Sandia National Laboratories

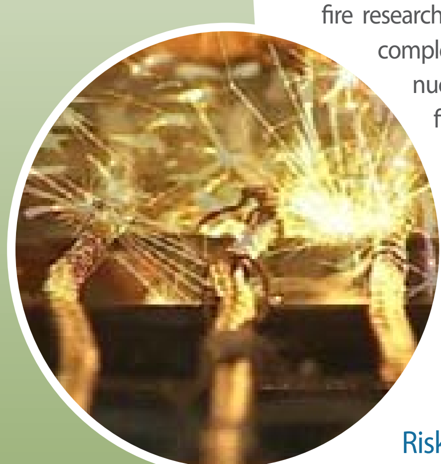
Energy, Climate & Infrastructure Security

Fire Science

Sandia National Laboratories uses modeling and experimental validation of fire behavior to inform and improve risk models and probabilistic risk assessments (PRAs) for nuclear energy infrastructure design and operation.

Historical Groundwork in Fire Research for the Nuclear Energy Infrastructure

The cable spreading room fire at Browns Ferry Nuclear Power Plant in 1975 illustrated the need for increased research into safety system reliability during abnormal events such as fire. Months prior to the incident, the US Nuclear Regulatory Commission contracted with Sandia to begin analyzing nuclear fire safety. For over 35 years, Sandia has conducted experimental nuclear fire research to address increasingly important and complex risk and reliabilities studies. Current nuclear-specific fire research investigates fire phenomenology and the effects of fire on various nuclear energy applications and components, including circuit reliability. Whether it's investigating fire induced small component failure or a large-scale configuration, this capability is used to quantify the overall fire risk of a nuclear power plant.



Electrical arcing behavior during dc-circuit fires.

Risk Assessment and Informed Decisions

Sandia's fire science research in nuclear energy infrastructure plays a significant role in ensuring the safe, secure, and responsible operation of nuclear power plants worldwide. In addition to providing the scientific basis for cable and circuit testing and evaluation, transportation vulnerabilities, metal fire phenomenology, and spent fuel pool ignition phenomena, Sandia's research is instrumental in developing accurate probabilistic risk assessments (PRAs). PRAs are used by industry and regulatory agencies to assess potential vulnerabilities by quantitatively characterizing risk through two factors: likelihood that the threat situation would arise and the severity of possible adverse effects. Through research and experimentation in areas including basic fire behavior, fire modeling, fire protection engineering, and structure fire protection regulation compliance practices, Sandia's nuclear fire protection work leads the field in characterizing and evaluating fire risks and protection strategies necessary for the safe operation of nuclear energy infrastructure.

(Above) Upper region of prototypic pressurized water reactor spent fuel assembly after ignition.

(Left) Sodium spray characterization.

Key Experimental Programs

Recent research by Sandia's scientists and researchers includes work in further characterizing fire behavior in nuclear-specific applications. The experimental data is also used to validate complex models of fire incident progression and dynamics. Sandia's Energized Cable Fire Program investigates elements of cable performance when exposed to a thermal environment. Cable performance research is applied to circuit reliability studies to investigate failure modes such as hot shorting behavior and spurious operation of components. Researchers use custom built equipment to test circuits and study electrical insulation degradation during thermal exposure.

Sandia researchers have worked on characterizing spent fuel assembly fires utilizing a phased experimental approach to study Zircaloy fires in prototypic spent fuel assemblies. Two test series were conducted to examine the behavior of prototypic boiling water reactor (BWR) and pressurized water reactor (PWR) fuel assemblies during a complete Loss-of-Coolant accident in a spent fuel pool. This work advanced the state-of-the-art in thermal hydraulics modeling during heat-up and the phenomenology of zircaloy combustion which supported computational simulation validation.

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U.S. DEPARTMENT OF ENERGY

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Significant research has also been conducted to explore the characteristics of liquid sodium fires. Advanced reactors may employ liquid metal coolants, such as sodium, because of the many desirable thermodynamic properties of the coolants. Because liquid sodium will auto-ignite in air, the fire safety concerns associated with accidental leaks were investigated by experiments with ranges of sodium pool fires and sodium spray fires. In addition, a sodium pool fire model was developed that incorporated the growth of the surface oxide layer in liquid sodium pool fires. This is an example of how Sandia research continues to impact regulations and industry guidance.

The Nation's Leading Fire Testing Facilities

Located in Albuquerque, N.M., the fire testing facilities available at Sandia include a large variety and range of capabilities.

• Thermal Test Complex (TTC): The TTC provides a controlled environment in which to evaluate the performance of components and assemblies under controlled temperatures (up to 2,200°C) or programmed heat fluxes (up to 200 W/cm2) and includes facilities such as the FLAME Test Cell, the Cross Flow Fire Test Facility, and the Radiant Heat Test Cell. These facilities provide capabilities in both quiescent (calm) wind and wind speeds up to 20 mph.

• Surtsey Test Facility: The Surtsey test facility features a sealed pressure vessel used to conduct accident phenomenology testing including steam explosions, hydrogen detonations, core melt progression, core concrete interactions, high pressure melt ejections, and liquid metal fire testing.

Illustration of the Thermal Test Complex.

• CYBL Test Facility: The CYBL facility features a scaled reactor pressure vessel system originally designed for severe accident cooling studies. It also provides an outstanding controlled environment for Sandia's recent spent nuclear fuel combustion experiments.

• Lurance Canyon Burnsite Facility: The facilities within Lurance Canyon are used to study both indoor and outdoor fires associated with nuclear material transportation and handling accidents for safety studies and for evaluating and certifying hazardous material shipping containers. Tests at Lurance Canyon also include rocket propellant fires and test units containing explosives. The facility includes an enclosed pool fire test facility, three open pools used to simulate liquid fuel fires, an igloo structure used to simulate building fires and hot spots in weapons storage bunkers, and a 1.8 m round pool enclosure for smoke reduction tests.

Fire Risk Analysis

By investigating and characterizing fire behavior in unique situations, fire risk analyses and modeling are made more accurate. Improved risk quantification and validated fire models support risk-informed decision making in the nuclear energy infrastructure design and operation and ultimately improve facility operation and promote public safety.

Publications

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