STP1336-EB/Oct. 1998

Overview

Time and again, it has been observed that the rules governing fire behavior appear to change as the intensity and scale of the fire increase. Sometimes, conditions combine to produce events that surprise and amaze all of us, often with tragic results. Well known examples of such severe fires include:

a) The Dupont Plaza hotel fire—hot, fire gases from a growing, ventilation-controlled fire in one part of the hotel/casino complex were transported to another part of the complex. This resulted in a rapid flashover in that area.

b) The Piper Alpha offshore platform—a sequence of explosions and fires eventually caused this platform to sink in the North Sea.

c) The Apollo Space Capsule fire—an oxygen-enriched atmosphere accelerated burning.

d) In Mississauga, Ontario—a tankcar fire generated a boiling liquid/expanding vapor explosion that destroyed a large area.

e) The Berkeley Hills fire—this fire in a wildland/urban interface demonstrated the importance of more fire resistive construction and the need to control vegetation near structures.

f) The Storm King Mountain wildfire in Colorado—a number of fire fighters were killed when the fire jumped over their position.

The keynote address for the symposium was appropriately titled "A Review of Very Severe Fires." Dr. John R. Hall, Jr. Assistant Vice President of the National Fire Protection Association, described a study of the 36 largest-loss fires of the quarter century from 1971 through 1995. In all of these fires, direct property damage equaled or exceeded $100 million in 1995 dollars. These incidents demonstrated several common situations—fires in the wildland/urban interface, a vapor cloud or other very large initiating explosion, gaps in sprinkler coverage or other sprinkler problems, or fires in areas where there was extremely high value per square foot of exposed space. In the study, special attention was given to the physical area involved in the fire and the distance over which the effects of the fire were felt. Such distance factors are important considerations in our ability to model or otherwise represent these important fires for purposes of performance-based design or other calculation-supported decision-making. The 36 fires ranged in size from a low of 1200 square feet for a cable fire in a telephone switching station to a high of 5.1 billion square feet (184 square miles) in a wildfire.

Fire losses in North America are high when compared to other developed countries. According to the Building and Fire Research Laboratory at the National Institute of Standards and Technology, the economic cost of fire safety and fire losses in the United States exceeds $100 billion per year. One of the keys to saving lives and reducing dollar losses is improved understanding of complex fire phenomena. Very large-scale fires, as described above, generally cause the greatest number of deaths, or the largest monetary losses, or both. As a result of their spectacular nature, they also generate the most headlines. The publicity produces calls for action on the part of government and fire safety organizations.

Fires involve several highly nonlinear physical phenomena, such as combustion and turbulence and radiation heat transfer. Individually, these phenomena are difficult to understand. Coupling of these nonlinear phenomena make understanding any fire a very challenging proposition. However, the changing rules in very large-scale fires is believed to be a result of strong coupling between these nonlinear phenomena.

Very large-scale fires are difficult, if not impossible, to replicate completely. Studying or modeling the accidents and conducting large-scale experiments provides insight into the coupling between the various fire phenomena. Large-scale experiments are needed to capture the important physics. However, these experiments are very costly. Given their complexity and volume, they are difficult to instrument and understand.

We use a variety of experimental and analytical tools in our attempt to understand the special hazards and risks associated with these fires. The tools of fire science include:

1) Developing scaling laws, correlations, and parametric models.

2) Developing numerical models ranging in complexity from zone models based on differential equations up to three-dimensional field models based on computational fluid dynamics codes.

3) Using forensic techniques to attempt to reconstruct the events in fires as well as guide both our models and experiments.

4) Conducting large numbers of laboratory experiments to study the physics and the materials' reaction-to-fire.

5) Conducting smaller numbers of intermediate and large-scale experiments as a means of validating scaling laws and analytical/numerical models as well as for evaluating fire protection techniques.

The Table of Contents indicates some of the many and varied types of fires that occur. We attempt to model and understand these diverse fires using this whole arsenal of tools because the events and phenomena are so complex. Although it would be desirable to have models that could accurately predict the complex behavior of fires, this is a long way off. Given the complexity and diversity of fires along with the assumptions and limitations inherent in any model, it is no surprise we often disagree. In this respect, studies of fire are no different than many other walks of life. Even though our models are not perfect, one thing must be remembered. *The purpose of all of these models is insight.*

What is important? To improve our understanding of fire behavior and translate this understanding into public practice to help reduce fire-related injuries and deaths. Through a lot of hard work, we keep learning and keep improving the tools in our arsenal. As documented in these proceedings, the capabilities of our experimental and analytical models are improving steadily.

ASTM Committee E-5 on Fire Standards sponsored this symposium to promote communication and aid progress in this important area of fire safety. All of the tools mentioned above were touched on during this symposium. In fact, a number of the papers demonstrated the effectiveness of using more than one type of tool in an interactive fashion. As in other areas of fire science, significant progress has been generated by using experiments to help develop analytical models and analytical models to help design experiments.

The symposium program was organized into three areas:

Rapid or Large Structure Fires

This section includes fires that develop rapidly, such as the wind-driven fire at the Branch Davidian Complex, fires in high-rise apartment buildings, techniques for extracting additional information from earlier test burns, and the High Temperature Accelerant Arson Demonstration Burn. In particular:

"Fire Development and Fatality Analysis of the 19 April, 1993 Fire at the Branch Davidian Mt. Carmel Center, Waco, Texas"—Fires were started in several locations in a large wooden structure; they were driven by the wind into a conflagration. Seventy-six people perished in the fire. This paper describes the results of an independent investigation into the events that occurred.

"Analysis of Full-Scale Fire Tests of Wall Linings in Ranch House"—Large-scale experiments of any kind are expensive. This paper looks at techniques for extracting and correlating additional information from the numerous test burns of houses that have been conducted over the years.

"High-Temperature Accelerant Arson—Revisited"—A series of unusual fires in the Pacific Northwest were eventually called the High-Temperature Accelerant Arson Fires. These were unusual fires given their extremely rapid development in large structures, even those with low fuel loads. They melted steel and caused premature collapse of heavy timber construction. The unusual fire characteristics resulted in the deaths of two fire-fighters. This paper describes a demonstration burn conducted in a 1900-square-meter, single-story, strip shopping center building to support the Seattle Fire Department's arson investigation. The burn produced flashover in approximately two minutes and a large backdraft event.

"Large Compartment Fire Tests on a Full-Scale Eight Storey Building"—A purpose built, high-rise, steel frame structure was used to study the behavior of multi-storey buildings subjected to real fires. The fire data are being used to validate models for structural analysis at elevated temperatures and evaluate parts of the forthcoming Eurocodes.

Industrial and Wild Land Fires

This session looks at the causes and character of fires and explosions. Topics include boiling liquid—expanding vapor explosions (BLEVE) which have caused massive damage in both LPG storage facility and railcar accidents, the development of a scale model experimental facility for studying the generation of dangerous fire whirls, characterization of large petrochemical fires, and the use of CFD modeling for studying fire brand transport in forest fires. In particular:

"Estimates of the Extent and Character of the Oxygen-Starved Interior in Large Pool Fires"—Large hydrocarbon pool and spill fires have very different characteristics than structural fires. There has been a concerted effort over a number of years to define the thermal exposure of objects engulfed by or adjacent to these fires. This paper describes experimental data from JP8 fires (19 meter diameter—heat release rate of 800–900 MW) and the use of CFD codes to help interpret the results.

"Time-Dependent Model of Forest Fire Spread in Turbulent Gusting Cross Winds"—Forest fires can produce tremendous updrafts and transport burning embers long distances. These fire-brands can cause spot fires well beyond the current fire line and pose a significant danger to fire fighters. This paper examines the development of a CFD model for predicting the trajectories of fire-brands. The purpose is to develop tools for forest fire management and reduce the risk of fighting these fires.

"Reconstruction of Very Large-Scale Fires—Fire whirls have been generated following earthquakes as well as in wars and forest fires. These whirls can produce tornado-like winds. A mass fire broke out following a severe earthquake in Tokyo; winds in a fire whirl generated by the mass fire were estimated to be over 70 m/s (157 miles/hour). This paper covers the development of a dimensional analysis and scale model test facility for studying the production of fire whirls.

"Boiling Liquid Expanding Vapor Explosions (BLEVE): Possible Failure Mechanisms"—BLEVEs can produce devastating explosions and highly radiative fireballs. A series of experiments exposed 2-ton, pressure liquefied gas vessels to jet fires. Based on an analysis of the catastrophic vessel failure, this paper postulates a two-step process. First, there is initiation of a crack in the vapor-wetted area of the vessel. Nearly instantaneous release of the contents results from rapid crack propagation (unzipping) in the tank wall.

Marine Fires

This session covers testing of Halon replacement agents such as water mists, the thermal exposure of radioactive material shipping containers in marine fires, and smoke movement in passenger ships. In particular:

"Evaluation of Large-Scale Marine Fire Protocols"—International agreements require the replacement of Halon-based fire suppression systems. Water mist or gaseous agent systems are potential replacements. This paper reviews large-scale experimental evaluations of the effectiveness of such systems for protecting critical machinery spaces.

"Experimental Measurement of a Shipboard Fire Environment with Simulated Radioactive Material Packages"—The public is concerned about the potential release of hazardous materials in fires. This paper describes a series of experiments used to define the potential thermal exposure of radioactive material shipping containers due to fires in a ship's hold. Large pipe calorimeters were used to simulate containers and measure heat fluxes generated by pool, spray, and wood crib fires. The experiments were conducted at the U.S. Coast Guard's large test facility in Mobile, Alabama.

"Full-Scale Model Tests of Smoke Movement in Ship Passenger Accommodations"—Ships and offshore platforms share special fire safety concerns because their relative isolation means they need to control fires by themselves for more extended times. In passenger ship fires, smoke has been identified as one of the major threats to the passengers and crew. This paper describes experiments, conducted in a specially built test facility, to study smoke transport away from the point of fire origin.