Fire PRA Insights from a Review of NPP Fire Events

Presented at

USNRC Fire Risk Research Workshop

August 23-24, 2001

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This presentation is based on:

Steven P. Nowlen, Mardy Kazarians, and Francis Wyant, "Risk Methods Insights Gained from Fire Incidents", U.S. Nuclear Regulatory Commission, NUREG/CR 6738, SAND2001-1676P, to be published September 2001.

Fire Risk Methods Program Task 5: NPP Fire Events Review

- Sponsored by USNRC/RES/PRAB
- One of several technical tasks designed to improve fire PRA methods in key need areas
- Task Objectives:
  - Identify fire risk/PRA insights from NPP fire events
  - Identify areas for improvement in fire PRA methods

Approach

- **Event Selection Criteria:**
  - “Severe” Fires - classical fire protection perspective
  - “Challenging” Fires - nuclear safety perspective
  - “Interesting” Fires - illustrates unique behavior

- **Analyzed each event from two angles**
  - Reviewed the chronology of each event to verify how fire PRA would address the elemental occurrences
  - Matched the elemental occurrences of an event against elements of a fire PRA

25 Nuclear Industry Fire Events Reviewed

- San Onofre, Mar. 12, 1968
- Mühleberg, July 21, 1971
- Browns Ferry, Mar. 22, 1975
- Greifswald, Dec. 7, 1975
- Beloyarsk, Dec. 31, 1978
- Fort St. Vrain, Oct. 3, 1987
- North Anna, July 3, 1981
- Armenia NPP, Oct. 15, 1982
- Rancho Seco, Mar. 19, 1984
- South Ukraine, Dec. 15, 1984
- Zaporozhye, Jan. 27, 1984
- Kalinin, Dec. 18, 1984
- Maanshan, July 1, 1985
- Waterford, July 14, 1985
- Ignalina, Sep. 5, 1988
- Oconee Jan. 3, 1989
- H. B. Robinson, Jan. 7, 1989
- Calvert Cliffs, Mar. 1, 1989
- Shearon Harris, Oct. 9, 1989
- Vandellos, Oct. 19, 1989
- Chernobyl 2, Oct. 11, 1991
- Salem, Nov. 9, 1991
- Narora, Mar. 31, 1993
- Waterford, June 10, 1995
- Palo Verde, Apr. 4, 1996

Key Observations

- Fire can pose a serious threat to nuclear safety
- Operator actions are influenced by and do influence the chain of events in a fire incident.
- Multiple fires are a possibility
- Fire in non-safety areas may be important

Key Observations (cont.)

- Materials of construction and plant layout can have a strong influence on the outcome of a fire
- Smoke propagation can be an important element of a fire scenario
- A fire involving cables may cause unexpected circuit faulting effects
- Long duration fires may not be so rare

Fire Posing a Serious Threat to Nuclear Safety

- Browns Ferry, 1975 – Loss of normal cooling
- Greifswald, 1975 – Station blackout, PORV fail open (independent event)
- Beloyarsk, 1978 – Significant loss of core cooling functions
- Armenia, 1982 – Station blackout
- Narora, 1993 – Station blackout

Operator Actions and Fire

- **Actions under adverse conditions:**
  - Browns Ferry, 1975 – Used an unconventional core cooling method
  - Greifswald, 1975 – Laid down cables to restore power
  - Armenia, 1982 – Laid down cables to restore power; worked in smoke filled control room
  - Narora, 1993 – Connected a diesel driven fire pump to recharge a steam generator
- **Actions that aggravated the chain of events:**
  - Waterford, 1985 – Called for the wrong pump to be shutdown
  - Waterford, 1995 – Delayed fire brigade activation
  - Oconee, 1989 – Operator error led to overcooling

Operator Actions and Fire (continued)

- **Actions prior to fire occurrence:**
  - **Browns Ferry, 1975 – Similar ignitions were experienced a few days before the March 22 fire**
  - **Armenia, 1982 and South Ukraine, 1984 – Fire suppression system was switched to manual mode**
  - **H.B.Robinson, 1989 – Maintenance crew error led to multiple fires**

Possibility of Multiple Fires

- An initiating event may lead to multiple fires
  - Armenia, 1982 – Multiple fires due to the same cause
  - Kalinin, 1984 – Pump motor failure led to other electrical fires
  - H.B.Robinson, 1989 – Maintenance crew error led to hydrogen release at multiple points
  - Calvert Cliffs, 1989, Sharon Harris, 1989, and Palo Verde, 1996 – Electrical short circuit led to multiple electrical and other fires.

Possibility of Multiple Fires (continued)

- A fire may lead to other (secondary) fires
  - Armenia, 1982 – Secondary fire occurred due to equipment failure
  - Kalinin, 1984 – Cable fire inside containment led to relay coil fire outside the containment
  - Browns Ferry, 1975 – Cable fire led to small fire inside a MCR control panel
  - Sharon Harris, 1989 – Hydrogen fire led to oil leak and fire.

Fire in Non-Safety Areas

- Large turbine building fires have had significant impact
  - Mühleberg, 1971 – Structural damage and potential loss of multiple trains
  - Beloyarsk, 1978 – Structural damage and propagation to control building.
  - Vandellos, 1989 – Multiple safety train failure, flooding in basement of turbine and auxiliary buildings, and structural damage.
  - Narora, 1993 – Significant cable damage and smoke propagation leading to station blackout, loss of control room habitability, and loss of power to alternate control station.
- Oconee 1989 - Overcooling incident occurred as a result of non-safety switchgear fire

Influence of Design Characteristics, Layout and Materials of Construction

- Location of cables influenced the outcome of the fire
- Self ignited cable fires were experienced (San Onofre and Soviet-designed plants)
- Rapid propagation of fire was experienced in cable shafts (Soviet-designed plants)
- Barrier failure was experienced under various conditions (Soviet-designed plants)
- Automatic fire suppression system was overwhelmed in a few cases

Importance of Smoke Propagation

- **Browns Ferry, 1975 – Smoke hindered recovery actions and fire fighting**
- **Beloyarsk, 1978 – Smoke adversely affected control room operators**
- **Armenia, 1982 – Smoke hindered fire fighting and entered the control room**
- **Fort St. Vrain, 1987 - Smoke entered control room forcing operators to use air masks**
- **Vandellos, 1989 – Smoke entered the control room and other parts of the plant**
- **Narora, 1993 – Smoke caused control room evacuation**

Circuit Faulting Effects Caused by Cable Fire

- Browns Ferry, 1975 – Possible wrong indications and spurious actuations
- Armenia, 1982 – Main generator breaker closed, diesel generator disconnected, and one feedwater pump started
- Ignalina, 1988 – Breakers opened and equipment tripped inadvertently
- Chernobyl, 1991 – Damaged cable initiated the chain of events
- Waterford, 1995 – Erratic indications on the control panel

Duration of Fire

Duration	# of events	
Less than 1 minute	**3**	Robinson, Calvert Cliffs, Palo Verde
1 to 10 minutes	**1**	Waterford (1985)
10 to 30 minutes	**3**	Fort St. Vrain, Rancho Seco, Salem
30 minutes to 1 hour	**3**	San Onofre, Ignalina, Oconee
1 to 2 hours	**2**	Greifswald, North Anna
2 to 5 hours	**4**	Mühleberg, Kalinin, Shearon Harris
between 5 and 10 hours	**6**	Browns Ferry, Armenia, South Ukraine, Vandellos, Chernobyl, Narora
greater than 10 hours	**3**	Beloyarsk (22 hrs.), Zaporozhye (18 hrs.), Maanshan (10 hrs)

Duration of Fire (Continued)

- Long fire duration can be attributed to:
  - Severity of fire
  - Dense smoke
  - Delayed decision to activate fire brigade
  - Delayed decision to use water on an electrical fire (three cases)

Conclusion

- Key elements of fire PRAs were found to be consistent with elements of the events
- Current techniques are capable of addressing most of the issues raised in this study
- Fire can lead to nuclear safety challenges