The NIST Station Night Club Fire Investigation: Physical Simulation of the FIRE

By Daniel Madrzykowski, P.E., FSFPE, Nelson Bryner, and Stephen I. Kerber

Introduction

A fire occurred on the night of February 20, 2003, at The Station Nightclub located in West Warwick, RI. A band that was performing that night used pyrotechnics that ignited foam insulation lining the walls and part of the ceiling of the platform being used as a stage. Based on a video from a news camera operator who was present at the time of the fire, the fire spread quickly along the ceiling area over the dance floor. Smoke was visible in the exit doorways in a little more than one minute, and flames were observed breaking through a portion of the roof in less than five minutes. Egress from the nightclub was hampered by crowding at the main entrance of the building. One hundred people lost their lives in the fire, and hundreds were injured.

Engineers from the National Institute of Standards and Technology (NIST) Building and Fire Research Laboratory arrived at the fire scene within 48 hours to provide a reconnaissance report to the NIST director. Based on that report, NIST, under the authority of the National Construction Safety Team (NCST) Act, established an NCST to determine the likely technical cause or causes of the building failure that led to the high number of casualties in that fire. The complete NCST report[1] that documents the procedures, experiments, studies, findings and recommendations of the investigative team can be downloaded from *www.nist. gov/public_affairs/ncst.htm#Rhode_Island_Nightclub*.

The focus of this article is an overview of the physical testing and computational modeling that was conducted to develop an understanding of the fire growth and spread in the nightclub, the development of untenable conditions, and the potential impact of fire sprinklers on the both the fire and conditions inside the nightclub. This part of the article will provide an overview of the incident, the investigation and the full-scale fire testing. The full article (available at *www.FPEmag.com*) addresses the computer modeling that was used in the investigation and the effect that sprinklers, if they were installed, would have had.

Overview

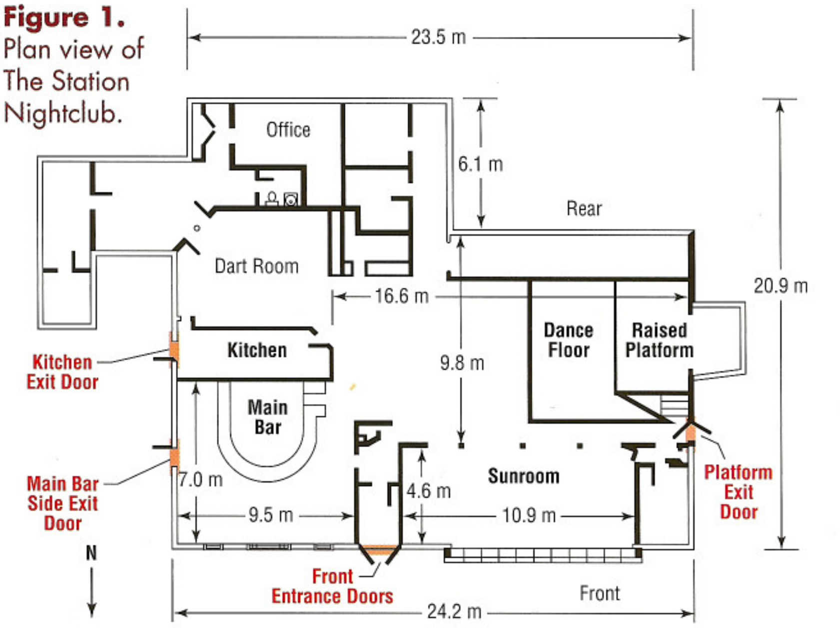
The Station Nightclub was a single-story wood frame structure with an area of approximately 412 m^2 (4484 ft^2). A plan view of the nightclub is shown in Figure 1. As with any fire investigation, it was important to develop a timeline of events and identify the fuel load inside nightclub, in terms of material type, quantity and location.

The timeline was developed from video footage taken during the fire by WPRI-TV,[2] published interviews with occupants by the *Providence Journal*, audio tapes and fire department records. The WPRI video and photographs from a variety of sources in addition to the post-fire site visit provided the information on the fuel load. These photos are included in reference 1.

Time "zero" was defined as the time that the polyurethane foam was ignited by the pyrotechnic devices. Two fires started, one on each side of the drummer's alcove. Approximately 30 seconds after ignition, the band stopped playing and the crowd began to evacuate. At 41 seconds after ignition, the fire alarm sounded and the strobes began to flash as the fire continued to spread across the back wall of the stage and in the alcove. The camera operator exited the building at 71 seconds after ignition, and smoke was flowing out of the front doorway. When the camera operator returned to the front doorway at 102 seconds after ignition, people were piled up in the doorway. People evacuated to the extent possible through the available doorways, broken windows in the sunroom and the windows in the main bar area. Occupants were still being assisted through the main barroom windows at four minutes after ignition. At approximately five minutes after ignition, flame came out of the front of the building. Seconds later, the fire department arrived and began to flow water in the area of the front door.

The first 300 seconds (five minutes) of the fire was the goal for the fire simulation. The type and composition of the materials that were identified as being present inside the nightclub were characterized generically as flexible polyurethane foam, ceiling tiles, wood paneling, carpet, gypsum board and an industrial pyrotechnic device. Photographs taken prior to the fire and the video taken the night of the fire were used to determine the quantity and location of the fuels that composed the interior finish. The materials testing conducted by NIST did not include any materials actually recovered from the nightclub.

Figure 1. Plan view of The Station Nightclub.



Technical Approach to the Simulations

In order to develop realistic Fire Dynamic Simulator (FDS)/Smokeview simulations, a significant number of physical experiments had to be conducted. The experiments were needed to characterize the interior finish fuels, especially the polyurethane foam, in terms that could be used as input to the FDS model.

Physical Simulations – Bench-Scale and Full-Scale Testing

Four test series were conducted: 1) polyurethane foam characterization; 2) cone calorimeter heat release measurements of interior finish materials; 3) pyrotechnic device tests; and 4) fire growth measurements in real-scale mockups of the platform, main floor and alcove.

Data from each of these test series provided insight into the material properties, fire spread, heat flux and fire growth of the different materials. The properties of the polyurethane foam that were measured included the density, ignition temperature and heat of vaporization, all of which are required to accurately simulate fire spread. The cone calorimeter measurements established an appropriate range of heat release rates for those materials tested. (Note that both fire-retardant and non-fire-retardant foams ignited and burned when exposed to an external thermal flux in the cone calorimeter.) The experiments that involved discharging pyrotechnic devices against a foam-covered wall verified that non-fire-retardant polyurethane foam could be ignited by a shower of sparks from a pyrotechnic device. The fire-retardant foam did not ignite in a similar test. The real-scale mockups of the platform, main floor and alcove provided data to evaluate the performance of the computer fire model. The information from all four test series led to an improved set of input data for the combustion model used in predicting the behavior of the fire and allowed a better understanding of the parameters that affected the performance of the computer simulation of the entire nightclub. The complete description of the testing, including experimental procedure, instrumentation and results, is given in the complete NIST report.[1]

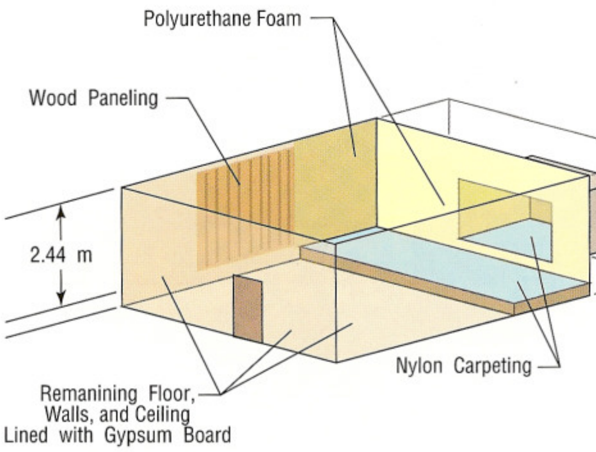


Figure 2. Floor plan showing the test area and the fuel locations.

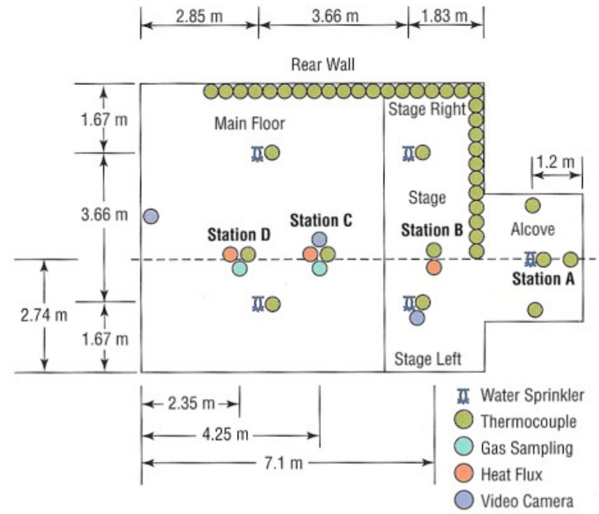


Figure 3. Schematic floor plan with instrumentation positions.

Real-Scale Experiments

Real-scale platform area mockup experiments were conducted to characterize the fire growth and spread in the early stage of the fire. Approximately 20 percent of the nightclub was reconstructed in real scale with polyurethane foam-covered walls, a drummer's alcove, a raised platform, carpeting and wood paneling. Data collected on fire spread (gas temperatures, heat fluxes and gas concentrations) allowed the performance of the computer fire model to be assessed. The degree to which the computer fire model is able to mimic the fire growth for this real-scale mockup is indicative of the quality of the simulation of the fire in The Station, within the limitations of uncertainty of the materials and imprecise dimensions for the actual nightclub.

Two real-scale experiments were conducted: one without automatic sprinklers and one with automatic sprinklers. By designing the real-scale mockup experiments carefully, in terms of controlling factors such as fuel and ventilation, the mock-up tests provided a means to determine the benefit of automatic sprinklers in a fire similar to what occurred in The Station and to gain insight as to conditions in the nightclub during the early fire growth and spread.

Test Configuration

The physical mock-up was recreated in the NIST large-fire laboratory. The overall floor dimensions of the test room were 10.8 m by 7.0 m, and the ceiling height was 3.8 m. A single opening, 0.91 m wide and 2.0 m high, was located in the wall opposite the alcove.

The test compartment was constructed with a structural steel frame lined with two layers of 12 mm thick calcium silicate board and covered with 12 mm thick gypsum board. The walls of the alcove and the raised floor area had 5.2 mm thick plywood paneling installed over the gypsum board, as shown in Figure 2. The plywood paneling extended 3.6 m from the raised floor along the rear wall of the test area. The rear wall was adjacent to the platform on the right as one stands on the platform facing the audience (stage right). A non-fire-retardant, ether-based, polyurethane foam was glued over the paneling in the alcove and along the walls on both sides of the alcove opening and to the rear wall, as shown in Figure 2. The foam was installed from the top of the wall down to 1.35 m above the floor. It was also applied to the ceiling of the alcove and extended for 2.4 m from the raised floor along the rear wall.

Instrumentation

The test room was equipped with thermocouples, video cameras, heat flux gauges, bidirectional probes, and gas extraction probes to measure carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), and hydrogen cyanide (HCN). In addition, fixed-temperature and rate-of-rise heat detectors were installed, as were sprinklers. In one test, the sprinklers were not supplied with water but were monitored for time to activation. Figure 3 is a schematic floor plan of the instrumentation positions.

Tenability Criteria

According to Purser,[3] a room becomes untenable for people when any of the following occur: the temperature exceeds 120°C (250°F), a heat flux exceeds 2.5 kW/m^2, or the oxygen volume fraction drops below 12 percent. These levels provide guidelines generally accepted by the fire protection engineering profession as leading to quick incapacitation but may be tolerated for a

	Temperature > 120 °C	Heat Flux > 2.5 kW/m2	Oxygen < 12 %	Hydrogen Cyanide > 0.02 %	Carbon Monoxide > 0.5 %
Sprinklered					
Location B	< 28 °C	not measured	not measured	not measured	not measured
Location C	< 24 °C	< 0.32 kW/m2	> 20.6 %	< 0.004 %	< 0.002 %
Location D	< 24 °C	< 0.21 kW/m2	not measured	< 0.0006 %	< 0.04 %
Unsprinklered					
Location B	71 seconds	not measured	not measured	not measured	not measured
Location C	76 seconds	61 seconds	87 seconds	71 seconds	82 seconds
Location D	71 seconds	61 seconds	85 seconds	75 seconds	92 seconds

Table 1. Time to reach tenability criteria, or maximum deviation obtained.

short (unspecified) time. Hydrogen cyanide and carbon monoxide also represent significant hazards to humans. The lowest concentration of a material in air that has been reported to have caused death in humans is termed Lethal Concentration Low (LCLo). The LCLo (inhalation) for hydrogen cyanide is reported as 0.02 percent for five minutes.[4] For carbon monoxide, the LCLo (inhalation) is listed at 0.5 percent for five minutes.[4]

Tenability Results

The upper portion of Table 1 summarizes the temperatures, heat fluxes, O_2 volume fractions, CO volume fractions and HCN volume fractions measured at locations B, C and D at an elevation 1.44 m above the floor (approximately head-height) for the sprinklered test. Also listed are the tenability criteria and LCLo levels. In the sprinklered test, conditions did not exceed any of the tenability criteria (temperature, heat flux or O_2 volume fraction) or the LCLo volume fractions for either HCN or CO during the entire duration of the test (> 200 seconds). The maximum values for temperature, heat flux, HCN and CO as well as the minimum value for O_2 that were recorded during the sprinklered test are shown in the table. Three of the five sprinklers installed in the experiment activated within 30 seconds of ignition. The other two sprinklers did not activate.

In the test with the unsprinklered mock-up (see Figures 4–6), the temperature criterion can be seen in Table 1 to have been exceeded in less than 76 seconds at all three locations. The thermal flux exceeded 2.5 kW/m^2 in about 60 seconds. At sampling locations C and D, the O_2 concentration dropped below 12 percent in less than 87 seconds. The HCN concentrations exceeded the LCLo in less than 75 seconds, and the CO concentrations reached the LCLo in less than 92 seconds.

Note that exceeding the tenability limit does not imply that any or all occupants who were present in that environment would succumb due to a particular limit exceeded. The length of time exposed, the rate of change of the environmental conditions, possible antagonistic effects and the susceptibility of the individual all play a role. Given the rapid spread of the fire and combustion products, it is probable that the victims succumbed to multiple conditions. If conditions developed in The Station in the same manner as during this experiment, most occupants likely would have had less than 90 seconds to escape under tenable conditions.

To view the full article, which includes computer model simulation of The Station Nightclub fire and recommendations that resulted from NIST's investigation, visit *www.FPEmag.com.*

Figure 4. Visible smoke spreading across ceiling, t = 30 s after ignition.

Figure 5. Flashover has occurred in alcove area, t = 60 s after ignition.

Figure 6. Visibility lost, t = 90 s after ignition.

Daniel Madrzykowski, Nelson Bryner and Stephen Kerber are with the National Institute of Standards and Technology.

References

1 Grosshandler, W.L., Bryner, N., Madrzykowski, D., Report of the Technical Investigation of the Station Nightclub Fire, NIST NCSTAR 2, National Institute of Standards and Technology, Gaithersburg, MD, June 2005.

2 Butler, Bryan, Video by WPRI, Channel 12, Feb. 20, 2003.

3 Purser, D., "Toxicity Assessment of Combustion Products," *The SFPE Handbook of Fire Protection Engineering*, Third Edition, National Fire Protection Association, Quincy, MA, 2002.

4 Lewis, R.J., *Sax's Dangerous Properties of Industrial Materials*, Ninth Edition, Van Nostrand Reinhold, New York, NY, 1995.