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FIRE PROTECTION Engineering

SPRING 2005

Issue No.26

FIRE PROTECTION ENGINEERING ECONOMICS

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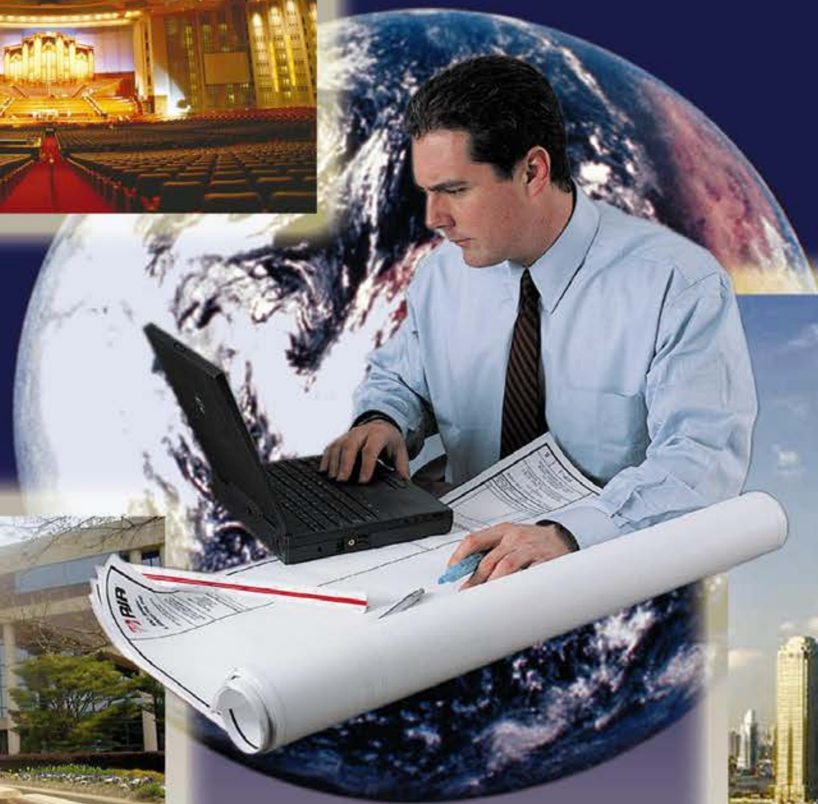

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letters to the editor

Dear Editor,

Ordinarily, I am pleased to see fire statistics used to provide useful insights into fire safety strategies. Unfortunately, Dr. Eisenberg's feature article in the Winter 2005 issue contained more problems than insights.

In the past 30+ years, I and my colleagues at NFPA have been involved in more than a dozen studies of the statistical relationships between fire outcome measures and potentially explanatory variables. We have compared state to state, city to city, and census tract to census tract. We have compared fires per million population and deaths per million population. Only one of these works is cited in Dr. Eisenberg's references, and perhaps that explains the problems in his article.

Previous studies have consistently found that certain variables – led by race and age of housing – show up as strong predictors when taken in isolation but do not fare so well when the effects of other, stronger variables, such as poverty and education, are factored in. High-poverty areas tend to have high fire rates and even higher fire death rates. Rural poverty is associated with an even higher risk multiplier than urban poverty, and that may be one crucial place where Dr. Eisenberg went wrong.

By excluding all but the most populous counties, including all the rural areas, he removed the counties that would have added to the statistical power of poverty as an explanatory variable. That would likely have produced a better r-squared than the 13% of variation obtained by Dr. Eisenberg (in Table 4). And the relative importance of other variables would have receded as well.

Newer homes tend to look safer because they typically are occupied by more affluent people. Whenever a study breaks that connection – as in NFPA's annual study of state fire death rates, where states like Vermont and Connecticut have a high proportion of old homes being occupied by the well-to-do – the explanatory power of age of housing melts away. As new homes change hands, they tend to pass down the food chain to relatively less affluent occupants, who bring their higher personal risks into the home.

When you look at the differences that are actually intrinsic to new homes, it becomes even clearer why you would not expect to see age of housing as a powerful factor in risk.

Dr. Eisenberg cites improved fire blocking and stopping, which he says results in better fire containment. However, the percentage of dwelling fires confined to the room of origin has been in the narrow range of 69%-71% from 1980 to 2002 except in 1981-1987, when it was higher. In other words, there is little statistical evidence of a trend up or down, but what trend there is indicates less containment is occurring, not more.

Dr. Eisenberg cites better heating and electrical design, resulting in less use of extension cords and space heaters. I don't know of any source of data on extension cord usage, but space heater usage soared in the late 1970s, driven by large changes in the cost and availability of different fuel and power choices. Fires involving space heaters soared, too, then dropped fast and far from about the mid-1980s on. However, the data I have don't show a comparable drop in relative space heater usage, as Dr. Eisenberg postulates. It looks more to me as if people are learning to use space heating safely rather than that there has been any flight, large-scale or otherwise, away from space heating.

Dr. Eisenberg cites improved fire ratings on upholstered furnishings, bedding, and sleeping attire. These are all positive developments, but they are most associated not with newer homes but with wealthier homes, which tend to be the first recipients of every new innovation.

Dr. Eisenberg cites the trend in smoke alarms. Smoke alarm usage exploded in the 1970s, and most purchases were made voluntarily. The building codes came along and mopped up the relatively few hold-outs. The push to interconnected, hard-wired smoke alarms is a positive development and one more driven by codes, but it remains an exception in homes even today. Most of the potential benefit from smoke alarms occurred with the initial acquisitions, which were not as unreliable as Dr. Eisenberg says.

Dr. Eisenberg says the post-1990 trend in cigarette smoking will no longer be of much help in reducing fire fatalities. From 1990 to 2001, the smoker percentage of the population declined from 25.4% to 22.7%, an 11% decline or 1% a year. But the number of cigarettes smoked declined by 24% from 1990 to 2003, which is more like 2% a year. Since the entire fire death problem declined by 45% from 1979 to 2001, or about 2% a year according to Dr. Eisenberg's figures, a 2% a year decline ain't bad. We not only have fewer people smoking each year, but our smokers are smoking less on average.

Dr. Eisenberg's regression analysis also cites mobile homes (actually, the preferred term is manufactured homes) as a risk factor. However, NFPA studies have shown that if you focus directly on a comparison of manufactured homes to other dwellings, the traditional difference in fire death rate relative to housing units has vanished. You might not pick that up in a study like Dr. Eisenberg's because manufactured homes

continued on page 4

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correlate with poorer neighborhoods and also average fewer people per unit, which means their fire death rate per person may be higher than their fire death rate per unit. But the main point remains: you cannot call manufactured homes a distinctive fire risk anymore.

Nearly all the points in this letter – the exception is the trend in fire confinement in dwellings – are taken from published analyses by NFPA staff. In other words, the substantiated rebuttals to Dr. Eisenberg's points are already on the record and have been widely circulated. It is unfortunate when an article with so many errors appears in a respected publication. It is troubling when readily available, technically sound information would have flagged those errors but was not consulted or addressed.

What should a reader take from this article, or more importantly the facts on these issues? If we build safer homes and safer products for those homes, while also teaching ourselves safer behaviors, we will become safer, either quickly or slowly depending on the degree of safety provided by each innovation and the rate of turnover in whatever is being changed. In that sense, newer homes probably are safer than older homes, but the changes in homes are not currently a primary driver of our move to greater safety. If we want them to be, we need to make changes in homes that will make a large difference in safety – like requiring fire sprinklers in new homes.

Greater safety does not come automatically; it comes only if we make it happen. All the statistics are only details on this essential point.

Sincerely,

John R. Hall, Jr., Ph.D.
Assistant Vice President
Fire Analysis & Research
National Fire Protection Association

Author's Response

While Dr. Hall has written extensively on fire deaths, his comments are based exclusively on non-peer-reviewed NFPA research and dismiss a large body of peer-reviewed articles which substantiate my findings.

Dr. Hall suggests that when "stronger variables" are included, race and age of housing do not fare well. Interestingly, the two variables he suggests were each tried, and the results obtained were very similar to those reported, suggesting that race and age of structure do matter.

His suggestion that I "went wrong" by excluding rural areas in the analysis is untrue. Had that data been available, they would have been included. Out of privacy concerns, the National Center on Health Statistics suppresses death data for counties with a population of less than 100,000 in 1990. However, because the dataset I used is specifically designed to capture the cause of death and is not based on a sample, it has advantages over both NFIRS and NFPA data.

Dr. Hall suggests that when the relationship between new homes and affluence is broken, the explanatory power of age of house "melts away." One could only wish that this were the case. By including house value in the equation, I, in fact, break the connection just as he suggests. However, the significance of age of house persists, again suggesting that age of structure matters.

Dr. Hall continues by suggesting that increasingly stringent building codes are not working, and as proof he suggests that fire containment is actually declining. That is precisely my point! We have come to the point of severely diminishing returns to code improvements with respect to fire deaths. Rather than continuing to strengthen codes in an effort to prevent possible future fire deaths, why not prevent current fire deaths by focusing our resources where deaths are occurring today, not where they may or may not occur many years in the future.

Later, Dr. Hall suggests that the entire decline in fire deaths may be attributable to declines in smoking. I wish it were that simple. Here Dr. Hall commits the ecological fallacy, as he makes inferences about individual smoking behavior based on aggregate group data.

Dr. Hall closes by recommending that fire sprinklers be installed in new homes. Unfortunately, as Dr. Hall says, "newer homes probably are safer homes." And if he is arguing that new homes will eventually become old and less fire-worthy, he requires that if and when sprinklers are needed, 30 or 40 years in the future, they will work. That is a big "if" because not "many" things in a house work after 40 years unless they are properly maintained and/or replaced. And unfortunately, unlike a hot water heater or dishwasher, if sprinklers do not work when they are needed, they are useless. Moreover, to repeat, to date there is no peer-reviewed evidence that sprinklers reduce fire deaths.

Rather that refuting every one of Dr. Hall's remaining arguments and prolonging this discussion about codes, variables, and statistical significance, let's resolve this debate once and for all. We are united in our desire to reduce fire deaths. Given that the NPFA has it within its purview to collect data on age of structure, I suggest that it be collected in the next NFIRS survey. With good data on age of house, this debate might resolve itself.

In short, I want to save lives by focusing life safety efforts where fire deaths are most prevalent now, using proven smoke detector technology. By contrast, Dr. Hall wants to try unproven remedies that may or may not saves lives in the distant future, that have no proven track record of success, and that do not help those in most need today.

Sincerely,

Elliot F. Eisenberg, Ph.D.
Housing Policy Economist
National Association of Home Builders

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viewpoint

Allocating Resources for Fire Protection:

A Building Owner's Perspective

By Tomi Sue Beecham, RBM, RPA

One of my favorite regular columns is the "Property Report" in every Wednesday's *Wall Street Journal.* A recent article by Ray A. Smith on February 23, 2005, pointed out that savvy investors in buildings (and we really are talking savvy) buy buildings not because of the value that they represent, but because of the income stream that they can produce. This is sage advice for anyone considering an investment in a building.

Yet, returns on an investment in a building can be considered, or even developed, in ways other than measuring cash flow. The sheer joy of owning an attractive piece of property, satisfaction in contributing to the visual appearance of a community, or providing a valuable service to the business community are all worthwhile considerations. There is satisfaction, too, in the knowledge that you are doing everything possible to keep your tenants and their important property as safe as possible. The return, of course, depends on how the owner defines it. Another return that is extremely difficult to measure in dollars and cents is the investment that an owner makes in fire protection.

The expenditures made for fire protection can be considered in two veins: those that are required by code or other regulations put forth by the local jurisdiction, and those that you have voluntarily budgeted with the expectation of gaining some return.

Expenditures required by building codes are mandatory for all building owners of a particular type of building. They represent the minimum that the community has determined are necessary for a safe building, and adherence is required.

The second type of investment for fire protection improvements are ones that are entirely discretionary for the building owner. These improvements and expenditures should be carefully and deliberately considered. Many of these decisions are made with the assistance of a fire protection engineer who guides the building owner through the task of determining which of the options should be chosen.

Choosing which features to include is difficult. Most building owners would like to have all the latest in fire protection/prevention incorporated into their buildings. It's a difficult thing to pay for and difficult for tenants to appreciate. It goes without saying that building tenants just expect that their environment is safe and free from the threat of fire and the severe disruptions that it can bring.

Older buildings require, for good reason, more resources for improving fire protection than in newer buildings. New buildings have the benefit of the latest in design for fire protection and prevention that have been incorporated in model building codes. Older buildings, obviously, generally do not. Depending on the age of the building and the amount of care provided previously, an older building can necessarily command quite a bit of attention when improving its fire protection/prevention system, and this attention can result in the expenditure of a great deal of money. This is not to say that an older building is unsafe – quite the contrary. It's just fair to say that an older building, in general, is going to require a bit more in the way of resources than a newer building. When an older building does present this situation, then the building owner is confronted with the challenge of which improvements to choose.

This is where the assistance of a qualified fire protection engineer comes into play when deciding on which improvements should be included and how to prioritize these decisions.

Some of the most important assistance that a fire protection engineer can provide is to furnish suggestions on the maintenance of a fire detection and suppression system. Having periodic inspections advances the operation of these systems and provides peace of mind that they will operate correctly and effectively if they are called upon.

Although building owners are ever-watchful for situations that appear to be fire hazards, an extra critical eye is helpful in looking for practices such as the improper storage of flammable materials or the dangerous use of an appliance or a piece of equipment by a tenant or building employee. One of the recommendations that a fire protection engineer can make is on improved exit signage to show the fastest emergency evacuation route. Another would be the evaluation of the fire alarm system.

The assessments that the fire protection engineer can make can be a good return on investment. Although it may not be part of the cash flow of the building, the services of a fire protection engineer do produce both a return in cash and the satisfaction of knowing that you are doing all that can be done to make the property as safe as possible. In allocating resources for fire protection/prevention in your building, strong consideration should be made to the retention of a qualified fire protection engineer.

Tomi Sue Beecham is the chair of the Building Codes and Voluntary Standards Committee of the Building Owners and Managers Association International and the senior property manager of a shopping mall in San Antonio, Texas.

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- The 2004 State of Home Safety in America – Trend Analysis and Executive Summary
- 10 Home Safety Council injury prevention brochures
- Home safety posters in English and Spanish, and much more.

The Home Safety Council is a nonprofit organization dedicated to helping prevent the nearly 21 million medical visits that occur on average each year from unintentional injuries in the home.

For more information, go to *www.homesafetycouncil.org*.

NFPA President Calls for Emergency Planning to Address Needs of People with Disabilities

The head of the National Fire Protection Association (NFPA) is calling on state and local safety officials, building owners, and facility managers to take additional steps to incorporate the needs of people with all types of disabilities into emergency planning.

"We know there have been times in which people who use wheelchairs were simply left behind during emergencies without any specific direction or instruction, presumably to wait for rescue," says James M. Shannon, NFPA president and CEO. "That is just not acceptable. People with disabilities deserve to know there is an effective emergency plan in place that will keep them safe. And these plans must be developed with input from accessibility experts and people with disabilities who will be affected by the plan."

For several decades, NFPA has developed many of the exiting (means of egress) requirements that are used in buildings all around the world.

"Clear procedures must be in place, ranging from relocation within the building to evacuation of the building. It is up to all of us involved in this issue to make sure people with disabilities are protected just as much as everyone else."

Shannon reaffirmed NFPA's commitment to work with accessibility experts to develop recommended steps and educational materials for use during emergency planning.

"As a building code developer, NFPA recognizes that more must be done to protect people with disabilities," said Kevin G. McGuire, a leading expert on accessibility and emergency evacuation requirements. "I look forward to working with NFPA and others as we strengthen recommended emergency procedures."

For more information, go to *www.nfpa.org*.

CORPORATE 100

The SFPE Corporate 100 Program was founded in 1976 to strengthen the relationship between industry and the fire protection engineering community. Membership in the program recognizes those who support the objectives of SFPE and have a genuine concern for the safety of life and property from fire.

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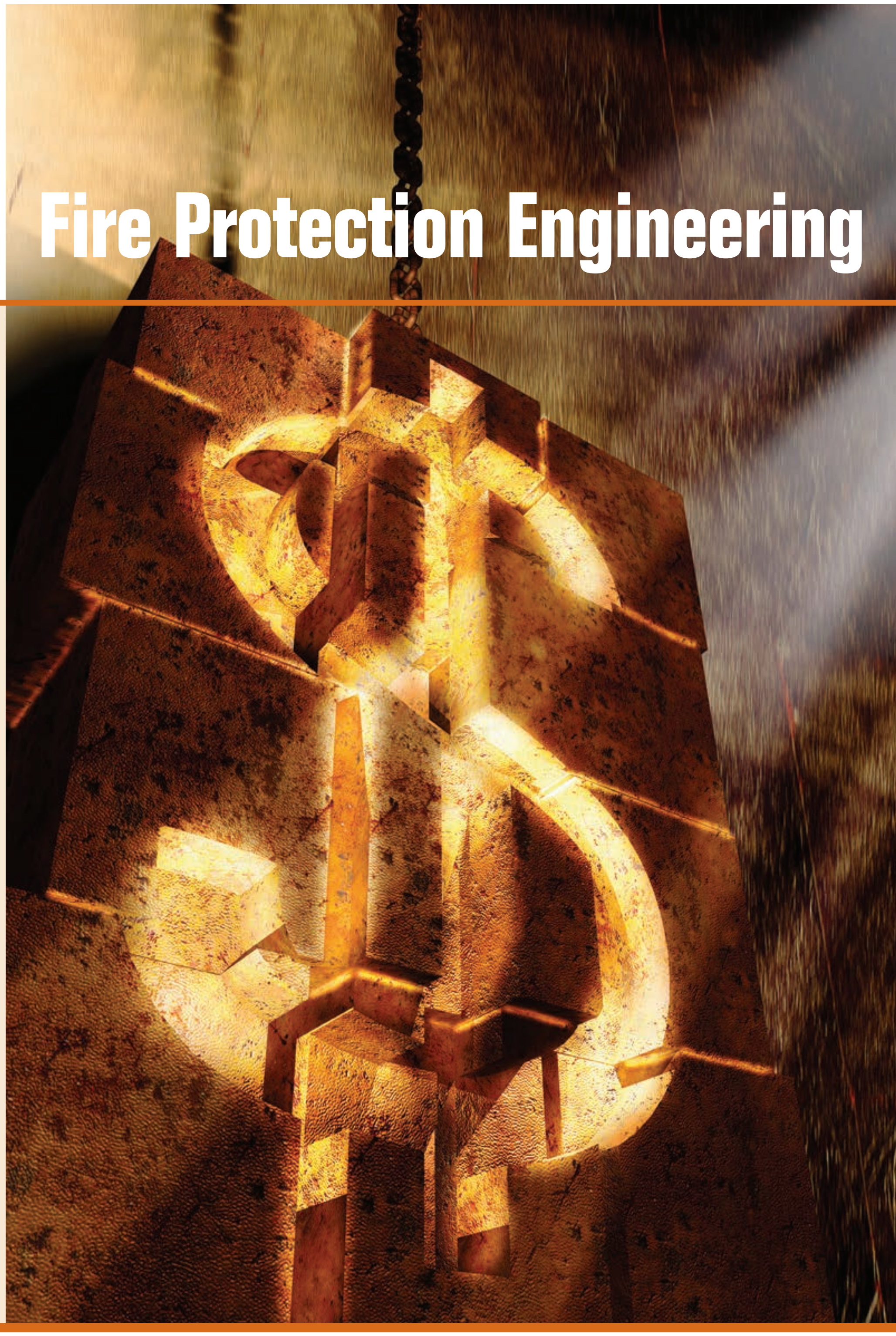

By John M. Watts, Jr., Ph.D., and
G. Ramachandran, Ph.D., D.Sc.

INTRODUCTION

One way to increase awareness and interest in fire protection is by means of the universally effective stimulus – money. The ultimate objective is to inject fire protection into corporate economics. Certain factors suggest the immediacy of this need.

- The dollar loss from fire is increasing. Even if this was attributable entirely to inflation, would it not be an effective attack on inflation to reduce losses due to fire?
- A small number of fires account for the majority of the world's fire losses. Economies of scale dictate that the trend toward bigness will continue, and more and more large-loss potentials are being constructed everyday.
- Few enterprises, private or public, could survive a large-loss fire in today's economic environment. There are already too few customers to go around. The interruption of production by fire would almost certainly shrink the share of the market at a time when profit is, at best, marginal.

Engineering economics is used in the analysis of proposed fire protection engineering projects to determine the net economic gains to be expected from alternative proposals. It deals with the time value of money and other cash-flow concepts and decision-making aids used to evaluate and optimize economic selection of fire safety strategies in combination with fire insurance or self-insurance options. This selection process would involve uncertainties caused by several factors affecting the occurrence of a fire in a particular building and the amount of damage or loss if a fire occurs. Essential background in the subject is provided in the *SFPE Handbook*,[1, 2] and in the book *The Economics of Fire Protection*.[3] There are many good texts on engineering economics from a more general perspective.[4, 5, 6, 7, 8, 9]

Economics

MINIMIZING COSTS

Figure 1 portrays the economic relationship between the level of fire risk and the cost of fire to society. Basically, as the level of risk increases, its cost increases. Similarly, as the level of protection increases, the social cost of losses due to fire decreases. The social cost is the sum of three rather broad categories. Direct losses refer to property value and those losses such as business interruption which are commonly covered by insurance. Indirect losses refer to financial detriments to a specific enterprise which are not normally covered by insurance, e.g., share of the market. Sociological losses are those which are not borne by the enterprise suffering the fire but by some segment of society, e.g., loss of tax base, loss of jobs, distress that an individual's death or injury in a fire would cause to family members, destruction of cultural heritage, environmental damage, etc. The curve representing total cost is the sum of losses or social cost and the cost of fire protection or risk control.

As may be apparent from Figure 1, the optimum level of risk or safety is provided by the fire protection strategy that minimizes the total cost. Some of the important aspects of microeconomics need to be understood and incorporated in fire risk assessment (versus macroeconomics, which refers to national and world economies of commodities, industries, and governments that affect more strategic business decisions).

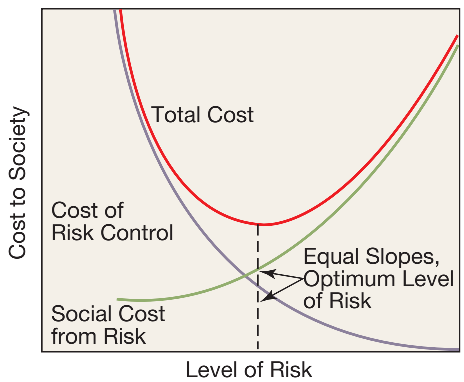

Figure 1. Cost Minimization.

TIME VALUE OF MONEY

The value of money changes from day to day because of three major issues:

- Cost of money
- Risk
- Inflation or deflation

Cost of money, also variously referred to as interest rate, rate of return, and discount rate depending on the analysis, is the most predictable and, hence, the most commonly addressed component of economic analysis.

Risk assessment is the essential objective. Incorporating risk into economic analysis involves models such as reliability and utility theory.

For many project comparisons, inflation can be considered a constant that will affect each alternative equally and not change the decision resulting from analysis.

INTEREST CALCULATIONS

Interest is the money paid for the use of borrowed money or the return on invested capital. The economic cost of construction, installation, ownership, or operation can be estimated correctly only by including a factor for the economic cost of money.

An example is the formula for the value of a future sum of money after N periods.

$$F(N) = P(1+i)^N \quad \text{Equation (1)}$$

Where:

P = Present sum of money ($)

F = Future sum of money ($)

N = number of interest periods

i = interest rate per period (%)

Interest factors are multiplicative numbers calculated from interest formulas for given interest rates and periods. They are used to convert cash flows occurring at different times to a common time. For example, in Equation (1), for finding the future value of a sum of money with compound interest, the mathematical expression $(1+i)^N$ is referred to as the compound amount factor.

Discounting is the inverse of compounding. The present value or worth of a future cost or benefit N time periods from now is given by:

$$P(N) = F(1+i)^{-N} \quad \text{Equation (2)}$$

And the expression $(1+i)^{-N}$ is referred to as the discount factor. The discount rate, i, may represent the opportunity cost of capital in the absence of inflation.

Values of the compound amount factor, discount factor, and other interest factors are tabulated for a variety of interest rates and number of periods in most texts on engineering economy. Example tables are presented in Appendix B of Section 5, Chapter 7, in the *SFPE Handbook*.[2] Calculators and computers have greatly reduced the need for such tables. Most notably, spreadsheet packages such as Quatro Pro and Excel have extensive sections on economic functions.

However, there is not a one-to-one mapping of these spreadsheet functions to the interest factors in Appendix B. Further complicating the situation is that spreadsheet functions do not use the standard engineering notation convention found in the *SFPE Handbook*. Not all practitioners follow a standard convention of notation, and care must be taken to avoid confusion when reading the literature.

ANNUAL LOSS

The loss expected to incur from a fire in a particular building can be estimated by applying one of the following techniques:

- Power functions
- Probability distributions
- Event trees
- Stochastic models

The magnitude of fire loss can also be estimated by performing simulations for several fire scenarios based on a deterministic zone or field model. The expected loss can then be expressed on an annual basis by multiplying the magnitude of the consequence by the annual frequency or probability of fire occurrence.

AMORTIZATION

Amortization is the most popular present method of estimating the annual equivalent of the cost incurred in the installation of a fire protection system. The annual cost is the product of installation cost and the capital recovery factor that, like other interest factors, depends on the interest rate and the planning period, usually the life of fire protection system or the life of the building or process protected.

But the methods described above only address the issue of direct loss. Thus, these approaches will not always justify an appropriate level of fire protection. For example, premium savings on a warehouse full of televisions will usually justify a full sprinkler system. The savings for a warehouse full of used automobile tires will seldom justify a sprinkler system, even though it may be a demonstrable environmental hazard. And a fire-resistive apartment house full of people will never economically justify a sprinkler system with premium savings, unless metrics for evaluating the cost of human life are employed.

VALUE OF HUMAN LIFE

For economic justification, the probable reduction in life risk due to any fire safety measure should exceed the costs involved in adopting the measure. For this purpose, it is necessary to assign a monetary value to human life. This value has to be a finite amount since no society can devote its entire resources to the elimination of life risk due to any accident.

Damage to life in terms of injuries and deaths is an important component of fire risk that needs to be assessed, particularly for incorporating appropriate safety measures in national codes, standards, or regulations. For establishing the economic justification of such measures, it is necessary to estimate monetary equivalents for fire deaths and injuries. Insurance claims provide some data for the valuation of injury, but they are likely to be limited to costs mediated by the marketplace, such as treatment costs and the value of work time lost. Monetary equivalents of pain, grief, and distress suffered by the families of fire victims are intangible costs which are more difficult to evaluate.

There are four basic methods developed in the economics literature for estimating value of human life:[3]

- Output
- Life insurance
- Court awards
- Willingness-to-pay

The first method is concerned with gross output based on goods and services which a person can produce if not deprived by death of the opportunity to do so. Sometimes, gross productivity is reduced by an amount representing consumption (net output). This approach usually gives a small value for life, especially if it is based on discounted values of net outputs over a period of years.

The second approach is the insurance method, which assumes that if an individual has a life insurance policy for $x, then he/she implicitly values his/her life at $x. The major advantage in adopting this method is that collection of necessary data from insurance companies is not a difficult task. But the major drawback is that a decision whether or not to purchase insurance and the amount of that insurance is not necessarily made in a manner consistent with one's best judgment of the value of one's life. This decision depends largely on the premium the assured can bear from his/her income, taking into account family expenditures.

The third method for assessing value of life involves court awards to heirs of a death. Here again, collection of necessary data is not a problem. Assessment of values of life could also be expected to be reasonably accurate since lawyers and judges have considerable professional expertise in the "ex-post" analysis of accidents.

"Willingness-to-pay" is the fourth approach, which is the one most widely adopted for valuing life. It is based on the money people are willing to spend to increase their safety or reduce a particular mortality risk. It rests on two principles. First, living is an enjoyable activity for which people would be willing to sacrifice some expenditure on other activities, such as consumption. Second, safety should be treated as a commodity like any other and valued according to the value individuals put on it. Despite this individual-oriented underpinning, this approach can also be used to develop a general figure for a typical person based on consensus patterns in the values individuals estimate. This, in turn, permits analysis of societal decisions.

Surveys have been carried out for estimating value of life according to the willingness-to-pay approach. These have shown variability and inconsistencies in responses, mainly due to the fact that most people find it difficult to accurately quantify the magnitude of a risk. It is also difficult to put a monetary value on intangible benefits such as enjoyment and peace of mind. Economists therefore use a variety of inferential methods, which include an examination of patterns from the other three approaches for valuing life. Studies have been done of the implied value of life associated with several regulatory actions related to safety and health. Studies could be done based on the price/demand curves for safety-oriented products, such as smoke alarms. Policymakers should carry out a sensitivity analysis using a range of values for human life to economically justify the recommendation of any fire safety measure. The safety measure cannot be economically justified if the implied value of life for adopting the measure is unacceptably large.

There are limitations to all the methods of valuing human life. For example, a common variation of the output method is the "livelihood approach." This method assigns valuations in direct

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proportion to income. The present value of future earnings of an individual is estimated and reduced by an amount equal to discounted consumption. This method gives a small value for life. It normally favors males over females, working persons over those retired, and higher-paid persons over lower-paid. Such preferences may not be acceptable socially or politically; however, they are often the basis for the third approach – court awards.

BENEFIT-COST ANALYSIS

The ratio of benefits to costs should exceed unity for selecting an investment project; the project should be rejected if the ratio is less than unity. In the context of fire protection engineering, the average annual benefit due to a fire safety strategy should exceed the annual amortized cost of installation plus the present values of future costs towards repairs to the system or replacement of parts.

The benefit-cost ratio can be constructed as the aggregated (total discounted) present value of the annual benefits likely to be realized in future years divided by the initial cost of installing a fire protection system.

For a property owner, the benefits due to fire protection are mainly in terms of savings in self-insured fire loss (or deductible), insurance premiums, and taxes. A property owner may select a strategy with the shortest payback or recovery period for the costs associated with the strategy as revealed by a year-by-year analysis of discounted benefits.

At a regulatory level of decision-making, i.e., for developing fire safety codes, the only benefit to be considered is the reduction in fire loss, most often the potential number of lives saved, as may be reflected in the valuation of human life described above. The fire safety strategy with the highest benefit-cost ratio is generally the economically best strategy.

UTILITY THEORY

In a cost-benefit analysis, the usual practice is to consider the monetary values of the costs involved and expected fire damage. This could lead to the unsound conclusion that "no insurance" is a cheaper option than "insurance," full or partial. This is due to the fact that an insurance firm generally adds two types of loadings to the expected damage – a safety loading and a loading towards operating costs. An insurance premium will, therefore, be greater than the expected damage. The expected value criterion can also lead to a wrongful rejection of an efficient fire safety measure.

The problem described above arises due to the assumption that a decision-maker is risk-neutral in the sense of putting equal weight on each monetary unit of cost. But most decision-makers have a risk-averse attitude and are keen to avoid risks, particularly those due to large losses. Such risk preferences can be quantified by applying utility theory and estimating the disutility associated with costs and losses.

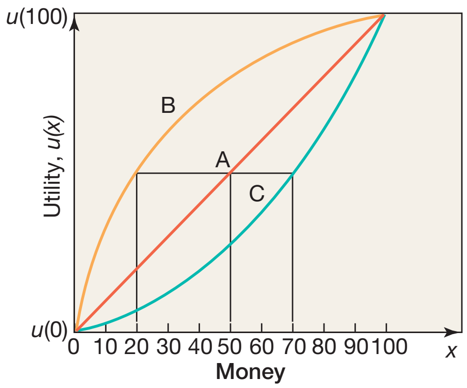

Figure 2. Typical Utility Functions.[3]

Utility is defined as the intrinsic value of a positive monetary outcome, i.e., gain. Its negative counterpart, disutility, is the intrinsic value of a cost or loss. Under a rule based on utility or disutility, the risky investment project with the highest expected utility or lowest expected disutility will be selected by a decision-maker, whereas, under the conventional cost-benefit analysis, the object is to maximize expected monetary gain or minimize the expected monetary cost or loss.

Figure 2 graphically shows three typical utility functions that are usually encountered in economic analysis. The utility function represented by the straight line *A* is appropriate for a decision-maker operating on an expected monetary value basis. This line represents risk neutrality. The concave curve *B* corresponds to a risk-averse decision-maker, where the utility is greater than the monetary value and so loss is to be avoided. The convex curve *C* would apply to a risk-taking decision-maker.

INFLATION

Understanding money requires an understanding of inflation. The dollar, the euro, the yen, or any other currency has no intrinsic economic value beyond the paper it is printed on. Money exists as an accounting measure. Yet, dollars and other currencies can be exchanged for goods and services.

In the U.S., the dollar is the standard of economic value. Just as the meter is used to measure distance, the kilogram to measure mass, the degree Celsius to measure temperature, the Watt to measure power, and other units are used for other types of measurement, the dollar is used to measure economic value. However, while physicists live in an ivory tower because their measurements do not change, the dollar is always in fluctuation.

But imagine the difficulties if the dollar did not exist. The economic value of every good and service would have to be evaluated in terms of every other good and service. With the dollar as a unit of measure, the economic value of each good and service can be expressed in terms of a single unit. Just as money serves as a standard of trade, it also serves as the unit of measurement in economic engineering analysis.

However, there is a danger in using dollars or other currency for economic analysis. Dollars are not the cost or the return, but only a measure of these quantities. Overlooking this simple, seemingly obvious point can cause people and companies to unwisely allocate money and measure economic success.

Inflation is an increase in prices paid for goods and services. This increase results from both cost inflation and price inflation. Cost inflation is the result of real cost increase to produce goods and services, that is, more input in terms of labor and capital are needed to produce a given amount of product. Society as a whole must work harder and invest more to produce the same goods and services as before. Cost inflation can result from a number of causes:

- Depletion of natural resources
- Natural disasters and catastrophes
- Social and political disruptions

Cost inflation is not related to money. It could occur in bartering economies. An important aspect of cost inflation is that it must be absorbed somewhere in the economy. It is the outcome of real cost increases, and that means some or all people must work more or spend less.

Price inflation is different. Price inflation is a money phenomenon not entailing any real costs. More is paid for everything, but people also earn more for their work.

Since the value of currency is an illusionary quantity and there is nothing to specifically set the economic value, it is free to float. The prices of goods and services may rise and fall, even when their net costs remain the same. This behavior in the national economy is price inflation. Causes and cures of price inflation are not well understood.

RELIABILITY

System reliability is another confounding factor in fire protection economic analysis. Fire safety systems are not absolute in terms of their ability to perform their design function. Reliability is a measure of the likelihood that a system will respond appropriately to conditions that occur during the system's lifetime. Estimating reliability for systems requires considerable historical information regarding the system and its operations.

For example, automatic fire control capability involves system availability, reliability, and effectiveness. With proper maintenance and monitoring, installed fire protection systems can be considered available with a high degree of certainty. While periodic inspection, testing, and maintenance can improve system reliability, the complexity of these mechanical devices retains an inherent possibility of failure. In some instances, such as a museum, it is also necessary to consider the possibility of a non-fire malfunction that can cause major economic or cultural damage.

In general, most fire protection systems lack adequate reliability data. While such information would be welcome, limitations in system reliability data did not prevent sending a man to the moon. Economic assessment models should include reliability considerations. In sophisticated analyses, reliability can be included in the same manner as other probabilistic events. A more simplistic approach is to evaluate a failure scenario, as prescribed by NFPA codes.

PERFORMANCE-BASED ENGINEERING AND TALL BUILDINGS

One very important application of fire protection economics is the valuation of unique fire safety designs. Fire protection for tall buildings against extreme events requires standards of passive and active fire safety measures higher than the standards specified for buildings of normal size and height. Such a high level of protection can be expected to be very expensive. Such huge costs can, perhaps, be justified since several thousands of people would be at risk in such buildings. Economic justification is difficult but necessary. The financial value at risk in these buildings and their contents may also be very high.

Prescriptive rules, if enforced rigidly, can lead to costly overdesigns, particularly for large and complex buildings. For example, certain egress requirements, area limitations, and fire-resistance ratings do not universally create better fire safety in every building situation. Recognizing this problem, a fire protection engineering approach has developed in the past decade as a viable substitute for prescriptive rules. Performance-based fire protection engineering allows decision-makers to select design options that meet consensus objectives and evaluate them for economic optimality in terms of costs and benefits.

For designing a large, tall, or complex building, a fire safety engineering approach is recognized as a viable alternative to prescriptive rules specified in fire safety regulations. Applying this approach, alternative fire safety strategies can be identified for the building, among which the most cost-effective strategy may be selected for adoption.

It is, however, necessary to evaluate quantitatively the performance and effectiveness of the alternative strategies considered. This is to ensure that the strategies would provide levels of safety, particularly to the occupants of the building, equivalent or greater than the life safety level implicit in the fire regulations. This task would involve a quantitative assessment of fire risk and of the effectiveness of different fire protection strategies.

Some strategies considered may involve combinations of active and passive protection measures. Evaluation of the actions and trade-offs between these measures would be a formidable task. For this purpose, deterministic and probabilistic models developed so far need to be improved and validated in the light of experimental, engineering, and statistical data. Such data are yet to be collected and analyzed, particularly for large, tall, and complex buildings, making the analysis more difficult but not eliminating its necessity.

In an economic assessment of fire protection strategies for large and tall buildings against extreme events, in addition to catastrophic property damage, monetary equivalents of large numbers of people likely to be killed or injured should also be evaluated and included in the economic analysis. The assessment should also include, if possible, quantitative (monetary) estimates of psychological and financial stress to the families of fire victims and other likely consequential losses. ▲

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THE ECONOMICS *of* Automatic Fire Sprinklers

By Stacy N. Welch, P.E.

Codes used today require automatic fire sprinklers in many occupancies. However, there are many new and existing buildings that are exempt. The benefits of sprinkler systems are widely known and documented, so why are they not used in more buildings? The NFPA states that nearly 80 percent of fire deaths occur in residential properties, the overwhelming majority of which are not required to be sprinklered.[1] The sad fact is that these deaths occur not because the technology to provide protection is not available, but because as stated in the Fire Sprinkler Incentive Act of 2003, "the major hurdle to be overcome to reach the next step of fire safety is that of economics."[2]

There are many aspects associated with the economics of fire sprinklers. Some of them are easy to define, such as the cost of design, materials, and labor. Then there are the more subjective components that should impact the decision-making process, such as the value of lives saved by a sprinkler system or the reduction in injuries to both occupants and firefighters. Sprinklers also lessen the severity of fires, reducing damage to property and diminishing the strain on the fire service and community resources. A full understanding of all of these aspects is critical to the more widespread use of fire sprinklers.

DIRECT INSTALLATION COSTS

Single-Family Home Construction

The United States Fire Administration estimates the cost to install fire sprinklers in new single-family residences to be $1.00 to $1.50 per square foot ($11 - $16 per square meter). This typically equates to about 1 percent of the construction cost, similar in magnitude to the cost of carpet.[3] However, some home builders are reluctant to offer or install sprinklers in homes because of the added cost and the additional work which could possibly delay construction.

When sprinklers are an option, or are required to be an option by the local jurisdiction, the builder markup may be substantial. This would be similar to the other options typically offered in new homes, such as a fireplace or upgraded flooring. When sprinklers are required in homes or buildings, the markup is greatly reduced or eliminated because the cost is now incorporated into the cost of construction, like plumbing or wiring. In this situation, since the requirement affects all builders, competition among contractors results in lower costs. For example, the City of Scottsdale, Arizona, passed an ordinance in 1985 requiring sprinklers in all new homes, and the installation cost for sprinklers dropped from $1.14 per square foot ($12.30 per square meter) to 59 cents per square foot ($6.40 per square meter).[4]

The United States Fire Administration, the National Association of Home Builders Research Center, and the International City Management Association have developed and are testing a guide to reduce the cost of installing sprinklers in residences. In Prince Georges County, Maryland, and in eight other locations, the cost of sprinkler installation dropped to approximately 80 cents per square foot ($8.60 per square meter) when the guide was used.[5]

Additional initiatives to reduce sprinkler installation cost are being examined. These include streamlining the design and permit process, alternatives to subdivision site plans, and building code trade-offs.[5] Site plan alterations may include setback, unit density, and hydrant spacing increases, in addition to street width, turnaround radius, and water main diameter decreases.[6] Some communities have provided trade-offs or incentives to builders for installing sprinklers. These have included reduction in the fire rating of gypsum wallboard, increased spacing for attic fire stops, and reduced fire-retardant standards for masonry walls and doors. Cobb County, Georgia, tested voluntary incentives for builders in multifamily dwellings and they have resulted in reduced construction costs.[5]

High-Rise Retrofitting

The cost for retrofitting sprinklers into an existing high-rise building is between $2.00 and $3.00 per square foot ($20 - $30 per square meter).[2] The use of plastic sprinkler piping has made these retrofits easier and more affordable. Further measures to reduce cost will make these retrofits more attractive to owners and will contribute to the likelihood of local governments instituting sprinkler ordinances.

Already, the 2003 edition of *The Life Safety Code* requires sprinklers to be installed in existing high-rise hotels and apartment buildings (with some exceptions) and requires either a sprinkler system or an engineered life safety sys-

tem for high-rise office buildings.[7] Many jurisdictions have adopted this code or are requiring sprinklers retroactively in specific occupancies. In addition, some building owners, corporations, and insurance companies have insisted on sprinklers being installed in their properties. This was the case at One Meridian Plaza in Philadelphia. In February 1991, a fire spread through eight unsprinklered floors until it reached an area where sprinklers had been installed at the request of a tenant. A chief from the Philadelphia Fire Department stated that "nine sprinkler heads on that floor stopped a fire the whole Philadelphia Fire Department couldn't stop." Three firefighters died in this fire, and 24 others were injured. Direct property loss was estimated to be $100 million while business interruption costs were at least that amount.[8] The cost to completely retrofit this building with sprinklers would have been a mere fraction of the loss it incurred.

INDIRECT SAVINGS

During 2002, U.S. fire departments responded to over 500,000 structure fires, and there was over $10 billion in direct property damage. There were also 3,380 civilian fire deaths and 18,425 injuries.[1] The direct property damage cost, in addition to the costs associated with loss of life, injuries, fire department services, insurance, legal expenses, etc., is staggering. The potential for savings by more widespread installation of sprinklers is also staggering.

Sprinklers are already required in many residential and commercial buildings, including industrial and manufacturing facilities, because of code requirements or insurance requirements. When these occupancies are sprinklered, benefits include reduced property damage and loss of life, diminished business interruption and continued work for their employees, and reduced experience-based insurance rates.[2] In addition, they do not suffer negative publicity by having a large-loss fire when it could have been prevented. This negative publicity has the potential to discourage consumers and could have a significant impact on the success of a corporation or business.

Functioning sprinklers reduce the magnitude of fires. The number of fire calls is not reduced, but the demands of and risks to the responding fire department personnel are decreased. This enables slower growth of fire department costs over time. The recovered resources may then be reallocated to other community needs, such as the growing demand for emergency medical services. Seven years after their sprinkler ordinance was passed, Scottsdale, Arizona, reported a savings of 30 percent to 50 percent by their citizens for fire service when compared to surrounding communities. They were also able to employ more personnel in areas such as arson investigation, plan review, education, building inspection, and fire administration.[5]

There are also insurance benefits to installing sprinkler systems. The most significant savings are for commercial and industrial buildings, and often insurance companies will insist on sprinklers prior to insuring a property. In multi-family dwellings, the savings may also be substantial. Owners of four multi-family units involved in a United States Fire Administration retrofit program received insurance reductions from 4 percent to 40 percent off of their entire insurance premium.[5] Because of the limited use of sprinklers in one- and two-family dwellings, the savings are not as great. The Insurance Service Office (ISO) recommends a reduction of 13 percent for these occupancies when sprinkler systems meeting NFPA 13D are used, with another 2 percent reduction for smoke detectors.[5] The savings in these occupancies may increase as sprinklers become more prevalent and insurance companies document resulting cost reductions.

TAX INCENTIVES

Federal tax legislation is currently being considered by the U.S. Congress, which could be a catalyst for making sprinkler systems much more viable in existing buildings. The legislation recommends use of the Modified Accelerated Cost Recovery System (MACRS), with a five-year class life, for the depreciation of sprinkler systems. Presently, a straight-line depreciation is used, with a basis of 39 years for commercial properties and 27.5 years for residential properties. The MACRS system shortens the depreciable life of an asset, which in turn provides greater tax deductions in a shorter time. These deductions not only make the installation of a sprinkler system more feasible, they also allow the savings to be reinvested into the business.

This legislation also discusses the fiscal impacts fire has on a community. These include increased firefighter workers' compensation, reduced tourism, negative publicity, litigation costs, lost revenue for destroyed business, and increased unemployment. These substantial impacts must be considered when assessing the loss of revenue from this tax incentive.

The tax incentive would also strengthen the economy. Approximately 65 percent of the cost of retrofitting a sprinkler system is labor. By installing more sprinkler systems, the demand for sprinkler designers and fitters is increased, in addition to a greater need for materials.[2]

THE COST OF NOT SPRINKLERING

Sprinklers save lives. There has not been a single fatality in a sprinklered residential building in Cobb County, Georgia, or in Napa, California, since their long-standing residential sprinkler ordinances were enacted. In addition, Scottsdale, Arizona, credits sprinklers for saving 52 lives since its sprinkler ordinance was passed in 1985.[5] This is dramatic, considering the NFPA states that eight out of ten fire deaths in the United States occur in residential structures, and there were 2,670 fire deaths in homes in 2002 alone.[1]

In addition to saving lives, sprinklers significantly reduce property damage costs. Cobb County and Napa both reported incidental or minimal damage when sprinklers activated in comparison to possible losses into the millions. From 1985 to 1995, Scottsdale's data has shown the average loss in a home with sprinklers to be $1,945, while the average loss for a home without sprinklers is $17,067.[4] The total property damages during this 10-year period were just $30,401 when the potential loss was estimated at $5.4 million. It should also be noted the population in Scottsdale during this time period increased 54 percent.[6] Fresno, California, states that property damage has been limited to $42,000 during the 10-year period that their residential sprinkler law has been in effect. In addition, NFPA statistics indicate that property damage in hotel fires was reduced by 78 percent in sprinklered buildings between 1983 and 1987. The average loss for sprinklered hotels during this period was $2,300, compared to the loss of $10,300 in unsprinklered hotels.[3]

The increased life safety and property protection provided by sprinklers may also be demanded by consumers and investors. The Hotel and Motel Fire Safety Act of 1990 requires federal employees on travel to stay in sprinklered buildings (when these hotels and motels exceed three stories). Federally funded meetings and conferences must also be held in sprinklered buildings. Because of the great numbers of federal employees who travel, this has a significant impact on hotel occupancy and use.

IS IT ALL ABOUT THE MONEY?

From the price of a sprinkler to the value placed on a lost life, the driving force behind the decision to install sprinklers is economics. This is why it is essential for fire protection professionals, lawmakers, code officials, and the sprinkler industry to continue exploring ways to make sprinkler installation more feasible in existing buildings and in occupancies that are not currently required to be sprinklered. ▲

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FIRE SAFETY MEETS ECONOMICS 101 –

How Chicago Achieved Balance in Its High-Rise Building Ordinance

By Carl F. Baldassarra, P.E.

INTRODUCTION

Choices... As individuals – and as consumers – people make numerous choices every day. For example, people make choices about where they live, where they work, where their children will attend school, and what goods they purchase. Many of these choices involve fundamental principles of economics. Individuals, families, and businesses make economic choices every day when they allocate their scarce resources on the basis of the perceived value of the goods and services that they purchase. When these decisions are made, people compare the costs and benefits of alternative courses of action. Because people make decisions by comparing costs and benefits, their behavior may change when the costs or benefits change, i.e., people will generally respond to incentives. In some cases, however, the costs and benefits are not readily apparent or measurable. In addition, decisions are frequently not "black and white," but usually involve many shades of gray.

Like individuals, families, and businesses, elected officials make choices to determine the level of safety for their communities when they adopt legislation concerning building and fire safety regulations. Many communities have been well-served by adopting model codes promulgated by the International Code Council and NFPA International that provide comprehensive, coordinated technical regulations affecting the broad scope of building designs and occupancies. The code development processes of the two model code organizations are such that the resulting regulations generally reflect the national consensus about society's "acceptable" level of safety. In reality, however, the resulting level of safety from the adoption of a model code or regulation is rarely quantified or specified. Hence, consideration of any alternatives and performance-based designs may lead to protracted debates about the adequacy of safety or the resulting safety factor. In a number of cases, the adoption of such model codes is further complicated when a state or local government includes amendments to reflect the specific local practices and conditions of a jurisdiction.

This article examines the code-development process leading to the adoption of an ordinance requiring fire safety improvements in existing high-rise buildings in the City of Chicago and the economic considerations which helped determine the scope of the ordinance. The following analysis focuses on the major requirements of the ordinance, specifically the requirements for voice communication systems, automatic sprinkler protection, stairway enclosures, and Life Safety Evaluations.

BACKGROUND

Like many other cities in the United States, the City of Chicago amended its building code in the mid-1970s to include provisions specifically applicable to new high-rise buildings. The current edition of the *Chicago Building Code* (CBC) defines high-rise buildings as those having a height of 80 feet (24 meters) or more. The high-rise provisions require automatic sprinkler systems, standpipe systems, occupant and fire department voice communication systems, stairway unlocking systems, and other passive and active systems similar to the provisions found in the model building codes. While the current high-rise provisions also include a "compartmentation option" that may find ready application in residential buildings, few or no buildings built after 1975 have exercised that option. At the present time, the City is very close to adopting new fire protection provisions based upon the 2003 edition of the CBC, including a local amendment to require automatic sprinklers in buildings having occupied floors greater than 35 feet (11 meters) above grade.

At various times since 1975, the City has considered regulations that would have required automatic sprinklers and other fire safety improvements after several infrequent – but attention-getting – fires in high-rise buildings. As recently as 1999, a multi-interest-sponsored high-rise building sprinkler retrofit proposal was developed but ultimately not supported by the real estate owners because of cost considerations.

Without diminishing the tragic consequences of each lost life, the frequency of fatal high-rise fires and the resulting number of fatalities are, fortunately, relatively

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low compared to low-rise buildings, as is the case with other municipalities. It is acknowledged, however, that the risk to high-rise building occupants is greater because of the well-known physical characteristics of high-rise buildings and the larger number of persons at risk. The number of fatal fires and total fatalities in Chicago, from 1946 to 2003, is shown in Figure 1. The total number of fatalities over the 57-year period is: 14 in office buildings, 57 in residential buildings, and 77 in hotel occupancies. In the 1980s, the City addressed hotel fire safety through an ordinance requiring a complete fire detection system in hotel occupancies (or a reduced level of detection in fully sprinklered buildings), and fire fatalities in hotels since then have dramatically declined.

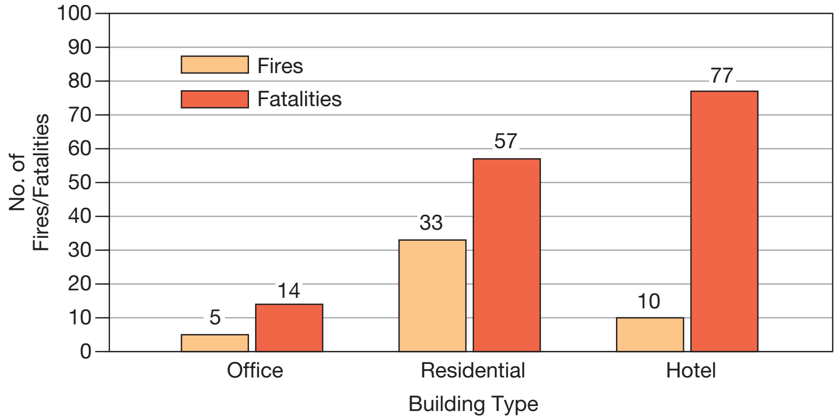

Figure 1. Fatal Fires and Fatalities in Chicago High-Rise Buildings, 1946-2003.

The Chicago Department of Construction and Permits estimates that there are approximately 1,700 high-rise buildings in the City. Of these, approximately 1,300 were built before 1975 and 400 were built after 1975. Of the 1,300 pre-1975 buildings, it is estimated that 1,100 buildings are primarily of residential occupancy. With the exception of New York, no other U.S. city has as many high-rise residential buildings and dwelling units as Chicago. In recent years, owners of high-rise buildings have been subject to a number of ordinances which have had a major financial impact upon some of the buildings. These ordinances require exterior building facade inspections and repairs (1996, 2003), emergency generators (2000), and evacuation plans (2001). Some building owners have reported expenses of millions of dollars to comply with these previously adopted ordinances. Clearly, there was a heightened sensitivity to an additional ordinance that may require costly fire safety improvements.

ORDINANCE DEVELOPMENT

In response to a multiple-fatality fire in the Cook County Administration Building on October 17, 2003, Chicago officials considered a number of proposals and began development of an ordinance to address fire safety for existing high-rise buildings in a comprehensive manner. The objective of the ordinance was to provide a reasonable level of safety for the occupants of high-rise buildings and to do so in a manner that sustains the City's economic strength, and preserves jobs and business opportunities. The City staff and its consultant reviewed the criteria in the national model codes, reviewed the experience of other cities and jurisdictions adopting similar legislation, and considered issues including practicality, effectiveness, experience, new technology, and costs. This work resulted in a comprehensive proposal developed by the City's administration.

The issue of safety for existing buildings is especially difficult because of practical difficulties and costs involved in making improvements in these buildings. Accordingly, the proposed ordinance was limited in its scope to fire safety features judged to be of basic fire safety importance. While some cities elected to essentially require their existing buildings to meet the same fire safety criteria required of new buildings, such was not the case in Chicago. For example, costly smoke control and pressurization systems, supplied by emergency power, were not deemed as minimum required features given automatic sprinkler protection for commercial buildings and the degree of compartmentation included in residential buildings.

Shortly after the fire and before the development of a comprehensive draft ordinance, the Chicago City Council adopted an ordinance that prohibits stairway doors locked against re-entry into the building unless such doors are equipped with automatic and manual unlocking systems. (A temporary provision allowed locked stairway doors on certain floors, similar to the criteria included in the *NFPA Life Safety Code*, until January 2005.)

Two proposals were presented to the Chicago City Council. One proposal by one of the City's aldermen would have required the provision of automatic sprinklers throughout all existing high-rise buildings within five years. The administration's comprehensive proposal, however, provided a reasonable balance between safety and the costs, and consisted of the following major elements:

- Evacuation plans for all high-rise buildings electronically filed with the City's 911 center;
- Prohibiting stairway doors locked against re-entry, except for automatic and manual unlocking systems, in all buildings with stairways serving four or more stories;
- Voice communication systems for occupant notification and fire department communication in high-rise buildings;
- Automatic sprinkler protection for commercial high-rise buildings;
- Life Safety Evaluations (LSE) to verify a minimum level of fire safety for nonsprinklered high-rise buildings;
- Modification of material and installation criteria to allow more economical installations and encourage optional fire protection improvements; and,
- A requirement for a minimum one-hour fire-resistive stairway enclosure in residential buildings.

In addition to the above proposals, the Administration is also seeking property tax relief and tax incentives for fire safety improvements at the state and county levels. This is in addition to the tax incentives included in pending federal legislation (see the article on page 18 for a description), generally applicable to commercial buildings.

Following development of the proposed ordinance, it was posted on the City's Web site and was the subject of a series of public hearings and community meetings, at which the proposal was discussed and comments from affected parties were received. Stakeholders included regulatory officials, elected officials, contractors, building owner organizations, labor organizations, real estate interests, trade associations, and citizens. Not surprisingly, the testimony of many citizens reflected the perception that fires are rare events, that they feel adequately protected, and that they do not need to spend substantial sums of money on fire protection improvements, particularly sprinklers. Issues such as the cost of sprinkler installations, the need for improved life safety, and potential insurance savings were frequently raised.

In addition, certain buildings were evaluated per the criteria in the ordinance, and cost estimates were obtained for compliance with the ordinance. As a result of the public comments and trial building evaluations, the ordinance was subsequently modified and was adopted on December 15, 2004. A second ordinance concerning broadening the application of the previously adopted building evacuation plan ordinance is pending.

The major elements included in the ordinances are discussed in the following sections.

EVACUATION PLANS

The proposed ordinance requires the owners of all high-rise buildings to file certain information about their buildings' systems and occupants, and electronic copies of evacuation plans with the City's 911 Center. The filings are to include typical floor plans and the locations of disabled persons to facilitate on-site search-and-rescue operations by communication with the 911 Center personnel. The City is also studying technology to allow the display of the information in fire department vehicles on the fireground.

STAIRWAY DOOR LOCKING

Prior to October 2003, a number of pre-1975 high-rise buildings maintained locked doors from the stairway side of the stair enclosure in the interest of maintaining building security. While prohibited for high-rise buildings constructed after 1975, the Chicago Building Code was silent on the application of such requirements in pre-1975 buildings. Shortly after the fire, the City Council adopted an ordinance that prohibited locking of stairway doors that would not allow occupants to re-enter the floors of the building, except when equipped with automatic/manual unlocking systems. The ordinance was subsequently revised and allowed temporarily locking of certain doors until January 1, 2005.

VOICE COMMUNICATION SYSTEMS

Human behavior studies indicate that it is important to provide timely and accurate information and instructions to building occupants.[1, 2] The current CBC criteria for new high-rise buildings require one-way voice occupant notification systems in public areas and office tenant spaces over 5,000 square feet (460 m^2). In addition, the current CBC criteria for new high-rise buildings require two-way communication systems for fire department use. These criteria were included in the ordinance for installation in existing high-rise buildings. Costs for these systems were judged to be reasonable when viewed on a per-dwelling-unit basis for residential buildings and on a per-area basis for commercial buildings. The ordinance allows a five-year installation period.

Nevertheless, a substantial number of public comments were received concerning this portion of the ordinance, particularly with respect to the cost of compliance with this provision. As a result, the current proposal now includes performance-based language that will permit other existing voice communication systems to be used, provided that the systems meet certain criteria and are judged to be acceptable by the fire department.

AUTOMATIC SPRINKLER PROTECTION

The benefits of automatic sprinkler protection are well known to City officials and need not be repeated here. While the frequency of fatal fires in high-rise commercial buildings was low, the large numbers of persons in commercial high-rise buildings, the nature of the occupancy, and typical building geometries were judged to present an unacceptable risk. On the other hand, an ordinance mandating sprinkler protection in a large number of residential buildings, costing hundreds of millions of dollars, was not considered necessary because of the nontransient nature of the occupants and the inherent level of compartmentation in residential buildings. A review of high-rise residential building fire records, in fact, showed a high degree of the buildings' ability to limit fires to the unit of origin. Buildings designated as landmarks were also considered to present practical difficulties and, therefore, were exempted from the draft ordinance. Nevertheless, there was a concern about verifying that the residential and landmarked buildings' construction integrity has been maintained since originally constructed.

The draft ordinance took a measured approach to the installation of automatic sprinklers in existing high-rise buildings. The ordinance mandates the installation of sprinklers in high-rise buildings, with the following exceptions: open-air parking facilities, open-air portions of stadiums, nontransient residential buildings, designated landmark buildings, and contributing (landmark) buildings. The requirement for sprinklers affects almost all commercial buildings in the City. In response to the concerns of the real estate industry, the ordinance was drafted to allow a 12-year installation period, providing that one-third of the installation is completed in each of three four-year incremental periods. A plan of compliance is required to be submitted to the City within one year.

Based upon a survey conducted by the Building Owners and Managers Association (BOMA), a trade association representing 269 commercial buildings and 94 percent of the commercial square footage in Chicago, approximately 29 percent of the responding buildings with 37 percent of the rentable square footage were built after 1975, the effective date of the City's high-rise provisions.[3]

The BOMA-Chicago survey identified 87 buildings representing approximately 24.7 million square feet (2,290,000 m^2) as affected by this provision. Most of these buildings are "Class B" and "Class C" buildings, an industry term reflecting that they are not the newer, higher rental rate properties, making it difficult for the landlords to raise rental rates to amortize the cost of the sprinkler installations. BOMA-Chicago estimated that there is a total of 35 million square feet (3,300,000 m^2) of unsprinklered office space in the City, 17 million square feet (1,600,000 m^2) of which may require asbestos abatement. Using a range of $6.25 to $14 per square foot ($67.20 to $150 per square meter) for installation costs and $16.25 per square foot ($175 per square meter) for asbestos abatement, BOMA-Chicago estimated the cost for city-wide compliance to be $636 million. It was noted that sprinkler retrofits frequently involve much more than the cost of the sprinkler system alone. For example, a major sprinkler retrofit installation will involve substantial upgrade or replacement of the building's fire alarm and supervisory system which monitors the sprinkler system, possibly triggering a further upgrade to achieve ADA compliance; cutting, painting, and patching; soffit and/or ceiling installations; and possibly light fixture replacement.

BOMA-Chicago asked for a longer compliance period and for the ability to have an alternative to a mandate for automatic sprinkler protection, as proposed for nontransient residential landmark commercial buildings. The BOMA-Chicago cost estimate was disputed as high by the fire sprinkler industry representatives. The fire sprinkler industry representatives also spoke against using a Life Safety Evaluation option (allowed for nontransient residential and landmark commercial buildings), suggesting that automatic sprinklers are necessary for a reasonable level of safety in all high-rise buildings.

LIFE SAFETY EVALUATION

To address the issue of providing a reasonable level of safety in the nonsprinklered high-rise buildings, the City used the *NFPA Life Safety Code*[i] as a standard of good practice and noted its published alternative to automatic sprinkler protection in existing high-rise business and residential buildings which prescribes a "Life Safety Evaluation (LSE)" to demonstrate that a minimum level of safety is provided. Although certain parameters are discussed, specific criteria for the LSE are not included in the *Life Safety Code*. Nevertheless, the *Life Safety Code* requires that the LSE be approved by the Authority Having Jurisdiction.

The definition of an LSE, specifically for existing nonsprinklered residential and landmark commercial buildings, first required that an objective be specified with respect to the desired level of safety. After due consideration, a policy decision was made to establish the minimum level of safety consistent with the provisions in the Chicago Building Code specifically applicable to existing buildings. It was the collective judgment of the team that rigorous compliance with the CBC provisions for existing buildings would provide a reasonable level of fire safety. From this review, it was later determined that the CBC requirement for minimum fire resistance-rated stairway enclosures in residential buildings was not clear and that a revision to clarify the requirement was necessary. This was included in a later version of the proposed ordinance.

Accordingly, because the CBC requirements differ for residential and commercial high-rise buildings, two LSEs were developed to implement this portion of the ordinance, one for nontransient residential buildings and one for commercial (landmark) buildings which need not be sprinklered per the proposed ordinance. The LSEs are similar to the Fire Safety Evaluation Systems (FSESs) included in *NFPA 101A*.[5] However, the LSEs were specifically developed to measure the buildings' level of compliance with the minimum provisions of the CBC under which they were designed and constructed. The use of *NFPA 101A* would simply demonstrate the fact that the building did not meet the criteria of *NFPA 101* and would be irrelevant to the objective.

Like other FSESs, the LSEs for this application include 18 major parameters: building height; construction type; compartment area; tenant separation; corridor walls; vertical openings; HVAC systems; smoke detection; communication systems; smoke control; number and capacity of the means of egress; dead-end corridors; exit travel distance; elevator controls; emergency lighting; mixed occupancy separation; automatic sprinklers; and auxiliary uses. The intention of the LSE is to demonstrate that a minimum level of fire safety is achieved in areas involving fire safety, means of egress, and general safety, and to allow alternative methods to achieve compliance if the minimum level of protection is not achieved. It is not intended, however, as a method to circumvent the minimum provisions of the CBC applicable to existing buildings. The ordinance requires that the LSE be conducted by a licensed architect or engineer and that a report be completed within 12 months after the passage of the ordinance. The City is responsible for reviewing and approving the LSE for each building, an objective measure of the relative level of safety of the building. Building owners will have up to seven years to complete repairs in order to achieve compliance with the LSE, or owners can elect to sprinkler the building within the 12-year time frame.

LSEs were conducted on a sample of existing high-rise buildings. It was determined that certain buildings would not meet the minimum criteria owing primarily to inadequate stairway enclosures. Again, it was judged that the existing condition was allowed to exist because of a lack of clarity of the stairway enclosure requirement. Certain maintenance-related deficiencies were also noted. It was the collective judgment of the staff and the City's consultant that the LSE identified potentially life-threatening conditions, as was intended, and that the corrective measures would be substantially less expensive than providing automatic sprinkler protection in the same buildings.

MODIFICATION OF INSTALLATION STANDARDS

The City has, over the years, enforced certain installation practices which exceed the criteria included in the applicable NFPA standards. In the interest of facilitating economical compliance with the proposed ordinance and to encourage the installation of protection systems which exceed the minimum requirements of the ordinance, e.g., automatic sprinkler systems in residential buildings, various modifications to the installation standards have been codified in the proposed ordinance. These include:

- Use of water supply criteria for the greater of either the sprinkler system or standpipe system demand, generally allowing the continued use of existing fire pumps;
- Use of all listed sprinkler piping and sprinklers per *NFPA 13*, 2002 edition;
- Use of *NFPA 13*, 2002 edition design criteria;
- Continued zoning of existing dry pipe systems;
- Installation of low-voltage electrical risers associated with fire alarm and communication systems within stairway enclosures;
- Installation of detection system and notification system wiring and components in the same electrical conduit and equipment enclosure, per *NFPA 72*;
- Central station monitoring using digital alarm communication equipment per *NFPA 72*.

The above modifications have been estimated to save as much as 25 percent of the installation cost of certain systems over the traditional installation methods.

ADOPTION OF THE ORDINANCE

As the elected officials determined the appropriate regulations for the City, they were faced with choices involving issues such as: What level of safety is needed for existing buildings? How much are the citizens willing to pay for the improved level of safety? These issues are definitely in the "shades of gray" category. This proposed ordinance differs from previous, unsuccessful attempts at a high-rise ordinance for existing buildings in that it includes a number of cost-saving provisions, tax incentives, reasonable compliance periods, and alternatives to a blanket requirement for automatic sprinkler installations. The legislative body adopting the ordinance, the 50-member City Council and the mayor, balanced the safety interests of the community against the costs of compliance and reached a consensus that the ordinance be adopted in its final form. While the technical issues and alternatives have been addressed by fire protection engineers and other professionals, the actual policy decision was made by the elected officials charged with that responsibility.

The City Council's action on this ordinance was its determination of an appropriate balance of fire safety and cost for the citizens of the community in order to provide a reasonable level of safety for the occupants of high-rise buildings. ▲

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Total Cost of Fire in the United States

By Patricia Frazier

Over the last three decades, many attempts have been made to estimate the total annual cost of fire in the United States. The total annual cost is much greater than simply the value of property destroyed by fire. The total cost includes the cost of fire services; the cost of fire protection built into buildings and equipment; the cost of fire insurance overhead; the many indirect costs, such as business interruptions, medical expenses, and temporary lodging; the value to society of the injuries and deaths caused by fire; the cost of government and private fire-related organizations; and the myriad of other related costs that add up to a very large economic impact.

The total cost of fire is in the range of $130 billion to $250 billion a year, depending on how loss and costs are defined and the estimation methodology used. Some may argue that disasters, such as fires, stimulate the economy, and that the economic multiplier effects of recovery activities such as rebuilding and redevelopment may offset some of the costs. Despite potential offsets, it is important to estimate these costs, specifically the cost of fire, as a measure of losses incurred and of expenditures caused by those losses that society might prefer to see spent otherwise.

Understanding the total cost of the fire problem is important for other reasons as well. Perhaps the most important reason is to raise the awareness of the public and decision-makers to the economic magnitude of the fire problem – a cost that is often underestimated. Losses due to fire are large enough, about 2 percent of the GDP, to encourage a national strategic plan to find avenues to prevent them. It is also useful to compare the fire problem with other problems facing the nation so that some rationale can be applied in the allocation of resources. Finding a common denominator for these comparisons is often difficult. Cost is one basis; the number of casualties is another. With a common basis, the fire service and decision-makers can track changes over time to gain a better understanding of the real-world effects of fire and to stimulate prevention and mitigation efforts.

It also is important to estimate and track trends in the magnitude of the main components of the total cost of fire to assist in fire protection policy trade-offs. Moreover, the apparent and hidden costs of fire protection need to be compared to the losses averted and losses incurred. Eventually, a quantitative understanding of how investments in protection affect total costs needs to be established.

ESTIMATES OF THE COST OF FIRE

One of the first attempts to estimate the total cost of fire for the United States in last thirty years, if not the first, was undertaken by a team of fire protection engineering students from Worcester Polytechnic Institute (WPI) circa 1980.[1] This initial estimate was based on first-cut thinking about the problem.

A further effort to estimate the total cost of fire was made in 1991 by economist William Meade for the National Institute of Standards and Technology.[2] Drawing heavily on the WPI study and relying on in-depth discussions with experts in a variety of fields, including many from industry, Meade expanded into the wide range of areas in which fire protection is built into society. The report made initial estimates of some new cost areas that, though crude, have yet to be substantially improved. Using a broader definition of costs – including an estimate of the value of volunteer firefighters' labor, but resisting placing a value on the human loss equivalent – Meade estimated the total cost of fire at the time to be between $92 billion and $139 billion. This estimate translates to a range of $133 billion to $202 billion in 2002 dollars. While some questioned the computation methods and estimates used in the Meade study, the study sparked interest not only into the magnitude of the cost of fire but also how those costs were determined and used.[3]

John Hall, of the National Fire Protection Association, has made a series of estimates of the total cost of fire built on the WPI and Meade estimates, with further development of the methodology. Notably, his methodological improvements segregate cost estimates into those that are more solid, based on verifiable data sources and inputs, and those that are based on broad understandings of the cost, but with less well-defined estimates. His most recent estimate of the total cost of fire, $187 to $251 billion, was released in 2004.[4]

The cost of core elements of fire protection, those more "solid" costs, has grown larger. In 1980, the cost of these elements was conservatively estimated by Hall to be on the order of $28.3 billion. By 2002, the estimate was $84.9 billion, triple the 1980 estimate. Almost half of this increase can be attributed to inflation, with the remainder of the increase largely attributable to increases in fire service costs. In terms of 2002 dollars, Hall estimated the overall net increase in these core costs to be $23.1 billion, or 37 percent. The remaining costs included a $36.7 billion component, based on Meade's 1991 estimate, for costs associated with fire protection built in to equipment, fire maintenance, and other areas; $39 billion for human loss; and a range of $47 billion to $90 billion as an estimate of the value of volunteer firefighter time.

In a related 1994 effort, Schaenman expanded the U.S. work on the total cost of fire by applying it to the Canadian fire experience.[5] The Canadian National Research Council had performed some original research on estimating the incremental cost of fire protection in structures. That research was incorporated in the analysis on the total cost of fire in Canada, solidifying the basis for some of

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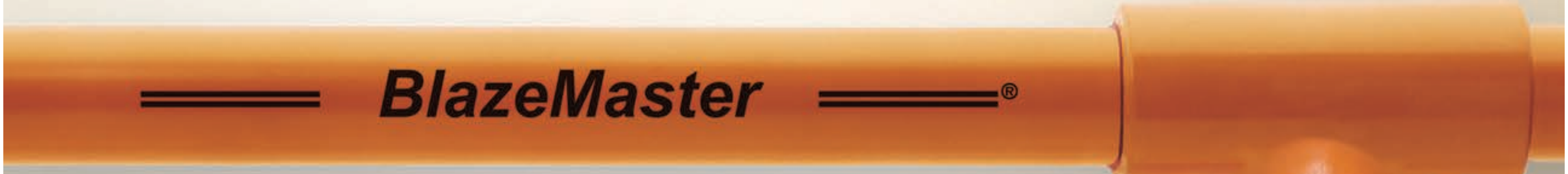

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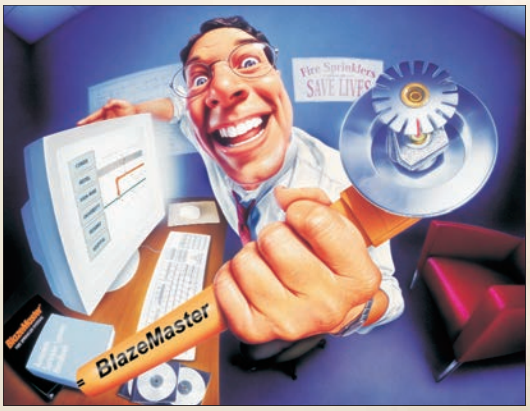

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the Canadian estimates. As a point of comparison, these estimates, converted and inflated to 2002 U.S. dollars, adjusted for the U.S. population, and using U.S. estimates for direct and human losses, yield a range of $119 billion to $159 billion dollars.

RELATED FIRE COST STUDIES

Building on this body of work, a variety of studies have estimated different aspects of the cost of fire or, more specifically, the losses resulting from fire. As part of the Fire Safe Cigarette Act, the Consumer Product Safety Commission developed estimates on the societal costs of cigarette-ignited fires, valued at the time (1992) at approximately $4 billion.[6] Much of this particular study focused on the economic costs resulting from burns and anoxia.

Table 1: Total Cost of Fire Components.

Cost Component	Contribution to Total Cost (%)
Direct Economic Losses	5% - 6%
Cost of Fire Service	30% - 45%
Built into Equipment, Buildings, etc.	25% - 35%
Net Fire Insurance	5%
Indirect Economic Losses	5% - 15%
Estimates of Human Loss	10% - 15%

(Based on information from references 2, 4, 5, and 7)

To understand the impact of its fire programs, the National Institute of Standards and Technology sponsored research on the cost of firefighter injuries.[7] Based on methods applied from economic studies, the estimated cost of addressing firefighter injuries and of the efforts to prevent them ranged from $2.8 billion to $7.8 billion. This later research incorporated newly published injury cost methodologies from The National Highway Traffic Safety Administration.[8] When this cost methodology is applied to all fire casualties, the resulting estimate of the cost of human loss is $30 billion – quite comparable to the estimate used by Hall.

In addition, the NFPA, as part of its annual report on fire loss in the United States (most recently published for 2003[9]), produces statistically derived estimates on the direct losses from fire. These estimates of the direct cost of fire in terms of property and human loss are widely used and are important inputs into the estimates for the total cost of fire.

TOTAL COST COMPONENTS

While the different approaches to computing the cost of fire may group subsets of the costs differently, generally speaking, there are six main cost components (Table 1). When people refer to the cost of fire, the most common statistic quoted is direct losses from fire – what was burned or damaged by fires – but this is only a small fraction of the total. Other categories of losses and costs must be taken into account to fully estimate the total cost of fire. Direct losses generally account for only about 5 percent to 6 percent of the total cost of fire.

When estimating direct losses, the question arises of what costs are reflected for property loss. Are these insurance estimates of actual loss or replacement cost? Are they fire department estimates of loss? How are uninsured losses accounted for? What is the extent of the unreported losses?

The largest cost category is the cost of the fire service. People often focus on the fires and forget the cost to the public and government to maintain a "ready army" of firefighters, equipment, and stations. This includes the cost of local paid and volunteer departments (although the latter includes an estimate of the equivalent cost of volunteer time, which is not a direct cost), forest fire management, and capital outlays for equipment. It may not include infrastructure improvements necessary to accommodate firefighting (e.g., increased water main capacity, road improvements to accommodate the fire equipment) and generally does not include the cost of federal and private fire brigades. This component can vary depending on the inclusion of the volunteer time and can vary from 30 percent to 45 percent of the total cost.

Nearly equal in size to the cost of the fire service is the cost of fire protection built into buildings, equipment, infrastructure, and business operations. Together, these costs run about 25 percent to 35 percent of total cost of fire. The cost of built-in fire protection in buildings is hard to quantify. While fire detection and suppression systems are identifiable costs, as are the incremental costs associated with fire-resistant materials, much of built-in fire protection also provides protection from other hazards (e.g., thick walls offer resistance to fires and provide structural integrity, electrical safety features reduce the hazard of electrical shock as well as fires).

The cost of fire protection built into equipment is even more difficult to estimate because there are so many more types of equipment than buildings. Equipment ranging from televisions to portable space heaters to cigarette lighters have special features to prevent them from becoming the equipment involved in ignition.

The cost of business operations affected by fire considerations includes the training of employees in fire safety, cost of special transportation for flammables, the use of special containers for flammables, and work time lost evacuating buildings from false alarms.

Net insurance cost, or insurance overhead, is the cost paid by the public for insurance, less what is returned to the public in payments for insured losses (which are accounted for as part of direct losses). Issues here include how to separate fire-related insurance from other kinds of hazard and peril insurance, and how to accurately estimate the overhead and profit that are paid for fire-related insurance. Insurance costs are less than 5 percent of the overall cost of fire.

Indirect losses from fire include business interruptions, costs of temporary lodging, tax losses, loss of market share, legal expenses, and many other categories. This is one of the most difficult categories to estimate with any degree of accuracy, in part because of the numerous and disparate categories that comprise this loss group and in part because disruptions in one category may be offset by transfers to others. Depending on what is included and how the costs are derived, this category can range from 5 percent to 15 percent. Many of these subtleties require in-depth study that has heretofore not been undertaken.

Finally, there is the cost of deaths and injuries to society. Part of these costs is conceptually clear, if difficult to estimate, such as the cost of medical treatment, funeral expenses, and time lost from work. Other costs, more conceptually difficult and to some distasteful, included in this category are the value of a life and of pain and suffering. Estimating these aspects of losses is often done as part of cost studies in other fields. The total of these attributed costs is about 10 percent to 15 percent of the estimated total cost of fire.

THE CHALLENGE

The fire protection engineering community is faced with a remarkable challenge. Using Hall's estimates,[4] for example, between $144 billion and $187 billion was spent (total cost less losses and insurance) to avert an untold number of fires and their resulting losses in 2002. A substantial portion of this estimated cost, $61 billion, was spent on built-in fire protection. Yet combined economic and human losses of $52 billion still occurred. This fact presents several confounding questions, not only about the resources that are spent to prevent fires and protect against them, but how to maximize the benefits of these resources.

First and foremost of these questions is how much more would it cost to reduce the current losses, and as important as this cost itself, is the incremental cost acceptable and defensible – that is, would the increased cost to prevent losses be worth more or less than the losses themselves? Using the estimates above, if 40 percent more could be spent in built-in protection, which resulted in a 50 percent reduction in losses, a near zero sum would be achieved – spending as much as was saved – a situation that may not necessarily make monetary sense but could achieve the valued societal goals of saving lives and property. A corollary question is, with increasing fire safety improvements in products and construction materials, whether more should be spent now to achieve lower losses in the future. This question has special prominence, as it is the nonloss (e.g., built-in protection) components that are the driving components in the total cost of fire. While investments, such as residential sprinklers, increase the short-term cost, the long-term cost savings may be substantial. These and other thorny questions are critical to pose and answer.

The $150 billion to $200 billion spent averts losses in addition to containing the losses currently experienced. How many incidents are averted (and how can this number be determined), and what would be the losses from these averted fires? It may well be that what is spent in fire protection services is more than paid back by the losses that are not incurred. Research to examine the cost savings current engineering options already afford would be beneficial.

The fire protection community also has a unique opportunity to provide additional support to the overall fire community. The role of the fire service has changed markedly in the past 20 years. Although fire protection is still far and away its primary job, the fire service plays an increasing role in the delivery of emergency medical services, the response and mitigation of hazardous materials incidents, and most recently, in homeland security responsibilities. The fire service is no longer "just" firefighters; it is now "first responders" with an increasingly wide array of services it provides. None of the costs discussed here are discounted for the increasing responsibilities the fire service plays outside of the traditional fire role. Increased efficiencies in built-in protection and promoting (or even requiring) built-in protection to reduce the incidence of fire have the added benefit of freeing up first responders to perform other, equally important functions. Innovative designs and cost-efficient solutions along with increased installation of sprinklers and fire-graded materials in residential structures would surely play a significant role here.

CONCLUSION

The total cost of fire is among the larger national problems in terms of its economic impact. It is important to consider each major cost element and tradeoffs among them when making fire protection policy. For example, the size of the fire service affects losses; the extent of built-in protection and engineering affects the cost of fire services and the losses incurred; the number and size of losses, etc., should affect net insurance costs. Changes in incremental costs of the major components of the total cost of fire should be analyzed and the results given more consideration in setting priorities.

Current estimates of the total cost of fire include a large component for the fire service itself. With the increasing roles of the fire service, the cost of the fire service's protection and prevention roles need to be disaggregated from the various other services it provides. Or it would be necessary to assess the overall costs of providing first responder services. This is an area where further refinement is needed.

Lastly, it is critical to understand that most methods used to estimate the total cost of fire are "soft," and few would stand up to the rigors of detailed analyses, if indeed the necessary data to perform such analyses were available. Efforts to date have most likely achieved an understanding of the order of magnitude of the problem and of the relative importance of each component. To effectively use this information in policy decisions, it is necessary to to establish good quantitative means to derive estimates. ▲

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Quantifying Total Losses Due to Fire – Remembering the Browns Ferry Nuclear Plant Fire

By Bernie Till

This year marks the 30th anniversary of the landmark fire at the Browns Ferry Nuclear Power Station. On March 22, 1975, employees inspecting penetration seals for air leakage accidentally started a fire, which damaged over 1,600 cables, including 628 that were "important to safety"[1] at the facility. The event has had far-reaching impact on the fire protection community – particularly in regard to cables and penetration seals, or more correctly, firestops.

Many lessons can be learned from this fire, but one stands out above others. The lesson of how a fairly small fire can cause tremendous financial disruption and damage is exemplified in this case as in few others. Certainly, other large-loss fires have been reported, and they too had far-reaching economic impacts in addition to their role in shaping fire protection. However, nuclear facilities are usually remote from populated areas, and often they are the major employer in an area, resulting in potentially greater local or regional economic impact in the event of a fire. What is the total monetary impact of a fire at one of these facilities? As with most large fires, a large value, which is often difficult to quantify. For example, for industrial fires, there is the actual fire loss – the facilities, equipment, or inventory directly impacted by the fire. Then there are the business interruption costs. This can move far beyond the actual loss to sales or other income, and in some cases may also include the costs of purchasing goods or services from competitors in order to meet obligations. The least visible of all is often the impact on the local economy.

THE INCIDENT[2]

On the day of the event, at approximately 12:15 pm, workers at the Tennessee Valley Authority facility near Athens, Alabama, were working to resolve an air leak in a fire penetration seal. As is normal in nuclear facilities, ventilation is designed to flow from areas of lower contamination levels to areas with potentially higher levels.

A cable penetration between the cable spreading room and the reactor

building had been identified as a leak point, and plans had been developed for repair. The penetrations were two "stacks" of five trays each which passed through a square four-foot by four-foot (1.2 m x 1.2 m) opening. The trays themselves did not pass through the two-foot (0.6 m) thick reinforced concrete fire wall. The seal, designed as both an air seal and a firestop, consisted of formed-in-place polyurethane with a fire retardant or protective material applied to the exposed polyurethane face. A candle was used to locate the specific leak point by observing flame movement caused by the airflow. Once the specific location was identified, polyurethane foam sheet material was inserted as necessary and the candle used to determine effectiveness of the repair. This time, however, the flame was pulled into the opening by the airflow. The polyurethane material, not yet protected by the fire-retardant material, ignited.

Attempts by the workers to extinguish the fire were complicated by the depth of the seal, the fact that the seal did not extend to both faces of the wall (the seal was installed at the reactor building side), impediments caused by the penetrating items, and by the lack of immediately available and appropriate means of extinguishment. Once obtained, a CO_2 extinguisher was perhaps compromised by the airflow, rendering it ineffective.

The fire ignited the polyvinyl chloride (and other) insulated cables. It was later estimated that about 4,000 pounds (1,800 kg) of cable insulation was involved, releasing an estimated 1,400 pounds (600 kg) of chloride to the reactor building. Damaged components included electrical power, plant control systems, and instrumentation cables.[1]

HOW MUCH? WHEN?... AND HOW?

Bad news travels fast, and reporting of a fire when it is "fresh" doesn't always offer the benefit of offering the total cost of the fire. The Browns Ferry Fire is a good example. The July 1976 *Fire Journal* reported that the "property damage... is estimated at about $10 million, and the cost of replacement power was approximately $10 million per month."[3]

Another factor is determining the period of time during which the loss estimates were established. In other words, is the estimate in current valuations, or is it the actual value when the event occurred? For example, if one uses a $100 million damage assessment under the assumption that the referenced value was in 1975 dollars, then, according to a conversion using the Consumer Price Index (CPI), the value in 2003 dollars would be $342 million.

Also of concern is the method for making the conversion. There are at least five methods for converting past values into current dollar estimates. All five will give different results, and choosing the most accurate is a point of debate, since there is no common agreement on which is the most accurate. The most commonly used is the Consumer Price Index. It is familiar to most people and is useful for comparing the cost of average household items. The Gross Domestic Product (GDP) Deflator is similar to the CPI, but includes all items produced in the economy. A third method, the GDP, is the market value of all goods and services produced in a year. The fourth is the GDP per capita, and the fifth is the Unskilled Wage Rate.

APPLES AND APPLES

Some estimates of the consequences of the fire refer only to the actual physical damage at the facility. In reality, this was very small for the Browns Ferry fire. It has been reported that only 20 feet (6 meters) of cables were directly involved in the fire. However, the consequences of this "small fire" resulted in what was determined to be a property damage estimate of up to $227 million – the cost of replacing all of the damaged cables – not just the damaged sections. Other sources report estimated damage at $500 million.[4]

Of larger importance are the costs of repairs and the loss of production capability. The fire in 1975 impacted both units at the site (a third was under construction). Each unit was capable of producing 1,065 MW of power, and both were out of service for eighteen months.

A review of the literature reveals a wide discrepancy in the total reported or estimated loss due to the fire at Browns Ferry. (See Table 1.) There are several reasons for this. First among these may be the fact that the facility was self-insured, and either a comprehensive assessment of the total impact of the fire was not performed or, if performed, was proprietary.

An obvious factor is scope of the estimate. Some references identify only fire-related property damage, while others include property damage and business interruption costs. None of the references reviewed captured the additional cost of repairs. SFPE Technical Report 77-2 offered a possible estimate of over 1,000 person-hours for repairs (including overtime).[2] Other costs for interaction with the Nuclear Regulatory Com-

Table 1. Reported Fire Loss Values Associated with the Browns Ferry Incident.

Reference	Loss Reported	Summary
Industrial Fire Protection Handbook[4]	$500 Million	Total loss, no breakdown of category
NFPA *Fire Protection Handbook*[5]	$227 Million	Described as property damage
Energy Power Research Institute (EPRI)[6]	$1 Million	Characterized as "direct" loss and identified a "forced outage of 550 days"
SFPE Technical Report 77-2[2]	$380 Million-450 Million	Includes property damage of $10 M, cost of replacement electrical power of $300,000 – $500,000 per day for 18 months (total $200 M-$270 M, loss of investment return of $170 M.
Fire Journal, July 1976[3]	Over $130 Million	Property damage of $10 M, replacement power costs of $10 M per month for over a year

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mission or testimony before the Congressional Joint Commission on Atomic Energy as well as recovery planning would also have added to the total cost.

The SFPE report also calculated a loss of return on investment of $170 million based on a 10 percent return on the $1 billion facility.

Direct loss is the term used to describe the damage to the building, its contents, and occupants (deaths or injuries), while costs associated with a fire following extinguishment are indirect or consequential losses.[7] Consequential losses include loss of production, profit loss potential, loss of employment, and costs of recovery, including repair and replacement. These losses can be particularly significant when specialized equipment or components are damaged and require long lead times for replacement.

LOCAL IMPACTS

One area of economic impact which is harder to quantify than others is that of the local economy. A major fire can significantly influence the economy of the local community – positively or negatively. In the case of a fire where the company decides to rebuild, the construction activities may bring jobs. Either new construction jobs become available or workers come from other areas. In the latter case, local lodging and food service establishments may benefit. Conversely, normally assigned workers may be laid off during the construction. If the plant decides not to rebuild, the local economy loses jobs. What is often not realized is the hidden impact of this job loss. For example, local businesses which rely on sales or services to the former employees will likely see a decline in revenue.

A fire protection engineer bears quite a responsibility when one considers that the potential consequences of a bad decision or poor judgment can reach far beyond the boundaries of the affected facility. Fire protection engineers also have to be salespeople – it is often their job to convince a client or manager of the need for fire protection systems or features. Recognizing the business interruption and other consequences of a fire is critical in making fire protection decisions. Fire protection engineers are necessary in evaluating risks and also providing balanced fire protection at a level appropriate to minimize the risk to acceptable levels. The SFPE report[2] indicates that this is one lesson learned from the incident – two fire protection engineers were added to the staff following the Browns Ferry event.

Ultimately, the total costs of the Browns Ferry fire will never be precisely known. Costs resulting from this fire include its effect on the commercial nuclear industry. New regulations, additional oversight, changes in procedures, new fire analyses, additional or more frequent inspections, and many more related activities came about following the fire. While incalculable, these costs have been estimated to be in the billions of dollars.

Of course, all of the economic impacts pale in comparison to the primary role of ensuring life safety and the consequences of failure on that front. Reflecting on the Browns Ferry fire can serve as an effective reminder of how important the fire protection engineering profession is – and how necessary. ▲

Bernie Till is with the Westinghouse Savannah River Company.

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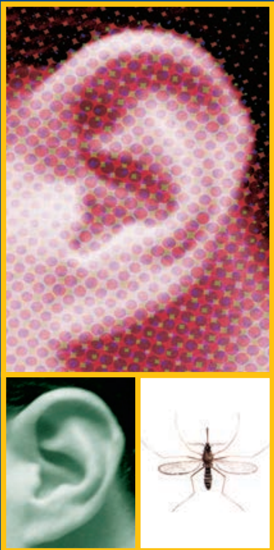

Part 2

The Mosquito and the Picket Fence –

A Modern-Day Fire Alarm Fable About Broadband versus Narrowband Signaling

In Part 1 of this article in the Winter 2005 issue, it was shown that sound is generally composed of many frequencies. An example of noise in a compressor room is shown in Figure 1 and listed in Table 1. It was also shown that as long as one of the alarm signal's frequency bands (pickets) is taller than the corresponding noise picket, the signal can be heard, even if the total broadband sound pressure level of the noise is greater than the total broadband sound pressure level of the signal. In this second part of the article, how one sound can penetrate another and the effects of masking will be introduced. The final article in this series, which will be published in the Summer 2005 issue, will present the signal-to-noise requirements of the *National Fire Alarm Code (NFPA 72)* and other factors, including the effects of distance, hearing loss, and hearing protection. The third article will also summarize advantages and disadvantages of narrowband signaling.

In Figure 1 and Table 1, the sound pressure level in dB for each frequency band is shown. The last two bars in the charts are the total, integrated sound pressure level. L_P is unweighted, while L_A has been adjusted according the A-weighting curve to approximate how the human ear hears different frequencies. Refer to the first part of this article in the Winter 2005 issue for an explanation.

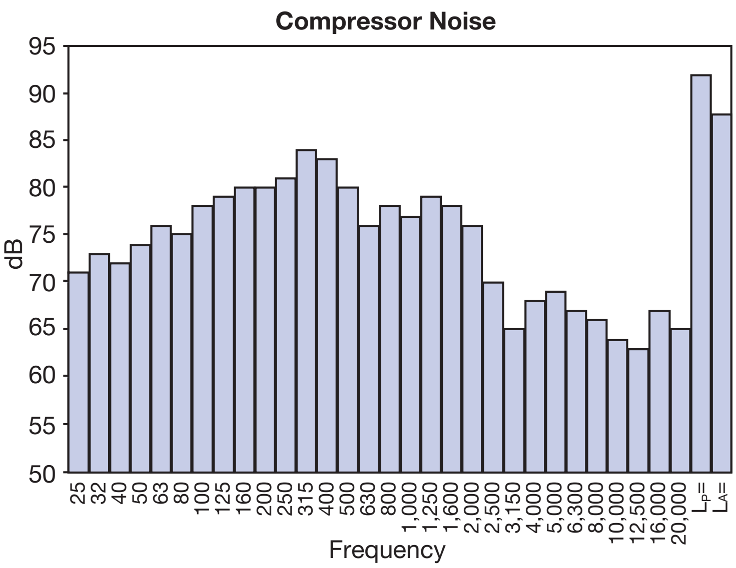

Figure 1. Compressor Room Noise.

Center Frequency (Hz)	dB	dBA
25	71	26.3
32	73	33.6
40	72	37.4
50	74	43.8
63	76	49.8
80	75	52.5
100	78	58.9
125	79	62.9
160	80	66.6
200	80	69.1
250	81	72.4
315	84	77.4
400	83	78.2
500	80	76.8
630	76	74.1
800	78	77.2
1,000	77	77.0
1,250	79	79.6
1,600	78	79.0
2,000	76	77.2
2,500	70	71.3
3,150	65	66.2
4,000	68	69.0
5,000	69	69.5
6,300	67	66.9
8,000	66	64.9
10,000	64	61.5
12,500	63	58.7
16,000	67	60.4
20,000	65	55.7
L_P=	**92**	
L_A=		**88**

Table 1. Compressor Room Noise.

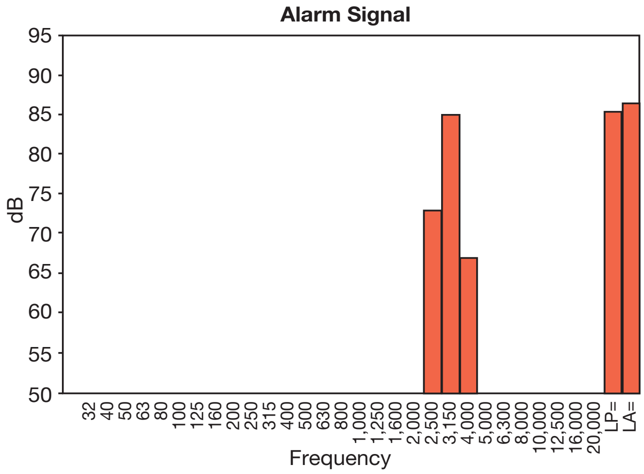

Figure 2. Fire Alarm Signal.

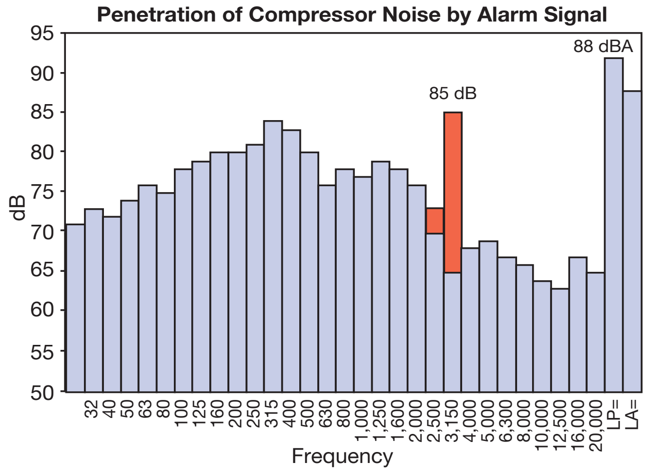

Figure 3. Combined Chart of Noise and Alarm Signal.

Center Frequency (Hz)	dB	dBA
25		0.0
32		0.0
40		0.0
50		0.0
63		0.0
80		0.0
100		0.0
125		0.0
160		0.0
200		0.0
250		0.0
315		0.0
400		0.0
500		0.0
630		0.0
800		0.0
1,000		0.0
1,250		0.0
1,600	30	31.0
2,000	36	37.2
2,500	73	74.3
3,150	85	86.2
4,000	67	68.0
5,000	49	49.5
6,300		0.0
8,000		0.0
10,000		0.0
12,500		0.0
16,000		0.0
20,000		0.0
L_P=	85	
L_A=		87

Table 2. Fire Alarm Signal.

SIGNAL PENETRATION

Figure 2 shows the frequency content of a typical piezo type fire alarm signal. The data for the signal are listed in Table 2. The measurements for both the ambient noise and the fire alarm signal must be taken at the same location in order to compare the relative loudness. Note that the total, A-weighted sound pressure level of the fire alarm signal is 87 dBA, while the noise (Table 1, Figure 1) produces 88 dBA. Clearly this would not meet the general broadband signaling requirements of the *National Fire Alarm Code*. One might be tempted to say that the fire alarm would not be audible over the noise of the compressor.

However, when the two charts are combined as shown in Figure 3, it is seen that the fire alarm signal "fence" is clearly "visible" behind the noise "fence." The chart shows that the fire alarm signal at 2,500 Hz and 3,150 Hz is audible above the ambient noise at those bands. The total, integrated 87 dBA of the alarm signal is hidden behind the 88 dBA of the noise. This is why the alarm signal can sometimes be heard, even though an integrating, A-weighted meter does not show the alarm to be any louder than the background noise. This same principle shows one reason why a mosquito can be heard over the drone of an air conditioner and the sound of a jet.

MASKING

Before the analysis is complete, it is necessary to account for the phenomenon of masking. Masking occurs when one sound prevents the ear from perceiving a second sound. Of course, sound in a particular frequency band can mask or cover other sounds in that same band whenever it has an equal or higher sound pressure level. But, in addition to that, a key element of masking is that sound in one frequency band can also mask sound in an adjacent, higher band.[1]

The term "effective masked threshold" is used to describe the sound level of an alarm signal at a particular frequency band that is just barely audible in the presence of a masking sound (noise).[2] In effect, masking by one frequency band can change the height of the dB bar for the next higher band. This makes it necessary for the alarm signal to overcome not just the noise level at that band, but the noise level plus the masking level imposed on the next lower frequency band. To make it more complicated, masking occurs only when the level of the lower (masking) frequency band is significantly greater than that of the next higher band.

NFPA 72 has adopted the requirements of ISO 7731 for the calculation of the effective masked threshold.[3,4] That standard defines the minimum slope for each frequency band as -7.5 dB per octave or -2.5 dB per 1/3 octave. The minimum slope may also be called a maximum roll-off of 7.5 dB per octave or 2.5 dB per 1/3 octave. The maximum roll-off (minimum slope) acts like a shadow on the next higher frequency band. Another way to visualize masking is to plot the data as a line chart rather than a bar chart. When connecting each data point to the next higher frequency data point, the minimum slope of the line is -7.5 dB per octave or -2.5 dB per 1/3 octave. See Figure 4.

Although the concept of masking is complex, the practical determination of the effective masked threshold is easy. Simply put, the noise data is adjusted as follows.

Center Frequency (Hz)	dB	Masked dB	Masked dBA
25	71	71.0	26.3
32	73	73.0	33.6
40	72	72.0	37.4
50	74	74.0	43.8
63	76	76.0	49.8
80	75	75.0	52.5
100	78	78.0	58.9
125	79	79.0	62.9
160	80	80.0	66.6
200	80	80.0	69.1
250	81	81.0	72.4
315	84	84.0	77.4
400	83	83.0	78.2
500	80	80.5	77.3
630	76	78.0	76.1
800	78	78.0	77.2
1,000	77	77.0	77.0
1,250	79	79.0	79.6
1,600	78	78.0	79.0
2,000	76	76.0	77.2
2,500	70	73.5	74.8
3,150	65	71.0	72.2
4,000	68	68.5	69.5
5,000	69	69.0	69.5
6,300	67	67.0	66.9
8,000	66	66.0	64.9
10,000	64	64.0	61.5
12,500	63	63.0	58.7
16,000	67	67.0	60.4
20,000	65	65.0	55.7
L_P=	**92**		
L_T=		**92**	
$L_{T,A}$=			**88**

Table 3. Effective Masked Threshold Noise Data.

FOR OCTAVE-BAND ANALYSIS:

Step 1: In the lowest octave-band, i=1, the threshold masked level is equal to the actual noise level data for that band:

$$L_{Ti,Oct} = L_{Ni,Oct}$$

Step n (n>1): In all subsequent octave-bands, the effective masked threshold is the greater of the actual noise data for that band or the masked threshold for the previous band less 7.5 dB:

$$L_{Ti,Oct} = \max\left(L_{Ni,Oct},\ L_{T(i-1),Oct} - 7.5\ \text{dB}\right)$$

Step n+1: Repeat step n for all subsequent frequency bands.

FOR 1/3 OCTAVE-BAND ANALYSIS:

Step 1: In the lowest 1/3 octave-band, i=1, the threshold masked level is equal to the actual noise level data for that band:

$$L_{Ti,1/3Oct} = L_{Ni,1/3\,Oct}$$

Step n (n>1): In all subsequent 1/3 octave-bands the effective masked threshold is the greater of the actual noise data for that band or the masked threshold for the previous band less 2.5 dB:

$$L_{Ti,1/3Oct} = \max\left(L_{Ni,1/3\,Oct},\ L_{T(i-1),1/3\,Oct} - 2.5\ \text{dB}\right)$$

Step n+1: Repeat step n for all subsequent frequency bands.

Table 3 lists the actual noise data and the effective masked threshold calculated using the above rules for 1/3 octave-band compressor room noise data.

Returning to the bar chart format, Figure 5 shows the actual noise data, with the effective masked threshold and the alarm signal.

In Figure 5, note how the effective masked threshold noise data is slightly higher than that of the base noise data – particularly in places where there is steep drop off going towards the highter frequencies. The fire alarm signal produces 85 dB at 3,150 HZ, which is 14 dB higher than the masked threshold of noise (71 dB). If the system were evaluated using an integrating meter set to A-weighting, the noise would measure at 88 dBA and the fire alarm 87 dBA (Table 2). Does this system pass or fail? The code requirements, the effects of changing the position of measurement, and the effects of hearing loss and hearing protective devices are presented in the next and final part of this article. That article will also discuss the concept of designing fire alarm signals.

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Editor's Note – About This Article

This is a continuing series of articles that is supported by the National Electrical Manufacturer's Association (NEMA), Signaling Protection and Communications Section, and is intended to provide fire alarm industry-related information to members of the fire protection engineering profession.

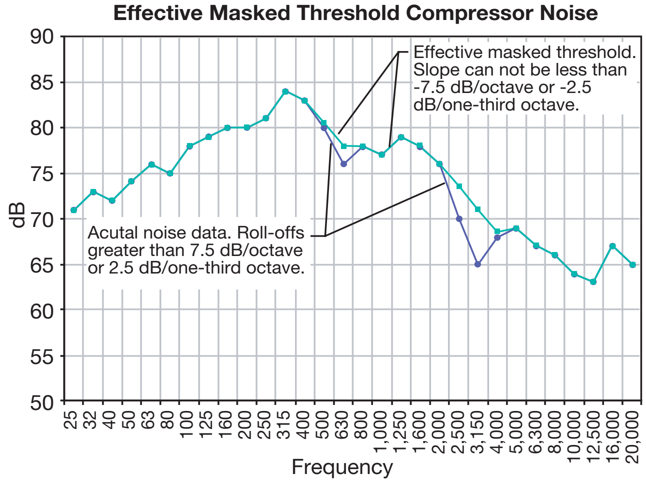

Figure 4. Noise Data and Effective Masked Threshold.

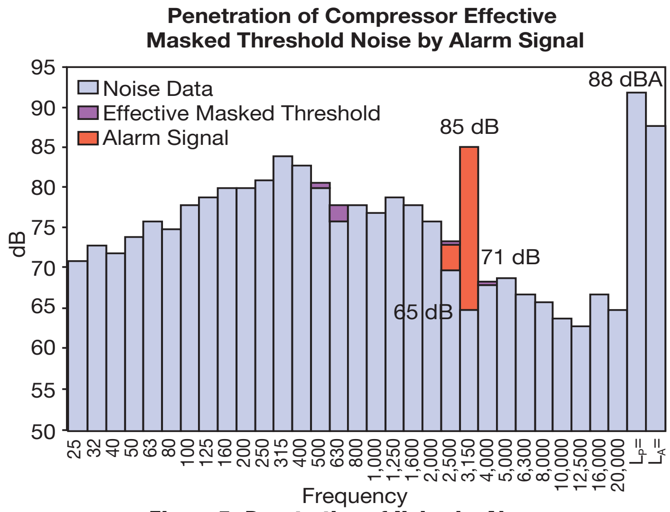

Figure 5. Penetration of Noise by Alarm.

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Resources

SFPE Annual Meeting and Professional Development Conference

October 17-21, 2005
Hyatt Regency La Jolla in San Diego, CA

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The SFPE Annual Meeting moves to San Diego!

Join your colleagues at the 2005 Annual Meeting and Professional Development Conference at the Hyatt Regency La Jolla in San Diego, CA. The Annual Meeting will include a technical program, a report on Society activities and finances, as well as the SFPE Picnic. This will be followed by the Awards and Honors Banquet, and by four days of educational events, including nine seminars, a symposium on Advances in Fire Suppression Technologies, and an expanded Technology Showcase.

The week features several NEW seminars: Advanced Fire Dynamics Simulator and Smokeview, Smoke Control, Structural Fire Protection, and Dust Explosion. Returning are the always-popular seminars on sprinkler design, human behavior, principles of fire protection engineering, and how to study for the FPE/P.E. exam.

For more detailed information visit *www.sfpe.org* or contact Julie Gordon, SFPE Education Program Manager, at *jgordon@sfpe.org* or by phone 301/718-2910.

Plan to be there and participate!

UPCOMING EVENTS

May 24-26, 2005
15th Annual International Halon Options Technical Working Conference
Albuquerque Marriott Hotel
Albuquerque, NM
Info: www.bfri.nist.gov/866/HOTWC

June 6-10, 2005
NFPA World Safety Conference and Exposition
Las Vegas, NV
Info: www.nfpa.org

September 28-30, 2005
3rd International Conference on Pedestrian and Evacuation Dynamics
Vienna University of Technology
Vienna, Austria
Info: www.ped2005.com

October 6-10, 2005
Fourth Mediterranean Combustion Symposium
Lisbon, Portugal
Info: Contact Federico Beretta, beretta@irc.cnr.it

October 17-21, 2005
SFPE Annual Meeting and Professional Development Conference
San Diego, CA
Info: www.sfpe.org

October 20, 2005
Fire Safety in Terrestrial Passenger Transportation
Santander, Spain
Info: grupos.unican.es/GIDAI

November 2-4, 2005
Fire Safety – Sea Road Rail International Conference
Melbourne, Australia
Info: www.rocarm.com/FSAS05CFP.htm

May 11-12, 2006
Fourth International Workshop Structures in Fire – SiF'06
Aveiro, Portugal
Info: www.civil.ua.pt/sif06.htm

MIJA, INC. | Case Study

Universities Eliminate Extinguisher Vandalism with Electronic Monitoring

MIJA, Inc.
11 Commerce Road
Rockland, MA 02370
888/ENGAUGE
www.mija.com

Student carelessness and vandalism can render fire extinguishers ineffective, directly compromising life safety. Extinguishers are highly successful tools for fighting fires, but to be effective they need to be in their proper place, accessible and working.

To ensure safety, many colleges and universities are installing electronically monitored fire extinguishers in their residence halls. The technology, EN-Gauge™, constantly monitors for presence and checks every 15 hours for pressure and obstruction to access. When an extinguisher is removed from its cradle, an alert is immediately sent to a monitoring station where safety officials can dispatch help in the event of a fire emergency – or catch potential vandals in the act.

EN-Gauge fire extinguishers were installed in two freshman residence halls at the University of Utah, Salt Lake City in October 2003. In the first year, there were no incidents of extinguisher vandalism. The only incident since then was immediately resolved as the RA was on the scene in seconds due to the EN-Gauge notification. Mike Halligan, associate director of environmental health and safety said, "We are definitely going to go campus-wide with this. There has been a huge decrease in vandalism and the comfort zone is priceless – knowing that extinguishers are available and going to work."

Suzanne Weaver, assistant director of environmental health and safety at Virginia Commonwealth University, said that the instant removal notification aspect was the biggest draw for her, "The technology is great – no question." Weaver is planning to install EN-Gauge fire extinguishers in two residence halls currently under construction. She is also working to get electronically monitored fire extinguishers included in the design phase of every new building going forward.

At Wesleyan University in Middletown, CT, where currently one residence hall is outfitted with wireless EN-Gauge extinguishers with several more planned, associate director for campus fire safety Barbara Spalding said providing an added sense of comfort to parents is another benefit. She noted that the University plans to include information about the increased fire and life safety in admissions information and new student orientation packets, "Parents entrust the safety of their children to us and we take that responsibility very seriously."

NOTIFIER® | Case Study

NOTIFIER's Superior Fire-Detection Technology Protects Sony's New Headquarters

NOTIFIER®
12 Clintonville Road
Northford, CT 06472-1653
203/484-7161
www.notifier.com

The Sony Corporation has become synonymous with consumer-electronic innovation, and Sony looks for the same technological superiority in its facilities. When investigating fire-detection systems for its new, sophisticated, 80,000-square-foot Mexico City headquarters, Carlos Aguilar, Sony Security Manager, put advanced technology as a top priority. Aguilar, who is responsible for the safety and security of all 300+ employees in the new facility, wanted a fire alarm system with strong early-detection capabilities.

After speaking with experts from various security and fire protection associations who offered strong testimonials about NOTIFIER, the world's leading manufacturer of engineered fire alarm systems, and part of Honeywell's Life Safety Group, Aguilar turned to Carlos Monroy, president of Conpel S.A. de CV, the local NOTIFIER Engineered Systems Distributor. Together with NOTIFIER, Monroy customized a system that would ensure Sony's specific emergency procedures were followed using the NFS-3030 intelligent Fire Alarm Control Panel, one of NOTIFIER's ONYX™ Series products. Ideal for medium to large-scale applications, the NFS-3030's modular design can be configured to meet virtually any facility's fire detection and emergency evacuation requirements.

Aguilar was firmly convinced that the most important feature of the NFS-3030 is its early-warning capability through ONYX Intelligent Sensing algorithms. In his opinion, only the NOTIFIER system would provide enough warning in the event of a fire to initiate all of the company's emergency procedures.

Ultimately, the NOTIFIER system blended seamlessly with Sony's business philosophy: to offer the best products to its customers while providing the best working conditions for its employees.

HONEYWELL POWER PRODUCTS

Case Study

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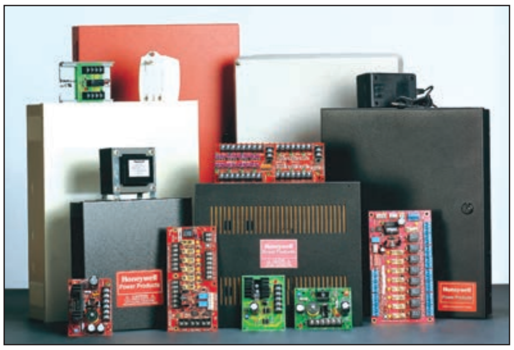

Honeywell Power Products (HPP) is providing the industry a new choice in power supplies. With a reputation for delivering unmatched quality, reliability, and value, these engineers perfected their game as part of Honeywell Fire Systems, manufacturer of the brands you trust today: Notifier, FCI, Fire-Lite, Gamewell and Silent Knight.

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HPP's fire-rated line includes the HPF602ULADA and the HPF902ULADA with 6.0 or 9.0 amps of notification power, direct AC power connections, an on-board charging circuit, and spacious backup battery space. Connectable to virtually any fire alarm control panel to provide additional power needed for notification appliance circuit expansion, these products deliver significant power and functionality with built-in synchronization protocols for all the popular strobes.

Honeywell Power offers total solutions for your power supply needs:

- An extensive warranty to assure reliable long term, trouble-free operation
- Comprehensive industry experience allows them to better understand the connections and operations of system products
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You can see all they have to offer by visiting *www.honeywellpower.com*.

Built on a customer-centered vision, HPP has developed products that deliver the power to run your most demanding applications. Be sure to check out Honeywell Power Products at the NFPA show (Booth #1159). They have products that fit your needs!

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www.honeywellpower.com

FIRE CONTROL INSTRUMENTS, INC.

Case Study

Multi-Purpose Little Rock Facility Gets Immediate Benefits From Fire Control Instruments' "Decisive" Fire Safety System

When your facility is comprised of different entities, your fire safety system needs to be a quick thinker: both decisive and responsive.

In the case of Little Rock, Arkansas's First Security Center, the fire safety system faced a trial by fire just weeks after the building opened.

The new 14-story mixed-use facility is comprised of a hotel, offices, and personally owned condos.

"We needed an incredibly functional, maintainable, and flexible system that was also economical," says Dave Carter, the building's property manager. "Our subcontractor, Advanced Cabling Systems (ACS), and Hargrave Consulting Engineers brought the Fire Control Instruments (FCI) system to our attention. It was clearly the way to go," says Carter.

Carter's firm – Moses Tucker Real Estate – opted for a state-of-the-art FCI NetSOLO fire alarm and voice evacuation system.

Among the 831 devices installed included a NetSOLO 7100 Fire Panel, NetSOLO VGC voice gateway, a NetSOLO VGX distributed amplification system, plus Analog Addressable Photo-Electronic Smoke Sensors, Analog Addressable Heat Detectors, Fixed Temperature Heat Detectors, and speaker/strobe notification devices.

ACS also installed a fiber network between 14 of FCI's NetSOLO panels distributed throughout the building. The system can pinpoint a fire to the exact detector.

Shortly after the building opened, a resident who failed to ventilate his gas fireplace accidentally caused an explosion.

The system responded instantly, detecting the heat and immediately sending the system into full alarm mode. Because of the system's addressable features, management was able to determine which device activated first, and the succession in which the other devices activated. "Luckily, the resident was OK," says Carter. "Also, the water damage to the offices below, from the activated sprinkler system, would have been worse without the accurate pinpointing of the trouble-spot."

Moses Tucker Real Estate will definitely consider FCI for future projects. "When we needed it, the system worked," says Carter. "And that's very good to know."

FCI FIRE CONTROL INSTRUMENTS by Honeywell

Fire Control Instruments, Inc.
16 Southwest Park
Westwood, MA 02090
781/471-3000
www.firecontrolinstruments.com

THE RELIABLE AUTOMATIC SPRINKLER

Case **Study**

The Model DDX Valve by Reliable

The Reliable Automatic Sprinkler Co., Inc.
525 North MacQuesten Parkway
Mount Vernon, NY 10552
800/431-1588
www.reliablesprinkler.com

The Reliable Automatic Sprinkler Company introduces a new deluge valve, the Model DDX, for use as the primary water control valve in deluge, pre-action (both single and double interlock), and Reliable's low-pressure dry systems. The DDX is available in 4 in. and 6 in. sizes, with 2, 3, and 8-in. versions to come.

The DDX is UL-Listed and FM-Approved for application in these various system types as detailed in Reliable's data sheets. Developed with the latest advances in design technology, the ductile iron valve body is:

- Compact – Takeout dimension for the 4-in. valve is 14 in.; takeout dimension for the 6-in. valve is 16 in.
- Lightweight – The 4-in. valve weighs 64 lbs.; the 6-in. valve weighs 95 lbs.
- Strong – 250 psi working pressure.

The Model DDX is a hydraulically operated differential-type valve. An intermediate chamber is designed into the valve body, eliminating the check valve previously required for other brands and Reliable's Model BX Preaction and LDX Dry Pipe Valve Systems.

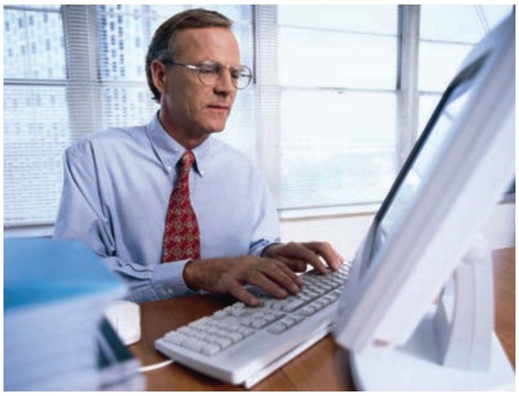
Other design features include a single main drain valve, grooved inlet and outlet connections, external reset by rotation of a comfortable hand-fitting knob, and a drop-in seat and clapper assembly for future maintenance. The Model DDX Valve requires no priming water for any of its applications. The low-pressure dry system may be hydrostatically tested with the clapper in the closed position.

The trim is designed to be compact and simple, resulting in faster installations with the valve and trim piping requiring less space. Each complete trim set may be ordered in either a pre-assembled segmented kit or a loose package. It is also available completely assembled trim to valve, with or without a butterfly control valve. To simplify ordering of the complete trim packages, one part number will provide you with all the trim components necessary for a complete installation.

UNIVERSITY OF MARYLAND

Case **Study**

University of Maryland Now Offers Online Graduate Courses



University of Maryland
Online Studies in Fire Protection Engineering
4321 Hartwick Road, Suite 208
College Park, MD 20740
www.onlinestudies.umd.edu/fire4

Engineers wishing to enhance their knowledge of fire protection engineering will be able to take individual courses completely online from the University of Maryland this spring.

Two graduate-level courses will be offered by the university's Department of Fire Protection Engineering beginning March 7. Smoke Detection and Management covers smoke analysis and response analysis of smoke detectors. The three-credit course is taught by University of Maryland faculty member Jim Milke. Advanced Fire Suppression, also a three-credit course, is taught by Maryland faculty member Fred Mowrer. It focuses on methods of flame extinction, including foam and sprinkler systems, among others.

To be responsive to the needs of working engineers, students have the option of enrolling in individual courses for professional development purposes without being admitted to the online Master of Engineering in Fire Protection degree program. Qualified students may wish to continue their studies and earn the full master's degree. Credits earned by satisfactorily completing online courses may be applied toward the degree.

Courses offer Web-based chat rooms, threaded discussions, and e-mail. Online students also benefit from online admission and registration as well as full technical support and access to the university's rich library resources.

February 21, 2005, is the deadline for submission of a completed application.

The Pennsylvania State University Selects AGF Model 1200 REMOTETEST TESTANDRAIN Valve for Sprinkler Retrofits

AGF Manufacturing Inc.
100 Quaker Lane
Malvern, PA 19355
610/240-4900

The January 2000 Seton Hall fire put sprinkler retrofit plans at colleges and universities nationwide into high gear. Administrators – becoming aware of the life safety benefits that sprinklers provide – began including them in most new construction and scheduled residence hall rebuilds. After January 2000, the installation of sprinklers became the driving force for residence hall retrofits.

While these initiatives have created safer environments, they have also posed a challenge for safety administrators: how to provide regularly scheduled system readiness testing for more buildings with limited staff already working at capacity. The solution for The Pennsylvania State University has been to include the AGF Model 1200 REMOTETEST TESTANDRAIN Valve in its sprinkler retrofits.

The first installation was for a five-building dorm complex with 50 individual inspector's test and drain valve locations. To provide a precaution against tampering, the test valves were located in locked closets with locked handles.

Now the process of testing goes quickly, taking one person a fraction of the time originally slated for the testing process (two people over several days). The AGF REMOTETEST Valves can be operated in numerous ways including through the Fire Control Panel (FCP). The University however opted to use one auxiliary panel located next to the FCP to control the 50 valves.

The UL Listed/FM Approved Model 1200 REMOTETEST meets all NFPA 13 and 25 testing requirements by performing conventional system testing from a single remote location. REMOTETEST has allowed the university to do more frequent testing – with existing staff – than would be possible with standard manual-only test and drain valves.

Based on this success, the AGF Model 1200 REMOTETEST Valve has become part of the University's sprinkler specification. They are installed in more than 20 residence halls and are being included in the new Food Science Building Complex, and historic McAllister Hall; with more sprinkled buildings being planned each year.

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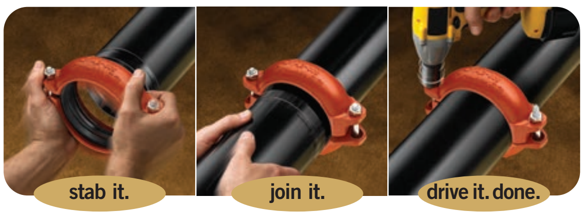
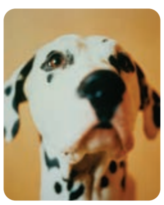


* This description and illustration does not represent the complete installation instructions. Refer to the Victaulic installation instructions supplied with the coupling for complete details.



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Products/Literature

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www.siemens.com

—Siemens Building Technologies, Inc.

Multi-Gas Detector

The new MultiPro multi-gas detector provides real-time readings of up to four gases with one-button operation via a backlit LCD display mounted on the front of the unit. The single "Mode" button controls all operations, including autocalibration. Other features include both audible and visual alarms, a Calibration Due reminder, and Sensor Span Reserve indicators for predictive maintenance. All sensors are field-replaceable.

www.biosystems.com

—Biosystems, LLC

False Alarm Prevention

The Ground Transient Terminator (GTT) was designed to reduce unnecessary disruptions to microprocessor-based equipment by controlling frequency rather than amplitude to prevent damaging voltages from entering. It offers a frequency range of 50 kHz to 2.0 GHz, with a fast response time for both current and voltage rise. The standard operating temperature range is -40°C to 85°C. The device measures 65 x 55 mm and retails for less than $100.

www.9corp.com

—9 Corp.

Extended Coverage OH Sprinkler

Viking's K-14 (20,2 metric) Extended Coverage, Ordinary Hazard (ECOH) Pendent Sprinkler produces the flows required to meet Ordinary Hazard density requirements at lower pressures than 8.0 or 11.2 (11,5 or 16,1) K-factor sprinklers. With its extended coverage capability, it is ideal for large open-type occupancies, such as malls or other retail structures. UL and cUL listed for coverage areas from 12 ft. X 12 ft. (3,7 m x 3,7 m) through 20 ft. x 20 ft. (6,1 m x 6,1 m).

www.vikingcorp.com

—Viking Corp.

UL W-Rated Firestopping Systems

3M's line of Fire Barrier Water Tight Silicone Sealants meets the UL W Rating, Class One requirements for watertightness when used on horizontal floor penetrations. Three sealants are available to meet a wide range of applications and conditions. Designed to help protect builders, owners, and occupants from potential problems associated with water and moisture intrusion. Ideal for use in fast-track construction.

www.3M.com/firestop

—3M

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www.wheelockinc.com

—Wheelock Inc.

Intelligent Addressable Control Panel

The FireWarden™ 100 Intelligent Addressable Control Panel is a single-loop panel with a capacity of up to 198 addressable NOTIFIER devices. Suited well for small building applications, it features advanced smoke detection capabilities and autoprogramming ease. Ideal for owners who need the flexibility of individual software zone mapping. Features include auto detector testing, drift compensation, maintenance alert, and auto device type verification.

www.notifier.com

—Notifier

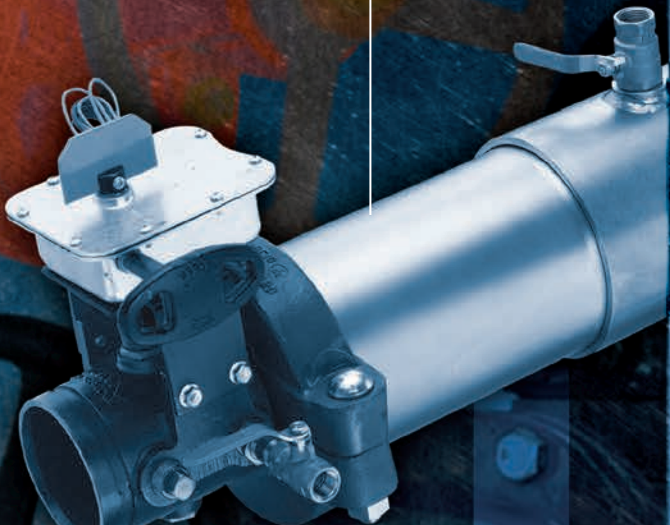
Control Panels

The MS-2 and MS-4 Fire Alarm Control Panels offer automatic strobe synchronization of audio/visual devices, enabling the control system to perform in compliance with ADA standards. Offering large-system protection for small environments, both panels operate at 24 volts with 3 amps of total power on board; the MS-4 is also capable of supplying 6 amps with an optional transformer. An optional converter is available for the MS-4 to allow for Class A wiring when necessary.

www.firelite.com

—Fire-Lite Alarms, Honeywell Fire Group

Dealing the Best in Backflow Technology...



Ames, once again, has outpaced the competition. Our new Colt & Maxim backflow assemblies feature the most advanced design on the market. Ames valves are manufactured from the best materials, offer the best performance, are the easiest to service & maintain and have the lowest installed cost of any backflow assembly in the industry. As if that weren't enough, check out these other great features:

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BRAINTEASER

In a game of poker, a player is dealt five cards. What is the probability of a player being dealt a "straight flush," i.e., five sequential cards of the same suit?

Solution to last issue's brainteaser

Yahtzee® is a game played with five 6-sided dice. Players take turns rolling the dice, trying to get certain combinations of 1s, 2s , 3s, etc. Players may roll the dice up to three times during each turn and are permitted to set aside any subset of the five dice after each roll.

After the second roll, a player has the following combination of dice: 1, 2, 3, 6, 6. If the player keeps the two 6s, what is the probability of obtaining a "full house" (three of one number and two of another) on the third and final roll?

In this scenario, there are two ways that a full house can be rolled – 6, 6, 6, x, x; or 6, 6, x, x, x. For the first case, the likelihood of rolling a 6 is 1/6. The probability of rolling one 6 and two of another number is (1/6)(1/36)=0.0046. Since double 1s, 2s, 3s, 4s, or 5s would be acceptable, there are five ways of achieving a full house. Also, there are $\frac{3!}{(3-1)!1!} = 3$ possible combinations, so the probability of rolling 6, 6, 6, x, x is 0.0046 x 5 x 6 = 0.069.

For the second case, the probability of rolling three of a number is $(1/6)^3$. Since there are five possible combinations of rolling three of a kind (that are not 6s, which would result in five of a kind), the probability of rolling three of a kind (other than three 6s) on the remaining three dice is 0.023. Therefore, the probability of rolling a full house is 0.069 + 0.023 = 0.092.

FIRE PROTECTION Engineering

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Index of Advertisers

from the technical director

Fire Loads and Fire Resistance Design

Morgan J. Hurley, P.E.
Technical Director
Society of Fire Protection Engineers

Few technological elements of modern society have endured in a form that has been essentially unchanged for periods of 80 or more years. An exception to this is the method that is generally used to design structural fire resistance in buildings.

Of course, the fact that this method has changed little over the last 80+ years is not, in itself, necessarily indicative that structural fire-resistance design is less than ideal. In fact, that buildings designed using the current method almost never experience structural failure in fire is a testament to the robustness of this design approach. However, these buildings have an unknown margin of safety (which is discussed more thoroughly in the "From the Technical Director" column in the Summer 2003 issue), and this method is not without its limitations.

There are two main underpinnings of the approach that is currently used for fire-resistance design in buildings: the standard fire test method and the minimum acceptable time before pass-fail criteria are exceeded.

The *Standard Fire Test Methods of Building Constructions and Materials*, first published as ASTM E-119 in 1918, specifies a standard time-temperature curve and pass-fail criteria for elements of structures subjected to the test. Limitations of designing based on the results of the standard test method are discussed in the "From the Technical Director" column in the Winter 2004 issue.

Building codes generally specify fire resistance in units of time, which corresponds to the time that the structural elements, with any supplementary protection applied, must withstand the standard fire exposure prior to exceeding the specified endpoint criteria. The technical underpinning of the system of hourly rating was first published by Simon Ingberg in 1928.[1]

The basis for the concept of specifying minimum fire ratings is the "fire load concept," which states that the integration with time of the temperature of a fire is indicative of the severity of the fire. For example, under this concept, a compartment fire with a temperature of 1200°C that lasts 30 minutes would be assumed to have equal severity to a 900°C compartment fire that burned for 40 minutes. To avoid completely nonsensical comparisons, temperatures below a threshold of about 300°C would be neglected.

The fire load concept has the advantage that it is easy to use. Equivalent fire exposures for typical occupancies can be determined based on results of full-scale fire tests. However, the fire load concept is not without limitations, some of which were identified by Ingberg when he initially published his work.[1] These include:

1. Heat transfer to bounding materials is not well represented by the product of temperature and time. While convection can be represented by the product of time and temperature, radiation varies with temperature raised to the 4^{th} power. A compartment fire with a temperature of 1200°C would have approximately two-and-a-half times the emissive power of a 900°C compartment fire.

2. The "fire load," whether expressed in units of mass per unit area (kg/m^2 or lb/ft^2) or energy potential per unit area (MJ/m^2) is not in and of itself representative of fire severity. The ease with which a material burns is also a factor. For example, although wood has a heat of combustion that is approximately half that of most plastics (in other words – burning one kg of a plastic can liberate twice the energy as burning an equal mass of wood), wood's heat of gasification (a measure of how much energy it takes to create vapors) is two to five times that of most plastics. In ventilation-limited fires, the rate of air flow into the enclosure will govern how much fuel vapor burns inside the enclosure, and fuel vapors that cannot burn inside the enclosure will vent from the compartment unburned. Therefore, a material that has a higher heat of combustion will not necessarily result in a more severe fire exposure within a compartment.

Additionally, use of the fire load concept suffers from the same limitations as use of the standard fire test method: other factors that affect fire severity are not considered, such as ventilation and compartment thermal properties; and single elements are tested in isolation so that structural behavior in fire is not considered.

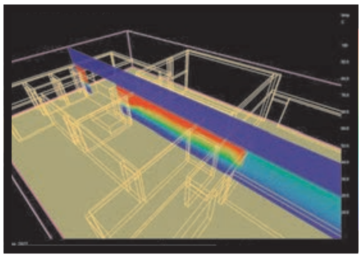
Fortunately, several organizations are conducting work that will help advance structural fire protection engineering practice. The American Society of Civil Engineers has a plan to develop a standard on performance-based structural fire-resistance design. An engineering guide[2] that SFPE developed and a standard that SFPE is in the process of developing are intended to facilitate this type of analysis. Additionally, the National Institute of Standards and Technology held a workshop to identify a path towards widespread performance-based structural fire-resistance design,[3] and they are in the process of assembling a best practices guide on the design of concrete and steel structures.

While the method that has been used to design structural fire resistance for almost a century has resulted in safe buildings, use of new design methodologies that overcome the inherent limitations of existing methods will result in greater flexibility in design, and equal or greater safety and economy to the public.

1 Ingberg, S., "Tests of the Severity of Building Fires," *Quarterly of the National Fire Protection Association*, July 1928, pp. 43-60.

2 *Engineering Guide: Fire Exposures to Structural Elements*, Society of Fire Protection Engineers, Bethesda, MD, 20814.

3 Almand, K., et al., "NIST-SFPE Workshop for Development of a National R&D Roadmap for Structural Fire Safety Design and Retrofit of Structures: Proceedings," NISTIR 7133, National Institute of Standards and Technology, Gaithersburg, MD, 2004.



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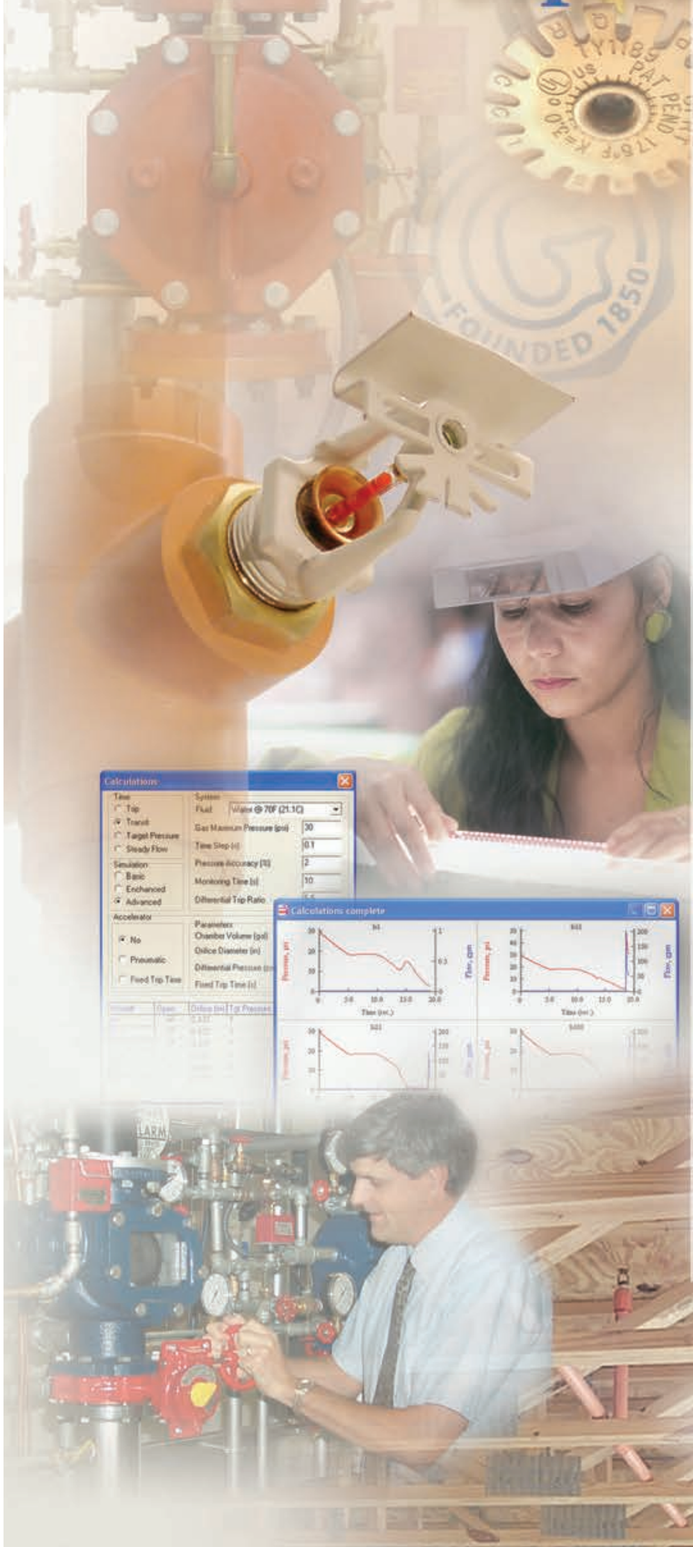

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