

NISTIR 6872

Evaluation of Fire Models for Nuclear Power Plant Applications: Cable Tray Fires

International Panel Report

Compiled by Monideep K. Dey, Guest Researcher

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National Institute of Standards and Technology
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*Fire Research Division
Building and Fire Research Laboratory*

June 2002



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TECHNOLOGY ADMINISTRATION
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**Appendix H: Benchmark Analysis with CFAST,
Juergen WILL, GRS, Germany**

Report

Benchmark Exercise #1 Cable Tray Fires of Redundant Safety Trains

**Blind Simulations using
CFAST 4.0.1**

International Collaborative Project to Evaluate Fire Models for Nuclear Power Plants

May 23, 2001

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1 COMPUTER CODE

All calculations were performed applying the multi-room zone model CFAST [1], most actual version 4.0.1. The older Version 3.1.6 could not be used because all available personal computers (PCs) were running under Microsoft WINDOWS NT operation system. Testing CFAST version 3.1.6 on a WINDOWS 98 platform also failed. PCs (without hardware handicaps) with WINDOWS 95 operational system were not available.

All the information referring to the model or the computer code was taken from

- NIST TN 1431: A technical reference for CFAST: An engineering tool for estimating fire and smoke transport. January 2000, [1],
- NIST Special Publication 921 2000 Edition: A user's guide for FAST: Engineering tools for estimating fire growth and smoke transport. January 2000, [2],
- NIST Technical Note 1299: CFAST, the consolidated model of fire and smoke transport. September 1995, [3]
- personal information given by Mr. G. Blume (iBMB of TU Braunschweig), who performed a lot of calculations with CFAST 3.1.6 in the past.

In our opinion it does not make a strong difference whether CFAST version 3.1.6 or version 4.0.1 is used. Comparing the manuals of these two program versions, no changes in the physical basis were found. Applying the more actual version does not seem to be as comfortable as the older one because the graphic user interface (GUI) FAST is no longer available and creating an input data file is a little more difficult.

2 BENCHMARK EXERCISE PART I

2.1 INPUT DATA FOR PART I

All the information was taken from "Benchmark Exercise #1: Cable Tray Fires of Redundant Safety Trains", revised September 11, 2000, [4].

The thermophysical data for walls, floor and ceiling as well as for the PVC insulation material of the cables were put in a new file THER_ST.DF as well as THER_ST.NDX. The cable of tray A was described on the one hand as a target, on the other hand as an object. Using the object model, a set of new files (OBJE_ST.DF, OBJE_ST.NDX) for the object properties was set up.

In each case of part I tray A was treated as an object or as a target. Preliminary calculations had shown that there is a considerable difference in the results using the unconstrained or the constrained fire algorithm. Therefore, these two algorithms were used in the calculations of the base case and of the cases 1 to 5. These two additional parameters lead to four different calculations for each case.

2.2 RESULTS OF PART I

2.2.1 Distance between tray A and trash bag (base case and cases 1 - 3)

From the base case up to case 3 the fire as well as the ventilation conditions were not changed. Therefore, it is obvious that the temperature of the upper and the lower layer, the depth of hot gas layer, the heat release rate and the oxygen content did not change either. The time curves of these parameters are shown in Figure 2.1 - Figure 2.5.

The course of the parameter describing the fire itself or the upper and lower layer is not affected by using different models (object or target) for tray A.

Starting the calculations, it was expected that in case of using constrained fire algorithm (fire type 2) the heat release rate is limited by oxygen consumption. But this did not happen, the heat release rate of the main fire (trash bag) is not affected by lack of oxygen (Figure 2.4). The oxygen content in the lower layer is not reduced by the trash bag fire (Figure 2.5). In the upper layer, there is a high amount of oxygen until the end of the simulation time, too.

Although it is not mentioned in the CFAST manuals, the two types of fire lead to totally different results with respect to the layer temperatures. Using the constrained fire algorithm, much higher upper and lower layer temperatures were calculated. This is surprising, because the interface height did not seem not to be affected (Figure 2.3) by the fire algorithm. But most surprising is the fact that in all runs of the program the surface temperature of tray A (as well as ceiling, walls and floor) is higher if the unconstrained fire algorithm is used, resulting in a lower gas temperature (Figure 2.6). For the analyst, it seems that something went wrong in calculating the convective and radiative heat flux on the target surface. Maybe in case of the unconstrained fire absorption by carbon dioxide and water vapour in the gas layers is ignored: Without absorption the layers do not heat up as much and the radiative heat flux on the ceiling, walls, floor and targets is higher, so that the surface temperature increases.

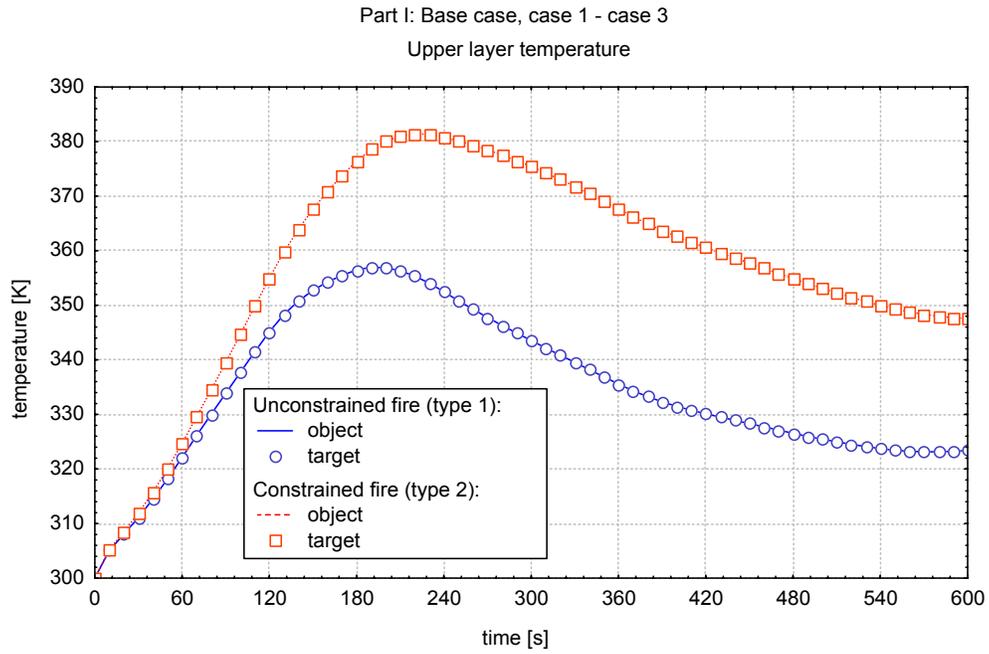


Figure 2.1 Upper layer temperature (base case, cases 1 - 3)

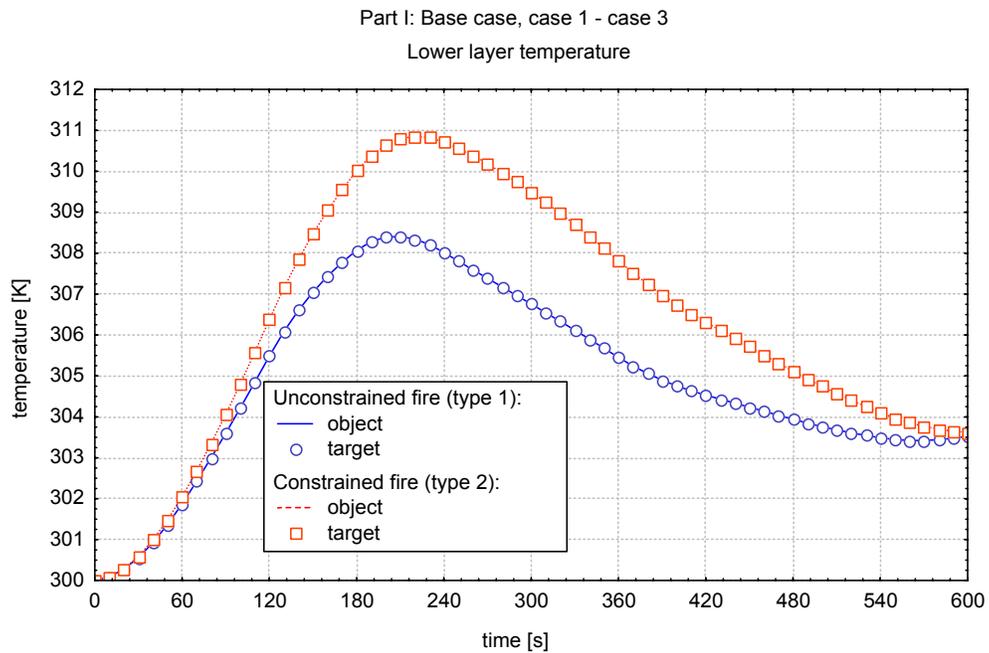


Figure 2.2 Lower layer temperature (base case, cases 1 - 3)

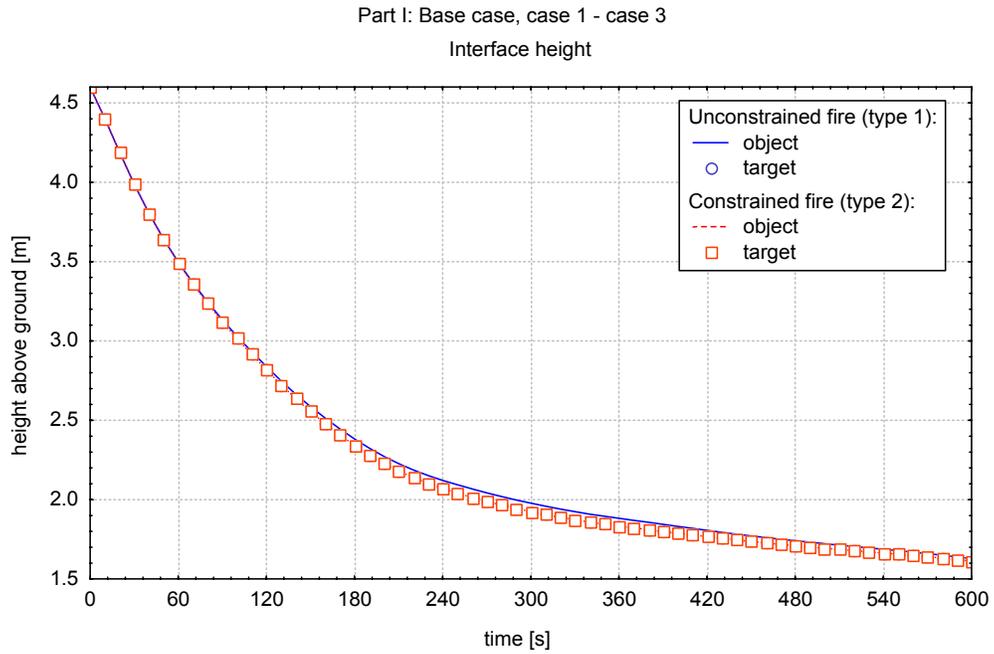


Figure 2.3 Interface height (base case, cases 1 - 3)

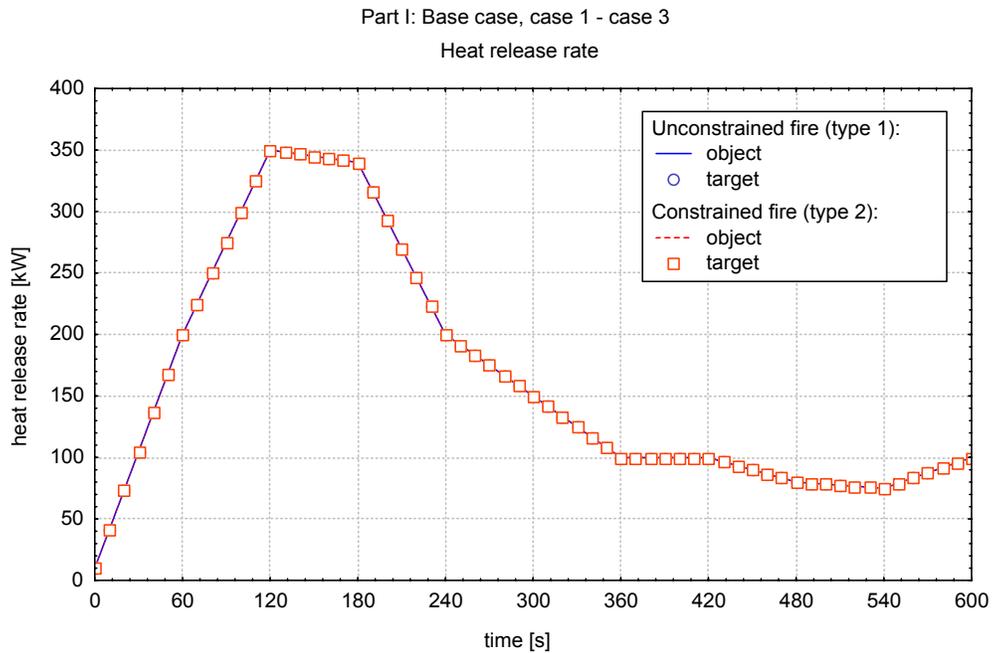


Figure 2.4 Heat release rate (base case, cases 1 - 3)

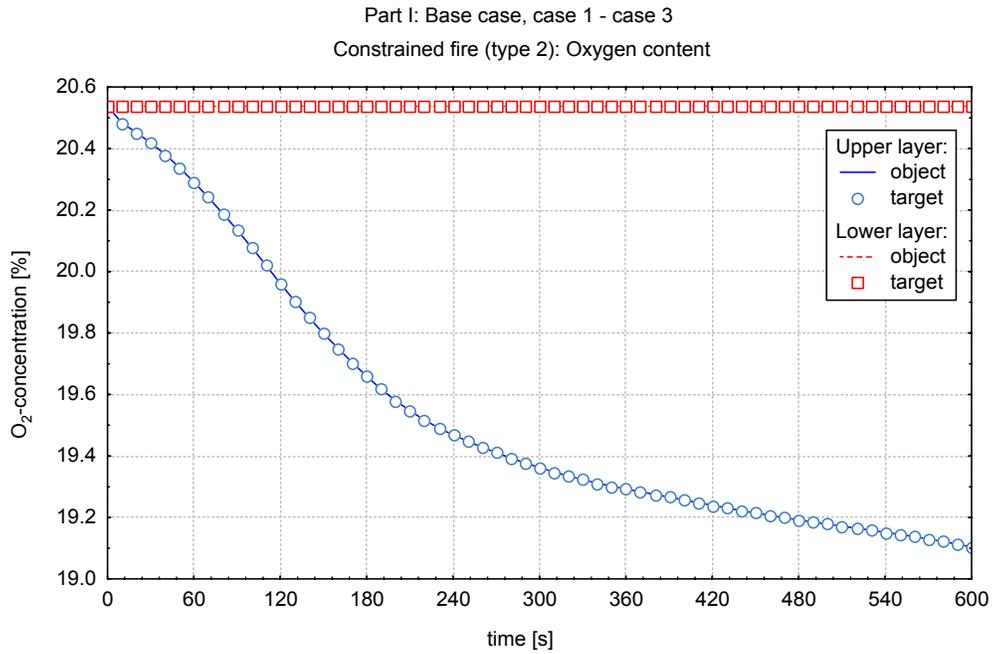


Figure 2.5 Oxygen content (base case, cases 1 - 3)

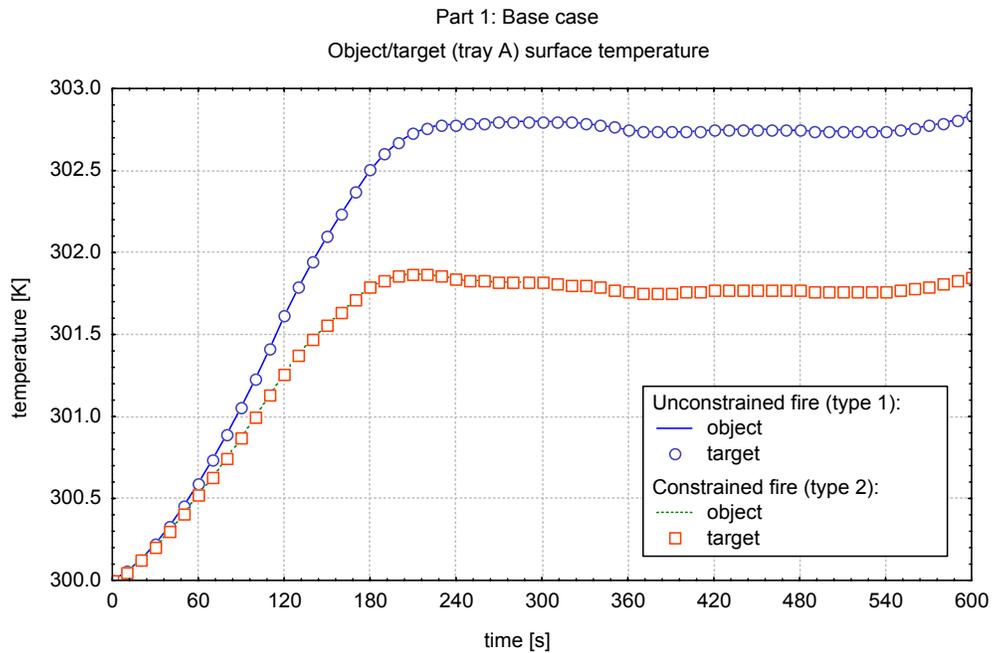


Figure 2.6 Surface temperature of tray A (base case)

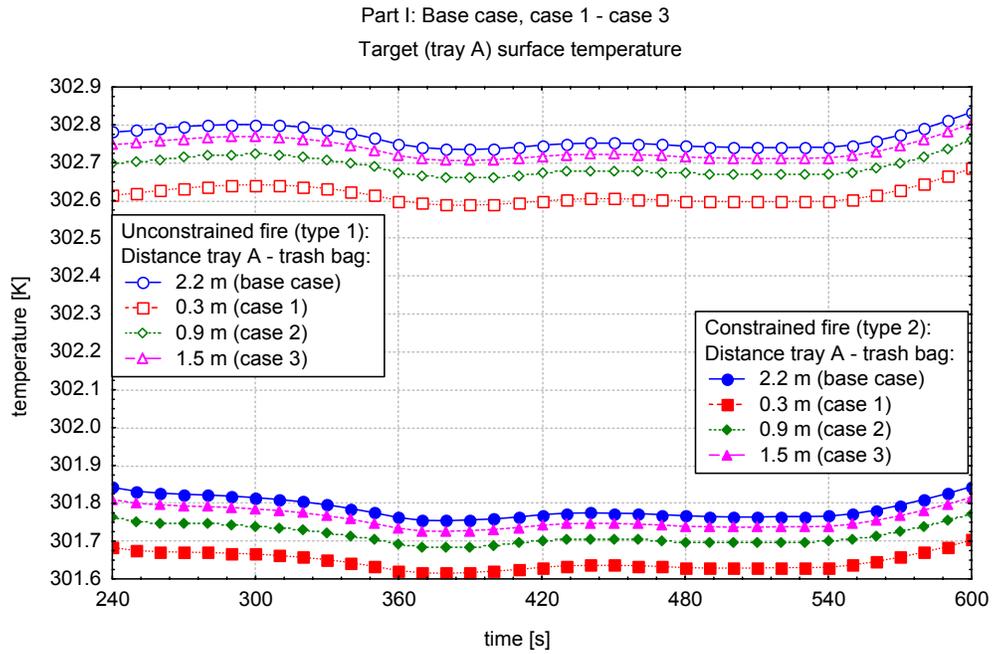


Figure 2.7 Surface temperature of tray A, unconstrained fire (base case, cases 1 - 3)

Comparing the surface temperature of tray A for different distances between the main fire (trash bag) and the target (base case, cases 1 - 3) is more amazing: Increasing the distance between target and heat source leads to an increase of the surface temperature (Figure 2.7), the opposite was expected.

As originally the x-position of the target (tray A) was fixed and the position of the main fire (trash bag) was moved in x-direction, further calculations were performed to find out what has gone wrong: Using the unconstrained fire algorithm (type 1), defining the door closed and the ventilation system switched off, the main fire (trash bag) was fixed in the center of the room (x-position 4.55 m), and the target (tray A) was moved in x-direction to get the distance of 2.2 m, 0.3 m, 0.9 m and 1.5 m between tray A and the trash bag. Looking at the results of these additional calculations (Figure 2.8), the amazing result is reasonable: The x- or y-position of a target does not affect the result of surface temperature, it was always treated as if it is positioned in the centre of the compartment. Only the position of the main fire (trash bag) will affect changes in the surface temperature of targets or objects. This weakness in the heat transfer model of CFAST is not mentioned in any manual. Due to this, in the former calculations the distance between tray A and trash bag was treated by the program as 1.15 m (base case), 3.05 m (case

1), 2.45 m (case 2) and 1.85 m (case 3), giving reasonable results for surface temperature (Figure 2.7) calculations.

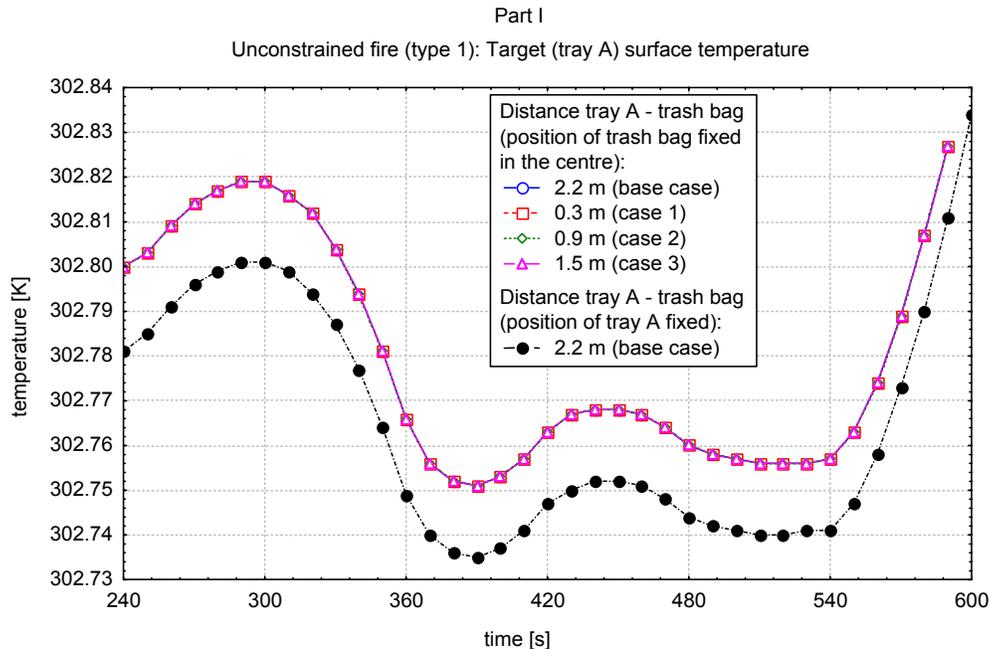


Figure 2.8 Surface temperature of tray A, constrained fire, position of trash bag fixed

2.2.2 Ventilation conditions (base case, cases 4 and 5)

The effects of different ventilation conditions should be shown by comparing the results of base case calculations and calculations with open door (case 4) or active ventilation system (case 5, case 5b).

It has been mentioned before that there have been some problems running CFAST with forced inflow (case 5). In this case, the oxygen content decreases until there is no more oxygen in the upper layer (Figure 2.9). It seems obvious that pure nitrogen was pumped into the compartment. There was no possibility in the input data file of CFAST to define the composition of the gas, which will be sucked in from the ambient into the compartment by a duct system. This problem did not appear in case of natural ventilation if the door is open (case 4). Thus the mechanical ventilation system was redefined: Concerning the following calculations, the outflow is managed by a fan and instead of the forced inflow a natural vent for horizontal flow is created to allow air to flow into the compartment (case 5b).

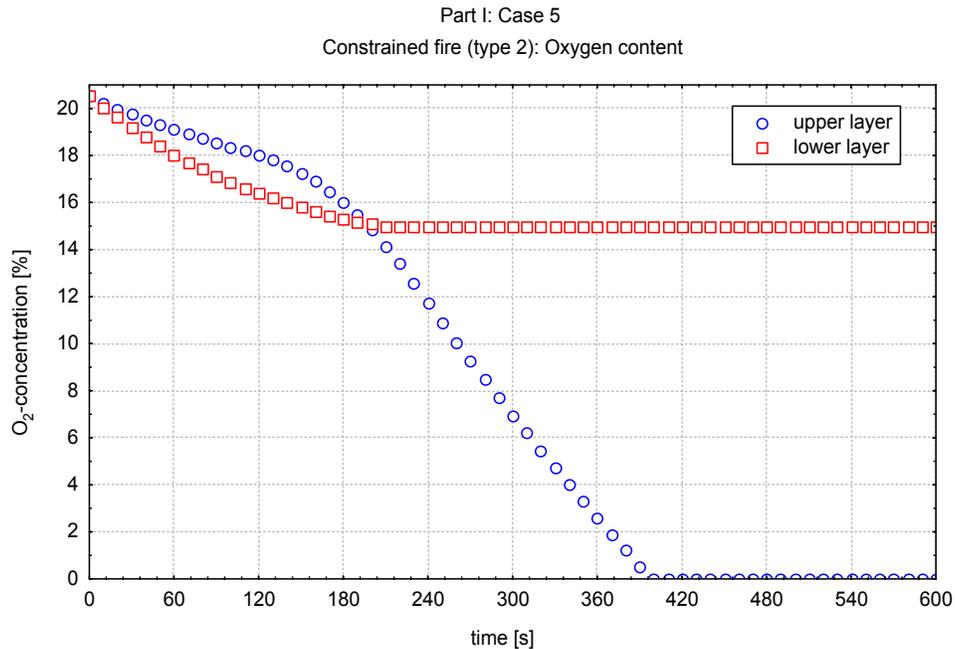


Figure 2.9 Oxygen content (case 5)

If an exchange of gases between the compartment and the ambient air is possible using openings as the door or a mechanical ventilation system, the temperature of the upper layer decreases nearly in the same magnitude (Figure 2.10, Figure 2.11). The increase in the lower layer temperature (Figure 2.12, Figure 2.13) and the decrease of the oxygen content in this layer are no longer important. Looking at the depth of the upper layer, which is not influenced by the fire type (Figure 2.14), and the oxygen content of this layer (Figure 2.15) it is discernible that the mechanical ventilation system (case 5b) is more effective than the natural ventilation by the open door (case 4). In case of the door opened or the mechanical ventilation system being active the surface temperature does not increase as much as without ventilation (Figure 2.16, Figure 2.17).

It has to be admitted that the increase of the oxygen concentration in the lower layer in case of an active ventilation (case 4, case 5b) is not reasonable. It has to be checked if the composition of ambient air and the air in the compartment at the beginning of the simulation are identical. It does not seem to be possible to define the gas composition in CFAST.

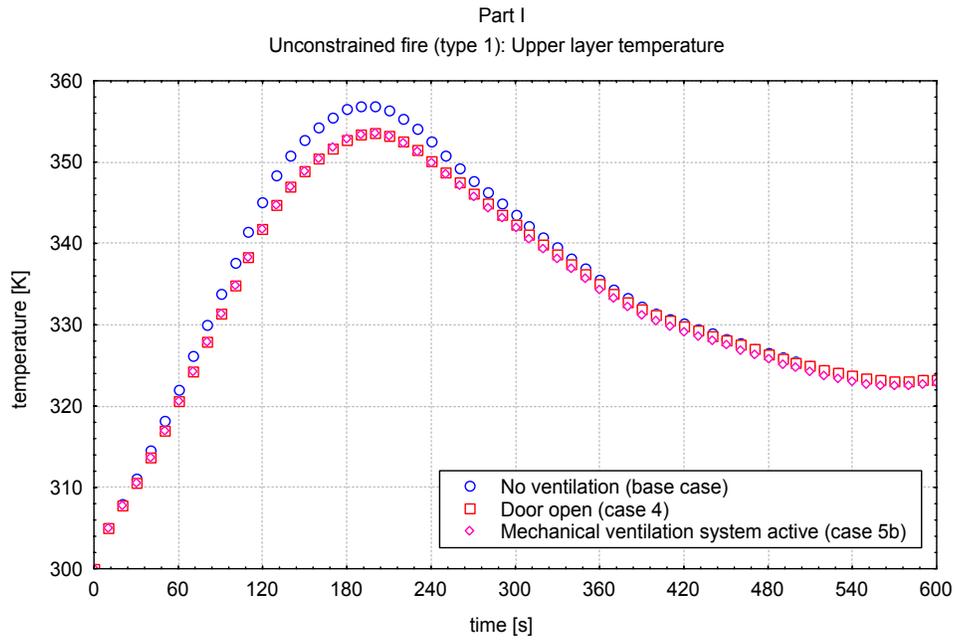


Figure 2.10 Upper layer temperature, unconstrained fire (base case, case 4, case 5)

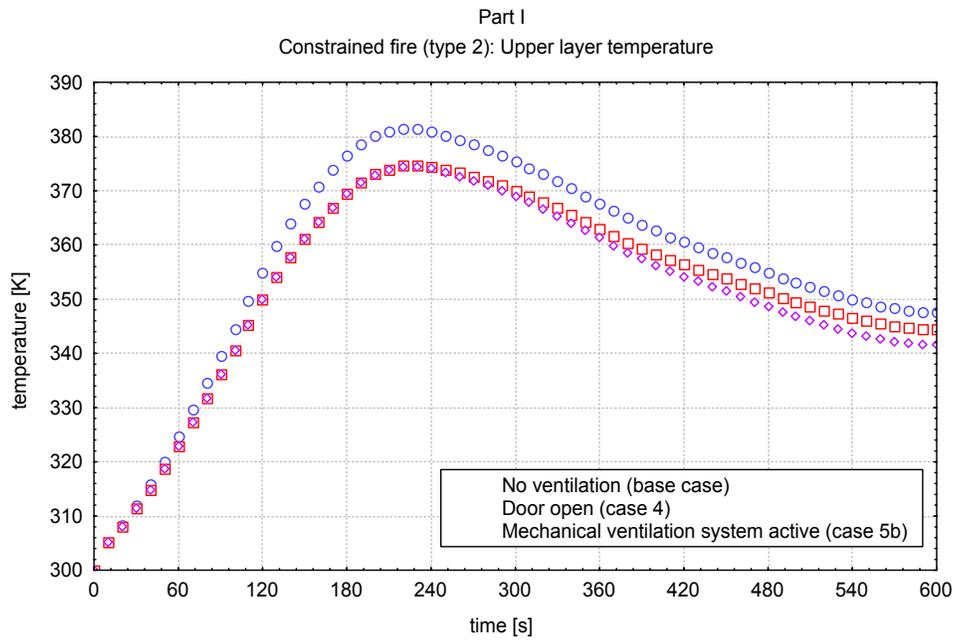


Figure 2.11 Upper layer temperature, constrained fire (base case, case 4, case 5)

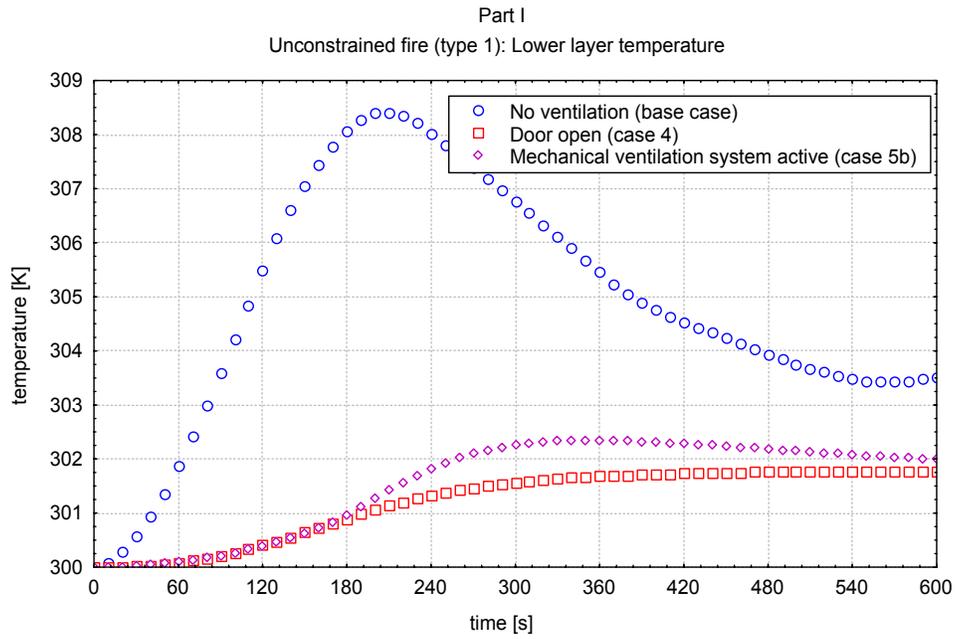


Figure 2.12 Lower layer temperature, unconstrained fire (base case, case 4, case 5)

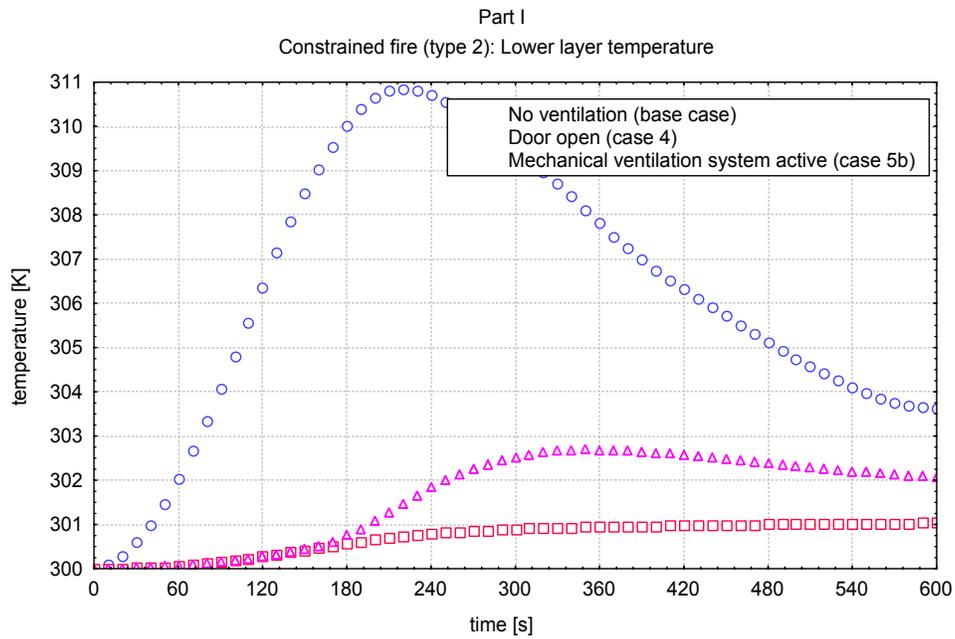


Figure 2.13 Lower layer temperature, constrained fire (base case, case 4, case 5)

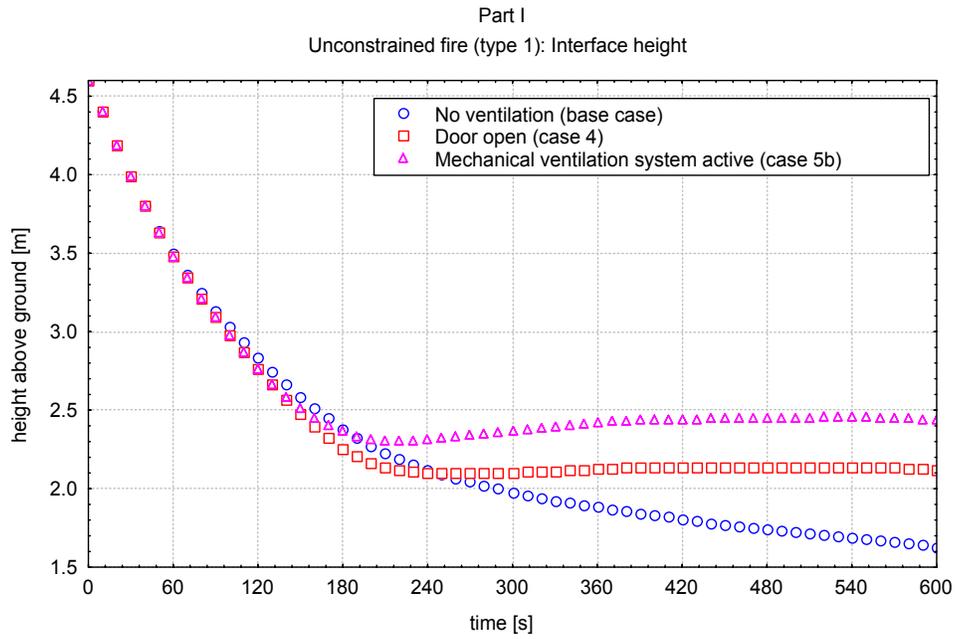


Figure 2.14 Interface height, unconstrained fire (base case, case 4, case 5)

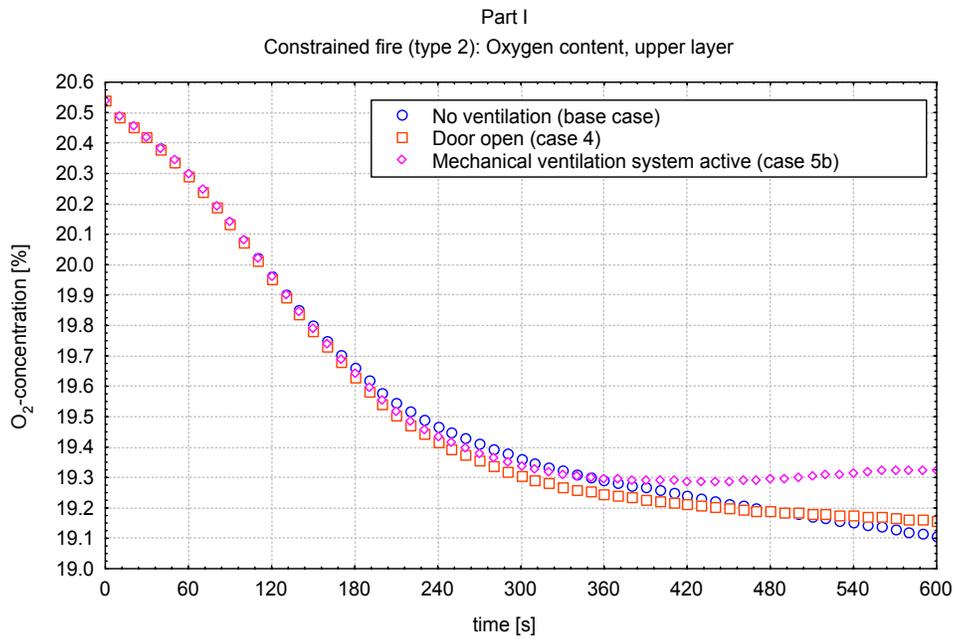


Figure 2.15 Oxygen content of upper layer (base case, case 4, case 5)

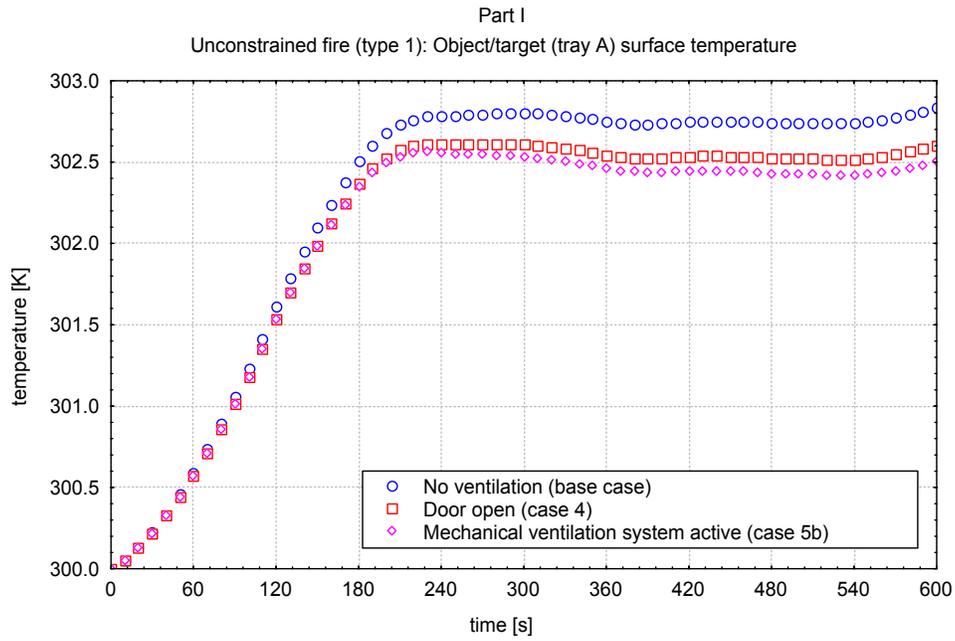


Figure 2.16 Surface temperature of tray A, unconstrained fire (base case, case 4, case 5)

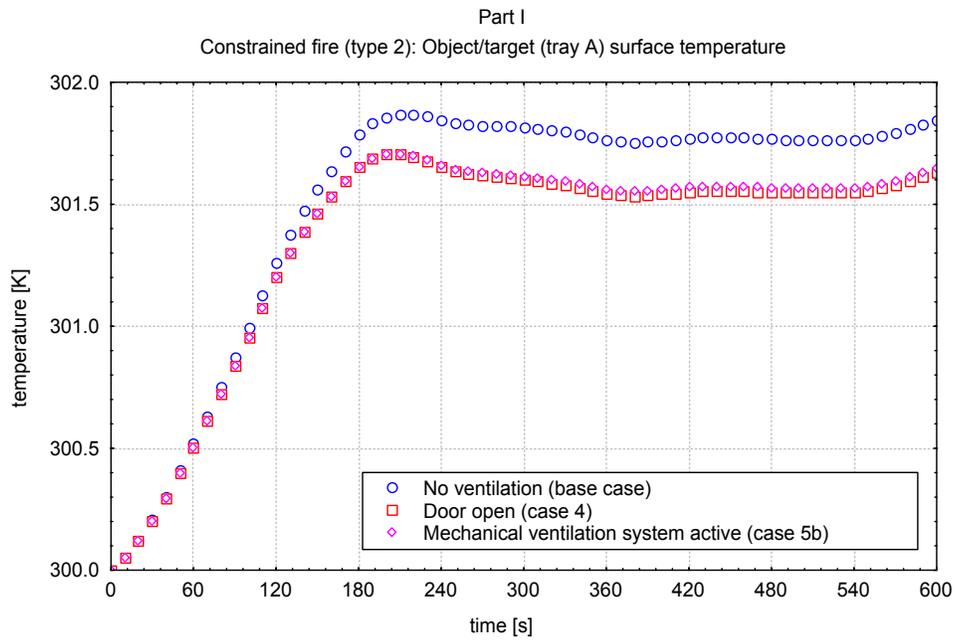


Figure 2.17 Surface temperature of tray A, constrained fire (base case, case 4, case 5)

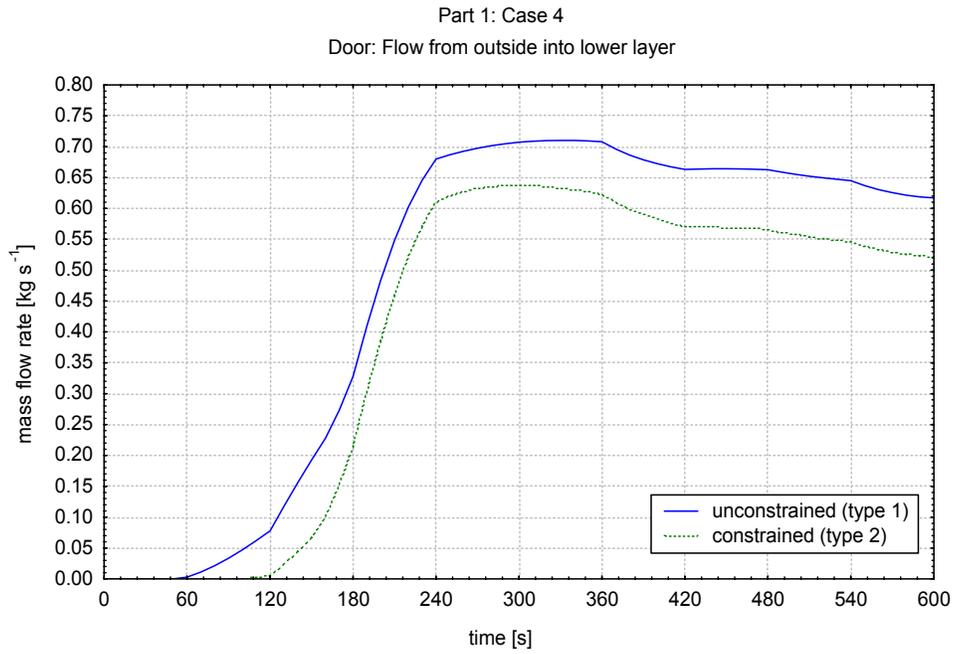


Figure 2.18 Mass flow rate through the opened door (outside - lower layer)

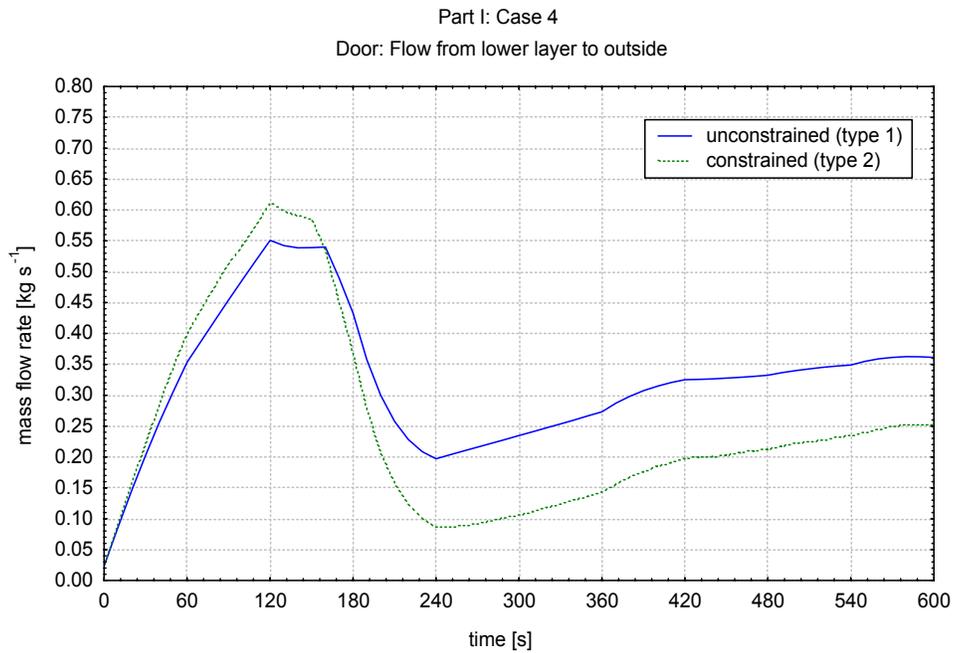


Figure 2.19 Mass flow rate through the opened door (lower layer - outside)

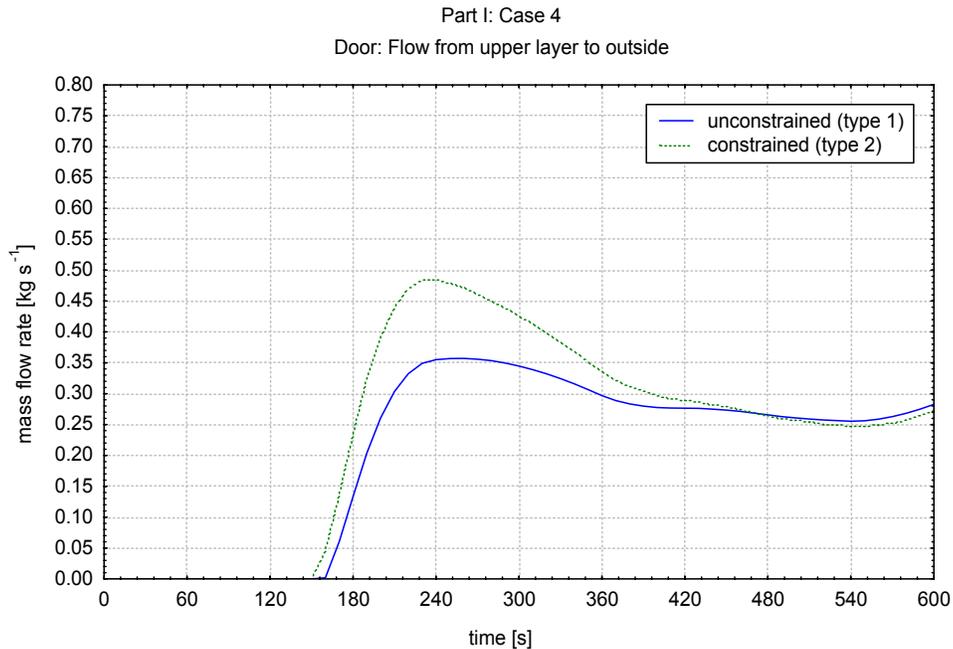


Figure 2.20 Mass flow rate through the opened door (upper layer - outside)

If the door of the compartment is opened (case 4), only lower layer gas flows out of the compartment. After approximately 2 minutes the interface reaches the top of the door, the gas flow from the upper layer to the outside starts, and the gas flow from the lower layer to the outside decreases (Figure 2.18, Figure 2.19, Figure 2.20).

In case 5b (mechanical ventilation system on but only for outflow, inflow by natural ventilation), the gas flows only in one direction through the opening (vent 1) from the outside into the lower layer (Figure 2.21). On the other hand, the fan sucks gas out of the lower layer until the interface reaches the bottom of the duct system opening. After that the fan sucks gas out of the upper layer.

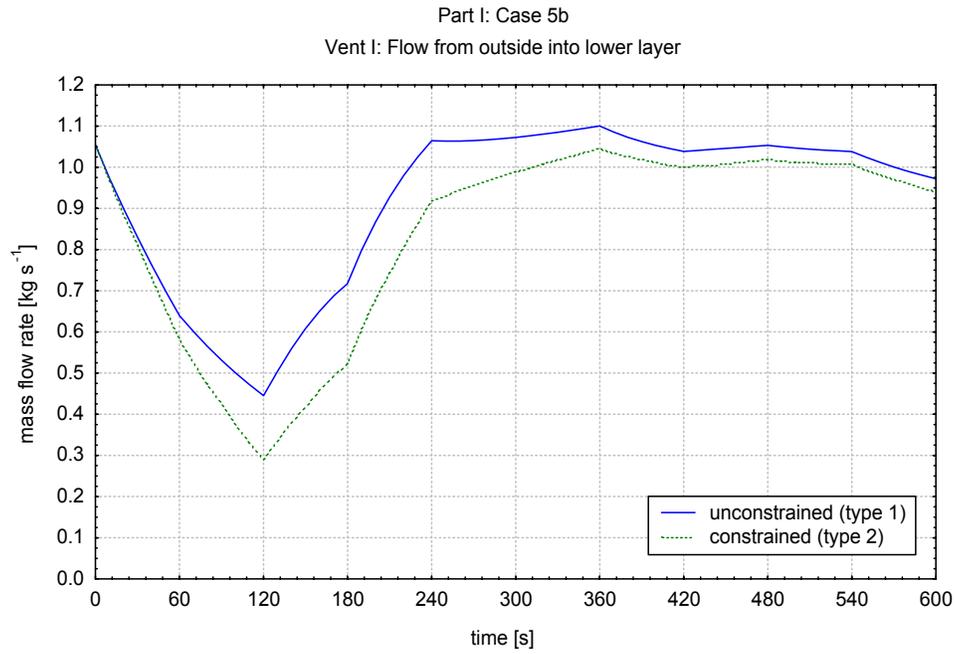


Figure 2.21 Mass flow rate through air inlet (outside - lower layer)

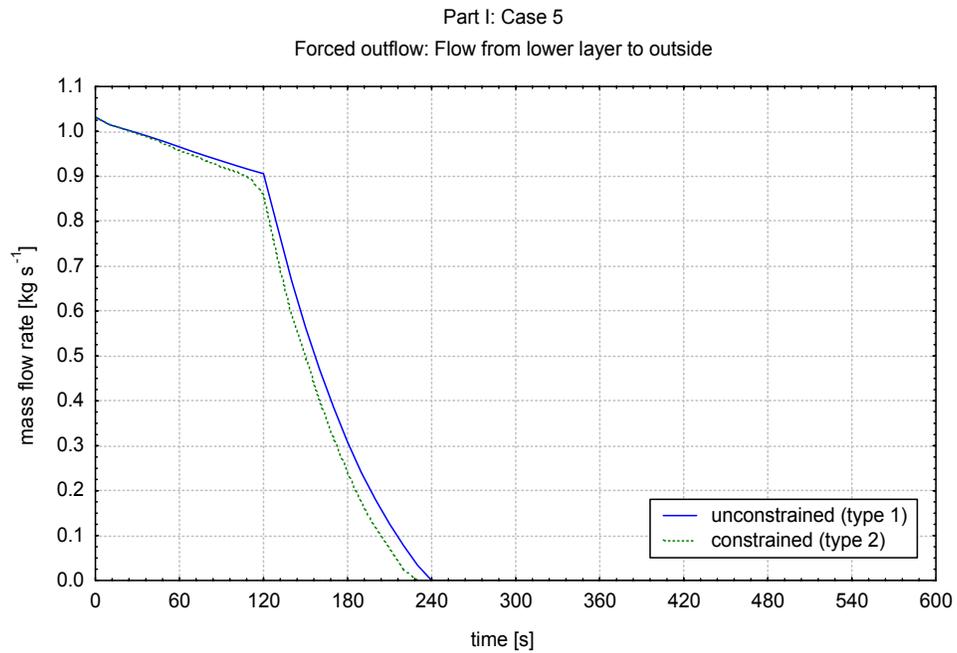


Figure 2.22 Mass flow rate of fan (lower layer - outside)

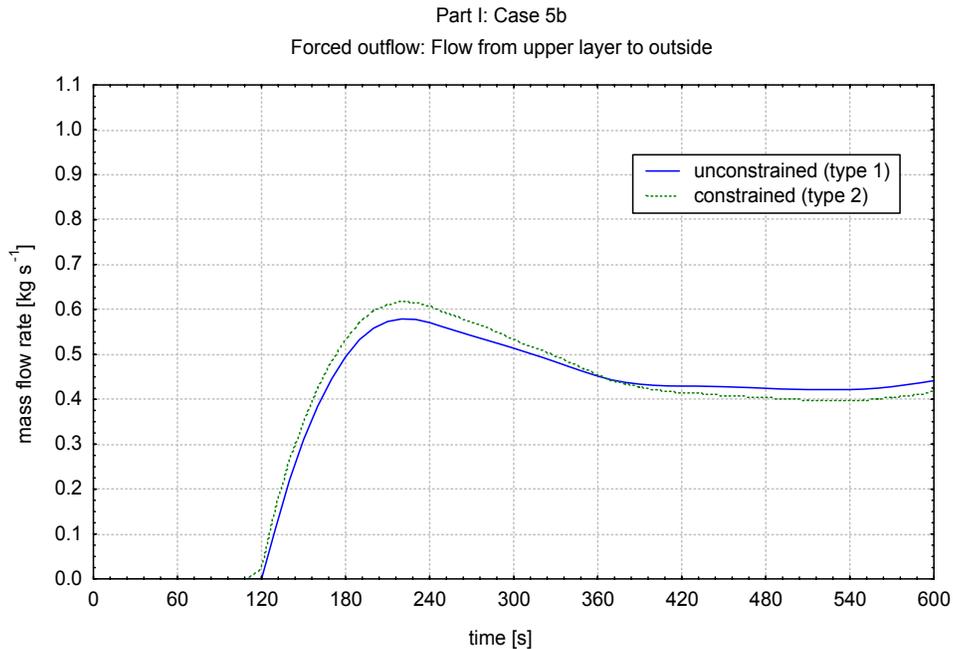


Figure 2.23 Mass flow rate of the fan (upper layer - outside)

Having a closer look at the pressure in the compartment it becomes visible that the base case is not realistic because the walls of the compartment (as well as the dampers of the ventilation system) have to resist a pressure of more than 10000 Pa (Figure 2.24). Even if a gap of 5 mm width under the door is assumed the pressure will reach a level of more than 1.000 Pa. If there is a sufficient ventilation area in the compartment like the open door (case 4), the pressure difference is very small (Figure 2.25). The pressure in the compartment hardly reaches the limitation of the fan in case of air being pumped into the room by a mechanical ventilation system (case 5), although another fan with the same sucks gas out of the compartment. (Figure 2.26). At least, if the mechanical ventilation system consists only of a fan sucking out gas and air flows into the compartment by natural ventilation (case 5b), the pressure inside the compartment is below atmospheric pressure (Figure 2.27).

In this context, it has to be pointed out that all results and statements are only valid in this special case of a very small fire of at least 350 kW heat release rate.

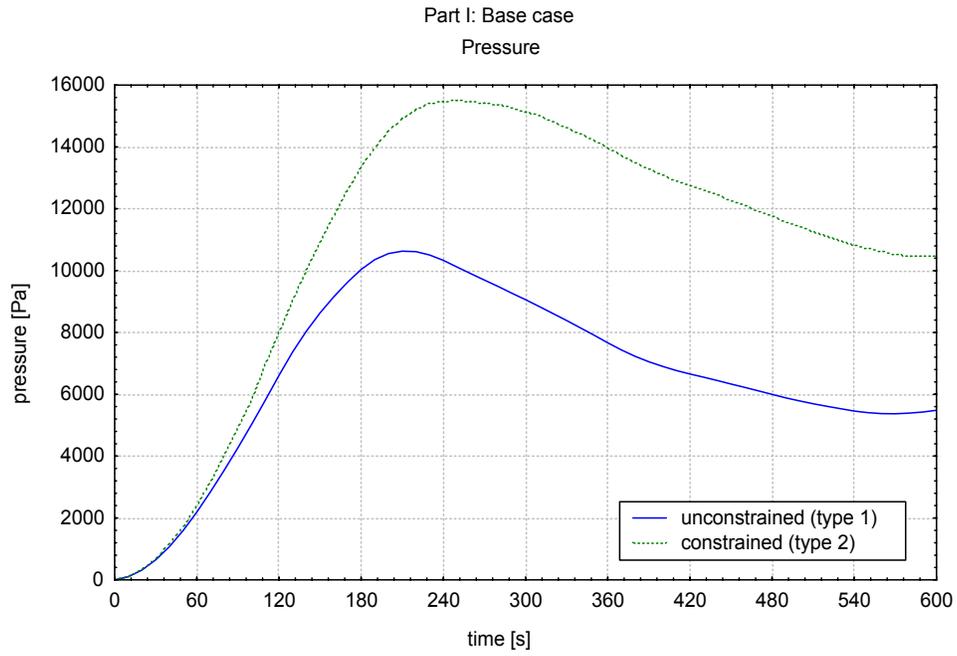


Figure 2.24 Pressure (base case)

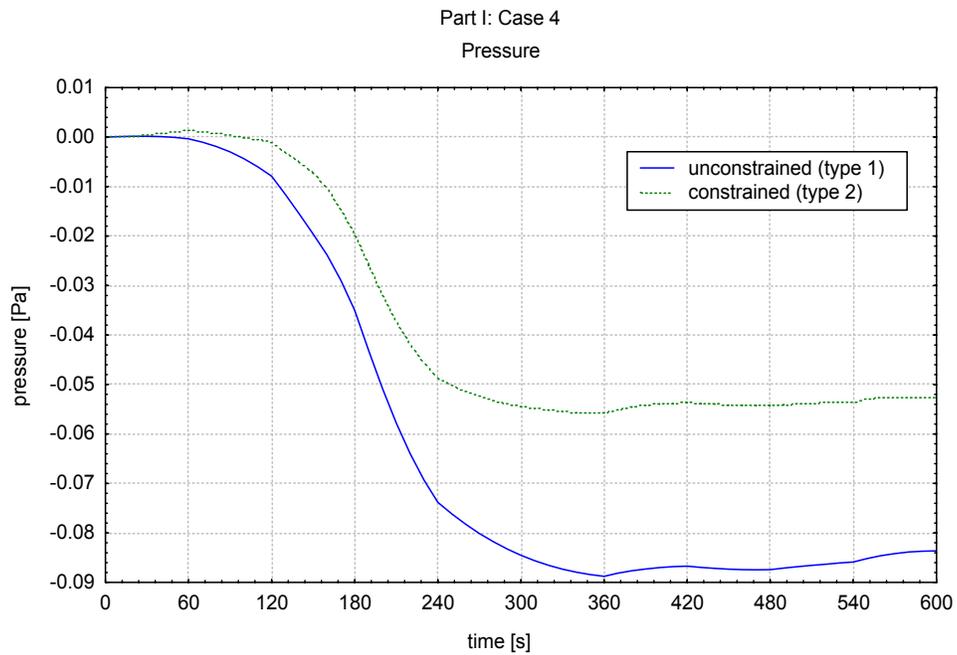


Figure 2.25 Pressure (case 4)

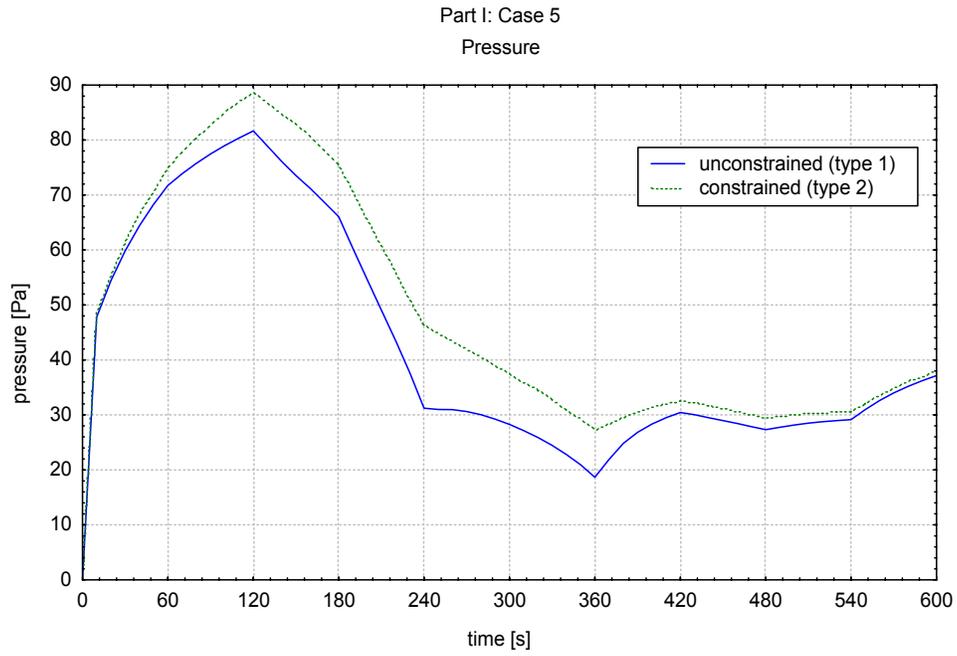


Figure 2.26 Pressure (case 5)

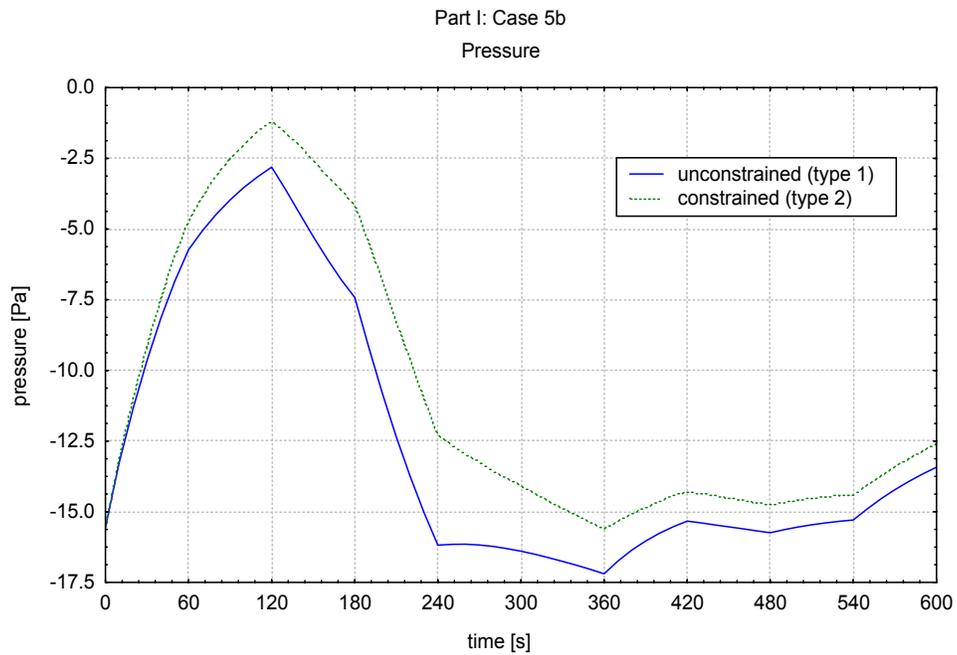


Figure 2.27 Pressure (case 5b)

3 BENCHMARK EXERCISE PART II

3.1 INPUT DATA FOR PART II

The thermophysical data for the walls, floor and ceiling as well as for the PVC cable insulation material were put in the former mentioned file THER_ST.DF as well as in the file THER_ST.NDX. As the heating of an object is treated like the heating of a target, only the object model of the files (OBJE_ST.DF, OBJE_ST.NDX) was used for cable tray B in part II. In all examined cases of part II both fire algorithms (unconstrained, constrained) were used. Using fire type 2 (constrained fire, the time curves of variables HCl, HCr, OD and CO were additionally specified. CFAST cannot treat a variable position of an object or target in the horizontal plane, therefore it was assumed that the object / target (tray B) was positioned in the center of the compartment and the main fire (tray A, C1, C2) was moved in y-direction to get the distances of 6.1 m, 4.6 m or 3.1 m (not in x-direction, because the compartment is not wide enough).

The mechanical ventilation system in case 9a and case 10 was defined in the same way as in case 5b of part I. To run the simulations for case 9, the variable CVENT was used, and two points were added to the time curve of the 1 MW cable fire.

The user of CFAST is not able to specify the volume flow rate of a forced ventilation (an option, which is included in the older zone model HARVARD 6) or to specify the capacity of a mechanical ventilation system as a function of time. Trying to run a simulation for a problem time of up to 15 min (with mechanical ventilation system being active and door closed) creates a restart file for this point of time. A restart of the simulation with a modified input data file (switch off mechanical ventilation system and door open) also failed. Therefore, case 9 was calculated on the one hand with mechanical ventilation (called case 9a) and without a mechanical ventilation system (called case 9b) on the other hand, while the door is opened after 15 min simulation time.

To run case 13, the file OBJE_ST.DF was modified: Instead of a panel thickness of 50 mm (third value in line 3) a thickness of 15 mm was applied to simulate a typical NPP specific instrumentation cable. Since the variations of the object elevation or thickness did not effect the surface temperature, case 11 to case 13 will not be mentioned anymore.

3.2 RESULTS OF PART II

3.2.1 Heat release rate

Using the unconstrained fire algorithm (type 1) the heat release rate reached the predicted level of 1 MW, 2 MW or 3 MW (Figure 3.1). On the other hand, if the constrained fire algorithm was used, the development of the heat release rate was limited by the position of the upper layer and the oxygen content of this layer.

Without natural or forced ventilation the heat release rate reached 1 MW (base case), stayed on this level for a short time period until there was no more oxygen in the upper layer. After that, the heat release rate decreased rapidly. A maximum value of about 1.3 MW was reached, although a peak heat release rate of 2 MW or 3 MW had been defined. After reaching this value the heat release rate decreased rapidly.

The heat release rate of the 1 MW fire was affected by opening the door after 15 min simulation time (Figure 3.2): The heat release rate did not increase as expected, but it decreased rapidly (base case - case 9b). More astonishing was the fact that the decrease of the heat release rate started earlier, if the mechanical ventilation system was active all the time (cases 9a, 10). This behaviour could be explained when looking at the position of the interface (Figure 3.15), which was a little bit deeper in case that the mechanical ventilation system was running and the main fire was placed in the pure oxygen layer at an earlier point of time.

In part I, the trash bag fire was very small (peak heat release rate of 350 kW) and did not last very long. In addition, the trash bag was positioned near the floor, so that the fire was in the lower layer and there was no lack of oxygen any time. In part II, the distance between floor and bottom of the main fire (cable fire of tray A, C1, C2) could influence the course of the heat release rate if the constrained fire algorithm (type 2) was used. To demonstrate this effect, base case (1 MW), case 5 (2 MW) and case 8 (3 MW) were modified so that the main fire was positioned on the floor ($z = 0.0$ m). Locating the fire on the floor even the peak heat release of 3 MW could be reached and kept for some minutes. If the fire was placed near the ceiling, it would be located inside the upper layer (with very low oxygen content) very soon and the fire development would slow down or stop. Therefore, a peak heat release rate of more than 1.3 MW could not be reached if the fire was placed 3.4 m above the floor. The course of heat release rate of main fire for the different cases is shown in Figure 3.3.

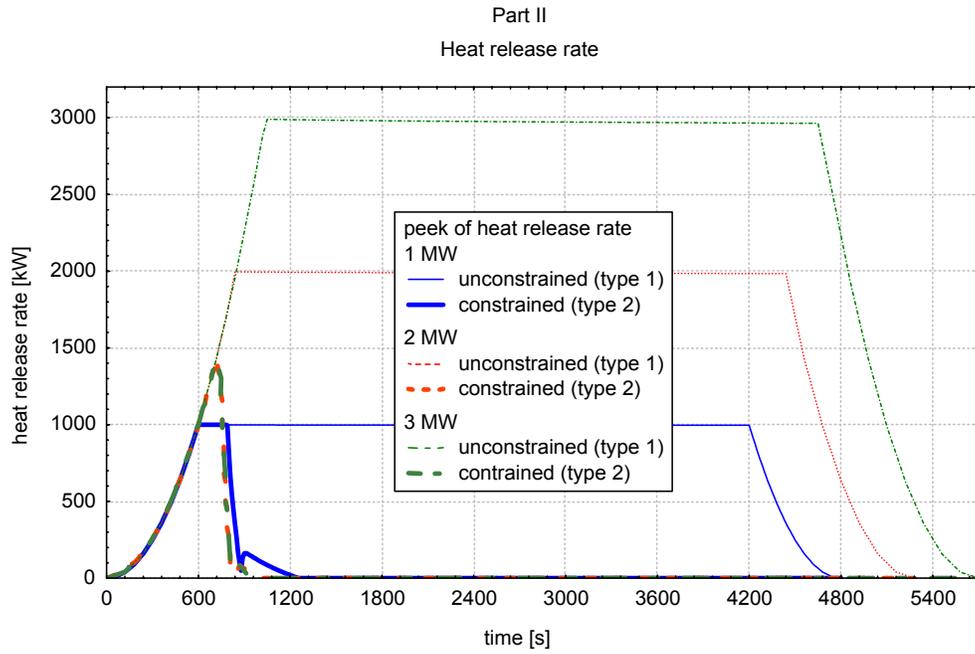


Figure 3.1 Effect of fire algorithm: Heat release rate

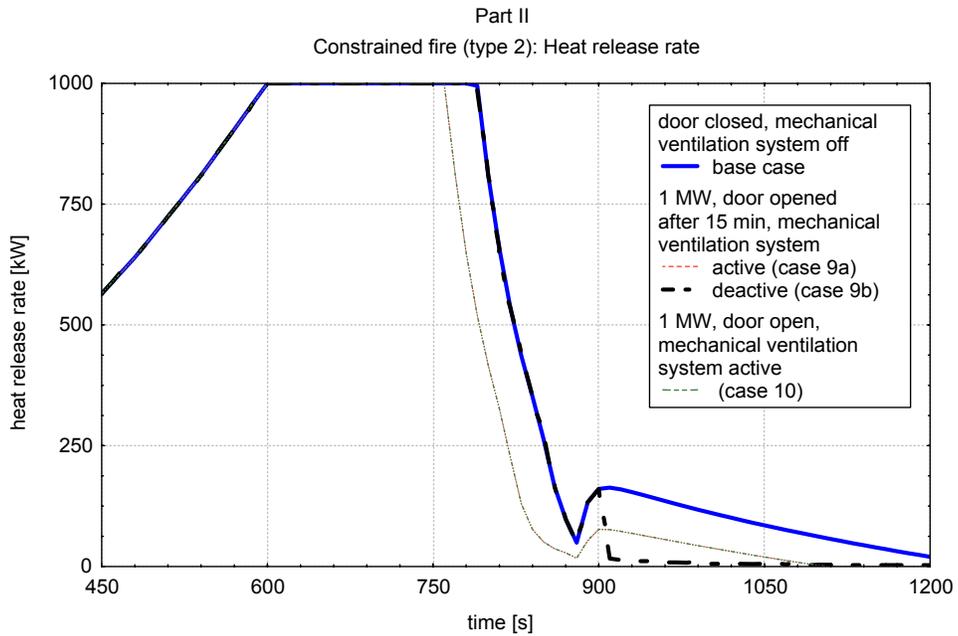


Figure 3.2 Effect of ventilation condition: Heat release rate

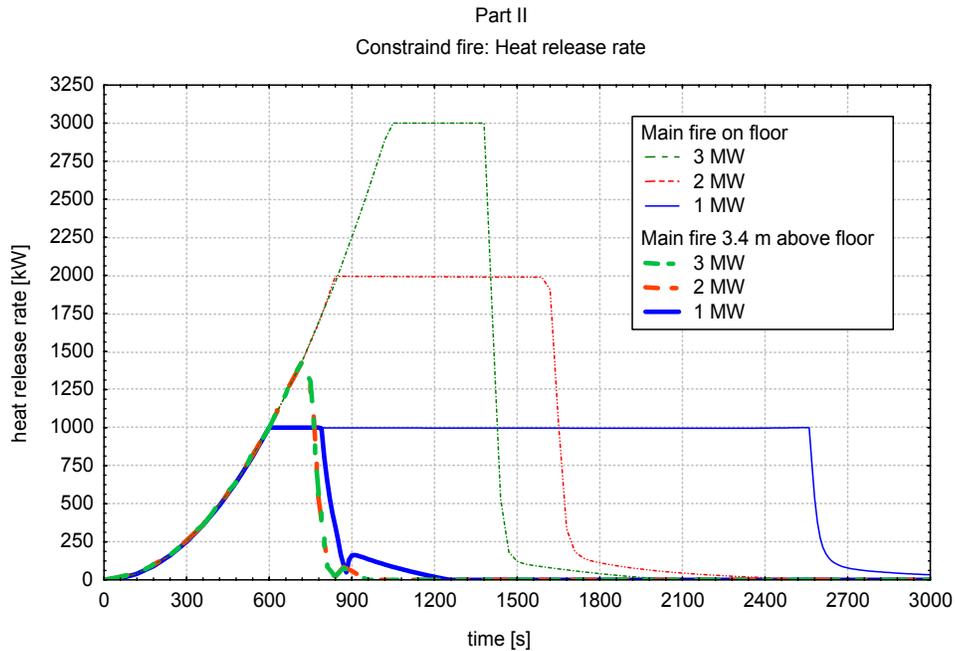


Figure 3.3 Effect of vertical fire position: Heat release rate

3.2.2 Layer temperatures and interface height

The distance between tray A, C1, C2 and tray B or the elevation of tray B do not affect the characteristics of the upper or lower layer. The temperatures of the layers and their thickness are mainly affected by the fire type, the heat release rate of the fire and the ventilation conditions.

Due to the fact that the fire growth is identical for the different cases of peak heat release rates (1 MW, 2 MW or 3 MW), the courses of the upper layer temperature (Figure 3.4, Figure 3.5), the lower layer temperature (Figure 3.6, Figure 3.7) and the interface height (Figure 3.8, Figure 3.9) are identical up to 600 s simulation time in all cases without any ventilation opening (base case - case 8, cases 11 - 13). Using the unconstrained fire algorithm (type 1), the course of these parameters runs simultaneously in case of a 2 MW fire and a 3 MW fire until a value of 2 MW is reached (840 s simulation time). The break in the course of the temperature and the interface height occurs earlier (750 s simulation time) if the constrained fire algorithm (type 2) is used. After reaching the break point (1 MW: 600 s, 2 MW: 840 s respectively 750 s), the temperature of the upper and the lower layer and the interface height develop in their own way in each different case of peak heat release rate.

To explain the influence of the ventilation conditions, the results of the 1 MW fire calculations (base case, cases 9a, 9b, 10) have to be compared. Looking at the course of the upper layer temperature (Figure 3.10, Figure 3.11), the ventilation conditions seem to have only a limited influence on the results. Obviously, the temperature of the lower layer is smaller if the door is open from the beginning and/or the mechanical ventilation system is active (Figure 3.12, Figure 3.13). The lower and upper layer cool down after 15 min simulation time if the door has been opened (base case - case 9b). In this case, there is also a discontinuity in the interface height (Figure 3.14, Figure 3.15). The lower layer temperature and the interface height do not differ if the door stays open all the time (case 10) or if it is opened after 15 min while the mechanical ventilation system has been active from the beginning (case 9a). Only the lower layer temperature grows a little bit higher if the door is closed at the beginning of the simulation and opened after 15 min (case 9b). The upper layer increases faster if the mechanical ventilation system is active all the time (case 9a, case 10).

The course of the upper layer temperature (Figure 3.16) is not affected by the fire algorithm used in the calculations until 600 s simulation time. But from 600 s until the point of time when a lack of oxygen occurs a faster increase of temperature is calculated using the constrained fire algorithm. This effect has also been observed in the simulations of part I.

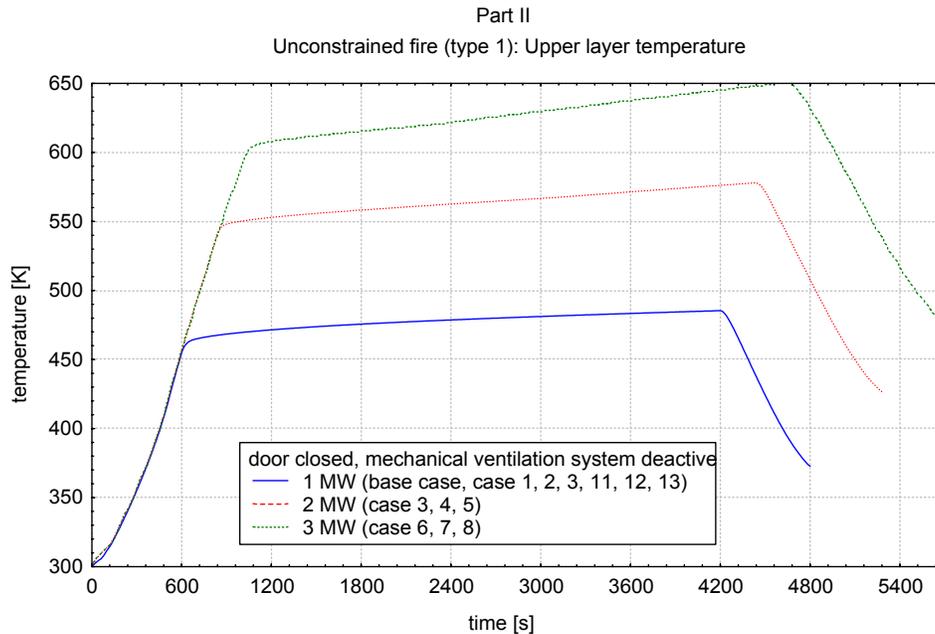


Figure 3.4 Effect of heat release rate: Upper layer temperature, unconstrained fire

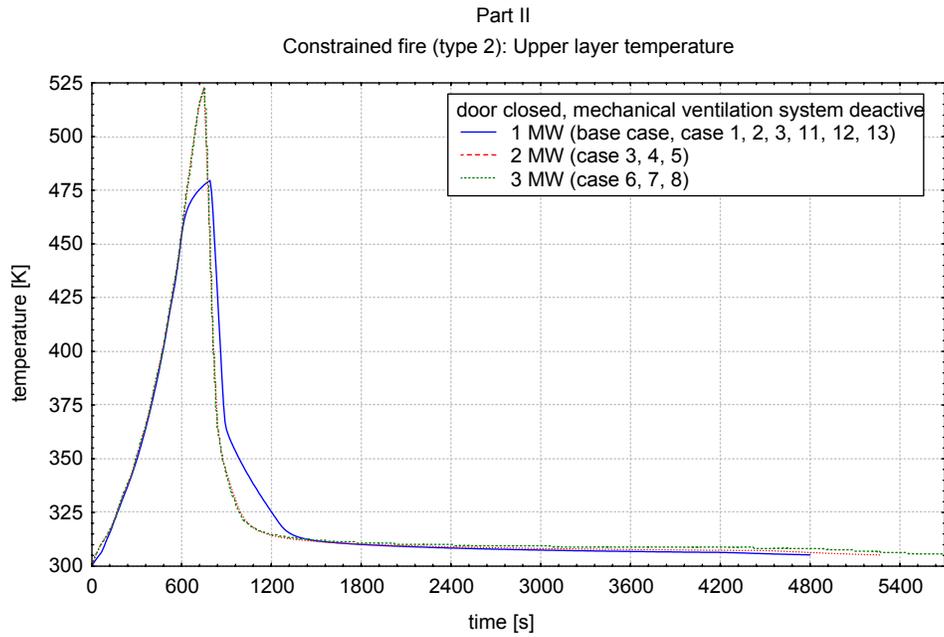


Figure 3.5 Effect of heat release rate: Upper layer temperature, constrained fire

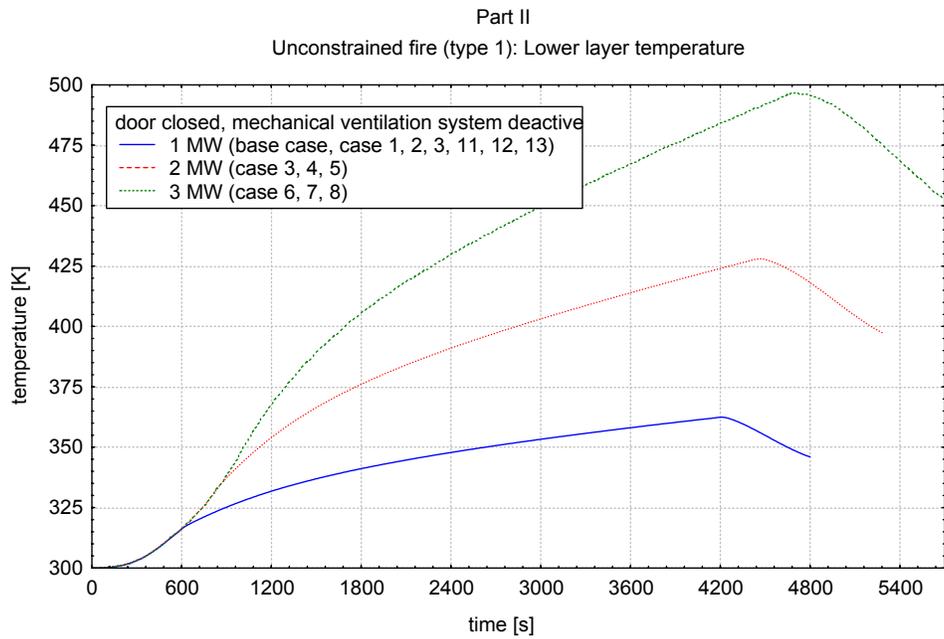


Figure 3.6 Effect of heat release rate: Lower layer temperature, unconstrained fire

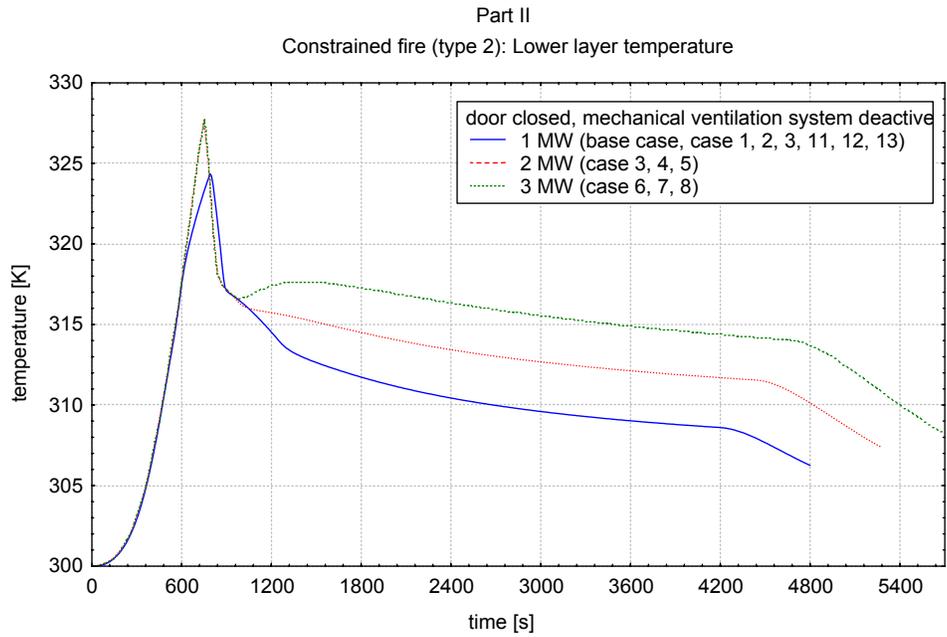


Figure 3.7 Effect of heat release rate: Lower layer temperature, constrained fire

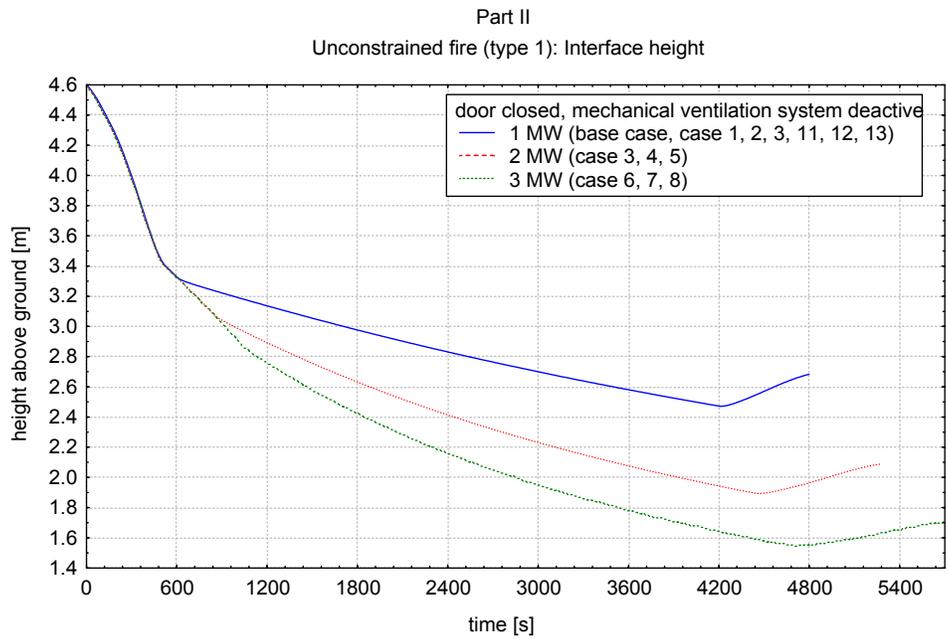


Figure 3.8 Effect of heat release rate: Interface height, unconstrained fire

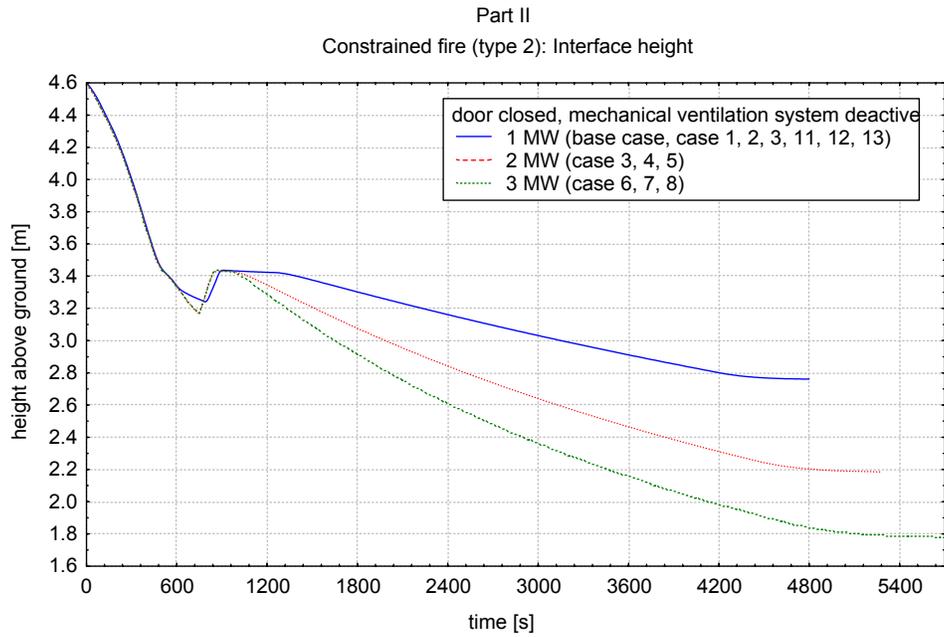


Figure 3.9 Effect of heat release rate: Interface height, constrained fire

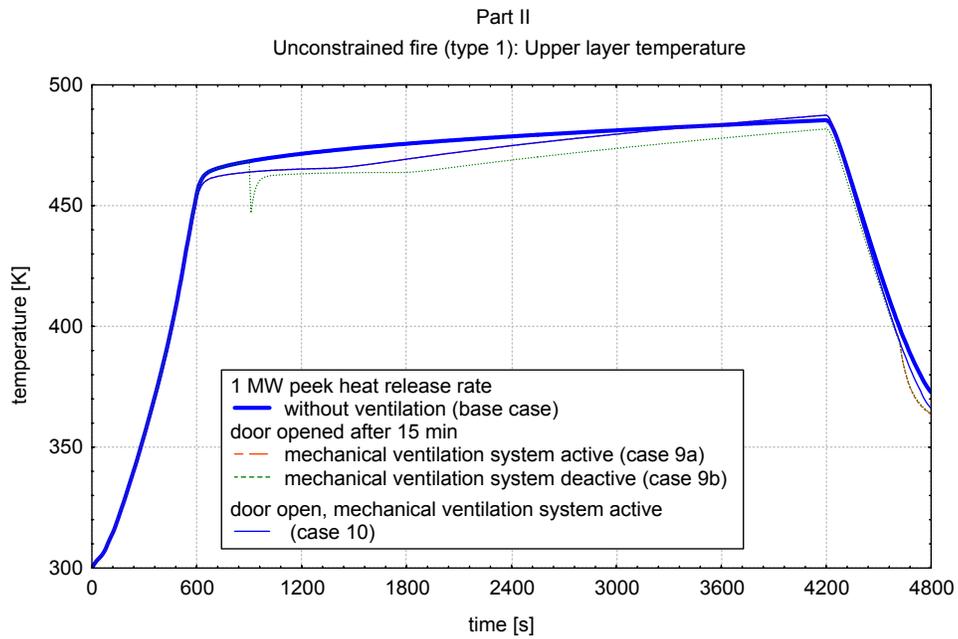


Figure 3.10 Effect of ventilation condition: Upper layer temperature, unconstrained fire

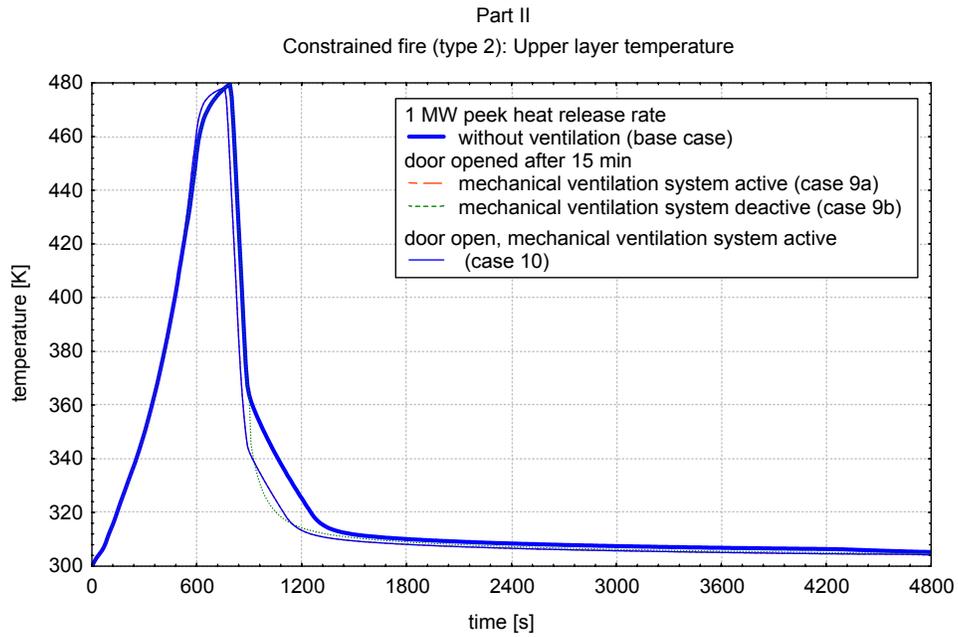


Figure 3.11 Effect of ventilation condition: Upper layer temperature, constrained fire

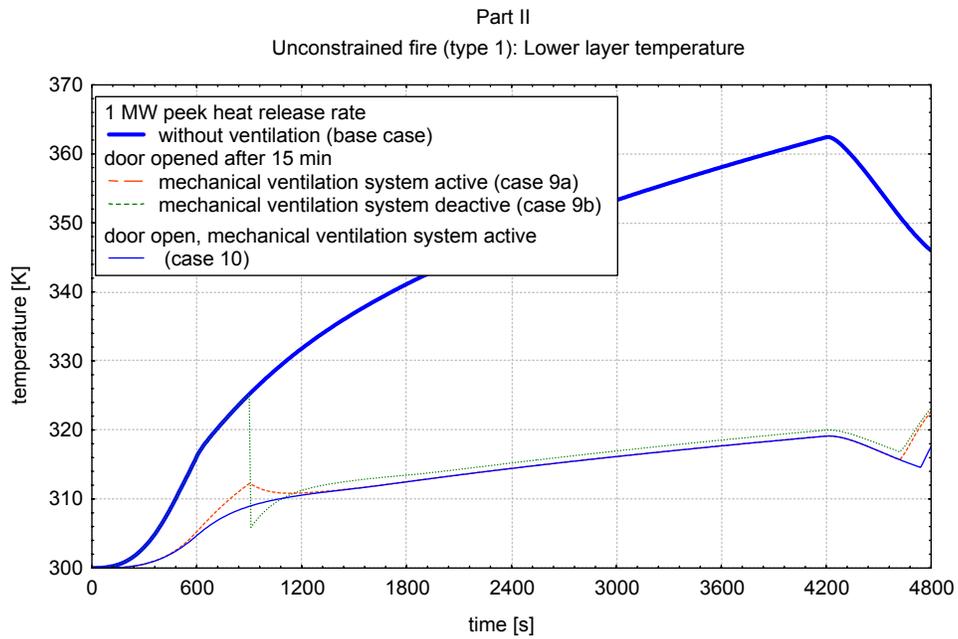


Figure 3.12 Effect of ventilation condition: Lower layer temperature, unconstrained fire

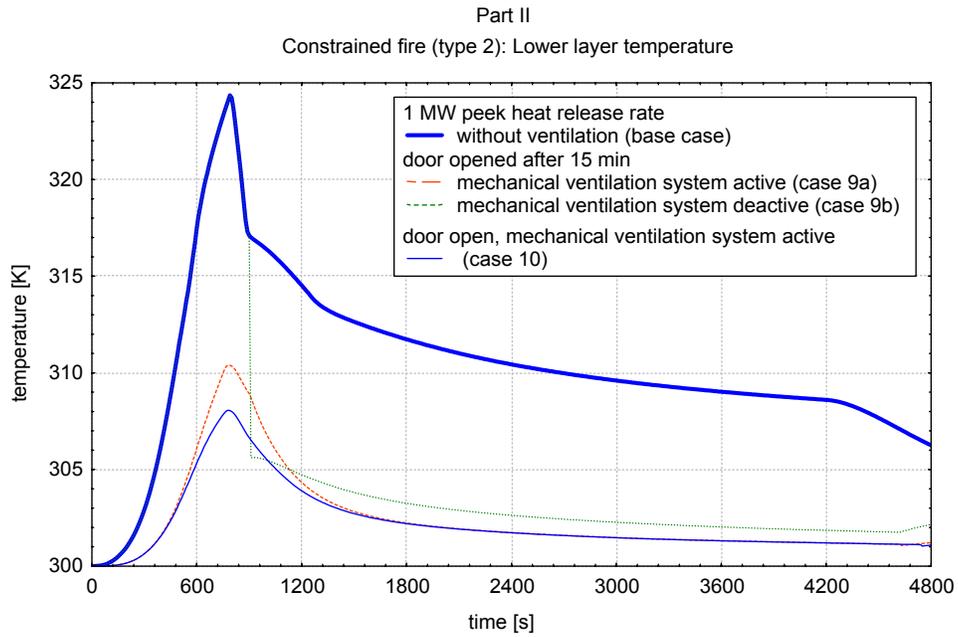


Figure 3.13 Effect of ventilation condition: Lower layer temperature, constrained fire

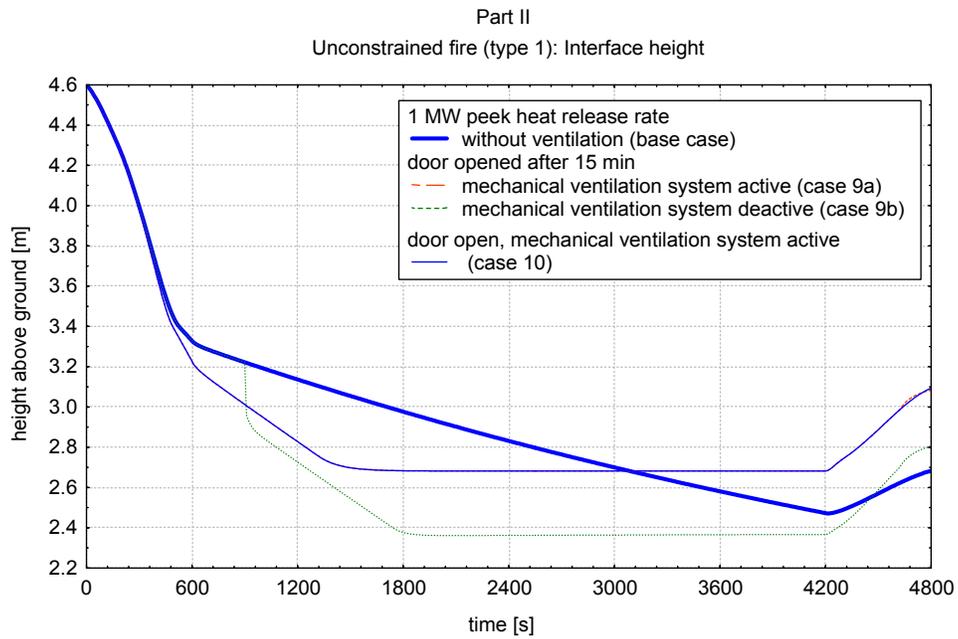


Figure 3.14 Effect of ventilation condition: Interface height, unconstrained fire

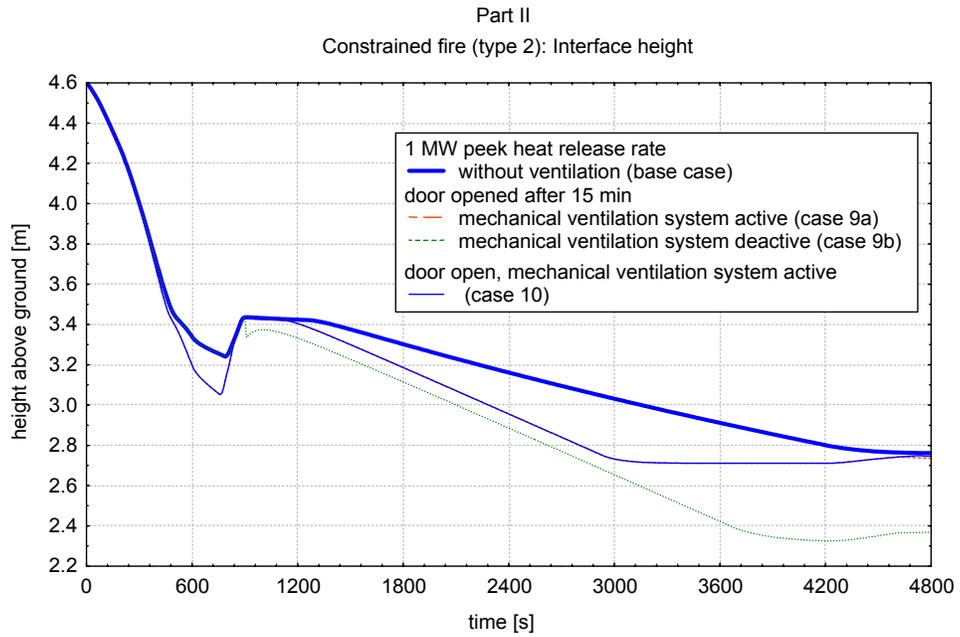


Figure 3.15 Effect of ventilation condition: Interface height, constrained fire

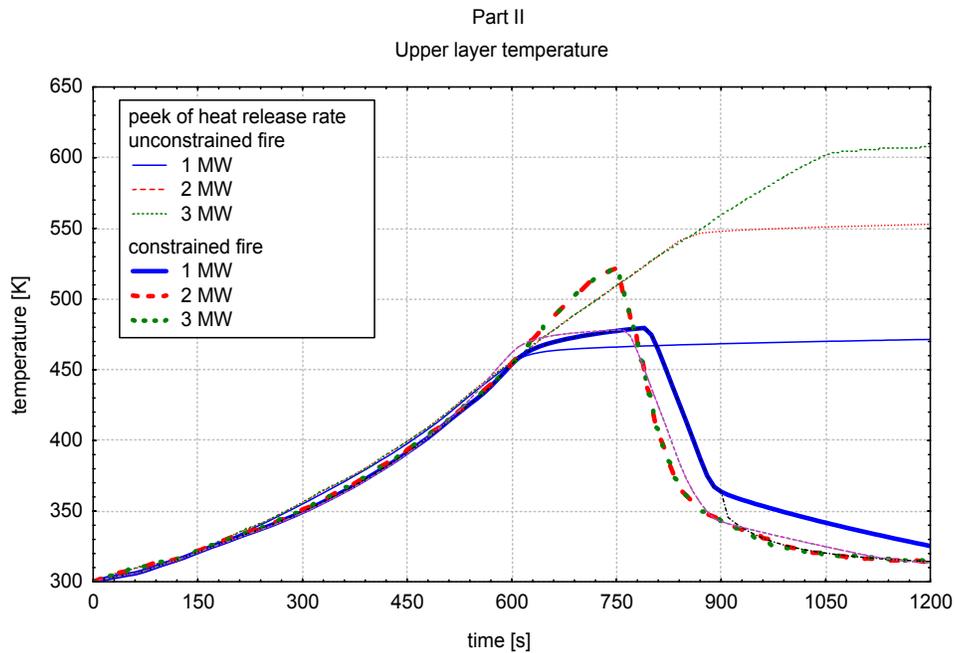


Figure 3.16 Effect of fire type: Upper layer temperature

Using the unconstrained fire algorithm (type 1), there is no restriction in the heat release rate. On the other hand, a maximum heat release rate of less than 1.5 MW is reached in case of using a constrained fire (type 2). In this case, a higher temperature of the upper layer is calculated until a lack of oxygen occurs. An increase of the heat release rate of course leads to an increase of the upper and lower layer temperatures and a decrease of the interface height.

Using the constrained fire algorithm (type 2), the oxygen contents of the upper and the lower layer are calculated. Neither the definition of the peak heat release rate nor the ventilation conditions seemed to have any remarkable influence on the oxygen content of the lower as well as of the upper layer (Figure 3.17).

It has been demonstrated that the vertical fire position has a strong effect on the course of the heat release rate. Using the same configurations and placing the fire on the floor level, the changes in the course of the upper layer oxygen content are calculated (Figure 3.18). The heat release rate decreases rapidly at that point of time at which the value of the oxygen content in the upper layer decreases to less than 1 %.

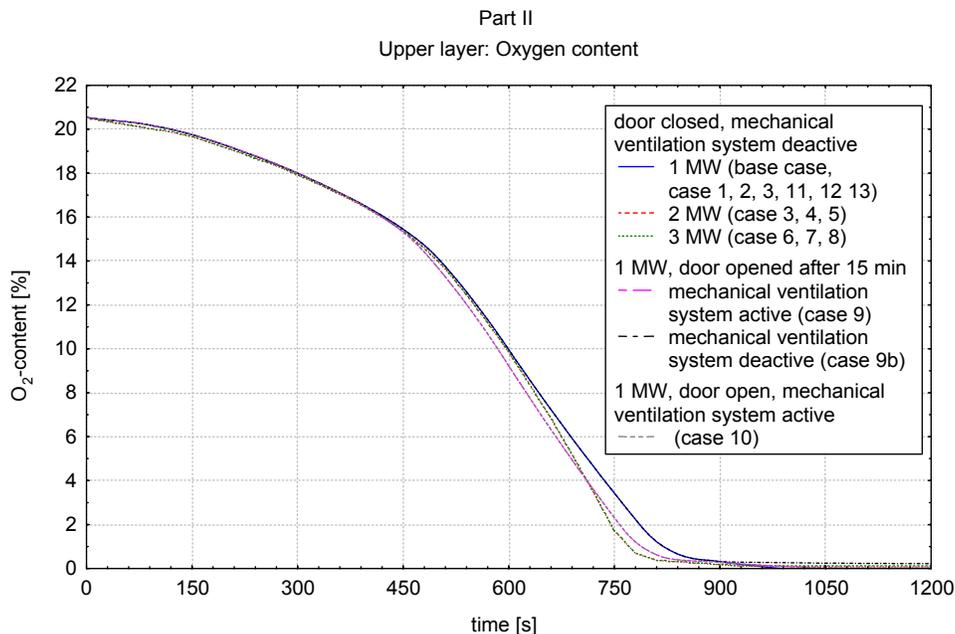


Figure 3.17 Effect of heat release rate and ventilation condition: Oxygen in the upper layer

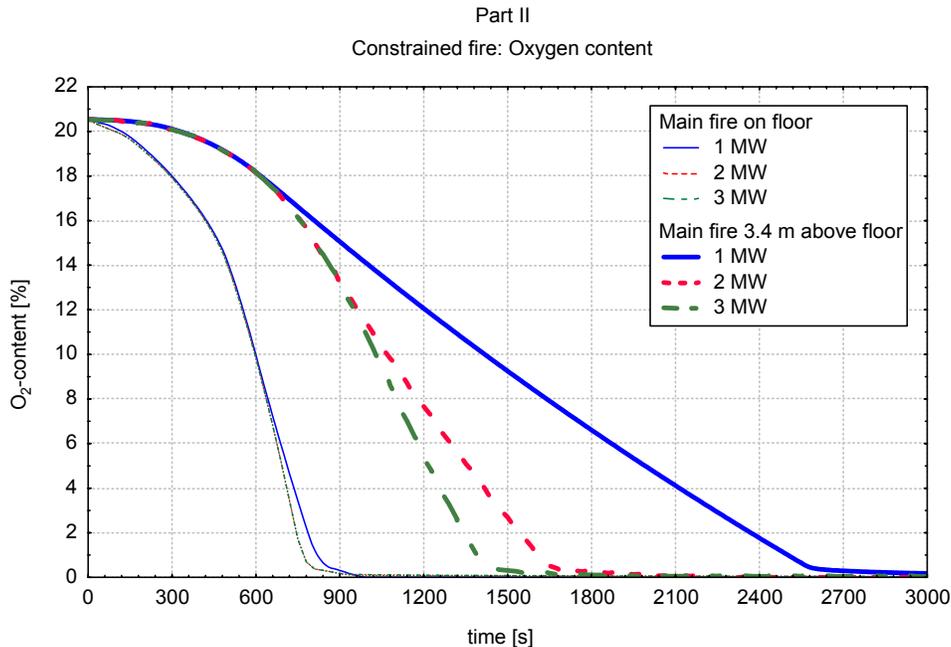


Figure 3.18 Effect of vertical fire position: Oxygen in the upper layer

If the mechanical ventilation system is active or the door is opened, only the upper layer temperature is affected. In case of using the unconstrained fire algorithm (type 1) it is slightly lower. The lower layer temperature is significantly lower in case of an additional ventilation and the interface height increases. In case of the door being opened and the mechanical ventilation system switched off (case 9b) the lower layer temperature reaches the lowest and the interface height reaches the highest level.

3.2.3 Mass flow rate of the mechanical ventilation system and through the opened door

Only in the cases 9 and 10 the door was assumed to be opened and the mechanical ventilation system was assumed to be used. As mentioned above, it was not possible to simulate deactivating the mechanical ventilation system while the calculation is still running, although it is possible to open or close a natural vent such as the door (using parameter CVENT).

The flow rates through the door and the vent (natural inflow) or the ducts of the mechanical ventilation system (forced outflow) are nearly independent of the fire algorithm until the fire is constrained by lack of oxygen. With very few exceptions, from this point of time the mass flow rates into the compartment and out of the compartment are higher if the constrained fire algorithm is used.

If there is no additional mechanical ventilation system (case 9b), nearly the same amount of gas flows through the door (after it has been opened) from outside into the lower layer as from the lower layer out of the compartment (Figure 3.19). As soon as the door has been opened while the mechanical ventilation system is running from the beginning (case 9a) the flow rates through the door become very soon equal to the flow rates calculated in case of the door being open all the time (case 10).

If there is no additional vent such as the door, a considerable amount of air flows into the lower layer through the vent (inflow) of the ventilation system (Figure 3.20). This mass flow stops and changes its direction (lower layer to outside) after the door has been opened (case 9a). Most of the gas, which is pumped through the ventilation system out of the compartment, is taken out of the lower layer (Figure 3.21). After 50 min simulation time a small amount of gas is also taken out of the upper layer (case 9a, case 10). The flow rates through the open door are not affected very much by the mechanical ventilation system. As soon as the door is opened the flow through the vent from outside into the lower layer stops.

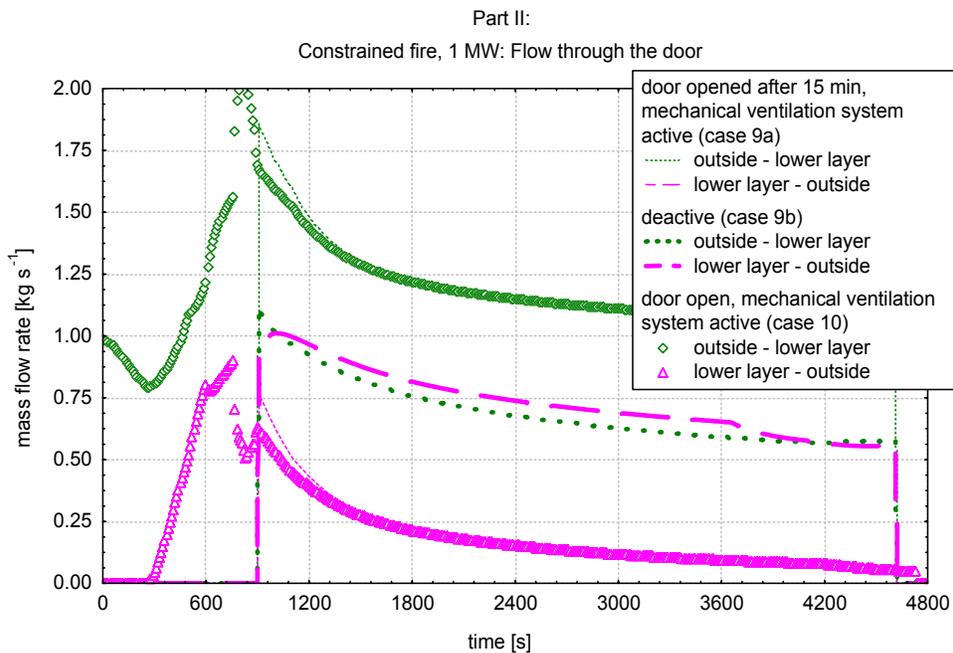


Figure 3.19 Effect of mechanical ventilation system: Mass flow rate through the door

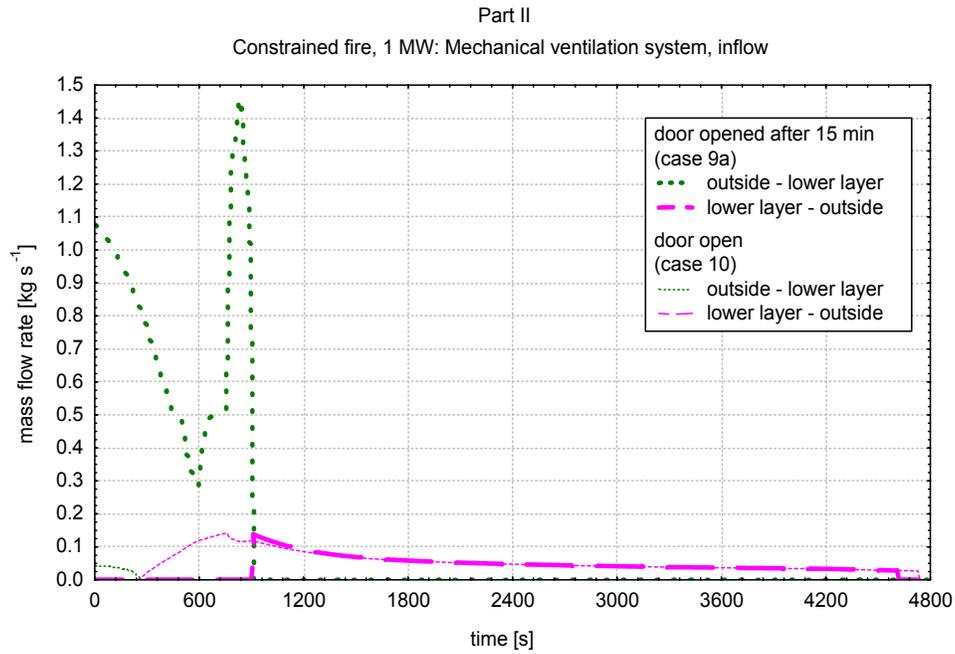


Figure 3.20 Effect of door opening: Mass flow rate through vent I (inflow)

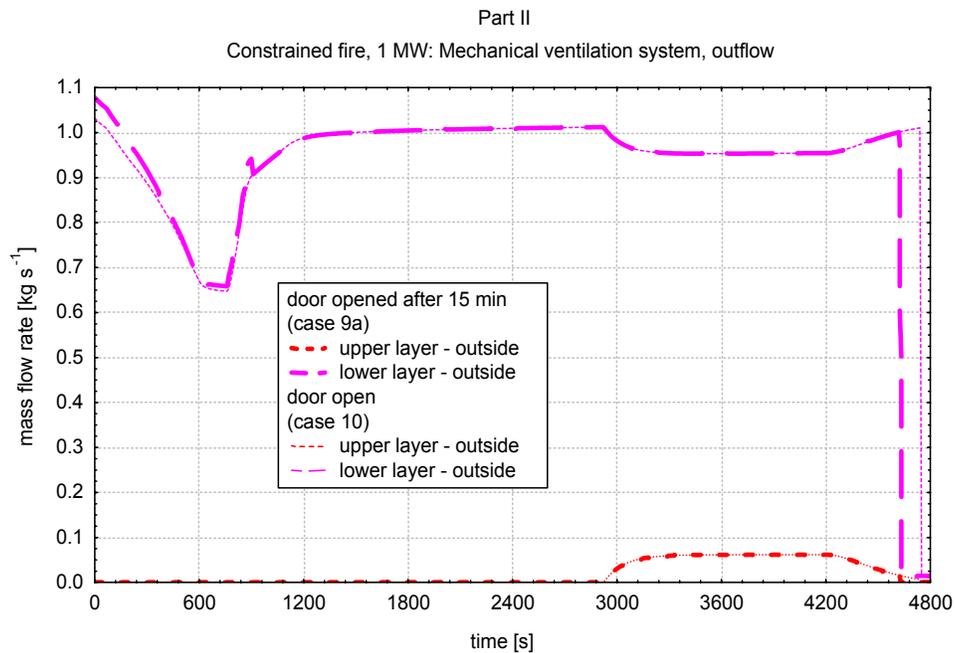


Figure 3.21 Effect of door opening: Mass flow rate through duct system (outflow)

3.2.4 Target surface temperature

Starting the calculations of Part II it was checked, whether the physical model of heating an object or target acts as in Part I, indicating that an object will always be assumed as being positioned in the center of a horizontal plane in the compartment. Obviously this happened, although the surface temperature is independent of the horizontal object position.

All other calculations of Part II were performed assuming that tray B (object / target) is placed in the center of the compartment (4.55 m, 7.6 m) and the main fire of tray A, C1, C2 (main fire) is moved in y-direction to get the distance D of 6.1 m (4.55 m, 1.5 m), 3.1 m (4.55 m, 4.5 m) or 4.6 m (4.55 m, 3.0 m). Prior to this calculations it had been demonstrated that it does not matter if the main fire is moved in x- or in y-direction.

The distance between the main fire of tray A, C1, C2 and the target tray B has only a minor effect on the surface temperature in case of an unconstrained fire (Figure 3.22). The differences between the maximum surface temperatures are small as well (Table 3.1). In case of a constrained fire the temperature does not increase very much (Figure 3.24). It does not make a difference whether the maximum heat release rate is 2 MW or 3 MW. This result is reasonable, because the calculations show that this level of the heat release rate is not reached. The distance between main fire and target has only small effects on the maximum surface temperature (Figure 3.26). The differences of the maximum surface temperatures are only 0.2 - 0.4 K.

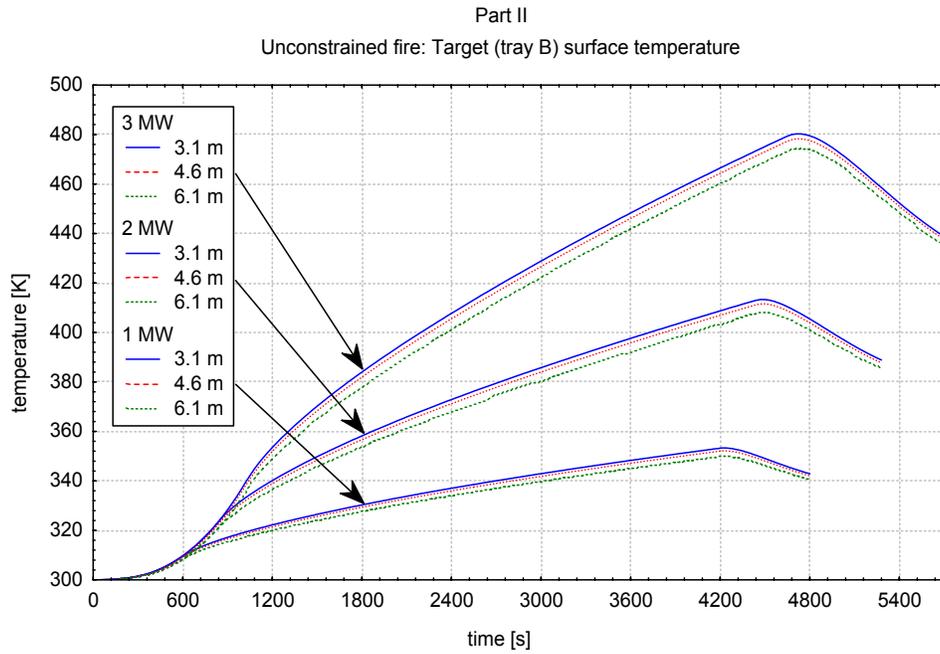


Figure 3.22 Effect of heat release rate and distance: Target (tray B) surface temperature

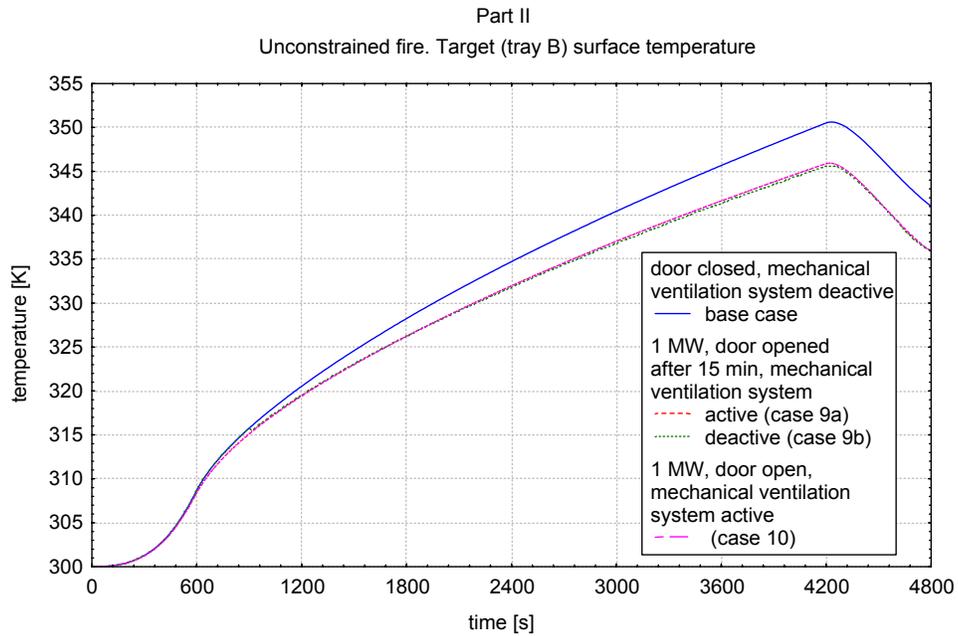


Figure 3.23 Effect of ventilation condition: Target (tray B) surface temperature

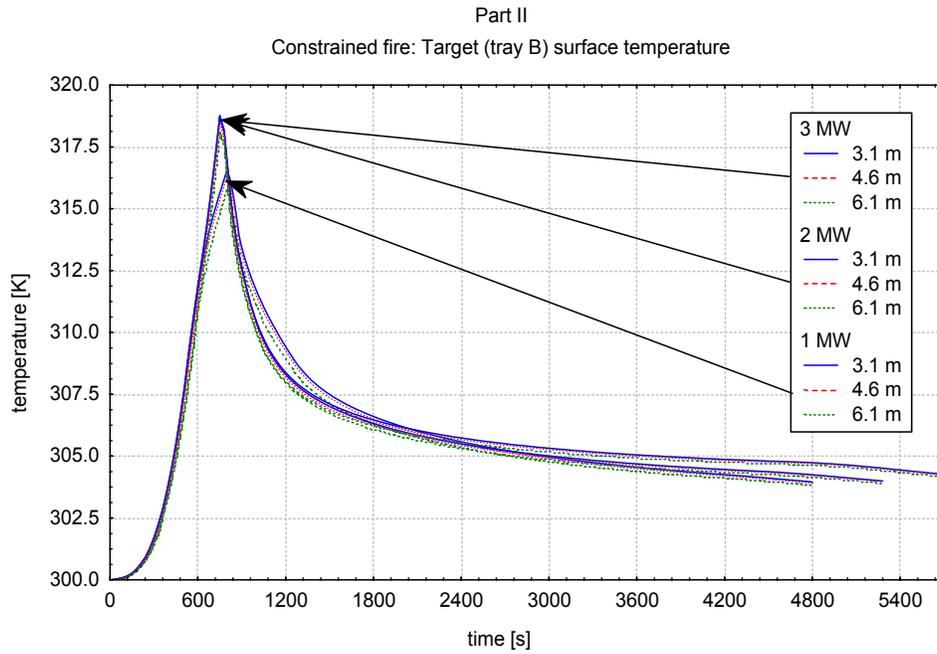


Figure 3.24 Effect of heat release rate and distance: Target (tray B) surface temperature

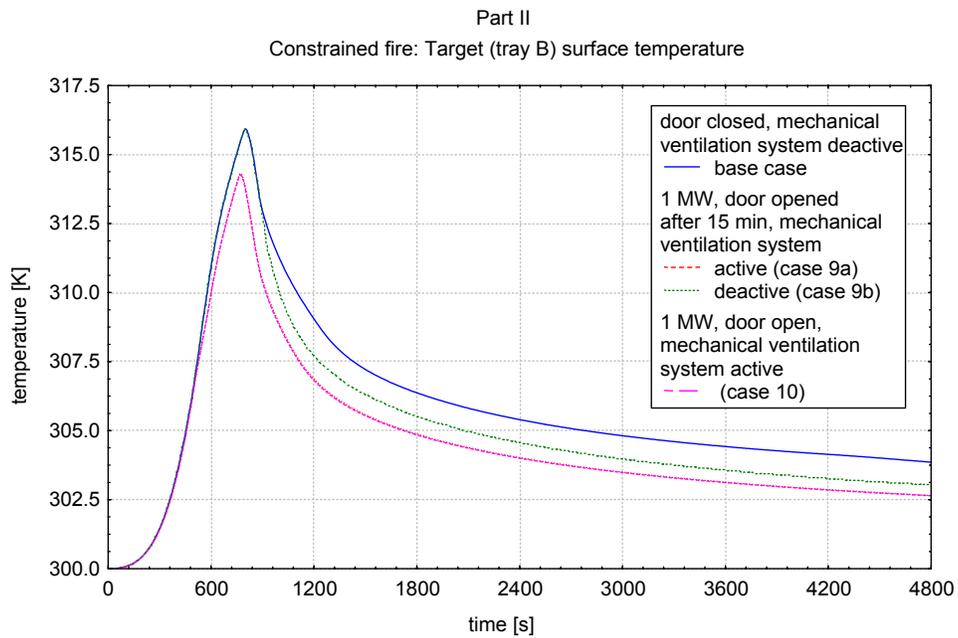


Figure 3.25 Effect of ventilation condition: Target (tray B) surface temperature

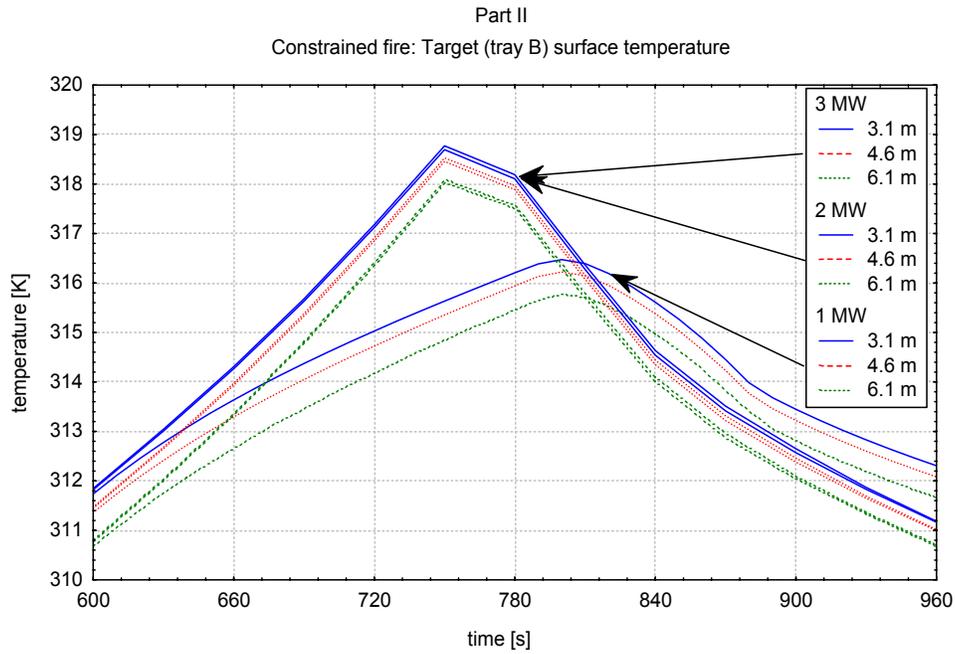


Figure 3.26 Effect of heat release rate and distance: Target (tray B) surface temperature

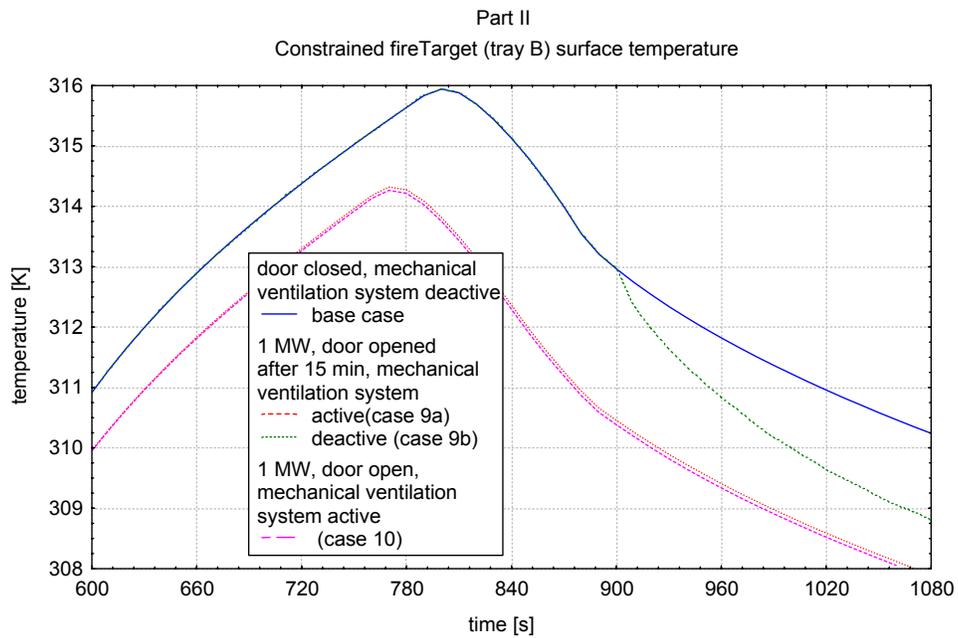


Figure 3.27 Effect of ventilation condition: Target (tray B) surface temperature

Table 3.1 Maximum target (tray B) surface temperature

Case	heat release rate	distance	maximum surface temperature	
			unconstrained fire	constrained fire
1	1 MW	3.1 m	353.33 K	316.22 K
2		4.6 m	352.17 K	316.47 K
base case		6.1 m	349.94 K	315.77 K
3	2 MW	3.1 m	413.33 K	318.70 K
4		4.6 m	411.56 K	318.45 K
5		6.1 m	408.08 K	318.02 K
6	3 MW	3.1 m	480.25 K	318.77 K
7		4.6 m	478.25 K	318.53 K
8		6.1 m	474.22 K	318.09 K

In case of an unconstrained fire the maximum target (tray B) surface temperature is approximately 6 K lower if the door is opened or the mechanical ventilation system is running (Figure 3.23). In case of a constrained fire, the maximum surface temperature is approximately 1.8 K lower if the mechanical ventilation system is running (Figure 3.27). In case that the mechanical ventilation system is not running and the door is opened after 15 min fire duration the temperature decreases a little faster (Figure 3.27).

4 CONCLUSIONS

The multi-room multi-zone model CFAST, version 4.0.1 has been applied to perform the calculations for the Benchmark Exercise # A “cable tray fires of redundant safety trains”. In Part I of this exercise the base case and five additional cases with varying distance between the trash bag as an ignition source and the tray A on the one hand and the ventilation conditions on the other are calculated. In addition, two fire algorithms are used. Defining a cable fire of tray A, C1, C2 the effects on cable tray B are studied in Part II of the Benchmark exercise. In this case, three different levels of heat release rate, different operation modes of the ventilation system, and door status as well as different cable diameters and tray elevations should be investigated.

The results calculated using the constrained fire algorithm seem to be more realistic. Nevertheless, there are some uncertainties. Particularly the upper layer temperature differs slightly in case

of a sufficient oxygen amount available comparing the two fire algorithms. The gas temperature and the layer thickness are calculated convincingly by CFAST. The mass flow rates through natural vents seem to be plausible. It is necessary to describe the main fire in more detail by defining the pyrolysis rate, the effective heat of combustion and the yields of combustion products, such as carbon dioxide, carbon monoxide and hydrochloride. It is obvious that the vertical position of the main fire has a strong influence on all results.

The computer code CFAST is not optimal for the Benchmark Exercise # 1 because the heat transfer to a target, as a main task of this exercise, is calculated by a very rough model. Due to this, no quantitative results can be produced. In addition, the forced ventilation model does not work in case of inflow. The composition of the incoming air seems to be wrong. Since it is not possible to define a time dependent fan power, switching the forced ventilation on or off cannot be simulated, but a mechanical ventilation system is a main tool to remove hot gases out of a fire compartment in a nuclear power plant.

Although CFAST does not seem to be appropriate for all of the questions of the given Benchmark Exercise, it is a very useful engineering tool for estimating fire and smoke transport in several other cases. The results of the CFAST calculations can be used to answer special questions such as heating of targets with more detailed models.

5 LITERATURE

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- [2] Peacock, R. D.; Reneke, P. A.; Jones, W. W.; Bukowski, R. W.; Forney, G. P.A : User's guide for FAST: Engineering tools for estimating fire growth and smoke transport. NIST Special Publication 921 2000 Edition, January 2000

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