Bringing service to life

serco

Modelling the thermal performance of cork and wood in the thermal test

Presentation to
PATRAM 2010

Presented by
Chris Fry

4th October 2010

Contents

- Why heat transfer through wood needs to be modelled
- Why this is a challenge
- Recommended approach – use of laboratory scale tests
- Examples of laboratory scale tests
- Example results of tests

serco

Introduction

- Cork and wood are used in the design of many transport flasks:
  - Large flasks used to transport used fuel
  - Small packages for transporting sources
- Used both in shock absorbers attached to flask or internal to the flask
- Used because:
  - Good impact absorbing properties
  - Good thermal resistance against fire
  - Relatively light weight
  - Low cost

Why heat transfer needs to be modelled

- In the past, the ability for a transport flask to satisfy the IAEA Regulations has been demonstrated by testing alone:
  - Prototype flask
  - Usually full scale
  - Heating test (normal transport)
  - Impact tests
  - Thermal (fire) test

serco

Why heat transfer needs to be modelled (cont)

- Today the thermal assessments required by many Competent Authorities is more rigorous.
- Shortcomings of trying to satisfy thermal test by testing only:
  - Solar insolation is not included in the initial temperature distribution
  - The initial temperature distribution does not correspond to an ambient temperature of 38°C
  - The initial temperature distribution (probably) does not include the effect of heat generation by the radioactive material
  - The ambient temperature during the cooling phase is not 38°C
  - Solar insolation is not included during the cooling phase

Challenges to modelling cork and wood

- Thermal modelling of the thermal test will therefore almost always be required to some degree
- If the transport flask contains wood or cork there are problems with modelling their thermal performance:
  - The evaporation of moisture
  - Carbonisation
  - The release of waxes and oils
  - Shrinking
  - Burning
- All these processes will have some affect upon heat transfer
- None of these phenomena can be modelled reliably at present

serco

Recommended approach

- Use of reference values for density specific heat and thermal conductivity, measured at around room temperature, cannot reliably be applied at temperatures up to 800°C.
- It is recommended that wood and cork be modelled as conducting solids with effective values of the density, specific heat and thermal conductivity obtained from to practical tests. These effective properties will include all the effects of the physical and chemical processes listed above.
- Tests can be laboratory scale but should represent the thickness of the wood or cork in the transport flask.

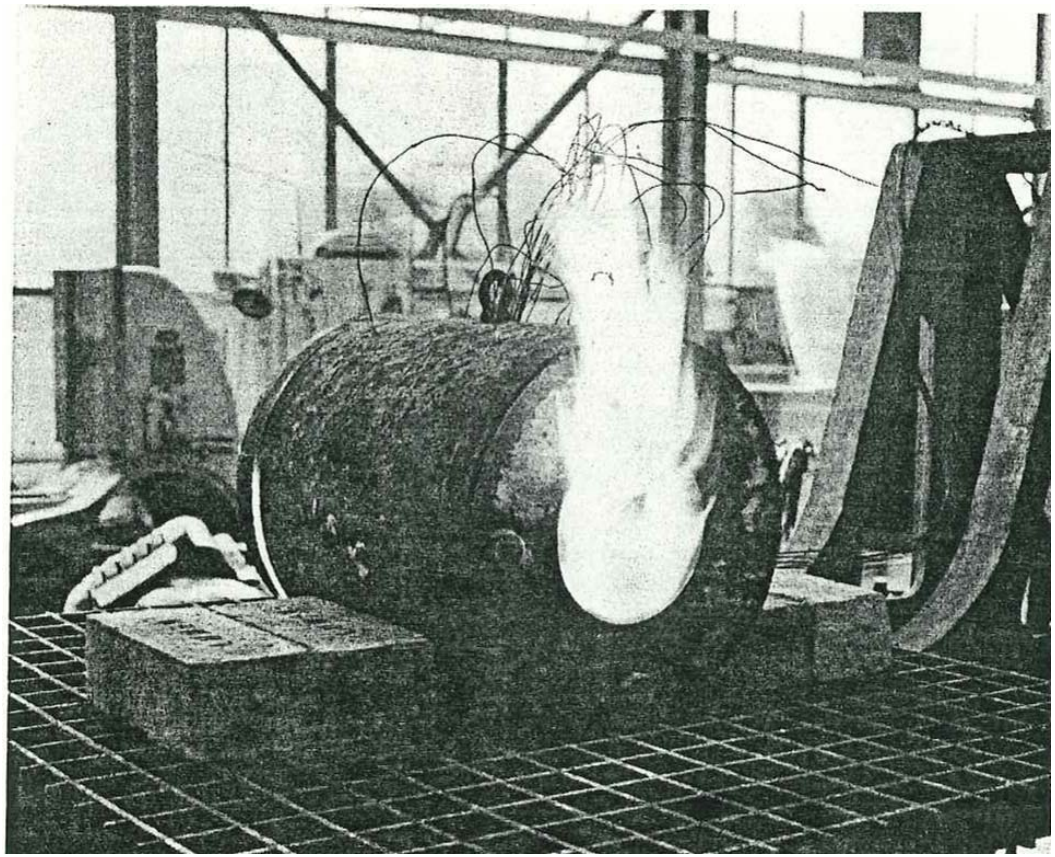
serco

Why not use the thermal test data ?

- The actual transport flask may have been subjected to a thermal test
- Could effective thermal properties of wood or cork be derived from this data?
- In principal yes. But:
  - Transport flasks are not designed for deriving thermal properties
  - Heat transfer paths may be complex
  - There may be more than one material with unknown effective thermal properties
- Better, if possible, to derive effective thermal properties from separate tests and then show that using these properties reproduces the thermal performance of actual tested flask.

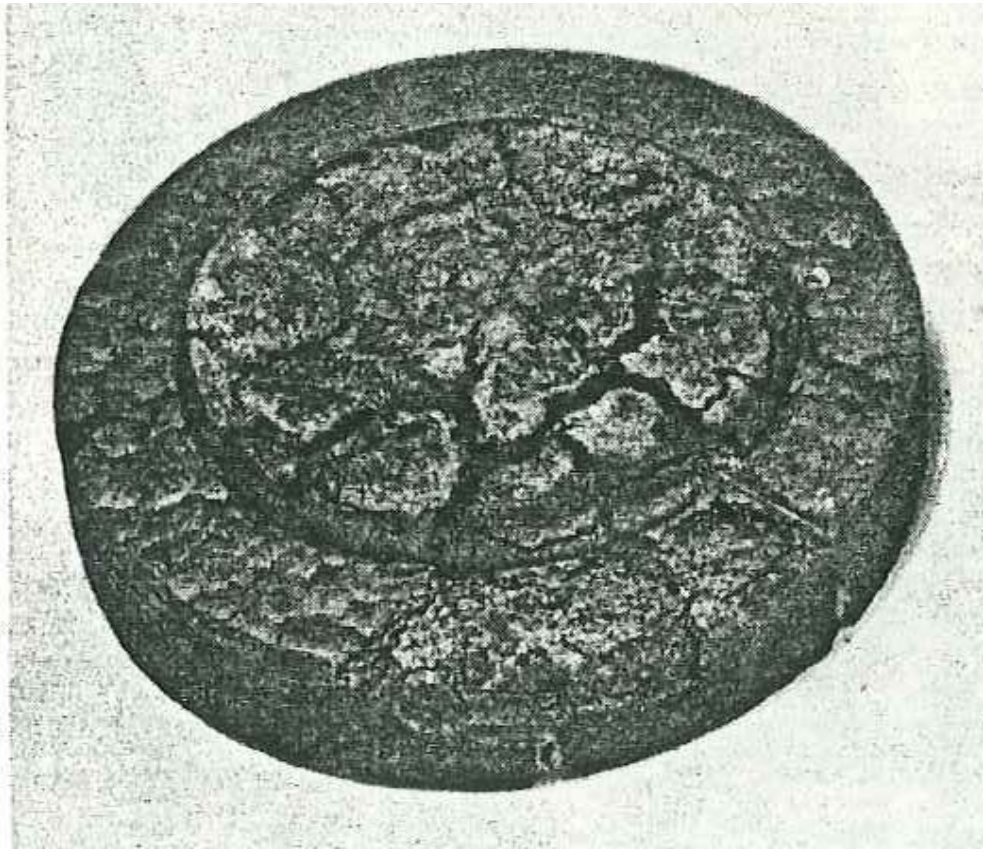
serco

Example of laboratory scale test 1 – simple test without calorimeter

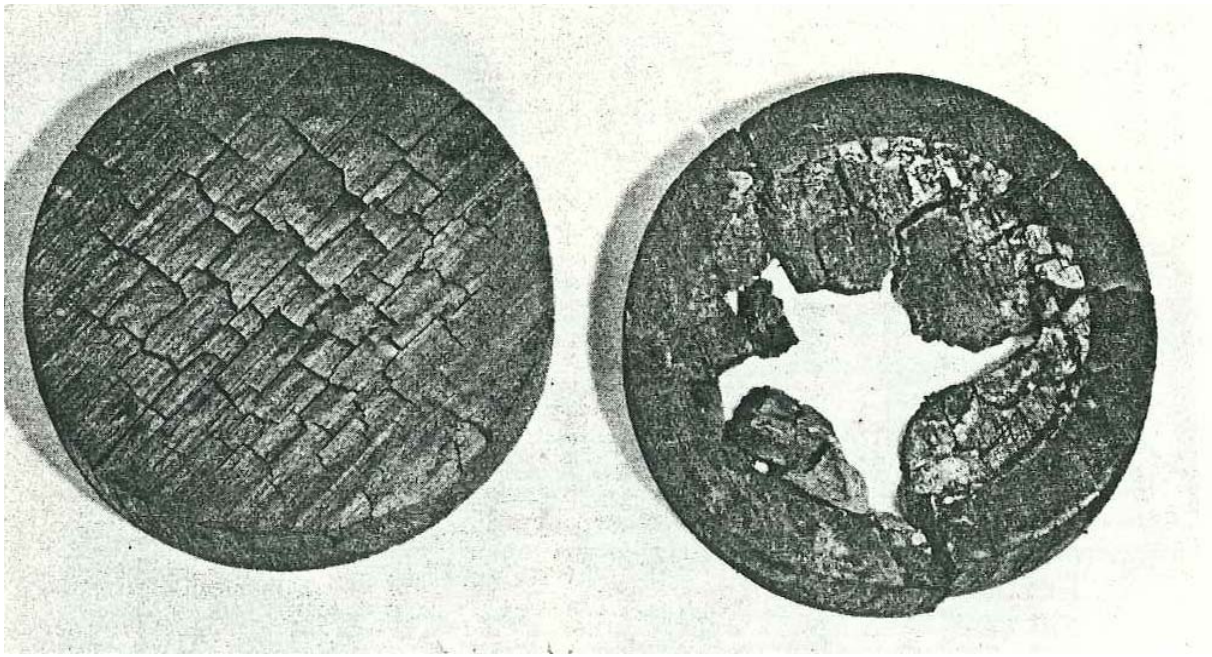


Harwell, 1975

Example of behaviour: cork



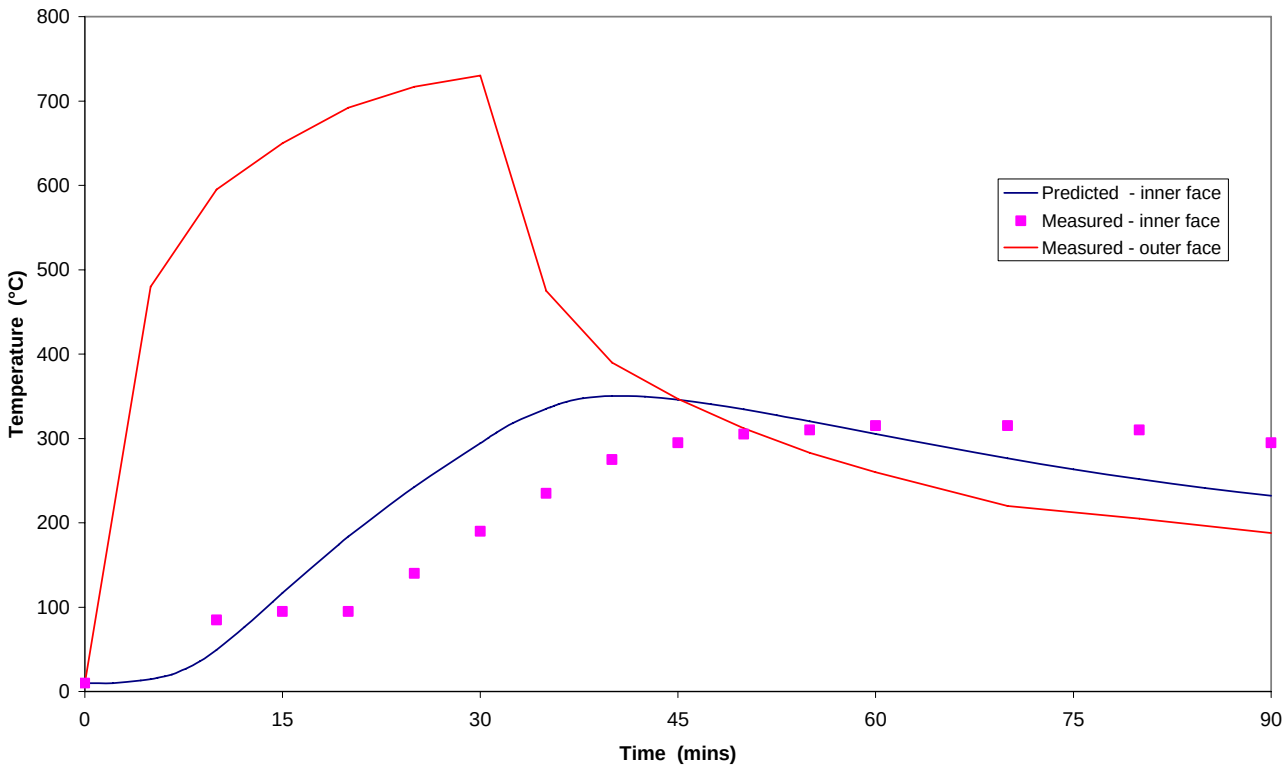
Example of behaviour : wood (iroko)



Clad

Bare

Example of results: cork



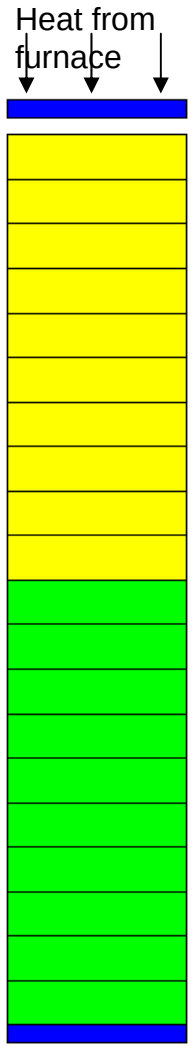
FE model used to derive thermal properties

Key

Green insulation - stillite

Blue - stainless steel

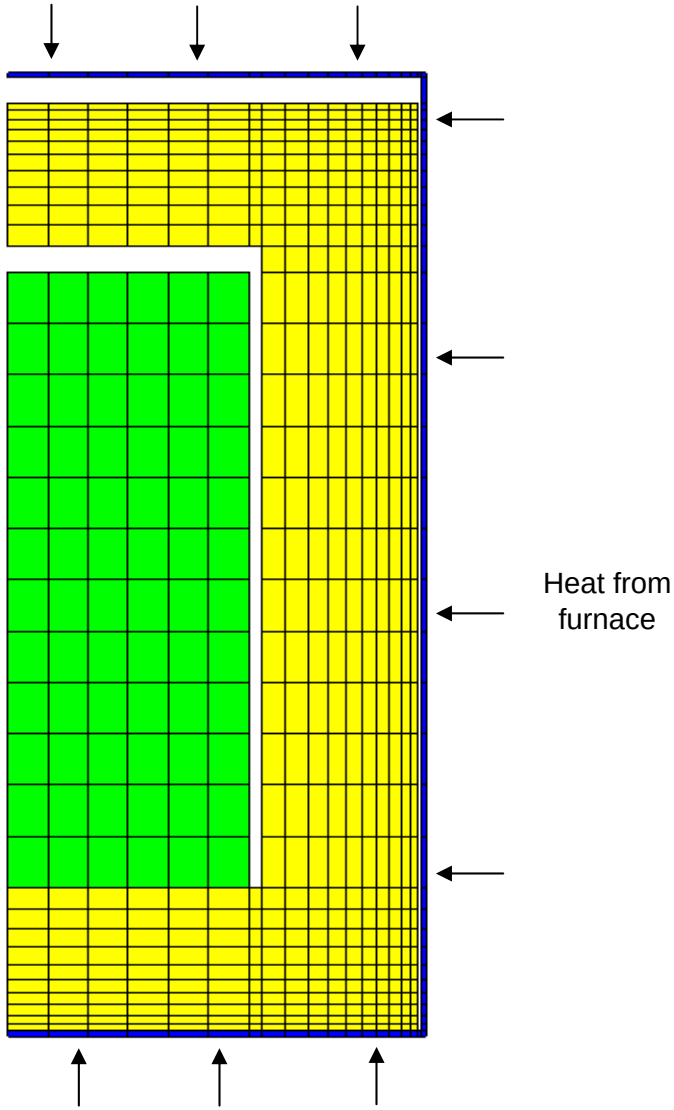
Yellow - cork



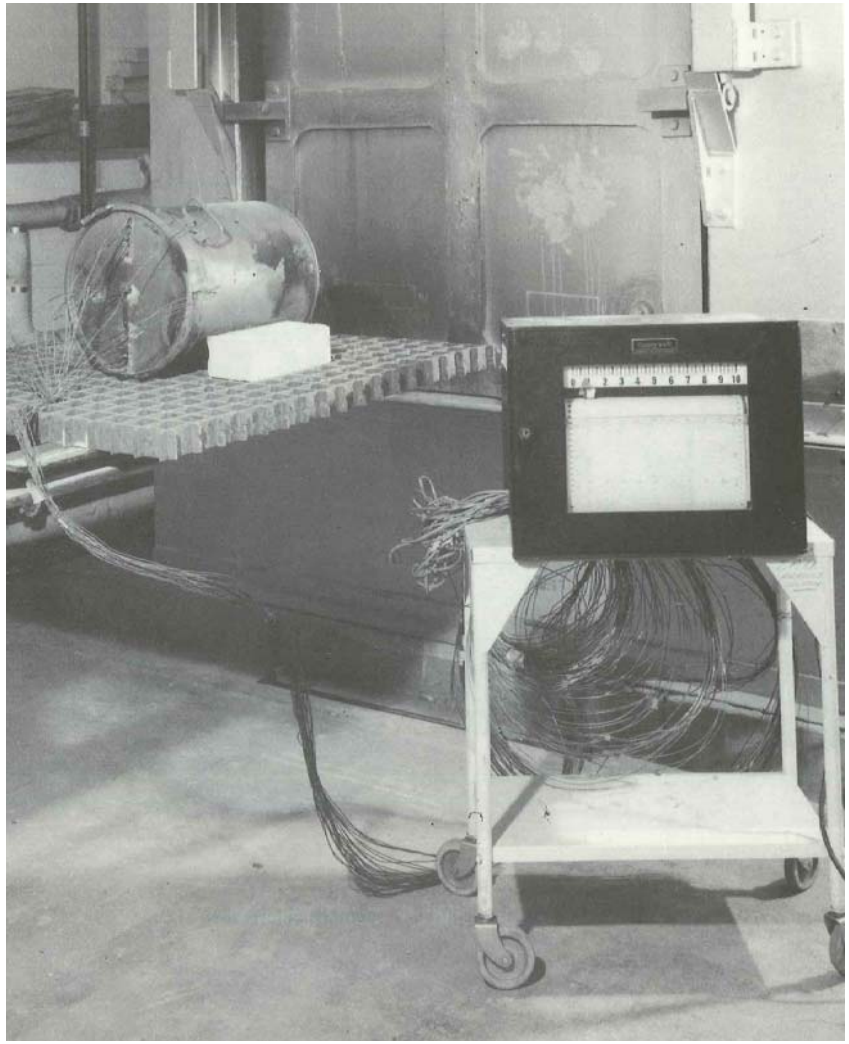
This design of test not ideal because no calorimeter – thermal capacity comes from properties of cork alone

serco

Example of laboratory scale test 2 – simple test with calorimeter

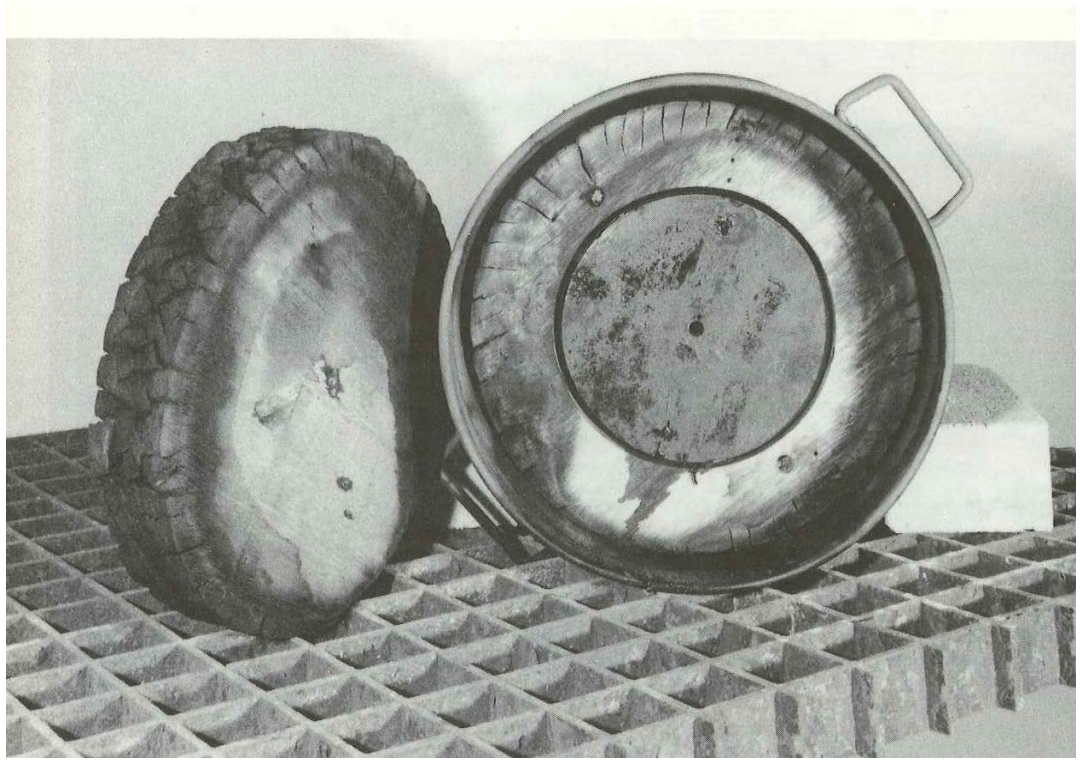


Example of laboratory scale test 2

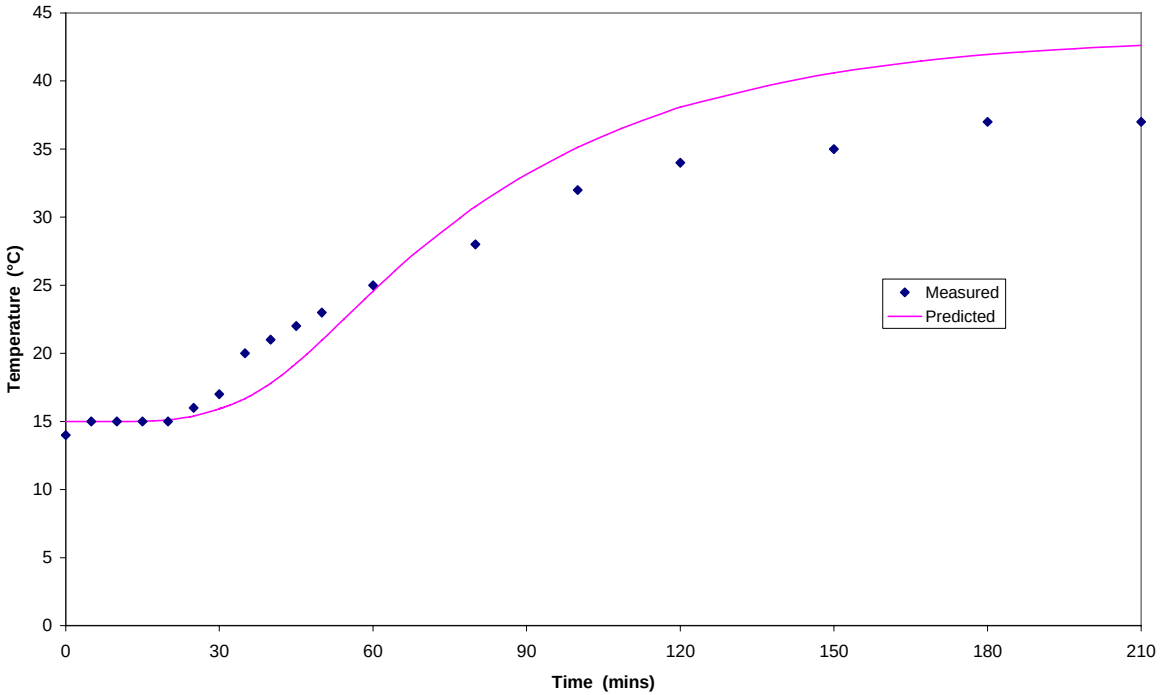


Harwell, 1979

Example of behaviour : wood (iroko)



Example of results: cork



Example of laboratory scale test 3

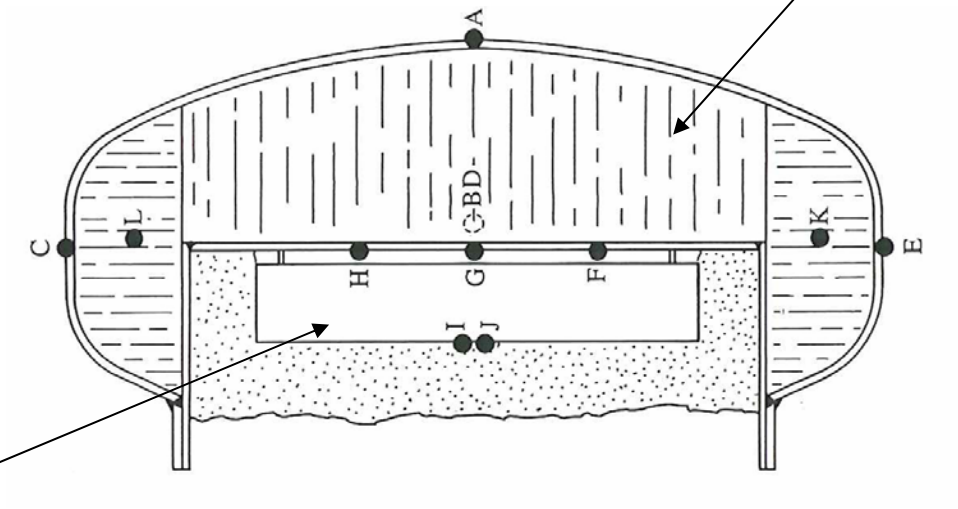
Croft

2010

Example of behaviour (foam)

Example of behaviour (foam)

Example of test of burning



Example of test of burning

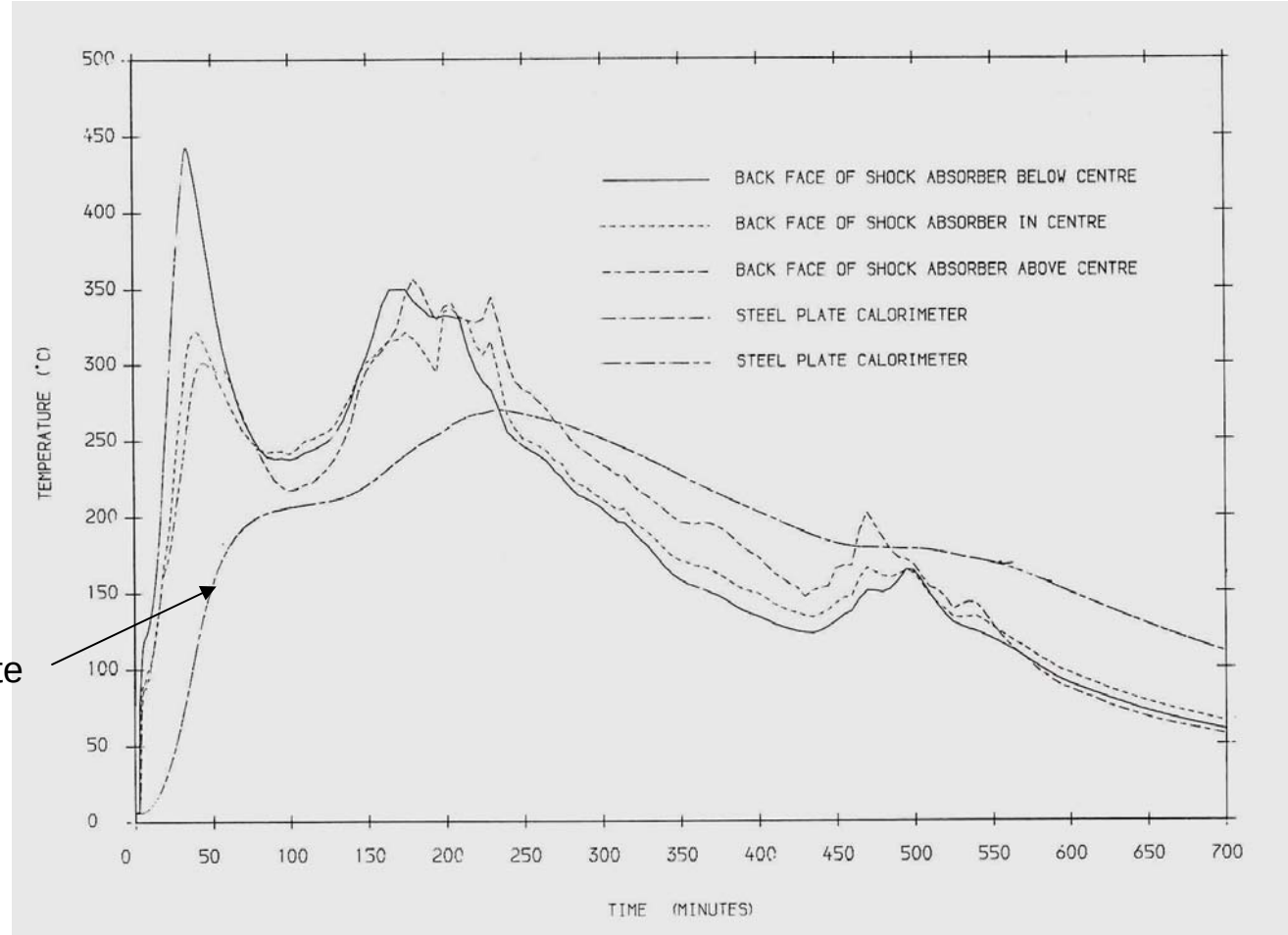
Winfrith

1990

Example of test of burning

Example of behaviour (balsa)

Example of Results - balsa



Steel plate

Conclusions

- Heat transfer through wood and cork in a thermal test needs to be modelled
- At high temperature physical and chemical processes occur which affect heat transfer
- Reference values of density, specific heat and thermal capacity, measured at room temperature are therefore unreliable at high temperature
- Recommended that effective values of density, specific heat and thermal conductivity be obtained by modelling laboratory scale tests
- Examples of such tests have been given

serco