



National Fire Protection Association

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Summary Fire Investigation Report Fatal Board and Care Fire September 19, 1990

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On September 19, 1990 an early morning fire in a board and care occupancy in Bessemer, Alabama resulted in four fatalities. Fortunately, eleven residents were evacuated by the prompt actions of a 16-year-old occupant awakened by a smoke detector. An inadequate water supply for an installed residential sprinkler system resulted in the system not operating properly, thus illustrating important code enforcement lessons. Had the system been properly designed, installed, and adequate water been supplied, it is likely that no loss of life would have occurred. The National Fire Protection Association would like to thank the Alabama State Fire Marshal's Office and the Bessemer Fire Department for their assistance in documenting this incident.

The approximately 40-year-old, single-story, wood-frame building was once a single-family residence that was expanded during the 1960s and converted to a nursing home. (See Figure 1) Interior partition and ceiling materials of the building were gypsum material while some walls had multiple layers of wallpaper. The occupancy classification was again changed in more recent years to a board and care facility and licensed by the Alabama Department of Public Health.

The caretakers of the facility provided only personal care services to its 15 occupants who were mostly elderly and had varying physical and mental impairments. In Alabama, the Department of Public Health defines such occupancies as "domiciliaries" and considers occupant capability for fire evacuation purposes to be "impractical." As a result of this determination, their enforcement of the NFPA 101, *Life Safety Code*,[®] Chapter 21, "Residential Board and Care Occupancies," mandates automatic sprinklers in all such facilities. NFPA 101 will then allow a system meeting the requirements of 13D, *Standard for the Installation of Sprinkler Systems in One-and Two-Family Dwellings and Mobile Homes*, to be installed in such "small" board and care facilities if certain enhancements to the minimum requirements of the Standard are met.¹ These enhancements require that all habitable areas and closets are to be equipped with sprinklers and a 30-minute water supply is to be provided.

1 Small residential board and care occupancy is defined in chapter 23 of NFPA 101 as those providing sleeping accommodations for not more than 16 residents.

Further impacting on the design criteria of such a system, NFPA 101 requires in such facilities that the automatic sprinkler system be supervised according to paragraph 7-7.2, "Supervision."

The building exits were arranged with a front, main entrance leading to a day room and onto a double loaded exit corridor. The corridor provided access to residents' rooms and to dining and kitchen facilities. The corridor then led to a second day room and the remaining sleeping areas. The second exit for the facility was from this centrally located day room. In slow and impractical facilities, NFPA 101 stipulates that the primary means of escape for each sleeping room shall not be exposed to common living spaces such as living rooms and kitchens. Residents of this facility were required to pass such a common space in exiting the building, which is significant considering the location of the fatalities of this fire.

Fire protection features provided in the facility included a fire alarm system having manual pull stations and ac powered smoke detectors. Pull stations were located near exits while the detectors were located in day rooms and in the exit access corridor. Activation of the system would sound evacuation alarms within the building but would not automatically notify the fire department. Individual, battery operated smoke detectors were provided in residents' sleeping areas.

The building had recently been retrofitted with a residential sprinkler system. The water supply to the building was provided from the municipal

system through a 1/2-inch galvanized steel water line approximately 40 ft in length, which was then attached within the basement crawl space, to a 1 1/2-inch CPVC (chlorinated polyvinyl chloride) plastic listed supply pipe and on to the sprinkler system riser. The remainder of the system was supplied with exposed, listed CPVC piping mostly installed in accordance with Underwriters Laboratories' listing criteria. It appears that the sprinkler system design was intended to conform to NFPA 13D. In addition, the design appeared to comply with the additional coverage requirements of NFPA 101, mentioned earlier. (See Figure 2) However, the system did not meet the supervisory requirements of paragraph 7-7.2.

Sprinkler plans prepared by a contractor indicate that the system was designed as a double loop system, consisting of mostly 1-inch diameter CPVC pipe with some dead-end lines of 3/4-inch CPVC. The first sprinklers to open in the vicinity of the origin of the fire were listed residential sidewall sprinklers of the frangible bulb type. These sprinklers have a nominal operating temperature of 155° F and a Response Time Index of about 68 (ft^{1/2}, s^{1/2}). System components also included listed residential pendent-type sprinklers. However, they were not considered in this analysis.

Under the provisions of their UL listing, the first such sprinkler operating must be provided with a minimum flow of 25 gpm at 21 psi, and the system must be capable of providing 36 gpm (18 gpm to each) with two sprinklers flowing, requiring a minimum pressure of 10.7 psi at each sprinkler. It should be noted that these flow requirements are considerably greater than the 18 gpm and 26 gpm minimums required by NFPA 13D, illustrating an

important checkpoint in the design of such a residential sprinkler system. Designers and code enforcement officials need to examine the listing requirements of residential sprinklers for they may vary from the minimum design criteria of 13D. In residential sprinkler designs where water supply is critical, such an error will likely impact on the performance of the system.

Listed CPVC piping is allowed to be exposed below a smooth, flat, horizontal ceiling where listed residential or quick response sprinklers are provided. Additional requirements of the listing for exposed CPVC piping specify that the sprinkler deflectors must be installed within 8 inches of the ceiling when using quick response sprinklers or in accordance with the listing when using residential sprinklers. There were some deviations from this requirement that were found on this system; however, they did not affect the performance of the system in this fire.

The fire originated in the centrally located day room. A couch positioned against one of the walls was ignited by an elderly occupant attempting to ignite his pipe. The open flame ignition of the couch soon resulted in activation of the smoke detector in the room, waking the owner's son. As he approached the day room, he observed the occupant seated in the center of the couch next to a cushion that was on fire; the flames were extending onto the wall and toward the ceiling. The 16-year-old began to lift the individual from the couch to carry him from the building. During this process, he heard a noise and felt a discharge of water from an operating sprinkler. This wetting action soon stopped, was followed by a second (but

similar) noise and a "sputter" from another sprinkler, and then no further action.

Several trips in and out of the building enabled the youth to rescue nine additional occupants from their rooms. Further, he instructed two others, a caretaker and an occupant, to move toward an exit and to stay low in the smoke. The youth continued the rescue action until the fire conditions drove him from the building. He then went to a mobile home on the property to alert his mother and stepfather of the fire. His mother called the fire department while his stepfather and the youth attempted to rescue additional occupants through the side exit. However, they were driven from the exit by flames that vented when they opened the exterior door.

Within four minutes of the 2:24 a.m. alarm, the first Bessemer fire company arrived on the scene and reported the fire had extended throughout the structure. Fire fighters began fire fighting and rescue operations. Because of the structure's high bedroom windows, the four remaining occupants were removed over ground ladders to the exterior. Despite the rescue efforts, four occupants perished as a result of the fire. The fatalities were all located in rooms between the central day room and the second means of egress; individual room doors were found in the open position.

The open flame ignition of the couch led to the rapid growth, development, and spread of the fire. Once ignited, the fire soon involved the polyurethane cushioning of the couch, which was the primary item burning when the first sprinkler activated, although it is believed that the multiple layers of

wallpaper contributed to the fire spread up the rear wall. As the unchecked fire continued to grow, it spread to other upholstered furniture in the day room, blocking the exits from this room and leading to untenable conditions and then flashover.

The activation of the smoke detector resulted in prompt alerting and rescue of the majority of the occupants. Inadequacy of the water supply to the automatic sprinkler system was a major factor in the outcome of the fire. Other factors also affecting the outcome appear to be the delayed alarm to the fire department and the arrangement of exits from the day room.

Investigators from the Bessemer Fire Department and the State Fire Marshal's Office concluded that the recently installed residential sprinkler system did not operate properly due to an inadequate water supply and that the domestic supply was incapable of providing the minimum water supply to even one sprinkler.

Water supply tests conducted after the fire indicate that adequate water supply was available from the municipal system along 19th Street. However, a flow test conducted of the 1/2-inch domestic supply revealed a considerable pressure drop and flow of approximately 5 gpm. Additional flow tests conducted at the riser determined that the supply for the system was 4-5 gpm at 1-2 psi. This inadequate water supply was present despite the high static pressures available to the system of 98 psi, illustrating the importance of understanding the differences between pressure and flow considerations in sprinkler system design, maintenance, and inspection. In addition to this major deficiency, the Bessemer Fire Department found

other deficiencies that further indicated the sprinklers system's noncompliance with 13D. They were:

- 1) Water flow alarm valve installed improperly.
- 2) Hangers not adequately secured.
- 3) Improper design to allow for proper testing of the system.
- 4) Some exposed CPVC piping not within the U.L. listing criteria.

Further, examination of the records revealed that the automatic sprinkler plans had not been submitted to the authorities for approval. The fire officials were not aware that the system had been installed and therefore did not inspect the installation for compliance with appropriate codes and standards and for adequacy of water supply.

Sprinkler drawings obtained by the investigators subsequent to the fire reveal that hydraulic calculations appeared to have been conducted on the system and that sprinklers specified on the plans were not the model actually installed.

Sprinkler Analysis²

The detector response computer model, DETACT-T2, was used to estimate the size of the fire at the time of sprinkler operation. Based on a presumed ambient temperature of 68° F, a radial distance of 3 ft to the sprinkler, and a

2 This analysis was done in cooperation with Russ Fleming of the National Fire Sprinkler Association.

vertical distance of the sprinkler 5 ft above the source of the fire, times to sprinkler response varied from 0.68 minutes for an "ultra-fast" fire to 2.64 minutes for a "slow" fire.³ (See Table 1) For surface ignition of foam-padded furniture, fire research has indicated that a fire growth rate between "medium" and "fast" appears most likely.⁴

Modeling Water Flow from Sprinklers

Because the sprinkler system was fed from the existing 1/2-inch domestic supply line, the water supply was severely restricted. It is likely that this domestic feed was the original installation, i.e., approximately 40 years old. Even with no simultaneous domestic use, the analysis indicates that the water supply was inadequate to support the residential fire sprinklers for more than a few seconds. In order to quantify the length of time sprinklers might have been supplied, the behavior of the sprinkler system was modeled as a small pressure tank. That is, at the time of the initial sprinkler operation the air trapped in the system would push out the water in the system. The water entering the system from the street main would play only a small role due to the restricted supply, i.e., 4-5 gpm at 1-2 psi.

Since there was no end-line test connection or drain, the system needed to be pressurized by incoming water against air at atmospheric pressure.

3 See NFPA 72E, *Standard on Automatic Fire Detectors*, Appendix C, and NFPA 92-B "Guide for Smoke Management Systems in Malls, Atria, and Large Areas," Appendix C.

4 See *The SFPE Handbook of Fire Protection Engineering*, Chapter 2-1.

Water would continue to flow into the system until the pressure reached the system static pressure (at the level of the sprinklers) of 98 psi or a total pressure of 112.7 psi (i.e., 98 psi [system] + 14.7 psi atmospheric).

The system's static pressure at the elevation of the sprinklers was approximately 113 psi. The volume taken up by the air trapped in the system (since again there was no test connection or drain) was estimated to be 2 gallons; total system volume was determined to be 15 gallons. This means that at the time of the fire, the system could have been expected to contain 2 gallons of air and 13 gallons of water.⁵

Calculations determined that the initial flow from the first operating sprinkler could have been expected to be about 54 gpm. This would quickly decline as the air was able to expand into the space of the vacated water and the pressure dropped.

The maximum time over which the sprinkler could have been supplied with water in accordance with its listing was determined to be 8.1 seconds. This corroborates the testimony of the young boy and clearly illustrates the inadequacy of the water supply and therefore the outcome of this fire.

5 The volume taken up by the air trapped in the system can be estimated assuming the air behaves as an ideal gas.

$$\begin{aligned}P_1V_1 &= P_2V_2 \\(14.7)(14.8) &= (112.7)V_2 \\V_2 &= 1.93 \text{ gal}\end{aligned}$$

A principal lesson from this incident is that residential sprinkler systems, as well as other fire protection systems and features must fully comply with all requirements of codes and standards. Sprinkler listing criteria must be closely examined to ensure compliance with the system's design. Further, we must not be deceived into thinking that adequate water supply is available because static water pressures are high. A flow test of the domestic supply to the building in this fire would have revealed this fact. Finally, building and fire officials must examine the approval, inspection, and licensing process for residential and other sprinkler installations to help ensure code compliance and life safety.

The record of life safety in buildings protected by sprinklers is excellent. The NFPA has no record of a multiple death fire in a completely sprinklered residential occupancy where the system was properly operating. Together with early warning detection, it has been demonstrated that residential sprinkler protection provides the highest level of firesafety for the home, where 80 percent of fire fatalities occur. NFPA investigation studies have demonstrated the life safety value of sprinkler systems in residential occupancies.

TABLE 1

Sprinkler Activation Times at Various Fire Growth Rates

<u>Fire Growth Curve</u>	<u>Time to Activation</u>	<u>Heat Release Rate At Activation</u>
Slow	2.64 minutes	69.9 BTU/sec (73.8 kW)
Medium	1.63 minutes	106 BTU/sec (112 kW)
Fast	1.04 minutes	174 BTU/sec (184 kW)
Ultra-Fast	0.68 minutes	299 BTU/sec (3415 kW)

Figure 1: Floor Plan and Fatality Location

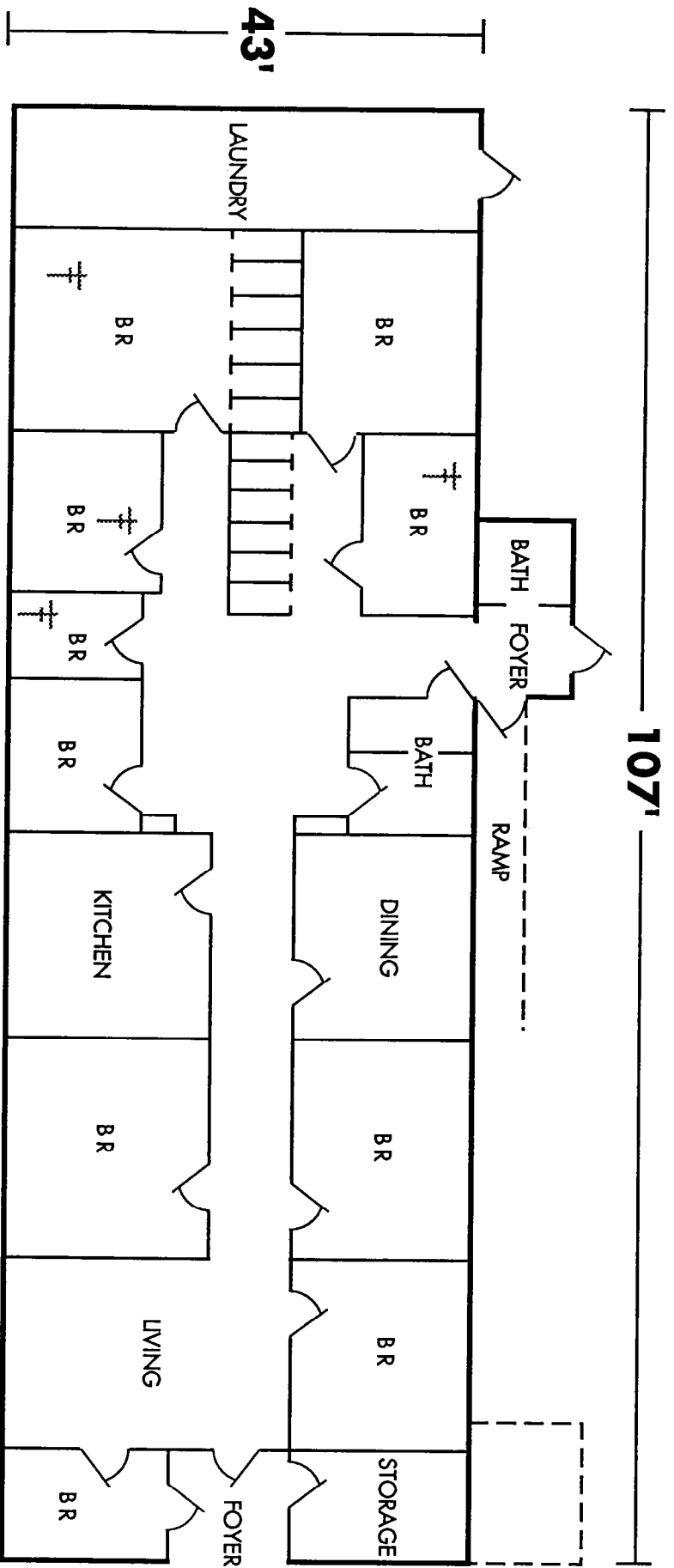


Figure 2: Sprinkler Locations

