# Preamble

All assessments on this module are individual work. The work you submit must be your own work. Submitting work that is copied in part or whole from another student with or without their permission is an assessment offence.

You must fully attribute/reference all sources of information used during the completion of your submission, failure to do so constitutes plagiarism, which is an assessment offence.

If you are not familiar with the definitions of plagiarism and collusion, more information can be found here: [http://www1.uwe.ac.uk/students/academicadvice/assessments/ assessmentoffences.aspx](http://www1.uwe.ac.uk/students/academicadvice/assessments/assessmentoffences.aspx)

Please ensure you are familiar with assessment procedures and policies, which can be found here: [http://www1.uwe.ac.uk/students/academicadvice/assessments/ assessmentsguide.aspx](http://www1.uwe.ac.uk/students/academicadvice/assessments/assessmentsguide.aspx)

# Structure of assessments

This module is assessed by three components, A, B and C:

* Component A is a coursework portfolio and is weighted as 45% of the final mark.
* Component B is a coursework portfolio and is weighted as 50% of the final mark.
* Component C is a library research exercise and is weighted as 5% of the final mark.

The coursework portfolio described here (Component A - Portfolio A) asks you to consider one problem entitled "**The roof is on fire! Flashover prediction in a building compartment**," which was designed to evaluate your competencies in computer programming fundamentals, including structure and best practice, and your ability to write programs to generate data for or to solve civil engineering problems.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **On** | **line** | **black** | **board** | **sub** | **mis** | **sion** | **due** | **on** | **July** | **18,** | **2022.** |

As detailed below, the final report on your coursework portfolio must include code routines developed for both elements in a text selectable form (no images or screenshots will be accepted).

1

# The roof is on fire! Flashover prediction in a building compartment

As the title suggests, **in this assessment you are asked to predict the development of a fire in a building compartment, for different types of compartment fires (a slow, a medium, a fast, and an ultra-fast fire)**. Being a bit more precise, you are asked to estimate the exact time when flashover is reached in the compartment, and the Heat Release Rate required for that to happen.

Here is a little bit of theory: The term "compartment fire" is commonly used to describe a fire in a room or "compartment" within a building. If allowed to burn itself out, and assuming sufficient fuel and ventilation, such a fire progress through three main stages: (i) the growth, or preflashover, stage, when the fire is localized in the vicinity of its origin and the average temperature in the compartment is still relatively low; (ii) **the fully developed, or postflashover, fire**, during which all the combustible items are involved and flames appear to fill the entire volume and emerge from the ventilation openings; and **the decay period**, when the fire begins to die down as the fuel is consumed. These stages are illustrated in Figure 1, where the size of the fire (defined in terms of rate of heat release [kW]) is shown as a function of the time.

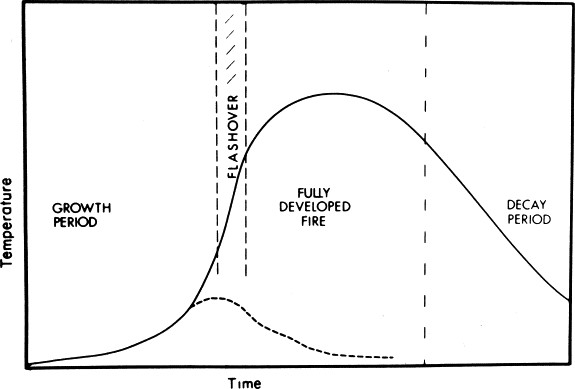
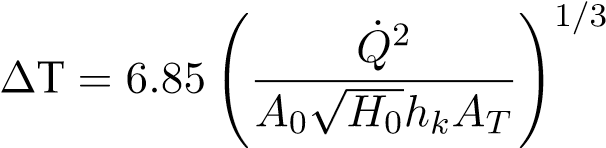


Figure 1: The course of a compartment fire over time [From Drysdale, D. (1998).

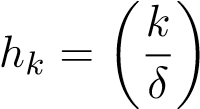
“Introduction to Fire Dynamics,” John Wiley and Sons, Chichester.]

The transition from the growth period to the fully developed fire is referred to as flashover, and it represents the most dangerous stage of a building fire. In fact, anyone who has not escaped from the compartment before flashover is unlikely to survive! Following this link [https:// www.youtube.com/watch?v=BtMmymOxdjc&t=193s](https://www.youtube.com/watch?v=BtMmymOxdjc&t=193s) to watch an excellent demonstration of the four stages of a fire. Jump to 2:45 – 3:00 to see just how intense the flashover is!

Different methods and approaches can be used to analyse the development of a fire within a building compartment. The one described in the following is known as MQH method. This method is based on experimental observations and gives the temperature increase in a room (∆T) as a function of the Heat Release Rate (HRR), size of a rectangular opening, room geometry and thermal properties of the boundaries:

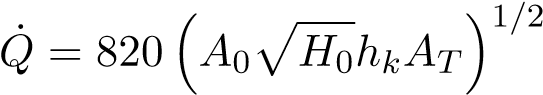
 (Eq. 1)

where *Q*˙ is the Heat Release Rate [kW], *A*0 is the area of the opening [*m*2], *H*0 is the height of the opening [m], *hk* is the heat transfer coefficient [*kW/m*2*K*] of room enclosure (*hk* represents several different modes of heat transfer and is not easy to determine; however, the following simplified expression can be used to get an estimate of *hk*) and *AT* is the total surface area, minus area of openings, in the room.

 (Eq. 2)

where *k* is the thermal conductivity [kW/mK] of the enclosure material and *δ* is the thickness [m] of the enclosure material.

Admitting that flashover occurs for temperature increase in a room ∆T = 600 ºC, and rearranging Eq. (1) in for *Q*˙ , it is then possible to obtain Eq. (3) which give us the Heat Release Rate, , required for the compartment to flashover.

 (Eq. 3)

Finally, it should be noted that different fires have different growth speeds – while some are very fast, others grow more slowly. Analytically, the time required for a fire to reach a certain Heat Release Rate (HRR) can be computed through Eq. (4):

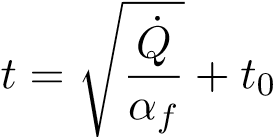
*Q*˙ = *αf* (*t* − *t*0)2 (Eq. 4)

where *αf* is a fire-growth coefficient [kW/s2] and *t*0 is the length of the incubation period [s]. The value of the fire-growth coefficient *αf* for different types of fire is given in Table 1.

Table 1: Fire-growth coefficient *αf* for different types of fire

|  |  |
| --- | --- |
| **Type of fire** | *αf* |
| Slow | 0.002778 kW/s2 |
| Medium | 0.011111 kW/s2 |
| Fast | 0.044444 kW/s2 |
| Ultra-fast | 0.177778 kW/s2 |

Rearranging Eq. (4) it is possible to obtain Eq. (5) from which the time necessary for the fire to reach a determined Heat Release Rate, *Q*˙ , can be obtained directly.

 (Eq. 5)

The following two sections describe the problems you are to develop scripts to solve. In each section (Part A & Part B), specific details of the tasks and outputs to feed in to your report are described. An overall summary of the assessment criteria is provided at the end of this document.

Note that the dimensions of the compartment (length, *l*, width, *w*, and height, *h*), the thickness of the enclosure material, *δ*, and the length of the incubation period, *t*0, that you must consider in your code are available on Blackboard Learning Materials > Coursework > Coursework values html file, or by following the URL [https://blackboard.uwe.ac.uk/bbcswebdav/ courses/UBGMSQ-15-1\_21sep\_1/my\_values.html.](https://blackboard.uwe.ac.uk/bbcswebdav/courses/UBGMSQ-15-1_21sep_1/my_values.html) In addition to those, please consider that the compartment has one door with 1.2 m x 2.1 m, and that the inner wall is covered with plaster (*k* = 0.46 W/mK), see Figure 2.

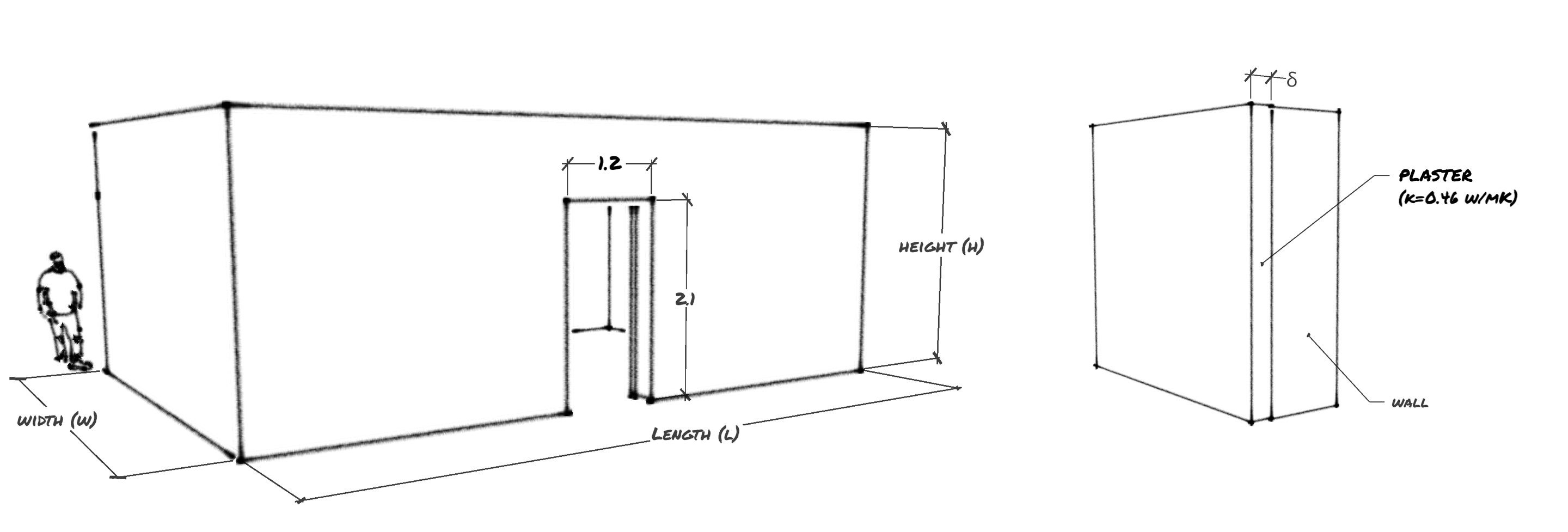


Figure 2: Schematic representation of the compartment.

## Part A. Computation of the heat release rate and flashover time

Using MATLAB/ Octave or other programming language, write a script to do the following:

A1. **For the four types of fire defined in Table 1, compute the HRR [in kW] required for the compartment to come to flashover and the time [in seconds] needed for that to happen** (consider that flashover occurs for a temperature increase ∆T = 600 ºC).

A2. Produce a graph with the increase of the temperature in the compartment over the time, for the four types of fire. The graph should include four time *versus* temperature curves, which must be plotted **from t***i***=0 to t***f***=Flashpoint, by using a vector of 100 linearly spaced values**. Note that **for the time period between the onset of the fire,** *ti* = 0**, and the end of the incubation period,** *t*0**, the value of temperature increase (**∆**T) must be set equal to zero**.

Details about the elements to be included in the graph and an illustrative example of the graph that you are asked to generate are provided in Appendix I.

Save your script as flashoverPAXXXXXXXX.m, where XXXXXXXX must be replaced by your student number, and submit it together with your report.

## Part B. Evaluation of the impact of changing the enclosure material

Now that you have computed the heat release rate and the time necessary for the compartment to reach flashover, for the four types of fire (slow, medium, fast and ultra-fast), the objective of Part B is to evaluate the impact of replacing the original enclosure material (the gypsum plasterboard panelling) by a new one with a different thermal conductivity value. For such, find in Appendix II a table with thermal conductivity values of different building materials.

You should now extend the piece of script you have produced in Part A so that it can complete the following tasks:

B1. Input the thermal conductivity value of the new material into your script. Then, compute the new HRR and time necessary for the compartment to reach flashover for the four types of fire.

B2. Finally, write the code necessary to produce a graph where **the eight final time *versus* temperature curves**, the four obtained in Part A for the original material, and the four obtained for the new material, are plotted together. All curves must be plotted **from t***i***= 0 to t***f***= Flashpoint, by using a vector of 500 linearly spaced values**. Also in this case, make sure that **the values of temperature increase for the time period between the onset of the fire,** *ti* = 0**, and the end of the incubation period,** *t*0**, are set equal to zero**.

Further details about this graph and an illustrative example of the graph that you are asked to generate are provided in Appendix I.

Save your script as flashoverPBXXXXXXXX.m, where XXXXXXXX must be replaced by your student number, and submit it together with your report.

# Reporting

Your report must address Part A and Part B, and include:

* A brief description of how each output has been obtained.
* A calculation of the **HRR required for the compartment to come to flashover**, computed according to Eq. (1). This value must be equal to the value obtained with your script.
* A calculation of the **time moment when flashover occurs**, obtained according to Eq. (5) for the four types of fire described in Table 1. This values must be equal to the value obtained with your script.
* A calculation of the **new HRR value obtained when considering the new material** and its comparison with the original situation. This value must be equal to the value obtained with your script.
* A brief discussion on how the thermal conductivity of the enclosure material affects the HRR value and the flashover times for the four types of fire. In particular, you are asked to discuss whether the new material that you have selected has led to a decrease or increase in the fire safety level of the building compartment. Your **conclusions must be supported by the results plotted in the figure produced in point B2**.
* A flowchart of the algorithm that underlies your analysis.

# Assessment criteria

Your report should contain the following and you will be assessed according to the criteria described in Table 2.

* **Problem description:** A summary of the problem you are attempting to solve, to include the assumptions needed to obtain a solution and any mathematical elaboration of the equations that are used within your computer program. **(15%)**
* **Program development:** A flowchart illustrating the algorithm used to solve the problem, together with an explanation and justification for your chosen numerical approach. Note that you are also required to submit, as part of your report, the code used to generate your results. **(40%)**
* **Presentation of the results**: To include plots showing the outputs from your work and accompanying text to describe their meaning. This section should include the outcomes of any validation exercises you undertake to demonstrate the correct functioning of the programs you develop. **(35%)**
* **Concluding comments**: To explain how your computer program could be extended or generalised for increased functionality. **(10%)**

Table 2: Assessment Criteria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| % | Descriptor | Problem description  **(15%)** | Program development  **(40%)** | Presentation  of results  **(35%)** | Concluding comments  **(10%)** |
| 80-100 | Outstanding | Problem descriptions  stated with outstanding clarity, with complete mathematical treatment | Outstanding program development,  with complete and  thorough  justification  for chosen approach | Outstanding clarity of  presentation  with fully  annotated plots, complete and fully correct results and validation test outcomes | Outstanding clarity of comments  on the  generalisa-  tion of the computer program |
| 70-79 | Excellent | Problem descriptions  stated with  excellent clarity, with comprehensive math-  ematical treatment | Excellent  program development,  with clear  justification  for chosen approach | Excellent  clarity of  presentation with well  annotated plots, complete and fully correct results and validation test outcomes | Excellent  clarity of comments  on the  generalisa-  tion of the computer program |
| 60-69 | Very good: 65-69  Good: 60-64 | Problem descriptions stated with clarity, with mostly complete mathematical treatment | Program development presented  that addresses the main aims of the task with clear  justification | Very good/good clarity of presentation  with well annotated plots, mostly complete and correct results and some validation test outcomes | Very good/good clarity of comments on the  generalisa-  tion of the computer program |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 50-59 | Competent: 55-59  Adequate: 50-54 | Problem descriptions  stated with adequate clarity, with basic mathematical treatment | Program development presented  that ad-  dresses  some aspects of the task with partial  justification | Competent/ adequate clarity of  presenta-  tion with plots, some complete and correct results and limited validation test outcomes | Competent/ adequate clarity of comments  on the  generalisa-  tion of the computer program |
| 40-49 | Weak | Problem descriptions lacking clarity, with minimal or only partially correct mathematical treatment | Program development presented  that ad-  dresses limited aspects of the task with limited  justification | Limited  clarity of  presenta-  tion with few plots,  incomplete results and limited validation test outcomes | Limited  clarity of comments  on the  generalisa-  tion of the computer program |
| 30-39 | Poor (FAIL) | Problem descriptions unclear, with incomplete or incorrect mathematical treatment | Program develop-  ment that is incomplete with very limited  justification | Poor clarity of presentation with very few plots, incomplete and incorrect results and limited validation  test out-  comes | Poor clarity of comments on the  generalisa-  tion of the computer program |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| <30 | Very poor (FAIL) | Problem descriptions  very unclear, with no math-  ematical treatment | Program development that fails to address the brief and lacks  justification | Very poor clarity of  presentation lacking plots, incomplete and incorrect results and very limited validation test outcomes | Very poor clarity of comments  on the  generalisa-  tion of the computer program |

# Appendix I - Details and examples for the preparation of the graphs

In order for your graphs to be considered fully correct, they must fulfill all the requisites listed below. When the script is completed, two graphs similar to the ones presented in Figures 3 and 4 should be automatically generated for Part A and Part B, respectively.

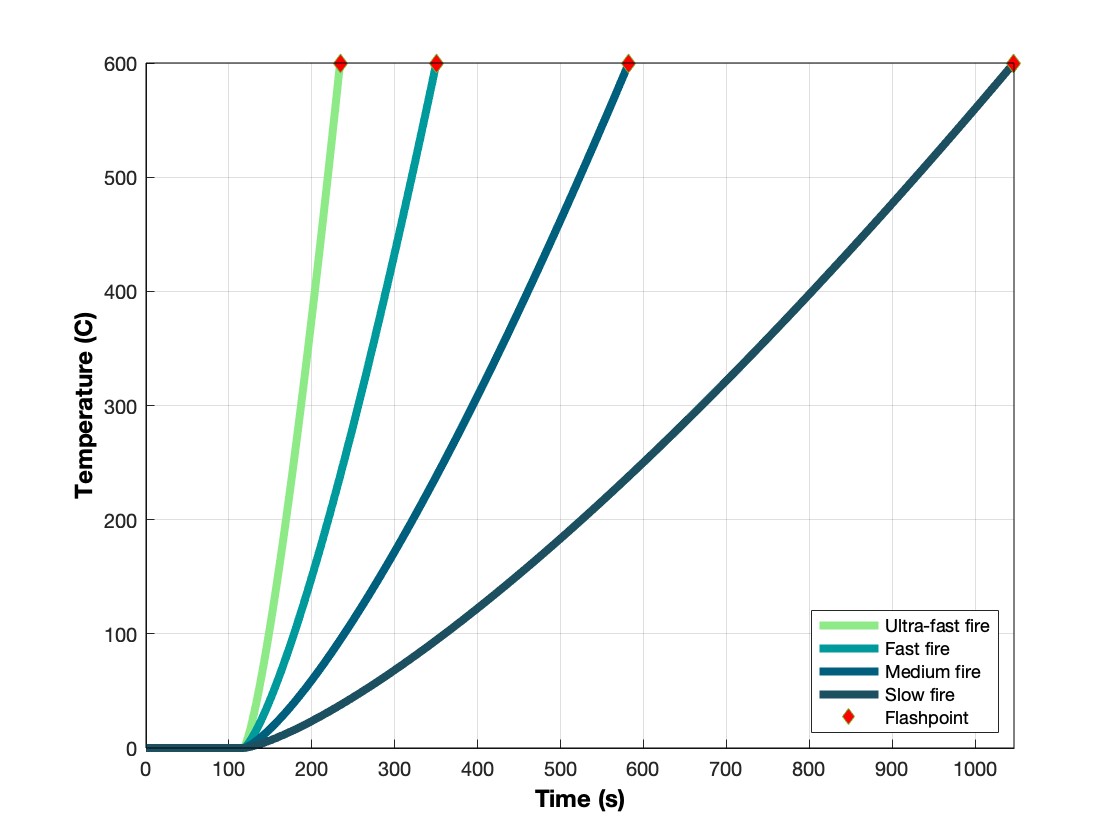


Figure 3: Time vs. temperature curves for the original material and different types of fire: ultra-fast, fast, moderate and slow.

When preparing the code to generate Figure 3, please consider the following:

* The x axis should range from 0 to the maximum time value obtained for the four types of fire. Similarly, the y axis should range from 0 to the maximum temperature value obtained for the four types of fire.
* The curves corresponding to the different types of fire should be plotted using a continuous line (line width=4.0) and the following colour scheme (RGB values): Ultrafast (0.554 0.917 0.530), Fast (0.000 0.605.613), Medium (0.000 0.373 0.490), and Slow (0.110 0.315 0.380).
* The four Flashpoints should be represented by red diamonds, size 50, placed over the curves.
* The x and y label’s font must be bold, size 12.
* The legend should include the representation of the four curves and the Flaspoint. Plus, it should be placed inside the graph, on the right side at the bottom.

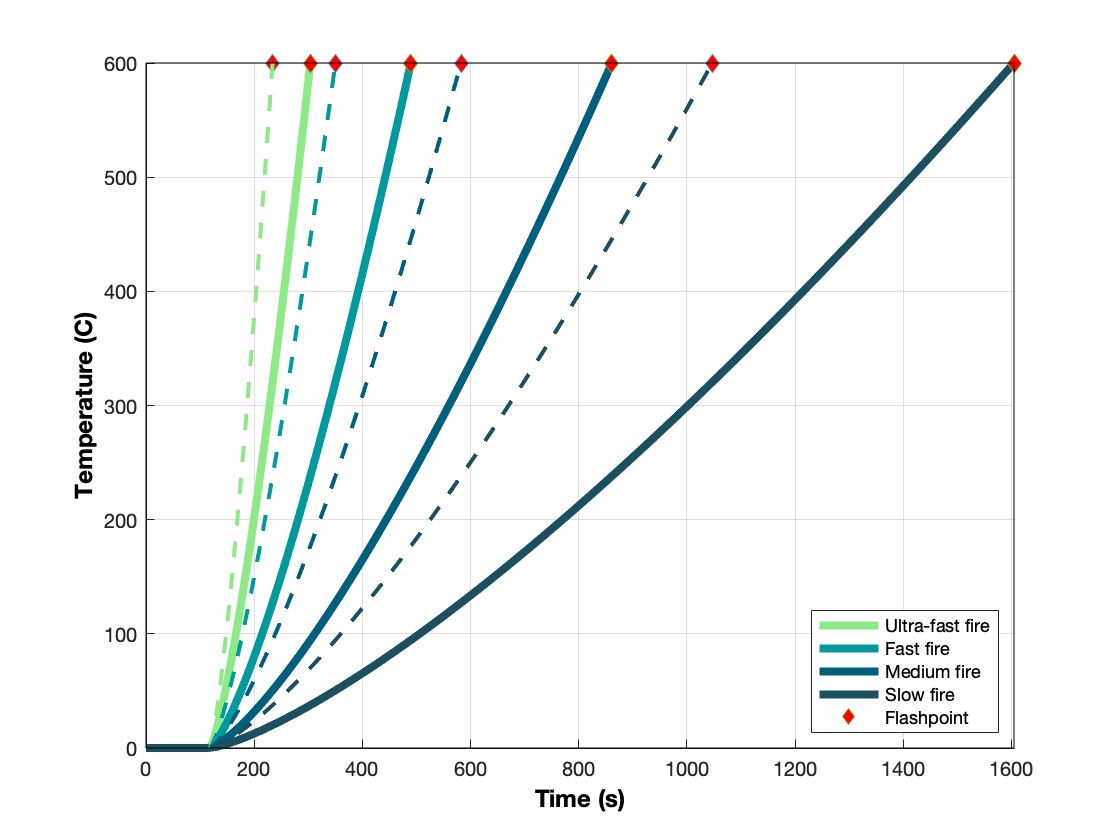


Figure 4: Time vs. temperature curves for the original and the new material.

When preparing the code to generate Figure 4, please consider the following:

* The x axis should range from 0 to the maximum time value obtained for the four types of fire, either it was obtained for the original or the new material. The y axis should range from 0 to the maximum temperature value obtained for the four types of fire.
* The curves corresponding to the original material should be plotted using a dashed line (line width=2.0), and the following colour scheme (RGB values): Ultra-fast (0.554 0.917 0.530), Fast (0.000 0.605.613), Medium (0.000 0.373 0.490), and Slow (0.110 0.315 0.380).
* The curves for the new material should be plotted using a continuous line (line width=4.0) and the following colour scheme (RGB values): Ultra-fast (0.554 0.917 0.530), Fast (0.000 0.605.613), Medium (0.000 0.373 0.490), and Slow (0.110 0.315 0.380).
* The four Flashpoints should be represented by blue circles placed over the curves. The circles representing the Flaspoints obtained for the original material should have size 2, whereas the ones representing the Flaspoints obtained for the new material should have size 4.
* The x and y label’s font must be bold, size 12.
* The legend should include the representation of the four curves and the Flaspoint. Plus, it should be placed inside the graph, on the right side at the bottom.

# Appendix II - Thermal conductivity of typical building materials

Thermal conductivity is a fundamental material property independent of thickness. It is measured watts per meter kelvin (W/mK). Thermal conductivity values of typical building materials shown in Table 3.

Table 3: Thermal conductivity of typical building materials

|  |  |
| --- | --- |
| **Material** | **W/mK** |
| Brick (exposed) | 0.84 |
| Brick (protected) | 0.62 |
| Chipboard | 0.15 |
| Concrete (aerated) | 0.16 |
| Concrete (dense) | 1.4 |
| Glass | 1.05 |
| Hemp slabs | 0.40 |
| Mineral wool | 0.038 |
| Mortar | 0.80 |
| Plaster | 0.46 |
| Plasterboard (gypsum) | 0.16 |
| Render (sand/cement) | 0.50 |
| Stone (limestone) | 1.30 |
| Stone (sandstone) | 1.50 |
| Stone (granite) | 1.70-4.0 |
| Timber (softwood) | 0.14 |
| Timber (hardwood - commonly used) | 0.14-0.17 |
| Woodfibre board | 0.11 |