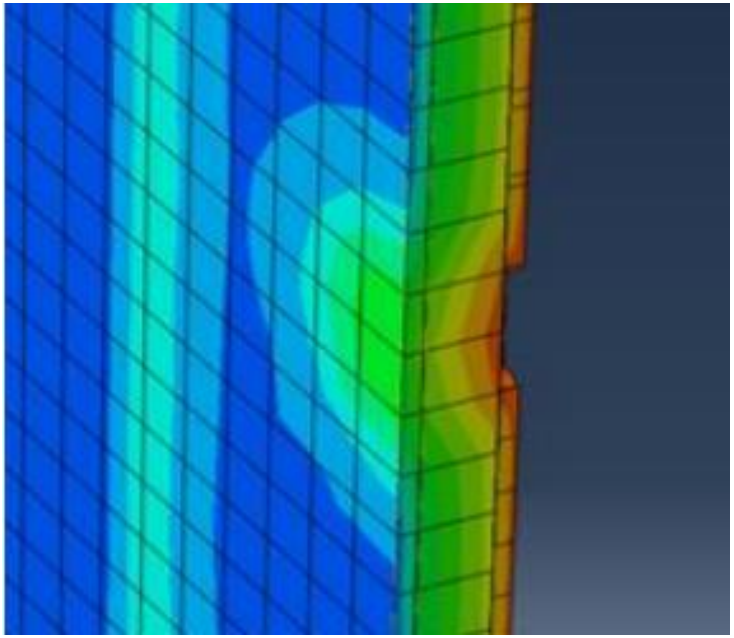

Reliability of fire Barriers – NKS project FIREBAN

Prof. Patrick van Hees

LTH - Fire Safety Engineering

Nordic nuclear safety research

Content

- Objectives
- Partners
- Problem description
- Example of Results for calculation of fire barriers:
  - LTH report 3205.
- Conclusions

Objectives

- The scope of the Fireban 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 were statistics, literature review, calculation and specific unique designed fire tests

Project Partners

- LTH FSE, Sweden
- Aalto University, Finland
- VTT, Finland.
- DBI, Denmark
- Ringhals AB, Sweden

Problem identification

- Fire Barriers prevent fires to spread from one fire compartment to another for a specific time e.g. 1 hour, called fire resistance rating (FRR)
- Examples are walls, doors, sealed cable penetrations, etc.

Problem identification

- Classic determination is through fire resistance tests.

- However few tests are conducted until failure and test specimen are perfectly prepared

Problem identification

- For risk based design it is important to know which uncertainty e.g. the 1 hour result has for real fires and scenarios

Failure Criteria

Insulation

- an increase of the average temperature on the unexposed surface by more than 140K
- an increase of the temperature at any location on the unexposed surface by more than 180K

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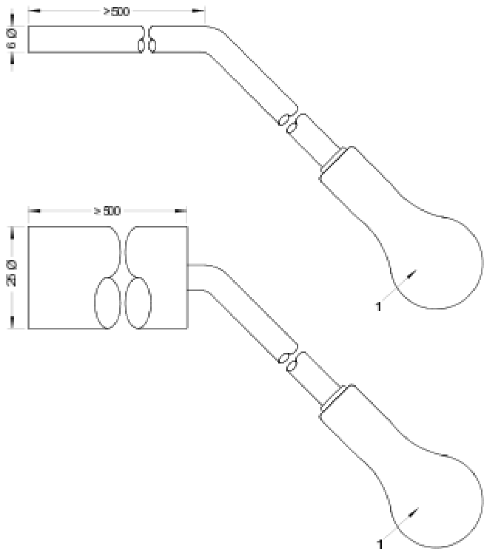
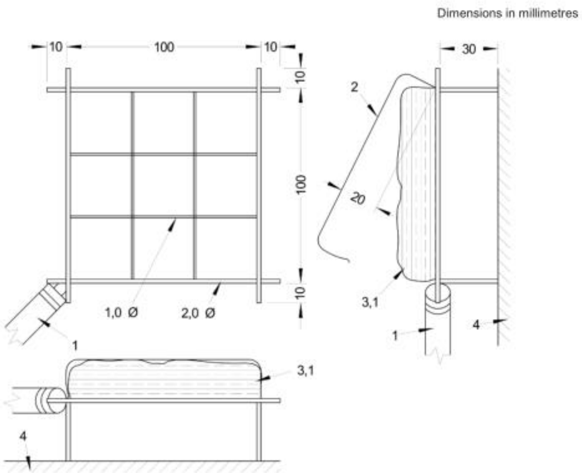
Failure Criteria



Integrity

- Prevent the penetration of a 6 mm diameter gap gauge for a distance of 150 mm along the gap
- Prevent the penetration of a 25 mm diameter gap gauge 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.

Failure Criteria



Integrity

- 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.

Failure Criteria

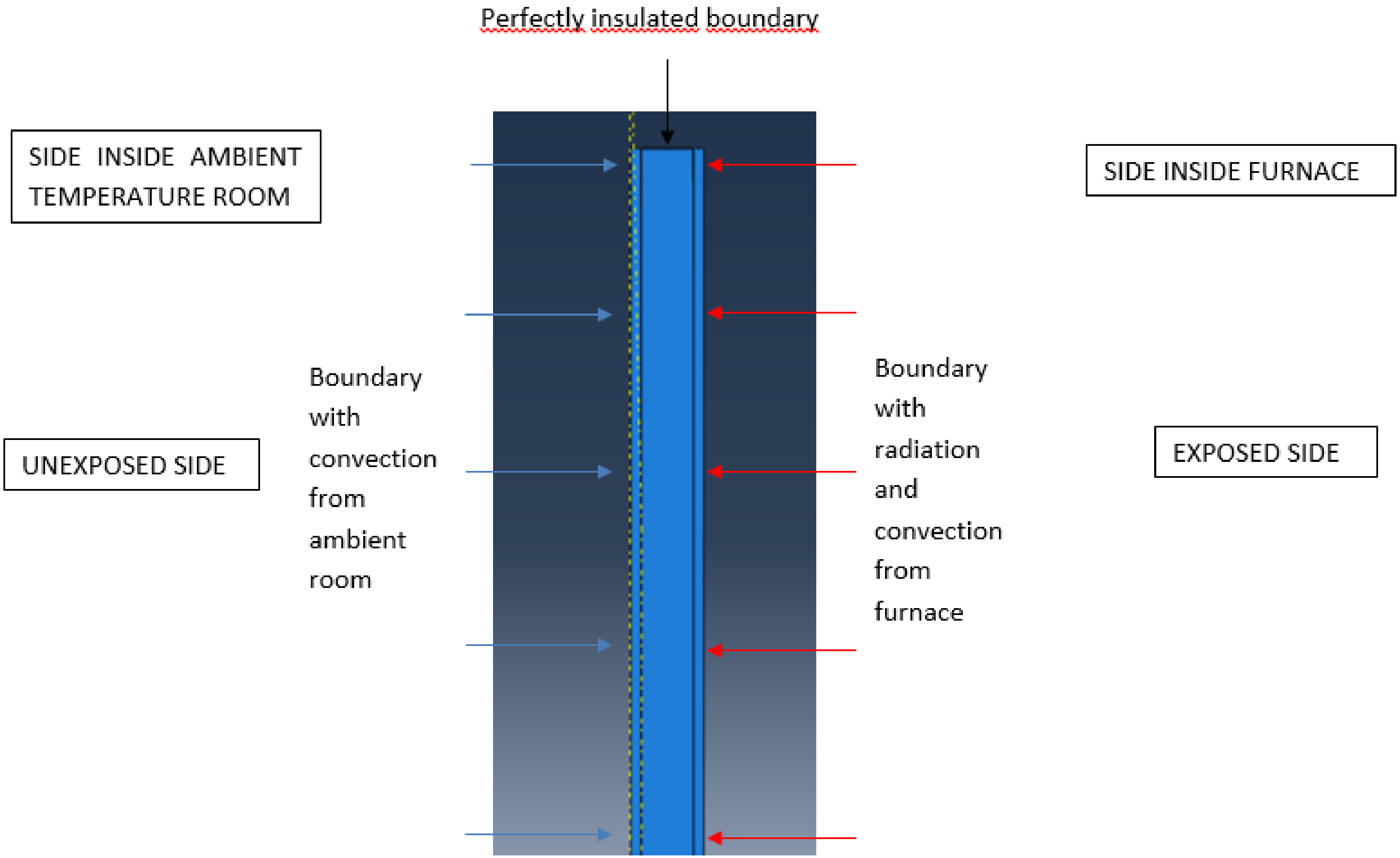
Stability

- Collapse of the fire barrier during the test

Alternative to testing is by calculations to allow different boundaries

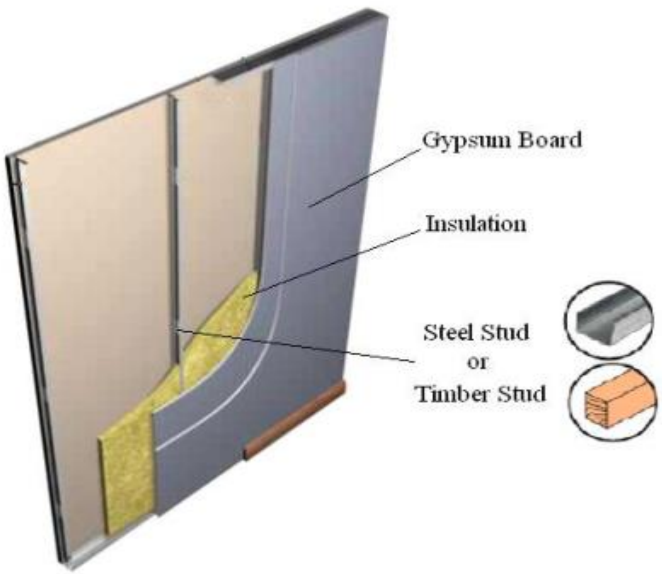
- 3-D Calculations with Abaqus (FEM program for heat transfer)
  - The objective of this study, is to investigate the effect of a reduced thermal insulation on the FRR of partitions
- Calculation with FDS (CFD program, fluid dynamics)
  - The objective of this study is to show how the FRR of partitions is affected by leakage.

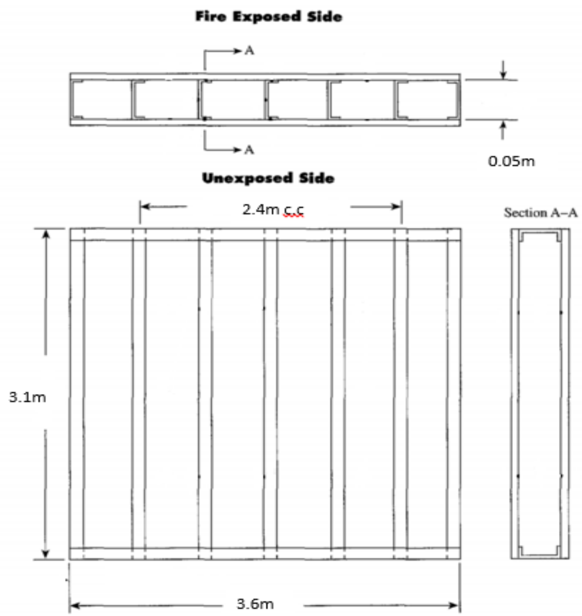
Heat transfer set-up in Abaqus



Partition Construction

- Light weight stud wall system
- Construction type A - 60 minutes fire resistance
- Construction type B - 120 minutes fire resistance
- Different number of gypsum boards





ABAQUS (FEM) Models Set-up

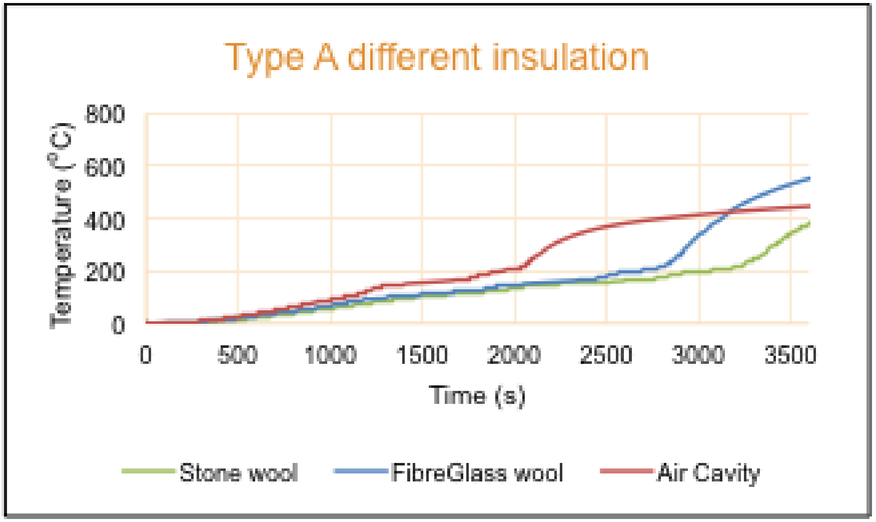
- The type of insulation (uninsulated, Stone wool, Fiber glass wool)
- Reduction of the insulation thickness. 4 scenarios with stone wool (Full depth, three quarter, half and quarter)
- Presence of hole in the exposed gypsum board. 6 models for different insulation type and for a large and small hole (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.

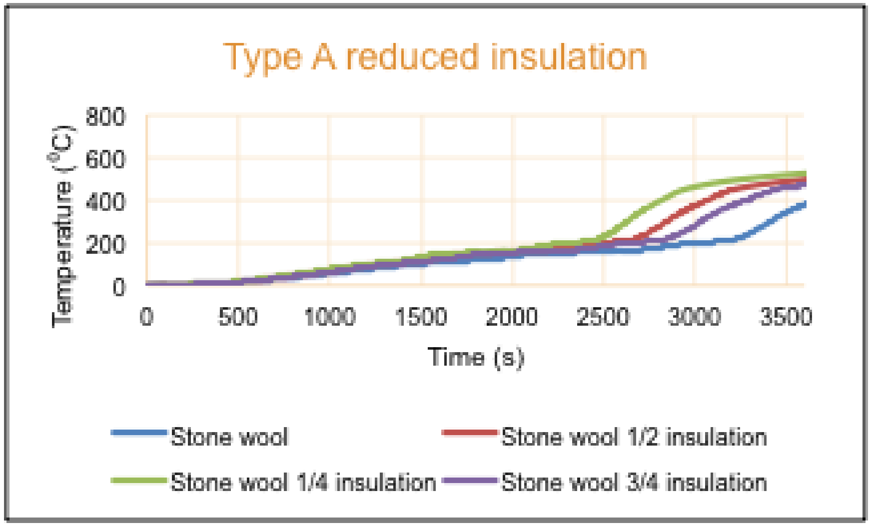
Validation ABAQUS

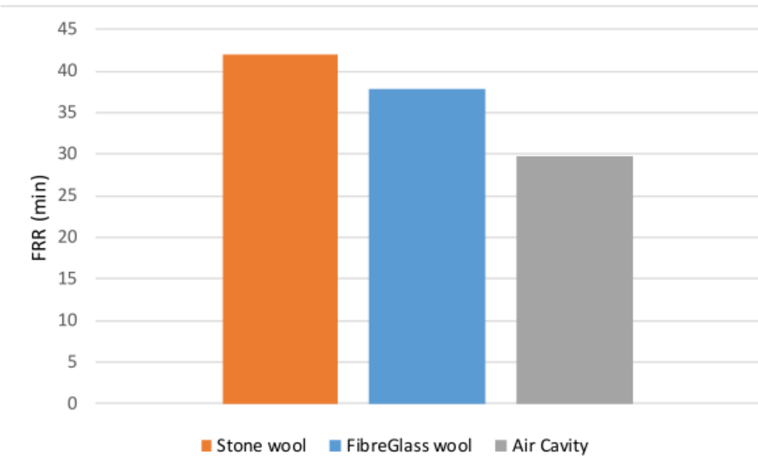
The FRR obtained for different experimental test samples were compared with the results obtained with the numerical model built with ABAQUS before the the different models were calculated

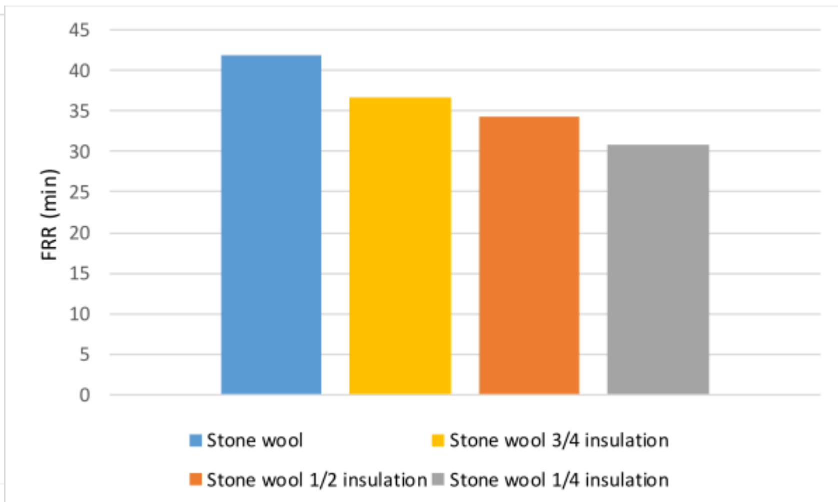
Type of assembly	Experimental test			ABAQUS	
	FRR (min)	Criterion	REF	FRR (min)	Relative error
1 x 1 - 9.5mm gypsum + 50mm Stone wool insulation	42, 41	T_{180}	[32]	45	+8%
1 x 1 - 12.5mm gypsum 50mm air cavity	38, 33, 34, 33, 36, 36	T_{180}	[32]	31	-11%
2 x 2 - 12.5mm gypsum 50mm air cavity	78, 77, 89, 91	T_{180}	[32]	89	+6%
2 x 2 - 15.9mm gypsum 90mm air cavity	52 min	T_{140}	[33]	37	-28%
1 x 2 - 15.9mm gypsum 90mm air cavity	66 min	T_{140}	[33]	78	+20%

ABAQUS results for different models

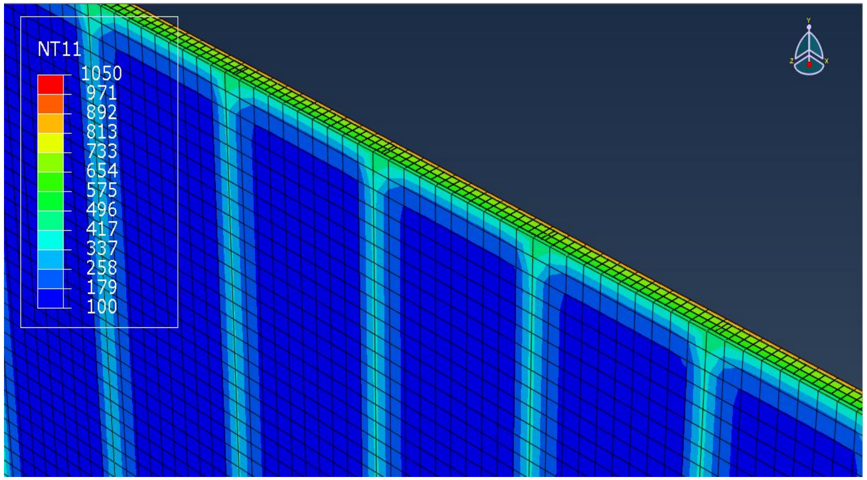


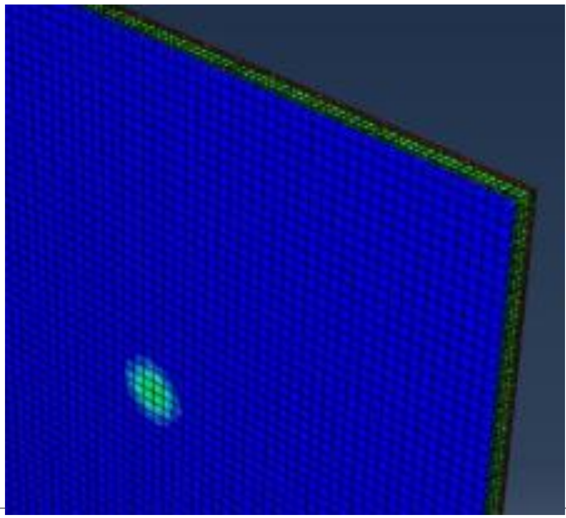


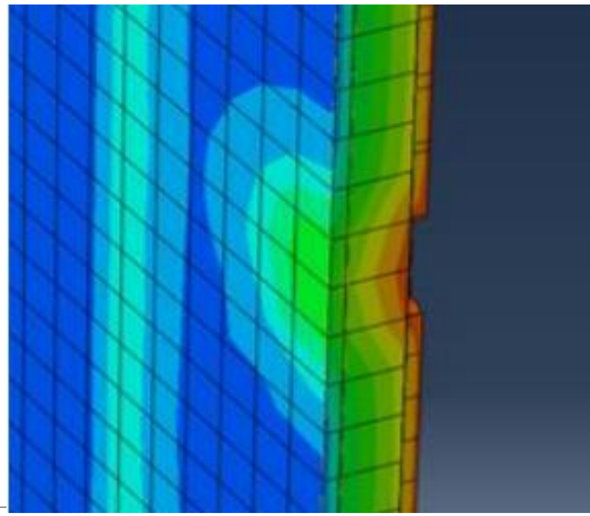




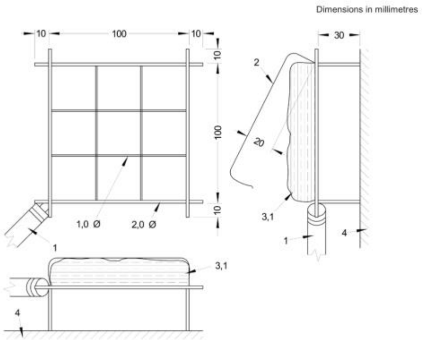
ABAQUS results







FDS Models



Reproduction of an existing furnace model was used.

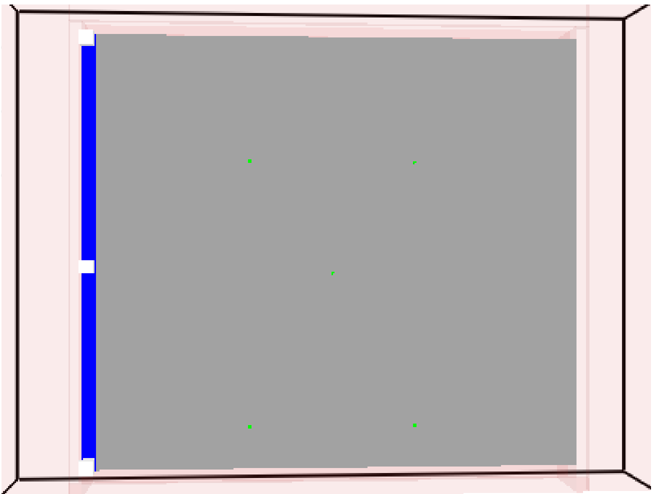
The furnace dimensions are 3.6m wide by 3.1m high by 600 mm deep and is lined with 38-mm-thick ceramic blanket.

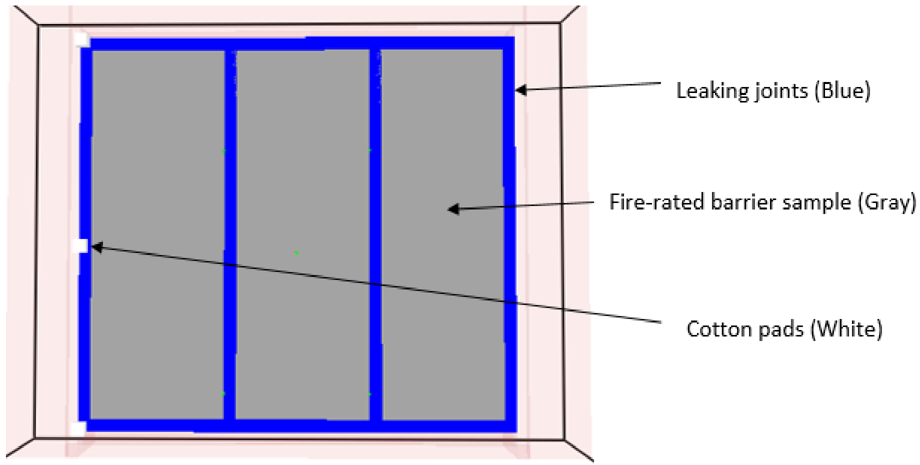
Cotton Pads were reproduced. The Temperature of ignition of the cotton pad was assumed to be at 400 ° C

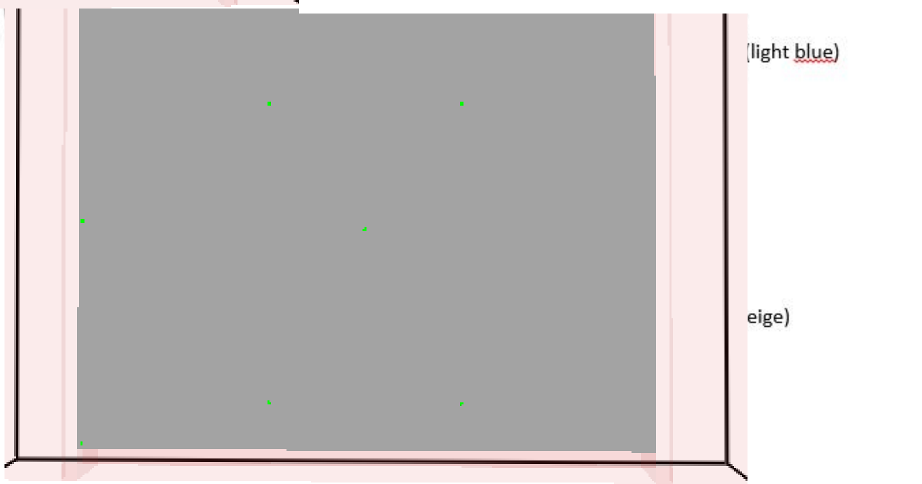
Cracks smaller then the gauge gap diameter in the tests for FRR

	Ceramic fibre blanket	Cotton Pad
Thermal conductivity (W/mK)	0.04	0.23
Specific heat (J/kgK)	1150	1339
Density (kgm^3)	160	150

FDS (CFD computational fluid dynamics)

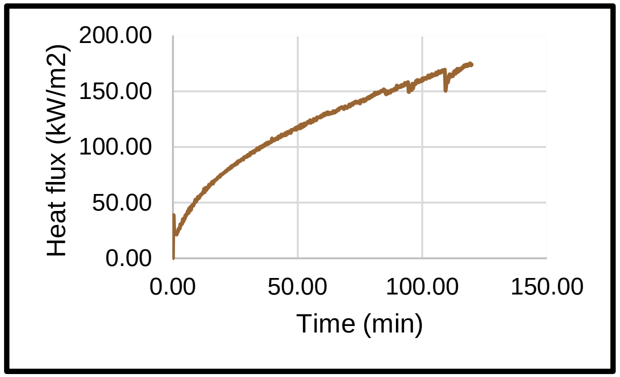


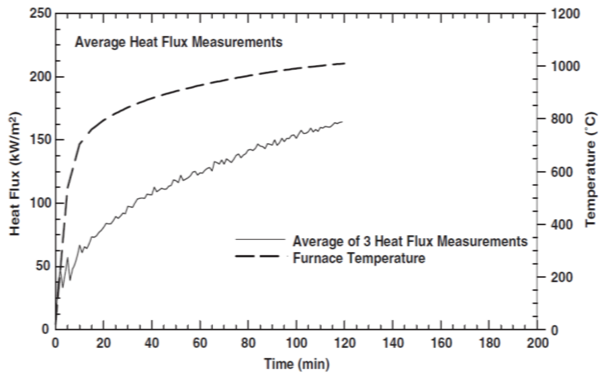


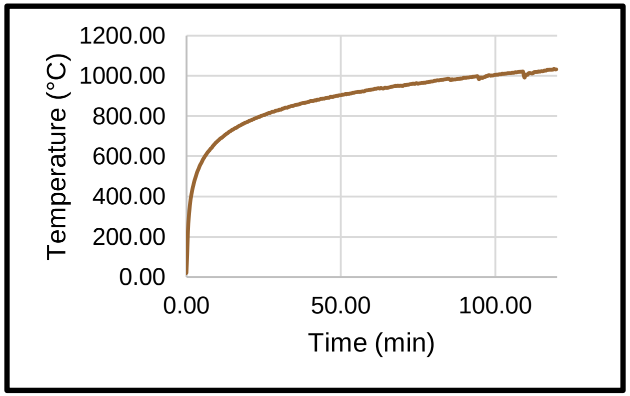


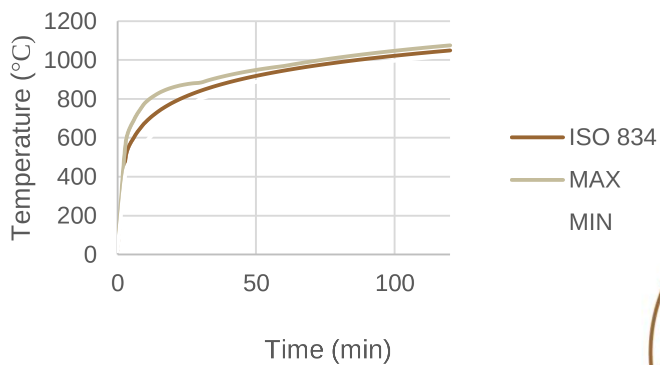
Validation FDS

In this project the furnace model was validated against the EN 1363-1 standard (FRR test standard) and experimental data.

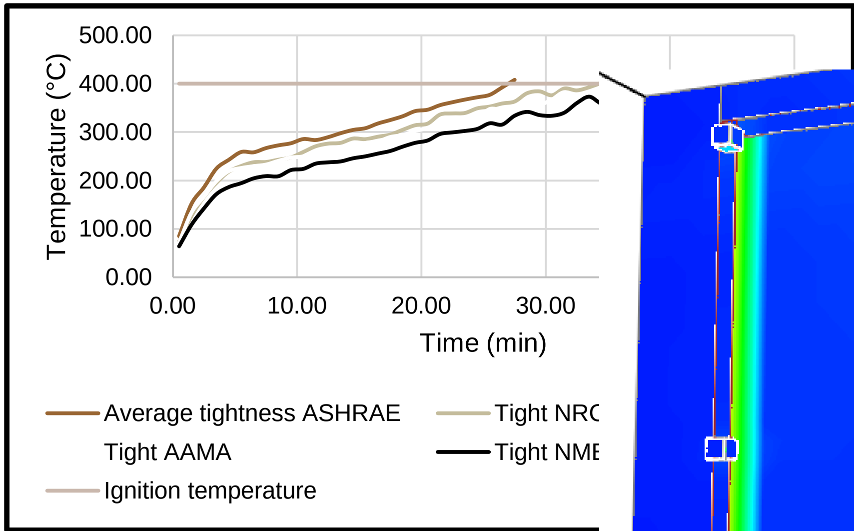


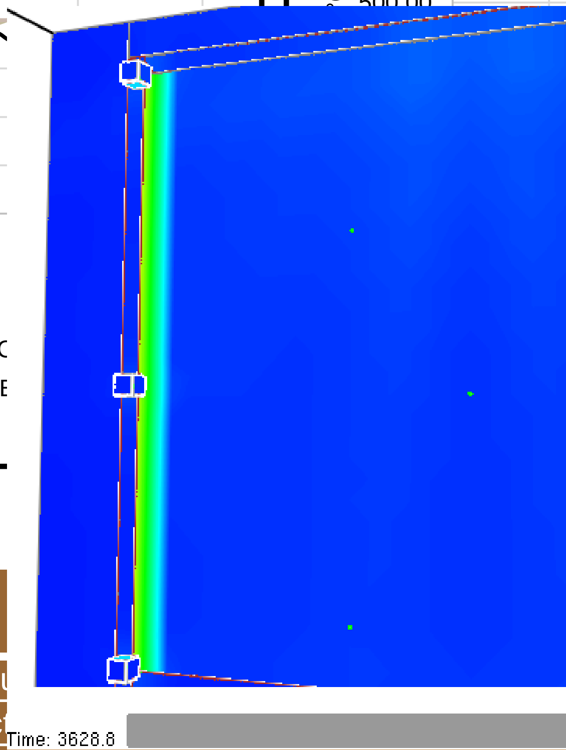


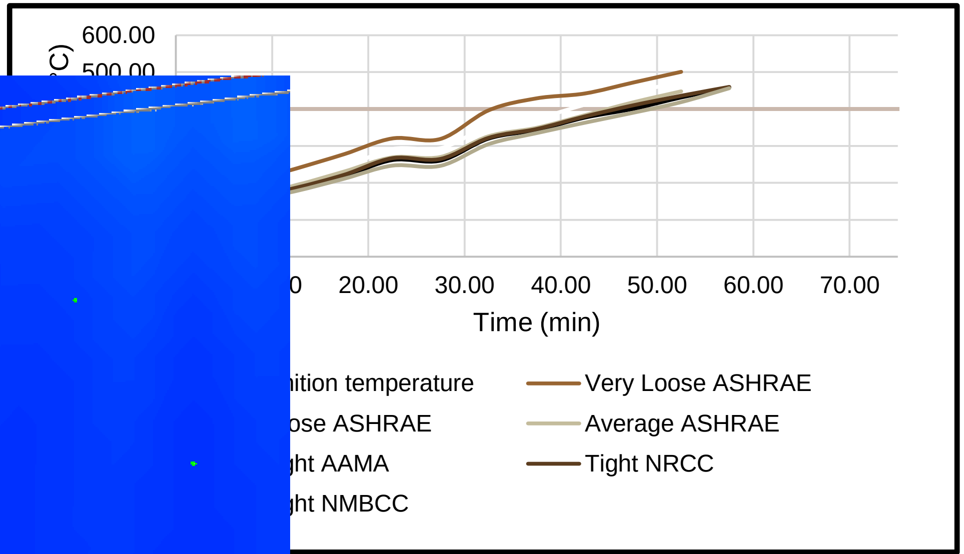




FDS results







Scenario		cotton pads (min)	
		se2	Case3
Very loose constru		32	46
Loose construct		40	50
Average construction	27	44	52
Tight construction (NRCC)	34	46	50
Tight construction (AAMA)	41	48	53
Tight construction (NMBCC)	46	50	52

Conclusion insulation

- For partition without deficiencies or alteration, stone wool insulation provided a FRR 13% and 40% higher compared to similar partition insulated with Fiberglass wool and uninsulated partition, respectively.

- Small breach (10mm radius) on the exposed layer of gypsum board did not affect the stone wool insulated partition, however the uninsulated partition FRR was found to be reduced by 50%.

Conclusion insulation

- Larger breach (50mm radius) on the exposed layer of gypsum board reduced the FRR by 50% for partition with fiberglass wool and uninsulated partition and by 40% for partition with stone wool.

- 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 up to 75%

Conclusion leakage

- Failure mainly due to the insulation criterion in minutes
- For integrity:
  - For an average air tight construction, leakage through a hole has FRR 38% lower compared to leakage occurring through joint on one side of the wall
  - For an average air tight construction, leakage through joint on one side give FRR 15% lower compare to leakage through all the joints of the wall
  - Leakage occurring through a hole caused a 55% reduction of the FRR, for an average air tight construction.

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