{\text{Construction Loss} + \text{Ventilation} + \text{Infiltration}}$$

substituting in equations yields

Overdesign Factor =

$$\frac{\text{Total Heating Output Capacity}}{(\text{U Total} \times \text{A Total} \times \Delta T) + (1.08 \times \text{CFM}_{\text{Vent.}} \times \Delta T) + (1.08 \times \text{CFM}_{\text{Inf.}} \times \Delta T)}$$

The denominator will be reviewed as three separate sections starting with the construction portion. The temperature differential (ΔT) depends on the inside and outside design temperatures. Since 1973, both code sections covering these areas have been numerically reduced, the extent depending on the particular occupancy and location. The total area will be assumed to be constant for both years. The U total value will undoubtedly decrease, due to reductions in the percentage of window areas, increasing use of insulating windows, and increasing use of insulation. The combination of these factors will result in a general reduction in the construction loss from 1973 to 1977.

The next two sections are closely similar, but the CFM amounts are derived differently. For ventilation, the CFM quantity is determined on a square footage or per person basis. For infiltration, the CFM value is often calculated by the designer on an air change method, generally ranging from one-half to one air change per hour. This value will be assumed constant over the years. The ventilation requirements for human occupancy have decreased since 1973 from 7-1/2 CFM/person to 5 CFM/person. Also, as mentioned above, the temperature differential has decreased numerically since 1973. Infiltration requirements have also been added to the code since 1973, which has resulted in reduced infiltration losses. These reductions will decrease the overall losses associated with the ventilation and infiltration quantities.

As shown above, many of the terms in the denominator have decreased, so that the overall effect will be a reduction in the numerical value of the denominator. The numerator, the total heating output capacity, is dependent on the total losses. This value has to be equal to or greater than the total losses. Since the over-design factor is larger in 1977 than in 1973, it appears that the numerator (the heating output capacity) is not being reduced as quickly as the calculations for the heat losses are. There appear to be two possible answers to this: 1. The heat loss calculations are being influenced by the thermal performance requirement, and therefore, the traditional "factor of safety" is being removed from the calculations by the designer. However, this "factor of safety" may be accounted for by providing equipment with larger capacity outputs. 2. The use of more efficient HVAC equipment that is sized for the full building load at partial capacity. Therefore, its total output may be higher than less efficient equipment operating at full load.

In summarizing the review of the total connected energy budget approach the following are major criticisms: 1. Energy for makeup air is excluded; 2. The connected load adjustments are not based on actual building construction; 3. The adjustments are incorrectly applied, resulting in varying values that are actually constants; 4. By limiting equipment sizes, this approach can require that less efficient HVAC systems be specified for buildings; and 5. Many sections of ASHRAE Standard 90-75 (such as HVAC equipment efficiencies, HVAC system design, service water heating and lighting power budget) are not covered by the budget.

The Wisconsin Thermal Performance Standard limits heat loss through above grade envelope areas to 13 Btu's per square foot of envelope area per hour. This value is consistent for all buildings within the jurisdiction of the Wisconsin Administrative Code. This requirement has incurred much criticism since its inception to the code in January 1975, and it was for a period rescinded. However, it has been continuously in effect since April 1976. One criticism that still plagues this requirement is that it is overly restrictive on high rise buildings. The thermal performance value is comprised of U-values and areas for the gross walls and roof. As the number of stories of a building increases, the gross wall area percentage increases and the roof area percentage decreases. The roof area, because it is a blank area, generally has a lower U-value than the gross wall area (with its various openings for windows and doors). Because the thermal performance requirement has a finite value, a limit to the acceptable number of stories is reached, as shown in Figure 1. This graph compares the calculated thermal performance value vs. the number of stories for buildings prior to the 13 Btu per hour per square foot rule. As can be seen by the graph, there is a general upward trend in thermal performance as the number of stories increase. One surprising fact shown by the graph is the relatively large thermal performance value for one story buildings. This can be assumed to be from large percentages of glazing in certain one story buildings (such as showrooms) and also buildings that are typically poorly (or not at all) insulated, such as warehouses.

The effectiveness of the thermal performance requirement is illustrated by Tables 2 and 3 which show the changes in the thermal performance value and the total heat loss per envelope area from 1973 to 1977 in tabular form. These changes are due mainly to the limiting of the construction loss per envelope area to 13 Btu's per hour per square foot of envelope area, although other code changes (such as reductions in design temperatures and ventilation amounts) have also contributed to the changes. As seen by the Tables, every occupancy saved energy (construction loss as well as total energy) from 1973 to 1977.

As shown by Figure 2, the construction loss (which is limited by the Thermal Performance requirement) decreased from 53.2 percent in 1973 to 50.4 percent of the total building losses, a reduction of 5.3 percent. The floor loss was reduced 11 percent, the ventilation load was reduced 24.7 percent, but the infiltration increased as a percentage of the total loss by 44.4 percent. This can be attributed to the fact that the infiltration was not controlled by building code rules, and the numerical value did not decrease. Meanwhile the total loss was decreasing from 1973 to 1977 by 56.7 percent, which results in an increased percentage for infiltration.

A frequent criticism of the thermal performance requirement has been that it restricts the use of glass in a building. It is interesting to note that the computer study shows that the window area, as a percentage of the gross wall area, decreased only from 14.4 percent in 1973 to 12.2 percent in 1977. This decrease of only 15 percent occurs despite the fact that the heat loss through the envelope area has decreased dramatically for 1977 buildings (see

Tables 2 and 3). The use of double and triple glazing has also increased since 1973, as shown by Table 4.

ASHRAE Standard 90-75 sets limits on exterior heat loss (Section 4) by establishing maximum coefficients of transmission (U-values) according to degree days. This is done for various components of a building, such as gross wall and roof. In addition to the U-values of the exterior envelope, ASHRAE also establishes heat loss criteria for floors and heat gain criteria for the exterior envelope, referred to as the overall thermal transfer value (OTTV). The Arthur D. Little Company, Inc. (retained by the Federal Energy Administration) analyzed the effects of ASHRAE Standard 90-75 on energy conservation. To make a comparison, they assumed five prototypical buildings (single family residence, low rise appartment building, office building, retail store and a school building) were built in four regions of the U. S. (Northeast--New York, North Central--Omaha, South--Atlanta, and the West--Albuquerque). They assumed that the buildings were identical from region to region. They also assumed that these buildings were built using approaches and design practices prevalent during 1973. They then applied ASHRAE Standard 90-75 to these buildings to illustrate what effect it would have. The Arthur D. Little report notes that the reduction in energy usage for single family residences is less than the other occupancies. They conclude that this "may in part be due to the moderately high overall thermal efficiency assumed for conventional residences" and that the northeast and north central regions met the standard with single glazing and a minimum reduction in glass area. Since single family residences are not covered by the Wisconsin Administrative Code, this phenomenon will not be further researched.

Table 5 compares the values developed by the Arthur D. Little Company to those generated by the Wisconsin computer program. This Table actually compares the effect of ASHRAE Standard 90-75 and code requirements within the Wisconsin Administrative Code on 1973 construction. It must be remembered that the Arthur D. Little figures are theoretical and that their regions of study differ climatically from Wisconsin. Therefore, a strict one-to-one comparison cannot be made, but rather a comparison of magnitudes must be made. Wisconsin's reduction of energy on a thermal performance level is impressive as just the energy through the envelope is being compared. The reduction in total losses (especially offices and schools) appears to be low, but it must be remembered that buildings built in Wisconsin in 1973 may differ drastically from buildings built in other areas of the United States in 1973. If Wisconsin's 1973 building code was more restrictive than other codes throughout the United States, then the reduction in energy from 1973 to 1977 in Wisconsin would not be as great, and the percentages would be lower. This assumption can be shown in the ventilation rates, as in 1973 Wisconsin allowed a minimum of 7.5 cubic feet per minute per person. Most codes and design practices were twice this value. It must also be remembered that Wisconsin's code did not affect HVAC system design, HVAC equipment efficiencies, service hot water or lighting design. All of these areas will affect the energy consumed by a building and were included by the Arthur D. Little Company in their analysis.

The Wisconsin computer data was broken down into four degree day zones--7,000, 7,500, 8,000 and 9,000. These degree day zones align with the outdoor temperature zones currently used in Wisocnsin Building Code, as shown in Table 6. The data, by degree day zones, has been compared to the exterior envelope requirements specified in ASHRAE Standard 90-75. Figures 3 through 6 illustrate how the means of the Wisconsin data for 1973 and 1977 fared against the ASHRAE requirements. As shown, the walls in 1973 ranged from approximately 40 to 55 percent compliance with ASHRAE to 91 to 100 percent compliance in 1977. This would possibly say that the ASHRAE U-values for walls is easily accessible for most buildings, and perhaps too high of a numerical value for Wisconsin's climate. Roofs range from approximately 3 to 16 percent compliance in 1973 to 36 to 58 percent compliance in 1977. The low percentage of buildings in 1977 complying with the roof U-values points to the ASHRAE value as being too restrictive. Compliance with ASHRAE's U-value for floors over unheated basements varied greatly for both years. Because the sample of buildings with this condition was small, it is vertually impossible to make any definite statement about this requirement. The slab insulation resistance values range greatly, but it appears that approximately one-third to one-half of all buildings with slab insulation comply with the ASHRAE specification. It would be quite simple to provide insulation with a higher resistance value so that this area will comply with the ASHRAE Standard. The length (or depth) of the slab insulation shows good compliance in 1973 and 100 percent compliance for 1977. This area obviously does not need improvement.

To further analyze the ASHRAE Standard 90-75 envelope requirements for Wisconsin, mean envelope data from the computer program has been compared to the ASHRAE requirements, as shown in Tables 7 through 11. These tables allow a one-for-one comparison of U-values by degree days. It is interesting to note that many 1973 U-values, such as Type "A" gross walls, comply with the ASHRAE values.

In an attempt to correlate the thermal performance requirement and the ASHRAE 90-75 standard, a relationship was developed using a "Typical" building developed by the computer for each number of stories and the ASHRAE envelope requirements for the gross wall and roof. The equation appears as follows:

$$\text{Thermal Performance Value} = \frac{(\text{GWA}) \times (\text{ASHRAE WALL}) + (\text{RA}) \times \text{ASHRAE ROOF}}{\text{ENVELOPE AREA}}$$

where:

GWA = Gross Wall Area

RA = ROOF AREA

ASHRAE WALL = ASHRAE Gross Wall U-Value

ASHRAE ROOF = ASHRAE Roof U-Value

This equation was calculated for the four degree day zones and ASHRAE building types ("A" and "B") and plotted in Figures 7 and 8. The data falls into smooth curves, with the exception of only a few points. From the graph for Type "B" buildings it is easy to see that the ASHRAE U-values for gross wall and roof produce thermal performance values much higher than the currently enforced 13 Btu's per hour per square foot. Because all public buildings and places of employment currently designed have to comply with the 13 Btu per hour per square foot rule, this graph also shows that the ASHRAE U-values for gross wall and roof must be higher than would be currently allowed. One other conclusion from this graph is that the present thermal performance value is overly restrictive for high rise buildings.

Another conclusion from the Arthur D. Little report on ASHRAE is that in the buildings they studied, glass areas were reduced in approximately two-thirds of the buildings. The reductions ranged up to thirty percent, but were generally twenty percent or less. The effect of the existing thermal performance rule on glazing has been compared to the effect of ASHRAE in Table 8. As illustrated in this table, the Wisconsin data resemblies the data for the north central region with the exception of the retail stores. If a trend can be drawn from the ASHRAE figures, it appears, that as the number of degree days increases, the percentage of glass area decreases.* The Wisconsin data would tend to confirm this finding.

In addition to the exterior building envelope section, ASHRAE 90-75 also has requirements on the HVAC systems, HVAC equipment, service water heating, electrical distribution systems and lighting power budget. This information is covered by Sections 4-9 of the ASHRAE Standard. Since all of these sections are beyond the scope of the thermal performance requirements, no comparison of standards is possible.

Information from the data collected pertaining to the specific areas listed above, in most cases, is insufficient in quantity to make any thorough comparison between design practice and ASHRAE Parameters. This is due mainly to the fact that the items mentioned above generally are not covered by the existing building code, and therefore, this information is not included with the submitted plans. Although the data available has been small in volume, an analysis of the ASHRAE 90-75 Section 9 power budget has been made for 1973 and 1977 data.

Data collected from plans is categorized into occupancies or tasks and separated by years as a check for noticeable trends in lighting power usage (watts/ft.^{2}) and type of light source, fluorescent, incandescent or high intensity discharge (HID).

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*Office buildings exhibit just the opposite phenomenon, with the glass area decreasing as the heating degree days decrease.

The ASHRAE lighting power budget is an upper limit to the amount of electrical energy available for lighting a proposed building. The budget conforms to a set of criteria and calculations used only for calculating a budget number and not for design purposes. Illumination level criteria referenced by ASHRAE Standard 90-75 are those listed in the Illuminating Engineering Society (IES) lighting handbook. The budget is calculated assuming lamps of a given efficiency and coefficient of utilization. The lighting power limit is calculated from the formula:

$$\text{WATTS} = \frac{A \times FC}{CU \times LE \times .70}$$

Where: A = Area in $ft.^2$

FC = Footcandle level

CU = Coefficient of utilization

LE = Lamp efficiency in Lumens/watt

.70 = Light loss factor (accounts for dirt on the lamp and walls, etc.)

The footcandle level is assigned by IES on a task area basis. Task areas are areas where one specific task is performed. The areas surrounding task areas are called general areas and are 1/3 the footcandle level of task areas but at least 20 footcandles. Noncritical areas are areas where no specific task occurs and are 1/3 the footcandle level of general areas but at least 10 footcandles. The total power budget consists of the sum of the power budgets for those three areas. Most occupancies or tasks in the data base are considered by IES as a single task, as hallways and garages. Some occupancies such as offices and classrooms are task lit and will contain general and perhaps noncritical areas. Table 13 compares the ASHRAE task area allotment with the lighting levels used in Wisconsin for 1973 and 1977. It must be remembered that the ASHRAE value is for task areas only and does not consider noncritical and general areas. The Wisconsin data contains all three lighting types.

There is considered to be no interaction between the lighting systems and the HVAC system in Table 13. Natural lighting is assumed not to contribute to the footcandle levels. The ASHRAE task area allotment appears to be high for several occupancies in comparison to the Wisconsin data. This is undoubtedly because the data contains noncritical and general areas, and the ASHRAE allotment is for task areas only.

Another explanation for a rise in some lighting levels can be found in the March 1974 Lighting Systems Study published by the General Services Administration, which states "Lighting levels in the United States and elsewhere have generally been on the increase. In this country, lighting levels in buildings such as office buildings and schools have doubled in the past twenty years. This increase has been facilitated by a more than corresponding increase in efficiency of the lighting systems employed (i.e., incandescent to fluorescent), coupled with a cost for energy that has remained relatively constant over this period of time."

The average 1977 lighting power (W/ft.^{2}) showed a drop of 7.4 percent from 1973 for the occupancies in common between the two years. The lack of data keeps us from pinpointing the reason, although there are several possible explanations: 1. Footcandle levels dropped. 2. Designers switched to more efficient lamps, as shown in Table 14. 3. Task lighting usage increased. The data does not reflect the results of increased usage of switching and dimming circuitry which possibly had a beneficial effect in reducing the wattage per square foot in 1977. It appears that the use of more efficient lamps did result in lower use of lighting energy, as efficient high intensity discharge lamps became a sizeable percentage of the total indoor lighting wattage in 1977.

The Arthur D. Little report indicates the effect of ASHRAE 90-75 on lighting in Table 15. This Table shows a reduction in lighting for three occupancies and a total reduction of 24 percent for lamps and 22 percent for lighting fixtures. These figures can be loosely compared to the 7.4 percent reduction in wattage per square foot from Wisconsin's data. It would appear that the trend in lighting design in Wisconsin is not as great as that obtained by implementing the lighting power budget from ASHRAE 90-75.

A further impact of implementing ASHRAE 90-75, regarding HVAC system capacities is shown in Table 16. The Arthur D. Little Company claimed that heating equipment capacities would drop an average of 42 percent and that air-conditioning capacities would drop an average of 31 percent. These reductions are because ASHRAE specifies minimum equipment efficiencies and recommends ventilation values. The Arthur D. Little percentages are compared to the overdesign values for heating and air-conditioning equipment from Wisconsin's data for 1973 and 1977 in Table 24. This Table shows that the overdesign factors increased from 1973 to 1977, while ASHRAE 90-75 can reduce system capacities. These figures cannot be used on a straight comparison, because the overdesign factor does not necessarily mean that the size of the system capacities in Wisconsin increased. It must be remembered that the overdesign factor is a ratio of system capacities to total losses. Therefore, the total losses could be reduced while the size of the specified HVAC equipment remains unchanged. This phenomonen would produce an increase in the overdesign factor. This increase can be thought of as a decrease in total losses of 40.3 percent for heating and a 53.1 percent decrease in heat gain for air-conditioning. This would mean that the HVAC system capacities for Wisconsin could decrease by the same value, which is in the same range as the ASHRAE reductions.

In addition to the above mentioned areas governed by ASHRAE Standard 90-75, ASHRAE includes guidelines that allow an equivalent system analysis and for nondepleting energy sources. The equivalent system analysis allows trade offs between components of the building and equipment specifications as long as the total energy allowed by the component method is not exceeded. Also, all energy from nondepleting sources shall be excluded from the total energy chargeable to the proposed alternative design.

CONCLUSIONS

The total connected load energy budget attempts to limit energy consumption by limiting the connected load. It controls the output capacity of the HVAC equipment and the lighting equipment, while completely ignoring other energy consumers. By exempting makeup air, this budget approach misses one of the largest energy consumers in many buildings. This approach does not even consider the efficiencies of such equipment. In limiting equipment output capacities, this approach may be advocating energy inefficient equipment, as the more efficient equipment may have higher output capacities.

The total connected load is based on an energy allotment figure that is adjusted for a particular building size and geometry. The allotment figure and the criteria that the adjustment equations are based on have no actual building construction basis. The four adjustment equations result in a progression of errors, as each equation is dependent on the previous equation. This progress of adjustments results in constants being varied by totally unrelated items.

The total connected energy load budget uses the lighting power in the calculation of the total connected load. But there is no attempt to limit or control the actual lighting levels. Other energy consuming areas are also ignored by this approach.

In reviewing the thermal performance rule (13 Btu's per hour per square foot) and ASHRAE 90-75, it is obvious that the ASHRAE Standard encompasses many areas not governed by the thermal performance rule. Of the areas the two approaches have in common, there are advantages and disadvantages to each. The wide scope and comprehensiveness of the ASHRAE 90-75 Standard makes it the preferred energy conservation standard. Its range of energy related areas allows it to control these areas and gives it the potential for the greatest energy savings.

It is recommended that ASHRAE 90-75 be used as a basis for a comprehensive energy conservation standard for the State of Wisconsin. However, because some envelope component's characteristics for the State of Wisconsin exceed those specified by the ASHRAE 90-75 Standard, new values consistent with Wisconsin's current practice should be substituted for the ASHRAE values.

TABLE 1

TOTAL-CONNECTED LOAD ENERGY BUDGET

ADJUSTMENT EQUATIONS

AREA ADJUSTMENT:	$Ba = B + 3.6 \frac{50,000}{A}$
NUMBER OF LEVELS:	$Bs = Ba\ (.77 + 0.23/n)$
LEVEL HEIGHT:	$Bm = Bs\ (0.8 + 0.2h/14)$
DEGREE DAY	$Bd = Bm + 0.0025\ (DD-7500)$
WHERE:	A = Total Floor Area
	B = Basic Energy Allotment
	n = Number of Levels
	h = Level Height
	Bm = Energy Allotment as Adjusted for Height
	Bs = Energy Allotment as Adjusted for Number of Levels
	Ba = Energy Allotment as Adjusted for Area
	Bd = Final Energy Allotment
	DD = Degree Days

THERMAL PERFORMANCE VALUES

FOR 1973 AND 1977 BUILDINGS

TABLE 2

OCCUPANCY	NUMBER OF PLANS		MEAN THERMAL PERFORMANCE VALUE		PERCENTAGE CHANGE
	1973	1977	1973	1977	
FACTORY/MACH. SHOP	38	13	21.384	9.008	-57.9
OFFICES	43	12	20.032	10.225	-49.0
RETAIL ESTAB.	91	8	20.167	8.662	-57.0
WAREHOUSE	37	2	18.692	8.533	-54.3
ARENA/FIELD HOUSE	3	2	17.000	6.000	-64.7
CHURCHES	15	3	16.733	7.767	-53.6
CLUB/LODGE	14	2	15.029	7.900	-47.4
ENTERTAINMENT	11	2	14.073	9.200	-34.6
RESTAURANTS	22	6	21.504	9.900	-54.0
ELEM. SCHOOL	8	4	13.425	8.050	-40.0
APARTMENTS	160	90	14.851	9.150	-38.4
DORMITORIES	6	3	17.300	8.600	-50.3
MOTELS	10	1	13.000	8.500	-34.6
GARAGES	30	5	21.833	8.960	-59.0
REPAIR AREA	11	2	21.027	11.050	-47.4
VEHICLE SERVICE	30	6	20.823	11.180	-46.3

TOTAL LOSSES PER ENVELOPE AREA

FOR 1973 AND 1977 BUILDINGS

TABLE 3

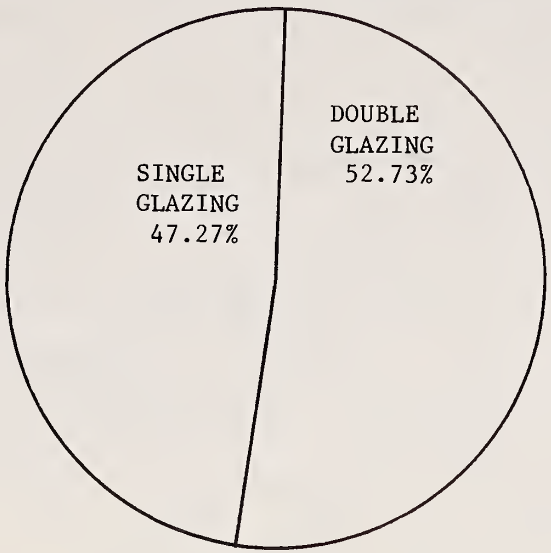
OCCUPANCY	NUMBER OF PLANS		TOTAL LOSSES PER ENVELOPE AREA		PERCENTAGE CHANGE
	1973	1977	1973	1977	
FACTORY/MACH. SHOP	38	13	35.26	12.61	-64.2
OFFICES	43	12	34.70	22.30	-35.7
RETAIL ESTAB.	91	8	35.28	15.78	-55.3
WAREHOUSE	37	2	29.52	12.50	-57.7
ARENA/FIELD HOUSE	3	2	33.60	11.90	-64.6
CHURCHES	15	3	40.09	10.22	-74.5
CLUB/LODGE	14	2	39.10	13.47	-65.6
ENTERTAINMENT	11	2	43.49	25.43	-41.5
RESTAURANTS	22	6	79.41	22.44	-71.7
ELEM. SCHOOL	8	4	31.19	22.93	-26.5
APARTMENTS	160	90	26.06	13.75	-47.2
DORMITORIES	6	3	28.05	17.29	-38.4
MOTELS	10	1	24.27	12.15	-49.9
GARAGES	30	5	41.84	11.62	-72.2
REPAIR AREAS	11	2	50.59	17.59	-65.2
VEHICLE SERVICE	30	6	44.77	16.29	-63.6

TABLE 4

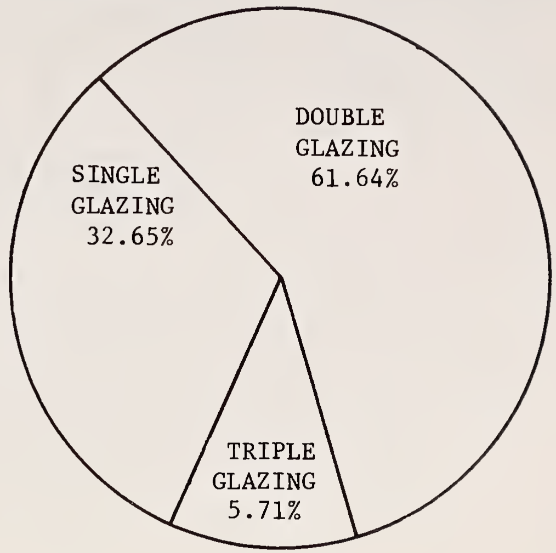
GLAZING DATA COMPARISON BY YEARS

YEAR	1973				1977			
TYPE	% WINDOW SINGLE	% WINDOW DOUBLE	% WINDOW TRIPLE	WINDOW % OF GROSS WALL	% WINDOW SINGLE	% WINDOW DOUBLE	% WINDOW TRIPLE	WINDOW % OF GROSS WALL
WEIGHTED AVERAGE	47.27	52.73	0.0	14.442	32.65	61.64	5.71	12.236

TYPES OF GLAZING BY YEARS
(Percentages of the Total Glazing Area)



1973



1977

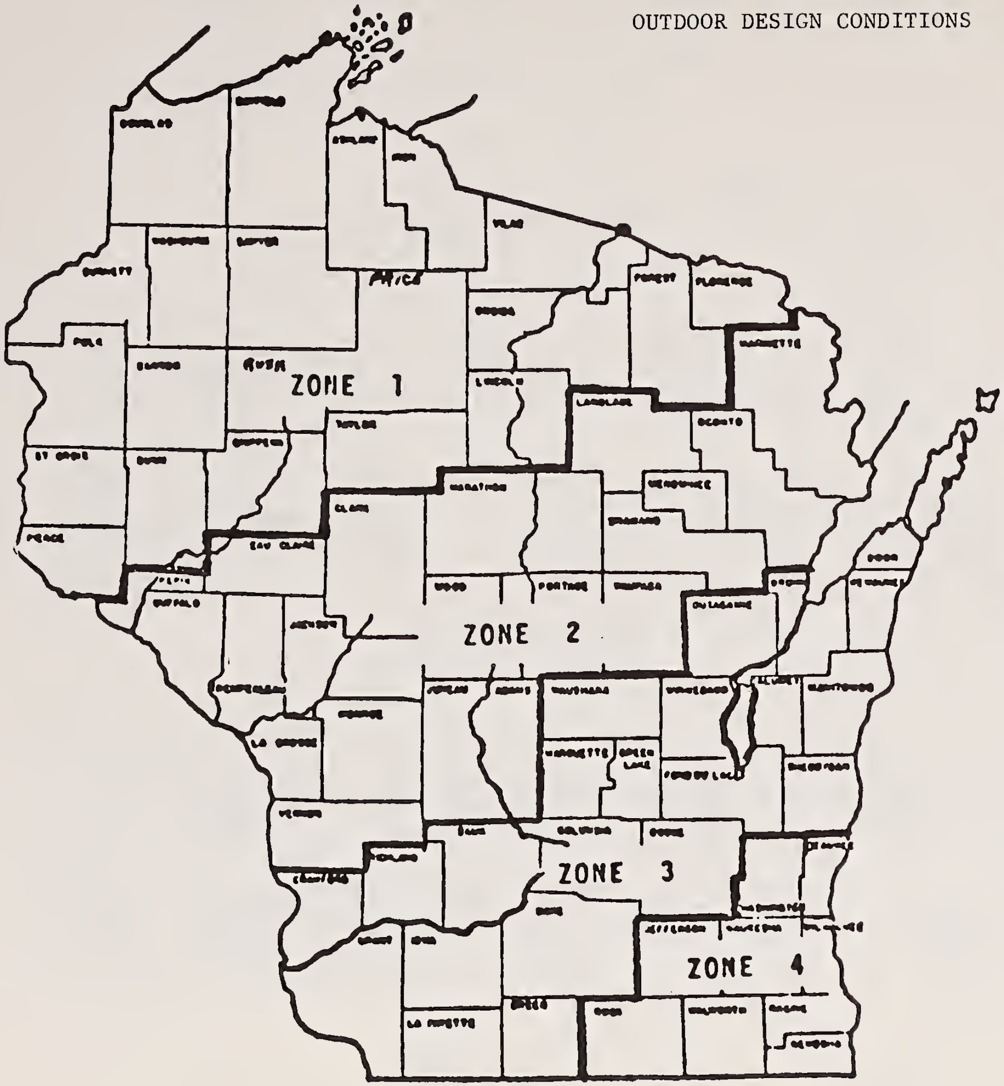
TABLE 5

REDUCTION IN ANNUAL ENERGY CONSUMPTION
BY BUILDING TYPE AND GEOGRAPHICAL LOCATION
(Percent)

	ASHRAE PROTOTYPICAL BUILDINGS					WISCONSIN DATA	
	Northeast (New York)	North Central (Omaha)	South (Atlanta)	West (Albuquerque)	Average	Thermal Performance	Total Losses
Single-Family Residence	14.7	15.1	7.7	7.5	11.3	NA	NA
Low-Rise Apartment Building	51.0	32.2	42.3	45.4	42.7	38.4	47.2
Office Building	61.5	61.2	58.7	56.9	59.7	49.0	35.7
Retail Store	41.6	42.5	37.9	38.5	50.1	57.0	55.3
School Building	45.6	44.4	51.5	51.1	48.1	40.0	26.5

TABLE 6

OUTDOOR DESIGN CONDITIONS



ZONE on map	WINTER		SUMMER	
	HEATING DEGREE DAYS (F.)	DESIGN TEMP. (°F.)	DRY BULB (°F.)	WET BULB (°F.)
1	9000	-25	86	73
2	8000	-20	87	74
3	7500	-15	87	74
4	7000	-10	89	75

COMPARISON OF MEAN ENVELOPE DATA TO ASHRAE REQUIREMENTS

TABLE 7

GROSS WALLS -- U VALUES

HEATING DEGREE DAYS	WIS ZONE	1973		1977		ASHRAE	
		ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"
9000	1	0.190	0.272	0.147	0.150	.2190	.2190
8000	2	0.171	0.278	0.172	0.141	.2380	.2380
7500	3	0.188	0.299	0.169	0.154	.2475	.2475
7000	4	0.237	0.344	0.150	0.173	.2570	.2570

TABLE 8

ROOFS -- U VALUES

HEATING DEGREE DAYS	WIS ZONE	1973		1977		ASHRAE	
		ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"
9000	1	0.077	0.113	0.037	.0830	.0400	.0600
8000	2	0.068	0.125	0.040	.0609	.0500	.0600
7500	3	0.088	0.137	0.052	.0753	.0500	.0640
7000	4	0.107	0.151	0.054	.0870	.0500	.0680

TABLE 9

FLOORS OVER UNHEATED SPACES -- U VALUES

HEATING DEGREE DAYS	WIS ZONE	1973		1977		ASHRAE	
		ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"
9000	1	0.053	0.095	0.060	–	.08	.08
8000	2	0.114	0.100	0.261	–	.08	.08
7500	3	0.190	0.082	0.128	0.080	.08	.08
7000	4	0.092	0.070	0.150	0.080	.08	.08

TABLE 10

		SLAB INSULATION RESISTANCE VALUE -- RESISTANCE VALUE					
		1973		1977		ASHRAE	
HEATING DEGREE DAYS	WIS ZONE	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"
9000	1	-	6.414	5.000	-	6.83	6.83
8000	2	4.800	6.723	3.143	7.267	6.15	6.15
7500	3	4.927	6.676	8.243	5.957	5.84	5.84
7000	4	6.025	6.232	5.000	5.22	5.50	5.50

TABLE 11

		SLAB INSULATION -- INCHES					
		1973		1977		ASHRAE	
HEATING DEGREE DAYS	WIS ZONE	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"	ASHRAE TYPE "A"	ASHRAE TYPE "B"
9000	1	18.00	30.12	56.00	-	24.0	24.0
8000	2	45.27	22.60	34.28	32.00	24.0	24.0
7500	3	48.00	30.14	37.71	32.89	24.0	24.0
7000	4	20.44	30.00	36.75	28.00	24.0	24.0

TABLE 12

REDUCTION IN GLASS AREA ATTRIBUTABLE TO APPLICATION OF ASHRAE 90 TO THE PROTOTYPICAL BUILDINGS VS. WISCONSIN DATA (Percent)

	Northeast (New York)	North Central (Omaha)	South (Atlanta)	West (Albuquerque)	Wisconsin Data
Single-Family Residence	0	-4.1	0	-1.3	NA
Low-Rise Apartment Building	-11.0	-21.3	0	-6.0	-16.0
Office Building	-16.7	-3.3	-30.6	-28.2	+5.3
Retail Store	0	-13.3	0	0	-43.4
School	-7.5	-20.0	0	0	-27.1

TABLE 13

IMPACT OF LIGHTING LEVELS BY OCCUPANCY FOR 1973 AND 1977

OCCUPANCY	IES TASK FC	ASHRAE TASK AREA ALLOTMENT	1973 FLOOR AREA	1973 WATTAGE	1973 WATTS PER FT.^{2}	1977 FLOOR AREA	1977 WATTAGE	1977 WATTS PER FT.^{2}	1973-1977 PERCENT CHANGE
BANKS	50	2.36	8,937	23,826	2.67	16,410	37,355	2.28	-14.7
CLASSROOMS	70	3.31	13,591	20,910	1.54	23,184	43,330	1.87	-21.4
CLUBS, LODGES	30	1.24	6,161	18,360	2.98	1,574	3,050	1.94	-34.9
CONFERENCE ROOMS	30	1.24	8,434	24,265	2.88	15,751	30,800	1.96	-31.9
GARAGES	10	0.37	27,418	16,770	0.61	24,280	15,250	0.63	+ 3.3
MACHINE SHEDS	100	4.72	29,136	28,150	0.97	30,360	20,120	0.66	-32.0
OFFICES	70	3.31	22,033	66,280	3.01	46,849	116,685	2.49	-17.3
RESTAURANTS-INTIMATE TYPE	10	0.57	2,652	4,953	1.87	2,414	4,845	2.01	+ 7.5
RESTAURANTS-LEISURE TYPE	30	1.70	9,206	20,060	2.18	2,929	7,310	2.50	+14.7
RETAIL	30	1.70	29,805	43,440	1.46	35,749	79,430	2.22	+52.1
WAREHOUSES	20	0.74	32,522	23,410	0.72	170,199	136,480	0.80	-11.1
AVERAGE	---	1.93	---	---	1.90	---	---	1.76	- 7.4

TABLE 14

TYPES OF LAMPS AND PERCENTAGES FOR 1973 AND 1977 DATA

	NUMBER OF DATA	% COMPLIANCE WITH 90-75	TOTAL WATTAGE FLUOR.	TOTAL WATTAGE INCAND.	TOTAL WATTAGE H.I.D.	PERCENT OF TOTAL % FLUOR.	PERCENT OF TOTAL % INCAND.	PERCENT OF TOTAL % H.I.D.
73	44	45.5	190,146	100,280	0	65.5	34.5	0.0
77	111	47.7	515,615	82,755	67,640	77.4	12.4	10.2

TABLE 15

IMPACT OF ASHRAE 90 ON LIGHTING

	Lamps (Percent)	Lighting Fixtures (Percent)
Office Buildings	-28	-25
Retail Store	-30	-25
School Building	-15	-15
Average	-24	-22

TABLE 16

IMPACT OF ASHRAE 90 ON HVA/C SYSTEMS

. Heating and Air Conditioning System Capacities Were Significantly Reduced In All Buildings Investigated:

	(PERCENT REDUCTION)	
	Heating	Air-Conditioning
Single-Family Residence	23	18
Low-Rise Apartments	50	33
Office Building	32	35
Retail Store	48	27
School Building	57	40
Average	42	31

. Auxiliary HVA/C Equipment (Pumps, Cooling Towers, Supply Fans, Etc.) Were Significantly Reduced. Also, Averaging 44% Less In Their Rated Kilowatt or Horsepower Requirements

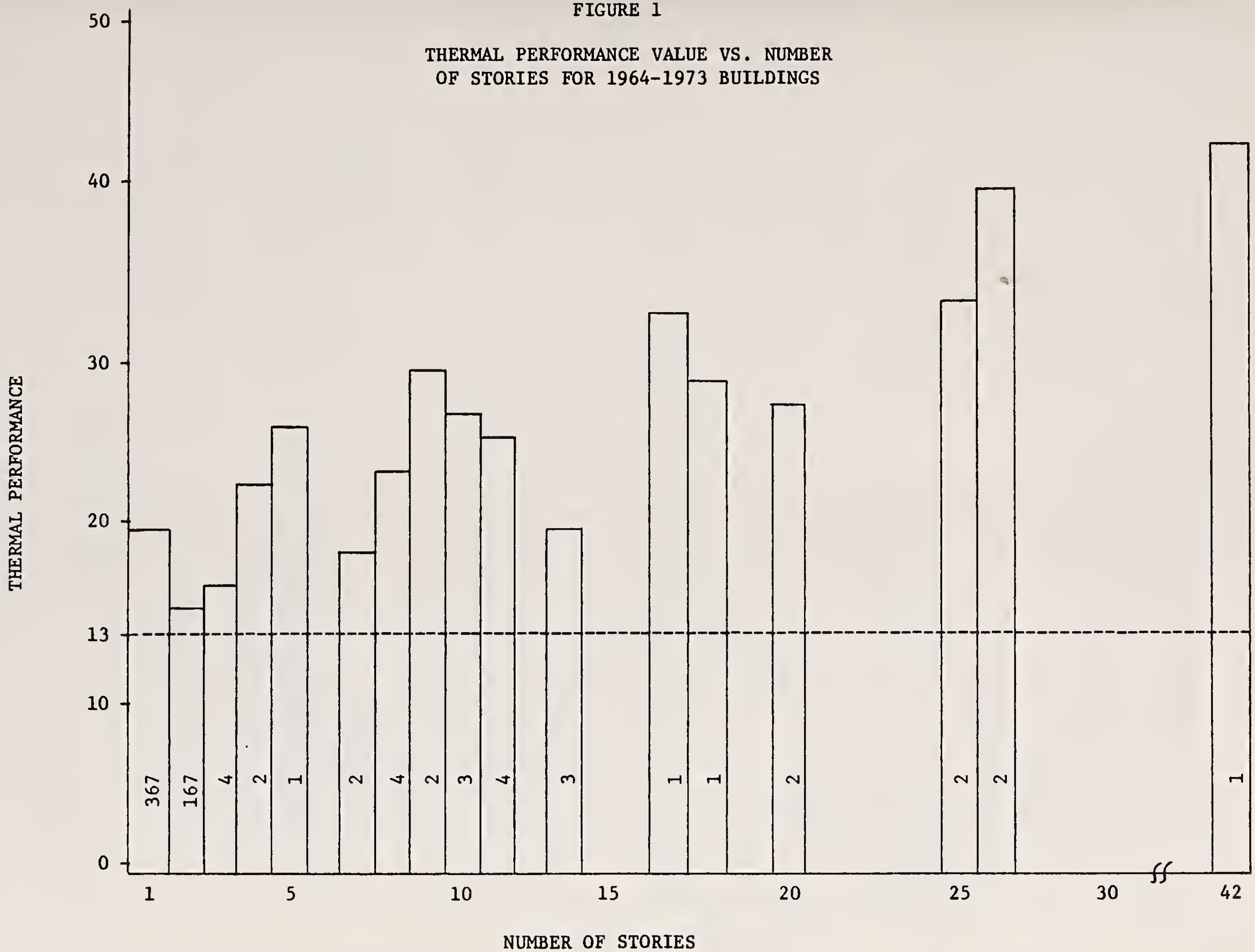
TABLE 17

IMPACT COMPARISON ON HVAC SYSTEMS

	Wisconsin Over-Design Data			A. D. Little - ASHRAE Change
	1973	1977	Percent Change	
Heating	1.29	1.81	+40.3	-42
Air-Conditioning	1.43	2.19	+53.1	-31

FIGURE 1

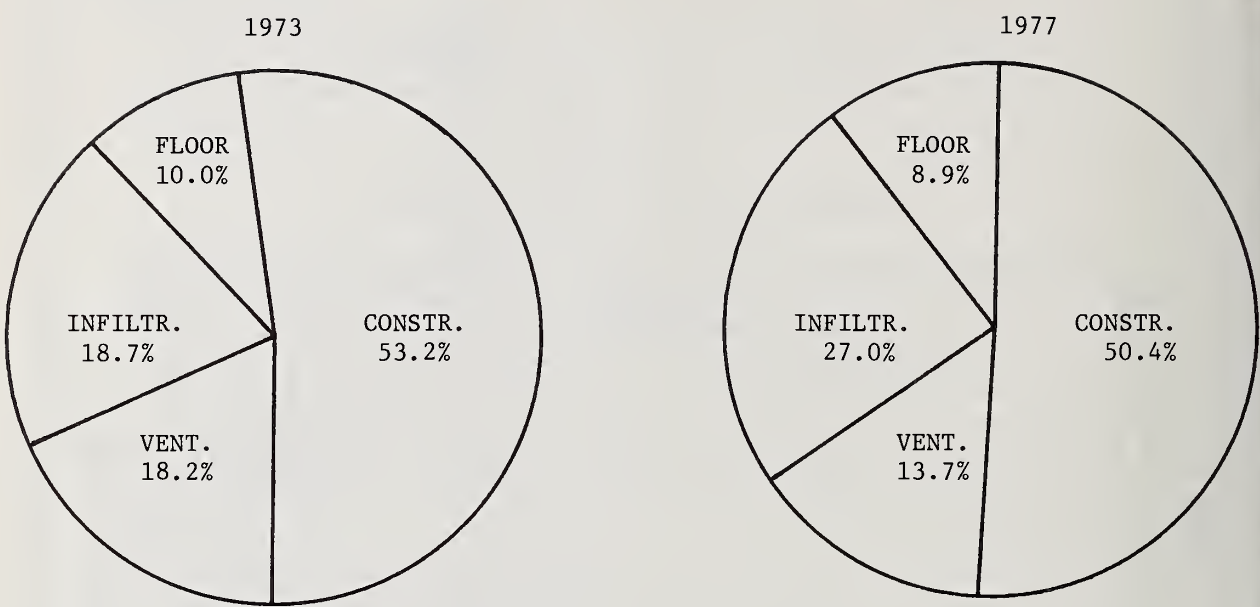
THERMAL PERFORMANCE VALUE VS. NUMBER
OF STORIES FOR 1964-1973 BUILDINGS



Notes: (a) The number within the'bars represents the number of buildings evaluated.

FIGURE 2

COMPONENTS OF TOTAL ENVELOPE HEAT LOSS
FOR ALL BUILDINGS



TOTAL HEAT LOSS PER SQUARE FOOT OF FLOOR AREA (ALL BUILDINGS):

1973	1977
55.35 BtuH / Sq. Ft.	23.97 BtuH / Sq. Ft.

TOTAL HEAT LOSS REDUCTION FROM 1973 TO 1977 = 56.7%

ASHRAE COMPLIANCE BY WIS. TEMP. ZONES

ZONE 4 -- 7000 DEGREE DAYS

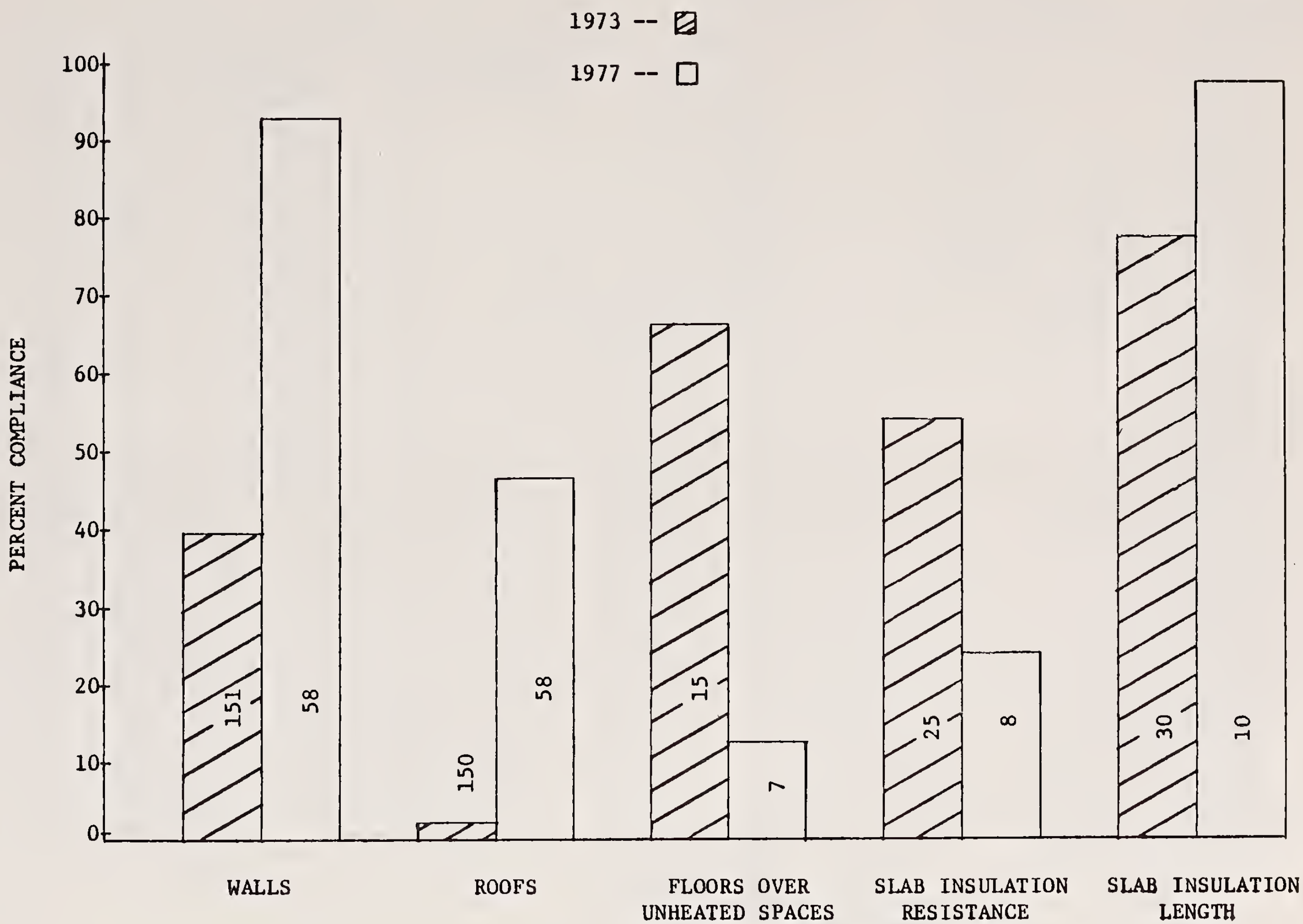
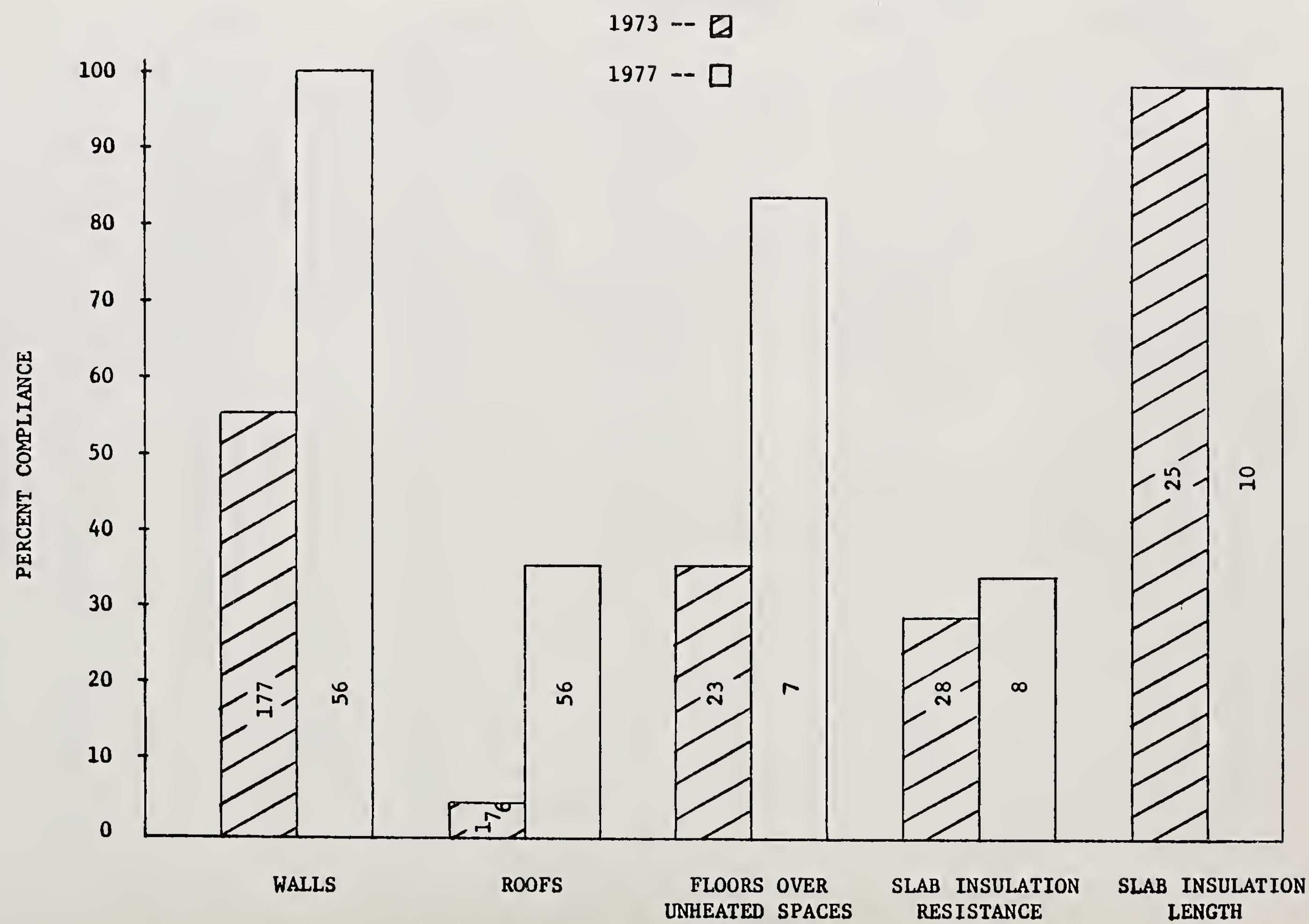


FIGURE 3

NOTE: NUMBER WITHIN THE BAR REPRESENTS THE NUMBER

ASHRAE COMPLIANCE BY WIS. TEMP. ZONES

ZONE 3 -- 7500 DEGREE DAYS



NOTE; NUMBER WITHIN THE BAR REPRESENTS THE NUMBER OF BUILDINGS EVALUATED.

FIGURE 4

ASHRAE COMPLIANCE BY WIS. TEMP. ZONES

ZONE 1 -- 9000 DEGREE DAYS

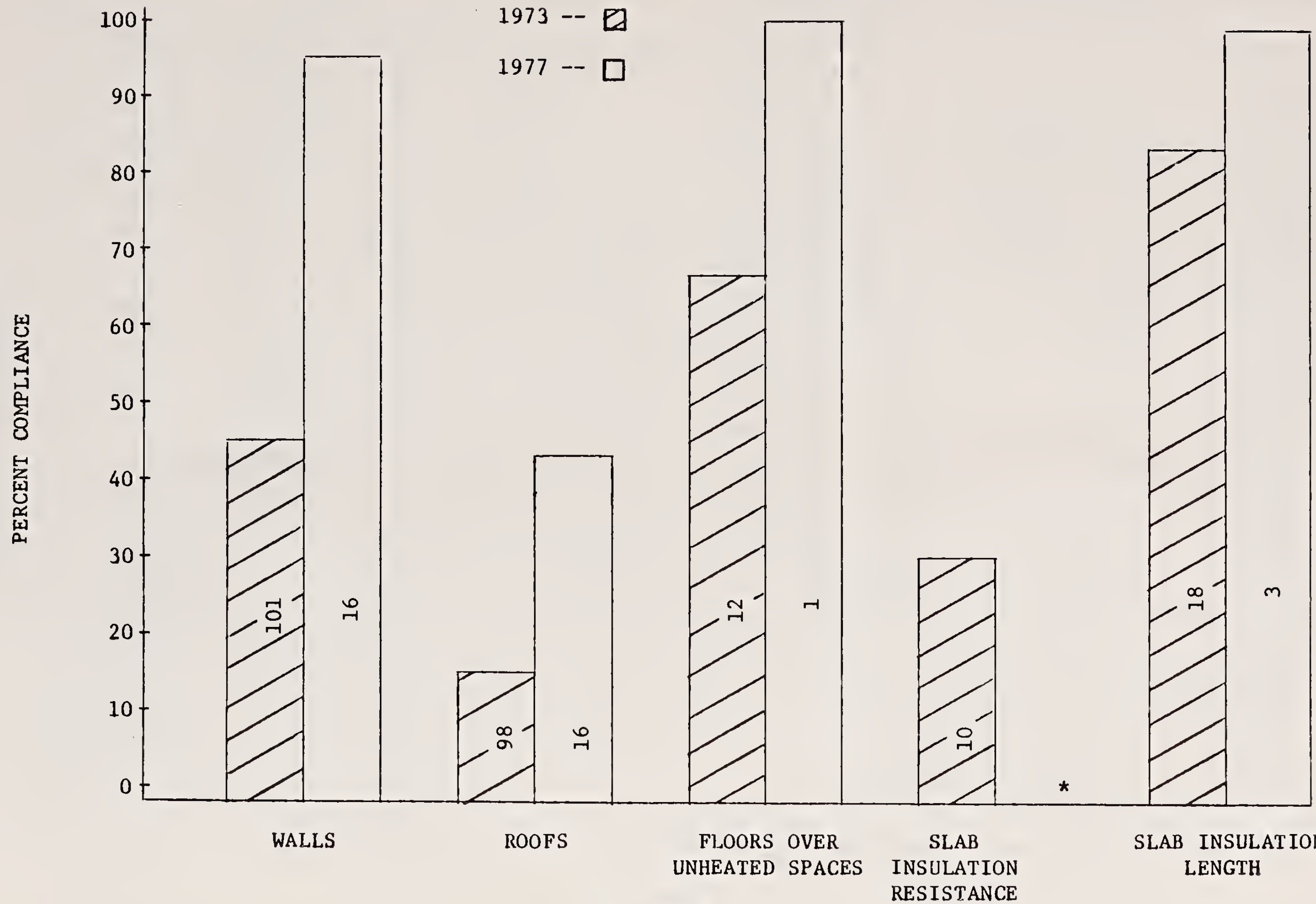


FIGURE 5

NOTE: NUMBER WITHIN THE BAR REPRESENTS THE NUMBER OF BUILDINGS EVALUATED.

* THE ONE BUILDING THAT WAS EVALUATED DID NOT COMPLY.

ASHRAE COMPLIANCE BY WIS. TEMP. ZONES

ZONE 2 -- 8000 DEGREE DAYS

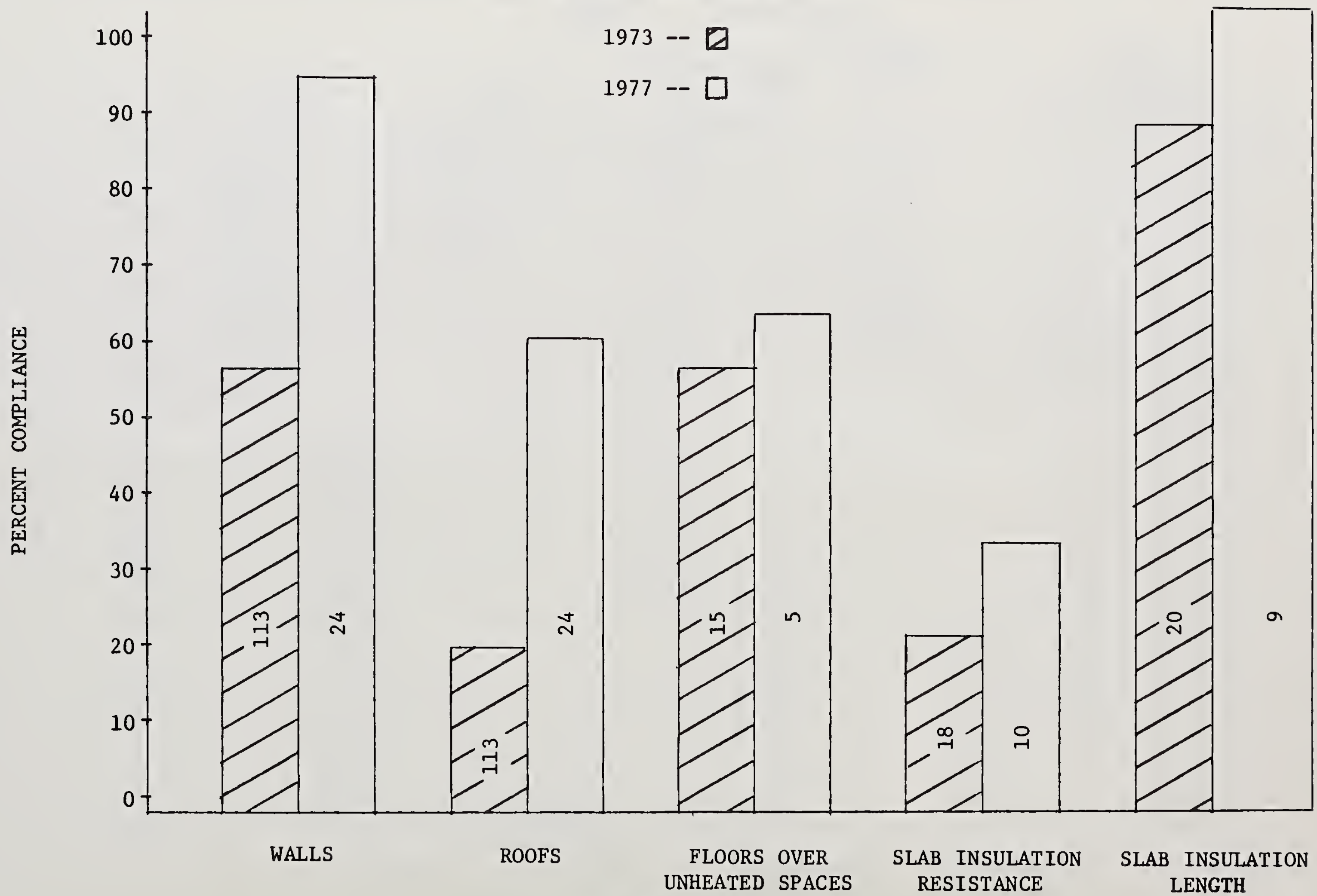


FIGURE 6

NOTE: NUMBER WITHIN THE BAR REPRESENTS THE NUMBER OF BUILDINGS EVALUATED.

FIGURE 7
DATA THERMAL PERFORMANCE VALUES USING ASHRAE 90 U-VALUES
VS. STORIES FOR FOUR WISCONSIN DEGREE DAY ZONES
(ASHRAE TYPE "B" BUILDINGS)

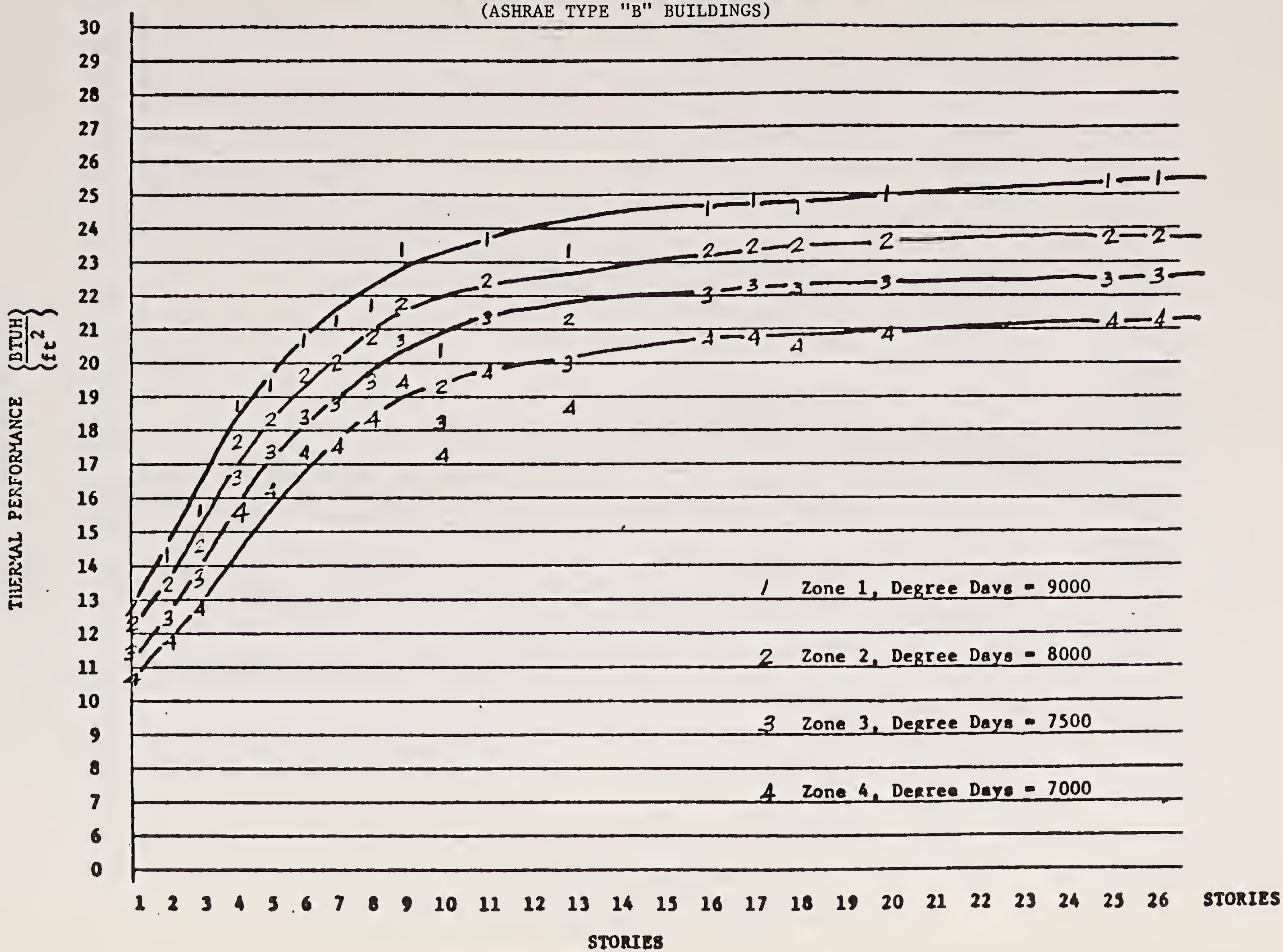
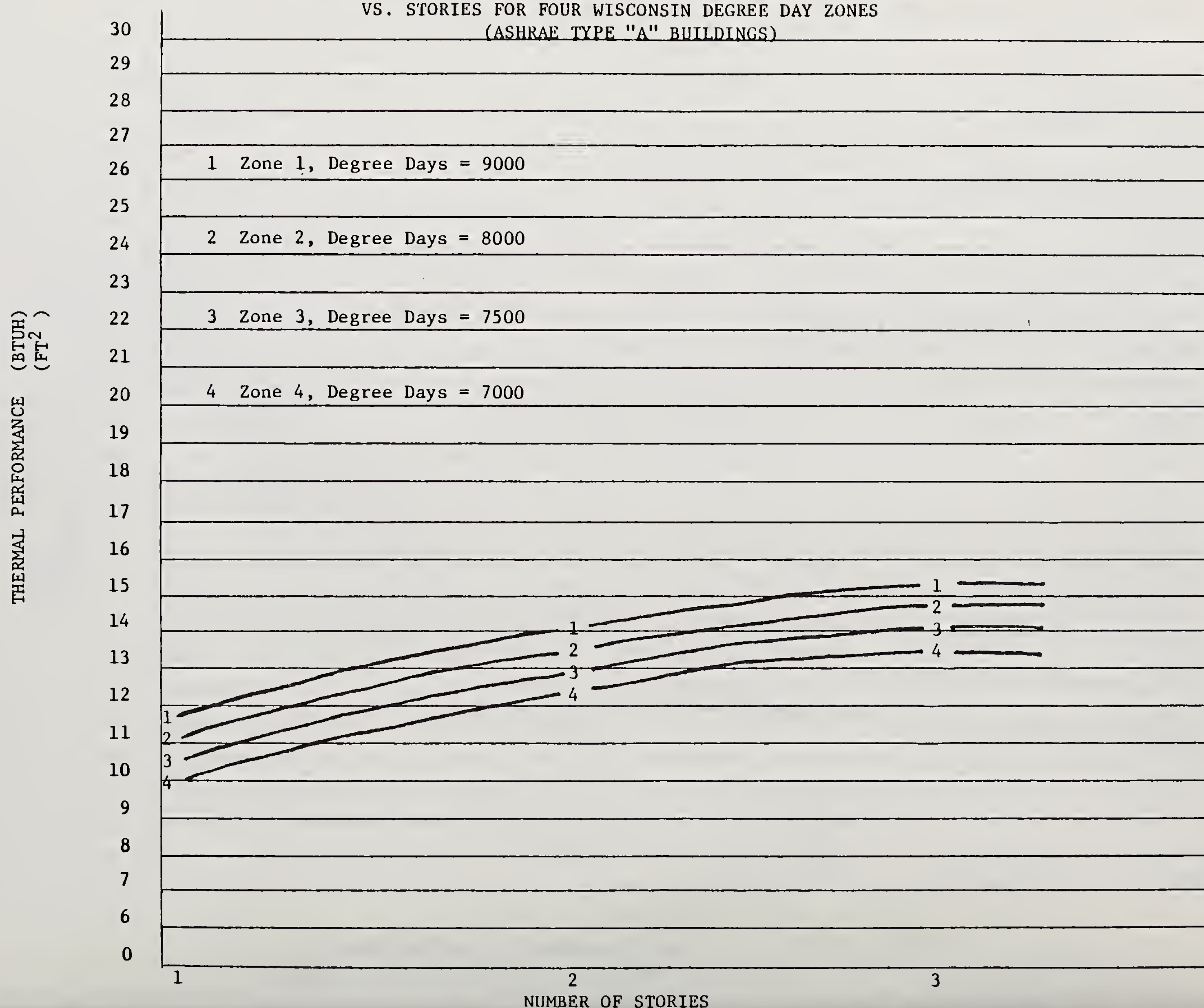


FIGURE 8
DATA THERMAL PERFORMANCE VALUES USING ASHRAE 90 U-VALUES
VS. STORIES FOR FOUR WISCONSIN DEGREE DAY ZONES
(ASHRAE TYPE "A" BUILDINGS)



REHABILITATION AS AN INSTRUMENT IN MEETING HOUSING NEED: CAN IT REALLY WORK?

by

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There is an increasing trend in city planning toward rehabilitating older buildings and conserving neighborhoods that might have become slums, but the rehabilitation process is slow and unreliable. Few builders are interested in rehabilitation, most preferring new construction in the suburbs. A major question is: can the rehabilitation process be changed to attract more builders and become a high-volume business?

The suggested answer is that criteria to identify buildings needing rehabilitation and to specify what repairs need to be made must be developed, using the cumulative knowledge of builders who have done such work and the insight of people involved in building regulation. These criteria should deal with the fundamental structural and safety characteristics of buildings, to provide a yardstick for selecting the right buildings and deciding how much work is required.

Key Words: Decision criteria; demolition; housing needs; physical condition rehabilitation.

INTRODUCTION

Housing costs have risen dramatically in the past few years, as we all know. The average cost of new homes is over $50,000; in 1970, the F.H.A. ceiling was $33,000 against today's $55,000. This kind of inflation has two consequences for the housing market. First, it stimulates demand for older buildings that are less expensive than new ones. Second, it puts more households into the "housing-poor" category, forcing them to spend too much income on housing or live in crowded or otherwise inadequate conditions. In today's market, even middle-class families are feeling the squeeze.

This situation has produced a growing market for older residential properties that calls for vastly improved rehabilitation techniques. Yet at present we lack even a method of assessing the magnitude of the problem, because we lack criteria for identifying dwellings that can and should be rehabilitated. Measuring housing need has historically been the business of sanitation specialists, social workers, and planners and economists working in government. The building industry has focused on supplying the buildings, once need is defined and incentive programs are in place. The result of this separation is the absence of any uniform standard of adequate physical condition for older buildings.

Many criteria have been tried by the Bureau of Census over the years, but each has been unsatisfactory in one way or another. Currently, HUD's criterion for adequate living conditions is that the dwelling contain complete plumbing, afford one room per person, and cost no more than 25% of household income. For owners, a building built before 1939 and valued under $10,000 is deemed inadequate. Specific physical condition of the dwelling, however, is left out. Our studies of housing need in Illinois indicate that this standard underestimates housing need by 30 to 50 percent, possibly 400,000 households. Much of this need can and should be met through rehabilitation. Low-income households cannot afford new construction; many are elderly owners who do not want to move. With the high cost of land and energy, higher income young households are also being attracted to older buildings.

The potential for a vast market is there, but the market can only be tapped once we have the means to measure the need and identify the buildings. The burden of this paper is to suggest that the industry, and the regulatory sector in particular, must become involved in developing the standards that identify buildings needing rehabilitation, to further its own interests and also to play its role in meeting the country's housing needs and preserving our cities and towns as good places to work and live.

MUST OLD BUILDINGS DIE OR ELSE JUST FADE AWAY?

One-third of the occupied dwellings in the United States were built before 1939, and 51% of them are occupied by renters. The rental buildings particularly are likely to need substantial rehabilitation, since landlords frequently defer maintenance and repairs. Where ill-maintained older buildings are located, neighborhoods gradually deteriorate and become slums. People who can afford it move farther and farther out to the suburbs, leaving behind the old neighborhoods, the old buildings, and the people who cannot compete in the broader marketplace. Such neighborhoods are like a cancer within the larger community; eventually the entire city is seen as an inhospitable place to live. Factories and offices then relocate to the suburbs, leaving the city's vast capital facilities and investments underutilized and financially overburdened. In short, in the absence of effective rehabilitation, whole cities may die.

One historical cure for older buildings is the bulldozer. Vast numbers of older buildings were demolished between 1950 and 1970, through urban renewal programs that emphasized slum clearance. Conservation and rehabilitation were among the tools in the renewal kit, but they were used rarely and discussed seldom because clearance was the vogue. Clearance paved the way for large-scale redevelopment and new construction -- more visible, more immediately profitable and less trouble than remodeling and repairs. Peace to the people who were "urban removed."

In the past five years, while housing costs and interest rates rose out of sight, rehabilitation has become a major focus of housing and community development programs. Where new construction was seen as the answer to our housing problems just ten years ago, rehabilitation seems to be taking its place. From neighborhood organizations to Congress and HUD, the word is out: save our neighborhoods; preserve old buildings; no more demolition, we shall not be moved! HUD now requires all cities applying for community development funds to identify all dwellings "suitable for rehabilitation," notwithstanding the lack of criteria.

This sudden interest in rehabilitation is not so much a new respect for old buildings but a reaction to the cost of land, construction, and energy. It appears that the need to maintain and restore older residential neighborhoods will become a permanent part of public programs and private investment. Yet the cost of rehabilitation remains high, cost estimates are repeatedly low, and the construction and lending industries continue to be wary. Rehabilitation is largely the business of small contractors who handle a few buildings and often fail to serve the owners' best interests. The owners feel plagued by unreasonable code requirements and ineffectual job specifications and cost estimates.

Clearly something is amiss. Even if rehabilitation must be costly because of the problems likely to be found behind old walls, the cost of new construction should by now have eliminated the question "Is it worth it?" and substituted the question "How can it be made more worthwhile?" On this question, the building industry are the experts.

TO REHAB OR NOT TO REHAB: HOW TO DECIDE?

Having approached a critical point in terms of high cost, perhaps we are on the verge of tackling the problem. One facet of the challenge is to identify the symptoms of the disease called deterioration and develop the criteria for deciding when minor surgery, or rehabilitation, is appropriate and when radical surgery -- demolition -- is required. These decision criteria operate on two levels. One is the national level, where we presently lack the criteria to estimate the total need and cost of undertaking rehabilitation where it is feasible. The other is the local level where we lack the systematic criteria to identify which buildings to rehabilitate; we select almost at random or oil the wheel that squeaks loudest.

Efforts have been made to develop these criteria, but a few examples illustrate the difficulty of the problem. The U.S. Bureau of Census has wrestled with the issue of identifying inadequate housing for 40 years and failed to come up with a satisfactory set of criteria. The one criterion which has persisted since 1940 is the absence of complete plumbing. On three occasions, however, the plumbing facilities specified to constitute "complete" plumbing have been changed. At the same time, with the extension of public water and sewer systems following World War II, incomplete plumbing has become almost statistically insignificant, found today in less than four percent of all dwellings.

From 1940 through 1960, enumerators were asked to identify variously dwellings needing major repair, or dilapidated buildings, or deteriorating buildings. Owing to the subjectivity of the enumerators and geographic differences, the results were inconsistent and the findings were harshly criticized. The new result was the omission of physical condition questions in the 1970 Census. One new inferential criterion was developed in a special tabulation prepared by the Census Bureau for HUD in 1974; the age-to-value relationship for owner-occupied single-family dwellings. A single-family home built before 1939 and valued at less than $10,000 in urban areas, or less than $7,500 in rural areas, was deemed inadequate. This criterion, unfortunately, is just as subjective as those used in earlier years, because the owner completed the questionnaire and may easily have understated or over-rated the value of the property. It is also of little use in rural areas where frequently there is no market and decent homes may sell for $5,000.

For the 1980 Census, the Bureau's housing advisory panel has thus far considered six factors and rejected three.

1) The presence of rodents, rejected because rodents are common in less developed areas and field mice in suburban homes are not the issue.

2) Bedrooms used as passageways, rejected because of probable misunderstanding and resentment among respondents and the possibility that all bedrooms with connecting doors to bathrooms might be counted.

3) Holes in floors or ceilings.

4) Crumbling plaster or peeling paint.

5) Holes in the roof, rejected on the grounds that it duplicated the above. In 1980, homes with roof and attic damage will not be identified, so long as the ceiling below is all right.

6) Whether or not there is a home improvement loan outstanding on the property -- regardless whether the loan is for a new patio or major repairs.

My intention is not to ridicule the panel wrestling with these questions. Rather, it is to show the difficulty of coming up with apt questions. More important, such criteria will not enable us to identify dwellings to demolish or those to preserve. If, in fact, rehabilitation can be successful in conserving basically good dwellings (and commercial buildings too), the magnitude of the problem and its geographic locations must be determined, in order to decide how much money is needed and where. Once this question is answered, a market can emerge and the construction industry move in.

Now the scene shifts to the local level. Even if we can competently assess rehabilitation need at the national level, we lack a system for deciding which buildings to rehabilitate when and how much to invest, and political decisions of one sort or another prevail. Indeed it appears at present that considerable sums of federal community development and weatherization money are being spent on band-aid and cosmetic repairs to very old, insubstantial dwellings which may remain in use just enough longer, because of these renovations, to become genuinely dangerous to life and health and to trigger or perpetuate the problem of neighborhood and community decay. In addition to criteria for when to rehabilitate and when to demolish, we need systematic criteria for determining what work must be done.

HOW MUCH REHAB IS ENOUGH?

The crux of the problem is to define a standard of adequacy and develop a sliding scale of physical condition for older buildings; for example, from "needing minor repairs" to "requiring demolition"--quantitative criteria by which buildings could be rated numerically. Some efforts have been made to design such a system, but none is widely used. A major problem is identifying the cutoff at which rehabilitation is not economical or appropriate. A related problem is that our codes often seem to require too much, driving costs up, rather than relating improvements to existing defects. A sliding scale would quantify defects in the building and rank them, giving greater weight to structural defects or immediate safety hazards. A building with too many points or too many immediate safety hazards would qualify for demolition. Rehabilitation would be indicated by scores within a lower range. Neighborhoods needing systematic housing code enforcement for minor repairs would fall into the lowest category. A major asset of this type of system is that it provides the defining characteristics of "buildings suitable for rehabilitation" and identifies precisely the work which must be done to rehabilitate a given building.

It may seem that codes do this job, but that is not the case. The codes contain all the requirements new buildings should meet, but some of them are inapplicable to older buildings because of difference in construction. In any case, the codes as we know them cannot directly be used to identify what is missing or what needs correction in a deteriorated old building. Nor can the codes be used to rate deficiencies by degree of hazard or rank buildings on a sliding scale. The code is not a policy tool, and these are policy decisions.

The codes in a sense, are part of the problem. For example, the codes state that the entire building shall meet the code when alterations valued at 50% or more of replacement cost are undertaken. Obviously this increases total rehabilitation cost. Perhaps not quite as obvious is the arbitrariness of this criterion. Surely it is the actual condition of the building, not the cost of alterations, that warrants spending the money to bring it up to code. A rating system that quantifies defects would provide a more reasonable basis for this decision.

On the other hand, if the 50% rule is removed from the code, the building department has no means of knowing what rules, that is, what code to apply. Where does the housing code stop and the building code begin? The answers to this question equally lie in the development of decision criteria based on experience to identify those conditions which must be corrected and those which may, while also affording some flexibility about the method of correction. It is not intuitively obvious that every feature of a building constructed in 1875 must comply with today's accepted standards -- which differ from those of only 20 years ago -- in order to afford safety and comfort to the occupants.

One argument frequently used against rehabilitation as a major tool in meeting housing needs is that each building is an individual case with its own problems which make the cost of time and materials totally unpredictable. This belief has also kept most builders out of the business and left the work to small short-lived firms. However, in the twelve years since the 1965 HUD

Act introduced the rehabilitation loan program, several thousand dwellings of various types and sizes have been rehabilitated all over the country. By now enough experience has been logged to enable us to discover what types of hazards are most common, what kinds of repairs and new installations are most often needed, and what problems are most frequently encountered during rehabilitation in various types of construction. This kind of information could be the basis for a system to identify buildings needing and suitable for rehabilitation, and the cumulative experience could provide a more efficient approach to rehabilitation which would open the door to high-volume construction work.

This is not a plea for "softness" or unsound decisions which jeopardize the inhabitants of buildings and the inspectors who determine compliance with codes. On the contrary, it is a plea for hard criteria based on actual construction experience to systematize the process of rehabilitation, from identification of suitable buildings to prompt completion of the work. This will enable us to rehabilitate more buildings faster and to eliminate those buildings harmful to occupants and communities more readily. If building regulation places emphasis on maintaining the quality of existing housing, it will make building maintenance and renovation a major component of the construction industry.

THE NATIONAL FIRE INCIDENT REPORTING SYSTEM: SOME USES OF FIRE LOSS DATA

by

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The National Fire Data Center of the National Fire Prevention and Control Administration is directed by law to collect, analyze, and disseminate data on the occurrence, control, and results of fires of all types. One of the major objectives of this activity is to provide the building code community with information it needs for writing and updating building codes so that they provide as much protection at as low a cost as possible. The fire experience data collected by the National Fire Incident Reporting System of the Center has a high potential utility for that purpose. However, the initial data collected need significant improvement in completeness and accuracy. This paper describes the basic design of the National Fire Incident Reporting System, and illustrates several ways in which the data collected by the system can be used to identify and rank fire hazards associated with building structures. The current status of the system, including efforts to validate the data, are described.

Key Words: Building codes; data collection; fire hazards; fire protection; National Fire Data Center; regulation; reporting system; scenarios; system design.

INTRODUCTION

In the United States fire is a major national problem. The National Commission on Fire Prevention and Control pointed out that the United States leads all major industrialized countries in per capita deaths and property loss from fire.

Acting on the recommendation of the Commission, the Congress passed and the President signed the Federal Fire Prevention and Control Act in 1974. The Act dealt with the entire national fire problem and it established the National Fire Prevention and Control Administration (NFPCA). It also assigned Federal-level responsibility for the collection, analysis, and dissemination of data on the occurrence, control, and results of fires of all types to the National Fire Data Center of the Administration. The legislative mandate specified that the program of the Data Center shall be designed to provide an accurate nationwide analysis of the fire problem, identify major problem areas, assist in setting priorities, determine possible solutions to problems, and monitor the progress of efforts to reduce fire losses.

This presentation describes the National Fire Incident Reporting System (NFIRS), a major ongoing effort undertaken in partial fulfillment of this mandate. It provides a very brief review of the basic concepts that shaped the design of the system, gives a report on its current status, and illustrates how it can be used to improve our understanding of the fire problem and thus, help make the building regulatory process more rational and cost-effective.

THE NFIRS DESIGN

The primary function of the National Fire Incident Reporting System is the collection of comprehensive national statistics on fires attended by the fire service. However, NFIRS is more than a tool for data collection. It provides assistance in the development of state, regional, municipal, and local fire data systems, and in the standardization of fire data reporting on all levels to help these jurisdictions in doing their jobs.

NFIRS is a national fire data network. It is based on the cooperation of local, regional, and state fire jurisdictions, and the NFPCA. The Data Center developed a training manual for use by instructors to train firefighters at the local level to collect data; a handbook for those who complete the forms; and a computer software package for processing the data. These materials and technical assistance by the Center staff are provided free of charge to participating jurisdictions. In addition, a "first year" grant of up to $20,000 and a small "second year" grant can be obtained by a state joining the network to partially off-set the initial costs of training, quality control, and data processing.

In the NFIRS network, local fire departments collect data on each incident they attend. Fire incident reports are sent to the appropriate state-level authority, generally the office of the state fire marshal, where they are processed onto computer tape. The data can also be processed at the local or regional level and then passed on to the state jurisdiction in computer tape form. The collected fire data are tabulated and analyzed and used by the state or municipality to produce annual and periodic reports to develop feedback reports to the participating fire departments and to analyze special problems. A copy of the computer tape with the fire incident data which has been processed at the state level with the standard NFIRS software package is sent to the National Fire Data Center. The Center analyzes the received data and prepares reports for feedback to the participating state sources as well as for dissemination to the fire protection community, government executives, and legislators, and such other interested groups as those concerned with building codes.

CURRENT STATUS OF NFIRS

At the present time, 18 states, Alaska, Delaware, Illinois, Iowa, Maine, Maryland, Michigan, Minnesota, Missouri, Montana, New York, Ohio, Oregon, Rhode Island, South Dakota, Utah, West Virginia, and Wisconsin participate in the system. The great majority of these states are just beginning, however, and Ohio is the only one for which we have a full year's data. We also have data from California which is not officially an NFIRS state but which has been operating a very similar fire data system for a few years. The Center plans to expand NFIRS to 21 states in 1978 and 34 states in 1979. We hope that, ultimately, all states in the Union will participate.

THE REPORTING FORM

The uniform classification for data reporting adopted by NFIRS was developed by the Nation's fire community through the voluntary consensus mechanism of the National Fire Protection Associations's Committee 901 on Fire Reporting. All data elements collected by NFIRS are based on this classification. They are all included in the incident and casualty report forms developed by the 901 Committee and adopted by NFIRS.

However, NFIRS does not require the use of any specified forms. Each participating jurisdiction is free to design its own as long as the data elements are based on the uniform classification scheme and the form includes the data elements that are being collected nationally. For example, Ohio, the first NFIRS state, uses what we call Layout 1 forms which were the official NFPA 901 forms in 1975. Figure 1 shows the incident report form and Figure 2 the casualty report form. States that joined NFIRS in 1977 use the Layout 2 forms, shown on Figures 3 and 4. Layout 1 and Layout 2 contain the same data elements and differ only in the way these data elements are arranged. The Fire Data Center has developed NFIRS software packages for processing data on these forms.

WHO, WHERE, AND WHEN. The NFIRS fire incident reporting forms are made up of blocks of data elements. The logic behind this arrangement is that for certain incidents it is necessary to record only a certain set of facts. The first block on Layout 1 form, which I will discuss here because I will be using Ohio data, contains the set of elements that is reported for even the simplest incident. These elements give the incident a unique ID and record the who, where, and when. They also provide information of importance to fire department management such as the number of fire service personnel, engines, aerial apparatus, and other vehicles used at the scene.

But while the NFIRS form has spaces to record all these data elements, NFIRS does not collect data on all of them. Collecting names of occupants would be of little value for national level analysis and could lead to problems under the Privacy Act. NFIRS does, however, collect the zip code and census tract data. Both of these constitute bridges which will permit relating fire incident data to demographic and other data organized by census tract. This may make it possible to investigate the relationship between demographic and socio-economic factors and the fire problem. Unfortunately, zip code and consus tract are among the data elements which are often not recorded properly. This may be because they are not known to the people who fill out the forms but perhaps also because their usefulness is not obvious. We hope that once meaningful analyses based on combining NFIRS and census tract data come out, this situation will change.

The utility of the other elements in the first block of the form is apparent. For example, plotting the number of incidents against the time of alarm, or day of the week, can indicate the existence of patterns that can be used to establish cost-effective staffing levels in fire stations. Data received from Ohio for 1976 show that the number of alarms is lowest at about 5:00 a.m., rises to a peak at the early afternoon, and then drops again (Figure 5). The day of the week, on the other hand, seems to have no effect (Figure 6).

STRUCTURE AND OCCUPANCY. Information on the place where the fire happened is provided by a series of questions in the second block on the form, lines H, I, and J. They deal with the type of structure in which the fire occurred, the construction type and method, and the use to which the property was put at the time of the fire. Data derived from answers to the first of these questions permits the analysis of fire incidence statistics in terms of the type of structures involved, such as buildings, tents, bridges, or underground structures.

Ten different categories of structure type can be coded and tabulating data by these categories makes it possible, for example, to identify what type of structure is associated with the greatest dollar loss (Table 1). Such information makes it possible to focus prevention programs where they are most needed. Information on fixed property use allows analysis of the fire problem by type of occupancy--one of the most popular ways of analyzing fire data. Table 2, for example, shows "where fire deaths occur" by fixed property use. It is obvious from that table that residential fires deserve much of our attention. Different occupancies may be required to provide different levels of safety, and many codes are directed at problems presented in terms of a particular type of occupancy. Comparisons of the fire experience of structures with different fixed property uses can be used in monitoring the effectiveness of codes and regulations and suggesting appropriate revisions. The rational way of deciding how to revise these codes and regulations, and how to decide which should be revised first, is on the basis of fire hazard associated with each occupancy type. These hazards can be identified and quantified by fire experience data.

Information on construction type permits analysis in terms of standard constructions that differ in fire resistance and stability under fire conditions, such as fire resistive structure, heavy timber, or unprotected wood frame. The terminology used in the system is based on an NFPA Standard (Table 3) which can be related to the several building codes in use in the United States such as the Basic Building Code, Standard Building Code, and the Uniform Building Code. For example, the NFIRS fire resistive category includes Basic Building Code Type 1A and 1B; Standard Building Code Type I; and Uniform Building Code Type I. Heavy timber includes BBC Type 3A; SBC Type III; UBC Type III (HT). This indicates that data collected by NFIRS can be used to investigate the relationship between construction type and actual fire loss experience and thus, help to identify ineffective codes and point out needed improvements.

Using the 1976 Ohio data of over 67,000 reported incidents, and selecting only residential fires, it appears that unprotected wood frame constructions had by far more fires than any other construction type (Table 4). These fires also show the highest cumulative dollar loss. This is not unexpected since most single family dwellings are of this type, and these data show totals, not rates. The National Fire Incident Reporting System does not collect data on how many buildings of what construction type there are in the reporting districts, and on what building codes are in force, so that fire risks associated with the different construction types and different codes cannot be established. NFIRS can provide a part of the answer but it is necessary to combine NFIRS data with data based on some kind of a pre-fire inventory of property at risk before relative fire risks for the various construction types can be established.

Data on methods of construction is meant to help in identifying differences that may exist between the behavior in fire of structures built on the site and those built in a factory in a modular form or assembled on the site. There are four major categories of construction methods (Table 5). Ohio data on this element indicate that most losses are associated with site-built structures (Table 6). Again, this is not unexpected since such structures dominate the field. We need information on how many buildings constructed by the different methods are "at risk" before we can say anything about the relative safety of these methods.

CAUSAL FACTORS. The third block of data elements on the NFIRS form, lines K and L, deal with the causes of fire. The form asks about equipment involved and lists four major types of causal factors because from a technical point of view fire does not have a single cause. To know how the fire started, we need to know the form of heat of ignition; the type of material first ignited; the form of material first ignited; and the ignition factor. The question concerned with whether the ignition source was a piece of equipment is of vital importance to equipment manufacturers as well as to such regulatory agencies as the Consumer Product Safety Commission because it identifies equipment and products that require further attention. For this reason, if it is a piece of equipment that was involved in ignition, further questions are asked about it on line T of the form -- the make, year, model, serial number, and voltage.

The other questions in this block ask about the form of the ignition energy (Table 7), the type of material first ignited (Table 8), the form or use (Table 9) of the first item ignited, and the ignition factor (Table 10). The ignition factor is the action or lack of action that permitted the heat from the ignition source to cause the ignition of the first item. The Ohio data shows that the most important ignition factor in terms of loss of life is "misuse of heat of ignition" which includes the leaving of a smoking material unattended (Table 11).

FIRE GROWTH. Information on fire growth is provided by the questions in the fourth block on the form, lines M, N, and O. It is made up of several components and like the information on causal factors, it is most useful when these components are related to each other and to other information about the fire. One component is concerned with the extent of the spread -- was the flame damage confined to the object of origin? to the room of origin? to the floor? did it extend beyond the building or origin? (Table 12). Obviously, this information in itself has a limited value. But if a high correlation were found between extent of flame damage and, say, polyurethane as the type of material first ignited, this would have important implications concerning the fire hazard of polyurethane products.

The second component of the fire growth complex is concerned with what helped it most to grow. After all, it is not always the first item ignited that is the important factor in fire spread. It could have been the second or even the third item ignited -- the drapery that spread the fire across the room in no time at all but was ignited from a small wastebasket fire started by a glowing match. The third component is concerned with the path taken by the spreading fire -- did it move up an open staircase? did it spread across a long hall without fire doors? or did it move through a hole in a fire wall? Inferences that can be drawn from data on these points would be of much value to those concerned with life safety codes and to architects, builders, or makers of furniture and furnishings. For this reason, the system provides for recording and collection of the data on NFIRS forms. However, the collecting of information on these two aspects of fire growth is a relatively new development in fire reporting, and during the initial stages, NFIRS does not collect it on the national level.

DETECTORS, SPRINKLERS, AND DOLLAR LOSS. The fifth block on the form, lines P, Q, and R, include questions concerning detector and sprinkler performance, and data on these points would also be of much value to those responsible for building codes (Table 13). Unfortunately, the NFIRS data available at this time has so few cases where detectors were present and operating that no statistically significant differences in deaths, injuries, and losses could be established between these cases and those where detectors were not present. As more smoke detectors come into use, and the NFIRS data base grows, we expect that such information will become available.

There is more data regarding the value of sprinklers. The data in Table 14 indicates that average loss is significantly less where automatic sprinklers are installed and operating properly than where there are no sprinklers.

The fifth block on the form also asks about dollar losses resulting from the fire. The dollar loss is, of course, of major importance to the owner of the burned property. It is also very important in determining priorities for, and determining the cost-effectiveness of programs aimed at combating the fire problem. Unfortunately, reliable dollar loss data are hard to come by because fire service personnel are not schooled appraisers. The multitude of methods for loss estimates -- original cost, market value, replacement cost -- is another obstacle to obtaining comparable data. Since information on total dollar loss is so important, both a dollar estimate and a range are asked for on line Q of the form. The instructions explicitly request that the estimates be made on the basis of cost of replacement in like kind and quality, and that only the direct physical loss -- to the structure, contents, machinery, equipment, and such, be considered. Table 15 shows that residential and non-residential structural fires account for about the same dollar loss, approximately 43% of the total, even though there were more than twice as many residential as non-residential fires.

CASUALTIES. The identification and characterization of casualties resulting from a fire has always been an integral part of fire reporting. NFIRS collects information on fire casualties on a separate casualty report (Figure 2) which calls for information on the victim's age and sex, affiliation, casualty type, and whether it was an injury or death. Other questions such as those concerning the nature of the injury, part of body injured, and disposition, or those concerning familiarity with structure and conditions preventing escape are designed to provide additional information about fire casualties. Such additional information is meant for analysis and correlation with the various fire incident parameters. For example, if the data show that lack of familiarity with structure is an important factor, an educational campaign to get people familiar with the structures in which they live and work would seem indicated. However, if correlation with incident data shows that lack of familiarity with structure is of importance only for certain types of occupancies such campaigns could be aimed more precisely and thus, be both more effective and more cost effective.

FIRE SCENARIOS. This ability to correlate one set of data elements against another, and thus to discover a trend, for example, is a major strength of the National Fire Incident Reporting System. The system also makes it possible to use another analytical technique for ranking fire hazards and evaluating different intervention strategies called the "fire scenario." A fire scenario describes the chain of events leading up to the fire. In the scenarios prepared at the Data Center, we are using the following attributes of a fire:

1. Fixed property use
2. Time of day
3. Form of material of ignition
4. Type of material ignited
5. Form of material ignited
6. Ignition factor

The Data Center has developed computer programs which query NFIRS data for combinations of these factors and print out those that occur most frequently. Such a computer printout, based on the 1976 Ohio data in the data base, is illustrated on Table 16. It shows that the most frequent scenario for residential fires is a cigarette left burning on a sofa while the smoker falls asleep, perhaps never to awaken. This scenario, incidentally, is believed to be responsible for over 50% of all deaths resulting from residential fires.

Once the most frequent fire scenarios are identified, the next step is to develop the most cost-effective intervention strategies. This is a difficult process because accurate valid data necessary to compare the outcomes of alternative strategies are often not available. In spite of these difficulties, however, the fire scenario technique is a promising tool for planning fire prevention and control programs. We expect that as NFIRS expands and the accuracy of its data improves, it will provide some of the necessary data.

CONCLUSION

This discussion of the National Fire Incident Reporting System has indicated what it can, and will, provide to help building code organizations to make more rational, cost-effective decisions. We would appreciate your comments and would welcome your suggestions for making the system more useful.

Fire Department ______________________ 902F 6/77

LAYOUT I

Fill In This Report
In Your Own Words

(ANY STATE) INCIDENT REPORT

1 ☐ Delete
2 ☐ Change

Row	Fields
A	**1** FD ID / Incident No. / Exp. No. / Mo. / Day / Year / Day of the Week / Alarm Time / Time—"In Service"
B	CORRECT ADDRESS: No. / Dir. / Name / Type / Zip Code / Census Tract
C	Occupant Name / Telephone / Room or Apt.
D	Owner Name / Address / Telephone
E	Method of Alarm from Public / Type of Situation Found
F	Type of Action Taken / Co. Inspection District / Shift / No. Alarms / Mutual Aid 1 ☐ Rec'd 2 ☐ Given
G	No. Fire Service Personnel Used at Scene / No. Engines Used at Scene / No. Aerial Apparatus Used at Scene / No. Other Vehicles Used at Scene

COMPLETE ON ALL INCIDENTS

Row	Fields
H	**2** No. Incident-related Injuries* (Fire Service / Others) / No. Incident-related Fatalities* (Fire Service / Others) / Structure Type
I	Fixed Property Use / Complex / Mobile Property Type**
J	Area of Fire Origin / Level of Fire Origin / Construction Type / Construction Method

COMPLETE IF CASUALTY OR FIRE

Row	Fields
K	Equipment involved in Ignition (if any)** / Form of Heat of Ignition
L	Type of Material Ignited / Form of Material Ignited / Ignition Factor

IGNITION

Row	Fields
M	Extent of Flame Damage / IF FLAME SPREAD BEYOND ROOM OF ORIGIN: Type of Material Generating Most Flame / Avenue of Flame Travel
N	Extent of Smoke Damage / IF SMOKE SPREAD BEYOND ROOM OF ORIGIN: Type of Material Generating Most Smoke / Avenue of Smoke Travel
O	Extent of Water Damage / Extent of Fire Control Damage / Termination Stage

FIRE GROWTH

Row	Fields
P	Time from Alarm to Agent Application / Method of Extinguishment / Detector Performance
Q	Estimated Total Dollar Loss / Property Damage Classification / Sprinkler Performance

COMBAT

COMPLETE IF FIRE

Row	Fields
R	Officer In Charge (Name, Position, Assignment) / Date
	Member Making Report (If Different from Above) / Date

COMPLETE ON ALL

*List name, age, sex, and description of injury for each casualty on form 902G.

** Complete Line S and/or T

☐ Check box if remarks are made on reverse side.

Row	Fields
S	**3** If Mobile Property / Year / Make / Model / Serial No. / License No. (If any)
T	**4** If Equipment Involved in Ignition / Year / Make / Model / Serial No. / Voltage (If any)

Figure 1

_______________________________________ Fire Department

Fill In This Report
In Your Own Words

(ANY STATE) CASUALTY REPORT

902G 6/77
LAYOUT I
Page ______
of ______

A	5	FD ID	Incident No.	Exp. No.	Mo.	Day	Year	Day of Week	Alarm Time

CASUALTY 1

Casualty Number	1 ☐ Delete	2 ☐ Change

U	Casualty Last Name	First Name	MI	D.O.B.	Age	Time of Injury
V	Home Address				Telephone	

W

SEX	CASUALTY TYPE	SEVERITY	AFFILIATION
1 ☐ Male	1 ☐ Fire Casualty	1 ☐ Injury	1 ☐ Fire Service
2 ☐ Female	2 ☐ Action Casualty	2 ☐ Death	2 ☐ Other Emergency Personnel
	3 ☐ EMS Casualty		3 ☐ Civilian

X	Familiarity With Structure	Location at Ignition	Condition Before Injury
Y	Conditions Preventing Escape	Activity at Time of Injury	Cause of Injury
Z	Nature of Injury	Part of Body Injured	Disposition

☐ See Remarks on Back ☐ See Additional Report

CASUALTY 2

Casualty Number	1 ☐ Delete	2 ☐ Change

U	Casualty Last Name	First Name	MI	D.O.B.	Age	Time of Injury
V	Home Address				Telephone	

W

SEX	CASUALTY TYPE	SEVERITY	AFFILIATION
1 ☐ Male	1 ☐ Fire Casualty	1 ☐ Injury	1 ☐ Fire Service
2 ☐ Female	2 ☐ Action Casualty	2 ☐ Death	2 ☐ Other Emergency Personnel
	3 ☐ EMS Casualty		3 ☐ Civilian

X	Familiarity With Structure	Location at Ignition	Condition Before Injury
Y	Conditions Preventing Escape	Activity at Time of Injury	Cause of Injury
Z	Nature of Injury	Part of Body Injured	Disposition

☐ See Remarks on Back ☐ See Additional Report

CASUALTY 3

Casualty Number	1 ☐ Delete	2 ☐ Change

U	Casualty Last Name	First Name	MI	D.O.B.	Age	Time of Injury
V	Home Address				Telephone	

W

SEX	CASUALTY TYPE	SEVERITY	AFFILIATION
1 ☐ Male	1 ☐ Fire Casualty	1 ☐ Injury	1 ☐ Fire Service
2 ☐ Female	2 ☐ Action Casualty	2 ☐ Death	2 ☐ Other Emergency Personnel
	3 ☐ EMS Casualty		3 ☐ Civilian

X	Familiarity With Structure	Location at Ignition	Condition Before Injury
Y	Conditions Preventing Escape	Activity at Time of Injury	Cause of Injury
Z	Nature of Injury	Part of Body Injured	Disposition

☐ See Remarks on Back ☐ See Additional Report

R	Officer In Charge (Name, Position, Assignment)	Date
	Member Making Report (If Different From Above)	Date

Figure 2

_______________ Fire Department

902F 6/77
LAYOUT 2

Fill In This Report
In Your Own Words

(ANY STATE) INCIDENT REPORT

1 ☐ Oelete
2 ☐ Change

1 — COMPLETE ON ALL INCIDENTS

A | FDID | Incident No. | Exp. No. | Mo. | Oay | Year | Day of the Week | Alarm Time | Time—"In Service"

B | CORRECT AOORESS | No. | Oir. | Name | Type | Zip Code | Census Tract

C | Occupant Name | Telephone | Room or Apt.

D | Owner Neme | Address | Telephone

E | Method of Alarm from Public | Type of Situation Found

F | Type of Action Taken | Co. Inspection Oistrict | Shift | No. Alarms | Mutual Aid 1 ☐ Rec'd 2 ☐ Given

G | No. Fire Service Personnel Used at Scene | No. Engines Used at Scene | No. Aerial Apparatus Used as Scene | No. Other Vehicles Used as Scene

2 — COMPLETE IF CASUALTY OR FIRE

H | No. Incident-related injuries△ Fire Service / Others | No. Incident-related Fatalities△ Fire Service / Others | Complex

I | Fixed Property Use | Mobile Property Type△△

ALL IGNITIONS — COMPLETE IF FIRE

J | Area of Fire Origin | Level of Fire Origin | Termination Stage

K | Equipment Involved in Ignition (if any)△△ | Form of Heat of Ignition

L | Type of Material Ignited | Form of Material Ignited | Ignition Factor

FOR STRUCTURE FIRE ONLY

M | Structure Type | Construction Type | Construction Method

N | Extent of Flame Damage | Extent of Smoke Damage | Extent of Water Damage

O | Extent of Fire Control Damage | Oetector Performance | Sprinkler Performance

P | IF FLAME SPREAD BEYOND ROOM OF ORIGIN | Type of Material Generating Most Fleme | Avenue of Flame Travel

Q | IF SMOKE SPREAD BEYONO ROOM OF ORIGIN | Type of Material Generating Most Smoke | Avenue of Smoke Travel

ALL FIRES INCIDENTS

R | Method of Extinguishment

S | Estimated Total Oollar Loss | Property Oamage Classification | Time from Alarm to Agent Application

COMPLETE ON ALL INCIDENTS

T | Officer in Charge (Name, Position, Assignment) | Date

Member Making Report (If Oifferent from Above) | Date

△ List name, ege, sex, and description of injury for eech casualty on form 902G

△△ Complete Below

☐ Check box if remarks are made on reverse side.

U | **3** | If Mobile Property | Year | Make | Model | Serial No. | License No. (if any)

V | **4** | If Equipment Involved In Ignition | Year | Make | Model | Serial No. | Voltage (if any)

Figure 3

Fill In This Report
In Your Own Words

____________________ Fire Department

(ANY STATE) CASUALTY REPORT

902G 6/77
LAYOUT 2
Page ______
of ______

A	5	FDID	Incident No.	Exp. No.	Mo.	Day	Year	Day of Week	Alarm Time

CASUALTY 1

Casualty Number | 1 ☐ Delete 2 ☐ Change

GA | Casualty Last Name | First Name | MI | D.O.B. | Age | Time of Injury

GB | Home Address | Telephone

GC | SEX: 1 ☐ Mele 2 ☐ Female | CASUALTY TYPE: 1 ☐ Fire Casualty 2 ☐ Action Casualty 3 ☐ EMS Casualty | SEVERITY: 1 ☐ Injury 2 ☐ Death | AFFILIATION: 1 ☐ Fire Service 2 ☐ Other Emergency Personnel 3 ☐ Civilian

GD | Familiarity With Structure | Location at Ignition | Condition Before Injury

GE | Condition Preventing Escape | Activity at Time of Injury | Cause of Injury

GF | Nature of Injury | Part of Body Injured | Disposition

☐ See Remarks on Back ☐ See Additional Report

CASUALTY 2

Casualty Number | 1 ☐ Delete 2 ☐ Change

GA | Casualty Last Name | First Name | MI | D.O.B. | Age | Time of Injury

GB | Home Address | Telephone

GC | SEX: 1 ☐ Male 2 ☐ Female | CASUALTY TYPE: 1 ☐ Fire Casualty 2 ☐ Action Casualty 3 ☐ EMS Casualty | SEVERITY: 1 ☐ Injury 2 ☐ Death | AFFILIATION: 1 ☐ Fire Service 2 ☐ Other Emergency Personnel 3 ☐ Civilian

GD | Familiarity With Structure | Location at Ignition | Condition Before Injury

GE | Condition Preventing Escape | Activity at Time of Injury | Cause of Injury

GF | Nature of Injury | Part of Body Injured | Disposition

☐ See Remarks on Beck ☐ See Additional Report

CASUALTY 3

Casualty Number | 1 ☐ Delete 2 ☐ Change

GA | Casualty Last Neme | First Name | MI | D.O.B. | Age | Time of Injury

GB | Home Address | Telephone

GC | SEX: 1 ☐ Mele 2 ☐ Female | CASUALTY TYPE: 1 ☐ Fire Casualty 2 ☐ Action Cesualty 3 ☐ EMS Casualty | SEVERITY: 1 ☐ Injury 2 ☐ Death | AFFILIATION: 1 ☐ Fire Service 2 ☐ Other Emergency Personnel 3 ☐ Civilian

GD | Familiarity With Structure | Location of Ignition | Condition Before Injury

GE | Condition Preventing Escape | Activity at Time of Injury | Cause of Injury

GF | Nature of Injury | Part of Body Injured | Disposition

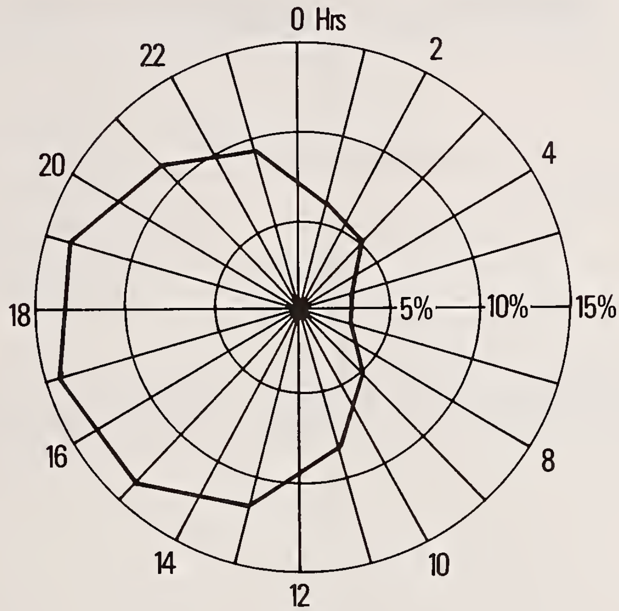
☐ See Remarks on Back ☐ See Additional Report

T | Officer in Charge (Name, Position, Assignment) | Date
Member Making Report (If Different From Above) | Date

Figure 4

FIGURE 5

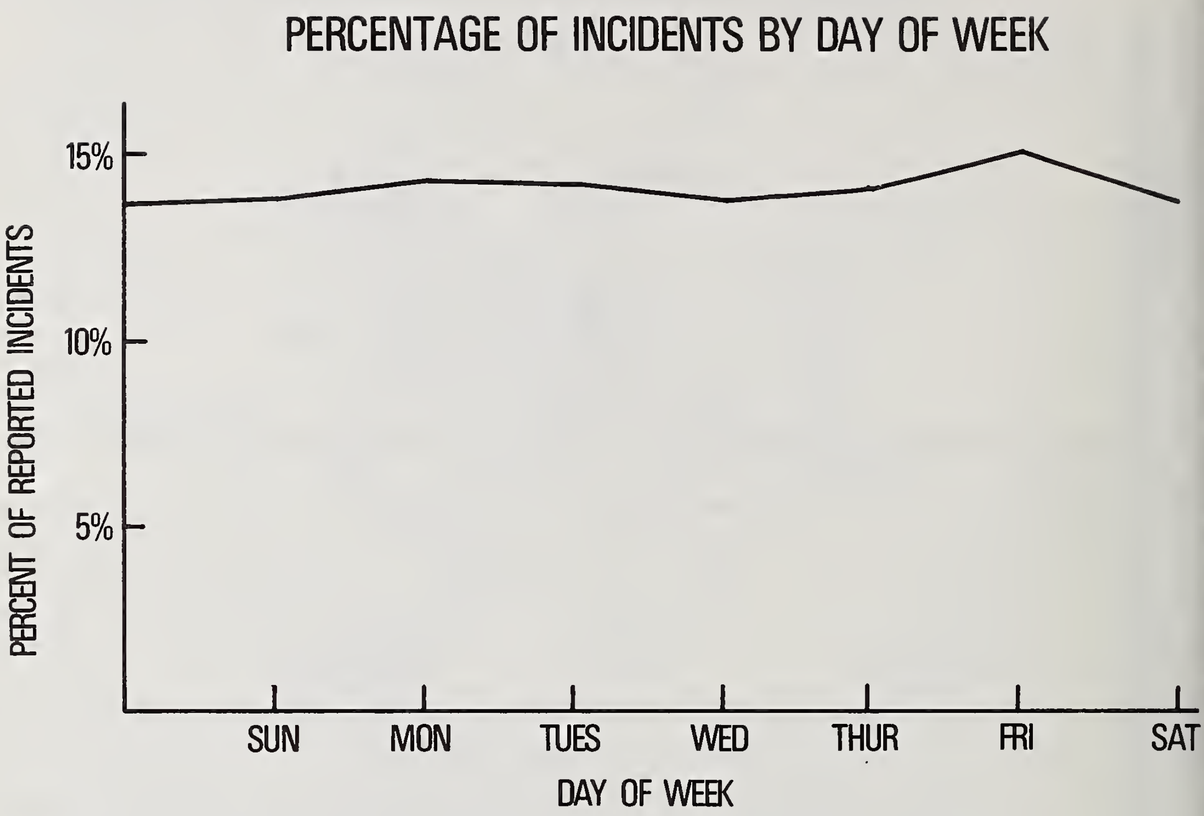
PERCENTAGE OF ALARMS REPORTED BY TIME OF DAY



TIME OF DAY

Source: Ohio, 1/1/76 - 12/31/76. Figure 5 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

FIGURE 6



Source: Ohio, 1/1/76 - 12/31/76. Figure 6 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 1

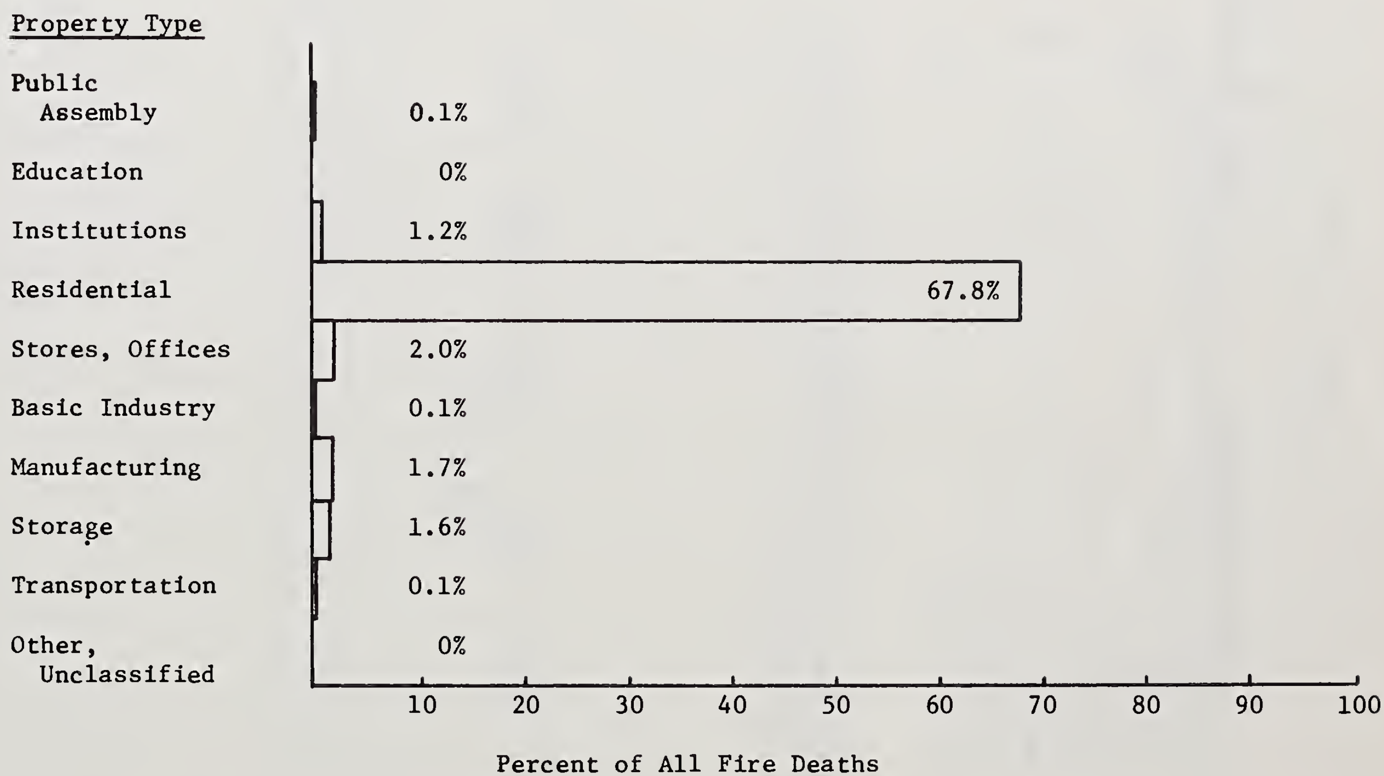
Dollar Loss by Type of Structure

Type of Structure	$ Loss, in 1000's
Building with one use	$ 114,913
Building with two or more uses	16,642
Open structure	386
Air-supported structure	26
Tent	8
Open & platform	21
Underground structure	2
Not a structure	96
Other structure	867

Source: Ohio, 1976. Table 1 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 2

Where Fire Deaths Occur



<u>Source</u>: Ohio 1976 NFIRS and California 1975 CFIRS data.

<u>Note</u>: Approximately 25% of the fire deaths in Ohio and California occurred in mobile or outside properties. These were not included in the above graph as it represents only deaths in structures. Table 2 includes preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 3

Types of Construction

1. Fire resistive.
   Includes BBC Types 1A, 1B; SBC Type 1;
   UBC Type 1.

2. Heavy timber.
   Includes BBC Type 3A; SBC Type III;
   UBC Type III (HT).

3. Protected noncombustible or limited combustible.
   Includes BBC Type 2A, 2B; SBC Type II, IV (1 hr.);
   UBC Type II, IV (1 hr.).

4. Unprotected noncombustible or limited combustible
   not qualifying for 3. Includes BBC Type 2C;
   SBC Type IV; UBC Type IV (N).

5. Protected ordinary.
   Includes BBC Type 3B; SBC Type V (1 hr.);
   UBC Type III (1 hr.).

6. Unprotected ordinary, not qualifying for 5.
   Includes BBC Type 3C; SBC Type V; UBC Type III (N).

7. Protected wood frame.
   Includes BBC Type 4A; SBC Type VI (1 hr.);
   UBC Type V (1 hr.).

8. Unprotected wood frame, not qualifying for 7.
   Includes BBC Type 4B; SBC Type VI; UBC Type V (N).

9. Type of construction not classified above.

0. Type of construction undetermined or not reported.

Source: NFPA 901, 1976.

Table 4

Number of Residential Fires and Associated Dollar Losses by Construction Type

Construction Type	No. of Residential Fires	Dollar Loss in Thousands
Fire resistive	980	2,782
Heavy timber	194	1,439
Protected non-combustible	331	1,408
Unprotected non-combustible	329	955
Protected ordinary	2,676	8,348
Unprotected ordinary	2,019	8,566
Protected wood frame	3,477	12,202
Unprotected wood frame	5,844	20,638

Source: Ohio, 1/1/76 - 12/31/76. Table 4 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 5

Method of Construction

1. Site built structure.
2. Factory built, site assembled.
3. Factory built modular.
4. Factory built mobile.
9. Method of construction not classified above.
0. Method of construction undetermined or not reported.

Source: NFPA 901, 1976.

Table 6

Number of Residential Fires and Associated Dollar Losses by Method of Construction

Method of Construction	No. of Fires	Dollar Loss in Thousands
Site built structure	15,452	55,215
Factory built, site assembled	220	498
Factory built modular	77	490
Factory built mobile	601	4,097

Source: Ohio, 1/1/76- 12/31/76. Table 6 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 7

Form of Heat Ignition

1. Heat from Fuel-Fired, Fuel-Powered Object.
2. Heat from Electrical Equipment Arcing, Overloaded.
3. Heat from Smoking Material.
4. Heat from Open Flame, Spark.
5. Heat from Hot Object.
6. Heat from Explosive, Fireworks.
7. Heat from Natural Source.
8. Heat Spreading from Another Hostile Fire (Exposure).
9. Other Form of Heat of Ignition.

Source: NFPA 901, 1976.

Table 8

Type of Material First Ignited

1. Gas.
2. Flammable, Combustible Liquid.
3. Volatile Solid, Chemical.
4. Plastic
5. Natural Product.
6. Wood, Paper.
7. Fabric, Textile, Fur.
8. Material Compounded with Oil.
9. Other Type of Material Ignited.

Source: NFPA 901, 1976.

Table 9

Form of Material First Ignited

1. Structural Component, Finish.
2. Furniture.
3. Soft Goods, Wearing Apparel.
4. Adornment, Recreational Material.
5. Supplies, Stock.
6. Power Transfer Equipment, Fuel.
7. General Form.
8. Special Form.
9. Other Form of Material.

Source: NFPA 901, 1976.

Table 10

Ignition Factor

1. Incendiary.
2. Suspicious.
3. Misuse of Heat of Ignition.
4. Misuse of Material Ignited.
5. Mechanical Failure, Malfunction.
6. Design, Construction, Installation Deficiency.
7. Operational Deficiency.
8. Natural Condition.
9. Other Ignition Factor.

Source: NFPA 901, 1976.

Table 11

Deaths and Injuries by Ignition Factor

Ignition Factor	No. of Deaths	No. of Injuries
Incendiary	9	297
Suspicious	8	307
Misuse of heat of ignition	58	796
Misuse of material ignited	17	514
Mechanical failure	35	720
Deficient design	5	180
Operational deficiency	51	409
Natural condition	3	54
Other	4	15

Source: Ohio 1/1/76 - 12/31/76. Table 11 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 12

Extent of Flame Damage

1. Confined to the object of origin.
2. Confined to part of room or area of origin.
3. Confined to room of origin.
4. Confined to the fire-rated compartment of origin.
5. Confined to floor of origin.
6. Confined to structure of origin.
7. Extended beyond structure of origin.
8. Not a structure fire.
0. Extent of Flame Damage undetermined or not reported.

Source: NFPA 901, 1976.

Table 13

Detector Performance

1. Detector(s) in the room or space of fire origin, and they operated.
2. Detector(s) not in the room or space of fire origin, and they operated.
3. Detector(s) in the room or space of fire origin, and they did not operate.
4. Detector(s) not in the room or space of fire origin, and they did not operate.
5. Detector(s) in the room or space of fire origin, but fire too small to require them to operate.
8. No detectors present.
9. Performance of Fire Detection Equipment not classified above.
0. Performance of Fire Detection Equipment undetermined or not reported.

Source: NFPA 901, 1976.

Table 14

Effectiveness of Automatic Sprinklers

Property Type	A. With Sprinklers Operating Average Damage Per Fire	B. Without Sprinklers Average Damage per Fire
Residential	585	3,736
Public Assembly	8,958	9,820
Education	70	9,572
Institutions	209	2,824
Stores, Offices	9,517	16,531
Basic Industry	3,767	10,739
Manufacturing	8,994	22,559
Storage:		
Residential Garage	0	1,620
Other storage	13,006	17,088
Total Structures		

Source: Ohio, 1/1/76 - 12/31/76.

Reported fire incidents shown here do not include all fires attended by fire departments; estimated completeness is roughly 50%. Fires in which sprinklers were present but failed or for which information was not available are not included. 1,083 structure fires falling in the category "Other Property Type" have not been included because there were only two fires reported in which sprinklers were operating. Table 14 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 15

Reported Fire Lossed for Major Occupancy Types --
California (CIFIRS 1975), Ohio (NFIRS 1976) Combined

Property Type	Number of Fires	Dollar Loss in Thousands
Residential, (Including mobile homes)	63,555	155,609
Non-Residential structure	29,275	150,884
Mobile Property	43,037	24,732
Outside Property (Rubbish, wildlands, etc.)	148,112	22,183
TOTAL	283,979	353,408

Reported fire incidents shown here include only fires reported to the states. Estimated completeness is on the order of 90% for California and 50% for Ohio. Table 15 includes data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

Table 16

Scenario Report on Number of Incidents for Major Fixed Property Use: Residential

Time	Form of Heat Ignition	Type of Material Ignited	Form of Material Ignited	Ignition Factor	Total Incidents	%
Night	Smoking Material	Fabric/Text/Fur	Sft Gds/Wrg Aprl	Misuse of Ht Ign	587	3.39
Day	Open Flame, Spark	Fabric/Text/Fur	Sft Gds/Wrg Aprl	Misuse of Ht Ign	396	2.28
Night	Smoking Material	Fabric/Text/Fur	Furniture	Misuse of Ht Ign	393	2.26
Night	Elec Eqp Arcing	Wood, Paper	Strct Comp/Finsh	Mech Failure/Mal	360	2.07
Night	Hot Object	Voltl Solid/Chem	General Form	Operational Def	352	2.03
Day	Hot Object	Voltl Solid/Chem	General Form	Operational Def	285	1.64
Night	Open Flame, Spark	Fabric/Text/Fur	Sft Gds/Wrg Aprl	Misuse of Ht Ign	279	1.61
Night	Unknown			Unknown	277	1.59
Day	Smoking Material	Fabric/Text/Fur	Sft Gds/Wrg Aprl	Misuse of Ht Ign	266	1.53
Day	Elec Eqp Arcing	Wood, Paper	Strct Comp/Finsh	Mech Failure/Mal	239	1.38
				Scenario Total Overall Total	3,434 17,314	19.83

Source: Ohio, 1/1/76 - 12/31/76.

Table 16 is based on preliminary data from a pilot test system and is presented for illustrative purposes only; it should not be presumed to be accurate.

PROPOSED DRAFT FOR NOISE CONTROL ABATEMENT FOR THE CITY OF NEW ORLEANS

by

C. Curtis Mann, P.E.
Chief Mechanical Inspector
Department of Safety and Permits
City of New Orleans
New Orleans, Louisiana

The everyday sounds of simply existing can be very deceptive to us as individuals. Music, for example, is soothing and refreshing to some persons while to others, the same music may be distracting and unpleasant. The rock-and-roll that brings pleasure to one individual might be found distasteful by another individual. We, as individuals "on the street" do not think of noise unless it becomes irritating to us or "gets on our nerves." It has been said that sound is not a "noise" unless it annoys.

This paper is a search into some of the large cities' approaches to their noise problems, with an added proposal to this same noise problem for the City of New Orleans. Many controls are being generated, developed and perfected, and as a result, future generations should have a quieter environment in which to live and work. Much is yet to be accomplished, however, and efforts toward this goal should not be lessened or allowed to become diminished.

Key Words: Awakening to problems; deceptive sounds; establish legal limits; tolerance level differences.

INTRODUCTION

To most people "noise" can be simply stated as unwanted sounds. This is partially true because there are sounds that add to the quality of the environment, just as there are those that do not. If the sounds have an annoying result, it will always be defined as noise, and is generally considered as noise pollution.

The Federal Government, through OSHA, has implemented many regulations regarding noise abatement and sound oriented safety. This is fine if it can be implemented; however, in many of the instances these regulations only confuse and frequently infuriate the regulated parties. And, as is with most regulations, if they are not written clearly and enforced properly, the parties will not take measures to quiet their equipment <u>nor</u> will the users attempt to protect their health from these hazards -- whether it is sight, breathing or hearing.

Even though the Federal Government has maintained a sort of "hands off" policy where the municipalities are concerned, their knowledge and assistance has been of much value in helping those localities and states to "get on their feet" and started in the right direction.

In preparing regulations one caution should be considered, though, in the form of possible regulatory overkill. This occurs if everyone tries to get on to the dying object "noise" and wants to regulate it to death. This occurs as a problem in all areas if the regulations and controls are made without a complete understanding of their implications. This can be seen happening with some areas of air pollution, such as the control devices on automobiles and the energy crunch, i.e.: Congress is taking a second look at the stringency of the requirements again, and they, along with many constituents, are now saying that they would, in essence, "put up with" an increase in the air pollutants, if they could trade off with an increase in the gas mileage that amount that the emission control devices eliminated, or if an increase could result in the country's self-sufficiency with fuels.

The regulatory overkill or excessive control can also occur if a State or municipality enacts such controls that are unfeasible and impossible to live with. Many communities are hesitant to adopt or modify their noise laws because of these regulatory experiences. Likewise, any ordinance adoption should be in scale with the needs of that locality.

The State of Illinois has what is considered one of the most comprehensive noise laws, and it applies to both the incorporated <u>and</u> unincorporated areas. However, its complete compliance is almost impossible without considerable instrumentation, expertise and a sizeable capital outlay.

There effectively can be no one ordinance that will fit <u>all</u> communities. A California city repealed its quantitative ordinance because it was of a too technical nature, and there was a lack of necessary professional personnel for its enforcement. It is possible, however, to utilize model noise ordinance guidelines and receive provided assistance in helping to tailor a program to fit the local conditions within the governing objective.

At this point it is necessary to emphasize that any ordinance derived will have to concern what is "called" environmental noise or community noise. This is also referred to as non-occupational noise, and includes zoning, curfews, traffic, nuisances, etc.

COMMUNITY NOISE

During the construction of any object, whether it is a bridge, building, highway, monument or whatever, there will always be associated noise, classed as the construction noise. Many spectators will view the noise of constructing these objects, if he has access during construction, as simply the noise of necessity of progress. This is acceptable, because he has the capability of leaving this area for a quieter location, if desired, especially if the noise annoys him. But what of the individuals that are confronted with noisy conditions that he can neither move away from nor control? This type of noise, expressed as "community noise" or non-occupational noise, has to have some method of control or at least abatement. An in-part answer to this problem, the 1972 Noise Control Act passed by Congress, required that the Administrator of the Environmental Protection Agency (EPA) develop and publish a criteria with respect to noise. Document 550/9-73-002 was established for that purpose to reflect honest appraisals of available knowledge relating to the health and welfare effects of the noise pollution. The effect that noise have on people will vary. Degraded hearing can occur and be attributed to the lack of individual protection and exposure excesses that they subject or allow themselves to be subjected to, even in non-employment conditions. There is a great area of response where hearing is concerned. The human ear can discern without pain, sounds ranging from a threshold of detection to sounds 10^{12} times as intense. This is in contrast with the human eye, which responds to light from detection threshold to an intensity of 105 times greater. A decibel (dBA) is the measurement scale for the sound strength or pressure. This decibel measurement is logarithmetic, and the units increase with the amplitude of the levels that are measured. As an example; from a threshold of 0, to 60dBA for normal speech, to 170dBA for a turbo-jet engine with afterburner.

One problem exists, human ears do not rate the pressure of noise to judge loudness. The noise rating of loudness is complex because the hearing is frequency (cycles per second) sensitive. The unit Hertz, Hz, is the standard designation for frequency, and sounds with frequencies in the 5,000-10,000 Hz range are the easiest to hear.

Frequency selectivity of the human ear can be shown by three single frequency sounds of 50, 500, and 5,000 Hz. When the strength of all three is adjusted until equally loud, the 50 Hz sound would be

19dBA stronger than the 5,000 Hz sound and 8dBA stronger than the 500 Hz sound.

Loudness can also be measured by filtering the microphone signal, to reduce the strength of the low frequency signals, and to give more weight to the frequencies in the 5,000-10,000 Hz range, (frequencies to which the ear is most sensitive). This is done with a standardized "A" filter network that makes adjustments throughout the frequency range that provides a decibel rating with a correction approximating the sensitivity of the ears. This measurement is referred to as A-scale or dBA level.

The A-scale is widely used throughout the world and is the adopted scale prescribing noise limits under the Walsh-Healey Act. These limits are on the industrial environment and are for individual protection. Every worker or citizen in a noisy environment should be aware of them. The exposure time limits decrease as the dBA levels increase; such as exposure to 90dBA should be for no longer than 8 hours to no more than 15 minutes for sound levels of 115dBA or more. Exceeding the time limits at the dBA level could result in hearing damage of the individual.

The A-scale is intended to match the response of the ear to low intensity sound. There are some sound meters equipped with a "B" and "C" scale and on later meters a "D" scale (proposed) will be introduced. The "B" scale is intended to match the response of the ear to sounds of moderate intensity, the "C" scale will then match the responses of high intensity. The proposed "D" scale will primarily be used to monitor jet aircraft noise.

SOUND INTENSITY

Sound may be stated in terms of three (3) variables; 1) Amplitude (loudness), 2) Frequency (pitch), and 3) Duration (time). The sound intensity is the average rate of the sound energy transmitter through a unit area. These values, when reflected to "community reaction," will show that up to 40dBA no noticeable complaint action takes place and 50dB-60dBA occasional complaints, to threats above 80dBA. The full picture would not be realized, because additional data of frequency and exposure time would <u>have</u> to be available before any authoritative body could take corrective action against any violating party. This still doesn't keep it from being a noise nuisance to the complaining party.

Regarding intensity and human response, we should remember that the ear is responsive to painful sound of a value much greater than the least audible sound. This extremely wide variation in values is what creates measurement and computation problems pertaining to noise, and is why the <u>level</u> concept is desired. As an example, the sound pressure levels are not directly additive to each other: i.e., a source producing an 80dBA sound, when added to another source producing 80dBA at the same distance, results in only a 3dBA increase, and not doubling to 160dBA as might be expected.

Noise Types Affecting the Public Health

For proper evaluation of the effect of noise, one has to define the types according to EPA criteria. The definition has to be fairly explicit since a complex sound usually involves a mixture of sounds. These sounds would vary in intensity, frequency, and pattern. Different types would be "ongoing" and "impulse." Some examples of ongoing noise are a waterfall, electrical substation, manufacturing processes, traffic, engine areas, etc. The impulse noise is an acoustical event, such as a gunshot, lasting less than 500 milliseconds, and has a magnitude of at least 40dBA during that time.

Municipality Noise Ordinances.

Historically the regulatory control of noise has existed throughout most of western civilization development. It has been reported that the Romans even invoked restrictions on chariot use. Then, later, medieval towns adopted ordinances regulating both stationary and mobile sources of noise. Ironwheeled carts could not operate freely on paved streets and nighttime restrictions were imposed on noise related commercial and industrial activities, including the town blacksmith.

The earliest noise regulations within the United States date back to 1850; however, it was not until early 1900 that national concern began to develop. Even by 1930 there were less than 20 American cities with laws regulating noise, and those were narrowly defined and non-quantitative in nature.

The provisions of a New York Commission report, written in 1930, included muffler requirements for motor vehicles and other internal combustion engines; restricted building development in residential areas between 5:00 p.m. and 8:00 a.m.; prohibited use of horns and whistles; regulated peddlers, hawkers and venders, and prohibited excessive noise from mechanical or electrical sound making or reproducing equipment.

Memphis, Tennessee, "proclaimed" the quietest city in America, adopted several of these provisions in their 1938 municipal noise ordinance regulating vehicles. Although it did not specify permissible sound levels in decibels, their nuisance type or non-quantitative ordinance became one of the most successful, due to an active enforcement program.

In 1955, Chicago adopted a most influential zoning ordinance, restricting noise related land use activity. This regulation contained quantitative noise emissions expressed in decibels for various octave bands. It represented a new approach to zoning which placed restrictions not on the type of industry, but rather on its performance in terms of noise emission. For the first time industry was being regulated according to specific acoustical criteria, rather than by a more vague nuisance provision.

Constitutionally, the power has been upheld to regulate noise for the health, safety and welfare of the public. The municipalities can regulate nuisances through use of police power. A nuisance refers to everything that endangers life or health, offends the senses, violates decency or obstructs reasonable and comfortable use of one's property. It is not at all surprising, then, that the majority of any municipal noise ordinance within the United States is based on nuisances. It also should be noted that even though most regulation exists for nuisance, other noise types exist, such as Zoning, Vehicle, Building and Aircraft.

Statistically the enforcement of nuisance ordinances containing provisions of the non-quantitative type have been ineffective. However, in spite of the vagueness, the Courts have ruled that nuisance type ordinances, or noise ordinances containing nuisance provisions, are constitutional.

ZONING

Zoning noise ordinances are the quantitative or performance type. In contrast, these type ordinances are based on acoustical criteria, and, therefore, they are more objective in nature. The acoustical criteria generally includes both the overall sound level measurements and/or frequency (Hz) requirements. This type of ordinance is in use where zoning is the predominately affected area, and should not be construed to exclude vehicles, buildings or aircraft, because they also play a major role in regulatory criteria.

The current Zoning Ordinance for the City of New Orleans is a quantitative type; however, there is no current way to measure the provisions and values that are given.

Any agency that is designated for the enforcement of the quantitative type of ordinance has an advantage over a nuisance ordinance due to the definition of the dBA level, but would have to have the necessary equipment that is required to perform the sound measurements that require enforcing. This type of equipment is expensive to purchase and requires some training to operate and understand. For this reason, any ordinance, of necessity, would have to completely encompass rigidity and simplicity. It would have to be comprehensive and complete, and yet simple enough to enforce so as not to require too much, if any, specialization for its implementation.

NOISE CONTROL

A major item in an effective noise control program is sufficient budget to support the necessary personnel and equipment. Despite the fact that there are nearly 300 ordinances regulating city noise, an EPA conducted survey indicated that less than 20 cities have adopted budgets to operate noise control programs.

In terms of manpower, New York ranks largest with a full staff, with approximately one-half directly assigned to their Noise Abatement Bureau. Chicago has full-time staff members in engineering and enforcement. Professional staffers, however, are very difficult to acquire, and the current demand for qualified professionals far exceeds the existing supply. As such, some cities have either delayed or abandoned their programs due in part to the unavailability of technically qualified personnel.

One precaution in preparation of the control program should be to make it as comprehensive as possible, for the technically affected people (architects, engineers), and still have it simple and precise enough for enforcement by non-technical personnel (police, inspectors). The requirement of these two functions has to be an overlapping and not simply an adjoining function.

An additional precaution will have to be understanding of the tolerance limits reflected in complaining individuals; i.e., the simple honking of a horn on an automobile, ringing of a bell, blowing of a whistle, etc., will not, by itself, singularly constitute a valid complaint claim, or, at least a claim that any authority should follow up on without a duration time limit specified.

A very high priority report to the Mayor of New York, with its recommendations and comments, was very much responsible in helping to steer New York officials toward controlling and abating the noise problem that it faced. The Legal Subcommittee of the report commission quoted, in a supplemental memo, some of the earlier New York cases and how they related to smells, indicating that abating smells was no different from that of abating noise -- giving the following quotations as revelant:

> "To constitute a nuisance it is not necessary that smell should be unwholesome, but sufficient if it renders enjoyment of life and property uncomfortable - it is sufficient if it produces that which is offensive to the senses and impairs enjoyment of life and property."

> "It is not sufficient that it is merely disagreeable, it must be an annoyance calculated to interrupt the reasonable enjoyment of life and property."

Professor W. H. Lloyd, University of Pennsylvania wrote in the Law Review:

> "Nuisance means literally 'annoyance' - the fact that an occupation was commendable in itself and carried on in a proper manner did not alone justify substantial injury to property or the infliction of material discomfort upon the residents of a neighborhood."

> "Indeed, air and sound conditioned houses may be the next luxury when luxury is resumed, to the profit of our inventors and engineers, who, having devoted one century to creating pandemonium, may spend the next century abating it."

He wrote this in 1934.

COMPARISONS, COMMENTS, AND CONCLUSIONS

There is a similarity in the noise control laws and regulations that are enacted by the various cities and states. For instance, the State of New York prepared regulations and enacted them to apply where there were no laws or ordinances of local government. If there were local laws or ordinances, they had to comply or compare with at least the minimum regulation for the state. This would not preempt any local government from enacting noise ordinances and could possibly provide those governments with the opportunity to develop their own noise control programs tailored to their own local conditions. All of the states primarily follow this type format, of giving the local governments their option.

The Federal Noise Control Act of 1972 states that the "....primary responsibility for the control of noise rests with State and local governments...." The Federal Act, administered by the Environmental Protection Agency, is designed to control the major noise sources in commerce which require national uniformity of treatment. With the exception of interstate railroad and motor carrier standards, the act states that "...nothing precludes or denies the right of any state or political subdivision thereof to establish and enforce controls on environmental noise through the licensing, regulation, or restriction of the use, operation or movement of any product or combination of products."

One problem exists, however, because most of the cities treated noise problems as a minor pollutant, with Air Pollution having and being under the greatest control and covering the greatest amount of defined limits. This would probably be because of the apparent innocuousness and thinking that the offended person could move away from the sound. The consensus of opinion of most of the legislators, complainers, individuals, etc., usually is that air pollution can be seen whereas noise pollution of any type cannot, so, maybe "out of sight, out of mind." But, as has been mentioned also, this is probably due to the ease and simplicity with which noise erodes the senses of the ear. The damage is so gradual that it will almost go unnoticed until a hearing problem actually exists and the damage is irreparable. But then it is almost too late because hearing cannot be corrected, as with the eyeglasses for eyes - it has to be supplemented with a hearing aid.

Also, unlike air pollution control, noise pollution control currently has no requirement for permit issuance to the various locations for thier equipment usage. This is similar in most cities, excepting that New York requires a permit to tunnel under the city and requires a means for the prevention of unnecessary noise during the tunneling process.

Agency permits for creating a noise disturbance in any city should not be allowed, primarily due to the fact that abatement or control is the reason for the agency's existence. Noise permits should be allowed only as means necessary to a particular end item, function or project. When that end item, function or project was finalized, the noise, allowed by permit, would also have to be finalized, and any noise would then be restrictive per a nuisance or zoning limited decibel standard or requirement.

New York City has an extremely comprehensive and inclusive ordinance. The desirous effect of control is easier to obtain if there is no doubt as to the ordinance or regulation values or coverage. If the coverage is too sketchy or incomplete, the results are left too much to interpretation; then, any decisions would possibly result from favoritism or even unfavoritism. Therefore, to remove any of the doubts, the requirements and values with the penalties should be included in order to be of value to the community that it regulates. The enforcement then can be concise, and its effectiveness can be a direct result of the enforcing agency. No regulatory agency wants to have to interpret the regulations that are within its responsibility. If interpretation is unavoidable, then the ordinance, being comprehensive for regulation, should also be simple for this interpretation. And, if generally this interpretation is not acceptable, then referral should be made to a Board of Appeals, but only as a safeguard, since that would preclude the regulatory overkill that was discussed earlier.

It is discouraging that most municipalities will not enact any form of measurement or abatement until it is "forced" on them or it is too late. Sometimes, cities will enact regulations strictly as a result of a court case in which the city or its citizens have been involved; or enactment would result due to some type of discrepancy, but the city would never enact on its own in order to provide good governing regulations. Then the tendency is always to overreact to the requirement with an unrealistic result. However, if much forethought and planning is involved, a good ordinance for all of the citizenry of the area or city can result.

PROPOSED NOISE CODE DRAFT INCLUSION

The most logical part of the New Orleans Building Code that should be utilized for noise control and abatement is the chapter pertaining to smoke control. Inclusion in this chapter, rather than choosing a new or different chapter, is primarily because the regulating has previously been provided, for Chapter #51, by the Safety and Permits Department. In addition to this inclusion, it will be easier to add additional articles to the existing chapter than to add another chapter.

References to airport noise will not be included because it is generally provided in the noise control documents as a separate entity. Any attempts to make a proposed draft include airport noise, still be comprehensive and possess simplicity for enforcement, would most assuredly be so clouded that approval by any Board would be very unlikely.

Traffic allowable noises are include primarily because the Federal requirements have been stipulated long enough that any action on the part of a city, New Orleans, will attest to its attempts to become responsive to the noise control area.

Enforcement, as proposed, will be one difficult part of the ordinance because of manpower. One likely requirement could be to utilize a commissioned force of inspectors similar to those provided for in Article 215 of the Building Code for inspection of mechanical equipment. In this article the Safety and Permits Department, Mechanical Inspection Section, commissions qualified personnel of the insurance companies within the city to inspect the applicable mechanical equipment that their companies insure. The completeness of the code of the City of New York is used as setting an example for this proposal to follow. Similarities in other utilized noise codes are interpreted as the excepted norm in cases where other alternate values could not be found from the guidelines that the Federal requirements have stated. This would, at least, allow the ordinance the flexibility necessary and desired that would be common for any municipality for which it is drafted. There would be many items that the other larger cities would have in common that would not affect or concern New Orleans and vice versa. The proposal, therefore, reflects this general thinking.

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RESIDENTIAL ENERGY CONSERVATION BUILDING REGULATIONS AND THEIR IMPACT ON THE BUILDING PROCESS

by

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In early 1977, a study was conducted under contract to the State of California. This work was a portion of a larger contract from ERDA to document the history problems and success of the California residential energy regulations adopted in February 1974. The resulting report, based on personal interviews with code enforcement officials, architects, developers, contractors, material suppliers and manufacturers, and homeowners, describes the impact and changes caused by these regulations on segments of the building industry. This paper will briefly discuss these impacts within the context of statewide energy conservation building regulations.

In addition, the paper will summarize the procedures of the State to develop and implement residential energy regulations. The paper concludes with procedural recommendations for Federal, State, and local government.

Key Words: Building regulations; enforcement; energy conservation; legislation; standards development; survey findings; training.

I. INTRODUCTION

This paper discusses the impact on various sectors of the building process by the adoption of residential energy conservation regulations by the State of California. We will discuss the response to these statewide regulations by local building enforcement agencies, architects and engineers, builders and developers, material manufacturers and suppliers, and the consumer (homeowner). Also the administrative efforts by the State to develop, adopt, and implement regulations will be discussed. The report identifies field experience after two years of enforcement. This study was performed under contract with the State of California Department of Housing and Community Development (HCD). The project was funded by the U.S. Energy Research and Development Administration (ERDA). This paper will summarize both the States' report and our report. Our work involved the actual field survey which included approximately 100 personal interviews; analysis of the data collection and recommendations for various levels of government to ease the implementation of energy conservation regulations.

II. BACKGROUND

Legislation

Legislation was passed in 1972 mandating the Commission of Housing and Community Development, by January 1, 1974, to adopt rules and regulations establishing minimum standards of energy insulation for all new residential buildings. Funding for the development and implementation of these was $35,000.

These rules and regulations were required to meet or exceed the current FHA "Minimum Property Standards for One and Two Living Units." Further rules and regulations independent of such standards were developed for hotels, motels, and apartment houses more than three stories in height. The enforcing agency is the local building department. Conditions for local adoption of more restrictive regulations were established. Regulations are not retroactive.

Advisory Committee

An advisory committee representing necessary areas of expertise was appointed to assist the Commission in the establishment of energy insulation regulations. Separate legislation requiring the adoption of minimum noise insulation standards for residential buildings also required that an advisory committee be appointed. The makeup specified for this committee was very similar to that required of the advisory committee for the energy insulation standards. It appeared, at the time, that it would be beneficial to form a combined advisory committee. This proved to be less feasible than had been thought since goals were different.

Regulation-Adoption Process: The development and adoption of energy insulation standards for the State of California involved the following:

Public advisory committee meetings.

Public fact-finding seminars.

Public hearings which were also meetings of the Commission of Housing and Community Development at which standards could be adopted.

Public meeting of the Building Standards Commission.

The advisory committee meetings were basically working committee meetings which were held both prior to and after the fact-finding seminars and public hearings.

Two informal fact-finding seminars were held to obtain additional data and public input on the proposed standards, one in the northern and one in the southern part of the State.

As required by the California Administrative Procedures Act, a public hearing was held in conjunction with a meeting of the Commission at which the energy insulation standards were proposed for adoption. However, due to public input, the Commission elected not to adopt the energy insulation standards at the first meeting. This required more advisory committee meetings and a fourth public hearing held in conjunction with a Commission meeting. At this meeting, the Commission did adopt the energy insulation standards.

Since the energy insulation standards contained building standards, approval was required and obtained from the Building Standards Commission to check for overlap and conflict with other building standards contained in State regulations.

Advisory Committee Meetings: The advisory committee appointed to assist in the development of energy insulation standards held their first meeting May 30, 1973. Ensuing meetings showed that many members were unable to attend consistently. A point to consider when utilizing an advisory committee is that some provision should be made to replace such members.

Public notification of the advisory committee meetings to develop energy insulation standards for residential buildings was accomplished by advertising in a trade newspaper and by mailing to interested parties. Attendance by the public at the committee meetings varied, increasing as the time for adoption approached. Meetings were held at various locations in order to provide wide opportunity for attendance.

State staff assistance to the advisory committee during development of the energy insulation standards was substantial.

In developing the standards, the advisory committee had, in addition to the legislative requirements, the following objectives in mind:

The standards should result in significant energy savings.

The standards should allow design flexibility.

The standards should be compatible with present California Residential-construction techniques so as to minimize the impact on the builder.

Eventually, four subcommittees were established to cover the following topics:

Data needs.

Enforcement problems.

Energy insulation standards.

Energy design manual.

Since the standards were adopted in February 1974, several changes were developed by the commission of Housing and Community Development in response to better input data or design and enforcement problems. Such changes included:

Subsection (c), related to alternate provisions, was changed to permit overall building envelope heat loss calculations and to allow credit for designs utilizing nondepleting energy systems.

Subsection (d)(2), which contains the definition for degree day, was revised to clarify that it is related to the annual heating load and not just the winter season of the year. The degree standards would be applicable to all new residential buildings and did not address additions, alterations, or relocated buildings. It was determined that if the existing building was required to be constructed in conformance with the standards, then it made sense that an addition to that building be required to comply with the standards.

In California, there are over 500 city and county building departments which enforce building regulations. Up to the time of the enactment of the energy insulation standards, the regulations enforced by building departments dealt with health and safety items only. Enforcement questions for the insulation standards required special consideration.

The main concerns of the enforcement subcommittee were:

That the standards would be implemented uniformly throughout the State.

That the cost of the enforcement of the standards would be minimal to the consumer.

That the enforcement officials understand the terminology used in the standards.

The enforcement subcommittee recommended that an energy design manual be developed to assist in the implementation of the standards.

The second recommendation of the enforcement subcommittee was that the regulations require that a compliance certificate be provided by the installer and the builder upon completion of the installation of insulation.

The third recommendation of the enforcement subcommittee was to have the standards become effective one year after the date of adoption of the standards. This one-year period would provide sufficient time for users to become familiar with the standards and to allow for a smooth transition period for compliance with the standards.

ENERGY DESIGN MANUAL

The Energy Design Manual for Residential Buildings was developed for the purpose of assisting in implementation of the energy insulation standards.

The subcommittee members charged with providing input for the development of the manual consisted of representatives of the building industry, utility representatives, suppliers, insulation contractors, enforcement officials, and designers.

The Manual contains administrative and technical information, including definitions, examples of standard insulation and glazing details, and climatological information. Also included are sections covering energy fundamentals and design.

Even though this manual was only a guide, it soon became an indispensible tool in the implementation of the standards and remains so today.

TRAINING AND PLAN CHECKING

As the development of the energy insulation standards progressed, it became apparent that a training program would be necessary in order to have orderly implementation of the standards. It was decided to develop a training program using the Energy Design Manual as the main training tool. The Department was left with the task of developing a statewide training program with a very limited budget.

Another problem was the timing of the training program. Work on the Energy Design Manual did not begin until after the standards were adopted. The Manual did not become available to the public until after the standards became effective. This delay further complicated the proposed training program.

With these obstacles of funding and timing, the Department proceeded on the development of a statewide training program.

It was decided that the following criteria would be used in setting up the training program:

The training sessions would begin no later than September, 1975.

The main emphasis of the training would be directed toward building inspectors who enforce the standards. It was felt that if the enforcement officials could develop a thorough understanding of the standards, uniform implementation would be obtained. In addition, these trained officials could provide assistance to builders and consumers in their jurisdictions.

The instructors of these courses would consist of Department staff and advisory committee members.

The Department would try to notify all groups and individuals who would be affected by these standards.

The Department would make an effort to have a Department representative familiar with the standards at any public meeting concerning energy.

After the first few training sessions were held, it became apparent that the following changes would be needed in the program:

The sessions would have to start with basic heat transfer theory due to the general lack of familiarity with heat transfer terminology.

The training sessions were too short (2 to 4 hours). It was evident that very little could be accomplished unless the sessions were extended to a minimum of eight hours. Several all-day sessions were incorporated into the training program which eliminated some of the apparent problems; however, due to the time available, a sufficient number of these sessions could not be provided.

When the energy insulation standards became effective, certain implementation problems still existed. The major problems were concerned with the following areas:

Unawareness of the standards by the general public, builders, and designers.

Limitations of design flexibility due to the restrictions on glazing.

Increased costs due to the standards.

General reluctance on the part of the public to accept the need for such standards.

Most of these areas which were problems at the time the standards became effective have now been resolved.

III. SURVEY FINDINGS AND ANALYSIS

INTRODUCTION

Studies were conducted after the standards had been in effect for approximately two years to determine the problems encountered in implementation, enforcement, and design. Data was collected by surveying enforcement officials, builders, and developers, architects and engineers, manufacturers and suppliers, and consumers. Interviews were selected to provide a representative cross section, considering the various sizes of city and county building departments, various climatic conditions and geographic locations throughout the State.

The consulting firm of Melvyn Green and Associates, Inc., El Segundo, California, was retained to assist in the collection of data and the preparation of recommendations. Mr. Green's report, "The California Residential Energy Regulations -- Their Impact on the Building Process," discusses his survey methodology and findings and presents recommendations based on the findings.

An independent survey was performed by the Department of Housing and Community Development, at interview locations not covered by the consultant. This provided a broader data base and the opportunity to compare the findings of the two surveys.

The findings represent the opinions and experiences of the individuals interviewed only and should not be construed to mean that all others agree with these opinions. Summaries of groups surveyed follow:

A. ENFORCEMENT AGENCIES

The energy insulation standards for new residential buildings in California are enforced by local enforcement agencies, generally the building department. The two principal functions of these agencies to assure compliance with the standards are plan review and field inspections. As a result, it is the local enforcement agency which has the daily contact with the builders and designers and is confronted with the question and problem.

Most of the questions regarding the standards are answered at the building department level. The Energy Design Manual is used as a reference. Sometimes, other enforcement agencies such as counties are consulted, or questions are referred to the State.

Plan Review: Plans, and calculations when required, are checked for compliance with the energy insulation standards. R values of required insulation are required to be shown on the plans.

About 95 percent of the dwellings constructed meet the specific or prescriptive requirements of the standards. The remaining 5 percent utilize the alternative of providing heat loss analysis calculations to show the equivalency of the designed house. Some rural areas report that the heat loss analyses submitted are poorly performed and people qualified to do these calculations are hard to find.

Inspection: Due to lack of time and manpower, many enforcement agencies do not inspect the installation of insulating products. These agencies accept the certificate of installation signed by the builder and installation installer, with spot checks in some cases. The majority of the enforcement officials feel the certificate means full compliance with the standards; however, no one certifies compliance with the glazing and weatherstripping requirements involved. One agency thought that building departments should only be required to enforce items related to health and safety. Hostility toward State mandated regulations was also mentioned. The remainder of the enforcement agencies (approximately 60%) are inspecting the installation of the insulating products. Frequently a copy of the signed certificate of installation is required prior to the final inspection. Some field reports note poor workmanship in the installation of insulation and weatherstripping.

Some agencies were not aware of the requirements for weatherstripping or labels on aluminum windows, and thus were not inspecting for these items.

Administration: Fee increases to offset the increased plan check and inspection tasks required varied widely. Frequently, the enforcement agency relied on the increased valuation provided by the insulation for additional income to cover the required services. Other cities and counties increased their fees in varying ways.

Although extra time is required to enforce the standards, few agencies reported hiring additional personnel. Local governing bodies appear reluctant to allow the building department to hire extra personnel because of new standards, even when income is adequate to support the position. As a result, when work is added, priorities on what gets done change.

Adequacy of Standards: Enforcement agencies generally felt the standards were adequate. Some thought they should also cover additions to existing buildings, HVAC systems, water heating, and other energy consuming elements within the building.

Some enforcement agencies by code amendment, required all additions to be insulated even though the State standards do not require it. Generally, the glazing area was not considered in these cases.

In some areas, the requirements for slab and underfloor insulation were considered too restrictive because of the difficulty of installation.

In areas where degree day zones adjoin, the significant change in the requirements between zones is questioned. An example is along the Eel River in Humbolt County. One side of the river is less than 4500 degree days, while the other is slightly over 4500 degree days. The local enforcement agencies expressed the opinion that there is a significant increase in requirements; i.e., double glazing, in a short distance and perhaps a more gradual scale would be appropriate.

Product Standards and Acceptance: Few enforcement agencies were aware that insulation is labeled and tested under a voluntary standard as compared to the independent laboratory testing and inspection process for traditionally regulated building products. Consensus is that a product certification and labeling program would be very helpful for plan checking and inspection and also provide needed consumer protection. There is also concern over conflicts between fire safety and energy conservation regulations.

Educational: Virtually all local enforcement agencies interviewed received some training relative to the regulations, usually at a state-conducted seminar or a building official's meeting. Information received at seminars or classes was used for training of other personnel within the agency. Many who attended seminars stated that the technical content of the class materials was not at the level they would have preferred.

One-man enforcement agencies were frequently unable to attend any class or seminar since they had no one to relieve them.

An area of significance is the manner in which the local agencies implemented the standards. The building department seemed to be the principal vehicle for educating the public about the regulations. The initial six months of the program was the most difficult period for implementation.

Much of this related to the changing of the regulations occurring during that period. Local enforcement agencies resent having to act as front man for the State and felt the State should take responsibility for the education of architects, designers, and contractors. However, a frequent comment was that the energy conservation standards were the easiest to implement of all recent State mandated regulations since the contractors and homeowners could see the return on their investment.

Nearly all the enforcement agencies were familiar with the Energy Design Manual for residential buildings and found it to be useful. In a few cases, the manual is treated as the law instead of a guideline, and if a material, method, or assembly is not contained in the manual, it is not permitted. The only complaint relative to the manual was that it was not available soon enough.

Suggested changes to the manual were:

Provide a simplified version.

Provide more data on insulating materials.

Provide more examples for average construction.

Provide example calculations for log cabin type buildings.

Develop simple rules of thumb for tradeoffs.

Provide specific insulation installation details.

Provide construction details for open beam ceilings, underfloor and slab insulation, and unvented roof panels.

B. BUILDERS AND DEVELOPERS

The builder is the individual in the design/construction process who must ultimately execute the work required by the standards and represented in the drawings and specifications. Builders must understand both the requirements and the intent of the standards in order to put them into effective practice. Builders often feel they are not receiving enough assistance from the State. Many feel that insufficient efforts are made to communicate with them.

Design: Builders reported that almost all houses comply with the prescriptive design requirements. Where compliance problems arise, the design is generally changed to meet the prescriptive requirements. Builders of higher quality tracts and custom houses use alternative heat loss calculations more frequently; especially in areas where the view is a saleable commodity. A few use the alternative method for all houses.

Design practice has been affected, and various minor problems and complaints were voiced with respect to this. Some problem has been encountered in satisfying the requirements where open beam ceilings are used. Design problems are also occurring in areas of high humidity; the specified details may result in significant moisture problems. Builders are not typically installing smaller HVAC units, even though the buildings are better insulated.

Construction: Most builders had no trouble with implementation of the regulations. Variation in enforcement and interpretations among enforcement agencies sometimes made the job difficult.

With respect to labor availability, there were no complaints about insufficient numbers of subcontractors, although there was some grumbling about "sloppy work." Predictably, areas with a limited construction season have more problems with delays and scheduling than do those where construction is possible year-round.

Adequacy of Standards: The standards are generally felt to be accepted, although typical complaint recur within environmental zones, showing patterns which point to deficiencies in regional applicability of the standards. Complaints occurred primarily in the severe-climate zones; the general consensus in mountain areas is that insulation requirements are adequate, and in desert areas, that the glazing and orientation provisions do not really address the problem; and that the insulation requirements are designed to save on heating energy rather than air conditioning.

Product Standards: Builders generally consider the performance of labeled products to be consistent with manufacturers claims. Some variability in window quality was noted. Solar products have proved to be so unreliable that most builders would not consider installing solar energy devices until independent and reliable testing for such products is initiated. Many builders would like to see independent testing and certification of all energy conservation products.

C. ARCHITECTS AND ENGINEERS

Involvement of architects and engineers occurs primarily in the design of multi-family dwellings. Most architects and engineers make use of the alternative heat loss analysis. It was found consistently that the reason for utilizing alternative design provisions was to provide more glass area -- for view, feelings of openness, and natural light.

The most frequent mentioned design problem imposed by the standards involves the detailing of an open-beamed (vaulted, cathedral) ceiling. Concrete block is rarely used now because of the difficulty in achieving wall insulation requirements. In the mountain areas, underfloor insulation posed significant problems due to moisture accumulation; alternative design details were called for. The architect of a high-rise hotel noted difficulty in developing a system to satisfy the roof insulation requirements.

Design problems and confusion were caused by changes made to the standards in the early stages of implementation. Problems were also created by nonuniform interpretation by enforcement agencies, probably caused by inadequate training relative to the standards. It was suggested that the State publish interpretations to achieve more uniform enforcement.

Adequacy of Standards: Several who work frequently with heat loss analyses feel a performance standard would be more desirable than the prescriptive standards now in force. As now written, the standards seem to have spawned such "no-think" solutions as using single pane up to the allotted twenty percent and double pane for the glass areas exceeding the limit. On the other hand, the opinion was expressed that the standards are pretty good now, and should not be made more complicated by adding life cycle cost analysis, etc.

Educational: Many architects learned about the energy insulation standards when applying for a building permit; one architect was told by his developer-client. As a result, many designs had to be re-worked to adjust glass areas when the standards first went into effect. Few architects had received any training directly related to the standards.

D. MANUFACTURERS AND SUPPLIERS

The effects of the standards on the insulation and glazing industries were very different. The window manufacturers said they already had windows which met the performance criteria before the effective date of standards. Problems arose with lower quality models, which were dropped or redesigned. The insulation manufacturers and subcontractors, on the other hand, were not required to change their products -- they only had to certify that their products were capable of certain levels of resistance and label them accordingly.

Insulation subcontractors liked the standards and were well prepared for their implementation. Insulation industry associations were a significant force in formulating the content and scope of the standards and in their adoption. The industry as a whole has not experienced any unusual shortages of materials, but increased demand has caused an allocation system to be set up in order to distribute the products statewide. Complaints seem to be centered around competitor's products.

Window manufacturers were generally opposed to the standards and any new restrictions. The loudest complaints were in the area of equity of compliance; i.e., they were complying but their competition was not. Inspection practices regarding windows and their labels and the window manufacturers noted that "unequal inspection creates an unfair market".

A mechanical contractor and supplier reports that it is standard practice to design the HVAC system for the most critical home in a tract. The home with the critical orientation and greatest heat loss is used for sizing the equipment for all the homes in the tract. This means that most of the homes would have oversized equipment. Heating equipment sizes usually cannot be reduced since the standard equipment sizing is controlled by the air conditioner size. Therefore, the heating system is generally oversized because of the air conditioning unit.

Adequacy of Standards: Window manufacturers consistently regarded the glazing standards as too restrictive. They observed that an air conditioned house with windows which eliminated heat gain to reduce cooling loads, worked to the detriment of the heating system in the winter. One suggestion, to remedy this situation, also heard from some builders, was to eliminate the original cooling restrictions, leaving only heating requirements, and instead place a performance specification on the cooling unit itself.

E. CONSUMERS

The California Residential Energy Insulation Standards were designed to reduce energy consumption in the heating and cooling of residential buildings -- and to benefit, ultimately, the consumer as well as the State as a whole. Therefore, in this study, it was thought important to conduct several representative interviews with occupants of residential buildings constructed after the effective date of the standards, recognizing that the information thus gathered might be limited by the average consumer's lack of technical sophistication in the field of energy conservation as well as his late entry into, and lack of control in the building process. Exceptions to these patterns would most likely occur in cases of custom-home building, where an early and often more active collaboration exists between the builder and homeowner. A significant number of homeowners interviewed complained of problems due to poor installation practices.

All of the homeowners interviewed felt that the regulations could be strengthened. Windows, doors, and weatherstripping -- the most visible features of the insulating package -- were most often mentioned as problem areas. The standards seem not to address the special cooling need of homes in very hot summer areas. There appears to be a consumer readiness for home energy conservation, but this is tempered by the consumers lack of sophistication in energy conservation matters.

IV. RECOMMENDATIONS

The following is a brief summary of recommendations resulting from analysis of the data collected.

A. FEDERAL ROLE

The Federal Government should provide funds for the development of educational material for all sectors of the building industry. The goal would be to minimize resistance to the standards by those affected and involved in the building process.

Funding for training and for demonstration projects should be provided at the Federal level since energy conservation is a national priority. Certain elements of energy conservation standards have a negative impact upon some industry groups; thus, there is little incentive for the private sector to develop adequate training courses.

B. STATE GOVERNMENT

Legislative: Legislation enabling the development of energy conservation standards should stipulate that both prescriptive and performance standards be developed.

Standards should not be limited to the envelope of the building, but should include plumbing, electrical, and climate control systems as well.

The legislation should fund continuing technical assistance to local building departments which enforce the standards. This program should include training in enforcement procedures, forms and procedures for review of building plans and specifications, development of an energy conservation manual, and adequate funding to accomplish the program.

Development and Adoption of Standards: The utilization of a representative advisory committee, to assist in the development of energy standards, provides an opportunity to obtain expertise and data on construction practices and the effects of such standards on housing. There should also be funding for consultants to the advisory committee. Even if the advisory committee concept is not used, funds for consultants should be provided.

The lack of public attendance at advisory committee meetings points out the need for additional notification and dissemination of information to obtain the interest of the public.

Administrative: Improve dissemination of standards and technical aids to all sectors of the building industry.

Supporting Implementation Information: The State should study, identify, and make available for the information and use by local agencies, information relative to the following:

Cost impact of the standards -- how much will the additional inspection and plan review cost the city.

Plan check and inspection aids for the several geographic regions of the State to assist local agencies in implementation of the standards.

Communication Channels: Two-way communication between State and local enforcement agencies should be established by a toll free phone number, staffed by individuals competent to answer technical questions.

IMPLEMENTATION AND ENFORCEMENT

Public Awareness: An extensive effort must be made to make the public aware of energy standards prior to their implementation.

Education and Training: A comprehensive educational and training program is necessary for uniform implementation and enforcement of energy standards.

Such a program must be made available to all affected by the standards. This is especially needed by the officials who enforce the standards and have the daily contract with those who must comply with them. The training sessions should be confined to small geographic areas to minimize travel.

A simplified handout should be developed, depicting conventional construction and what is required for conformance with the prescriptive requirements of the standards. There is also a need for education related to good construction practices and details for the insulation of open beam ceilings, floors, slabs, and unvented roof panels. Industry research and development of new and better methods are needed.

C. LOCAL GOVERNMENT

Staffing: Local government officials should understand the need for energy conservation and that its effective implementation will rely on adequate staffing of local building departments.

Communications: Local enforcement agencies should be encouraged to develop better communication with contractors and designers to ease implementation of energy standards.

Relations with the State: Local enforcement agencies should be encouraged to provide input to the State regarding standards, implementation problems, and technical problems.

Equal Enforcement Needed: Local enforcement agencies should uniformly enforce the standards.

TECHNICAL

Inspection Sequence: Local enforcement agencies should be encouraged to require a minimum of one additional called inspection after rough-in to inspect insulation. Additional called inspections for floor and rigid roof insulation should be specified when appropriate. Development of the enforcement sequence could be in concert with local contractors.

Educational: Staff personnel at all levels should be encouraged to take educational offerings relative to energy conservation. Local officials should be encouraged to provide time off, tuition reimbursement, etc., as required for personnel to attend such classes.

Product Approval and Standards: This aspect must be strengthened to improve acceptance of energy conservation products. Testing, certification, labeling, installation, and fire resistance of insulating products should be considered in any standard developed.

The R value for various insulating materials is open to self-certification by the manufacturer, or it is based on R values listed in engineering handbooks. Similar products are advertised and sold with a wide range of R values. Uniform test procedures and certification methods need to be established.

Also, some products are not properly labeled, creating field inspection problems. Labeling criteria need to be established.

Installation of insulating products is also important to the effectiveness of products. Installation instruction should be required.

THE ENERGY CONSERVATION CODE: IMPLEMENTATION IN NEW MEXICO

by

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Officials of the State of New Mexico agreed in September 1976 to adopt the proposed Chapter 53 of the Uniform Building Code (UBC) published by the International Conference of Building Officials (ICBO) with scheduled implementation of July 1, 1977. This paper describes the key elements of an implementation scheme through the utilization of innovative research, development of code Applications Manual, and the conduct of a formal statewide training program for all building officials.

Key Words: Building code; code officials; effective "U" values; energy conservation; implementation; professional competence; training programs.

INTRODUCTION

Because of the prospect of dwindling energy supplies and skyrocketing energy costs, energy conservation in buildings is a major focal point of national policy and legislation as well as the subject of wide interest to the man-on-the-street.

The 1973 oil embargo, and the subsequent energy crisis, had the positive effect of making us all aware of serious national energy problems in terms of the enormous quantities of energy consumed and the equally enormous amounts of energy waste.

In the haste to develop analytical tools to achieve energy savings in buildings, a national consensus standard was assembled which relied on off-the-shelf and widely accepted techniques centering around established steady-state "U" values. The "U" value designates the amount of heat (Btu's) that will pass through one square foot of material in one hour when the temperature on one side is different from the temperature on the other side. U values were used for many years to help determine the size of heating and cooling equipment required to condition the interior of a building for human comfort. The assumption was made that a building in a given area of the country would be subject to maximum and minimum temperatures during the hottest and coldest days. Steady-state heat transfer calculations were then made for those extreme conditions -- how much heat would be lost through the building components (roof/ceiling, walls, and floors) made of materials which would give a particular U value. This method established the maximum amounts of energy which could possibly be required for comfort. The maximums would tell the heating, ventilating and air-conditioning engineer or contractor the size of equipment needed to meet these extreme "peaks". Though it was inaccurate in some respects, the sizing procedure worked reasonably well, because it was not important to be more precise when energy was cheap.

The problem with the method of using steady-state, laboratory U values in such an analysis, as in Project Conserve, is that it does not consider or reflect diurnal temperature cycles, solar radiation, mass effect, thermal storage, re-radiation to the night-black sky, or wind conditions. As a result, it has become apparent that the steady-state analysis of energy consumption is at best approximate; it always results in the oversizing of heating and cooling equipment from 30% to 70%. This oversizing uses more energy than necessary, as well as costing more for the oversized equipment.

In spite of these shortcomings -- "peak" analysis rather than accounting for effects of local climatic conditions -- the building codes proposed for adoption by various States throughout the nation regulate the thermal performance of the building envelope based on the steady-state analysis.

THE NEW MEXICO RESPONSE

The desire to save energy and natural resources is no less intense in New Mexico than anywhere else in the nation -- even though the State is a large energy producer and a relatively small energy consumer.

Under the leadership of Governor Jerry Apodaca, State officials agreed in September 1976 to adopt the proposed Chapter 53 of the Uniform Building Code (UBC) published by the International Conference of Building Officials (ICBO). Implementation was scheduled for July 1, 1977. It was recognized, however, that the strict interpretation of the code would jeopardize certain traditional and innovative construction techniques unique to New Mexico. Therefore, this action was taken with the proviso that research would be undertaken to study the code and devise methods for implementing the provisions of the code specifically for New Mexico. Another stipulation was that a training program be developed and presented to building officials throughout the state prior to the code implementation date.

Research and development projects funded by the New Mexico Energy Resources Board were immediately initiated through the New Mexico Energy Institute at The University of New Mexico. These projects were to focus on innovative concepts which would specifically address the shortcomings of the code and advance the technological state-of-theart in heat transfer and energy conservation.

An analysis of the problems of implementing the energy conservation code in New Mexico resulted in the conclusion that the key problem was a failure to distinguish between the steady-state U values of different materials and their dynamic performance. Therefore, the main thrust of the research centered on New Mexico's varying climatic regions (from low arid desert to high Canadian alpine) characterized by large diurnal temperature differences and a very high incidence of solar radiation. It is well known that solar gains are present in every building and may be used to effect a net reduction in the total building energy requirements. Hence, the research objective was to establish a quantitative basis for the incorporation of the basic concepts of solar flux through windows and onto walls into architectural design. The proposed strategy was to replace steady-state U values, in the overall prescriptive analysis, with effective U values which characterize the dynamic performance of various wall types. In essence, the effective U value, which takes into account solar input and time-dependent boundary conditions, is a measured average heat transfer or, more specifically, the ratio of the average heat flux on the inside surface of the wall over an extended period of time to the average temperature difference between inside and outside over the same time interval.

The preliminary results of the theoretical analysis of effective U values have been astounding; they have led to a better understanding and documentation of the performance characteristics of building components in the climatic regions of New Mexico. Most importantly, the research has pointed the way toward implementing the prescriptive energy conservation code through the utilization of performance-based criteria.

The unique aspect of these efforts in New Mexico is reflected by the fact that the results of this innovative research are being applied directly to implementation of the energy conservation code by utilizing effective U values in determining code compliance. Effective U values for 26 different wall types in 11 climatic regions of New Mexico have been tabulated and disseminated throughout the State. Thus, the potential for achieving energy savings in new structures will be greatly enhanced while obtaining construction savings at the same time.

While energy conservation codes specifically address new buildings, a great deal of insight on all existing buildings may be obtained in relation to energy consumption data, energy audit capability, and developing retrofit opportunities. Once the performance of building components is thoroughly understood and documented, a realistic cost/benefit life cycle analysis of retrofit actions may be recommended. This potential makes technology transfer to other states even more significant.

THE TRAINING PROGRAM

Recognizing the complex language of the energy conservation code and the degree of sophistication required to understand it, the State, through the Energy Resources Board, awarded contracts to the New Mexico Energy Institute to 1) develop an "Applications Manual" interpreting Chapter 53 specifically for New Mexico, and 2) develop and conduct a training program for building officials based on the manual. This work, to be completed by 30 June 1977, was undertaken with the stipulation that it would be fully coordinated with the New Mexico Construction Industries Commission as well as a review committee consisting of representatives of various building industries throughout the State.

As the agency legally responsible for the enforcement of building codes adopted by the State, the Commission exercises administrative control over all building officials, whether employed by individual municipalities or by the State, and is the largest source of information concerning them. This information and other technical assistance provided by the Commission staff proved vital to the development and implementation of the training program.

Further assistance was provided through participation with the ERDA-sponsored program entitled "Energy Conservation Technology Program for State and Local Building Officials" developed by NCSBCS, a consortium of building code organizations. Information acquired through coordination with this program assisted in the development of the basic organization and content of both the Applications Manual and the training program.

THE APPLICATIONS MANUAL

An Applications Manual was designed and developed to serve as the nucleus of the training program and as an educational text for use by building officials during the workshop program as well as a working reference guide to be used later on the job. In its final form, the manual contained over 100 pages of charts and tables incorporating data pertinent to code enforcement in the eleven different climatic regions in New Mexico. The following, from the manual's table of contents, briefly summarizes its organization and content.

INTRODUCTION

What This Applications Manual Is All About, and Why?

Some important questions are discussed as to the need for this course and fulfillment of the State law, the origin and nature of the building code, background knowledge required to apply the new code fairly, an appreciation of the variety of factors to be considered in the overall appraisal of energy conservation materials and techniques, and the role of the building official in the enforcement of the new code.

Part I

What You Need To Know About ENERGY FUNDAMENTALS

Introductory remarks about energy and heat transfer presented for general knowledge rather than as an exhaustive treatment with emphasis on an appreciation of the problems that may be met when considering the many factors of energy conservation in buildings ... including heat measurement, the flow of heat, heat loss, fundamentals of human comfort, and factors affecting energy consumption in buildings.

Part II

What Does THE CODE Mean?

A presentation of detailed information of the content, Chapter 53 of the Uniform Building Code, intended to provide the building official with all aspects of the code, how the various sections work together through the specific requirements of the building envelope, the mechanical systems, and the electrical systems regulated by the code.

Part III

APPLICATIONS of The Code

After learning the basics of energy fundamentals and the details of the energy conservation code, how is the knowledge applied on the job? Three elements of construction are tied together in this Part: the builder needs to know what is required of him for code compliance; the plan checker needs to know all elements of acceptable code compliance; and the field inspector needs to know what he is looking for on the job and to relate the information on the plan to the construction site.

APPENDICES

Reference Materials And Aids

A collection of charts, tables, schematics, drawing details, and checksheets provided to aid the builder, the inspector, and the plan checker in working out whatever calculations may be required for field use of the knowledge gained in energy conservation construction.

As mentioned previously, the unique feature of New Mexico's approach to implementing Chapter 53 involves the concept of "Effective U Values." These values, unlike traditional steady-state U values, take into account the large diurnal temperature differences and the high incidence of solar radiation relatively unique to New Mexico. This concept significantly alters more established concepts concerning the thermal performance characteristics of building materials commonly used in New Mexico.

On a limited basis, the Construction Industries Commission has authorized the use of effective U values in determining code compliance. Individual pages tabulating effective U values for a number of wall types were included in the Applications Manual. Since research continues, and many more pages are contemplated, the manual was produced in loose-leaf form for ease in updating. In addition, manuals were numbered and accounted for by owner to facilitate the updating process.

DEVELOPMENT OF THE TRAINING PROGRAM

Since the Applications Manual was designed to form the basis for the training program, a critical effort centered around the presentation. It was determined early in the program that, excluding administrators and senior supervisors, building officials may be divided into two job categories:

1. <u>Plan Checkers</u> -- officials who review and approve plans for code conformance prior to issuance of a building permit, and

2. Field Inspectors -- officials who inspect actual construction to assure compliance with plans and codes.

Of the roughly 120 building officials in New Mexico, approximately 15% are Plan Checkers. Plan Checkers typically have completed 16 years of education and have a Bachelor's degree in Architecture, Engineering, or some similar field. Field inspectors constitute the remaining 85% of building officials. Field inspectors typically have completed 12 years of education and have a high school diploma. Based upon this and other information furnished by the Commission, it was determined that the training program should have the following characteristics:

1. It should be structured as a workshop requiring a high level of active participation by the building officials. Interaction between the officials and the instructors was to be encouraged at all times. Sample problems directly related to the officials' specific role in code enforcement should be presented and solved during the workshop.

2. The presentation should employ a wide variety of film strips, slides, and other visual aids to illustrate the more abstract concepts of energy fundamentals and to lead the officials step by step through the various mathematical calculations required by the code.

3. The portion of the workshop dealing with the actual application of the code should be divided into two sections: one for Plan Checkers concentrating on their role of reviewing plans for code conformance, and one for Field Inspectors concentrating on their role of conformance of construction to the approved plans and the intent of the code.

4. The overall program should be conducted in a single eight-hour day. Although eight hours is probably short of the time needed to fully absorb the material, it represents the maximum amount of time the average building official, given his normal workload, can spend away from his job. The approximate subject-time allotment of the workshop was as follows:

Introduction	3/4 hours
Part I - Energy Fundamentals	2 1/2 hours
Part II - The Code	1 1/2 hours
Part III - Application of the Code	2 1/4 hours

INSTRUCTORS

The selection of instructors for the program was recognized as critical since the material to be presented was comprehensive and complex. The ability to relate to building officials and to establish a comfortable rapport with them was important, and this, together with the fact that the program was largely vocational in concept, suggested that the instructors should have a strong vocational education background. The vision of the university professor lecturing down to the building official seemed to guarantee a turned-off audience. Therefore, the Albuquerque Technical Vocational Institute was contacted and arrangements ultimately were made for the release of two instructors to team-teach the workshop.

Both individuals have architectural degrees and 4 to 5 years experience as vocational education instructors. In addition, both were familiar with building codes and both had interacted with building officials in a variety of situations. This combination of qualifications fit the requirements well and proved to be extremely successful.

MARKETING THE TRAINING PROGRAM

Planning for the implementation of the program involved such matters as the promotion of the program, the selection of appropriate facilities in which to conduct the workshops in each of the five designated cities, and the scheduling of the workshops in those cities.

Promotion of the program to ensure maximum attendance was suggested by the Institute and conducted by the Construction Industries Commission. The Commission first arranged for the Governor of New Mexico to send a letter to the mayors of all municipalities urging them to release their building officials to attend the training program. The Commission followed this letter with one of its own addressed to individual building officials to strongly suggest and request their attendance. In addition, an announcement was made in the monthly newsletter of the New Mexico Chapter of the American Society of Building and Construction Inspectors as well as other publications throughout the State including the local newspapers.

This marketing approach was extremely successful as reflected in the 97% attendance record.

FACILITIES

The five cities in which the workshops were to be held were located geographically throughout the State for the convenience of the building officials. The five separate workshops assured minimum commuting time for officials and, if necessary, the opportunity to attend an alternative workshop at a more convenient date and location.

The amount of time allocated for the preparation of the Applications Manual and the development of the training program made it apparent from the outset that the workshops should be scheduled as late in June as possible. The schedule called for workshops in Las Cruces and Roswell in the southern part of the State in one week, Santa Fe and Farmington in the northern part of the State the following week, and Albuquerque, the largest city, on the final Saturday of the month. Because of the level of construction activity in Albuquerque, the Superintendent of the Building and Inspection Division for Albuquerque opted to hold the workshop on a Saturday so that the Division would not have to miss an entire working day. This schedule also provided the Institute the opportunity to conduct planning and evaluation sessions with the instructors on days between workshops.

In view of the desirability of holding the building official group together for the entire workshop day, it was determined that motels or inns with integrated restaurants were the most appropriate facilities in which to hold the workshops. Building officials and instructional staff were released in a group to the restaurant for lunch and tended to remain on the premises until resumption of the workshop. In this manner, an orderly transition from the morning to the afternoon was assured.

TRAINING PROGRAM EVALUATION

In total, the workshops attracted over 97% of building code officials throughout the State, and their reaction to the program was very enthusiastic.

At the conclusion of a workshop, each building official was asked to complete a course evaluation giving his opinion of the categories of materials presented and the methods of presentation. Comments and suggestions were also solicited. In most instances, the evaluations were returned unsigned. Approximately 90% of the officials rated both categories "Very Good" to "Excellent" (4 to 5 on a 5-point scale). The most critical comment offered concerned the length of the presentation. Many officials felt it was too short. This reaction was not unexpected, and funding has already been approved to conduct the follow-on workshops at six-month intervals through June 1978.

The consensus of Construction Industry Commission officials and administrators is that the workshops contributed greatly to the knowledge of building officials and were a stimulating experience for them. They believed that building official participation in the workshops will result in fewer job-related problems and better code enforcement.

SUMMARY

In conclusion, from all indications, the overall program has been a resounding success. There is little doubt that this stems in part of the fact that it filled a specific need for timely energy conservation information as well as fulfilling the mandate of public law. Many workshop participants pointedly expressed gratitude and appreciation for the training and stated that it may have been the first time they had seen a government organization do something right.

The success of the training program has prompted the initiation of another project to present the same course to building contractors, architects, and engineers. Such a program is already underway.

IMPACT OF STATE MANDATED THERMAL EFFICIENCY STANDARDS ON COUNTIES

by

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Nineteen States have adopted energy-related building regulations since the 1973 Arab oil embargo, but there is considerable variation among the States according to performance and prescriptive criteria, mandatory and voluntary regulations, etc.

The remaining States will soon be adopting thermal efficiency codes as part of their State Energy Conservation Plans, and the Department of Housing and Urban Development is currently developing a national standard for new buildings.

Hundreds of counties have been required to enforce the existing State-mandated codes, and many hundreds more will become involved in the near future.

The National Association of Counties Reasearch Foundation studied the effects of State-mandated thermal efficiency codes on five counties. We found that those codes requiring only a minimal amount of insulation and double glazing for windows appeared to present no major legal, political, operational, or financial problems for counties. Experience with more sophisticated codes is limited.

Key Words: Buildings; counties; energy conservation; enforcement; insulation; regulations; standards; State legislation; thermal efficiency.

INTRODUCTION

The purpose of the study was to determine what effect on counties the implementation of State-mandated Thermal Efficiency Codes (T.E.C.) has had, if any.

When this study was undertaken (July 1976), there were nineteen (19) States with authority to regulate energy use through the regulation of the design and the construction of new buildings.

In sixteen States a statewide building code was a vehicle for energy regulations:

Connecticut	North Carolina
Florida	New Jersey
Idaho	Ohio
Massachusetts	Oregon
Michigan	Rhode Island
Minnesota	Virginia
Montana	Washington
New Mexico	Wisconsin

Three States have energy regulations separate from statewide building code authority: California, Nevada, and New York.

From among these, four States were selected from among which four counties would be chosen. The criteria used in the selection process were:

1) Has the State made progress on energy conservation standards?

2) Representation of different climatic and geographical regions?

3) Amount of construction activity?

4) Type of construction activity (residential: wood, frame, brick, other)?

5) Representation of varying population sizes and characteristics.

6) Sophistication of the enforcement system?

7) Local authority and interaction between the States and counties?

8) Energy consumption patterns?

The States of California, Minnesota, North Carolina and Oregon were selected for study.

The criteria used to determine which counties should be studied follows:

1) Was the county implementing a State thermal efficiency code?

2) Was sufficient building activity occurring to provide experience and a data base?

3) Did the county have a professional staff willing to participate in the study?

4) The urban-rural mix, size of county, growth rate and any unique features were also considered?

The five counties selected for study were:

Lane County, Oregon; Mecklenburg County, North Carolina; Montgomery County, Maryland; Sacramento County, California; and Washington County, Minnesota.

Montgomery County, Maryland, was added to the list of counties to study because of their effort to undertake a local T.E.C. in the absence of a State code.

Since the majority of States do not have either a State energy or building code, a free-standing process might be of interest to a large number of counties in the country.

The methodology of the study was:

a) Background information: familiarization with Federal energy law; energy code issues (prescriptive vs. performance); status of State codes and background gathering on the roles of Federal and State energy agencies.

b) A task force composed of five elected and five appointed members reviewed the proposed project activities. They also reviewed and approved the final report.

c) The field study (data gathering) involved reviewing the State and local energy codes, and interviewing numerous State and local officials involved with energy. Interviews with builders, lenders, architects, and citizen committee members were also conducted.

d) The data was analyzed to determine what effects were reported. They were grouped into four broad categories: legal, political, financial and operational effects.

e) A draft report was prepared which reported each of the case studies and the conclusions drawn from them. The task force reviewed and approved the report on March 3, 1977.

It became apparent in the course of the study that State mandated thermal efficiency codes should be analyzed in the context of the total situation because a number of factors external to the T.E.C. affect the type and degree of impacts. For example, the particular climate of the county affects the number of heating/cooling degree days and the energy consumption patterns. It became apparent that the degree to which the population believes a need for energy conservation exists appears to affect the timing and extensiveness of the energy legislation. Consequently, the energy situation in each State was examined to reveal supply and consumption patterns and shortages, if any.

The energy situation affects the economic health of the State and the county. Without adequate supplies of energy, growth cannot occur. Counties in a growth situation respond to demands for new subdivisions through their planning function. New homes mean more streets and highways, water and sewer system growth. Increased gasoline usage brings additional per capita excise tax revenue to counties. Franchise taxes on utilities provide added income. As patterns of growth expand over a long period of time, counties become accustomed to increased increments of revenue and expenditure.

Without adequate energy supplies the growth situation of the counties would change dramatically.

The growth experience of each county in the area of single family homes is presented below:

Number of Single Family Housing Permits
1970 - 1976

	1970	1971	1972	1973	1974	1975	1976
Sacramento	2269	2712	2914	2428	2990	3500	5490
Lane	569	680	675	574	476	481	609
Washington	-	-	1261	1015	1038	980	1416
Montgomery	2685	3006	3238	3265	1730	590	1178
Mecklenburg	3341	5198	7660	8088	1966	1628	2140

The energy conservation codes examined are both prescriptive and performance codes. That is, if the builder produces component parts (walls, floors and ceilings) which meet the thermal transmittance values of a prescriptive code the building is presumed to achieve the desired thermal performance. A performance code permits the builder to vary the thermal resistance of the component parts so long as the desired overall thermal performance is achieved.

OVERVIEW OF STATE THERMAL CODES

The chart on page 328 compares the codes of our States and Montgomery County (Proposed) to the draft Model Energy Conservation Code. (ERDA, January, 1977.)

The model code is based on the ASHRAE 90-75 standard. The comparison reveals important differences between the model and the codes.

The codes are divided into two categories:

a) First generation codes refer to the initial energy conservation codes adopted by California, Oregon and North Carolina. Their scope is limited to residential buildings and they each establish standard construction practices as the minimum. They address the thermal efficiency of the building envelope, i.e., wall, ceiling, floor and window components. A major revision of the energy code is under consideration in each of these States.

b) Second generation codes address a different magnitude of concern. They apply to all building, and establish minimum standards for the building envelope. They also address the environment of the building, i.e., its relationship to the sun, wind, shade trees, etc. The performance capability of heating/cooling equipment, water heaters, manufactured doors and windows--the operating systems--are addressed. The standards applied may exceed the current practices of both builders and manufacturers.

A major difference between the model code and the codes of the three States and Montgomery County is the 70 degrees or lower design temperature for winter compared to 72 degrees for the model code. (North Carolina has no specific standard in its code). The lower design temperature saves fuel at the rate of approximately 3 percent per degree.[(1)]

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[1] The report by Arthur D. Little Company (July, 1976) asserts that the ASHRAE 90-75 Standard as applied to residential buildings produces approximately an 11 percent energy savings. The same report estimates a 50% energy savings for office buildings constructed according to the ASHRAE 90-75 Standard. In each case the initial per square foot cost for building construction is reduced.

COMPARISON: MODEL CODE WITH THE CODES OF THE FIVE COUNTIES STUDIED

		FIRST GENERATION CODES			SECOND GENERATION CODES	
ITEM	MODEL CODE	CALIFORNIA	NO. CAROLINA	OREGON	MARYLAND*	MINNESOTA
Scope	All new buildings w/human occupancy	Inhabited residential structures	1 & 2 family; and multi-family bldgs 3 stories or less in height	Residential bldgs 3 stories or less in height	All conditioned buildings	All condi- buildings incl. remodeling and additions
Design Parameters	72° winter 78° summer	70° winter 78° summer		70° winter	70°winter 78°summer	68° winter 78°summer
Alternative analysis system permited	yes	yes	yes	yes	yes	yes
Thermal transmittance values	values of each component related to no. of degree days					
-ceilings		.05	.05	.05	.05	.05
-walls		.08	.08-.17	.08	.04 residential	.17
-floors (slab on grade)		.0-.08	.12-.08	.20-.09	varies w/const.	
Fenestration	no area limits Uo varies w/% of fenestration	no area limits	no limits; where fenestration exceeds 20%, Uo must equal .65	no limits; where fenestration exceeds 20%, Uo must equal .70	no limits; Uo value declines as fenestration increases	no area limits but heat transmission limited to 120BTU/hr/ sq. ft.
Condensation Control		none	vapor barrier	vapor barrier		specified
Air infiltration		Ansi Stds.	weather stripping required	none	ASTM E-283 Std. applies	ASTME-283 Std. applies
Limitation on capacity of heating/cooling system	design requirements specified	none	none	none	specifies minimum COP**	equipment limited to: a) heating 115% of design capacity b) cooling 100% of design capacity
Workmanship standards	none	none	yes	none	none	yes
Building Orientation to sun	none	none	none	none	none	yes

*Source: "Draft Energy Conservation Amendments" by Charles Rand, Assistant County Attorney, December 1976

** Coefficient of Performance

The combination of condensation, air infiltration and workmanship determine to a large extent the thermal effectivemess of a building. No standard has been adopted for condesation control although two States specify vapor barriers and the presumption is they are adequate. In the first generation code States of California, North Carolina and Oregon, only one (California) has adopted standards limiting the air inflow per linear foot of crack. North Carolina requires weather stripping only and Oregon establishes no standard. Workmanship standards are mentioned only in North Carolina and in neither of the other two first generation States.

By contrast the second generation codes of Maryland and Minnesota specify air infiltration standards. Maryland is silent on condensation and workmanship while Minnesota is specific in legislating in both categories.

Although the thermal transmittance values vary among the State codes, the degree of variation is low considering the extreme difference among the weather conditions of the different counties. For example, Sacremento County has 2800 degree days annually whereas, parts of Lane County exceed 7000 degree days.

Fenestration (windows) is the greatest source of hat lost in the building envelope, yet all of the codes are premissive to the extent that they do not limit te amount of fenestration rather they require double glazing when fenestration exceeds 20 percent of the wall or floor area.

WASHINGTON COUNTY, MINNESOTA

The Minnesota Energy Agency reports energy consumption for 1975 and projects usage in 1985 as follows:

Energy Consumption 1975 - 1985
(Figures in Trillion BTU)

Source	1975	Percent of total	1985	Percent of total
Petroleum	485	44	669	41.0
Natural Gas	326	29	281	17.3
Electricity	111	10	123	7.6
Coal	183	17	553	34.1
Total	1105	100	1626	100

The Agency's conclusions are:

a) Petroleum will maintain its relative share of the market.

b) Natural gas will be in short supply and occupy a declining share of the market.

c) Electricity cannot bear a greater proportion of the energy load because the long lead times prevent generating capacity from coming on line by 1985.

d) Coal consumption will increase significantly. Considerable shifting from natural gas to coal by industry is expected.

e) The total BTU's consumed will increase from 1105 trillion in 1975 to 1626 trillion in 1985. A 47% increase.

Some important assumptions are made:

a) Canadian crude oil which made up 25% of the total energy supply for the State in 1975 will no longer be available. The Agency believes either Alaskan or Arab oil will be available and can be delivered. However, existing capacity in the pipelines entering the State are not adequate to serve 1985 needs and it is assumed an adequate delivery system will be available.

b) Since natural gas will decrease in total volume, industry will convert to another fuel. Only coal appears to be available. Whether adequate environmental standards can be met is not known.

c) A 47% increase in consumption for the decade 1975 - 1985 is projected. The assumptions are:

   1) fuel will be available in sufficient quantity, and,

   2) fuel prices will not be so high as to divert growth to lower energy cost areas of the country.

Washington County is in the growth path of the Minneapolis - St. Paul metro area. The building department work-load is generated mainly by the volume of new building activity created by the growth phenomenon. If growth is energy dependent and if the state's supply projections prove high, the current demand for new buildings in Washington County could slacken.

The Minnesota Energy Code is the most complex and far reaching of the five states studied because:

a) It applies to all buildings.

b) It is a minimum and a maximum code - none of the other codes are both. The minimum aspects relate to thermal efficiency standards while the maximum apply to equipment sizing and use of energy in humidification, dehumidification, and lighting.

c) It is both a performance and a prescriptive code. The builder may choose the Alternate Energy Analysis Method. The amount of staff time required is much greater if the performance approach is selected.

d) The code provides for local enforcement.

e) The number of items is more extensive than the other codes.

f) The code permits the application of an orientation standard for siting buildings.

The effects of the Minnesota Code on Washington County are assessed below.

EFFECTS OF CODE

Operational Effects:

The County Building Official began accepting responsibility for the Minnesota Energy Code during its preparatory stages. The Building Official attended meetings, hearings, read drafts, commented and otherwise participated in the code preparation.

Subsequent to passage, the Building Official established administrative policies governing implementation by:

a) defining plan check and building inspection work;

b) creating a work flow system;

c) controlling the quantity and quality of work through a checklist system and an energy evaluation form;

d) determining that training was needed and designating those who should receive it.

The work of the Washington County plan checker is more difficult than in other States where plans are reviewed only for the appropriate "R" value of insulation. Specifically he must:

a) determine and/or review calculations of areas and thermal transmittance values for exterior walls, roof-ceiling areas, windows, doors, floors over unheated spaces, air infiltration and water vapor condensation, based upon the minimum provisions of the Code;

b) perform a site and shape analysis;

c) check for code conformance of heating, ventilation, air conditioning systems, service water heating, electrical distribution and lighting systems under the maximum provisions of the code;

d) be capable of using the Alternate Energy Analysis Method.

The building inspector's task is also different as he:

a) conducts on-site inspection to ensure that insulation is properly installed (foundation, walls, ceilings);

b) checks to see that manufactured components such as windows, doors, skylights, etc., are as specified in the plans and are correctly installed;

c) determines that the heating equipment operates within 115% of the design standard and that the air conditioning does not exceed the design standard;

d) makes observations of air infiltration and fenestration.

Washington County implementation costs for the Minnesota Energy Act are estimated as follows:

a) initial administrative work cost about $500;

b) initial training costs were $1,000 for the first year and estimated at $500/year thereafter;

c) plan check time has increased about 45 minutes per set of plans. At an hourly rate of $7.25/hr. the average cost per set of plans is $5.43. Gross first year costs are about $7,700 for 1416 dwelling units;

d) inspections require about 120 minutes per house including travel time. Cost is estimated at $15 per house and $7,500 total for the year;

e) total impact equates to one full-time staff position equivalent in the estimation of the Building Official.

Political Effects:

The Chairman of the Board of County Commissioners can discern no political effects from the Minnesota Thermal Efficiency Code. The affected public responded to interview questions as follows:

a) builders accept the code as fair and complete. interpretation by Administrators has also been fair;

b) architects accept the code and note that no official position was taken from their State Association. The flexibility provided by the Alternate Energy Analysis method is respected. They point out, however, the code as written requires a "double design," i.e., a standard component design plus the alternate. Thus, it is likely the systems analysis approach will not be widely used.

Builders, architects and public officials report high public acceptance of the code. The fact that the State brought affected parties together to help write the code seems to have increased the acceptance level.

Legal Effects:

The County Attorney reports no legal actions involving thermal efficiency standards. He notes, however, that a State law imposes a requirement to act on the part of county officials and a failure to act could create some legal consequences.

Because the Alternate Energy Analysis Method allows flexibility in designing and constructing buildings and because the affected parties believe administrative interpretations have been fair, little incentive for legal action exists.

Financial Effects:

The principal economic effects of the thermal efficiency code are two-fold: somewhat higher capital costs for the home buyer and higher administrative costs for the county.

A builder of quality homes believes the State requirements have not increased costs to him because his construction practices exceed requirements adopted. A builder of more moderately priced homes ($25,000 to $30,000) finds his insulation costs increased approximately $150 per home. The builders report the code is cost-effective.

The public costs were examined in detail by the Building Official and he reports:

> The public costs for current administration, training, forms, overtime, approach $15,000 per year for up to 1,500 homes. No budget increases occurred during the first year due to a lack of actual experience data. For the second year of the program, one additional staff position was

added, at approximately $15,000 per year, directly attributable to energy code enforcement.

Existing fee schedule, which was originally established in 1972, was not increased during first year of program; however, based upon the experience of the first year, the fees are projected to be increased during the second year, only in part due to the impact of energy code requirements. Fee increases related to Energy Code are anticipated to average $20.00 or less per single family dwelling.

REFERENCES

Minnesota Energy Agency, "Minnesota's Energy Situation, A Biennial Report to the Governor," January, 1976.

Minnesota Energy Agency and Building Codes, "Implementation of a Statewide Energy Code for Buildings," August 27, 1976.

Minnesota State Regulations; SBC 60001-6013, "Energy Conservation in New Buildings, Additions and Remodeled Elements of Buildings."

MECKLENBURG COUNTY, NORTH CAROLINA

North Carolina has been a pioneer in the field of State building regulations. The first building laws were passed in 1903. The authority to promulgate a statewide building code was delegated in 1933 to a Building Code Council composed of citizens. In 1957, the Council adopted a policy of permitting local variations only if "absolutely necessary" in an effort to make the code more uniform throughout the State. The Council adopted Chapter XXXII, Building Insulation Standards in September 1974 and made them effective as of January 1, 1975.

IMPLEMENTATION EFFECTS

Operational Effects:

On January 1, 1975, Mecklenburg County began enforcing the North Carolina Building Insulation Code for all residential dwellings of three stories or less in height. In the past two years, the code has been applied to 3700 new residential units. The administrator of the county building department interprets the North Carolina Code as both a prescriptive and performance code.

A prescriptive code requires the builder to meet a specific thermal transmittance (Uo) value for the component of the building envelope. A performance code permits the Uo values of the component parts to vary, providing the equivalent overall thermal performance is achieved.

The county decided on a series of actions in order to implement the code:

a) job descriptions were amended to include a thermal element in the plan check and site inspection functions;

b) work flow was organized;

c) a check list of activities for the plan checker and building inspector was developed to control work quality.

The energy code did not require any reorganization of the Building Inspection Department. The roles of the electrical, mechanical, and plumbing divisions did not change.

The implementation of the State Insulation Code has two principal effects on Mecklenburg County:

1) the plan check process required 10 additional minutes per residential building;

2) the site inspection process required 15 more minutes (if the insulation was not ready when the framing inspection was conducted an additional hour for the return inspection became necessary).

The added work did not require additional staff although some additional training was necessary the cost of which was absorbed in-house. The management and operation of the county building department has been minimally affected by the State Insulation Code.

Political Effects:

The chairperson of the County Commission finds high public acceptance of the county's involvement in numerous energy conservation activities. She reports no negative repercussions from the county's enforcement of State Mandated Building Insulation Standards.

Financial Effects:

The enforcement of State Building Insulation Standards has had a minimal fiscal effect on the county. Revenue to the county has not increased. Permit fees have not changed. Total budget costs have not increased. The added work load has been absorbed without changes in staffing patterns. No capital outlays have been requested. Overhead cost increases have been minimal, i.e., a few hundred dollars for training and printing new forms has been absorbed in the current budget.

The additional time required to process plans (10 minutes each) and perform site inspections (15 minutes normally) has been absorbed by current staff.

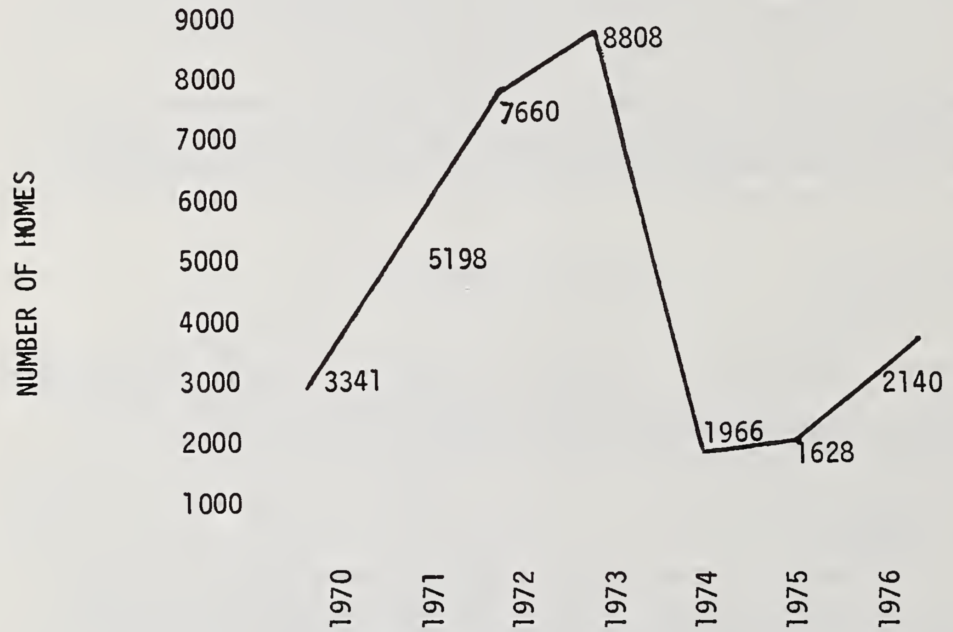
Building activity has declined from a high of 8,088 new single family units in 1973 to 2,140 in 1976 due to changing economic conditions, not thermal standards.

The recent history of rapid fluctuation in housing starts has permitted the Building Department to allocate time to other energy-related matters such as energy management of county buildings, a citizen's survey committee and demonstration projects, in addition to the enforcement of the energy code.

Figure I illustrates the changing annual volumes of single family housing starts between 1970 and 1976.

FIGURE I

MECKLENBURG COUNTY SINGLE FAMILY HOUSING STARTS
1970 - 1976



When the county recovers its previous growth rate, more staff will be required to handle the same number of permits because of the time required by the thermal code. However, at the present time, the fiscal impacts on the county budget are deferred because of factors external to the state code.

The private costs are not deferred. Builders report the selling price of a "typical" three bedroom house has increased from $38,500 in 1974 to $42,500 in 1976. Approximately 10% of the $4,000 increase is attributed to energy-related equipment such as storm windows, improved heating units, and additional insulation. But, builders report that energy improvements are cost-effective because the increased costs are returned through lower heating and cooling bills within a five year period according to a cost-benefit analysis. The impact on the cost of homes varies. The "budget" home may not have been constructed to the standards of the new insulation code. A new home may cost about $200 - $400 more.

No delays in the plan approval process have been experienced by builders. The latter is confirmed by the Building Official. One builder reports construction delays are caused by the State insulation code. He says a slab-on-grade foundation inspection can now require two additional days. Insulation at the foundation parameter can mean a one day delay. If a crawl space is built instead of a heated basement, a delay of one day can occur. No estimate of the dollar cost of construction delays is available. The delays are disputed by the County, the County Engineer and Building Official.

A lender reports the loan quality of buildings is affected by insulation standards:

a) a loan request would be adversely affected by the absence of insulation;

b) a high degree of thermal efficiency enhances the loan quality particularly if the home is all electric;

c) financial capacity of the borrower remains the dominant criteria for granting loans.

This lender reports that only a few years ago the ability of the borrower to carry the principal and interest was the determining factor for lenders. Today the cost of operation is a consideration. This lender will permit monthly principal and interest payment to exceed 25% of monthly income and may range in the 27 - 28% area.

Legal Effects:

In the County Attorney's opinion:

a) the county has incurred no additional liability from the enforcement of State code;

b) the prescriptive and performance characteristics of the code have not increased the county's legal liabilities for acts performed under the code.

Summary:

The County experienced no difficulty in the start-up phase of implementing the new North Carolina Building Insulation Standards. Its experience with 3,700 single family housing units built under the code has been:

a) No adverse political and legal ramifications.

b) Lenders recognize the value of thermally efficient buildings and are adjusting loan practices accordingly.

c) Financial effects are:

   1) Cost of previously uninsulated and under-insulated homes has increased $200 - $400.

   2) The administration of the code has caused no delays in the plan approval process.

   3) Construction delays are alleged due to site inspection related reasons. The county disputes the allegation.

   4) The code requirements are cost effective.

d) The operational effects are minimal. The additional work has been absorbed by existing staff.

NORTH CAROLINA REFERENCES

The North Carolina Department of Military Affairs, Energy Division (the responsible agency) supplied the following documents:

1) North Carolina's Energy Outlook for 1975; (February, 1975)

2) North Carolina's Energy Outlook for 1976; undated

3) Typical Energy Cost Increases for the Raleigh Area and Some Factors Affecting the Increases; October, 1974.

4) Energy Consumption in North Carolina Manufacturing Industries; 1972; (June, 1975)

5) North Carolina Petroleum Distribution; (March, 1975)

6) North Carolina Inter-Agency Task Force Report on Natural Gas; (November, 1976)

7) North Carolina Building Code, Volume I, General Construction plus amendments adopted January 1, 1967, then January 1, 1976.

Oregon is one of sixteen States with energy regulations in effect at the present time. The Oregon Building Code is a statewide code based on the Uniform Building Code (UBC). The recommended provisions for an energy code are found in Chapter 53 of the UBC which the State modified and limited to residential structures.

The energy situation in Oregon has been analyzed by the Oregon Department of Energy. Data pertinent to this study is summarized below.

Four trends in residential energy consumption are depicted in Table I:

a) the average annual rate of growth is 5.7 percent per year for total residential consumption;

b) petroleum declined from 46.9 to 21.6 percent of the residential market;

c) electricity grew from 38.1 percent to 49.8 percent of the residential energy market replacing petroleum as the prime energy source.

TABLE I

RESIDENTIAL ENERGY CONSUMPTION

YEAR	TOTAL (10^{12} BTU)	PETROLEUM* 10^{12}BTU	%	ELECTRICITY 10^{12}BTU	%	NATURAL GAS 10^{12}BTU	%
1962	53.5	25.1	46.9	20.4	38.1	8.0	15.0
1963	58.7	27.9	47.5	21.7	36.9	9.1	15.6
1964	66.0	31.2	47.2	23.6	35.8	11.2	17.0
1965	64.7	28.9	44.8	24.1	37.3	11.6	18.0
1966	67.1	28.2	42.1	25.7	38.3	13.2	19.7
1967	67.6	26.6	39.4	26.7	39.5	14.3	21.1
1968	71.7	27.1	37.8	28.6	39.9	16.0	22.3
1969	78.1	27.6	35.3	31.7	40.5	18.8	24.1
1970	77.9	25.6	32.9	32.7	41.9	19.6	25.2
1971	85.0	26.5	31.2	36.1	42.4	22.4	26.3
1972	86.7	25.8	29.7	37.8	43.6	23.2	26.7
1973	84.1	21.9	26.0	39.1	46.6	23.1	27.4
1974	80.0	17.3	21.6	39.9	49.8	22.8	28.5

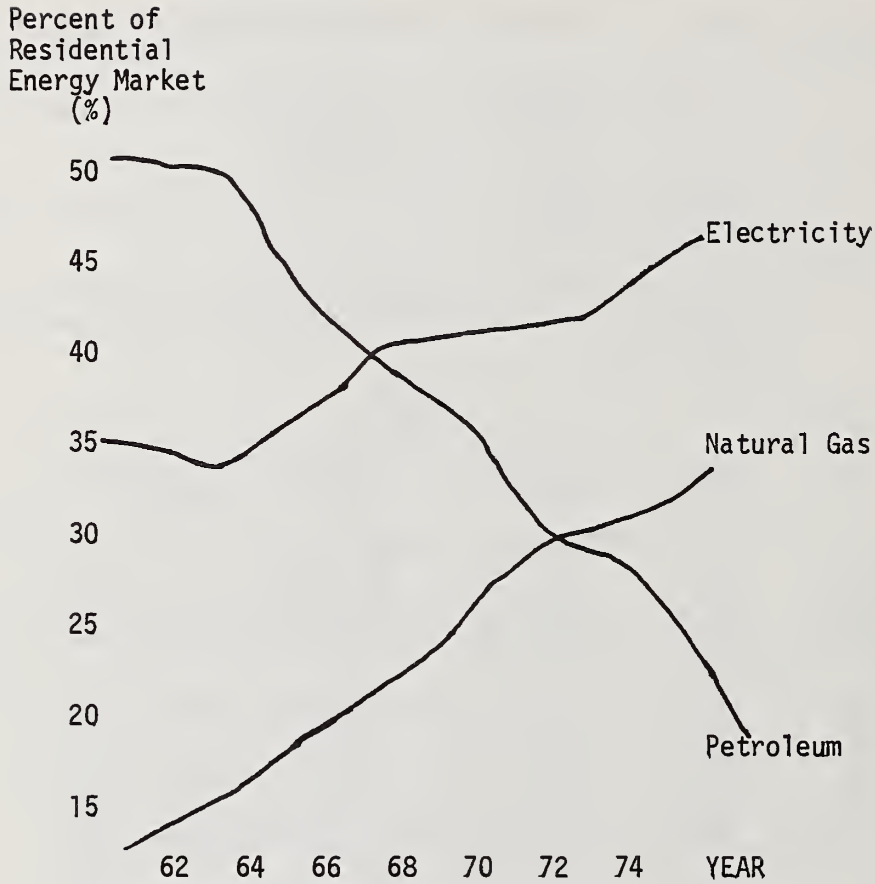
*the residential/commercial Petroleum is divided 2/3 to residential customers and 1/3 to commercial customers.

SOURCE: Oregon Department of Energy. "Future Energy Options." July 1, 1976, p.46.

The trends are dramatically illustrated by Figure 2 below.

FIGURE 2

Changing Composition of Energy Consumption
in the Residential Sector



Source: Oregon Department of Energy "Future Energy Options" p. 47

Data about the type of fuel used in dwellings is available for Lane County.

TABLE II

FUEL USE IN DWELLINGS BY TYPE

	ELECTRIC	GAS	OIL	HARDFUEL	TOTAL
Incorporated area	15,545	4,415	6,305	9,023	27,188
Unincorporated area	9,571	2,141	4,419	2,627	18,758
Total	25,116	6,556	10,724	3,550	45,946

Two conclusions are drawn from a comparison between the State and Lane County consumption patterns:

a) natural gas is less frequently used as a fuel source in the unincorporated areas. Population densitites often do not warrant the installation of gas pipelines;

b) the type of fuel used is not otherwise significantly different (except the State does not report hard fuel).

The types of fuel used affects the kind of inspection provided by the county, i.e., an electrical inspector examines the installation when it is the heat source. A mechanical inspector examines the installation otherwise. There is no discernable effect on the energy conservation code nor on insulation requirements. The County Building Inspection Department began enforcing the State Energy Code in June, 1976. The Building Code did not require insulation or other thermal efficiency measures prior to that date.

The county applies the thermal efficiency standards as both a performance and a prescriptive code as provided for by the State law. The county has the staff expertise to implement the performance procedure if the builder selects that method.

The implementation of the State thermal standards is a two-step process in Lane County. First, residential building plans are checked by building inspectors, i.e., they determine if the required insulation with the appropriate "R" values is shown on the plan. Two copies of the plan are similarly marked. One is submitted to the contractor and the other is used for reference by the building inspector. An on-site four-step inspection is made. Foundation, framing, sheetrock, and final inspections have been customary under the State code. The insulation inspection occurs during the framing inspection.

The amount of time required for thermal inspection and plan checking in Lane County has increased. The Chief Building Official estimates the thermal check of residential plans requires an additional 15 minutes. Field inspections demand little time as only a visual observation of the insulation and the workmanship is necessary.

Organizational Effects:

The organizational impacts resulting from the enforcement of the State code are:

a) no reorganization of the building department has been necessary;

b) no new staff has been added;

c) no changes in the work flow or other procedures have been needed;

d) no budget increases have occurred.

The Lane County Building Department conducted in-house training seminars and participated in State-sponsored training programs for the purposes of acquainting plan checkers and inspectors with the State thermal efficiency requirements.

Economic Effects:

Oregon's Energy Conservation Standards for residential properties has created minimal public and private costs. The home builder's report a capital cost increase of between $100 and $200 per house. Since the typical three bedroom house is reported to cost about $4,500 more in 1976 compared to 1974, insulation is not a major factor in the price rise. The new code has not caused either construction delays, processing costs or loan costs. Therefore, only the cost of added insulation has been passed on to the purchaser. Housing is reported to be scarce in Lane County, consequently, thermal efficiency is not a consideration in the housing market.

The economic impact on the public agency is near zero. There have been no detectable shifts in the location of new residential buildings. Therefore, revenue generated by building activity has not shifted between jurisdictions. The fee for building permits remains unchanged, i.e., $150-170 per 1400-1500 square foot single family unit.

The public costs for servicing a permit are:

a) $1.67 - 2.23 per single family permit; or

b) a total of about $1,000+ per year for the county at an average of 500 new units per year; and

c) training costs estimated at $500.

The County budget has not increased because the work load has been absorbed by existing staff.

Political Effects:

The Chairman of the County Commission reports:

a) State mandated thermal efficiency standards have imposed no additional burden on the County Commission;

b) political capacities have not been affected;

c) the climate for action in the energy conservation arena is positive;

d) the county has assumed a leadership role in the energy conservation field.

Legal Effects:

No law suits nor any legal inquiries about the State Energy Code have occurred since its inception. The Assistant County Attorney reports no legal impacts are likely as the only exposure comes from a failure to implement the State code as required and that is highly unlikely.

OREGON REFERENCES

Future Energy Options for Oregon, Oregon Department of Energy, July 1, 1976.

Oregon Revised Statutes, Chapter 456, Sections 750-885, Lane County.

Energy Conservation and Management Program, A.J. Mandel; Lane County (6-76).

Resource Recovery Facility (R.F.P.), Lane County (2-76).

Public Service Building: Architects, Uthank, Seder, Peticia (12-76).

The California legislature created the State Energy Resources Conservation and Development Commission in 1974 for the purpose of recommending energy policy to the legistature. The Commission is also empowered to adopt energy conservation regulations. The Energy Insulation Standards for Residential Buildings were promulgated as administrative regulations on December 23, 1975. California does not have a statewide building code.

Energy Situation:

The Commission's Energy Policy Committee prepared a Policy Overview Report for the Legislature (October, 1976) which draws three conclusions:

1) national energy policy is: a failure, technically unachievable and sloganeered;

2) State Energy Policy has floundered because deep-seated and fundamental disagreement exists about what, if anything, needs to be done;

3) no coherent energy policy exists in California.

The Committee described three comprehensive possible future energy situations for the State. They concluded, however, that none of the three courses of action could succeed because:

1) economic and technological uncertainties exist;

2) environmental uncertainties exist; and,

3) there is a general lack of concensus.

In their opinion all possible courses of action involved risk except conservation which the Committee recommended should be pursued to the maximum extent politically and economically feasible.

The legislation passed in 1974 established three tests which energy conservation regulations must meet:

1) adverse environmental impacts are not permitted;

2) net energy savings must occur; and,

3) they must be cost effective.

Energy insulation standards for residential buildings were adopted in December, 1975. The standards for non-residential buildings were adopted by the Energy Commission on February 6, 1976, and were due to go into effect on February 6, 1977. The Construction Industry Association challenged the latter in the Alameda County Superior Court. The issue upon which the suit was brought dealt with the distinction between prescriptive and performance standards and a writ of mandate enjoining enforcement was issued.

Thus, as of December, 1976, the county has not enforced non-residential standards although they anticipated doing so early in 1977.

The circumstances in Sacramento County are the most complex of the five counties studied. The county is currently implementing the State's 1975 Residential Building Standards. The Energy Commission is in the process of revising its 1975 Residential Building Standards. The non-residential standards will go into effect as soon as legal obstacles are overcome. In addition, the county has drafted its own Energy Conservation Standards for Residential Buildings, on which three hearings have been held. Adoption of the county standards is expected in early 1977. All persons interviewed were asked to respond to questions in the context of regulations in place. Information about proposed regulations and anticipated effects were recorded separately.

Operational Effects:

Sacramento County's Building Inspection Division applied the 1975 State Residential Insulation Standards to 5490 single family units in 1976. The Associate Building Engineer in charge of the program describes the State code as 99% prescriptive. The county used a simple, direct process to implement the code:

a) two sets of building plans are filed and logged by the Building Inspection Division;

b) either a plan checker or building inspector reviews single family dwellings plans for compliance with the energy regulations;

c) a commercial plan checker reviews plans for multi-family structures.

The time required by the plan check process is approximately two minutes per set of single family building plans. The time required to process plans is reduced because Sacramento County has several large builders who use four or five basic models. Thus, familiarity with the models diminishes the time required to process plans.

Field inspectors obtain a written certification from the contractor which states:

a) the insulation is installed;

b) the thickness of the insulation; or,

c) the "R" value of the "blown-up" type if used.

The inspector also checks for double glazing if fenestration exceeds 20% of the floor area.

There are virtually no work-load impacts arising from the implementation of the State building standards for energy conservation using these procedures.

The county responded to the question. Have the State insulation regulations required the addition of any staff, training, space, vehicles, supervision or other items? The answer was uniformly no. Fees have not been altered.

Political Effects:

Mr. Ted Sheedy, a Sacramento County Supervisor who also serves on the County Energy Council, reports the State regulations have created no additional burden on the county supervisors. The political capacities of the county have not been affected.

Financial Effects:

Builders report that the "typical" three bedroom house has increased in price from $40,000 in 1974 to $48,000 in 1976. The price rise attributable to the State energy conservation regulation is

a) windows - zero;

b) air conditioning - zero;

c) heating - zero;

d) insulation - $200/house;

e) weather stripping - $50/house.

The fenestration limitations have had the effect of reducing somewhat the amount of glass installed and a marketing impact is expected but unknown. Concern exists because the California style house normally contains considerable glass. The current energy regulations have not caused delays in either the plan approval process nor in the inspection process.

Thus, construction delays have not occurred and cost increases are limited to insulation and weather stripping.

The loan quality of residential buildings has not been affected according to the President of Guild Savings and Loan. No problems have arisen from the implementation of the State energy regulations.

Legal Effects:

The Assistant County Counsel for Codes provided a three-part response to the question: What legal implications for the county has the State-mandated energy regulations had?

a) Standards imposed by the State must be enforced or liability could occur from non-compliance;

b) When a county legislature acts to adopt a standard based on reasonable data, no liability is incurred;

c) A County legislature is acting administratively when its judgment is required in the application of a code, i.e., a performance code. It acts ministerially when applying a standard where no judgment is involved, i.e., a prescriptive code. The greater legal exposure flows from the former circumstance, however, a legislature is granted considerable discretion.

Proposed Thermal Regulations for Sacramento County:

The State of California permits counties to adopt energy regulations more stringent than the State Code. The proposed Energy Conservation Standards for Residential Structures for Sacramento County was prepared by the Living Systems consulting firm.

The goals of the proposed standards are:

a) Save about 50% of the energy needed for heating;

b) Add no capital cost; and,

c) Reduce operational cost.

However, the goals can be achieved by either a prescriptive or a performance method. The prescriptive method established minimum requirements for: insulation (ceiling, walls, floors), roof color, glazing area, glazing shading, and ventilation. The performance method provides for component heat transfer calculations to demonstrate that the standard is met. The performance concept is to "design with climate," i.e., a climatological data base is established and buildings are designed to maximize natural benefits such as solar radiation in winter and cool summer breezes in summer.

Table III on the following page establishes the performance required of residential structures. (Source: Energy Conservation Standards for Residential Structures by Living Systems, Dec. 1976.)

TABLE III*

DETACHED GROUP I DWELLING UNIT THERMAL STANDARDS

Floor Area (sq. ft.)	Winter Heat Loss (BTUs/(sq.ft.)(days)	Summer Heat Gain (BTUs/(sq.ft.)(day)
500	341	84
1000	228	76
1500	201	72
2000	186	69
2500	178	68
3000	172	67

Note: Direct interpolation shall be used for floor areas not shown.

* Infiltration and internal heat production are not considered under the requirements of these standards. These are very important considerations in the real performance of a building and must be estimated when sizing heating and cooling devices whether conventional or solar. However, for the present purpose they are too variable to be standardized.

This proposal has been fully coordinated with the proposed 1977 revisions to the State Energy Code and is entirely consistent except for:

a) Roof color - County requires a light color.

b) Floor insulation - County proposed to require floor insulation at 2800 degree days. The State proposes a cut-off at 3000 degree days.

c) Glass - County proposes to limit glass to 12½% of floor area whereas, the State proposal limits glass to 20% of floor area.

The reactions to the proposed standards are summarized below:

County Supervisor Sheedy - "The proposal is expected to be controversial. The problems are expected to be worked out before the Board of Supervisors receives the proposal for action."

Mr. Bill Streng, Builder and Mr. Jim Merry, Director of Building Industry Association said:

"The energy situation does not warrant this kind of response. The limitations of glass may affect the marketability and pleasantness of homes. The permit approval process is expected to require three (3) weeks based on their City of Davis' experience. (Davis has a similar code.) Construction plans will have to be changed. Delays in the inspection process are not anticipated based on the Davis experience."

"The County Administrative Staff and Builders design staff are not now qualified to implement the proposed code. Substantial training is expected. The time required to process the plans will demand additional staff at substantial cost to the county and the private design cost of the home will be increased. Costs will be passed on to the home buyer."

The Associate Building Engineer, Mr. Gene Platt confirmed that more staff will be required to implement the proposed energy conservation standards.

REFERENCES

The following were supplied by California Energy Resources Conservation and Development Commission:

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2) Electricity Forecasting and Planning Report; September 24, 1976

3) Quarterly Fuel and Energy Summary, Volume 1, No. 4, Fourth Quarter 1975

4) Sub-Chapter 4: Energy Conservation, Article 1, Residential Building Standards, December 23, 1975

5) Revised Report on Energy Conservation Standards for New Residential Buildings, November 17, 1976

Sacramento County supplied Draft: Energy Conservation Standards for Residential Structures; by Living Systems, Dec. 1976.

MONTGOMERY COUNTY, MARYLAND

The previous studies have reported the impacts of State-mandated energy conservation codes on counties. The context of the Montgomery County report is different. This County developed its own code and is in the process of adopting it. Consequently, there are no impacts derived from implementation. The purpose of this section of the study is to review the policy development process and examine its impact on the final product. Since most of the counties in the country do not come under a State building code, this kind of examination may have high transferability value to them. Maryland does not have a statewide building code.

The State of Maryland has developed a model building code which counties and cities may adopt under permissive State legislation. The Model Performance Building Code as it is called is recommended by the State and it now includes an energy efficiency chapter.

The Montgomery County Building Code is a Building Officials and Code Administrators (BOCA) code modified to meet local needs. The county proposes to add an energy section entitled: "DIVISION IV THERMAL ENERGY CONSERVATION."

Montgomery County first considered an energy conservation code for philosophical reasons. Two members of the County Council and the County Executive believe in energy conservation and have publicly supported conservation as a proper role for a county government. Accordingly, the County Council resolved:

> On July 1, 1975, the Montgomery County Council adopted Resolution No. 8-311, recognizing an immediate need for developing energy conservation standards in the construction of buildings and in the use of heating, cooling, and lighting equipment. This resolution established a Citizens' Advisory Committee on Energy Conservation Standards in the County Building Code. The Committee was charged with reviewing the current provisions of the County building code and recommending areas in which amendments are needed in order to enhance energy conservation in the County. The Committee was officially appointed on December 9, 1975, and charged with producing an initial report by June 9, 1976.

The Committee was composed of nine prominent citizens many of whom possess expertise in research and/or conservation.

The committee used ASHRAE 90-75 Energy Conservation in New Building Design as a source document. Since ASHRAE 90-75 is a standard and not a code, the Committee relied on the "BOCA Preliminary Code Revisions of Energy Conservation" for guidance in converting the standard to code language.

The committee also established two tests which its recommended code had to meet:

1) the recommendations must be practical, understandable and capable of adoption; and,

2) they must be enforceable.

The committee decided it could use one or both of two approaches to energy conservation in buildings. First, the transfer of heat through building surfaces could be controlled by specifying maximum permissable values for thermal transmittance. Second, air leakage through cracks, seams, and other openings could be reduced. The proposed changes address both issues. Both are achievable within the standard practice of the construction trades in their opinion.

The proposed Montgomery Code is summarized below:

SUMMARY: MONTGOMERY COUNTY CODE (proposed)

Item	Montgomery County Proposal
Scope	all conditioned buildings
Design Parameters	70° winter 78° summer
Alternative analysis system permitted	yes
Thermal transmittance values	
-ceilings	.05
-walls	.24 residential
-floors (slab-on-grade)	varies w/const.
Fenestration	no limits; Uo value declines as fenestration increases
Condensation Control	none
Air infiltration	ASTM-283 standard applies
Heating/cooling system	minimum coefficient of performance specified

The policy development process used in Montgomery County is not at all uncommon and is summarized below.

Policy Development Process:

a) County Council actions

1) declares need

2) appoints committee

3) gives committee its charge and a time line

b) Committee actions

1) defines the problem;

2) establishes the tests for its product, i.e., practical, understandable, enforceable and capable of adoption.

3) collection and analysis of data

4) considers alternatives

5) reviews drafts

6) approves and recommends a report

c) County Council

1) receives report

2) calls hearings on recommendations

3) schedules action on report for June, 1977

The committee appointed was composed of prominent, capable people with excellent skills in the field, including architects, builders, and engineers.

They had the benefit of a large professional county staff committed to the enterprise. They also took advantage of their Washington location and drew on the professional skills of the National Bureau of Standards, Building Officials and Code Administrators, International Inc. (BOCA), Suburban Maryland, Homebuilders, National Capital Heating and Air Conditioning Association, NOJC, and Shefferman & Bigelson Company (a consulting firm).

The conclusions of the committee were that an energy code was practical and:

1) The proposed code is recommended.

2) The proposals are energy conserving and cost-effective.

3) They are practical, understandable and enforceable.

In the judgment of the committee, the impacts of the recommended code are:

a) Homeowner effects

No dramatic changes in the construction of the home, but some added material cost with a payback generally less than four years is expected.

b) Commercial User effects:

1) Average annual reduction of 40% or more in energy consumption.

2) Reduced construction cost in every case.

c) Construction Industry Effects:

1) Design approaches will have to be modified, especially for commercial buildings.

2) More design effort required of builder because the building must meet higher standards.

d) County Government effects:

1) An additional plans examiner will be required (a mechanical engineer).

2) Cost will be $25-30,000/yr.

3) One additional on-site inspection will be required and the cost can be absorbed initially.

Inasmuch as the code has not been adopted, legal, financial, and political impacts are not impossible to document, and therefore are not included in this County study. There are three important principles to be derived from the Montgomery County experience.

a) The Council made three critical judgments at the outset by declaring its values.

1) energy conservation is important.

2) there is a role for the County government to play.

3) the process used to define the substance of their role would be democratic.

b) The County's approach to the committee was professional:

1) the change to the committee was clear.

2) the time line was explicit

c) The code development process was logical and professional:

1) problem definition

2) data gathering and analysis

3) available alternatives

4) debate

5) conclusions and recommendations

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1) Report of the Citizens Advisory Committee in Energy Conservation Standards in the County Building Code, Montgomery County, Md. (June, 1977)

2) Energy Conservation Plan, Montgomery County (Oct. 1976)

3) "Memorandum on the Proposed Energy Conservation Amendments," Charles Rand, Assistant County Attorney (Dec. 24, 1976).

CONCLUSIONS

The thermal efficiency codes examined contained numerous similarities:

a) each is an amendment to an existing building code (except California);

b) all require enforcement by local code officials;

c) all are both prescriptive and performance codes;

d) all are minimum codes except for Minnesota which is both a minimum and maximum code;

e) the thermal transmittance values vary remarkably little considering the wide difference in weather conditions;

f) the design standard is 70° for winter (68° for Minnesota), The previous standard was 72°.

There are some differences among the codes:

a) Three limit their scope to residential buildings.

b) Only Minnesota applies the code to all buildings. The Montgomery County proposal is intended to apply to all buildings.

c) Only Minnesota permits the county to require a building site analysis which maximizes solar radiation. Sacramento County proposes to add such an item.

d) Condensation control is not uniformly regulated, although three states require a vapor barrier.

e) Three states have adopted a standard for air infiltration.

f) A workmanship standard is legislated in only two states.

The enforcement of an energy conservation code has produced many similar results for counties:

a) Elected officials report no political impact from the implementation of State-mandated thermal efficiency standards. Some concern has been expressed about the proposed revisions which may be controversial.

b) County Attorneys report neither legal action nor inquiries arising from the implementation of thermal efficiency standards. They all report that a failure to implement a State code would give the county its greatest legal exposure - an unlikely event in their opinion.

c) Counties have implemented State-mandated thermal efficiency codes on time and without major problems.

   - no new personnel have been added as of December, 1976 - no reorganizations - no fee increases (one increase proposed for 1977) - no capital outlay - minor additional cost increases have been absorbed in current authorizations

d) No delays in the plan approval process have occurred as a result of the review for conformance to thermal efficiency standards.

e) The on-site inspection for required thermal efficiency items has not caused construction delays in the opinion of county officials. Most builders agree.

Counties report dissimilar financial impacts as illustrated by the chart on the following page.

A caution about the use of this financial data is in order. Local conditions have a direct impact on costs. For example, all of the counties had increased workloads in 1976 compared to 1975. Yet, four had experienced a decline in the amount of building activity between 1972 - 1975. Thus, an ability to absorb added work existed in these organizations during the period of this study (1976). Further, the limit to which added work could be absorbed was reached in Washington County in 1976. Sacramento County reports a need to augment staff to accommodate changes proposed in the revised energy code.

Three counties expect to add staff to the Building Inspection Division in the future:

a) Sacramento County - Due to extraordinary growth and an estimated need if revised energy standards are adopted.

b) Washington County - One person has been added to the 1977 budget at a cost of $15,000.

c) Montgomery County - The proposed code includes the addition of one mechanical engineer in part due to the energy code and due to the current absence of such a position. Estimated cost is $25,000 to $30,000.

Builders report increased cost for labor materials in order to comply with the State codes. Cost experienced to-date ranges from $100-400/unit.

Builders report that most of the costs are experienced by the "budget" builder. Those who are building homes in the $40,000 and above range say their practice exceeded the standards and no cost increase has been experienced. The single exception is Montgomery

FINANCIAL IMPACTS

ITEM	FIRST GENERATION CODES			SECOND GENERATION CODES	
	CALIFORNIA	NO. CAROLINA	OREGON	MARYLAND*	MINNESOTA
1976 price of a typical three bedroom house	$48,000	$42,000	$42,000	$60,000	$50,000
Public Costs					
Estimated enforcement costs (time and overhead)	$2,300	$2,500	$1,200	$25,000** (proposed)	$15,000
Number of units processed	5,490	2,140	481	3,000	1,416
Cost/unit	$.45	$1.17	$2.50	$8.00	$10.60
Private Costs					
Typical cost/home for insulation	$250	$400	$100 $200	$1,200***	$150
Permit fees for thermal element	0	0	0	0	0****

*Proposed county code.

**Estimate cost predicated on an existing need for a mechanical engineer position only partly related to the thermal code.

***The proposed code requires certified vendors at an estimated cost of $400-500 per home and the remainder is for design fees.

****A request for a fee increase of between $10-25 per unit is expected in 1977.

County where a builder believes manufactured windows will cost $400-500/unit and higher design fees will be necessary to comply with the proposed codes.

All builders report the codes are cost-effective within five years. Two builders (NC and MD) based the judgment on a professional cost-benefit analysis. The others rely on their experience and judgment.

Finally, the situation in each State is dynamic. Several are considering modifications in their codes which, if adopted, will affect the implementation process and its effects on counties. This investigation concludes that counties having a building code and an experienced staff can accomodate an energy code which establishes certain standard practices as a minimum.

As the complexity of the code increases and as the degree of change from common practice is required of builders, the time and effort on the part of the county will increase. Each of the major categories of analysis--legal, political, financial, and operational--will be impacted to varying degrees.

REGULATORY ADMINISTRATION: A FUNCTION OF PERCEIVED PRIORITIES, COSTS AND BENEFITS

by

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This paper discusses the problems of building regulatory agencies in facing rapid advances in the technology and scope of building regulation and the implied increase in volume of work. The paper attempts to identify distinct classes of obligation for the regulatory agency based on a range of requirements starting with those proven critical to life safety and those mandated by legislation and highly visible to the public to those which represent the possibility of applying wide discretion in judging risk and assigning a priority based on community benefits. The paper gives examples of how decisions affecting risks versus benefit might be implicitly applied in every day operations of an agency and the significance of these judgments in terms of an acceptable risk level. As workloads increase and technology and mandatory legislation increase in scope and volume, local regulatory agencies, faced with limited resources, must make decisions which reflect a systematic prioritization of functions based on judgments of risk, costs, and benefits.

Key Words: Building codes; cost-benefit; decision making; priorities; regulatory agency; resources; risk.

INTRODUCTION

Building regulatory agencies are faced with rapid advance in the technology of regulation of buildings. In addition, there are also rapid increases in the number and character of Federal, State, and local constraints and mandates imposed on the regulatory process. As technology advances and the scope for doing either good or harm seems to expand, government at all levels becomes activated in response to observed dangers and risks, or in anticipation of future benefits.

One of the results of this burgeoning technology and awareness is the recognition that regulatory agencies, limited in both staff and expertise, must make decisions, either explicitly or tacitly, on allocation of its limited resources. This paper attempts to look at this allocation of resources according to different levels of constraint based on legal mandates, observable compliance, and the use of discretion in assessing risk and benefit to the community as a whole.

DEMANDS OF NEW TECHNOLOGY

Recently we have seen an unprecedented number of events and reactions at all levels of the regulatory process. Model code groups have made many significant changes in their codes to reflect the increased sophistication of understanding of building code problems. The code groups have also reacted to technology fostered crises, and improvements, with many code changes.

The development of the high-rise and its proliferation in great numbers led to a higher statistical probability of observing faults in the regulation of high-rise structures. The reaction to the danger, proven by several disastrous high-rise fires, was to immediately create a multitude of specialized requirements for the design of such structures and the equipment in them. In many cases, the regulations, in either identical, similar, or differing forms were promulgated concurrently by agencies at State and local levels.

The ubiquitous intrusion of plastics into virtually everything has created an even more critical problem for all types of buildings, and therefore, regulatory agencies. However, this technology expands and changes so quickly that it is difficult to determine what the risks are before a new field of use has been developed and has created a different scope of risks. Once again, as the observation of the problem generated a realization of the risks, reactions were generated across a broad band of levels, from Federally imposed restrictions, to standard-making bodies, to local authorities and fire departments. In conjunction with the new technology of evaluating the risks of plastics used in different construction circumstances, a new set of regulations for controlling their use has been developed and is continuing to be developed.

The threat of earthquakes and the problems of establishing the risk and doing something about it in both new buildings and existing buildings has been emphasized by recent events in other countries. In response to a recognized threat in Massachusetts, the State promulgated a uniform mandatory set of new regulations far more comprehensive than were previously in effect anywhere in the State.

Finally, we can refer to an entirely new and extensive set of regulations controlling energy conservation. A review of the status of energy conservation regulations reflects the fact that regulations are being imposed at many levels; local, State, model code, and in national standards.

The general tendency appears to be that we are adding regulations, codes, statutes, laws, and standards to the building regulatory system at a rate that is greater than that at which any material is being deleted. In fact, I would guess that the rate of adding material is an increasing rate. In addition to adding material, the material represents a technology which is relatively complex compared to the rest of the regulatory technology; involves many new standards and extensive demands on allocation of agency resources.

Among the four examples of recent developments in code technology cited above, there are some interesting points to be observed. The response of codes to the problems of high-rise construction was in answer to a serious life safety hazard. Previous technology had accepted basic concepts of code provisions as acceptable to provide adequate life safety in high-rise structures. However, the result of disasters which occurred showed that previous concepts erred greatly both in gross requirements and equally in details such as recognizing the problems of vertical chases and penetrations, and the need for complex systems of communications and mechanical equipment control.

The plastics problem represents a serious life-safety threat across all the range of uses in all buildings where it occurs. It has rapidly replaced conventional materials, which historically have not been a serious hazard, or which through experience, have been controlled in use, and created potential new hazards in both gross application and in details. While it is now possible to deal with some of these hazards effectively, an entire new technology is required to bring the use of the material within a range of hazard which is more understandable to regulatory agencies.

The earthquake problem represents a uncompromising evaluation of risk, primarily life-safety, versus benefits. The risk involves an evaluation of likely return period for a specified level of events. As a broad generalization, it can be said that for the same level event, as the return period increases in length, the design requirements tend to be diluted. And, in general, they are diluted in terms of the detail required to be enforced. This is an implicit reflection of perceived risk and benefit. There is no perceivable benefit to addressing in detail events, even one likely to be catastrophic, which are predicted to occur several thousand years apart.

Finally, if we look at energy conservation in terms of traditional code tenets, we must come to the conclusion that we are addressing an unabashedly new area of code enforcement - enforcement of national policy. It is clearly not related to life safety or health and only vaguely related to general welfare.

In addressing these four issues, four clearly differentiated aspects of the administration of the regulatory function emerge. In the high-rise we see a high risk, a highly visible and identifiable structure demanding a high concentration of effort and attention to detailed systems, and to quality control. In plastics we see a unique material with a multitude of hazards and uses associated with it demanding careful attention to use under any circumstances, careful identification of its existence and follow through in its control in all buildings. In the regulations for seismic design a wide spectrum of requirements are available which can be justified based on a perceived risk/benefit determination. Based on this determination, the amount of detail in administration of the regulations can also be established over a wide range. And finally, in energy conservation, we are faced with what, in code terms, can only be described as a mandated legal obligation, having little to do directly with life safety or health.

OBVIOUSLY MANDATORY REQUIREMENTS

There are obligations in regulatory administration which may be termed obviously mandatory. Generally, these are items whose enforcement represents major considerations of life safety and are easily observed or are established by specific statutory requirements. An example might be the awareness that wood frame construction is very limited in height allowances, and a five story wood frame building would bring instant recognition of major code violation. In many jurisdictions, high rises require sprinkler systems and there is a general recognition of this requirement. The lack of compliance becomes instantly observable and the danger to the public is as well understood by the public as by the regulatory agency and the design professional. As a third example we might consider the requirements for egresses. The availability of at least two adequate egresses in most places of assembly can be easily recognized even by the public as critical to their safety.

In addressing these requirements, there is a compelling necessity for compliance for four basic reasons: 1) They have been proven critical to life safety, 2) they are highly visible, 3) there is a general awareness of the requirement in the general public, 4) they are mandated either by law or by very specific, uncompromising regulations.

REQUIREMENTS WHICH ARE NOT OBVIOUS

In the administration of the codes, there are many areas where the result of enforcement would not be obvious to observers, users, builders, or even regulators. In the normal course of construction many elements regulated by code are covered and hidden from view and only sampling techniques of enforcement can be used to try to ensure compliance. Some examples are the placement of reinforcement in reinforced concrete structures and in reinforced masonry construction; the use of properly graded lumber wherever required; and the placement, quality, density, and thickness of sprayed-on fireproofing. In many of the examples cited, variations from the code or even non-compliance would only be apparent under extreme conditions of use. Conditions which would represent an extremely low probability of occurrence. In the case of placement of reinforcing steel and the use of graded lumber, we are most likely concerned only with structural load-bearing capacity. In the case of firestopping and fireproofing, we may only be dealing with exposure to a significant fire. For all of these requirements, there is some decision required about the extent of commitment of time and resources to quality control before the items are hidden from view.

REQUIREMENTS WHICH ARE PRIMARILY BASED ON ADMINISTRATIVE POLICY

Finally, there is a considerable portion of the regulatory agency's work which is adaptable to enforcement criteria established by local policy decisions. Most code administrative sections provide great latitude for local discretion in both the detail and the vigor with which much of the code is enforced. This is especially true with respect to existing buildings subject to alterations and change of use. Certainly the typical sections of codes which establish the extent of code compliance based on cost of repairs related in percentage to value of buildings provides both the building official and the municipality with broad range of cost/benefit options based on locally perceived risks. Even simple standard requirements in codes relating to required egress lighting levels and ventilation requirements can be administered in accordance with a degree of accuracy which, while always subject to measurement, may only create an awareness by its existence or absence. Surely measuring light levels at all locations and cubic feet per minute of ventilation required to a close tolerance could create a significant burden on both a building department and a builder.

Finally, it seems probable that energy conservation requirements may represent a single area which has characteristics most adaptable to discretionary decision-making and prioritization in terms of perceived costs and benefits. Virtually none of the requirements are fundamental to life safety, and they might only be related to health and welfare by a tenuous bridge of economic necessity - presumably outside of the normal context of code application. The allocation of departmental resources to deal with the extensive additional detail of energy regulations represents a significant burden which has to be thrown into the entire pot of legal obligations, risks, and benefits.

RISK AND ITS INFLUENCE ON BENEFIT-COST

Chauncey Starr[1] in discussing the question "How safe is safe enough?" discusses several interesting points related to involuntary risk taking in what he calls our "sociotechnical" systems. He comes to the conclusion that the rate of death from disease is an upper guide in determining the acceptability of risk - somewhat less than 1 in 100 years.

He also states that natural disasters ("acts of God") tend to set a base guide for risk - somewhat more than 1 in a million years and that man-made risks at this level can be considered almost negligible and may be neglected if they are several magnitudes less. He concludes that there is a risk trade-off range of one million for societal policy related to acceptability of public risks associated with sociotechnical systems. This translates basically into a risk of from one fatal accident in one hundred years, to one in a million years.

This implies that even some arbitrary decision making by the regulatory agency to accommodate what may be called community benefits may represent a very safe risk within this total range of apparently acceptable risks.

As a simple example of some of the possibilities involved in benefit risk decision making, let us consider a multifamily residential building. For the sake of example only, consider the requirements of the BOCA code (an identical example could be made with any of the model codes) for a type 3B construction, R-2 multifamily residential use building. The basic code area limitation is 13,200 square feet. This basic fire area represents a code measurement for a certain hazard criterion. It must be presumed that variation from this value establishes a new hazard, or risk. To be allowed to exceed this area even by a small amount, there is required a significant construction penalty. It is assumed that the only remedies available are fire walls or sprinklers. While we are not sure what the original risk involved was, it is evident that by marginally increasing the area a stiff price must be paid and we must surely reduce the risk by several orders of magnitude by the addition of a fire wall or sprinklers. If marginal variations in area are ignored and allowed, there is a tremendous savings in cost and a probability that the risk is still within a perfectly acceptable range.

In the same building, the following fire ratings for elements are applicable:

1.	Interior bearing walls and partitions	1 hour
2.	Fire enclosure of exitways	2 hours
3.	Exitway access corridors and vertical separation of tenant space	1 hour
4.	Floor construction including beams	1 hour

If these elements are constructed of sheetrock and wood studs, the assemblies necessary to achieve the fire-ratings are specified in great detail in an appropriate catalog of fire rated assemblies. To ensure compliance with the code would require extensive commitment of time for quality control in the form of inspection. It is rarely possible to allocate more than enough time to spot check. And spot checking implies the possibility of variations from standards and a possible change or risk based on required fire ratings. In fact, the extent to which inspections of such assemblies are carried out and the degree of detail checking is a discretionary decision of the regulatory agency based on its available resources and the particular importance attached to the control of such assemblies by the particular regulatory agency.

A particularly interesting and direct application of recognizing a level of risk and its effect on cost-benefits occurred in the City of Long Beach, California. The City of Long Beach contracted with the J. H. Wiggins Company to recommend new earthquake provisions for the city. Two of the risks itemized by John Wiggins[2] were as follows:

1. "Developed new code criteria based on equating involuntary earthquake risk with other voluntary risk situations such as auto accidents. This introduces the new concept of Balanced Risk design."
2. "Provided a means by which representatives of lay citizenry can establish or modify code limits recommended. Several strengthening tables were prepared that related to the death-risk expectancy."

CONCLUSION

There are many levels of application of building regulatory requirements. At some level of application there is either an explicit or a tacit application of priorities in terms of perceived costs and benefits. While the priorities generally are related to risks, whether understood in terms of risk/hazard or not, the influence of availability of resources and their application and political and social pressures alter the priorities and the consequent cost benefit arrangement.

Lester B. Lave[3] in his paper on "Risk, Safety, and the Role of Government" says:

"Similarly, increasing the safety of an automobile increases its price and denies the product to the poor. Denying a man his livlihood and mobility in order to increase his safety by one change in a hundred thousand hardly seems optimal."

And further:

"However, as increasingly higher safety standards are imposed at increasingly higher prices, more and more people, particularly the poor, will be hurt by being priced out of the market."

And finally:

"To set safety standards well, one must determine the cost of satisfying the standards and the benefit to society from the added safety. This is very difficult to do properly."

All three of the previous statements by Mr. Lave could be applied equally well to building construction and especially housing.

As the technology, scope, and demands of the regulatory process expand, the more expensive and demanding it becomes for municipalities to fulfill their obligations. With limited resources available, it becomes a matter of necessity for local governments to fulfill their obligations based on a perception of those requirements which are relatively absolute in nature and those which can be established on the basis of priorities reflecting apparent acceptable risk balanced against community benefits.

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DEVELOPMENT OF INTERFACE BETWEEN THE REGULATOR
AND THE MANUFACTURER'S QUALITY CONTROL PERSONNEL

by

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The subject of this paper encompasses the manufacturer's commitment to quality control including designation of inspectors who are held accountable. Other aspects will include coverage of:

- Development of inspection aids
- Regular monitoring of both product and inspection personnel
- Training of personnel in a formal classroom environment including required annual recertification
- Classroom written examination, grading process, and PFS Quality Assurance Council review
- Progress reports after classroom training and as a prerequisite for final written certification
- Maintenance of year-to-year certification
- Decertification procedures
- Case histories of decertification
- Impact on product quality

Key Words: Certification; compliance assurance programs; industrialized building construction; inspection; personnel qualifications; quality control manual; regulations; Third party agencies; training.

It has been my privilege to be involved in compliance assurance programs for industrialized constuction for over 20 years, and I am convinced that any program which is not centered in an effective hour-by-hour policing by the manufacturer of his own production in his own behalf will have serious flaws no matter who is coming in from the outside to inspect or how often he is coming. In recognition of this, it was fifteen years ago that Product Fabrication Service, the third party independent inspection and testing agency I now head, made this an integral part of their program. We require that the manufacturer have a sound quality control program before we will certify quality based on our audit inspections. However, in recognition of the fact that very few manufacturers have such programs or have expertise and trained manpower to set up a program on their own, the PFS staff will assume a major part of the chore. This involves the preparation of a quality control manual which establishes procedures, quotas, tests, record keeping, including forms, certificates and labels, and it involves the training and subsequent examination and certification of in-plant quality control personnel. Then there is a continuing surveillance and supervision of the Certified PFS Inspectors by the PFS Staff Audit Inspectors who are in the plant on a regular basis. We think this is one of the most important services that PFS provides.

Most of the regulatory bodies which have established requirements and approval procedures for industrialized housing have adopted this concept and require that the manufacturer submit, in addition to plans and specifications, a plant procedural manual which sets forth in detail an in-plant quality control system which is audited on a frequent and continuing basis by an approved third party agency.

Organizationally, the manufacturer's quality control personnel should answer to management above the level of the Production Manager. Lines of authority should never place the inspector in the position of passing judgment on work for which his boss is directly responsible. His organization chart should clearly show that quality control personnel are not subject to this kind of pressure. On the other hand, quality control can make a substantial contribution to solving production problems in an atmosphere where each group realizes the value of each other and works together in turning out production in which the entire company can take pride.

As far as quality control personnel qualifications are concerned, if they are working with an agency which has a training program and assists in setting up their quality control system, they do not need to have people with previous quality control experience -- neither do they have to possess craftsman ability in the trade whose work they inspect. A particular academic background is also not required. PFS advises the manufacturer to look for a man who has a broad background in construction -- he should have had supervisory experience at least at the leadman level of responsibility -- and this should have been in an industrialized housing situation. He should have reasonably good judgment, be able to get along well with fellow workers, and should be able to make decisions with resolve. He should be able to say "no" with both tact and firmness.

Some background in building codes would be helpful, but is not necessary with agency training. General code interpretation is not involved since the inspector is always working with very detailed plans and specifications which have previously been evaluated by the appropriate authority.

The manufacturer's quality control system should begin with an acceptance procedure for raw materials as received at the plant. It will involve a spot check on an established quota basis of the work as it is accomplished at the various work stations throughout the plant. It should include a check of all plumbing, electrical, mechanical, and structural systems after the work is complete but before it is covered up by subsequent work. It will include the procedures by which non-compliance at any point can be brought to the attention of production so that it can be repaired or replaced before the unit reaches the end of the line. The in-plant quality control will want to include not only those things about which the regulatory body is concerned, but also checks of those things that are important in their relations with their customer in seeing that he gets the colors and patterns specified, scratch-free finishes, etc. They will want good records of all inspections so that regulatory bodies can be satisfied and so that they will have accurate information if complaints are subsequently received.

The Quality Control Manual is prepared by the manufacturer's inspection personnel usually. It includes the inspection aids the Certified PFS Inspector will need to implement and maintain an effective quality control program at his plant. These aids include inspection check lists, testing equipment, and the plans and specifications.

The in-plant inspector must know how to use the test equipment and check for its calibration. He must know how to read plans and specifications correctly and to know enough about the material specifications to be able to refer to his codes and standards library when references are made in the specs, such as "plywood shall meet PS-1-74."

This in-plant inspector truly must be a very knowledgeable person. Yet, throughout the industry today little is done by management to assure his competence. Many manufacturers, indeed, rely entirely upon production supervision and monitoring by the inspection agency for compliance; however, it is a condition of every PFS contract that the manufacturer must have a comprehensive quality control department including in-plant inspectors certified by PFS.

The Certified PFS Inspector must meet rigid closely monitored performance criteria to obtain and remain certified. Not only are there initial qualification requirements, but once certified, the inspector must continue to maintain his expertise or he will loose his certification. He must attend one additional seminar annually to remain eligible for recertification.

Once chosen as a trainee by management and accepted by PFS, he must attend the next regularly scheduled PFS Training Seminar. The Training Seminars are organized by PFS Staff twice annually and held in either Madison, Wisconsin or some prominent eastern city. They run for two days during which time the trainee receives special instructions in a classroom-like atmosphere. These instructions cover such things as: lumber and plywood grading, electrical and plumbing codes, professional quality control techniques, latest code changes, heating and ventilation, including an emphasis on condensation, record keeping, product liability, energy, adhesives and mechanical fasteners, and fire safety. (Refer to Tables 1 and 2)

At the end of the second day, each inspector must take a written examination. Recently, part of their examination has included a practical exam where inspectors visit a mobile or modular plant and actually conduct an inspection of products on the assembly line.

In these cases, PFS Staff prepares the product on the line with deliberate violations of the regulations covering subjects which have specifically been discussed during the classroom training.

The examination is graded using statistical methods. Grades are distributed into a "normal" or bell curve, and grades below the first standard deviation of the mean are considered failing. This results in a minimum passing grade which varies with each exam depending upon the grade distribution. However, this process is necessary because the instructors are each asked to submit five questions for the exam based upon what their subject will cover. This process assures that the instructors will cover the exam questions and that the exam questions are always different for each exam.

Once the grades are compiled, they are submitted with my recommendations to the PFS Quality Assurance Council Chairman for his review. If agreed, each attendee is advised that he either passed or failed the exam. He is not certified at this time. He is certified by the Quality Assurance Council only after a satisfactory <u>progress report</u> is received from the PFS Quality Assurance Inspector supervising him and his plant. The progress report includes an evaluation by the PFS Inspector of the trainee's record keeping, knowledge of his job and time on inspection. (Refer to Figure 1).

After the trainee passes the exam <u>and</u> receives a recommendation for certification by the Staff Inspector, the trainee receives a signed certificate. (Refer to Figure 2).

This certificate includes the signature of the Quality Assurance Council Chairman and the Executive Vice President of PFS. Worth noting --- the certificate expires after one year automatically.

Every Certified Inspector must attend at least one PFS Seminar annually to retain his certification. Regular Certified Inspectors are usually backed up by a second man, sometimes from Engineering, to cover him in case of illness or vacation. These back-up men are required to perform one complete inspection per month minimum to remain certified.

Monitoring of the performance of the Certified Inspector protects the integrity of the program. Even in states or under the HUD Mobile Home Program where each unit must be seen by a PFS Staff Inspector, the manufacturer must still have a Certified Inspector in his employ. Monitoring includes not only a check of the product on the assembly line, but a check of the inspection records and test equipment used by the Certified Inspector. Any glaring and obvious inconsistency between the inspection records and the product on the line is a tip-off that the in-plant inspector is not doing his job.

You have probably noticed my reference to a PFS Quality Assurance Council and are wondering what or who they are. The QAC consists of six members of the public who serve without compensation. QAC members are invited by Council action to participate as Members of the Council.

Qualifications include being well known and of good reputation in the building industry. Several members of the Council must represent local building officials; others include professionals and consumers.

No members of the Council may in any way be associated with the building industry. The present Chairman of the Council is Bernard E. Cabelus, Building Official, State of Connecticut. The immediate Past Chairman is Charles Hagberg and his predecessor was Harry Stone.

The function of the QAC is to monitor the training and educational programs of PFS and to assure that only qualified staff meeting minimum qualification requirements are employed.

Getting back to the certified inspectors, a log is kept on the performance of each inspector including various exam grades and changes of employment. The inspector can remain certified even though he changes jobs provided his job duties remain substantially the same. Hence, the Certified Inspector Training Program is truly an educational program of particular value to the inspector himself. This value helps assure that he will do his best to do a proper job. It is not difficult to be decertified! To date, the PFS Quality Assurance Council has decertified two individuals and reprimanded a third.

CASE HISTORY A

A small firm insisted upon the production superintendent being the back-up Certified Inspector. This man personally was a strong supporter of the Certified Inspector Program and assisted actively in implementing the in-plant quality control program.

He voluntarily commented after attending his first seminar that for once he finally understood what the grademark meant on lumber. This man is about fifty-five years old and has been involved in the building trades most of his working life. He knew building construction, but had a tough time learning about code enforcement.

At his second seminar, required to maintain his certification, he failed the written exam by two percent. He was decertified. Today he is no longer employed by the manufacturer, but the manufacturer is still a PFS client in good standing.

CASE HISTORY B

A mobile home producer in the midwest used the company engineer to also do in-plant inspection and apply HUD labels between visits by a PFS staff inspector. This manufacturer and his engineer were not particularly enthusiastic supporters of the program. After numerous attempts by the staff inspector to get cooperation, he went back immediately the next day following a routine inspection to check on several red tagged items.

He found them covered, the units labeled and about to be shipped out. In addition to other actions taken to correct the mobile homes in violation, he filed a written report concerning the actions, or lack thereof, of the certified inspector.

In this case, the certified inspector was immediately decertified by me subject to confirmation by the Qaulity Assurance Council. Confirmation came at the next regular QAC Meeting.

This incident occurred about three months ago. The manufacturer is now looking around for a new DAPIA/IPIA.

CASE HISTORY C

During monitoring, it was found that a change was made in a house which was not covered by a design approval.

PFS does permit certain minor plan or design changes which are judged to not affect the house safetywise.

The change affected the house structurally and should not have been authorized without PFS office approval.

The Certified Inspector admitted that he made an error in judgment in approving the change but said he thought the change was minor.

In this case, the president of the company responded to our inquiry by hiring a new Quality Control Manager over the Certified Inspectors. He did this after conducting his own investigation into the reasons for the foul up.

Because the Certified Inspector did not willfully violate Code regulations, it was decided by the PFS QAC to merely give him a written reprimand advising him that the reprimand would remain part of his file at PFS for one full year. After one year of satisfactory performance, the letter will be destroyed.

CONCLUSION

For the manufacturer, the Certified PFS Inspector Program does involve a substantial investment in both time and money.

Yet at this time very little official recognition exists for the program. Few states hold the Certified Inspector accountable in any way. Likewise, HUD has not chosen to recognize the program officially in any way. Considering this, it is extraordinary that PFS enjoys virtually 100% support for the program from industry. We know that some of our clients have joined PFS substantially because of the training program.

Our experience shows that many inspectors are lost due to promotions up into the organization. In fact, management often uses our training program for people they have their eyes on for management positions later.

That the program is successful is obvious. We only hope that you as the final authorities will work with PFS to develop the usefulness of this program even further.

Table 1

LIST OF SUBJECTS TAUGHT AT PFS
TRAINING SEMINARS
Since Beginning (September, 1973)

SUBJECT	HOURS
Introduction to Equipment	2
Records - Control	6
Quality Control	11
Relationship Bewteeen CI & Authority Having Jurisdiction	2
Codes and Standards	4
Lumber Grading Rules	6
Equipment Calibration	1
Inspection to U.B. Code	2
ANSI A119.1 Standard	6
In Plant Test to ANSI 119.1	2
Plumbing	20
Plywood Grading Rules	7
NEC	14
Heating, Ventilation & R. Valves	11
Fundamentals of Attic Ventilation	6
In-Plant Inspections	1
Agency Grademark on Lumber	7
PFS Program	5
Fire Safety and Protection	4
Adhesives	6
Mechanical Fastenings	2
Design of Mobile Homes Travel Frames	1
All-Plywood Beams - Mobile Homes	1
Mobile Homes Safety	1
Structural Analysis	4
Plan Review	1
Product Liability	2
HUD Standard for Mobile Homes	9
TOTAL	144 Hours

Table 2

SEMINAR ATTENDANCE SUMMARY

SEPTEMBER, 1973 THROUGH APRIL, 1976

There were 9 seminars with a total attendance of 136 men:

96 of these men were certified at one time	71%
82 of them are still certified	60%
14 of them are no longer certified	10%
40 of them were never certified	29%
1 of them was decertified because of exam failure	
1 of them was decertified until he complies	

Number of men who attended one seminar	85	63%
Number of men who attended two seminars	31	23%
Number of men who attended three seminars	14	10%
Number of men who attended four seminars	5	4%
Number of men who attended six seminars	1	1%

Figure 1

Confidential

PROGRESS REPORT
INSPECTOR TRAINEE

Date of Report:

Audit Inspector's name: ______________________________

Trainee's name: ____

Manufacturer's name: ____

Plant: ____

This is the ( ) first, ( ) second, ( ) third report on this trainee.

Length of time under your supervision: _____________________________

Evaluations

Record Keeping:	( ) acceptable	( ) unacceptable
Time on Inspection:	( ) acceptable	( ) unacceptable
Knowledge of his job:	( ) acceptable	( ) unacceptable
Other:	( ) acceptable	( ) unacceptable

Remarks: ____

____

____

I ( ) do ( ) do not recommend this trainee be Certified as a PFS Inspector.

Audit Inspector
Signature: ______________________

(This report will not be shown to the manufacturer or trainee without prior clearance of the audit inspector)

PFS FORM #25 4/74

Figure 2

PRODUCT FABRICATION SERVICE

IT IS HEREBY CERTIFIED THAT

HAS DEMONSTRATED THROUGH SATISFACTORY COMPLETION OF 16 HOURS OF FORMAL CLASSROOM INSTRUCTION AND EXPERIENCE HIS CAPABILITY IN PERFORMING THE REQUIRED RESPONSIBILITIES AND IS THEREFORE, DESIGNATED A

CERTIFIED PFS INSPECTOR

OF FACTORY BUILT COMPONENTS OR HOUSING UNITS MEETING THE STANDARDS OF PRODUCT FABRICATION SERVICE AND PRODUCED IN THE PLANT OF

ISSUED THIS DAY OF , 19

CHAIRMAN, QUALITY ASSURANCE COUNCIL

EXECUTIVE VICE PRESIDENT

THIS CERTIFICATE EXPIRES ONE YEAR FROM DATE OF ISSUE

LEGAL ASPECTS OF THE BUILDING REGULATORY PROCESS

by

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Massachusetts State Building Code Commission
Boston, Massachusetts

Building regulations had a beginning, a middle and will have no end. Since the time man first built a shelter which in some way affected the shelter of another, building and housing regulations out of necessity arose. As man progressed and his needs improved, laws were enacted to control his activities and a few of these laws regulated the use and construction of his shelter. It will be attempted here to briefly illustrate the ways in which this shelter has been regulated and misregulated and to show that in several years we have not yet reached an atomic age in the building regulatory process. As the building regulatory process becomes more complex and technical, the building official must become more knowledgeable and technical. It will also be seen how the courts have reminded the building official that the public need not tolerate a building code requirement simply because it is so written.

Key Words: Building official; building regulations; code enforcement; construction; court decisions; disasters; economics; legal approach; regulatory process; violations.

POLITICAL IRRATIONAL APPROACH

In the Year 27, a wooden amphitheatre near Rome collapsed and killed or injured some 50,000 people and shortly thereafter we had the beginnings of a politically oriented building regulatory system. As a result of a house fire in Boston in 1630 which spread to another house, it was decreed by the elected officials that chimneys could not be built of wood, and houses could not be covered with thatch. Because of sickness in Boston in 1652, it was required that there be at least twelve (12) feet between a privy and the street. It immediately became necessary to have all passenger ships inspected before leaving the docks due to the tragic capsizing at its pier of the passenger ship General Slocum in 1904 in which over 1,000 people lost their lives. In 1903, 600 persons lost their lives in the Iroquois Theatre fire in Chicago resulting in sweeping changes in the laws affecting theaters, not only in Chicago but by almost every state in the union. In 1938 the Massachusetts legislature enacted the so called Boston Building Code subject to ratification by the City of Boston's City Council. The City of Boston suffered through its obsolete building code until the fateful evening of November 28, 1942 when a Boston night club, the Cocoanut Grove, overcrowded with football festive people, found themselves in the midst of a small fire which quickly got out of control and panicked over a thousand patrons. Nearly five hundred (500) people lost their lives almost instantaneously and another five hundred (500) received varying degrees of burns.

On February 15, 1943, Boston's City Council referred to committee the building code passed by the legislature in 1938 an on May 10, 1943, less than six (6) months from the fire that touched in some way every Boston resident, and five (5) years from legislative passage, the Boston Building Code became effective for the City of Boston. It was felt by those rational technicians, at the time, that this code could not have prevented the fire nor the loss of life resulting therefrom, but no one can argue that a modern building code was implemented out of the ashes of this holocaust.

These are but a few of the many thousands of cases which a tragic incident had to occur before a public outcry resulted in safety requirements being implemented by those charged with enacting laws. I dare say that although the cited cases range from the year 27 to 1943, the more classic cases not mentioned occurred prior to the year 27 and go beyond 1943. This political method of enacting codes by reacting to a holocaust achieves an end result that is far from an acceptable method of public safety protection.

AN ECONOMIC APPROACH

A tragic happening is often followed by an overaction by those charged with enacting building regulations. These regulators totally disregard the economic problems that they have created. This irrational approach in building codes sometimes is later tempered by code technicians who consider the feasibility of enforcing such requirements by analyzing its cause and effect. In the simplist terms they wonder why the regulators designed a short fused bomb to kill a few household insects instead of improving on the fly swatter.

In 1974, the Massachusetts legislature overwhelmingly enacted a law requiring sprinklers be installed in all new buildings over seventy (70) feet in height and an automatic fire warning system installed in all new buildings not exceeding seventy (70) feet in height occupied for residential purposes. In spite of a 1972 law establishing a State Building Code Commission charged with adopting a mandatory state wide code to be effective on January 1, 1975, the legislature charged the local fire officials with the interpretation and enforcement of these two (2) laws over the objection of the industry, the governor, and the building code commission. During 1975, it was found that the 351 local fire officials enforced these laws in the manner fearfully expressed by the opponents. Many of the fire officials lacked the technical expertise to draft guidelines for sufficient, but not absurd, requirements. Thus we had requirements in several communities for heat and/or smoke detectors in every compartment, (closets, cabinets, attics, cellars and rooms), on the theory that "two is better than one and three affords much more protection than two, etc." Several communities required any residential building with over two (2) units to have their system tied directly into the fire station, stating that they had no loss of life since instituting these requirements, however, their statistics could not determine if one detector in each unit, not connected to the department, would also have saved these same lives. Would not statistics also have shown that an early warning system is to alert the occupants in order for them to evacuate before it is too late since seldom will the fire department be at the scene before all able bodied persons have evacuated due to this early warning. The legislature in mid 1975 then heard a cry for help from its constituents and the sophisticated fire officials, for a modified law which would be uniformly enforced interpreted and thus less costly.

Heeding the cry, the law was amended so that the requirement and interpretation was left to the State Building Code Commission who enlisted the aid of a Fire Protection - Fire Prevention Board composed entirely of fire specialists (11) such as fire department personnel, fire engineers, and fire signal persons. With the aid of this board, a fire prevention - fire protection section of the building code was adopted giving the Commonwealth perhaps the best regulations in the country for such things as an early fire warning system and effective fire suppression system.

As a code oriented group, generally only the building officials seem to recognize that presently no one can prevent the loss of life, health, and property losses caused by God (flood, lightening, etc.) and intentionally man caused catastrophies (bombs, arson, etc.). With modern technology today, it may be possible to nearly eliminate our personal losses but is the public ready to accept the cost of such protection both financial and aesthetic? Would the public want to pay for and endure a fully sprinkled and detector equipped house containing no toxic emitting or flammable personal property? Certainly we are reaching for a compromise to limit the life and property losses but we are a long way from accepting the charge of total elimination. Since we cannot totally eliminate these losses but can limit them, we must consider so called tradeoffs. If we require or allow compartmentalization in a high rise building, it should not be also necessary to totally sprinkle the building. Are we sophisticated sufficiently to regulate the contents of a building such as furniture, waste baskets, papers not in fireproof containers, clothes, etc. Certainly this loading of a so called fire proof building with flammables and toxic materials creates a problem too lengthy here to discuss but it is worthy to consider trade-offs with other protective means.

What then single conclusion can be drawn from any of this? Or is this merely a rambling of unconnected theories, statements, facts and considerations! I feel that a rationale approach is needed in the building regulatory process. No longer can we afford to have the political-irrational approach to building laws and enacted by legislatures who are lawyers, doctors, barbers, educators, etc., enforced by inept building officials making political and/or irrational decisions in their interpretation, enforcement and sometimes enactment of building regulations. The utopian method would be to discard all present building codes and enter into a marriage with all specialty groups engaged in the safe occupation of buildings. These "buildings code" specialists would be charged with not only drafting a code, which has already been done, but, more importantly in the case of each regulation, explaining why it is a necessary regulation. For example, we presently establish the maximum number of occupants allowable in a place of assembly but we do not consider that instead of able bodied persons there may be in this same place of assembly a meeting of wheelchair equipped handicapped persons. If our examination discloses that a hall may have 300 occupants should we allow or prohibit 300 people in wheelchairs from occupying this space? Why do we regulate the height of the exit doors at 6'8" when we have persons today standing over 6'8", so why not set the requirement of 7'8" or 8'? And if the door height is required 6'8" minimum, why is the ceiling height minimum set at 7'6" and not at 6'8" or 8'? Is the ceiling height a truly public safety regulation or is it a matter of public health or merely public convenience? Is the width of the required exit door set at 36" or 32" for public safety or is it for purposes of getting furniture or caskets in and out of doorways? I believe the unit of egress width for all approved types of means of egress parts and facilities is 22" and half the unit is 12", so what would be the rationale to 32" or 36"? I certainly do not advocate 22" doors but I do ask, as a public safety requirement, all to consider how we arrived at the 32" or 36" instead of responding that 36" is far safer than 34". Consider also if 34" is considered sufficient, would the additional cost of adding or reducing by 2" the width of the required exit door be prohibitive? It must be remembered that unlike any period of time before, public servants must be responsive to the public which it serves. Today there are consumer groups, tenant groups, parent teacher organizations, etc., and they want rational answers. How long can we afford to enforce building laws that have their beginnings dependent on the political strength of mills, fabricators, insurance companies, construction firms, labor unions, politicians and in some cases even building officials. If we concede that a specification oriented code is obsolete and costly, are the building officials, the technicians, architects and engineers ready and willing to accept a true performance oriented code? The building official must be capable of evaluating the results of performance data; the architect and engineer must be willing to accept a true performance oriented code. The building official must be capable of evaluating the results of performance data; the architect and engineer must be willing to justify his design. Some feel that often the architect and engineer oppose a truly specification code because the "tried and true" methods do not result in a great varying degree of competition. Given the personal requirements of a client for a building, and no building code, how many of us would take on the responsibility of designing the building with only the consideration of the client and public safety? We probably would first consider the safe evacuation of the occupants and if it becomes impossible to totally evacuate safely the occupants, we would provide for them a so-called area of refuge. I do not believe we are prepared to eliminate building codes or accept a truly performance oriented building code but we are sophisticated enough to question each section of the building code and ask, "why is this a requirement" or "why cannot the architect or engineer exercise some ingenuity and imagination in his design?" National organizations such as NCSBCS must have a voice that can be heard over the irrational designers of building regulations; a voice that in this technology motivated world is deserving of a specialists approach to a building regulatory system.

A LEGAL APPROACH

We must consider the constitutional rights of the individual which are often opposed by the collective rights of the public. This delicate balance of the individuals right to the quiet enjoyment of his property and person has only recently been attacked in the courts. Consider a building occupied as a place of assembly and built prior to a building code. Can a building official impose new regulations on this pre-code building? Consider a new litter law; can one be prosecuted for littering the streets yesterday when the law was not in effect until today? This litter law is clearly effective for those littering after its effective date but the new building code requirements do not cite the building for being built in violation of the law but of being in violation of the law (regulation) after its effective date. Violations of the building and housing codes are continuing violations and not a one incident violation. Building officials were accused of invading the constitutional guarantee of Vested Property Rights but the courts have responded that building code regulations are a proper exercise under the States police power for the preservation of life, health, and morals. To date, most building code regulations have survived the test of reasonableness but have been successfully attacked as to the reasonableness of enforcement by the building official.

If a police officer demanded entry into one's home because he suspected a member of the neighborhood or household of committing a crime, would we consider it reasonable to allow entry for the official to search and question our household? I think not very easily. It is then reasonable for building officials to demand entry into the non-public portion of a building for purposes of inspection and possibly obtaining evidence to be used against such occupant in a court of law? In the case of the police officer, the evidence could be destroyed and the suspect could escape from the area in the time he needs to get a warrant but still the court requires a warrant be obtained for entry except in very limited instances. As to the building officials demanded entrance being denied, and now requiring him to procure a warrant for a legal search and entrance, the suspected violator, in the meantime, may leave at any time without any problem to the building official and if the violation is corrected in the time it takes to get the warrant, the building official has only been inconvenienced but should be pleased.

The fourth amendment to the constitution guaranties "...The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures...and no warrant shall issue, but upon probable cause, supported by Oath and Affirmation, and particularly describing the place to be searched, and persons or things to be seized." These protections have been extended to State proceedings by the fourteenth amendment.

In 1959, the U. S. Supreme Court in Frank vs. Maryland, had to answer an important question - What constitutes an "unreasonable" search. The court held in a 5-4 decision, that upon being refused entry to inspect, a warrantless search was not unreasonable since the evidence obtained was not intended for use in a criminal prosecution although the refusal to allow entry was punishable criminally. The majority of the court felt that there is no absolute right to refuse consent to an inspection designed solely for the protection of the community's health. In this case, the violation could be seen without entry onto the premises of the defendant. In 1960, the same court in Ohio ex rel Eaton vs. Price heard a similar case but because it was a 4 to 4 decision, the Maryland decision was allowed to stand; the only significant difference was no physical indication of a probable violation in the Ohio case. All judges held their position but the ninth judge (Stewart) was from Ohio and took no part in this Ohio decision. It must be mentioned that he probably would have voted to affirm the Maryland decision since he so voted with the majority in that case. In 1967, by a 6-3 vote the court in Camara vs. San Francisco and See vs. the City of Seattle, reversed the Maryland and Ohio cases and stated that not only must a warrant be obtained but without a warrant there must be a voluntary intentional waiver of the fourth and fourteenth amendment which cannot be gained under the guise of submittal to an authority (i.e. "in the name of the law" or "under the color of ones office-his badge"). It is interesting to note that none of the Justices in the Ohio or Maryland cases changed their vote, but two of the justices who voted against the need for a warrant were no longer on the court and their replacements voted with the four (4) voting in favor of requiring the warrant. Do we dare conclude, therefore, that even the Supreme Court of the United States vote their own personal convictions, and decisions can hang on the make up of the court? If we read the results of the cases decided we must realize that a 5-5 or 5-4 or 6-3 decision is not a comfortable margin on the side of right but it is the best system for reaching an end. An often forgotten conclusion drawn by this court is very important to code enforcement officers and that is the authority of building and housing codes to "...impose and enforce such minimum standards even upon existing structures" has therein been solidified.

VIOLATIONS OF THE BUILDING CODE

Any building code, like any law or regulation is merely a compilation of requirements necessary to do or to prohibit certain tasks. As any tool it is best used in the manner for which it has been designed, or the tool must be designed to do a specific task. How many of us would adhere to a fifty-five (55) mph speed limit if there were no enforcing officers watching and threatening reprisal? We certainly would not push the accelerator to the floor and travel ninety (90) miles an hour on a windy road only because of a fear for our own personal safety. We would most probably not be as concerned traveling at seventy (70) mph on a highway. So too with building code regulations. Without violation penalties and code officials to enforce them would the construction and maintenance of buildings be accelerated beyond the point of public safety? I cannot believe that it would be pushed beyond endurance but I accept the fact that compliance could be compromised so as to possibly endanger the public; to believe otherwise would be to forget the need for the original code requirements and the constant revisions made necessary from time to time. Building officials must have the power to reasonably enforce the codes. If a dangerous condition exists in an occupied building in the middle of a highly congested area is it reasonable to give the violator thirty (30) days in which to make the necessary corrections? Conversly if the same conditions exist in an isolated non-occupied building the thirty (30) days is not so crucial.

Non-compliance with a building code in a majority of the cases is of little trouble to the building official since most provisions of the code deal with new construction and the item of non-compliance is so because of the building officials interpretation. If the person desiring the building permit wants to proceed, he must determine first if the building official is correct in his interpretation, if so, he may comply with the code or he may seek a variance or waiver from a higher authority. If he disagrees with the building officials interpretation, he may comply anyway or appeal such interpretation to a higher authority, a board of appeals, or the courts. In most instances it is cheaper to comply. Appeals to a higher authority take too much time, and time is money. So in 90% to 95% of the cases, we have voluntary compliance in new construction and 5% to 10% of the non-compliance items are appealed. The important factor not known is how many cases were incorrectly interpreted and completed the building officials way, since the applicant could win the battle but lose the war. He cannot forget that this same building official will later issue the building permit, the certificate of inspections, and the use and occupancy permit, and in many instances certain licenses.

Perhaps the most troublesome nonconforming cases the building official deals with are those of existing buildings that are found to have violations of the building code. If the "violator" is not seeking a building permit how does the building official receive compliance on a voluntary basis? If the violator is faced with a political or economic loss he will no doubt try to avoid such loss by correcting the deficiencies, and we have seen that the loss or threat of not renewing a license is a great deterent, but what of the remaining cases where the violator merely stalls the official attempts to bring political pressure or appeals such rulings to a higher authority merely to gain time.

What requirements, therefore, of the building code are intended to apply to existing buildings? Most building codes state that no further requirements may be imposed on an existing building unless the building official deems them necessary for the general safety and welfare of the occupants and the public. Since an existing building must be presumed to have been legally built and nothing about the building has changed, the building has been maintained in a safe and sanitary manner, how then can we justify the imposition of added requirements? It seems the building owner and public need to know what prompted this change, and a developer also would like to know why more stringent requirements are placed on his building than on the existing buildings.

I suppose an answer could be that a rural road built in 1930 could have justified in 1930 a speed limit of 45 mph but because that same road today is not in a rural area, the traffic is far greater; the vehicles are improved but the risk, or potential risk, is therefore, far greater and a 30 mph limit is perhaps more reasonable. In short, the road did not change but other factors have. So too, must we impose greater restrictions on existing and new buildings and structures today. No one can doubt that never before have so many spent so much of their daily lives in buildings and structures. We are not nomads; we eat, sleep, work, and even play in buildings and structures and we are entitled to be safe at these endeavors even though those charged with the responsibility of seeing to this safety are not generally acknowledged and appreciated for the tasks they perform so well. It is most important that the building code regulators keep up with the technology and, where necessary, impose further regulations on existing buildings and, where possible, allow a relaxation of code requirements determined now to be obsolete or unnecessarily stringent.

Building officials very often are the defendants in suits seeking to restrain them from certain action or seeking to require them to take certain action. Many times the building official must resort to the courts himself in order to get compliance. He can proceed on the civil side by instituting an action to prevent unlawful construction or to restrain, correct, or abate a violation, or to prevent illegal occupancy of a building, structure, or part, thereof, or to stop an illegal act, conduct, business, or use of a building. He may also institute an action on the criminal side of the court against the violator if the violation is not corrected "promptly." The courts have wrestled with the requirement of "promptly" for many years and have ascertained only that such order of the building official shall be "reasonable" and therein lies the bigger problem.

What is "reasonable?" Is 24 hours reasonable to contract for a demolition contractor to transport the necessary equipment and manpower to remove a dangerous wall? Is seven days a reasonable time to require that an illegal occupancy be removed? Or is thirty days reasonable in order to remove lead paint from a dwelling unit? It is unlikely that we can answer without more facts in these cases but the building official is required to ascertain in what circumstances would his order be reasonable. In the case of a dangerous wall located in a congested area where demolition people are available, the twenty-four (24) hours would probably be reasonable. If the dangerous wall is a barn away from everyone and everything, twenty-four (24) hours would probably be deemed unreasonable.

The frustrations of the building official are greatest in the process of getting these violations corrected. If he does not get voluntary compliance with his violation notices, he may have no alternative but to seek from the courts the necessary support. Unfortunately, by the time he enters the case in court, several days, weeks, or even months have gone by, so that for that period of time at least the "violator" has won. When it finally comes to trial, the court is usually sympathetic but rarely finds the violator guilty of not complying with the officials order but feels obligated to go beyond this and require compliance and then dismissal. The court now wants to hear the background of the case. The violation of the officials order now seems insignificant. The court will invariably order the corrections to be made, something the building official has already attempted, and this adds more days or weeks to the frustrations. Often the building official feels that the courts do not consider this a crime as compared to a robbery of a person. Consider, however, that the robbery has already been committed and ordinarily no one is any longer in danger resulting from that crime; and whether the defendant is tried immediately or in six months will not increase any hazard to the victim. Now consider the building code violation that is continuing as though every day the defendant is "robbing" the same victim. Unfortunately, we are unable in a majority of cases to convince the courts of the severity of building code violations.

ALTERNATIVE CODE ENFORCEMENT TOOLS

Perhaps the building official needs another tool for enforcement. The building official could prosecute the case before a municipal administrative tribunal which could access reasonable costs for noncompliance of the order and could make reasonable orders. The violator would then have a choice of either compliance or the burden of appealing the administrative order. If he did neither, he could be sued on the civil side of the court in order to collect the costs imposed or to enforce the administrative order. It is possible that any such suit would not require the testimony of the building official and he would be free to bring another action against the violator before the administrative tribunal.

Local banks do not print money; they cannot invest or pay interest on deposits unless they invest the money held on deposit. If a neighborhood bank holding neighborhood deposits (investors) lends money for mortgages on local real estate, do they not owe an obligation to its investors (depositors) to protect such investment? If the investment has deteriorated or is deficient in some way, should not these banks do something to protect their investors? If these lending institutions would perform from time to time inspections in order to protect their investments, they may procure for their depositors a greater dividend in profits or in property values; such periodic inspection would also aid the building official in his job since noncompliance with the mortgagees' order could result in a foreclosure. No other business does as little to watch its investments in the monthly payments being made, and if there is a loss of life due to a building code violation, it does not greatly concern them; if the building becomes vacant or has a fire that, too, does not concern the banks; after all, a fire insurance policy provides for the proceeds to be paid to the bank so that the asset is protected. What they have not done is protect their local investors who perhaps live in the building which is in violation. A building which has deteriorated to the extent that it has become a liability to the community is no longer an asset to anyone. Perhaps then we should consider assessing responsibility on anyone having a substantial interest in a building or structure.

CONCLUSION

The building regulatory process from its crude beginnings of responding to disasters has come a long way but such distance has been traveled most in the past forty years and the greatest distance is yet to be traveled. We are still well behind technology, technology that is not yet tough enough to overcome our own questioning. We must be willing to listen and be able to accept the mandate of the people; we must look for new ways of getting things done and accomplishing compliance. The courts have placed an obstacle in the path of code enforcement in requiring certain procedures be followed prior to entry and inspection but it is not an obstruction at all, only the courts method of playing catch-up with technology. Technology itself will not make for a better building regulatory process unless the building officials are properly and continually trained in the use of their new technology.

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