Cost/Benefit to Society for Having Sprinklers in One- and Two-Family Dwellings – A Pessimistic Analysis

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The National Fire Sprinkler Association (NFSA), at the request of the NFPA Technical Committee on Residential Occupancies, performed a Cost/Benefit analysis regarding sprinklers for all new one- and two-family dwellings for the development of the 2006 editions of the Life Safety Code (NFPA 101) and the Building Construction and Safety Code (NFPA 5000). The analysis was first submitted with Proposal 101-502 for the 2006 edition of the Life Safety Code. It was criticized by several of the committee members in their negative ballots on that proposal. The analysis was refined to take these concerns into account and resubmitted for the ROC during the public comment phase. The analysis was also presented at the NFPA Fall Meeting in Miami Beach, FL and has been further refined following the comments and suggestions made at that meeting. Through all of these refinements, one conclusion has been constant; fire sprinkler systems are cost effective.

The purpose of this analysis is not to show how well sprinklers perform, nor is the purpose of this analysis to show when residents of sprinklered homes might begin to see a financial benefit to their sprinkler systems. Instead, the purpose of this analysis is to show that even if all of the pessimistic things that opponents of mandatory sprinkler protection predict will come true actually do come true, fire sprinkler systems are still cost-beneficial (as well as life safety beneficial) to society at large.

The NFSA honestly believes that residential fire sprinkler systems will prove to be even more cost-beneficial than this analysis reveals, but wanted to show that even if the opponents of sprinkler systems are correct, a complete program to sprinkler all new homes built in the future will pay off for the general public in less than 40 years.

One of the criticisms to this analysis at the proposal stage for NFPA 101 was that the NFSA stated that its analysis was not "definitive". To that we respond that the information that we have presented is true and accurate. The non-definitive aspects of this analysis are those that would improve the benefits of sprinkler performance, but are difficult to quantify. Since these benefits have not been quantified, they have been eliminated from this analysis. If these intangible items could be clarified, the situation would be even more beneficial to fire sprinklers.

Another of the criticisms was that the data submitted was contradictory. To that, we respond that the data is not contradictory. Many different studies were presented to show the wide range of data and information in existence. In each case, for the cost/benefit analysis, the NFSA chose the most conservative value for input.

For each of the decisions in this cost/benefit analysis, the NFSA has taken the most conservative (non-beneficial to sprinklers) in order to show that fire sprinklers can be cost effective, even if everything our opponents says about them is true. We know that many of these issues are much better and more favorable towards sprinklers, but have attempted to utilize the most conservative approach possible.

The data for this analysis is presented in two tables. Table 1 shows the number of homes (sprinklered and unsprinklered) as well as the fires that would happen in those homes, the numbers of lives that would probably be saved and the numbers of injuries that would probably be prevented. Table 2 shows the values for the savings and adds them up, comparing them to the total costs. The following is a complete description of each of the items in the cost/benefit analysis:

Year – This analysis looks at the costs and benefits to fire sprinkler systems over a 40 year period. The assumptions that go into this analysis are that the homes (with the sprinkler systems in them) are built and paid for on the first day of each year while the sprinkler systems are not put in service until the last day of the year. Therefore, in each year, all of the costs associated with the sprinkler system start with the first year the home is proposed, but the benefits don't begin until the next year. In reality, sprinkler systems will be put in service before the end of the year and the benefits will begin before the end of the year, but this assumption is more conservative.

Number of Sprinklered Homes – The assumption is that all of the 1.9 million homes built in the United States will be sprinklered.

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According to the National Association of Homebuilders, this is the typical number of homes built in each year. While this number starts out as a relatively small percentage of total homes, after 40 years, the number of sprinklered homes grows to approximately 45% of the total housing stock, a substantial number that will have a significant effect on future fire losses. If the analysis were continued out to 50 years, more than 50% of the housing stock would be sprinklered.

Total Number of Homes – The total number of homes (one- and two-family dwellings) has been reported by the National Association of Home Builders (NAHB) at 90 million prior to the start of this analysis. As 1.9 million new homes are built each year, the total number of homes grows at the same rate. The assumption in this analysis is that the new homes built are not replacements for existing homes.

Number of Fires in Sprinklered Homes – This variable is almost a ratio of the number of sprinklered homes to the total number of homes. The NFPA fire incident data has shown that the number of fires each year in one- and two-family dwellings has averaged 300,000 fires per year fairly consistently. The NFSA believes that the number of fires in sprinklered homes should be a direct proportion of the number of sprinklered homes. However, the NAHB has contended that new homes are safer than older homes (a statement they have never been able to justify). Never-the-less, this analysis will agree with the NAHB position and state that fires are 50% less likely to occur in homes that are 10 years old or less. For the first 10 years of this analysis, the number of fires in sprinklered homes is calculated by taking the ratio of sprinklered homes to the total housing stock, multiplying by the number of fires (300,000) and then dividing that number in half. Starting with the 11th year of the analysis, the homes that are at least 10 years old experience fires as a direct ratio to the housing stock, while the homes that are not yet 10 years old continue at the reduced rate.

Number of Fires in Unsprinklered Homes – Since fire sprinklers do not actually prevent the fire from occurring, the total number of fires still has to add up to 300,000. So, the total number of fires in unsprinklered properties each year is equal to 300,000 minus the number of fires in sprinklered homes.

Number of Lives Saved – According to NFPA fire data, there is approximately 1 death for every 100 fires and this figure has remained relatively constant for many years. The number of potential lives that would be lost in sprinklered buildings is then a straight ratio of the number of fires that occur in sprinklered buildings. The NFSA has never stated that fire sprinklers will save 100% of the people who die due to a fire. Estimates of sprinkler effectiveness have ranged from 63% to 99% by different sources. The 63% effectiveness estimate (the lowest of any estimate) was made by NIST on a theoretical analysis (prior to the widespread installation of residential sprinklers) of the kind of deaths that occur in fires and the theoretical performance of what residential sprinklers might be able to do. We know now, with more than 20 years of experience, that the NIST study was extraordinarily conservative. For example, the NIST study states that no person that is intimate with ignition will ever be saved by a fire sprinkler. In reality, there have been a significant number of fires in sprinklered homes where people have been intimate with ignition and have been saved by the sprinklers and there has only been one reported situation where a person in a sprinklered home was intimate with ignition and died (an older home sprinklered with standard response sprinklers). There are many people walking around today who were intimate with ignition and a fire sprinkler saved their life, in direct opposition to the NIST estimate. Even knowing that the NIST estimate is needlessly conservative, we have used 63% as an estimate of the number of lives that will be saved by the sprinkler systems. Note that this analysis only looks at civilian deaths and does not take into account fire fighter fatalities.

Number of Injuries Prevented – The NFPA estimates that there are 4.3 injuries per every 100 fires that occur in one and two family dwellings. The number of injuries that could happen in sprinklered buildings would be expected to be proportional to the number of fires that occur in sprinklered homes. Similar to the number of lives saved, the number of injuries that can be prevented by fire sprinklers has been estimated between 44% and 99%. Once again, the worst estimate comes from the NIST study that was performed as a theoretical analysis prior to residential sprinkler systems actually being installed. Even though we disagree with

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this low percentage, we will use this value in our analysis. Note that this analysis only takes into account civilian injuries and does not take into account fire fighter injuries.

Value of Lives Saved – While the value of a human life is constantly debated, the NFSA has used $2 million in this analysis. The $2 million per life saved has been utilized by three independent sources as the average value of a human life. The first source has been settlements from large loss fires (some of these fires happened over 20 years ago, so the present value of those settlements might be more than $2 million per life in 2005 dollars). The second source is the Federal Government for sponsoring cancer research (if the cost of the research per life saved is $2 million or less, the government will fund the research). And the third source is the 9-11 commission that paid families after the events of September 11, 2001. The commission awarded an average of a little over $2 million for each life lost during that tragic day. In comparison, Dr. Hall of the NFPA has stated in correspondence with the NFSA that he uses a figure of $5 million per life saved in his experience when trying to determine the value of a human life.

Value of Injuries – The most difficult variable to quantify in this analysis has been the dollar value of an injury. First, in order to qualify as an injury, the person has to have been hospitalized (this definition of an injury is consistent with NFPA and NFIRS definitions, injuries that do not require hospitalization also occur during fires and cost the public in lost wages, medical bills and reduced productivity as well as reduced quality of life, but those injuries are not accounted for in this study). With hospital costs continuously rising, keeping this analysis constant over 50 years is extremely conservative. The value of $30,000 per injury was taken from an OSHA website as the average of the kind of injuries that occur in a fire. However, burn injuries are extremely expensive as multiple surgeries for skin grafts are frequently needed. It is quite possible that fire sprinklers can save many times what is estimated in this analysis. For comparison, Dr. Hall at the NFPA has stated in correspondence with the NFSA that he uses more than $200,000 per injury in his experience.

Value of Property Saved – This value comes directly from fire department reports and compares the average loss in a fire in an unsprinklered building ($17,000) to the average loss in a fire in a sprinklered building ($1900). Note that fire departments only estimate the direct property loss (value of building and value of items that burned).

Value of Indirect Savings – As stated above, the property saved only deals with the value of the building and the value of the items that burned. What also needs to be taken into account is the value of the goods and services that need to be used while a person's home is being rebuilt after a fire. The Red Cross provides temporary housing on

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Table 1 - Numbers of Homes (Sprinklered and Unsprinklered) Fires, Lives Saved, and Injuries Prevented

Year	# of Spr. Homes (Millions)	# of Total Homes (Millions)	# of Fires Sprinklered Homes	# of Fires Unsprinklered Homes	# of Lives Saved	# Injuries Prevented
1	0	90.0	0	300,000	0	0
2	1.9	91.9	3,101	296,899	20	59
3	3.8	93.8	6,077	293,923	38	115
4	5.7	95.7	8,934	291,066	56	169
5	7.6	97.6	11,680	288,320	74	221
6	9.5	99.5	14,322	285,678	90	271
7	11.4	101.4	16,864	283,136	106	319
8	13.3	103.3	19,313	280,687	122	365
9	15.2	105.2	21,673	278,327	137	410
10	17.1	107.1	23,950	276,050	151	453
11	19	109.0	28,761	271,239	181	544
12	20.9	110.9	33,408	266,592	210	632
13	22.8	112.8	37,899	262,101	239	717
14	24.7	114.7	42,241	257,759	266	799
15	26.6	116.6	46,441	253,559	293	879
16	28.5	118.5	50,506	249,494	318	956
17	30.4	120.4	54,444	245,556	343	1030
18	32.3	122.3	58,258	241,742	367	1102
19	34.2	124.2	61,957	238,043	390	1172
20	36.1	126.1	65,543	234,457	413	1240
21	38	128.0	69,023	230,977	435	1306
22	39.9	129.9	72,402	227,598	456	1370
23	41.8	131.8	75,683	224,317	477	1432
24	43.7	133.7	78,871	221,129	497	1492
25	45.6	135.6	81,969	218,031	516	1551
26	47.5	137.5	84,982	215,018	535	1608
27	49.4	139.4	87,912	212,088	554	1663
28	51.3	141.3	90,764	209,236	572	1717
29	53.2	143.2	93,541	206,459	589	1770
30	55.1	145.1	96,244	203,756	606	1821
31	57	147.0	98,878	201,122	623	1871
32	58.9	148.9	101,444	198,556	639	1919
33	60.8	150.8	103,946	196,054	655	1967
34	62.7	152.7	106,385	193,615	670	2013
35	64.6	154.6	108,765	191,235	685	2058
36	66.5	156.5	111,086	188,914	700	2102
37	68.4	158.4	113,352	186,648	714	2145
38	70.3	160.3	115,565	184,435	728	2186
39	72.2	162.2	117,725	182,275	742	2227
40	74.1	164.1	119,835	180,165	755	2267

Table 2 - Cost/Benefit to Society for Having Sprinklers in One- and Two-Family Dwellings - A Pessimistic View

Year	Value of lives saved ($Mil)	Value of no injuries ($Mil)	Value of saved property ($Mil)	Value of Indirect ($Mil)	Value of Insurance ($Mil)	Value of Const. Sav. ($Mil)	Value of FD on scene ($Mil)	Income Tax Savings ($Mil)	Savings of Sprinklers ($Billions)	Cost of Sprinklers ($Billions)	Net Cost 0.0 ($Billions)	Cumulative Net Cost ($Billions)
1	0.0	0.0	0.0	0.0	0.0	2375.0	0.0	94.2	2.5	1.6	-0.9	-0.9
2	39.1	1.8	46.8	14.0	142.5	2375.0	27.9	188.4	2.8	2.2	-0.6	-1.5
3	76.6	3.4	91.8	27.3	285.0	2375.0	54.7	282.6	3.2	2.8	-0.4	-1.9
4	112.6	5.1	134.9	40.2	427.5	2375.0	80.4	376.8	3.6	3.4	-0.1	-2.0
5	147.2	6.6	176.4	52.6	570.0	2375.0	105.1	471.0	3.9	4.1	0.2	-1.9
6	180.5	8.1	216.3	64.4	712.5	2375.0	128.9	565.2	4.3	4.7	0.4	-1.5
7	212.5	9.6	254.6	75.9	855.0	2375.0	151.8	659.4	4.6	5.3	0.7	-0.8
8	243.3	11.0	291.6	86.9	997.5	2375.0	173.8	753.6	4.9	5.9	1.0	0.2
9	273.1	12.3	327.3	97.5	1140.0	2375.0	195.1	847.8	5.3	6.5	1.3	1.5
10	301.8	13.6	361.6	107.8	1282.5	2375.0	215.5	942.0	5.6	7.2	1.6	3.1
11	362.4	16.3	434.3	129.4	1425.0	2375.0	258.9	1036.2	6.0	7.8	1.7	4.8
12	420.9	19.0	504.5	150.3	1567.5	2375.0	300.7	1130.4	6.5	8.4	1.9	6.7
13	477.5	21.5	572.3	170.5	1710.0	2375.0	341.1	1224.6	6.9	9.0	2.1	8.9
14	532.2	24.0	637.8	190.1	1852.5	2375.0	380.2	1318.8	7.3	9.6	2.3	11.2
15	585.2	26.4	701.3	209.0	1995.0	2375.0	418.0	1318.8	7.6	10.3	2.6	13.8
16	636.4	28.7	762.6	227.3	2137.5	2375.0	454.6	1318.8	7.9	10.3	2.3	16.2
17	686.0	30.9	822.1	245.0	2280.0	2375.0	490.0	1318.8	8.2	10.3	2.0	18.2
18	734.1	33.1	879.7	262.2	2422.5	2375.0	524.3	1318.8	8.5	10.3	1.7	19.9
19	780.7	35.2	935.5	278.8	2565.0	2375.0	557.6	1318.8	8.8	10.3	1.4	21.3
20	825.8	37.2	989.7	294.9	2707.5	2375.0	589.9	1318.8	9.1	10.3	1.1	22.5
21	869.7	39.2	1042.3	310.6	2850.0	2375.0	621.2	1318.8	9.4	10.3	0.8	23.3
22	912.3	41.1	1093.3	325.8	2992.5	2375.0	651.6	1318.8	9.7	10.3	0.6	23.9
23	953.6	43.0	1142.8	340.6	3135.0	2375.0	681.1	1318.8	10.0	10.3	0.3	24.1
24	993.8	44.8	1190.9	354.9	3277.5	2375.0	709.8	1318.8	10.3	10.3	0.0	24.1
25	1032.8	46.5	1237.7	368.9	3420.0	2375.0	737.7	1318.8	10.5	10.3	-0.3	23.9
26	1070.8	48.2	1283.2	382.4	3562.5	2375.0	764.8	1318.8	10.8	10.3	-0.5	23.3
27	1107.7	49.9	1327.5	395.6	3705.0	2375.0	791.2	1318.8	11.1	10.3	-0.8	22.5
28	1143.6	51.5	1370.5	408.4	3847.5	2375.0	816.9	1318.8	11.3	10.3	-1.1	21.5
29	1178.6	53.1	1412.5	420.9	3990.0	2375.0	841.9	1318.8	11.6	10.3	-1.3	20.2
30	1212.7	54.6	1453.3	433.1	4132.5	2375.0	866.2	1318.8	11.8	10.3	-1.6	18.6
31	1245.9	56.1	1493.1	444.9	4275.0	2375.0	889.9	1318.8	12.1	10.3	-1.8	16.8
32	1278.2	57.6	1531.8	456.5	4417.5	2375.0	913.0	1318.8	12.3	10.3	-2.1	14.7
33	1309.7	59.0	1569.6	467.8	4560.0	2375.0	935.5	1318.8	12.6	10.3	-2.3	12.4
34	1340.5	60.4	1606.4	478.7	4702.5	2375.0	957.5	1318.8	12.8	10.3	-2.6	9.8
35	1370.4	61.7	1642.3	489.4	4845.0	2375.0	978.9	1318.8	13.1	10.3	-2.8	7.0
36	1399.7	63.1	1677.4	499.9	4987.5	2375.0	999.8	1318.8	13.3	10.3	-3.1	3.9
37	1428.2	64.3	1711.6	510.1	5130.0	2375.0	1020.2	1318.8	13.6	10.3	-3.3	0.6
38	1456.1	65.6	1745.0	520.0	5272.5	2375.0	1040.1	1318.8	13.8	10.3	-3.5	-2.9
39	1483.3	66.8	1777.6	529.8	5415.0	2375.0	1059.5	1318.8	14.0	10.3	-3.8	-6.6
40	1509.9	68.0	1809.5	539.3	5557.5	2375.0	1078.5	1318.8	14.3	10.3	-4.0	-10.6

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a short term basis (which needs to be paid for) then people may need to stay in alternative housing for a longer period of time while their home is rebuilt. All kinds of other indirect losses build up including longer commutes to work/school from alternate locations and replacement costs for items exceeding costs covered by insurance. The value of indirect losses that can be saved by sprinklers is estimated as $5000 per fire and is only taken for 90% of the fires, again in recognition that in some small percentage of fires, sprinklers might not be so effective.

Value of Insurance Savings – The NFSA received some criticism of the value used in the ROP in this column. Even though we stand behind the value used in the ROP, we have lowered the value used in this analysis to $75 per home per year. Actual discounts for fire sprinkler systems vary by insurance companies between 8% and 15%. If the average homeowner's policy is $750 per year and the average savings is 10%, the average savings of $75 per year is extremely defendable, and most definitely lower than actual experience.

Value of Construction Savings – The NFSA also received some criticism for the value we estimated that builders could take advantage of regarding construction savings. While it is true that there are limited construction savings in the Life Safety Code, it is also true that there are many opportunities for builders to take advantage of zoning and site development incentives to reduce the total cost of construction and to increase their profit while installing fire sprinklers. This analysis assumes that half of the homes built each year will not be able to find any savings. The other half will only save an average of $2500 per home, an incredibly low number considering the tremendous power of zoning and site development incentives. Such incentives include the savings of the infrastructure including the downsizing of underground mains and the separation of fire hydrants. In previous issues of Sprinkler Quarterly, an example showed how site development incentives could save over $12,000 per home in a small development with only six houses. This is a powerful example of how easy it should be to meet this target of averaging $2500 in savings per home for only half of the homes built.

Value of Fire Department On-Scene – Where fires occur in sprinklered buildings, fewer man-hours are spent fighting the fire. As such, fire fighters are freed up to handle other tasks necessary of the fire department without having to employ additional personnel. Also included in this category are the savings in materials used to fight a fire such as fuel for fire trucks, which are left running during a fire event, and water, which costs the utility money to clean and make available at the hydrant. Fires in buildings with sprinkler systems use thousands of gallons of water less than fires that occur in unsprinklered property. The value that we have used in this analysis of $10,000 per fire is extremely conservative given the value of labor, the number of fire fighters necessary to fight house fires and the value of materials like fuel and water. In addition, we have accounted for the fact that some sprinkler systems may not work and will therefore not save the fire department any money. The savings have only been taken for 90% of the fires that occur in sprinklered buildings.

Income Tax Savings – The increase to the cost of the building for the fire sprinkler system is rolled into the cost of the mortgage. The interest on the mortgage is tax deductible at the income tax rate of the individual paying the mortgage. See the "Cost" section of this analysis for the exact details of the mortgage assumptions. The tax bracket in this analysis is 28%. In addition, the amount of interest is assumed to be constant from year to year, the number that has been used is the average amount of interest across all 30 years of the mortgage. This assumption is extremely conservative given the fact that all mortgage lenders "front-end load" their mortgages so that the interest is substantially more in the first years of the mortgage rather than in the last years. In reality, the interest paid at the beginning of the mortgage is much more than the average, which would only improve the tax savings presented in this column in real life.

Savings of Sprinklers – The total of all of the savings columns for each year.

Cost of Sprinkler Systems – The average home is 2500 sq ft according to the NAHB. Sprinkler systems average less than $2.00 per sq ft, but we will use $2.00 per sq ft in this analysis, or $5,000 per home. However, people don't pay cash for homes. Instead, the home is financed over a period of time. This analysis is based on someone putting 10% of the cost of the home down and financing the rest over a 30 year period. The sprinkler system is expected to be a proportional amount of that down payment and monthly mortgage bill. In addition, this analysis assumes that people don't hang onto their homes for 30 years. Instead this analysis assumes that after 15 years, the person has sold their home at a profit and paid off the original mortgage. The new buyer does not pay specifically for the sprinkler system in the existing house since it is rolled into the general value of the property. The assumption that people will stay in their homes for 15 years is extremely conservative given that there are current studies that show that the average homeowner moves once every 5 years.

Net Cost – The total cost of the sprinkler systems minus the savings for each year.

Cumulative Net Cost– The net cost added from year to year to show that the total money spent on sprinkler systems is recouped by a community over time (approximately 38 years).

Another criticism that the NFSA has received regarding this analysis is that there is no cost associated with the maintenance of the sprinkler system. To that we respond that the sprinkler system in a one- or two-family dwelling does not need the same level of scrutiny that the sprinkler system in a commercial property needs. The maintenance items are more a function of what not to do to the system. As long as somebody does not paint the sprinklers, hang items from the sprinklers or close the control valve, there is nothing extra that needs to be done for maintenance. Since there isn't a cost associated with NOT doing things to a system, there is no cost in this analysis.

Finally, the NFSA has received some criticism of the fact that we have not included

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any factor for inflation in this analysis. To that we reply that the main focus of this exercise has been to calculate the costs and the benefits for each year and to determine which is higher in any given year. If we were to apply a correction factor for inflation, it would be applied to both the costs and the benefits equally for each year, which would not change the final outcome of assessing which number was higher. While the correction factor for inflation might have some small effect on the cumulative net cost, it would appear to be a variable that adds a layer of complexity without providing any significant additional information. In the long run, the analysis shows that the sprinkler systems have more benefits than costs. Any consistent application of a correction factor would still provide the same result, just with a slightly different order of magnitude.

Analysis

Once all of the variables have been defined, it is time to start putting numbers into each column for each year (see Table 1 and Table 2). It is interesting to note that the first seven years of the analysis show a negative Cumulative Net Cost (meaning that society is making money right from the start) but that this number turns positive from years 8 to 37. This is because of the numbers of people paying their mortgages. Consider the first year, only the people that purchased homes with sprinkler systems in this year are paying mortgages that include sprinkler systems. In the second year, there are two sets of people paying mortgages that include sprinkler systems, those that purchased a home in year 1 and those that purchased a home in year 2. This situation continues to grow until year 15, when people start selling their homes.

The Cumulative Net Cost column peaks at year 25 with a total cost of $23.9 billion spent putting sprinkler systems into homes. But that money is recouped by year 38 and people begin to make money on the fact that sprinklers are installed. By year 40, society makes a total of $10.6 billion because sprinklers are installed. If the analysis were continued to include additional years, the amount of money made by society would continue to climb. By year 50, society would be making a profit of $6.2 billion per year for a total cumulative profit of $62.8 billion.

Conclusion

Fire sprinkler systems are worth the money that is paid for them. Even using the pessimistic assumptions of the opponents to sprinkler requirements, it can be shown that sprinklers are cost effective. In less than 40 years, the value of the sprinkler systems can be returned to the general public that paid for them

In addition, placing sprinklers in all residential homes will significantly save lives. Using the pessimistic analysis here, hundreds of lives will be saved each year and tens of thousands will be saved over the 40 year period of the study. Using more realistic data on the effectiveness of sprinklers, the total number of lives saved is impressive.