# FIRE PERFORMANCE OF TRUSSES

# REFERENCE GUIDE

by

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## Summary of the Purpose and Goals of this Fire Presentation

The purpose of this presentation is to succinctly provide the following concepts:

- Metal plate connected wood truss (truss) construction represents the future in residential and commercial construction, and engineered wood products are here to stay.

- The building code does not require truss construction to be protected in many occupancy types. When any construction is left unprotected, it is subject to collapsing earlier than expected and with less warning. All unprotected construction is dangerous to the fire service.

- Providing a single layer of gypsum protection to any unprotected floor system will significantly enhance that structural system's fire performance.

- The use of sprinkler systems have a proven record of fire containment and extinguishment when properly installed and maintained.

- Pre-fire planning and actual fire ground training are very important in dealing with the destructive power of fire and protecting fire fighter lives. Just as tactics have to change when fighting high rise fires and again for light steel structure fires, new engineered wood products will require different fire ground tactics to meet this fire challenge.

- We also need help from the fire service. The fire problem with trusses is not well defined. We need clear and very detailed examples of situations where trusses have performed poorly in fire ground situations. We also need examples of situations where trusses have performed well. Using both scenarios, we can learn more about how to make the fire ground safer for firefighters.

- As an industry, our goal is to supply an environmentally sensitive, affordable, and safe construction product that also meets the public's expectations for fire safety. We are certain this is achievable, but it is only achievable if we are willing to work together.

## Key Presentation Concepts Expanded Upon

### Change is Taking Place in the Construction Industry—Be Prepared

One of the overriding purposes of this presentation is to reflect the change that is going on in all facets of society and particularly in the construction industry.

Changes are taking place in all professions, even the fire service:

> In the US, *Fire Engineering Magazine* states that there are significant changes taking place within the fire service. Both staffing levels and budgets that fire departments have to operate with are reducing. This is going to require fire departments to operate more efficiently, employ techniques like pre-fire planning, and become better educated on

each of the many construction related fire ground changes taking place, to reduce the risks that go with the job.

The construction industry is also undergoing change, because the North American public's focus is on social and environmental responsibility. This means that we must use our precious natural resources wisely. In the spirit of change, the forest products industry has implemented the design, development and use of a new generation of structural wood products that have an engineering foundation.

Change is never easy for any industry, and this industry has overcome much resistance to the use of engineering principles to produce a new generation of products whose time is arriving. There is no turning the clock back; engineered products are the products of the future. Society is demanding that we make this change.

The results of this demand are products like trusses, I-joists and laminated veneer lumber. These products have evolved with the design in mind to efficiently utilize wood fiber, resulting in less cutting and less waste of the trees needed to manufacture them. A product that embodies the true spirit of this evolution toward wood fiber conservation is the truss.

It is important think about the following concepts:

- Wood is the only renewable building material.
- Wood is going to become more valuable.
- trusses reflect this value and optimize the use of wood.
- truss industry growth is demanded by the public

  The truss industry, begun in the early 50's, is a very important high growth segment of the forest products industry. An industry estimate is that about $4 billion worth of trusses were produced in 1995. This leads to jobs directly within the truss industry and for countless others that work with building products or are in the building trades that sell, distribute or use these products.

  The public is demanding engineered wood products like trusses. Given this, these products represent the future in residential and commercial construction.

**Why Develop and Use a Truss?**

Being environmentally responsible also means utilizing our raw materials as efficiently as we can. Trusses are engineered to use our forest resources efficiently.

The key to understanding a truss is its shape. Wood fiber is used only where its strength is needed and all the wood is connected together with high strength metal connector plates. Using wood and truss engineering design principals, strength and performance are designed into each truss that is manufactured.

This wood re-combination process randomizes the strength-reducing characteristics, like knots, that the natural lumber has. This process produces a product that is stronger than the original wood. Equally as important, though, is that re-creation produces a product with more consistent design properties than the raw material that it comes from.

**Key Concepts on the use of Unprotected Assemblies**

The building code allows construction of buildings of every type to use floor-ceiling or roof-ceiling assemblies where the structural elements are directly exposed to a potential fire. This means that in many buildings, the structural floor or roof system is not protected by any kind of fire-rated membrane or coating, or by sprinklers. The fire resistance is strictly the resistance of the structural member itself. The code recognizes the increased possibility of greater fire damage in this unprotected construction, by restricting the size of the building.

As examples are the following:

- Type 5 Construction
  - Made of any structural framing material, steel, wood, concrete, masonry.
  - All structural elements can be left unprotected except shaft enclosures must be one hour rated.
  - In R-1 construction (hotels, apartments that house more than 10 persons) the allowable area for an unprotected structure is 6,000 sq. ft and 40 ft high.
  - In R-1 construction the allowable area increases to 10,500 sq. ft. and 50 ft. high when 1 hour protection is applied.
- Type 3 Construction
  - Non-combustible fire resistive walls must be used with any structural framing.
  - All structural elements can be left unprotected except shaft enclosures must be 1 hr. rated and exterior walls must be 4 hr. rated.
  - In R-1 construction the allowable area for an unprotected structure is 9,100 sq. ft and 55 ft high.
  - In R-1 construction the allowable area increases to 13,500 sq. ft. and 65 ft. high when 1 hour protection is applied.

As greater protection is installed using sprinklers, larger building areas and greater building heights can be used.

**Very little testing has been performed on assemblies that contain structural elements that are not protected, since the code does not require these types of assemblies to be fire rated. Consequently, pre-fire planning is very important where buildings contain unprotected**

**structural assemblies. Knowing that the structural element has no fire protection, and not knowing the fire intensity nor how long it has been burning, is reason enough that no one should risk walking on this type of floor or roof. If one has to be inside unprotected structures for any reason, it must be recognized as extremely dangerous and appropriate precautions should be taken.**

Testing performed, using a standardized test procedure, on unprotected steel joist, wood truss, and solid wood joist assemblies has shown that times to failure range from 4 - 6 minutes for the steel products to 6 - 13 minutes for the wood products, which is not very much time. These times were derived from assemblies tested under full design load, using severe fire conditions. A summary of this testing can be found in the National Fire Protection Research Foundation report entitled, *National Engineered Lightweight Construction Fire Research Project.*

| Test | Structural Member | Spacing | Assemb. Rating (min:sec) | Structural Failure (min:sec) | Avg. Defl. at Floor (in.) | Loading (psf) - % Design Stress | Comments |
|---|---|---|---|---|---|---|---|
| FM FC 209 | 2 x 10; 23/32"ply. w/vnl[5] | 24 in. o.c. | N/A | 13:34 | 2.83 | 62.1 (100%) | ASTM E119 |
| FM FC 212 | 2 x 10 ;23/32"ply. w/cpt[5] | 24 in. o.c. | N/A | 12:06 | 3.58 | 62.4 (100%) | ASTM E119 |
| NBS 421346 (2) | 2 x 10; 2-½" ply. | 16 in. o.c. | N/A | 11:38 | 2.7 | 63.7 (100%) | ASTM E119 |
| NBS 421346 (4) | 2 x 10; 2-½" ply. w/cpt.[5] | 16 in. o.c. | N/A | 11:38 | 3.3 | 63.7 (100%) | ASTM E119 |
| NBS 421346 (9) | 2 x 8; ½ in. ply. w/blk[5] | 16 in. o.c. | 10:00 | 13:00 | 7.0 | 21.0[1] (40%) | ASTM E119 |
| NBS 421346 (10) | 2 x 8; 5/8 in. ply. T&G[5] | 16 in. o.c. | 9:00 | 13:00 | 12.0 | 21.0[1] (40%) | ASTM E119 |
| FPL | 2 x 10 | 16 in. o.c. | N/A | 6:30 | 4.0 | 79.2[6] (100%) | ASTM E119 |
| FPL | 2 x 10 | 16 in. o.c. | N/A | 13:06 | N/A | 40.0[1] | ASTM E119 |
| FPL | 2 x 10 | 16 in. o.c. | N/A | 17:54 | 1.7 | 11.35[1] | ASTM E119 |
| FM FC 250 | 12 in. MPCT[7] | 24 in. o.c. | 7:30 | 10:12 | 11.5 | 60.0 (100%) | ASTM E119 |
| NFPA Tech Report 1 | 4 x 14 Wood Beam | 3 ft. 7 in. o.c. | N/A | > 13:00[2] | 0.5 | 30.0[1] | ASTM E119 |
| NFPA Tech Report 1 | 14 in. Steel bar joist | 3 ft. 7 in. o.c. | N/A | 13:00[2] | 18.0 | 30.0[1] | ASTM E119 |
| FM FC 208 | 7¼ in. Steel C-joist | 24 in. o.c. | 7:24 | 7:30 | 7.0 | 69.8 (100%) | ASTM E119 |
| FM FC 211 | 7¼ in. Steel C-joist | 24 in. o.c. | 5:12 | 5:12 | 10.0 | 69.8 (100%) | ASTM E119 |
| NBSIR 73-141 | 6 x 1¾ in. C-joist | 24 in. o.c. | 3:15 | 3:45 | N/A | 51.4[1] | ASTM E119 |
| NBSIR 73-164 | 6 x 3 in. 14 ga C-joist | 48 in. o.c. | 8:45 | 9:00 | N/A | 40.0[1] | ASTM E119 |
| NFPA Tech Report 3 | 7 x 21 Wood Beam | Sngl. Elmt. | N/A | > 30:00[3] | 2.25 | 30.0[1] | ASTM E119 |
| NFPA Tech Report 3 | 16 WF 40 Steel Beam | Sngl. Elmt. | N/A | 30:00[3] | 35.5 | 30.0[1] | ASTM E119 |
| NIWT (1) | 11.5 X 9.3 in. Beam | 5 PC. Beam | N/A | 55:00 | N/A | 7,374 ft.-lbs. | ISO 834 TPSB[7] |
| NIWT (2) | 11.5 x 10.8 in. Beam | 6 PC. Beam | N/A | > 60:00 | N/A | 7,674 ft.-lbs. | ISO 834 TPSB[7] |
| NIWT (3) | 3.77 x 7.79 in. Beam | 2 PC. Beam | N/A | 20:00 | N/A | 2,957 ft.-lbs. | ISO 834 TPSB[7] |
| NIWT (4) | 5.66 x 9.3 in. Beam | 3 PC. Beam | N/A | 50:00 | N/A | 4,435 ft.-lbs. | ISO 834 TPSB[7] |
| BMS 92 | 2 x 10 | 16 in. o.c. | 15:00 | N/A | N/A | N/A | 1000 psi mx.$F_b$ ASA A2-1934[7] |
| IITRI J6397 | 12 in. Steel Bar Joist | Sngl. Elmt. | N/A | 10:06 | N/A | dead ld | FMRC Test F;1100°=Fail.[4] |

1 Assumed to be a limited load test. Loading not 100% of design load.
2 1/2 in. deflection of wood; 18 in. deflection for steel; 80% of wood undamaged.
3 2.25 in. deflection for wood beam at 30 min.; collapse of steel at 30 min.; 76% of wood undamaged.
4 Time bottom chord reached 100° F is assumed to be failure.
5 vnl = vinyl covering; cpt = carpet covering; blk = 1 x 3 end blocking; T&G = tongue-and-groove.
6 Whether or not this test was at full design load or greater than full design load has been questioned. The structural failure time listed may not be correct.
7 MPCT = Metal Plate Connected Truss; $F_b$ = fiber bending stress; TPSB = Truss Plate Spliced Beam.

| Test | Structural Member | Spacing | Assemb. Rating (min:sec) | Structural Failure (min:sec) | Avg. Defl. at Floor (in.) | Loading (psf) - % Design Stress |
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| FPL | 2 x 10 | 16 in. o.c. | N/A | 6:30 | 4.0 | 79.2[2] (100%) |
| FM FC 250 | 12 in. MPCT[1] | 24 in. o.c. | 7:30 | 10:12 | 11.5 | 60.0 (100%) |
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| FM FC 211 | 7¼ in. Steel C-joist | 24 in. o.c. | 5:12 | 5:12 | 10.0 | 69.8 (100%) |

1 MPCT = Metal Plate Connected Truss; MPSWT = Metal Plate Steel Web Truss; TJL = Truss Joist L-Series Truss; TPSB = Truss Plate Spliced Beam; $F_b$ = fiber bending stress.

2 Whether or not this test was at full design load or greater than full design load has been questioned. The structural failure time listed may not be correct.

*Table 1. ASTM E119 Unsheathed Assembly Tests at Full Design Load.*

Fortunately, "real life" structures are only loaded to about 25% of full design load, which provides an additional load-carrying margin of safety for a structure under fire.

Test fires are also much different than actual fires. In actual fire scenarios there are never two fires that burn in an identical manner. There will always be different contents, fire origin, fire paths and combinations of building materials. To compare structural member performance under these conditions is very difficult at best, and can lead to poor conclusions about the actual fire performance of the structural member.

A given fire scenario may lead to the appearance that the floor system collapsed suddenly, even though it had been on fire quite some time and still was showing no significant deflection because it was not heavily loaded. Given this, it is probably not wise to use deflection or sponginess as a predictor of imminent collapse for any structural system. There are too many "real life" variables that cause this to be a misleading and very dangerous indicator. The best possible approach to safe fire analysis is knowing the type of structure you are dealing with, the fire protection systems in use, and the contents involved in the fire, through the use of comprehensive pre-fire planning. Without this information a proper assessment is not possible.

The path to destruction is to rely on warning signs that the strength of the floor or roof has deteriorated to the point that it will no longer support any load. By the time one determines this, it is often much too late.

It is safe to say that all unprotected systems are vulnerable to unexpected failure or collapse, depending on the specific fire conditions at the fire scene.

## Protected Assemblies

### *1- hour Rated Assemblies*

Fire endurance testing must be performed on floor and wall assemblies where the building code requires use of 1-hour and 2-hour rated assemblies. This testing is performed following the ASTM E-119, ANSI/UL 263 or NFPA 251(all are the same) test method.

The National Fire Protection Research Foundation report entitled "National Engineered Lightweight Construction Fire Research Project" has this to say on the subject of ASTM E-119 testing:

> ASTM E119, "Standard Methods of Fire Tests for Building Construction and Materials," is the primary standard used to measure the fire performance of floor/ceiling, roof/ceiling, and wall assemblies and columns, and is the test recognized and accepted by most building codes. The key elements of the ASTM E119 test are[1]:
>
> - Each test follows the ASTM E119 standard time/temperature curve.

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[1] **ASTM Fire Test Standards**, sponsored by ASTM Committee E 5 on Fire Standards, 2nd Edition, 1988, pp. 43-69

- The assembly to be tested is fully instrumented with at least 9 thermocouples, which in the case of roofs, floors and walls are located on the unexposed surface of the specimen. The instrumented locations are specified to provide measurement of thermal transmission through the assembly. This is one of three criteria used to determine the assembly's fire resistance rating.
- The test specimen is intended to represent the construction for which classification is desired. Each specimen is conditioned prior to testing so that its temperature and moisture content is representative of the assembly in its actual environment.
- The area of the assembly exposed to fire is defined. The area for walls and partitions shall not be less than 100 $ft.^2$, and the area for floors and roofs shall not be less than 180 $ft.^2$.
- The load applied to the test specimen shall be a constant superimposed load that, unless specified by the sponsor, applies the maximum allowable design stresses pursuant to recognized structural design criteria.
- The conditions of acceptance for a particular assembly classification are:
  - The specimen shall sustain the applied design load for the duration of the test.
  - At no time during the test duration shall cotton waste be ignited while placed over the unexposed surface.
  - The average temperature rise on the unexposed surface shall not increase more than 250° F (139° C) above its ambient temperature.
  - The temperature at any single thermocouple shall not rise more than 325° F (181° C) above the initial temperature.
  - For steel structural members, the temperature of the steel shall not exceed 1300° F at any location during the classification period.
  - The average temperature on the steel specimens shall at no time exceed 1100° F.
  - In concrete specimens with tension steel, the temperature shall not exceed 800° F for cold-drawn pre-stressing steel, or 1100° F for reinforcing steel.
  - In wall assemblies, the test specimen is also subject to a hose stream test. For 1-1-hour assemblies, the water is applied at 30 psi for one minute to simulate specimen stability under suppression activities.
- The rating periods are typically expressed in terms of time, i.e. 45 min., 1-hour, 2-hour, etc.

A figure that shows the severity of the ASTM E119 time/temperature in terms of material properties has been prepared and is shown in Figure 1.

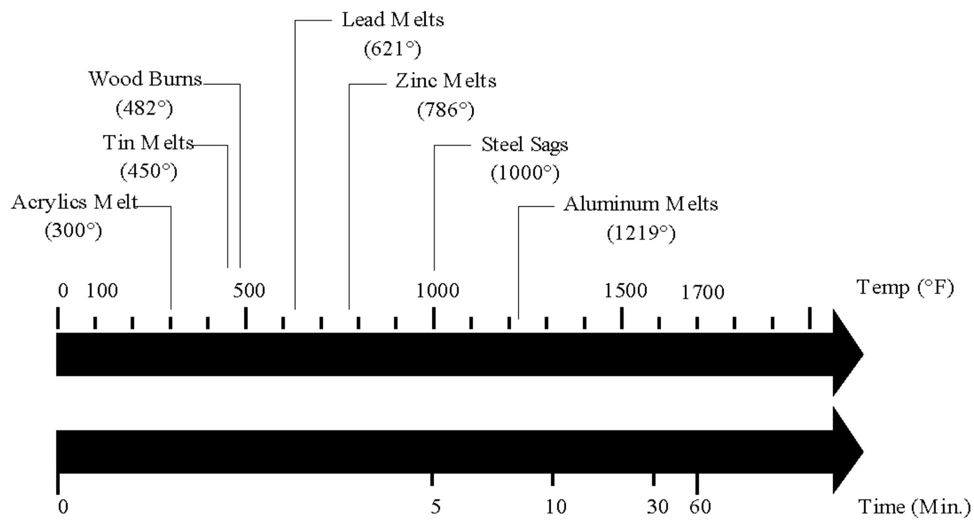


*Figure 1. ASTM E119 Standard Fire Exposure* [2]

Small-scale tests are often performed using the ASTM E119 time/temperature curve to evaluate the performance of a combination of materials prior to testing in the large-scale furnace. In some cases, the small-scale test facilities have the capability of applying load. In others, it is mainly a means of evaluating the temperature profiles developed in the small-scale furnace, to predict their performance in large-scale tests.

The ASTM E119 test was developed under the consensus standards development procedures of ASTM, and can be used to satisfactorily *compare* performance of materials under standardized test conditions. Several other tests have been performed on assemblies under what would be termed 'ad hoc' conditions.[3] When a test is conducted using this type of procedure, it is very difficult to compare the performance of one assembly to another.

In other cases, 'ad hoc' testing is done using parts of the ASTM E119 standard. Often, the time/temperature curve is used while the load and assembly size are varied. These tests are usually performed primarily for gathering information, not for model code acceptance.

In order to meet these building code requirements, the truss Industry has performed extensive fire endurance testing. This has resulted in rated assemblies using various combinations of fire-rated gypsum wallboard, resilient channels, suspended ceiling panels and other materials.

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[2] Truswal Systems Corporation, "What About Wood Trusses and Fire?" Copyright 1984.

[3] Instances when testing was done using non-standardized procedures will be denoted in the summary of the reports.

***Use of Sprinkler Systems***

Another proactive approach to improving fire safety is adding sprinklers to the building design.

In general, by using sprinklers, building areas that are specified in the building code may be tripled in one-story buildings and doubled in buildings with more than two-stories. The building height may also be increased by one story. This is clear evidence that adding sprinkler systems to a building has proven to greatly reduce the risk of loss to life and property when a fire starts.

Sprinkler statistics bear this out. In fact the National Fire Protection Association states; "Sprinklers are so demonstrably effective that they can make a major contribution to fire protection in any property." The chances of dying in a fire in a building with sprinklers is 66% less than the chance of dying in a building without them. Property loss is also reduced by 50%. If unreported fires could be included in these statistics and well maintained, properly designed and installed systems isolated, sprinkler effectiveness would be seen as even more impressive.

Installation of sprinkler systems in buildings follows the latest edition of the NFPA 13 "Standard for the Installation of Sprinkler Systems." Sprinkler systems are easily applied with trusses as the load carrying structural element. The open web construction allows for water to be sprayed throughout the truss system. The key provisions of NFPA 13 that apply to trusses are found in section 4-4.1.3 and 4-4.1.4.

To use trusses with sprinklers, the truss manufacturer's connection details must be used to safely support the sprinkler piping. The Wood Truss Council of America has developed a brochure on the proper application of sprinkler systems with truss construction.

As can be seen, trusses can easily be used in buildings that permit un-protected, one- and two-hour rated, and sprinklered assembly applications.

## What are the Key Fire Related Statistics and What do they Say About This Subject?

The National Fire Protection Research Foundation report entitled ***National Engineered Lightweight Construction Fire Research Project*** has this to say on the subject of residential and apartment fires:

> In order to have a base from which to perform a risk assessment in the future, and to provide a guide with which to focus efforts on areas that are critical from a fire endurance perspective, it is helpful to review the statistics surrounding this issue. This information can provide a view of the magnitude of various aspects of fire loss, as well as clarify issues that require further review.
>
> **3.1 One- and Two-Family Dwelling Fires**
>
> A view of the fire problem in the United States can be obtained by defining where that fire problem exists. 75 percent of the fire-related fatalities in 1988 occurred in residential properties. 5 percent were in non-residential properties. 67 percent of fire-related injuries in

1988 occurred in residential properties with 13 percent in non-residential properties. These data are shown in the two Figures below, and are virtually the same as data for 1983.

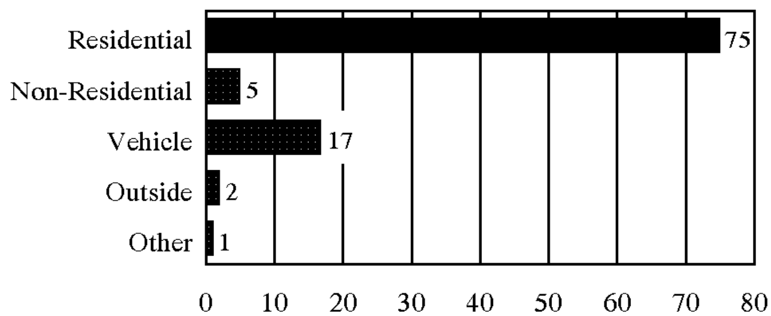


*Figure 2.* *Percent Fatalities*[4]

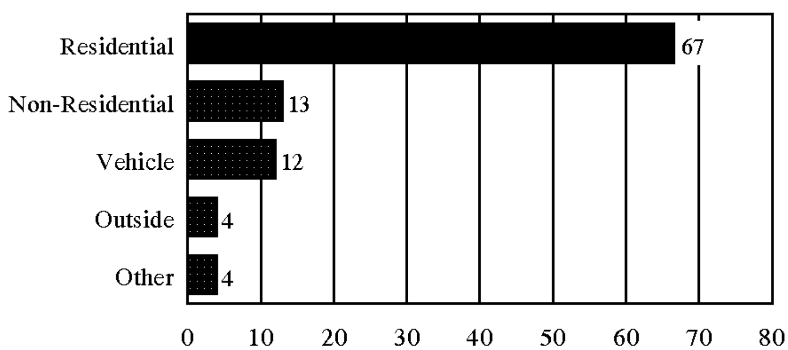


*Figure 3.* *Percent Injuries*[5]

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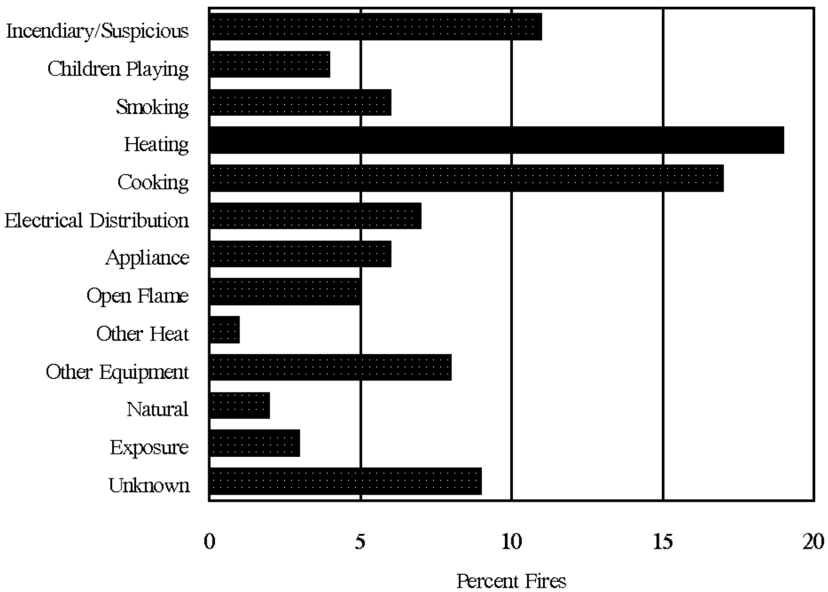
[4] Federal Emergency Management Agency (FEMA), **Fire in the United States**, 7th ed., August 1990.

[5] Ibid.

Figure 4 below details the leading causes of residential fires in 1988.[6] A similar trend is seen in the 1983 data.[7]




| Raw% | Adjusted% |
|---|---|
| 11 | 12 |
| 4 | 5 |
| 6 | 7 |
| 19 | 22 |
| 17 | 19 |
| 7 | 8 |
| 6 | 6 |
| 5 | 6 |
| 1 | 1 |
| 8 | 9 |
| 2 | 2 |
| 3 | 3 |
| 9 | |

*Figure 4. Cause of Residential fires*[8]

Heating fires are those where the equipment involved in ignition includes: central heaters, fireplaces, portable space heaters, fixed-room heaters, wood stoves, and water heating. The central- and water-heating portions of the problem have remained relatively unchanged over the years, while fires due to portable space heaters, wood burning stoves and chimneys rose very sharply from the late 1970s to the early 1980s, then subsided somewhat.[9]

Cooking—the second leading cause of residential fires—was the leading cause of fires in the 1980s, but was passed by heating with the surge in use of alternative space heaters and wood heating in the late 1970s. Cooking is by far the leading cause of fire injuries. Most cooking fires come from unattended cooking, rather than equipment failures.[10]

It is assumed most often that arson (incendiary/suspicious fires) is a crime against businesses. In fact, the statistics indicate that there is a very large arson problem in the

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[6] FEMA, **Fire in the United States**, 6th ed., July 1987.

[7] FEMA, **Fire in the United States**, 7th ed., August 1990.

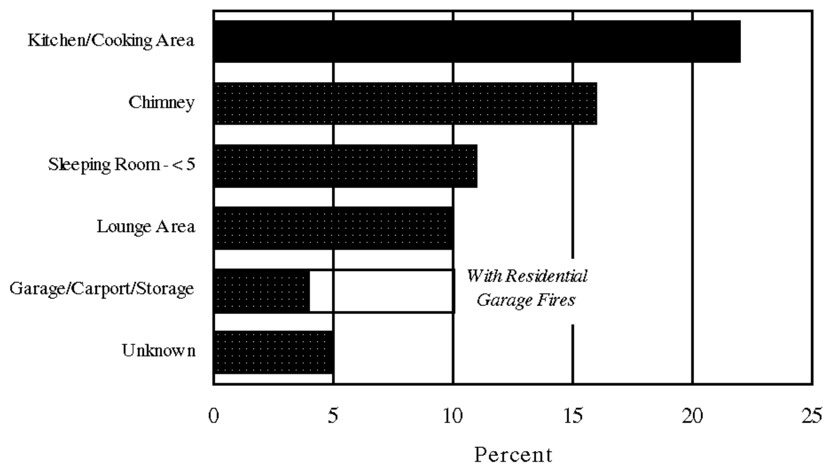
[8] Source: National Fire Incident Reporting System (NFIRS)

[9] Ibid.

[10] Ibid.

home. The causes range from vandalism fires set by youths and revenge fires set to end quarrels, to fraud against landlords or insurance companies. Residential arson fires are set most often in bedrooms.

Additional insight into residential fires is gained by looking at the leading rooms of origin for fires in one- and two-family dwellings (see Figure 5). This is virtually the same as data from 1983.




| Raw % | Adjusted % |
|---|---|
| 22 | 28 |
| 16 | 17 |
| 11 | 12 |
| 10 | 11 |
| 4 | 4 |
| 5 | |

Note: The white bar for garage fires indicates approximately how large they would be if the residential garage portion of storage fires was added here. All of the other bars would decrease and would have to be re-computed because the added garage fires would increase the total number of fires by 6 percent.

*Figure 5. Leading Rooms of Fire Origin for Residential Structures* [11]

[11] Ibid.

**Fires - 544,000 Civilian Fatalities - 3,900 Civilian Injuries - 14,100**

| | Percentages | | |
|---|---|---|---|
| **Area of Origin (901 Code)** | **Civilian Fatalities (For Ranking)** | **Fires** | **Civilian Injuries** |
| Living room, den, lounge (4) | 40.2 | 11.6 | 21.9 |
| Bedroom (21-22) | 24.1 | 11.6 | 20.9 |
| Kitchen (24) | 14.0 | 20.6 | 27.5 |
| **Structural Area (70-79)** | **5.8** | **15.5** | **7.4** |
| [Crawl space (71)] | (1.5) | (3.2) | (2.9) |
| [Unspecified (79)] | (1.0) | (1.0) | (0.7) |
| [Balcony, porch (72)] | (0.9) | (1.1) | (0.9) |
| [Ceiling/Floor Assembly (73)] | (0.7) | (0.8) | (0.5) |
| [Ceiling/Roof Assembly (74)] | (0.6) | (2.3) | (0.7) |
| [Wall Assembly (75)] | (0.6) | (2.0) | (0.8) |
| Dining room (23) | 2.3 | 1.1 | 1.6 |
| Heating equipment room (62) | 1.9 | 3.7 | 3.6 |
| Bathroom (25) | 1.2 | 1.7 | 1.9 |
| Hallway, corridor (01) | 1.2 | 0.9 | 1.1 |
| Garage* (47) | 1.1 | 3.4 | 3.7 |
| Interior stairway (03) | 1.0 | 0.4 | 0.4 |
| Closet (42) | 0.9 | 1.2 | 1.3 |
| **Other known single area** | **4.2** | **26.6** | **7.5** |
| [Chimney (51)] | (0.4) | (18.9) | (0.7) |
| Multiple areas (97) | 0.8 | 0.7 | 0.6 |
| Unclassified, not applicable (98-99) | 1.3 | 1.0 | 0.6 |
| **Total** | **100.0** | **100.0** | **100.0** |

* Does not include dwelling garages coded as property type, which is a larger number.

*Table 2. Annual Averages of Fatalities and Injuries in One- and Two-Family Dwellings and Mobile Homes, 1980-1984* [12]

Table 2 (above) provides even greater detail, and shows that fires originating in structural areas made up 15.5% of fires during the study period. **Of all fires, 0.8% started in a floor/ceiling assembly area and 2.3% started in a roof ceiling assembly area.** Fires that began in a concealed floor or roof space or crawl space caused 2.8% of the civilian fatalities and 4.1% of civilian injuries. 81.8% of the civilian fatalities and 73.8% of civilian injuries occur in fires that start in main living areas of residential structures.

[12] NFPA Standard 13D, 1989 Ed.

The leading areas of fire origin, taken from a more recent study, are shown in Table 3. Here, fires began in structural areas less than 2 percent of the time. Forty-nine percent of the time fires began in a living area that typically would be compartmentalized.[13]

| Area of Home | Heating | Cooking | Incendiary | Electrical Distribution | Smoking | Children Playing | Total |
|---|---|---|---|---|---|---|---|
| Lounge | 5,442<br>13.1% | | 2,116<br>13.5% | 1,529<br>12.4% | 1,919<br>25.8% | 698<br>10.6% | 11,704<br>11.0% |
| Sleeping Under 5 | 1,160<br>2.8% | 85<br>0.4% | 2,778<br>17.7% | 2,333<br>18.9% | 2,957<br>39.8% | 3,122<br>47.6% | 12,435<br>11.7% |
| Kitchen/Cooking | 1,037<br>2.8% | 22,416<br>95.0% | 1,218<br>7.7% | 1,400<br>11.3% | 569<br>7.7% | 448<br>6.8% | 27,088<br>25.4% |
| Lavatory | | | | | 282<br>3.8% | | 282<br>0.3% |
| Closet | | | | | | 355<br>5.4% | 355<br>0.3% |
| Garage/Carport/ Vehicle Storage | | 97<br>0.4% | | 631<br>5.1% | 199<br>2.7% | 314<br>4.8% | 1,241<br>1.2% |
| Chimney | 21,524<br>52.1% | | | | | | 21,524<br>20.2% |
| Heating Equipment Area | 3,843<br>9.3% | | | | | | 3,843<br>3.6% |
| Exterior Balcony/Open Porch | | 169<br>0.7% | | | | | 169<br>0.2% |
| Ceiling/Roof | | | | 980<br>7.9% | | | 980<br>0.9% |
| Exterior Wall | | | 932<br>5.9% | | | | 932<br>0.9% |
| Court/Terrace/Porch | | 85<br>0.4% | | | | | 85<br>0.1% |
| Multilocation/Use | | | 1,048<br>6.7% | | | | 1,048<br>1.0% |
| Unknown | | | | | | | 25,254<br>23.7% |
| **Total Fires** | **41,286** | **23,322** | **15,706** | **12,342** | **7,435** | **6,559** | **106,650** |

Note: For each cause, the five most common rooms or areas of origin reported are shown. Data here are NFIRS raw counts, NOT national estimates. Percentages shown are column percentages (e.g., percentages of heating or cooking fires, not percentages of lounge fires).

*Table 3. Leading Rooms of Origin by Cause for One- and Two-Family Dwelling Fires*[14]

**Finally, a 1986 national survey by the National Association of Home Builders on residential fire fatalities found that newer homes were much safer than older homes: 43 lives were lost in homes less than five years old. In sharp contrast, approximately**

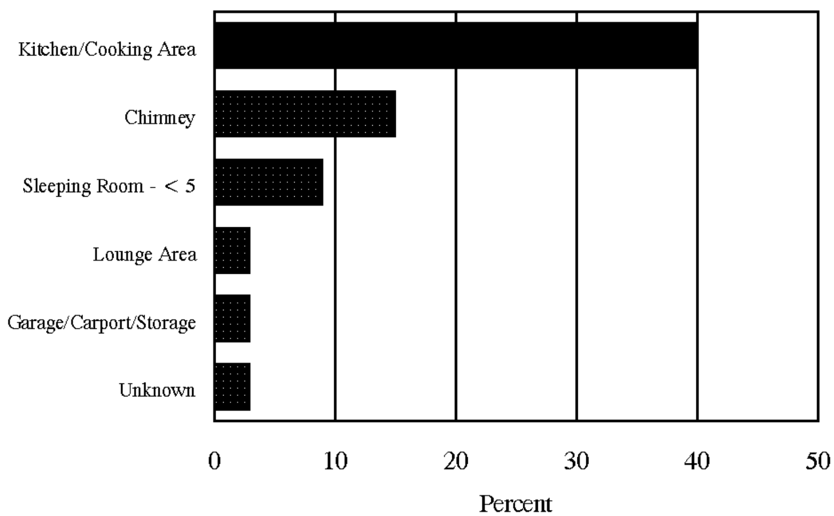
[13] FEMA, **Fire in the United States**, 7th ed., August 1990.

[14] Ibid.

**4,100 lives, or 89% of all residential fire fatalities during the study period, occurred in homes that were 20 years old or older.**[15]

### 3.2 Apartment Fires

A trend similar to that of single-family residential fires is seen for the leading room of origin in apartments (see Figure 6). The exception is that apartments do not have as many chimney fires.




| Raw % | Adjusted % |
|---|---|
| 40 | 41 |
| 15 | 16 |
| 9 | 10 |
| 3 | 3 |
| 3 | 3 |
| 3 | |

*Figure 6. Leading Rooms of Origin in Apartment Fires, 1987*[16]

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[15] **Nation's Building News**, October, 1991

[16] FEMA, **Fire in the United States**, 7th ed., August 1990.

**In a study shown in Table 4, fires that originated in a structural areas made up 8.1% of all fires.[17] Of these, 0.7% began in a structural assembly area.**

**Fires - 123,000 Civilian Fatalities - 930 Civilian Injuries - 5,4700**

| | Percentages | | |
|---|---|---|---|
| **Area of Origin (901 Code)** | **Civilian Fatalities (For Ranking)** | **Fires** | **Civilian Injuries** |
| Living room den, lounge | 38.50 | 11.30 | 23.20 |
| Bedroom | 28.70 | 17.40 | 27.10 |
| Kitchen | 9.80 | 35.30 | 27.20 |
| Hallway corridor | 4.30 | 3.20 | 3.40 |
| Interior stairway | 3.20 | 1.00 | 1.10 |
| **Structural area** | **3.10** | **8.10** | **3.50** |
| Balcony | (1.20) | (1.30) | (0.70) |
| Unspecified | (1.00) | (0.50) | (0.20) |
| Ceiling/Roof Assembly | (0.30) | (0.70) | (0.30) |
| Lobby | 1.30 | 0.60 | 0.70 |
| Dining room | 1.20 | 0.80 | 1.00 |
| Closet | 1.20 | 1.90 | 1.90 |
| Balcony, porch | 1.20 | 1.30 | 0.70 |
| **Other known single area** | **4.10** | **17.80** | **8.80** |
| Bathroom | (0.60) | (2.10) | (1.30) |
| Multiple Areas | 1.60 | 0.70 | 0.90 |
| Unclassified, not applicable | 1.80 | 0.60 | 0.50 |
| **Total** | **100.00** | **100.00** | **100.00** |

*Table 4. Annual Averages of Fatalities and Injuries in Apartments, 1980-1984* [18]

[17] NFPA 13 R, **Installation of Sprinkler Systems in Residential Occupancies up to Four Stories in Height**, 1989 Edition.

[18] Ibid.

A more recent study details the leading rooms of origin in apartment fires (see Table 5).[19]

| | Leading Causes | | | | | | |
|---|---|---|---|---|---|---|---|
| **Area of Home** | **Cooking** | **Arson** | **Smoking** | **Heating** | **Children Playing** | **Open Flame** | **Total** |
| Interior Stairway | | 308<br>4.5% | | | | | 308<br>0.9% |
| Hallway | | 755<br>10.9% | 140<br>2.6% | | | | 895<br>2.7% |
| Lounge Area | | 739<br>10.7% | 1,427<br>26.7% | 379<br>14.6% | 293<br>11.5% | 295<br>13.2% | 3,133<br>9.4% |
| Sleeping Under 5 | 66<br>0.5% | 1,137<br>16.5% | 2,049<br>38.3% | 251<br>9.7% | 1,331<br>52.2% | 460<br>20.5% | 5,294<br>15.8% |
| Dining | 32<br>0.2% | | | | | | 32<br>0.1% |
| Kitchen/Cooking | 13,333<br>96.4% | 444<br>6.4% | 355<br>6.6% | 221<br>8.5% | 193<br>7.6% | 269<br>12.0% | 14,815<br>44.3% |
| Lavatory | | | | | 59<br>2.3% | 195<br>8.7% | 254<br>0.8% |
| Closet | | | | | 194<br>7.6% | | 194<br>0.6% |
| Trash Area/Container | | | 322<br>6.0% | | | | 322<br>1.0% |
| Chimney | | | | 281<br>10.8% | | | 281<br>0.8% |
| Heating Equipment Area | | | | 660<br>25.4% | | | 660<br>2.0% |
| Exterior Balcony | 121<br>0.9% | | | | | 88<br>3.9% | 209<br>0.6% |
| Court/Terrace/Patio | 38<br>0.3% | | | | | | 38<br>0.1% |
| Unknown | 241<br>1.7% | 3,520<br>51.0% | 1,061<br>19.8% | 808<br>31.1% | 481<br>18.9% | 932<br>41.6% | 7,043<br>21.0% |
| **Total** | **13,831** | **6,903** | **5,354** | **2,600** | **2,551** | **2,239** | **33,478** |

Note: For each cause, the five most common rooms or areas of origin reported are shown. Data here are NFIRS raw counts, NOT national estimates. Percentages shown are column percentages (e.g., percentages of heating or cooking fires, not percentages of lounge fires).

*Table 5. Leading Rooms of Origin by Cause for Apartment Fires, 1987*[20]

**In this study, no fires were recorded as beginning in structural member areas. The fires began in areas that were compartmentalized 70.7% of the time.**

[19] Ibid.

[20] Ibid.

### 3.2.1 Observations on One- and Two-Family Dwelling and Apartment Fires

Based on statistics, residential fires are the nation's most serious fire problem. Three-quarters of all fire-related fatalities and two-thirds of all fire-related injuries occur in residential properties. **Fire and code officials have focused attention on the need for smoke detectors. Getting people out of a burning structure early is the best way to save lives.**

The significance of the high number of fire-related fatalities in residential properties indicates that the greatest impact can be achieved by solving problems associated with compartments. The issues here include penetrations of protective membranes and concealed spaces, assuring that compartments comply with code-conforming construction techniques, installing the proper rated assembly, residential sprinkler protection, etc. **The Figures and Tables above show that sprinklers placed in the living space could effectively contain many of these fires and reduce losses to civilian lives, property and, consequently, the potential loss of firefighter lives.**

The foregoing data suggest that the majority of fires begin in areas where there is compartmentation. **In residential construction fires began within a structural space 3.1% of the time and caused 2.8% of civilian fatalities and 4.1% of civilian injuries. This suggests that most fires originate within compartmentalized rooms where a protective membrane separates the structural system from the fire.** In these instances, the performance of the protective membrane will be vital to the performance of the overall structural system in a residential fire.

**The key to compartment effectiveness is having the compartment remain intact prior to and during a fire. Any penetration will cause the fire to spread rapidly to other areas of the structure. With proper compartmentation, one can expect a given period of satisfactory performance for structural elements in the majority of fires that occur in residential properties.**

**What about Sprinkler Performance?**

The National Fire Protection Research Foundation report entitled "National Engineered Lightweight Construction Fire Research Project has this to say on the subject of sprinklers:

> Statistics provide evidence that automatic sprinklers reduce fire loss in industrial properties. This evidence is shown in Table 6, which shows statistics on the impact of sprinkler systems from 1980 to 1983.

| Property Class | No Sprinklers | Sprinklers Present | Percent Reduction |
|---|---|---|---|
| All manufacturing, industry, utility, defense | 20,700 | 8,800 | 57 |
| Plastic product manufacturing | 59,900 | 36,400 | 39 |
| Sawmills, planing mills, wood product mills | 22,600 | 12,600 | 44 |
| Metal product manufacturing | 15,100 | 5,300 | 65 |
| Motor vehicle manufacturing, assembly | 19,000 | 5,600 | 70 |
| Paper, pulp, paperboard manufacturing | 16,800 | 4,800 | 71 |
| Machinery manufacturing | 17,700 | 3,300 | 81 |
| Furniture, fixture, bedding manufacturing | 34,600 | 4,900 | 86 |
| **Total** | **206,400** | **81,700** | **60** |

Loss figures are expressed to the nearest hundred. Estimates are based on the annual NFiPA survey and the Federal Emergency Management Agency's (FEMA's) National Fire Incident Reporting System, using statistical methods developed by analysts of NFIPA, FEMA, and the US Consumer Product Safety Commission. Complete and partial sprinkler systems are not distinguishable. The property uses included in manufacturing, industry, utility, and defense are codes 600-799 in NFPA 901, **Uniform Coding for Fire Protection**.

*Table 6. Average Loss Per Fire in Dollars, 1980-1983* [21]

As shown in this table, the average loss per fire for industrial properties is cut by more than half when sprinklers are present. The table also shows results for those specific industrial property classes that have enough fires to give meaningful data. Also note that properties showing the lowest percentage reductions in dollar loss per fire tended to have more severe fires. The actual dollar savings per fire was at least $9,800 in all categories.[22]

When viewing Table 6, one should be cautious about the following points:

- Loss figures are very sensitive to the influence of a few large-loss fires, even when a multiple-year average is used.
- The databases supporting these calculations cannot distinguish complete from partial systems, which may cause an underestimation of the impact of sprinkler systems.
- Evidence shows that sprinklered properties tend to be larger than comparable non-sprinklered occupancies, so the implied savings may be even greater than these figures indicate.[23]
- Sprinklered properties may also be better built and maintained from a fire safety standpoint. This may mean that the statistics shown are crediting sprinklers with loss

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[21] NFiPA Fire Analysis Division, "Automatic Sprinkler Systems Do Have an Impact in Industry," **Fire Journal**, January, 1987.

[22] Ibid.

[23] F.E. Rogers, "Fire Losses and the Effect of Sprinkler Protection of Buildings in a Variety of Industries and Trades," Building Research Establishment current paper 9/77, Borehamwood, United Kingdom, February, 1977.

reductions that were actually caused by many factors. This effect tends to overstate the specific impact of sprinklers.[24]

The statistics in Table 6 include only fires reported to fire departments and, as such, may omit some of the most dramatic sprinkler successes. This has also been a problem with sprinkler statistics in the past. Success stories in small- and even medium-size fires were not reported. Where sprinklers were not successful, human error was often the problem: water was shut off, primarily by closed valves; maintenance was inadequate; or water distribution was obstructed in other cases. These reasons were the cause of unsuccessful sprinkler performance in 47% of the cases from 1925 to 1969.[25]

Operation Life Safety, a program of the National Association of Fire Chiefs, monitors sprinkler activations. Information pertaining to sprinkler performance in the United States for the period of 1983 to 1991 is found in Figures 7 and 8, and Tables 7 and 8.

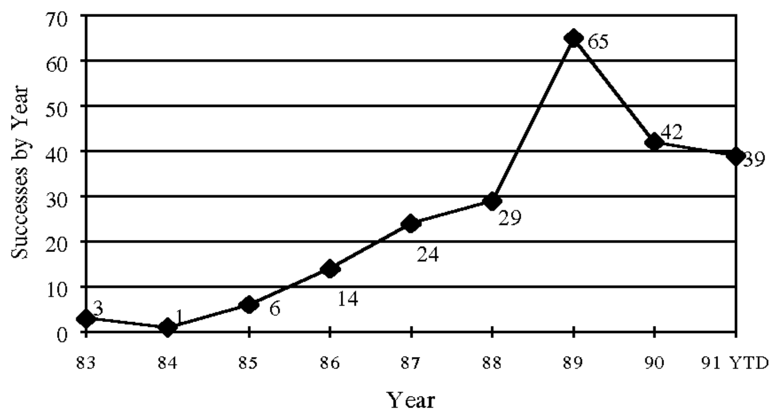


*Figure 7. Reported Activations by Year* [26]

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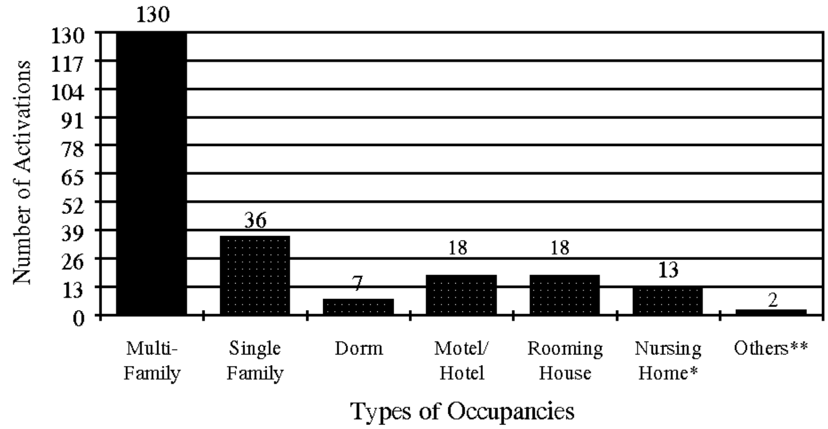
[24] NFIPA Fire Analysis Division, "Automatic Sprinkler Systems Do Have an Impact in Industry," **Fire Journal**, January, 1987.

[25] Ibid.

[26] **Operation Life Safety Newsletter**, 6(12), December, 1991.




* Includes home care, convalescent and retirement home facilities
** Includes high-rise and child-care facilities

*Figure 8. Reported Activations by Type of Occupancy, 1983-1991* [27]

| Description | # Activations |
|---|---|
| One-head activations | 165 |
| Two-head activations | 15 |
| More than two-had activations | 2 |
| Not Reported | 41 |

*Table 7. Sprinkler Activations Per Fire, 1983-1991* [28]

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[27] Ibid.

[28] Ibid.

| Room of Origin | # Activations | Percent |
|---|---|---|
| Kitchen | 86 | 38.6 |
| Bedroom | 33 | 14.8 |
| Living room | 20 | 8.9 |
| Closet | 10 | 4.4 |
| Laundry room | 8 | 3.5 |
| Storeroom | 6 | 2.7 |
| Bathroom | 6 | 2.7 |
| Garage | 3 | 1.3 |
| Basement | 3 | 1.3 |
| Dining room | 2 | 0.9 |
| Chimney | 1 | 0.4 |
| Others | 17 | 7.6 |
| Not Reported | 28 | 12.5 |
| **Total** | **223** | |

*Table 8. Room of Origin, 1983-1991* [29]

**Obviously, firefighter safety is enhanced by the presence of sprinklers. Since most fires are controlled by the activation of one sprinkler head, the fire never gets to a size that is dangerous. This contributes to fire ground safety.**

### 3.4.1 Observations on Sprinkler Performance

It is interesting to note that of all the sprinkler activations shown in the above figures and tables, one head usually controlled the fire. Also, the room of origin for these fires was consistent with those shown in the statistics on residential and apartment buildings. Generally, the room of origin is in an area that is compartmentalized and a primary living area, such as the kitchen, bedroom or living room. This further suggests that the focus ought to be on protected lightweight building components.

There is no question that sprinklers can be important in diminishing the impact of fires in any type of construction. It is proven that sprinklers reduce property loss and life loss. There is also a strong possibility that sprinklers could reduce firefighter fatalities, since they contain, and even extinguish, fires prior to arrival of the fire department. Sprinklers are currently the most pro-active fire safety approach in building construction.

## Do Trusses and other Engineered Wood Products Really Kill Firefighters?

The following information was taken from The National Fire Protection Research Foundation's report entitled ***National Engineered Lightweight Construction Fire Research Project*** on the subject of firefighter fatalities:

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[29] Ibid.

Figure 9 shows the number of firefighter fatalities for each year from 1977 through 1990.

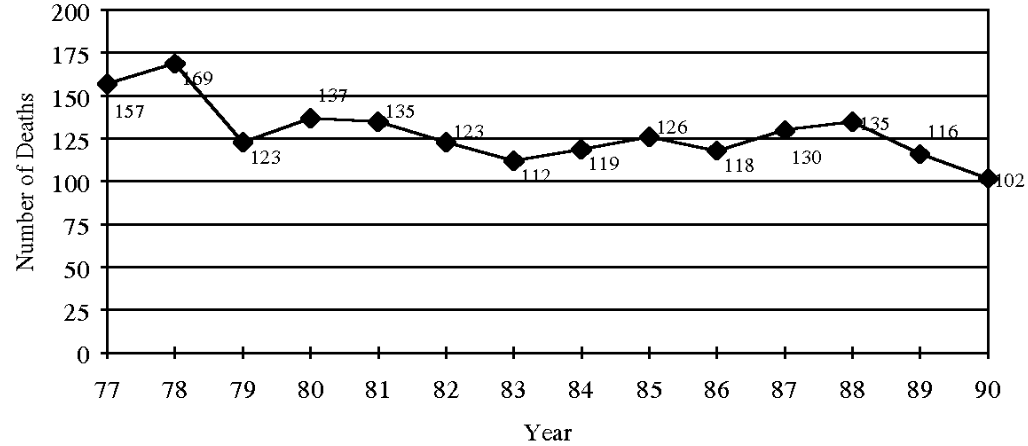


*Figure 9. Firefighter Fatalities 1977-1990* [30]

As can be seen, there is a downward trend in firefighter fatalities. Why this is so is not immediately apparent from the literature. One could surmise that firefighters are staying more physically fit, are taking more safety precautions, are better educated on fire ground techniques, etc. **This may also be due to the fact that building codes are continuously being upgraded to add new life safety measures, and construction materials and methods are improving, which may result in greater firefighter safety on the fire ground.**

Figure 10 details firefighter fatalities by type of duty in 1990. Of all on-duty firefighter fatalities, 43.1% were on the fire scene where the structure could have contributed to the loss of life.

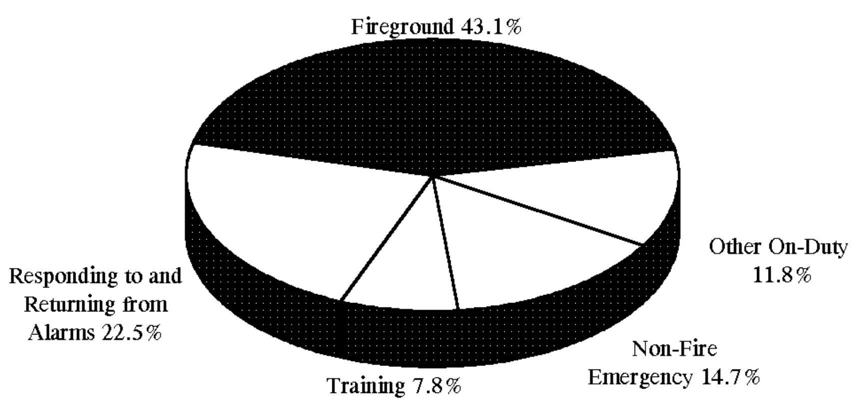


*Figure 10. Firefighter Fatalities by Type of Duty, 1990* [31]

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[30] Washburn, AE, LeBlanc, PR, and Fahy, RF, "Report on Fire Fighter Fatalities," **NFPA Journal**, July/August 1991, p. 47.

To gain a better sense of firefighter fatalities and their causes, data were reviewed from ***Fire Command Magazine*** Fire Incident Reports from 1980 through 1989. Each of the fatalities detailed were reviewed for cause. The statistical breakdown is detailed in Table 9 and Figures 11 and 12.

| | | Cause | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Fatalities** | **Heart Attack** | **Fell or Struck by Object** | **Structural Collapse** | **Exposure to Fire Products** | **Electrocution** | **Other Conditions** |
| 1989 | 110 | 59 | 9 | 7 | 6 | 3 | 26 |
| 1988 | 129 | 51 | 5 | 17 | 2 | 2 | 52 |
| 1987 | 124 | 62 | 6 | 3 | 4 | 0 | 49 |
| 1986 | 113 | 58 | 13 | 2 | 8 | 1 | 31 |
| 1985 | 119 | 48 | 12 | 7 | 5 | 1 | 46 |
| 1984 | 116 | 38 | 15 | 3 | 7 | 2 | 51 |
| 1983 | 106 | 52 | 10 | 3 | 6 | 1 | 34 |
| 1982 | 117 | 54 | 8 | 12 | 8 | 2 | 33 |
| 1981 | 123 | 64 | 7 | 2 | 5 | 0 | 45 |
| 1980 | 134 | 60 | 11 | 6 | 7 | 1 | 49 |
| **TOTAL** | **1191** | **546** | **96** | **62** | **58** | **13** | **416** |
| **PERCENT** | **100%** | **45.84%** | **8.06%** | **5.21%** | **4.87%** | **1.09%** | **34.93%** |

*Table 9. Firefighter Fatalities Taken From Fire Command Magazine, 1980-1989* [32]

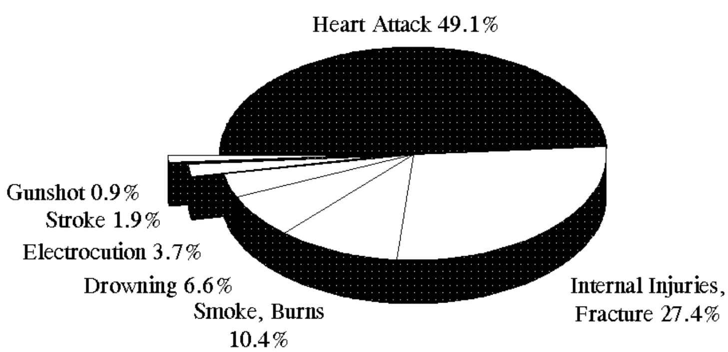


*Figure 11. Firefighter Fatalities by Nature of Injury, 1983*[33]

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[31] Ibid.

[32] Fire Command statistics compiled by the NFPA Fire Analysis and Research Division. Prepared by authors

[33] Source: NFIRS

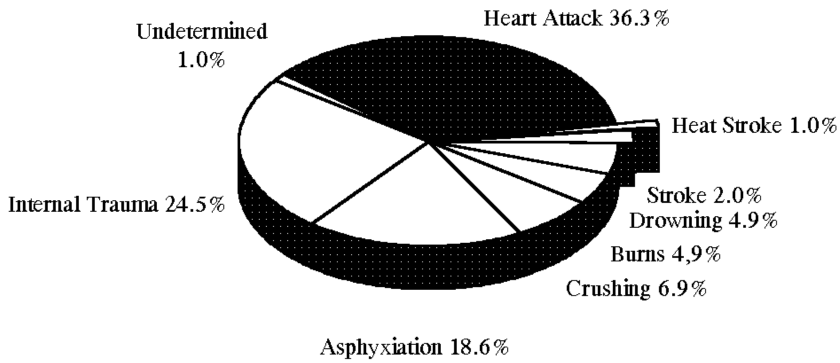


*Figure 12. Firefighter Fatalities by Nature of Injury, 1990*[34]

The structural collapse cause of fatality data shown in Table 9 was further broken out when the incident report stated specifically that the cause of fatality was due to structural collapse. This includes any conditions that would allow even an inference that the cause of fatality was by structural collapse. For example, a ceiling collapse was included in the structural collapse category, yet it was unknown whether it was the structural supporting member that collapsed, or simply the ceiling material. Therefore, when there was enough detail in "Fell or Struck By Object" (again from Table 9) to place it into the structural collapse category, this was done. This is believed to provide a more realistic picture of structural collapse-related fatalities. This detailed breakdown is shown in Table 10.

[34] FEMA, **Fire in the United States**, 7th ed., August 1990.

| Year | Total Fatalities | Non-Comb. Wall | Wood Frame Products | Ordinary Roof/Floor[q] | Non-Combust. Roof/Floor | Light Frame Wood Trusses[a] | Timber Trusses | Comb. Wall |
|---|---|---|---|---|---|---|---|---|
| 1980 | 134 | 1.0 | 3.0 | 1.0 | | 1.0[f] | | |
| 1981 | 123 | 1.0 | | 1.0 | | | | |
| 1982 | 117 | 5.0 | 1.0 | 4.0 | 2.0[o] | | | |
| 1983 | 106 | 1.5[h*] | | | 1.5[hn*] | | | |
| 1984 | 116 | | | 2.0 | | 1.0[e] | | |
| 1985 | 119 | 1.0[l*] | 2.0 | 4.0[l*] | | | | |
| 1986 | 113 | | 0.5[k*] | | | 1.0[d] | | 0.5[k*] |
| 1987 | 124 | 1.5[g**] | 1.5[gj*] | | | | | |
| 1988 | 129 | 3.5[c*] | 6.0[i] | | 2.0[m] | 0.5[c*] | 5.0[p] | |
| 1989 | 110 | 2.0 | 2.0 | | 1.0 | 2.0[b] | | |
| **TOTAL** | **1191** | **16.5** | **16.0** | **12.0** | **6.5** | **5.5** | **5.0** | **0.5** |
| **PERCENT** | **100.0%** | **1.39%** | **1.34%** | **1.01%** | **0.55%** | **0.46%** | **0.42%** | **0.04%** |

* In five cases (c,g,h,k,l) more than one failure mode is referenced in the event description.
a Unless otherwise noted, all fatalities are in light commercial structures. Truss type is not defined in the description.
b Assumed metal plate connected trusses in Orange County Gift Shop (Mercantile Occupancy). Description does not say.
c Trusses collapsed causing concrete block wall to fall on a firefighter (Mercantile Occupancy).
d A Johnsonville, South Carolina Church (Assembly Occupancy) Truss roof collapsed. Truss type unspecified.
e An apartment building (Group R-2 occupancy) under construction caught due to a fire placed in an unfinished chimney. Roof truss collapsed. Truss type unspecified.
f A delicatessen/restaurant (Mercantile Occupancy) fire roof truss collapse. Truss type unspecified.
g Wood frame roof collapsed causing concrete block chimney to fall.
h 15,000 ft.$^2$ manufacturing plant assumed to use steel bar joists. Caused brick wall to collapse.
i Assumed wood frame in a single-family residence ceiling collapse.
j 100-year-old wood frame church
k Wood frame structure collapsed causing facade to collapse.
l Wall collapse due to roof collapse. Roof type not designated.
m Collapse of concrete floor on steel beams, 1 Fatality. Steel Beam the other.
n Steel bar joist collapse.
o 4 in. concrete floor poured over original joist floor.
p Hackensack, New Jersey Fire. Bolted Timber Bowstring Girder Trusses.
q Description only says the building was of ordinary (type 3) construction.

*Table 10. Cause of Fatality by Collapse/Structural Failure*[35]

Table 10 was generated by reading each summary in *Fire Command Magazine*, from 1980 through 1989, and ascertaining the specific structural collapse cause of fatality. Unfortunately, the detail of the incident report is often not specific enough to identify the specific structural product. These were categorized in the wood frame products or ordinary category due to the use of 'wood frame' or 'ordinary' in the incident description.

The total fatalities that appear to be attributable to structural framing of the floor or roof system over the period of 1980 through 1989 are 45, 3.8% of the total firefighter fatalities for this period.

[35] Firefighter fatalities taken from NFiPA **Fire Command Magazine.** Statistics compiled by the NFiPA Fire Analysis and Research Division. Summary prepared by Kirk Grundahl.

A similar study done by the Fire Analysis and Research Division of NFiPA for the Federal Emergency Management Agency (FEMA) in August, 1989, provides specific information on firefighter fatalities in structural collapses. For the purpose of this study, structural collapse was defined as: "The failure of structural members resulting in the collapse of a structure or portion of a structure." Two categories of structural collapse were used: the first when firefighters were caught or trapped by a collapsing roof, wall, floor or ceiling; the second when firefighters were struck by a collapsing roof, wall, ceiling or piece of wall.[36]

The study reported that from 1979 through 1988, 93 firefighters were killed in structure fires as a result of structural collapse. Of these 93 victims, 56 were caught or trapped, and 37 were struck by a collapsing roof, wall, etc. Figure 13 shows the number of firefighter fatalities according to these two categories:

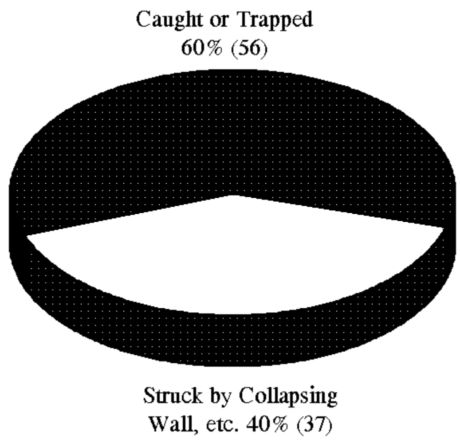


*Figure 13. Firefighter Fatality by Category* [37]

[36] "Analysis Report on Firefighter Fatalities," Prepared by Fire Analysis and Research Division, NFPA for the Federal Emergency Management Agency, August 1989.

[37] Ibid.

Of the 56 who were caught or trapped by structural collapse, 31 were asphyxiated, 13 died of burns, and 12 died as a result of crushing injuries or internal trauma. These data can be seen in Figure 14.

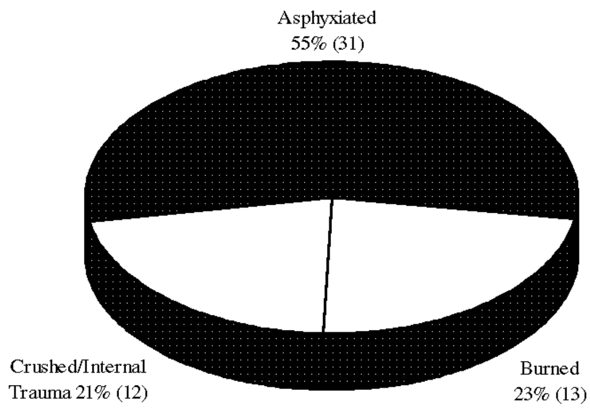


*Figure 14. Firefighter Fatalities Resulting From Being Caught or Trapped by a Structural Collapse (56 fatalities)* [38]

The building components involved in the collapses were the roof (30 fatalities), floor (19 fatalities), ceiling (5 fatalities), and walls (2 fatalities). These data can be seen in Figure 15.

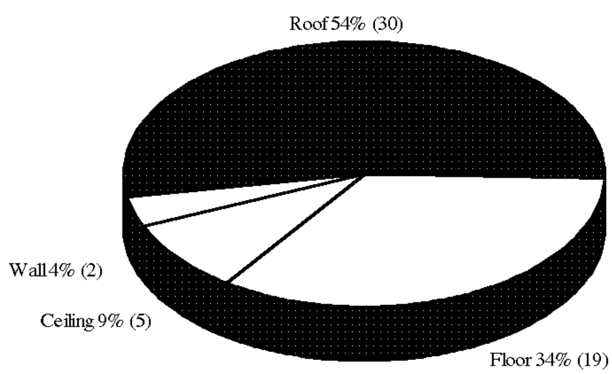


*Figure 15. Building Components Involved in Firefighter Fatality* [39]

The 30 fatalities in roof collapses occurred as follows: 10 of the victims were on the roof performing ventilation, 17 were inside performing fire suppression activities, 2 were inside pulling ceilings, and 1 was involved in a search for occupants. These data are shown in Figure 16:

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[38] Ibid.

[39] Ibid.

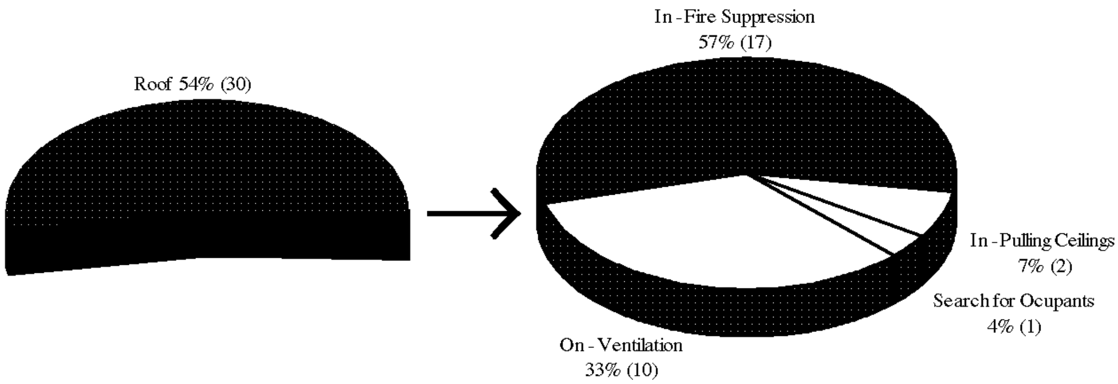


*Figure 16. Firefighter Activity During Fatality-Causing Roof Collapse* [40]

Figure 17 summarizes the type of occupancy where firefighters were caught or trapped in a structural collapse.

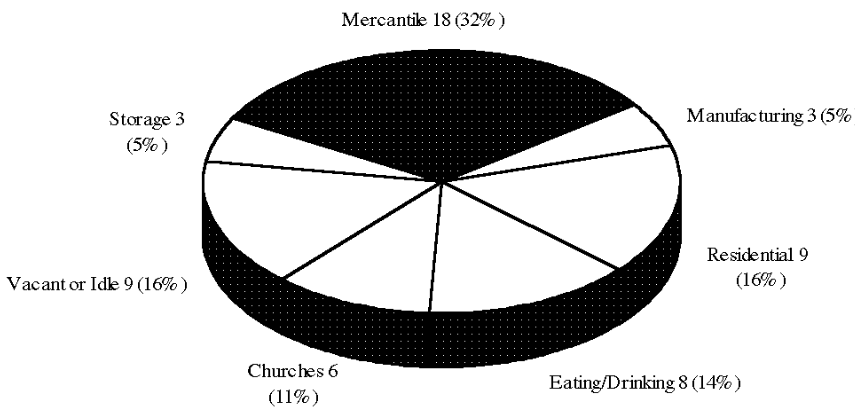


*Figure 17. Firefighters Caught or Trapped in Structural Collapses, 1979-1988*

Of the 93 fatalities reported in the study, 37 occurred by being struck by a collapsing wall or piece of wall while outside the structure. Of these 37 victims, 30 were operating hand lines (one from an elevated platform) or performing other suppression activities, 3 were killed while escaping from the building, 2 were attempting to move vehicles (in separate incidents), 1 died when a natural gas explosion caused a wall collapse as he and others were attempting to rescue an elderly woman from a fire escape, and 1 was attempting to open a door with a ceiling hook when the wall collapsed on him. These data are shown in Figure 18:

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[40] Ibid.

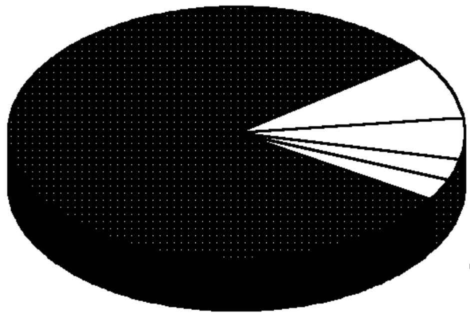


*Figure 18. Firefighter Fatalities Caused by Wall Collapse, by Activity (37 fatalities)* [41]

In 12 of the wall collapse fatalities described above, the roof was also reported to have collapsed; and in another, the floors collapsed, causing the walls to collapse by being pushed out. The failure of firefighters to maintain an adequate distance between themselves and the building appears to have been a factor in almost all wall collapse fatalities.[42]

3.6.2.1 Fatalities Due to Truss Roof Collapse

The NFiPA study also identifies collapses involving truss roofs. Seven of these collapses were reported to involve truss roofs. Eleven firefighters died when they were caught or trapped in six of the collapses. The seventh collapse resulted in a firefighter being struck by a collapsing wall after the roof collapsed. The most severe incident occurred in Hackensack, New Jersey, in 1988, when five firefighters were killed when a wood bowstring truss roof collapsed.[43] This seems to confirm the numbers developed from Fire Command Magazine as shown in Table 10 above.

It seems fairly clear from this data that to blame firefighter deaths on truss construction is probably not appropriate. Light frame trusses including Metal plate connected wood trusses can be tied to only **0.46%** (less than 1 percent) of all firefighter fatalities for the period from 1980 through 1989.

## Concluding Thoughts

As we've seen, trusses:

- are an environmentally sensitive building product. These products have evolved with the design in mind to efficiently utilize wood fiber, resulting in less cutting and less waste of the trees needed to manufacture it. They are manufactured from the only renewable raw material that exists for construction products—wood.

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[41] Ibid.

[42] Ibid.

[43] Ibid.

- provide many jobs in the construction business and therefore have a significant economic impact on the US economy.

- are being demanded by a society concerned with the efficient use of natural resources. This demand will only increase in the future. Therefore, trusses and other engineered wood products are products that are here to stay.

- are designed in compliance with the building codes and can easily be used to achieve the overall building fire safety goals, through the use of fire rated assemblies.

It is expected that engineered wood products, like trusses, are going to help build North America in the years to come, and that trusses can be applied in a manner that meets building fire safety expectations. Fire fighting tactics should be constantly reviewed and evaluated in order to safely combat fires that involve engineered wood products. The industry is eager to provide any technical information necessary that would help in this area.

We also need help from the fire service. The fire problem with trusses and other engineered wood products is not well defined. We need clear and very detailed examples of situations where these products have performed poorly in fire ground situations. We also need examples of situations where they have performed well. Using both scenarios, we can learn more about how to make the fire ground safer for firefighters.

Most important to providing safe fire fighting conditions is the use of pre-fire planning. By being knowledgeable of the risks that may be encountered on the fire ground, it is far easier to make wise fire ground decisions.

As an industry, our goal is to supply an environmentally sensitive, affordable, and safe construction product that also meets the public's expectations for fire safety. We are certain this is achievable and that everyone will benefit.

## NFPRF Report Appendix C: Comparative Risk Statistics

To put the risk of firefighter fatality due to lightweight components into comparative perspective, Table 43 delineates fatalities per year for firefighters, agricultural workers, construction workers, mining workers, and police officers. This will provide a basis upon which to ascertain the level of risk firefighters face in their workplace.

| Year | Agricultural[a] | Construction[a] | Mining[a] | Police[b] | Firefighters[c] |
|---|---|---|---|---|---|
| 1980 | 2000 | 2500 | 500 | 165 | 137 |
| 1981 | 1900 | 2200 | 600 | 157 | 135 |
| 1982 | 1800 | 2100 | 600 | 164 | 123 |
| 1983 | 1800 | 2000 | 500 | 152 | 112 |
| 1984 | 1600 | 2200 | 600 | 147 | 119 |
| 1985 | 1600 | 2200 | 500 | 148 | 126 |
| 1986 | 1700 | 2100 | 400 | 133 | 118 |
| 1987 | 1500 | 2200 | 200 | 158 | 130 |
| 1988 | 1300 | 2100 | 300 | 155 | 135 |
| 1989 | 1300 | 2100 | 300 | 146 | 116 |

a Source: Accident Facts, National Safety Council, 1981-1990 eds.
b Source: Statistical Abstract of the United States, 1991 ed.
c Source: NFPA Journal, August 1991.

*Table 43. Fatalities in Selected Fields, 1980-1989*

In order to get a better idea of how fatalities compare between these occupations, Table 44 contains the same data normalized to show fatalities per thousand people in each occupation.

| Year | Agricultural[a] | Construction[a] | Mining[a] | Police[bc] | Firefighters[ad] |
|---|---|---|---|---|---|
| 1980 | 61 | 45 | 50 | 0.38 | 0.12* |
| 1981 | 54 | 40 | 55 | 0.35 | 0.12* |
| 1982 | 52 | 40 | 55 | 0.37 | 0.11* |
| 1983 | 54 | 37 | 50 | 0.34 | 0.10 |
| 1984 | 46 | 39 | 60 | 0.31 | 0.11 |
| 1985 | 49 | 37 | 50 | 0.31 | 0.12 |
| 1986 | 52 | 33 | 50 | 0.28 | 0.11 |
| 1987 | 49 | 35 | 38 | 0.33 | 0.12 |
| 1988 | 48 | 34 | 25 | 0.32 | 0.13 |
| 1989 | 40 | 32 | 43 | 0.29 | 0.11 |

a Source of fatality statistics: Accident Facts, National Safety Council, 1981-1990 eds.
b Source of fatality statistics: Statistical Abstract of the United States, 1991 ed.
c Source of total number of police officers: U.S. Department of Justice, Federal Bureau of Investigation, "Crime in the United States," 1980-1989 eds.
d Source of total number of firefighters: Michael J. Karter, Jr., "U.S. Fire Department Profile Through 1990," Fire Analysis and Research Division, NFiPA, November 1991.
* Total number of firefighters was not available for these years. Data were extrapolated.

*Table 44. Fatalities in Selected Occupations per 1000 People in Each Occupation in the U.S., 1980-1989*