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RP

BURN MODE ANALYSIS OF
HORIZONTAL CABLE TRAY FIRES

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ABSTRACT

Electrical cables constitute a serious fire hazard for nuclear power plants because the plastic insulation material is combustible and large quantities of cables are used in the plants. Nuclear power plant fires often continue to burn in the presence of smoke, whereas building fires usually burn in the presence of clear air, since smoke escapes through windows and doors before descending to the fuel. Fire growth classifications (realms) by the National Fire Protection Association (NFPA) thus may not be completely applicable for fire hazards analyses of nuclear power plants.

Electrical cable fire tests have been conducted at the Sandia Fire Research Facility in Albuquerque, New Mexico, in order to evaluate cable tray fire safety criteria for the Nuclear Regulatory Commission. A burn mode concept was developed in order to describe and classify the thermodynamic phenomena which occur in the presence of smoke and to compare the fire growth and recession of different cable types under otherwise unchanged fire test conditions. The importance of deep seated fires in cable trays from the standpoint of propagation, detection, and suppression is emphasized. The cable tray fire tests demonstrate that fire recession and deep seated fires can result from a descending smoke layer and that reignition and secondary fire growth is possible by readmission of fresh air.

V. SUMMARY AND CONCLUSIONS

Quantitative temperature records from 21 fire tests of horizontal cable trays were reduced to thermodynamically defined burn modes in order to develop a physical classification of fire phenomena which meets NRC Regulatory Guide 1.170 requirements for fire hazards analysis. This data base is neither statistically significant nor extensive enough to cover the wide range of architecture, ventilation, and fire protection design parameters encountered in LWR plants. The tests do, however, provide important insight as to how a suitable classification of fire phenomena might be developed, especially for electrical cables.

Burn modes describe local volatilization and combustion reactions which have been observed in many porous fuel and flammable liquid fires. A preliminary classification method was developed which identifies such reactions using only the time history of fuel internal and surface temperatures.

The classification of raw data records from 21 special effects cable fire tests into data segments, which reflect one burn mode each, confirmed flame aspects of the generic burn mode reactions with independent observations of flames and post-test inspection of charred surfaces. There was good correlation between the phenomena indicated by burn mode analysis with flame and char observations from tests for which TV films were available. These tests covered three different types of fire retardant materials, two different cable combinations and four different tray stack geometries as well as a full scale 17 tray replication of an LWR fire zone. This partial verification of burn modes encourages us to think that our preliminary test record classifications might indeed give generic descriptions of fire phenomena that are applicable for a wider range of architectural fire zone parameters as well as for a wider range of ventilation and fire suppression system operations. Further verification of the generic nature of burn modes is warranted.

The following conclusions are tentative, since they are based on the 21 test data base which is considered meager as mentioned above. They are nevertheless given to illustrate the insight which burn mode analysis can provide for confirmation or modification of fire protection requirements.

1. The cable fire burn modes reflect volatilization reactions and oxygen consumption modes, that have been observed previously in full scale compartment fire tests. This commonality should provide a

technical basis for confirming or modifying principles of industrial fire prevention and control for LWR plants.

2. Duration of burn modes and transitions between burn modes depend on fuel chemistry, fuel arrangement and smoke descent. A reproducible simulation of entire fire life cycles is unlikely since many different patterns of fire growth and recession can develop from the same fuel configuration once the fuel is volatilized.
3. Burn mode analysis provides a new physical definition of deep-seated fires that allows monitoring on-line. The screening method of this paper illustrates the principles for such monitoring, and also reveals that both propagation and reignition of cable fires are frequently preceded by a deep-seated fire in excess of 1 minute duration. The temperature criteria for deep-seated fires thus represent a direct indicator of fire growth potential that has been derived from a cable fire replication test and 21 associated special effects tests.
4. Burn mode analysis of fire confinement and fire suppression verification tests is needed to confirm that prevention of deep-seated fires will prevent fire propagation between fuel elements that meet Regulatory Guide 1.75 separation requirements. With this information NRC fire protection requirements could possibly be verified in special effects tests without replicating full-scale LWR fire zones and/or protection system operations.
5. Deep-seated fires were generated in the electrical cable tests by a hovering layer of burned gas. In horizontal cable trays such hovering was caused by a descending fire ball and/or by a descending smoke blanket. Consideration should thus be given to inspecting existing porous fuel arrangements for previously unknown fire propagation hazards associated with trapping of burned gas.
6. The use of fire retardant materials (IEEE-383 cable qualifications, cable tray coatings) tend to increase the duration of deep-seated cable fires. A reasonable doubt thus exists that industrial experience with IEEE cable qualification and fire retardant coatings applies fully to multiple cable tray arrangements.

The use of fire retardant materials does significantly reduce the probability of self-sustained surface fires, but associated longer-lasting deep-seated fires might increase the probability of propagating surface fires once started.