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Determination of Fire Barriers reliability for fire risk assessment of Nuclear Power Plants (FIREBAN) – Report Year 1

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Abstract

Fires in nuclear power plants can be an important hazard for the overall safety of the facility. An important factor in reducing the spread of the fire is the use of fire barriers. However, it is important to be able to quantify the uncertainty of the result of the fire resistance of a fire barrier for fire risk assessment of nuclear power plants. The first-year report summarises three activities: reliability of fire barriers by calculation with help of Abaqus and FDS, determination of uncertainty and sensitivity of input parameters with modelling of fire resistance of fire barriers.

Key words

Fire, nuclear power plants, fire barriers, modelling, uncertainty

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Fires in nuclear power plants can be an important hazard for the overall safety of the facility. An important factor in reducing the spread of the fire is the use of fire barriers. However, it is important to be able to quantify the uncertainty of the result of the fire resistance of a fire barrier for fire risk assessment of nuclear power plants. The first-year report summarises three activities: reliability of fire barriers by calculation with help of Abaqus and FDS, determination of uncertainty and sensitivity of input parameters with modelling of fire resistance of fire barriers.

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Preface

This report is the first year report of the Fireban project financed by NKS under project number NKS-R(16)119/6, which is gratefully thanked. Furthermore, the authors would like to thank all who provided them with literature and information on the subject of fire barriers. As this project is a co-financed project the following other financing bodies are thanked:

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NKS conveys its gratitude to all organizations and persons who by means of financial support or contributions in kind have made the work presented in this report possible.

Lund, May 2017.

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C. REPORT ALTO UNIVERSITY [Reference 14]

D. FIRE AND MATERIALS PAPER (no open ACCESS, available on request from the authors) [Reference 15]

1. Introduction

1.1. Background

Safe shutdown of a reactor after internal or external events is a key factor in the overall safety design of a nuclear power plant. In many cases, fire is a significant event that can affect the reactor safety and the capability of safe shut down. When the event is a fire, it is not only about shutting down the facility but also prevent the destruction of critical components necessary for a safe shut down process. For prevention purposes, redundant systems are used to decrease the probability of unsuccessful shutdown processes. When analysing the fire consequences, the functional performance of components such as cables, and electronic circuits, for example, is of highest importance. With respect to fire, events can be classified in 3 major groups depending on the position of the subsystems, as illustrated in Figure 1. [1, 2, 3]. In the first class (left), the redundant systems A and B are located in the same enclosure within a fire compartment. A fire can have a great impact on one or both subsystems and the risk of loosing the redundancy is consequently high. Probability for failure might e.g. be 1 on 100 years. In the second class of events, the systems A and B are in the same fire compartment but not in the same enclosure and the risk of failure will depend on the fire spread between enclosures. Probability will be 1 on 1000 years. Finally, the subcomponents A and B can be in 2 different fire compartments, and the risk for loosing both subsystems will be due to failure of fire compartmentation, a seldom consequence, but could trigger an bigger event such as Fujiyama accident [4, 5].

The utilization of the physical separation is an important part of the defence-in-depth principle of NPP safety. The consequences of loosing the physical separation may not be well known because these events are often ignored in fire-PSA as a result of the screening process [2]. The loss of separation may take place in various ways: i) most importantly by the unavailability of barrier components (e.g. an open fire door), ii) by mechanical damage to the fire barrier or structure (e.g. by earthquake), iii) by the penetration of heat and smoke through the fire barriers (e.g. heat conduction and leakages), or iv) through the ventilation system. This project will focus on the assessment of mechanisms iii. While in the POOLFIRE project the focus was on the fire source e.g. a pool fire, and the propagation through the ventilation systems [1], it is also important to know the risk of multi-compartment failures. Risk of failure between components inside the same enclosure and compartment (Events 1 and 2) can be treated by advanced fire modelling [9] or by using engineering methods [8]. For the risk of barrier failures, the calculation methods are incomplete. Fire barriers are often tested using standard fire tests such as EN 1363-1 and standardized exposure but we do not know how they perform at different exposures or in the presence of small changes or deficiencies. A large Marie Curie project is currently conducted between DBI and Lund University to investigate the effect of different exposures [10], but for the second source of uncertainty, only little is known.

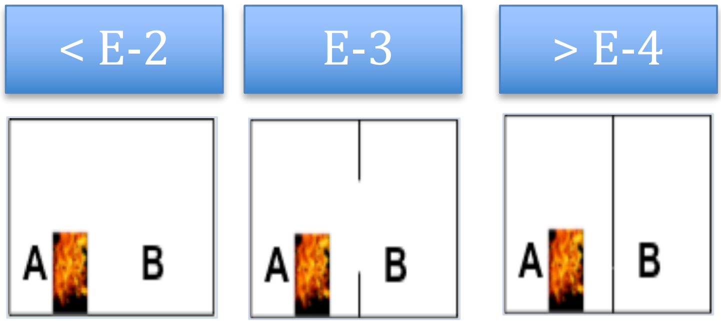

Figure 1 Example of event classification for fire incidents with probability for failure [1]

One way to determine the overall risk in a PRA analysis is by using probabilistic methods and statistics [6, 7]. For earthquake fires, some data is available [4, 5] but we also need to have the information for normal fire hazards. Another possibility is to investigate the likelihood of barrier failure using calculation methods, which predict e.g. the heat transfer in the wall or the possible leakages of gases from one compartment. This is a so-called deterministic approach, which can complement the probabilistic methods in PRA. Most of the work now has been done in predicting the result from standard fire tests according to e.g. EN 1363-1. But the links between the standard testing and modelling, risk-based design and PRA are still missing.

In a recently conducted and on-going OECD PRISME projects [3], large amount of experimental data has been gathered with respect to mechanically ventilated enclosure fires. A number of tests in the first project have been done with leakages in walls and they can give a first indication of failure rates. This international project constitutes an important and unique dataset of experiments. The focus of PRISME projects was mainly on the fire tests while the use of the test results and the validation of CFD models is a national or regional responsibility and subject to local funding.

Until now, Sweden and Finland have participated on national basis but it is clear that synergy is possible between the research groups involved in the project (Lund university, Aalto University and VTT). Activities were related to the validation of the most widely used CFD tool called FDS [9] and to the sensitivity analyses for this tool for pool fires [1]. Incorporating DBI (Danish Institute for fire and security technology) will allow for the project partners to have access to the research of 5 Marie Curie PhD students working in the Firetools project and connections with industry. The work in this project focuses on modelling the heat transfer through fire barriers. Finally, a NPP (Vattenfall Ringhals) from Sweden is involved as end-user.

1.2. Scope, objective and methods

The scope of the project is to investigate and assess the reliability of fire barriers in NPP during realistic fire scenarios to support the plant-scale risk assessment.

The objective is to establish data and methods to determine the conditional probabilities for failure of fire barrier. The Methods used will be statistics, literature review, calculation and specific unique designed fire tests.

1.3. Limitations of this report

This report only deals with the results obtained during the first year of the report.

This report includes the results of work package 1 and the status of work package 2. Work package 5 (management) is not reported.

2. Overview of the FIREBAN project

This chapter gives a short overview of the overall 3-year project. The project major core of activity is the to investigate and assess the reliability of fire barriers and will contain the following work packages.

2.1. Work package 1: State-of-the-art for fire barrier reliability assessment

The first work package will collect the state of the art on methods and experiences to determine the reliability of fire barriers. Methods used are literature review of validation data available within open literature and other projects as well as other discipline areas (e.g. mechanical stability). Use of statistics will also be considered for probability assessment. The result of this work package will be an overview of the need for possible further development and the requirements for additional data both as input data for the PSA models.

Responsible organisations: Aalto, VTT and Lund University

2.2. Work package 2: Risk-based assessment of barrier performance

In this work package, we will determine the relationship between the standard-fire based fire resistance classification and the failure risk under real fire conditions and real protection objectives.

First, the <u>risk-based acceptance criteria</u> will be established, as the standard criteria for test protocol do not necessary correspond to the situation at the plant. The criteria will be determined for insulation, integrity and stability, considering the different spaces to be protected, such as the cable rooms (criterion based on cable material thermal stability), and control room (life safety and working conditions).

Next, we will determine a number of <u>risk-based fire curves</u> for NPP rooms based on real fire scenarios. This includes for example:

- Small rooms fires
- Large rooms with local fuels
- Large rooms with plenty of fire load.

On the basis of the risk based fire curves, suggestions for practical fire test design will be presented.

*Responsible organisation*s: All partners

2.3. Work package 3: Reliability determination

This work will contain four major routes of determination:

2.3.1. Use of existing test fire test data in combination with new test data

Test data from existing tests will be analysed and also unique test will be performed with small deficiency (representing cracks and lack of full insulation)

2.3.2. Use of statistics

Statistics data will be gathered from different sources and the input to this work is the outcome of Work package 1.

2.3.3. Use of modelling for the fire barrier performance assessment.

In this case, a combination of thermal heat transfer models and CFD models such as FDS will be used. Means to integrate the reliability estimates into PRA will be proposed. In addition to the model application, we will analyse the propagation of model/parameter uncertainty to the final risk estimate.

2.3.4. Practical test design

Testing environment will be compared with realistic installations in order to document fire performance.

Responsible organisations: Aalto University, DBI and Lund University

2.4. Work package 4: Dissemination of results

Results from the project will be reported in scientific journals and at conferences. A small workshop for interested parties will be organised at the end of project. Due to the fact that some data from the OECD project PRISME might be used the partners will follow the rules of OECD for publication of the results. The most efficient way is to report by means of scientific papers, which are approved by the OECD project group. The co-operation with other national projects, such as the SAFIR2018 programme in Finland, will also take place in this work package.

Responsible organisations: All partners

2.5. Work package 5: Management

For the management of the project, we include activities such as communication with partners, meeting organisation, economical follow up and progress follow up. The management work will also include the set-up of a confidentially agreement between the partners with respect to the OECD project PRISME and the FIRETOOLS project. Vattenfall Ringhals, VTT, Aalto University and LU are now part of the PRISME project but not DBI. DBI and LU are part of the Firetools project but not Aalto University and VTT. However, no hinder is foreseen in establishing this contract.

Responsible organisation: Lund University

3. Conducted studies

This chapter summarises three of the studies conducted during the first year of the project.

3.1. Reliability study of fire barrier by calculation with ABAQUS and FDS [13]

3.1.1. Introduction

In order to restrain fire spread and to contain the fire in one area, a building can be sub-divided into compartments separated from one another by fire-resisting constructions. This passive fire protection method can help by giving more time for the occupants to evacuate, by reducing the fire size thus reducing the fire service work and by reducing property damage and business interruption time. The fire resistance rating of light weight construction, especially Cold-formed light gauge steel frame (LSF) stud wall systems, has become critical to the building safety design as their use has become increasingly popular in all areas of building construction[11].

The fire resistance rating (FRR), given in unit of time, is the time for which a building element can withstand the exposure to defined heating and pressure conditions, until failure. Usually those time range between 60min and 120 min[11]. Traditional fire resistance testing is done in furnace test and based upon ASTM standard E119 or the international standard ISO 834. According to the code EN 1363-1, the failure criterions are based on three parameters: integrity, stability and insulation[12]. The stability criterion relates to the structural capacity of the structure at elevated temperature. In this study the stability criterion will not be investigated, thus it is assumed that the walls do not collapse, do not show excessive deformation or deflection. The insulation criterion relates to the ability of a building component to restrict the heat transfer through its boundaries to a certain level. According to the EN 1363-1 code, failure of the insulation criterion is observed in two ways[12]. The code states that the specimen must maintain its function for the duration of the test without developing temperatures on its unexposed surface such as:

- An increase the average temperature above the initial average temperature by more than 140 °C, called T_{140};
- An increase at any location (including the roving thermocouple) above the initial average temperature by more than 180 °C, called T_{180}.

The integrity criterion represents the ability of a building component to prevent the passage, through its boundaries, of flames and hot gases and to prevent the occurrence of flames on the unexposed side. The requirements from the relevant code [2] are the following:

- Prevent the penetration of a 6 mm diameter gap gauge that can be passed through the test specimen, such that the gauge projects into the furnace, and can be moved a distance of 150 mm along the gap
- Prevent the penetration of a 25 mm diameter gap gauge that can be passed through the test specimen such that the gauge projects into the furnace.
- Prevent the ignition of a cotton pad applied for a maximum of 30 s or until ignition positioned at least 30 mm from the unexposed surface and 10 mm from the boundaries of the wall. Charring of the cotton pad without flaming or glowing shall be ignored.

In the industry the fire rated partition are built according to specifications coming from plasterboard manufacturers, providing fire resistance ratings. Those rating are based on full-scale furnace tests using the required standard. Often, the fire barriers tested in the furnace are highly optimized in order to reach the required fire resistance. The test results remain confidential and the number of samples, which fail is not documented. In practice, the construction of the fire rated barrier can slightly differ from the optimized one tested in the furnace test. Furthermore, with time, the quality of the barrier can be altered thus reducing its ability to contain the fire. This raises concerns about the reliability of fire resisting partition as an effective mean of passive fire protection. Little research has been done with respect to the impact of reduced insulation and leakage on the reliability of fire resisting partition. It is not known what kind of safety factor can be expected of fire barrier and often, the designer relies simply on the obtained rating. For this reason, research is necessary in order to determine the reliability of fire barriers.

3.1.2. Objectives

The first objective of this study is to show how the FRR of partitions is affected by leakage. To do this, the FRR obtained from simulations of partitions with localized leakage, distributed leakage, different leakage size and location will be compared to an airtight partition.

The second objective of this study, is to investigate the effect of a reduced thermal insulation on the FRR of partitions. Insulation can be reduced in multiple ways, the scenarios which will be investigated are: localized missing piece of different size of insulation, reduced thickness of insulation, different type of insulation, partition without insulation, hole of different size on the exposed boundary of the partition and hole through the partition. Those assumed 2 parameters and features are meant to represent ways in which a fire rated wall could be altered before being exposed to a fire.

3.1.3. Method

The methods that were used are hand calculations for basic heat transfer through the wall, hand calculations of infiltration and pressure inside the furnace, CFD modelling using the CFD tool - FDS and Finite element modelling using ABAQUS to replicate the standard fire furnace tests. A case study method is used in this work. More precisely, the effect on the FRR according to the insulation criterion were examined for the following parameters: The type of insulation or absence of insulation, the reduction of the insulation thickness inside the cavity, breach in the gypsum board exposed in the furnace, breach through the fire barrier and missing piece of insulation inside the cavity. Also, the effect of leakage on the FRR based on the integrity criterion was investigated assuming that the barrier leaks before it is submitted to the standard fire. Different levels of airtightness were assumed and different leakage scenario. The first scenario aims at simulating the effect of hole through the barrier. The second and third scenario was looking at the effect of leaking joint improperly sealed. In order to validate the models, comparison of model's results to experimental data of wall tested in actual furnace were made. Thus, the report also holds a study of model validity, to see whether simple calculations and modelling are able to replicate heat transfer in a furnace test.

3.1.4. Limitations

This study was limited to walls and did not include doors, windows, ventilation ducts. Studies were mainly done with respect to smoke leakages and reduced thermal insulation. The stability criterion relates to the structural capacity of the structure at elevated temperature. In this study the stability criterion was not investigated, thus, it is assumed that the walls do not collapse, do not show excessive deformation or deflection. Also, it is assumed that the defects and features investigated are already part of the wall before the fire. Hence this study was not looking at the deficiencies due to the fire effects.

3.1.5. Results

This paragraph only gives a summary of the results. More information can be found in [14].

1. ABAQUS simulations

The calculations were done on a light-weight stud wall system with two type of construction:

- Construction type A - 60 minutes fire resistance
- Construction type B - 120 minutes fire resistance

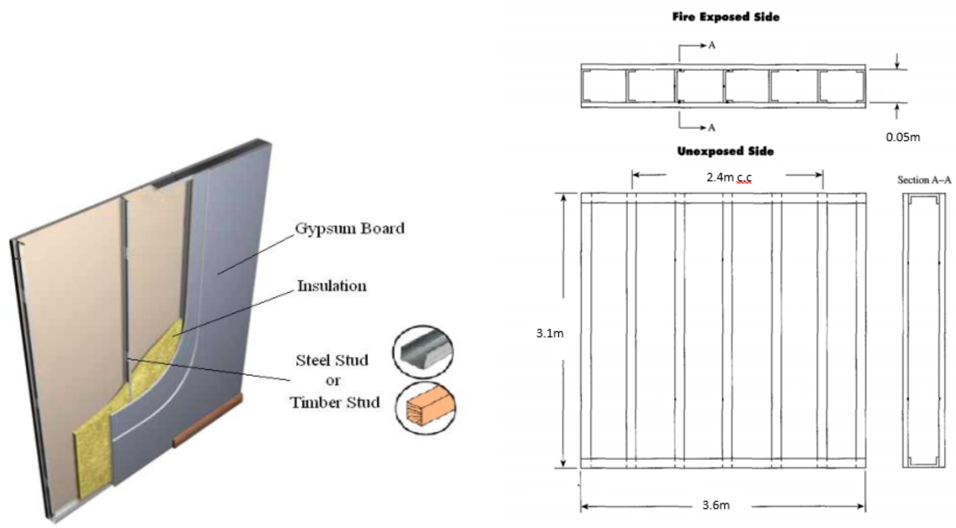

Figure 2 Schematic of the barriers used for calculations

The following different type of set-ups were tested:

- The type of insulation (uninsulated, Stone wool, Fiber glass wool)
- Reduction of the insulation thickness. 4 scenarios with stone wool (Full depth, three quarter, half and quarter)
- Presence of a hole in the exposed gypsum board. 6 models for different insulation type and for a large and small hole (50mm, 10mm radius).
- Hole through the fire barrier, with stone wool insulation. 2 models large hole 50mm radius and small hole 10mm radius.
- Missing piece of stone wool insulation of different size large part 100mm radius and small part 50mm radius.

Figure 3 shows a result of the simulation when a hole is present in the barrier construction on the exposed side.

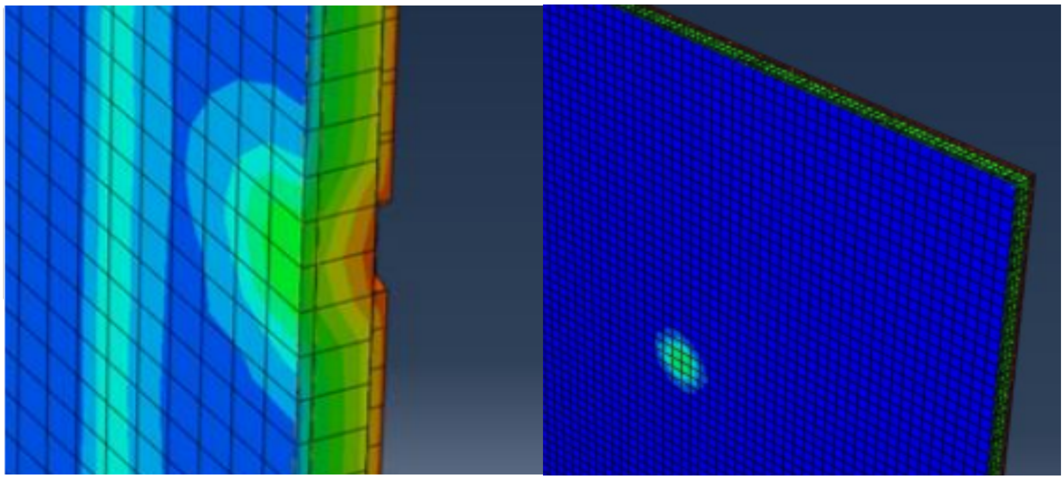

Figure 3 Example of a calculation with a hole on the exposed side.

Figure 4 shows the results of fire barriers with different insulation (left) and reduced thickness (right)

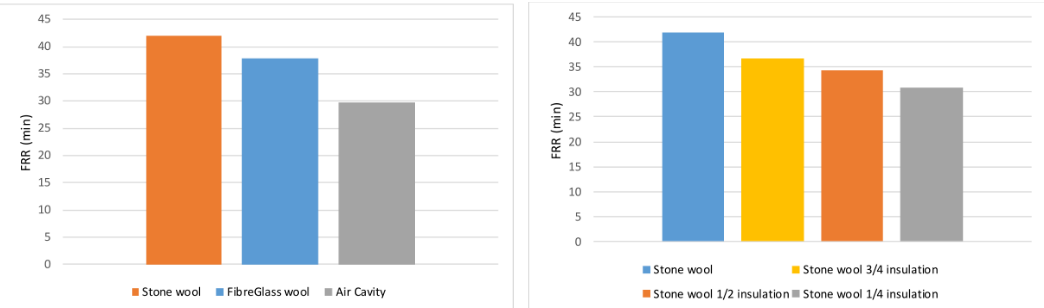

Figure 4 Results of heat transfer calculation – Reduction in FRR for two parameters.

The results can be summarised as follows:

- Barriers insulated with stone wool provided a FRR higher compared to barrier insulated with Fiberglass wool or uninsulated (air gap).
- Small or large hole on the exposed layer of the barrier insulated with stone wool, provided a FRR approx. 20% and 70% higher compared to Fiberglass and uninsulated partition, respectively.
- A hole through the partition reduced the FRR by more than 75%
- Reduction by up to 25 % of the FRR was observed for reduction of the insulation thickness by 75%.

2. FDS simulations

FDS simulations were performed simulating a fire barrier in front of a fire resistance furnace. Different types of leakages were simulated as can be seen in figure 5. The model was calibrated against a fire resistance test.

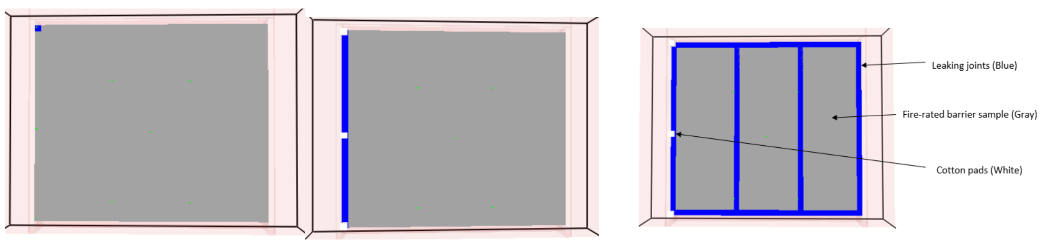

Figure 5 Different leakages: hole, (left); gap (middle); general leakage at joints(right)

The results of the FDS simulations revealed the following:

- For an average air tight construction, a leakage through a hole has a FRR 38% lower compared to leakage occurring through a joint on one side of the wall
- For an average airtight construction, a leakage through a joint on one side gives a FRR 15% lower compared to a leakage through all the joints of the wall.
- Failure was mainly due to the insulation criterion.
- A supplementary calculation using a concrete wall revealed the same results for integrity.

3.1.6. Conclusions

Fire rated partition are constructed according to specification taken from manufacturers. However, what happen to the FRR if the construction is built differently or is altered before it is subject to a fire. This study looked at the safety factor inherent in fire resistant structures with regards to the insulation and integrity criterion. This was done using numerical tools such as FDS for the integrity criterion and ABAQUS for the insulation criterion. No experiment was done during this study, however the models were validated using experimental data. It was found that all the tested partition with increased leakage or reduced insulation had a FRR too low to fulfill their purpose. This imply that there are no safety factor inherent in fire resistant barrier and that they should be built and kept exactly as specified by the manufacturer in order to give FRR acceptable by codes. Also, results showed that it is much more likely that the wall will fail due to the insulation criterion than due to the integrity criterion, if leakage occurs. Finally in order for the partition to be reliable it is necessary that it is built and remains exactly as tested by the manufacturer. This work showed method to simulate fire resistance test with the help of numerical tool. This could be very useful especially when considering the high cost of testing samples in furnaces. Still, much works needs to be done in order to accurately model a fire resistance test. Experiments are needed in order to be able to validate properly the models, especially for cavity radiation and heat transfer through leakage area.

3.1.7. Further Research

In order to improve models on fire resistance test, further work should include the following:

- The effect on heat transfer of hot gases leaking through partition should be studied experimentally.

- The effect of heat transfer in empty cavity by radiation during a fire resistance test should be investigated. This would allow validating the numerical models and helping to find a way to reduce the heat transfer to the unexposed gypsum layer in an empty cavity partition.
- Numerical models of thermal expansion and deformation of the partition component such as steel studs, wooden studs and gypsum board, in order to include the stability criterion.
- The impact on the fire resistance rating of lightweight partition using steel or wooden studs.
- The influence of the heat generation in some wool insulations materials and the impact on the FRR.
- The combustibility of the insulation material inside the cavity and its effect on the FRR.
- The dependency of FRR on the water movement inside the partition caused by water vaporization from the gypsum.

3.2. Model uncertainty propagation in Fire-barrier performance analyses [14]

The aim of this work was to study the nature of uncertainty propagation between the physical model used for the performance analysis of fire barriers. We selected a typical concrete wall as fire barrier. A FEM based matlab model was used to predict the barrier temperature. Uncertainty propagation analysis was carried out for different combinations of input setup. The propagated modelling error has been presented in terms of bias factor and the random error. Results show that the type of dominating heat flux (convective, radiative or a combination of both) as well as the nature of input distribution can have significant influence on both, the bias factor and the random error. It is found that the model error parameters may vary pertaining to time at which they are evaluated. Similarly, the measure of low probability failure criteria is affected by both.

The later part of the study shows that one can accurately estimate the true distribution of the output quantity from the observed one provided that the model error parameters are available for the given simulation scenario (Figure 6). This result can be used in the future to pose accuracy requirements for the individual sub-models, given an overall uncertainty requirement. The overall uncertainty requirement, in turn, should be related to the width of the consequence distributions in PRA; modelling uncertainty should not dominate the result of PRA over the input uncertainties. More information can be found in [14].

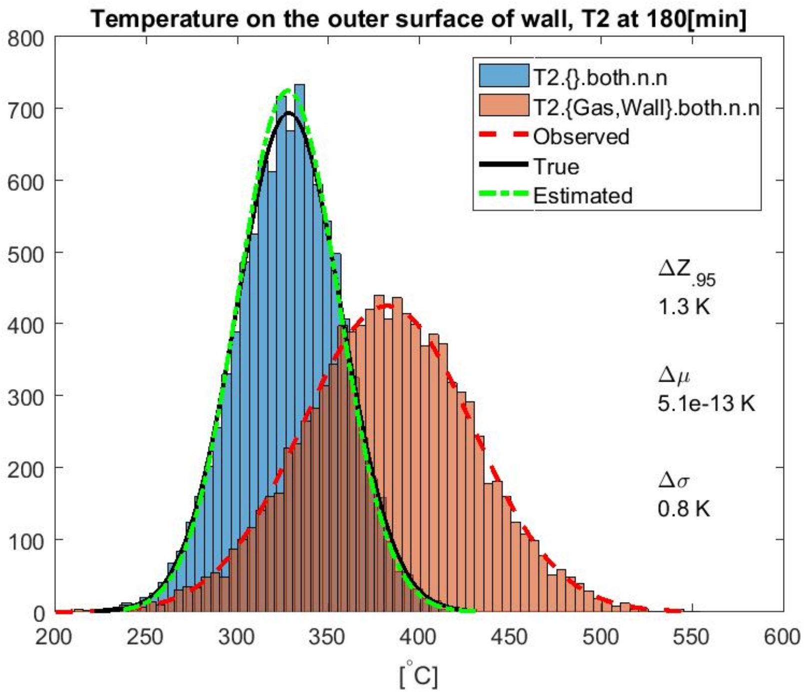

Figure 6 Estimation of true distribution from the simulated one.

3.3. Uncertainties in modelling heat transfer in fire resistance tests: A case study of stone wool sandwich panels [15]

Modelling fire performance of building fire barriers would allow optimising the design solutions before performing costly fire resistance tests and promote performance-based fire safety engineering. Numerical heat conduction analysis is widely used for predicting the insulation capability of fire barriers. Heat conduction analysis uses material properties and boundary condition parameters as the input. The uncertainties in these input parameters result in a wide range of possible model outcomes. In this study, the output sensitivity of a heat conduction model to the uncertainties in the input parameters was investigated. The methodology was applied to stone wool core sandwich panels subjected to the ISO 834 standard fire resistance temperature/time curve. Realistic input parameter value distributions were applied based on material property measurements at site and data available in literature. A Monte Carlo approach and a functional analysis were used to analyse the results. Overall, the model is more sensitive to the boundary conditions than to the material thermal properties. Nevertheless, thermal conductivity can be identified as the most important individual input parameter.

More information can be found in [15]. Figure 7 gives results for one of the cases.

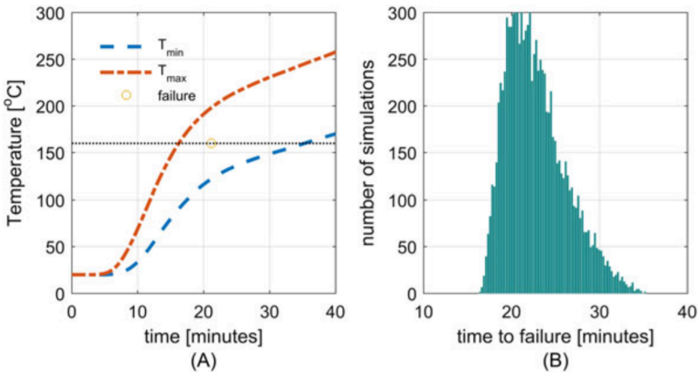

Figure 7 A, modelling results for 50 mm stone wool sandwich panel; B, time to failure distribution of 10 000 simulations [Colour figure can be viewed at wileyonlinelibrary.com]

4. Dissemination

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4.1. Publications

Following publications were obtained:

- Vallée, J. Reliability of fire barriers, Report nr xx Master thesis Erasmus Mundus, Lund University, 2016.
- Paudel, D., Hostikka, S., Model uncertainty propagation in Fire-barrier performance analyses, Aalto University, 2016. (Accepted also as a poster to 2017 IAFSS Symposium in Lund, June 2017).
- Livkiss, K., Andres, B., Johansson, N., van Hees, P., Uncertainties in modelling heat transfer in fire resistance tests: A case study of stone wool sandwich panels, Fire and Materials Journal DOI 10.1002/fam.2419, Wiley, 2017.

4.2. Participation at conferences

The Firetools PhDs participated at Interflam 2016 and the Nordic Fire Safety Days in Copenhagen.

5. Conclusions

The report gives an overview and summary of the major achievements obtained in year 1 of the FireBan project.

It is related to three publications and can be summarises as follows:

1. Different deficiencies in fire barrier can result in reduction of the fire resistance by up to 75 %. Deficiencies investigated were: reduced thickness of insulation, other type of insulation, holes in protections board and fire barrier and different types of leakages.

2. One can estimate the true uncertainty of the output quantity from simulated one with a priori knowledge of model uncertainty.

3. A case study of stone wool sandwich panels presents that simple statistical methods can be used to assess the most influential input parameters when modelling resistance to fire testing.

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Annex A Acronyms

ABAQUS: FEM Software package

Brandforsk: Swedish Board for Fire Research

CFD: Computational Fluid Dynamics

EN: European Standard

FDS: Fire Dynamics Simulator software programme

FIREBAN: Acronym for project "Determination of Fire Barriers reliability for fire risk assessment of Nuclear Power Plants"

FIRED: Acronym for project "Fire risk evaluation and Defence-in-Depth project"

FIRETOOLS: Acronym for Marie Curie project FIRETOOLS. Fire Tools is a European Industrial Doctoral Program (EID) jointly funded by European Commission and DBI under the European Union's (EU) 7th framework program under Marie Curie Actions. The overall objective of the FIRE TOOLS project is to develop tools for obtaining the fire properties and behaviour on a continuous scale for individual products, composite products and complete systems.

FRR: Fire resistance rating

FSE: Fire Safety Engineering

IRSN: Institut de radioprotection et de sûreté nucléaire

ISO: International Standardisation Organisation

LST: Light Gauge Steel Frame

NBSG: National Fire safety group (composed av SSM, SKB and nuclear power plants at Oscarshamn, Forsmark and Ringhals)

NEA: Nuclear energy agency

NKS: Nordic Nuclear Safety Research is a forum for Nordic cooperation and competence in nuclear safety, including emergency preparedness, serving as an umbrella for Nordic initiatives and interests.

NKS-R: The NKS-R programme from NKS is focused on Nordic research in the area of reactor safety including organisational issues and decommissioning of nuclear installations.

NPP: Nuclear Power Plants

OECD: Organisation for Economic Co-operation and Development

POOLFIRE: Acronym of the project Poolfire: Prediction and validation of pool fire development in enclosures by means of CFD

PRA: Probabilistic risk assessment

PSA: Probabilistic safety assessment

PRISME: The acronym PRISME comes from the French phrase propagation d'un incendie pour des scénarios multi-locaux élémentaires, which in English can be translated as "fire propagation in elementary, multi-room scenarios".

QRA: Qualitative Risk Analysis

SAFIR2018: The Finnish Research Programme on Nuclear Power Plant Safety 2015 - 2018

SKB: Svensk kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company)

SSM: Strålsäkerhetsmyndigheten (Swedish Radiation Protection Agency)

SVN: Apache Subversion (formerly called Subversion, command name svn) is a revision control system initiated in 2000 by CollabNet Inc. Developers use Subversion to maintain current and historical versions of files such as source code, web pages, and documentation

TS: Technical Specification

VTT: Technical Research Centre of Finland Ltd

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Abstract max. 2000 characters	Fires in nuclear power plants can be an important hazard for the overall safety of the facility. An important factor in reducing the spread of the fire is the use of fire barriers. However, it is important to be able to quantify the uncertainty of the result of the fire resistance of a fire barrier for fire risk assessment of nuclear power plants. The first-year report summarises three activities: reliability of fire barriers by calculation with help of Abaqus and FDS, determination of uncertainty and sensitivity of input parameters with modelling of fire resistance of fire barriers.
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