Fire Events in Nuclear Power Plants – Operating Experience Collected in the OECD/NEA FIRE Database

Dr. Marina Röwekamp (GRS, Germany)
- Chair of the FIRE Database Project -

ENSREG

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Introduction

- Background
  - Due to the significance of fires and their risk contribution the FIRE Database Project was initiated in 2001 for collecting and analysing fire event data from NPPs
  - Meanwhile in Phase 6 (2020 – 2022), the Project has 14 member countries from Europe, Asia and North America
    - Belgium
    - Canada
    - Czech Republic
    - Finland
    - France
    - Germany
    - Japan
    - Republic of Korea
    - Netherlands
    - Spain
    - Sweden
    - Switzerland
    - United Kingdom
    - United States of America
  - Actually, there is interest from two other countries for participation

Objectives

- Collect fire event experience by international exchange in an appropriate format in a quality-assured and consistent database
- Collect and analyse fire events over the long term so as to better understand such events and their causes, and to encourage their prevention
- Generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences
- Establish a mechanism for efficient operation feedback on fire event experience including the development of policies of prevention, such as indicators for risk-informed and performance-based inspections
- Record characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies

FIRE Database Applications

- One goal of data collection: generation of generic fire frequencies for different reactor types and plant operational states (POS) for PSA use
  - FIRE covers meanwhile more than 550 events representative for 9.726,81 ry
  - 534 of these events have not been excluded from statistics
    - 340 during power operation
    - 153 during low power and shutdown modes (shutdown, hot stand-by, start-up, long-term safe shutdown)
    - For the remaining 41, no frequencies can be assigned (e.g. events during construction)
- Other applications with significance for regulatory assessments include but are not limited to:
  - In-depth investigations of fires as singular events and as combined events of fires and other events (mainly other hazards)
  - Analysis of apparent and root causes of fire events
  - Modelling of real fire scenarios, e.g. by a common benchmark exercise for a cable fire event selected from the FIRE Database

Generic Fire Occurrence Frequencies

- For generating generic fire frequencies for NPPs in FIRE Database member countries, corresponding observation times are systematically collected and updated for each reactor on a yearly basis
- Information according to FIRE Database Coding Guideline:
  - Plant identification
  - Reactor type
  - If reactor is part of a multi-unit and/or multi-source NPP site
  - As far as applicable; start and end dates of
    - Commercial plant operation, sub-divided into power operation and low power and shutdown phases
    - Post-commercial safe shutdown
    - Observation period
  - Periods (years), for which the event data submission is complete

Room Type Specific Fire Occurrence Frequencies (1)

Room types per buildings table to be filled for each NPP

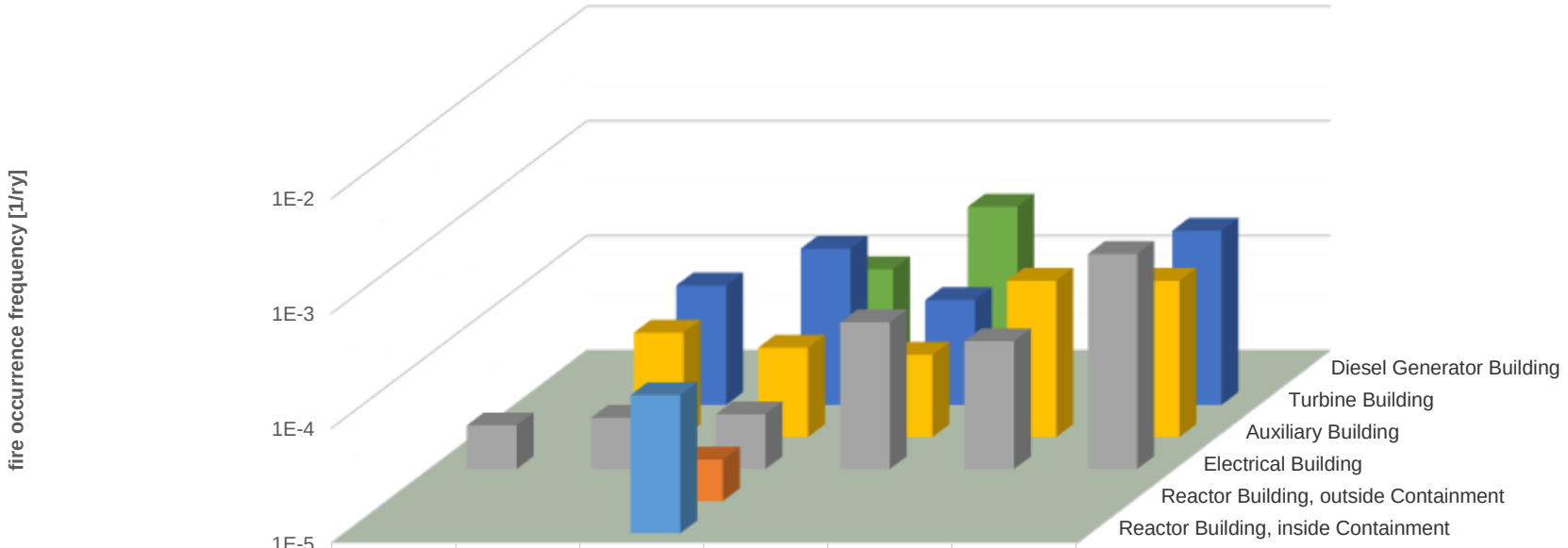
OECD FIRE Database – No. of Rooms (Compartments) per Building Plant ID: Date:

Room Type / Building	Cable rooms		Room for electrical control equipment incl. MCR	Switch-gear room	Battery rooms	Room for ventilation	Room for off-gas equip-ment	Process room	Staircase / corridor	Office	Workshop	Storage rooms			Diesel gene-rator room	Trans-former room / bunker	H_2 cylinder bunker	Other room	Total
	Cable spreading room	Other cable room										for nuclear waste	for other waste	for com-bustibles					
Reactor Building																			
Contain-ment																			
Outside Contain-ment																			
Electrical Building																			
Auxiliary Building																			
Turbine Building																			
Diesel Generator Building																			
Intake Building																			
Spent Fuel Building																			
Independent Emergency Building																			
Workshop Building																			
Other building																			
Total																			

Note: Definitions of rooms (compartments)and building , see OECD FIRE Coding Guideline 2017:02, par. 3.2.3 and 3.2.4

Room Type Specific Fire Occurrence Frequencies (2)

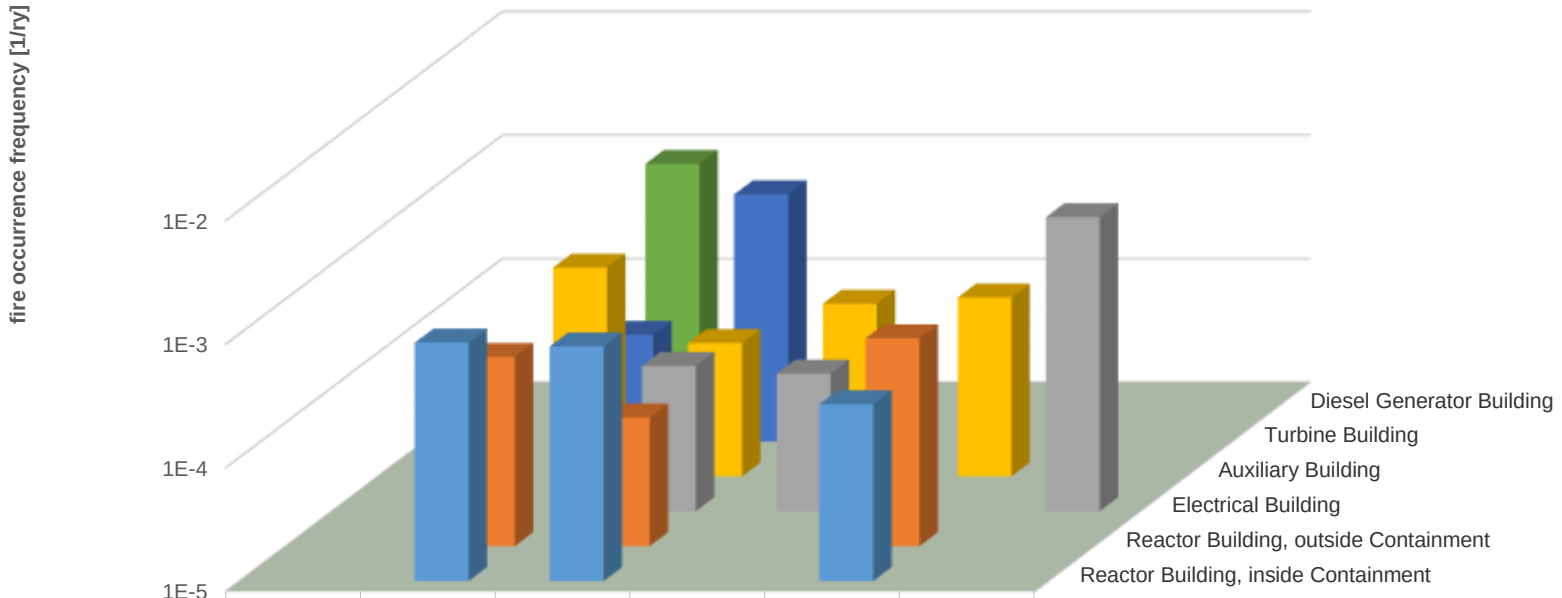
Fire occurrence frequencies for different room types in PWR during power operation



	other cable room	other type of room	process room	room for electrical control equipment	room for ventilation	switchgear room
Reactor Building, inside Containment			1,6E-04			
Reactor Building, outside Containment			2,3E-05			
Electrical Building	2,4E-05	2,8E-05	3,0E-05	1,9E-04	1,3E-04	7,50E-04
Auxiliary Building		8,1E-05	6,0E-05	5,2E-05	2,3E-04	2,30E-04
Turbine Building		1,1E-04	2,3E-04	8,2E-05		3,30E-04
Diesel Generator Building			8,0E-05	2,8E-04		

Room Type Specific Fire Occurrence Frequencies (3)

Fire occurrence frequencies for different room types in PWR during low power and shutdown



	other cable room	other type of room	process room	room for electrical control equipment	room for ventilation	switchgear room
Reactor Building, inside Containment		8,5E-04	7,9E-04		2,7E-04	
Reactor Building, outside Containment		3,4E-04	1,1E-04		4,8E-04	
Electrical Building			1,5E-04	1,3E-04		2,40E-03
Auxiliary Building		4,9E-04	1,2E-04	2,5E-04	2,8E-04	
Turbine Building		7,3E-05	1,0E-03			
Diesel Generator Building		9,2E-04				

Component Specific Fire Occurrence Frequencies

Fire frequencies during power operation and low power and shutdown states

Fire Frequency [1{y]	Power Operation			Low Power and Shutdown		
Component Type	Mean Value	,Lower Confidence Level	Upper Confidence Level	Mean value	Lower Confidence Level	Upper Confidence Level
Diesel generator	3,96E-04	1,03E-04	6,90E-04	4,79E-04	1,00E-07	1,02E-03
Electrical cabinet: high or medium voltage (non-HEAF ≥ 1kV)	3,30E-05	1,57E-05	5,04E-05	3,24E-05	4,01E-06	6,09E-05
Electrical cabinet: low voltage (non-HEAF,< 1kV)	4,40E-06	2,74E-06	6,05E-06	4,13E-06	1,43E-06	6,83E-06
Fan	7,09E-06	2,46E-06	1,17E-05	6,49E-06	1,00E-07	1,38E-05
Fixed heater	2,68E-06	5,37E-08	5,31E-06	1,16E-05	1,43E-06	2,17E-05
Pump: reactor coolant pump (RCP, for PWR)	1,52E-04	3,05E-06	3,01E-04	3,22E-04	1,00E-07	6,85E-04
Rectifier, inverter, or battery charger	1,49E-05	1,84E-06	2,80E-05			
Transformer: high voltage (voltage ≥ 50 kV)	7,34E-04	1,00E-07	1,08E-03	4,88E-04	1,00E-07	9,65E-04
Transformer: medium or low voltage (voltage level < 50 kV)	4,40E-05	1,35E-05	7,46E-05	1,40E-04	4,85E-05	2,31E-04
Turbine generator	4,15E-03	2,46E-03	5,85E-03	2,04E-03	4,28E-05	4,03E-03

Indications Regarding Causes of Fire Events in the FIRE Database

Major apparent causes

Type of Cause	Number of Events							
	Corresponding Occurrence Frequency [ry]							
Reactor Type	Total		PWR		BWR		PHWR	
POS	FP	LPSD	FP	LPSD	FP	LPSD	FP	LPSD
Observation Time [ry]	2274.80	488.10	1491.71	300.42	311.06	63.20	472.00	125.05
Hot short	10	4	6	3	4	0	0	1
Short to ground	5	0	5	0	0	0	0	0
HEAF	13	6	8	4	3	1	2	1
Mechanical overheating	16	8	7	4	4	3	5	1
Electrical overheating	18	11	10	7	7	4	1	0
H_2 fire	3	0	1	0	1	0	1	0
Oil/lubricant fire	14	9	4	4	10	3	0	2
Hot work	30	22	18	5	6	10	6	7

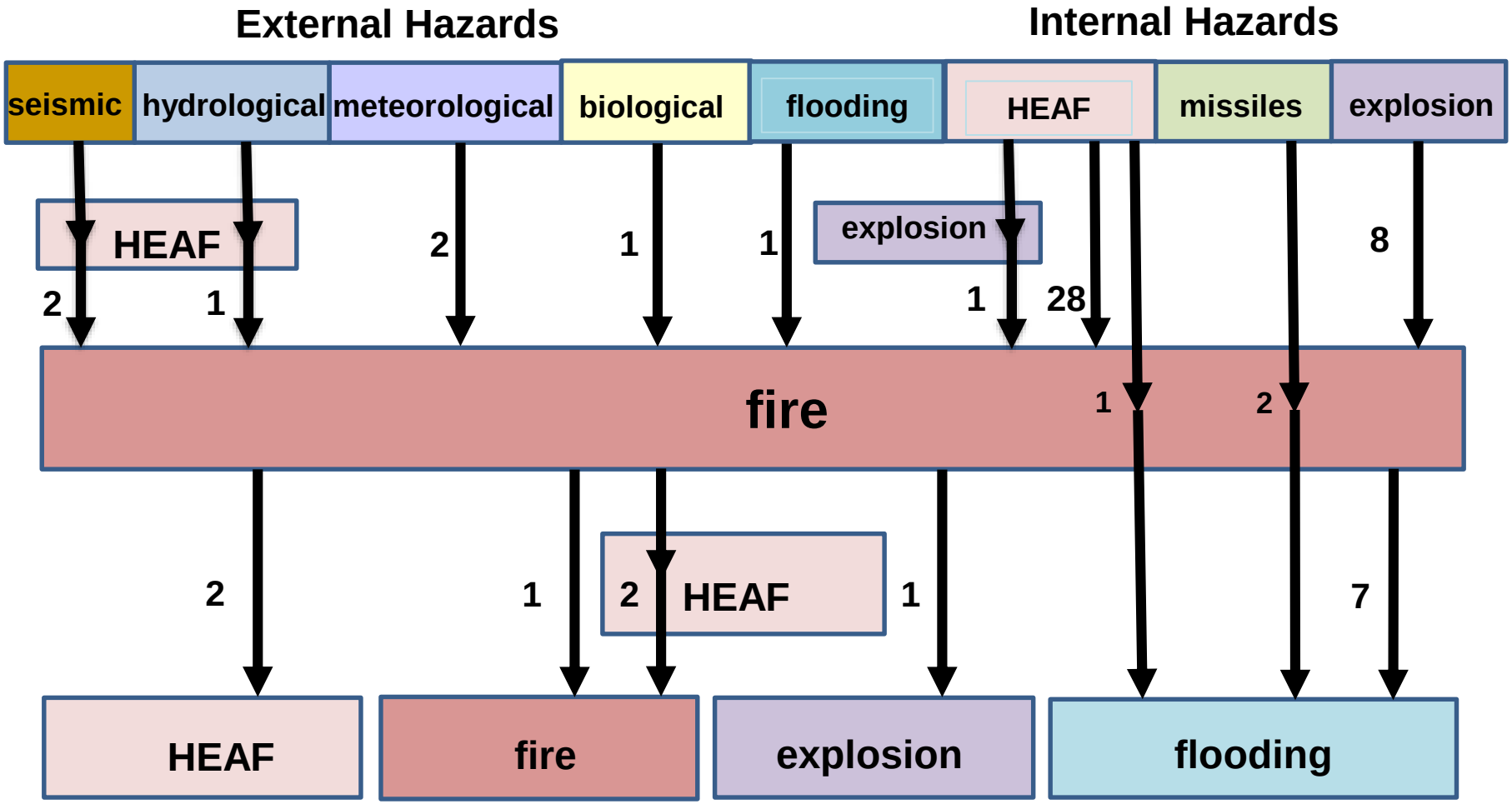
electrical overheating (34 % human error), mechanical overheating (25 % human error), HEAF (26 % human error), hot work (100 % human error)

Root Causes of Fire Events in FIRE Database for Different Plant Operating Modes

- First rough analysis of root causes regarding the 3 typical categories
  - Technical causes: equipment
  - Typical human erroneous actions: human
  - Inappropriate procedures or not following procedures: procedures
- Basis 480 events with known root causes not excluded from statistics:
  - 331 events during 7,460.65 ry of power operation
  - 149 events during 2.266,16 ry for low power and shutdown phases including post-commercial permanent safety shutdown

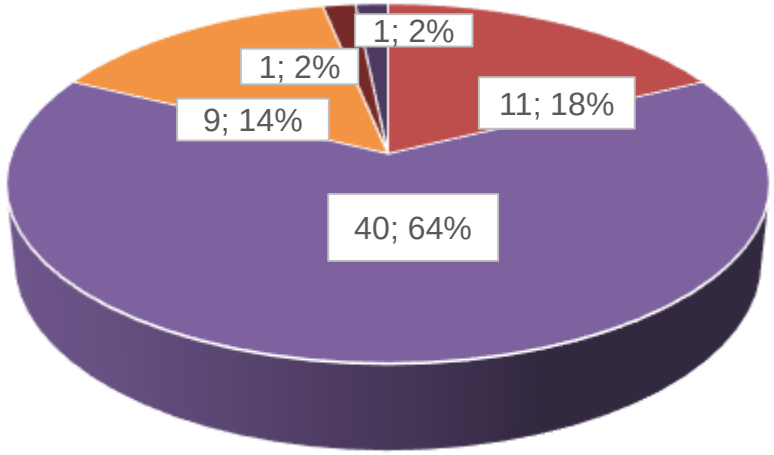
Type of Root Cause	Number of events, where the root cause type occurred, and Corresponding Frequencies [1/ry]	
	Power Operation	Low Power and Shutdown
Equipment	78 %	27 %
Human	29 %	19 %
Procedures	14 %	6 %

Event Combinations of Fire With Other Hazards (1)



Event Combinations of Fire With Other Hazards (2)

- 62 fire event combinations (~ 12 % of all fire events not excluded from statistics)
- Some of these did not affect plant safety, but are significant precursors

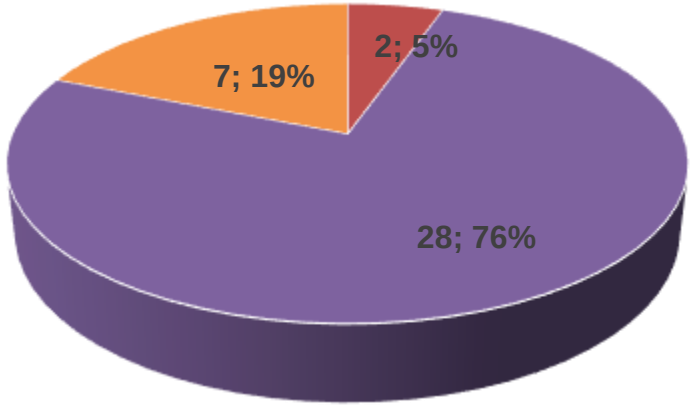


High Energy Arcing Fault (HEAF) Induced Fires

- OPEX indicates importance of high energy arcing faults (HEAF) as important phenomenon for causing fires
- 65 HEAF induced fire events (occurrence frequency of ~ 6.7 E-03 /ry)
  - 37 of the HEAF induced fires are event combinations (see also slide 12 before)
  - Non-negligible contribution of HEAF induced fires to the overall fire risk, even if a nuclear unit had stopped commercial operation

➢ HEAF should be considered in NPP design and operation

- Some national and international standards and guidance take HEAF and HEAF induced fires already into account



fire and consequential HEAF	2.0 E-04 /ry
HEAF and consequential fire	2.9 E-03 /ry
event chain with fire and HEAF	7.0 E-04 /ry

Summary of Ongoing FIRE Database Activities

- The following activities are actually ongoing in the OECD/NEA FIRE Database Project:
  - Fire ignition frequency bins from member countries´ generic operating experience in the FIRE Database compared to plant specific frequency bins from Fire PSA
  - In-depth investigations of apparent and more details on the root causes of fire events in the Database
  - Fire suppression success analysis (fire extinguishing systems and/or manual firefighting) (=> Topical Report)
  - Organisational and administrative fire protection at NPP sites in FIRE member countries – insights from the FIRE Database for potential improvements in member countries (=> Topical Report)
  - Comparison of fire resistance standards applicable to nuclear installations in FIRE member countries

Outlook

- Intended extensions of the data collection:
  - Fire event data collection from reactor units under decommissioning (some events have already been recorded) and respective modifications of the Coding Guideline
  - Fire event data collection from research and demonstration reactors and corresponding adaption of the FIRE Database
  - Fire event data collection from reactor units under decommissioning (some events have already been recorded) and respective modifications of the Coding
- Potential for further extensions of the fire specific data from the operating experience:
  - Cross-cutting topics between OECD/NEA Databases FIRE and ICDE on common cause failures (CCF) of active fire protection features
  - Possibility of collection of fire event data from sodium cooled reactors
  - Fire protection in SMRs – possible fire event data collection and corresponding adaptions of the Database

Thank you for your attention

For further questions, please contact

NEA Secretariat Markus Beilmann Markus.BEILMANN@oecd-nea.org

or

FIRE Management Board Chair Marina Röwekamp Marina.Roewekamp@grs.de

All NEA publications and institutional documentation available at
www.oecd-nea.org