Clarifying The Issue of Fire Protection Balance

- A White Paper -

By Richard Licht
Technical Director, Alliance for Fire and Smoke
Containment and Control

The United States and Canada have the worst fire death rate of all industrialized countries for which we have comparable data according to a study conducted by United States Fire Administration (USFA. According to a USFA report "America Burning, Recommissioned: Principal Findings and Recommendations", the fire problem in America remains as severe as it was 30 years ago. While there have been improvements over the last 30 years - fires down by 21 % per capita, deaths and injuries by 27%, and adjusted dollar loss by 28% - we still exceed many European nations by about two to three times in fire deaths, and the European average by about 20%.

When the U.S. Fire Administration was established in 1975, annual fire deaths were estimated at 12,000. The goal was to reduce deaths by 50 percent within 25 years; that goal was met. The greater use of smoke alarms is thought to account for a significant part of the decrease in reported fires and deaths over the past two decades. Other important changes have been the increase usage of sprinklers systems, better code enforcement of fire and smoke resistant construction methods, as well as newer "fire rated" construction materials.

Although we have made much progress in the last decade, the United States continues to have one of the highest per capita fire death rates in the world. Will changes in the new building codes set the U.S. back by a decade? Will over-reliance on sprinklers and elimination of fire rated construction eliminate many of the gains that have been achieved over the past 30 years?

A strong controversy has developed among fire protection, building design and construction interests over the past several years on the subject of balancing active (sprinklers) and passive (fire and smoke resistant construction) elements in fire protection. This issue has come to light as a result of changes in construction requirements as defined in the new International, IBC 2000 and the New NFPA 5000 building codes.

Over the past 30 years, the three national model building codes have called for increased use of sprinklers, while steadily rolling back requirements for fire-resistant components such as walls, floors beams, trusses, girders, dampers, doors, cables and columns, as well as concrete, fireproofing, fire duct wrap, firestop systems, fire rated glazing, and fire rated wall and ceiling boards. These components and materials help control the spread of fire, limit the damage to a burning building and surrounding structures, and allow sufficient time for occupants to escape and firefighters to do their work before the structure collapses.

The IBC 2000 represents a compilation of three regional codes: the Building Officials and Code Administrators International (BOCAI), Southern Building Code Congress International (SBCCI) and the International Conference of Building Officials (ICBO). In merging these codes the IBC found it generally necessary to settle on the least restrictive provisions of the three in order to reach common agreement. Consequently the new code represents an overall reduction in standards levels, and thus in life safety effectiveness.

For example, a claim was made that less stringent provisions that have been in force in BOCA and SBCCI areas have enjoyed good success in practical application, and thus it is reasonable to adopt them universally. In fact, however, there have been significant differences in fire protection effectiveness between areas of the U.S. due to differing building code requirements, demographics, and public awareness of fire and smoke hazards.

Greater loss of life has been recorded in the less restrictive areas such as the south and northeast compared to regions such as California where higher standards have been in force. (Figure 1.) These code differences between U.S. regions have included values in allowable height and area tables for building spaces, and the required mix of active and fire resistant construction.

Figure 1 - Fire Loss Rates Nationwide and by Region, 2000

Region	**Number of Fires per Thousand Population**	**Civilian Deaths per Million Population**	**Civilian Injuries per Million Population**	**Property Loss per Capita**
Nationwide	6.2	14.8	81.6	$40.9
Northeast	6.2	17.3	111.7	$36.5
North central	6.4	15.6	92.1	$36.8
South	7.2	17.7	70.5	$42.2
West	4.5	7.0	62.2	$46.2

Source: NFPA's Survey of Fire Departments for 2000 - U.S. Fire Experience
U.S. Fire Experience by Region, by Michael J. Karter, Jr. (NFPA Fire Loss in the United States During 2000, Michael J. Karter, Jr. Fire Analysis & Research Division, NFPA, Quincy, MA.)

The new IBC/NFPA 5000 represents not only compromises to least restrictive provisions of the parent codes, but also further relaxes certain standards.

- The BOCA National Building Code allowed certain buildings with sprinklers to be constructed with no area restrictions or “fire ratings” as long as they were only one-story high. Under the IBC and the NFPA 5000, these buildings can now be two-stories high and still need not be fire-rated.
- The SBCCI Standard Building Code required fire walls to have a four-hour fire resistance rating. The new codes have reduced the ratings to as little as two or three hours in most cases, depending on the buildings occupancy and use.
- The ICBO Uniform Building Code allowed sprinklers to be used to increase either the allowable height or the allowable area of buildings, but not both, as is allowed by both the IBC and NFPA 5000, while not requiring increased fire-resistant construction,

It is estimated that the revised code will reduce the cost of new commercial construction by 2% to 5% because of substantial increases to height and area tables and reductions in fire resistant construction requirements, as shown in Figure 2. These less restrictive construction regulations and fire resistant construction requirements are based on increased reliance on sprinkler systems.

As tables C and D below show, the IBC allows the construction of spaces with substantially greater height and area values than in the past.

IBC Use Group	Code	IBC Type of Construction								
		Type I		Type II		Type III		Type IV	Type V	
		A	B	A	B	A	B	HT	A	B
B Business	BCMC	UL	37,000	23,000	17,000	22,000	17,000	23,000	17,500	12,500
	IBC	UL	*UL*	37,000	23,000	28,500	19,000	36,000	18,000	9,000
	NBC	UL	34,200	22,500	14,400	19,800	14,400	21,600	15,300	7,200
	SBC	UL	*UL*	25,500	17,000	21,000	14,000	25,500	13,500	9,000
	UBC	UL	39,900	18,000	12,000	18,000	12,000	18,000	14,000	8,000
F-1 Factory Moderate Hazard	BCMC	UL	24,500	16,000	12,500	15,500	12,500	16,000	12,500	8,500
	IBC	UL	*UL*	25,000	15,500	19,000	12,000	33,500	14,000	8,500
	NBC	UL	22,800	15,000	9,600	13,200	9,600	14,400	10,200	4,800
	SBC	UL	*UL*	31,500	21,000	22,500	15,000	31,500	15,000	10,000
	UBC	UL	39,900	18,000	12,000	18,000	12,000	18,000	14,000	8,000
R-2 Apart. House	BCMC	UL	15,000	11,000	8.000	10,500	7,500	11,000	8,000	4,500
	IBC	UL	*UL*	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	NBC	UL	22,800	15,000	9,600	13,200	9,600	14,400	10,200	4,800
	SBC	UL	*UL*	18,000	12,000	18,000	12,000	18,000	10,500	7,000
	UBC	UL	29,900	13,500	9,100	13,500	9,100	13,500	10,500	6,000

Table C - Allowable Areas (table values) of BCMC, IBC and Model Codes

IBC Use Group	Code	IBC Type of Construction								
		Type I		Type II		Type III		Type IV	Type V	
		A	B	A	B	A	B	HT	A	B
B Business	BCMC	UL	7	4	3	4	2	4	3	2
	IBC	UL	11	5	4	5	4	5	3	2
	NBC	UL	7	5	3	4	3	5	3	2
	SBC	UL	UL/80	5	2(5)	5	2(5)	5	2	2
	UBC	UL	2	4	2	4	2	4	3	2
F-1 Factory Moderate Hazard	BCMC	UL	5	3	2	3	2	3	2	1
	IBC	UL	11	2	2	3	2	4	2	1
	NBC	UL	6	2	2	3	2	4	2	1
	SBC	UL	UL/80	2(4)	2(4)	2(4)	2(4)	3(6)	1	1
	UBC	UL	12	4	2	4	2	4	3	2
R-2 Apart. House	BCMC	UL	12	4	2	4	2	4	3	2
	IBC	UL	*11*	4	4	4	4	4	3	2
	NBC	UL	9	4	3	4	3	4	3	2
	SBC	UL	UL/80	5	2(5)	5	2(5)	3	3	2
	UBC	UL	12	4	2	4	2	4	3	2

Table D - Allowable Heights (table values) of BCMC, IBC and Model Codes

While the IBC allows new buildings with sprinklers to be taller and larger than before, it reduces or eliminates the ratings of fire protection features such as protected steel columns, doors and firewalls and other fire resistant wall assemblies, such as corridors. This places occupants and firefighters at greater risk in the event of a fire. Fire resistant construction has been clearly shown to help restrict spread of toxic fumes, flame and smoke in building fires, and help save lives. Unfortunately therefore, the IBC 2000 and the NFPA 5000 may have the effect of reducing safety for building occupants in coming years.

In most societal aspects of public life safety, regulations are determined by governmental authority and isolated, at least to some degree, from direct financial interests. For example, automobile air bags, seat belts, crash worthiness standards and similar requirements have been established primarily on the basis of public good rather than economy. These requirements clearly benefit the public by reducing death and injury, and are not likely to be traded off selectively to reduce costs in exchange for an acceptable level of mortality.

Commercial aircraft safety requirements are also based primarily on public benefit rather than private interests. Stringent aircraft regulations and costly redundant systems have not been eliminated in favor of economy, even though they may be needed very infrequently.

Opponents to preservation of balanced active fire resistant construction assert that fire-resistant construction is being promoted for commercial interest. In fact, there are financial interests on both sides of this regulatory issue. The controversies surrounding active/passive trade-offs in the new IBC 2000 have been strongly influenced by building and design interests on one side, and the fire resistant construction industry on the other.

The challenge in achieving effective fire protection is to reach a regulatory equilibrium that accommodates practical financial interests, builds on fire performance experience and established data, and delivers optimum life safety for both the near and long term that is centered on the public interest. Serious reductions in fire resistant construction result in immediate cost savings and unfortunate and disastrous safety implications long into the future.

Records show substantial reductions in the number of civilian deaths annually related to major structure fires over the period 1979 to 1999 (Figure 3). This positive trend is largely due to the effective performance of balanced fire protection elements in buildings constructed in recent years where there have been serious fires. It takes years to record and analyze the results of changes in codes and construction standards, and if the lowered standards in the new code are widely implemented, it is likely that studies in the next decade and beyond will report an unfortunate toll in human life that can be traced to compromises such as expanded height and area tables and less stringent egress provisions.

The relatively good fire record in commercial construction is due largely to the conservatism of the previous two decades of fire protection engineers, who incorporated BOTH active and passive measures in their designs, even to the point of identifying the practice as “redundant”. This approach has borne good results to date, but with code changes, that trend in not likely to continue. As a practice, designers do not generally specify beyond "minimum standards", and the new minimums are actually sub-standard.

Figure 3- Civilian deaths annually related to major structure fires, 1979 to 1999

Reported to Fire	**Compared To**			
Departments	**1999**	**1998**	**1989**	**1979**
Fire Incidents	1,823,000	Up 4%	Down 14%	Down 36%
Civilian Deaths	3,570	Down 12%	Down 34%	Down 53%
Firefighter Deaths	112	Up 23%	Down 5%	Down 10%
Civilian Injuries	21,875	Down 5%	Down 23%	Down 30%

Sources: Fire Loss in the United States, (1979, 1989, 1998 and 1999), by Michael J. Karter, Jr. Fire Incident Data Organization, U.S. Census Bureau.

Sprinkler Performance

Sprinkler systems are clearly a life safety asset for commercial buildings. Nevertheless, it must also be acknowledged that sprinkler systems can and do fail, because of human error, neglect, and mechanical malfunction. Occupants in a building not equipped with the protection of fire resistant construction are subject to substantially increased danger when a sprinkler failure occurs.

Unfortunately, complete data on sprinkler performance is lacking. In 1970 the NFPA determined that it would no longer record and report instances of sprinkler failures in the U.S., ostensibly because data was restricted primarily to instances where sprinklers failed and did not include circumstances where sprinklers performed as intended. As a result, some interests may place greater confidence in sprinkler system performance than is warranted by experience.

Sprinklers can and do malfunction in buildings due to accidental deactivation, malfunction or improper maintenance. When a fire occurs under such conditions, the results can be devastating, but the event may not be reported as involving a sprinkler failure. The simple, practical and inescapable fact is that when a sprinkler system is in place but does not operate or effectively control a fire, for whatever reason, it must be acknowledged as a sprinkler failure.

An article in the July 20, 2001 edition of the San Francisco Chronicle reported, "A new national code, already adopted in 10 states, allows buildings with sprinklers to have more stories, more open space, narrower stairwells and fewer exits. They also can have fewer fire doors, fire dampers and firewalls, and less fire protection in roofing. ""I'm very pro-sprinkler, but when you're talking about fire safety, you can't have just one line of protection," said Don Bliss, New Hampshire state fire marshal. “If we're depending on a sprinkler system to function and it fails, people will be at considerably more risk.""

An NFPA report, U.S. Experience with Sprinklers, September 2001, summarizes fires in public buildings including public assembly, educational, health care, correctional, apartments, hotels/motels, department stores, offices, and industrial, manufacturing and storage structures during the period 1989-1998. In those structures with sprinklers, the sprinklers operated during 82.7% of the fire instances, and failed to operate in 17.3% of fire instances (Figure 4)

Figure 4 - U.S. Experience with Sprinklers

Property Use	% of Fires with Sprinklers[1]	% of Fires Where Sprinklers Operated[2]	% of Fires Where Sprinklers did not Operate
Public Assembly	23.0	73.9	26.1
Educational	21.6	79.6	20.4
Health Care & Correctional	51.2	80.0	20.0
All Residential	2.6	84.6	15.4
1&2 Family	0.7	80.0	20.0
Apartments	6.6	82.7	17.3
Hotels & Motels	32.8	82.7	17.3
Department Stores	52.0	84.9	15.1
Offices	24.2	80.6	19.4
Industrial	12.6	85.9	14.1
Manufacturing	49.8	91.1	8.9
Storage	3.0	84.0	16.0
TOTAL		82.7	17.3

1 Estimated as percentages of structure fires with sprinklers present divided by the number of structure fires with sprinkler status known.
2 Excludes fires where sprinkler was present but fire was coded as too small to test operational status of sprinklers.
Data source: NFPA Report, U.S. Experience with Sprinklers, September 2001. National estimates based on 1989-1998 NFIRS and NFPA survey.

Sprinkler head design and performance has been a serious issue in the U.S. A July, 2001 release by The U.S. Consumer Product Safety Commission (CPSC), and Central Sprinkler Company announced a voluntary replacement program for 35 million Central fire sprinklers with O-ring seals, along with a limited number of O-ring models sold by Gem Sprinkler Company and Star Sprinkler, Inc., totaling about 167,000 sprinkler heads. This recall followed an earlier incident in 1998 when the same company recalled more than 8 million defective sprinkler heads in response to a lawsuit.

In 1999 The Mealane Corporation voluntarily recalled up to 1 million defective sprinkler heads that had been manufactured from 1961 through 1976, which had been installed nationwide, primarily in nursing homes, but were also found in hospitals, schools, resorts, stores, office buildings, warehouses and supermarkets.
http://www.cpsc.gov/CPSCPUB/PUBS/cpsr_nws21.pdf

Microbial contamination and corrosion can disable a sprinkler system, interfering with water delivery and clogging heads. This problem resulted in a sprinkler system failure at a nursing home in Lamoni, Iowa, in 1998. Iowa state fire marshal Roy Marshall reported that examination of healthcare facilities in the state revealed that one-third of all sprinkler systems suffered from some degree of microbial induced corrosion. This problem develops over a period of years, and can be expected to affect other installations as time goes on, particularly in older buildings.
(Sprinkler Age, Vol. 17, No. 9, 1998) http://www.fcia.org/articles/sprinklers.htm

A January, 2000, NFPA report (U.S. Experience with Sprinklers, Kimberly D. Rohr, NFPA Fire Analysis and Research Division, January 2000, ©NFPA, Quincy, MA) concludes that the major factors in unsatisfactory sprinkler performance are poor operational maintenance, partial coverage, antiquated installations and inadvertent disabling. This report stresses the importance of fire protection balance, saying, in part, "Even a well-maintained, complete, appropriate sprinkler system is not a magic wand. It requires the support of a well-considered, integrated design for all the other elements of the building's fire protection." The author concludes, "Unsatisfactory fire protection performance can occur if the building's design does not address all five elements of an integrated system - slowing the growth of fire, automatic detection, automatic suppression, confining the fire, and occupant evacuation."

A total of 3,134 fires were reported to NFPA for the period 1925 to 1969 in which sprinkler performance was deemed unsatisfactory. Of these, 75% were in industrial facilities, 12% were in storage facilities, 5.6% were in stores, and 7.4% were in all other properties. Figure 5 summarizes the causes for these failures.

Figure 5. Groups of Leading Reasons for Unsatisfactory Sprinkler Performance

Problem Group	**% of Cases**	**Problem**	**% of Cases**
A. Failure to maintain operational status of system	53.4	Water shutoff Inadequate maintenance Obstruction to water distribution System frozen	35.4 8.4 8.2 1.4
B. Failure to assure adequacy of system for complete coverage of current hazard	21.6	System not adequate for level of hazard in occupancy System designed for partial protection only	13.5 8.1
C. Defects affecting but not involving sprinkler system	15.9	Inadequate water supply Faulty building construction	9.9 6.0
D. Inadequate performance by sprinkler system itself	5.6	Antiquated system Slow operation of sprinklers Defect dry-pipe valve	2.1 1.8 1.7
E. Other	3.6	Exposure fire Other or unknown	1.7 1.9
Total	100.00		100.00

Source: "Automatic Sprinkler Performance Tables, 1970 Edition, "Fire Journal, July 1970, page 37.

Approximately 15% of commercial building fires in the U.S. are arson related. The NFPA estimates that 75,000 of the structure fires that occurred in the United States in 2000 were of an incendiary or suspicious nature, and these fires took the lives of 505 civilians, and caused an estimated $1,340,000,000 in property damage. (Fire Loss in the U.S., Michael J. Karter, Jr., NFPA, Fire Analysis and Research Division .) Arson is a clearly a serious and deadly problem across the country. An arsonist's objective is to cause damage and destruction, and in most cases it is an easy matter for a perpetrator to disable the sprinkler system before setting a fire. Yet such instances may not be considered or reported as sprinkler failures.

In the NFPA Fire Journal November/December 2001 issue, Stephen G. Bader reported that there were 55 large loss structural fires in the U.S. during 2000 (defined as fires where damage exceeded $5 million). Sprinkler systems were in place in 17 (34%) of these buildings. Of that total, eight sprinkler systems failed to operate, and seven operated but failed to control the fire. Some of these systems were old and antiquated, some were disabled for unknown reasons. In only two of the 55 fire occurrences did suppression systems extinguish or control the fire.

Naturally, passive devices such as air duct dampers and fire doors can also fail due to human error, malfunction or intentional disabling. If a door is improperly blocked, or a wall penetration seal has been disturbed and left un-repaired, fire resistant construction has failed and life safety has been degraded. Both active and fire resistant construction elements must be constantly inspected, maintained and verified in order to maximize life safety.

Unfortunately there are few official safeguards to protect building occupants against lapses in active and fire resistant construction in the U.S. Poor inspection is a systemic problem across the country. A substantial number of sprinkler malfunctions were detected in the city of Chicago during routine fire inspections. Yet after a full year, follow-up inspections confirmed that not one of these sprinkler problems had been rectified.

Data shows that monitoring and maintenance of sprinkler systems is more stringent in countries such as Europe and Japan, and consequently sprinklers have a superior performance record in those areas. "*Estimate of the Operational Reliability of Fire Protection Systems",* R.W. Bukowshi, E.K. Budnick and C.F. Schemel In the U.S., in contrast, sprinkler performance clearly does not match theoretical expectations, and given serious regulatory and maintenance deficiencies across the country, it is not reasonable to rely solely or primarily on sprinkler systems for fire protection.

With expanded height and area standards allowed in the new code along with mandated sprinklers, it will be possible for fires to grow larger, with more combustibles, greater potential for rapid spreading to adjacent areas, and much more difficult conditions for fire fighters. New modified exit corridor standards with longer distances, narrower widths and elimination of passive smoke control further compounds life safety risk. These code compromises are predicated on and will depend absolutely on sprinkler dependability, yet the record shows that this faith is not well founded.

Unacceptable Compromises

There is an international trend away from traditional *prescriptive-based* code development (with firm established standards for rated walls and floors, smoke control, etc.) to *performance-based* codes, which are based on fire hazard analysis with acceptable levels of life loss potential. Unfortunately, the performance-based approach makes provision for creativity, local subjective choice, and identification of loopholes motivated by selective cost reduction opportunities. The comparatively vague and subjective nature of performance-based codes will potentially open the door to unprincipled business and hidden life-safety compromises.

Conclusion

Because of tradeoffs in IBC 2000 and the NFPA 5000 that exchange height and area restrictions and fire resistant construction for increased sprinkler use, we will be building structures in the future with potentially reduced safety levels. Under these new codes, fires will be larger, with increased combustible loads, egress protection will be reduced, and there will be fewer firewalls to restrict fire propagation.

The key issue is not the conflict between active and passive approaches to fire protection, but rather the overriding question of life safety. Practical fire experience clearly demonstrates that realistic design standards and a careful balance of fire protection assets, with responsible inspection and enforcement, will save lives and help control property losses.

Given the small but significant potential for sprinkler system failure (one in six fires), universal deficiencies in inspection and maintenance enforcement, and the serious compromises made in fire resistant construction requirements, the sprinkler trade-offs and the height and area table changes of the IBC/NFPA 5000 should be re-evaluated and revised to reflect the life safety effectiveness of the more conservative provisions in the Uniform Building Code.

The new building code should reflect the experiential regional loss data in hand, and not simply take the least restrictive requirements from each of the parent model building codes based on the unscientific assumption that all codes provided equal protection in the past. If we truly wish to provide a reasonable level of fire and smoke protection for occupants and firefighters in the future, we need a building code that defines a balanced level of protection by integrating the proven elements of detection, suppression, and compartmentation.

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The Author
Richard R. Licht is Technical Director of the **Alliance for Fire and Smoke Containment and Control** (AFSCC), Tarrytown, New York. This organization was established in 1999 by building enforcement, construction, design, and manufacturing professionals in response to the need for a well-coordinated educational effort to promote the value of balanced fire protection design in the built environment. Its members consist of companies, organizations and individuals in the construction industry that share important goals including promoting passive protection as a component of "balanced design" in fire protection; promoting proper protection and public welfare as well as life safety; educating and informing code officials and designers on fire protection issues; promoting fire fighter safety; and, facilitating effective fire fighting efforts. http://www.afscconline.org/

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