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What is the difference between these two pancakes?

Answer:
Heat transfer coefficient

Could this be happening in polymer processing?

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Heat Transfer in Polymers: Outline

- Heat transfer coefficient
  - Development of a new measurement method
- Thermal conductivity
  - Improvement and expansion of scope
- Industrial demonstrations
  - In partnership with IAG members
- Documents available & next steps

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Heat Transfer Coefficient

- It is the heat flux (q) across a surface from one material of temperature T_1 to another material of temperature T_2 :

$$h = q/(T_1 - T_2) \qquad \text{units: } Wm^{-2}K^{-1}$$

- The parameter that describes heat transfer across a surface
- Voted number one new measurement topic during programme formulation
- In injection moulding & compression moulding
  - Polymer to metal heat transfer
  - The focus decided at the last meeting
- This project will build apparatus to measure heat transfer coefficient

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Specification of H.T.C. Apparatus

- Previous meeting discussed specification
  - Several useful suggestions incorporated
- Main features of specification
  - 30 to 300^{o}C
  - Pressure to at least 500 bar (2000 bar possibly)
  - Disc shape 2 to 15 mm thick, 100 mm diameter (may need to reduce slightly)
  - Molten and solid materials
  - Air gap option
  - Thermocouples, heat flux sensors plus calorimeter

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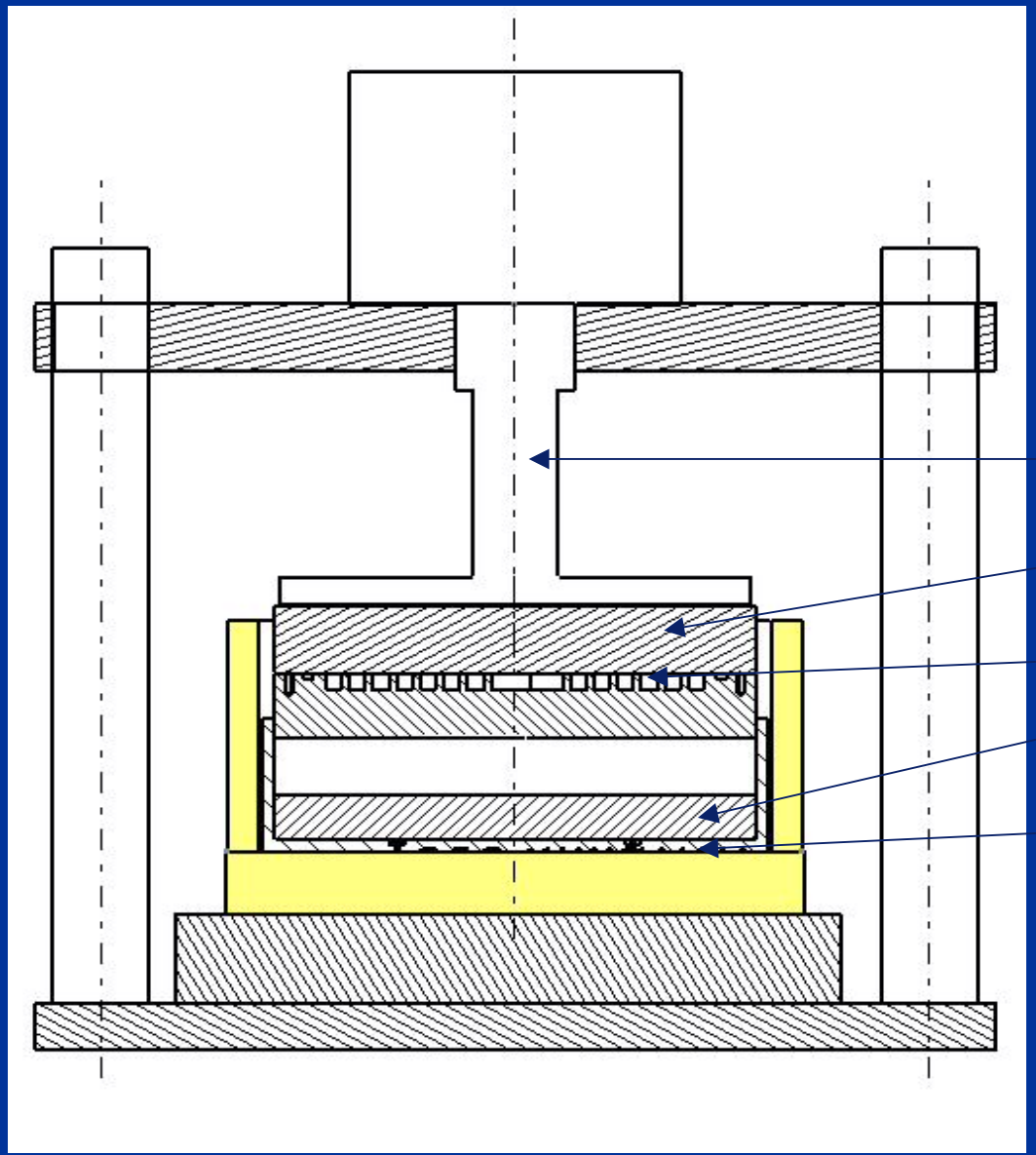
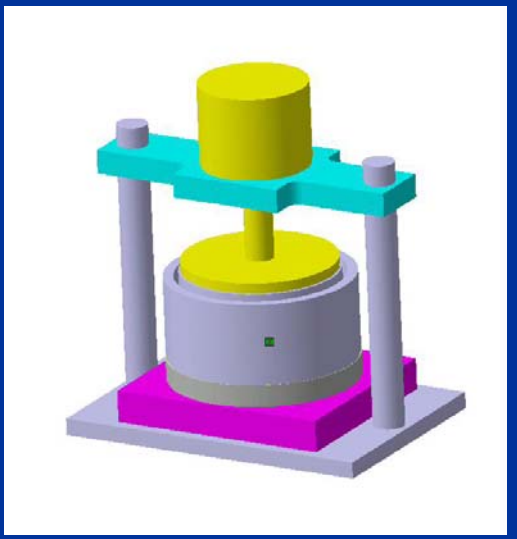
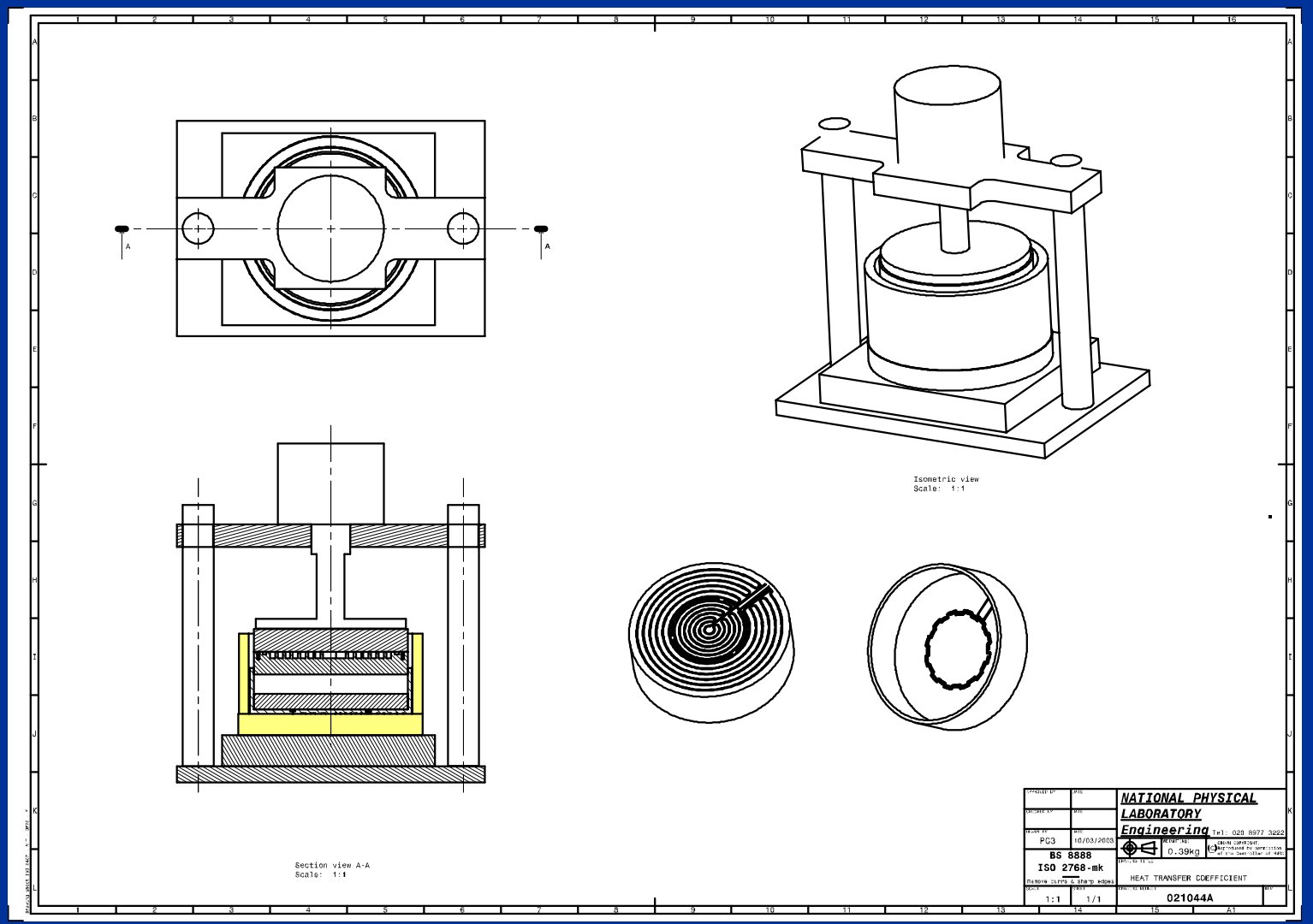
Heat transfer apparatus: general schematic





First set of engineering drawings



Features

- press
- heating and cooling circuits
- air gap option
- variable thickness

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Heat Transfer Coefficient: Future Plans

- Complete design by April 03
- Capital investment case by July 03
- Construction status report by Dec 03
- Build complete by June 04
- Commissioning complete by December 04

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Thermal Conductivity

Work in this project includes:

- Uncertainty analysis
- Extending the scope of material types beyond thermoplastics
- Comparability study

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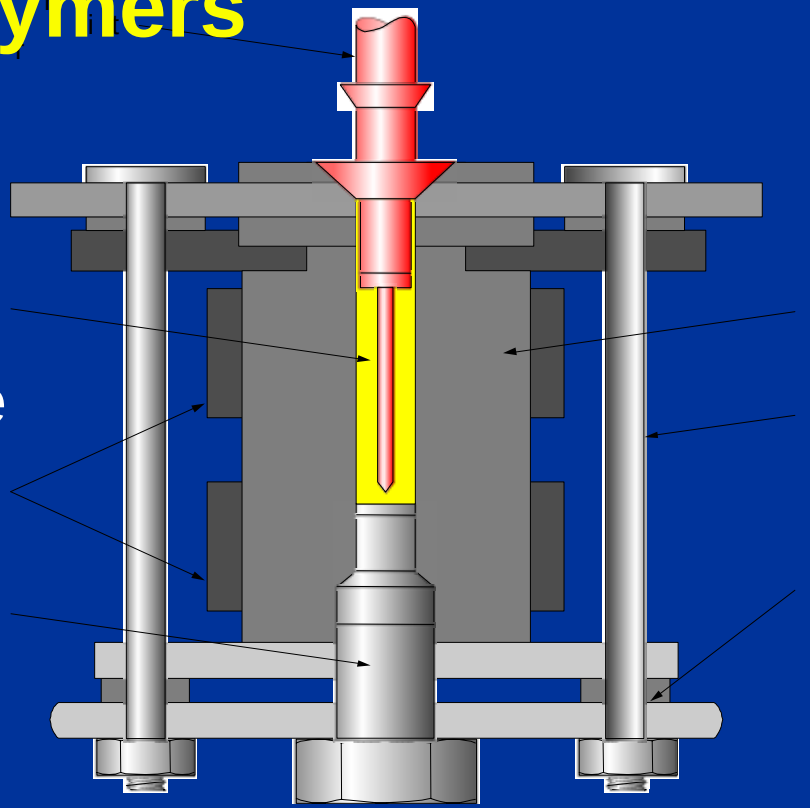
Thermal Conductivity of Polymers



Uncertainty analysis

- Proposed material: a BP HDPE grade
  - Used for previous intercomparisons
  - Tested for thermal stability
- Work to be complete by October 03
- Data to be used in simulation studies
- Aim to increase confidence in the data

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Thermal Conductivity: Extending the Scope

- Six materials can be studied in all

- From last meeting, from recent requests and from proposal:
  - Two thermosets (from Railko)
  - One rubber (from Avon Rubber)
  - One powder (further offers or a rotational moulding PE grade)
  - Two “nano-materials” sample plus control(s)

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Thermal Conductivity:Thermosets

- Suggested two of four requested by Railko
  - Other materials (including acetyl) could be covered if co-funded

- Phenolic with high graphite level
- Phenolic without fillers or fibres
- Polyester/glass
- Polyester
- Acetyl (POM) unlubricated
- Acetyl (POM) lubricated

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Thermal Conductivity

- Avon rubber grade used for engine mountings
  - Potential interest for a heat transfer industrial demonstration
- Powder
  - Thermal conductivity difference between melt, powder & solid
- Nano-material
  - Do very fine particles help or hinder heat transfer?
  - Can representative samples be prepared and measured easily?

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Industrial Demonstrations: Update

- Suggestions were requested at last meeting

- Five suggestions received

Avon Rubber

  - Heat transfer during injection moulded of an engine mount, rubber with nylon and metal inserts

Zotefoams

  - Heat transfer within polyolefin foam during solidification and cooling (potential TCS project link)

Railko

  - Study of the effect of additives on the heat transfer of polyesters, acetyls and phenolics

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Industrial Demonstrations

- Corus
  - Extending the study from the last project to include heat transfer across surfaces, changes during processing and modelling the coating line (Swansea University)

- AWE
  - Measurement of thermal conductivity of PU foam including thermal contact investigation

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Industrial Demonstrations: requirements

- A two page case study should result
  - Covering the measurement method and its applicability
  - Can exclude sensitive data & other confidential information
- Partner company contribution
  - Quantifiable in-kind contributions
  - Cash
    - 25% of NPL work, DTI pay the other 75%
    - E.g. £3k provides for work to the value of £12k
- Negotiations to continue with these five
  - Possibility of doing more than two if funds allow
- Timescale
  - Throughout the rest of the project; review at mid-term

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Eureka Project

- An associated Eureka project (AIMTECH) has been won.
- Its aim is to improve productivity of injection moulding
  - Main focus is on the moulds
  - NPL's role is the mould/polymer interface + the melt
- It will use measurement methods from this project
- Six UK companies involved
- NPL will measure some of their materials
- £25k co-funding contribution

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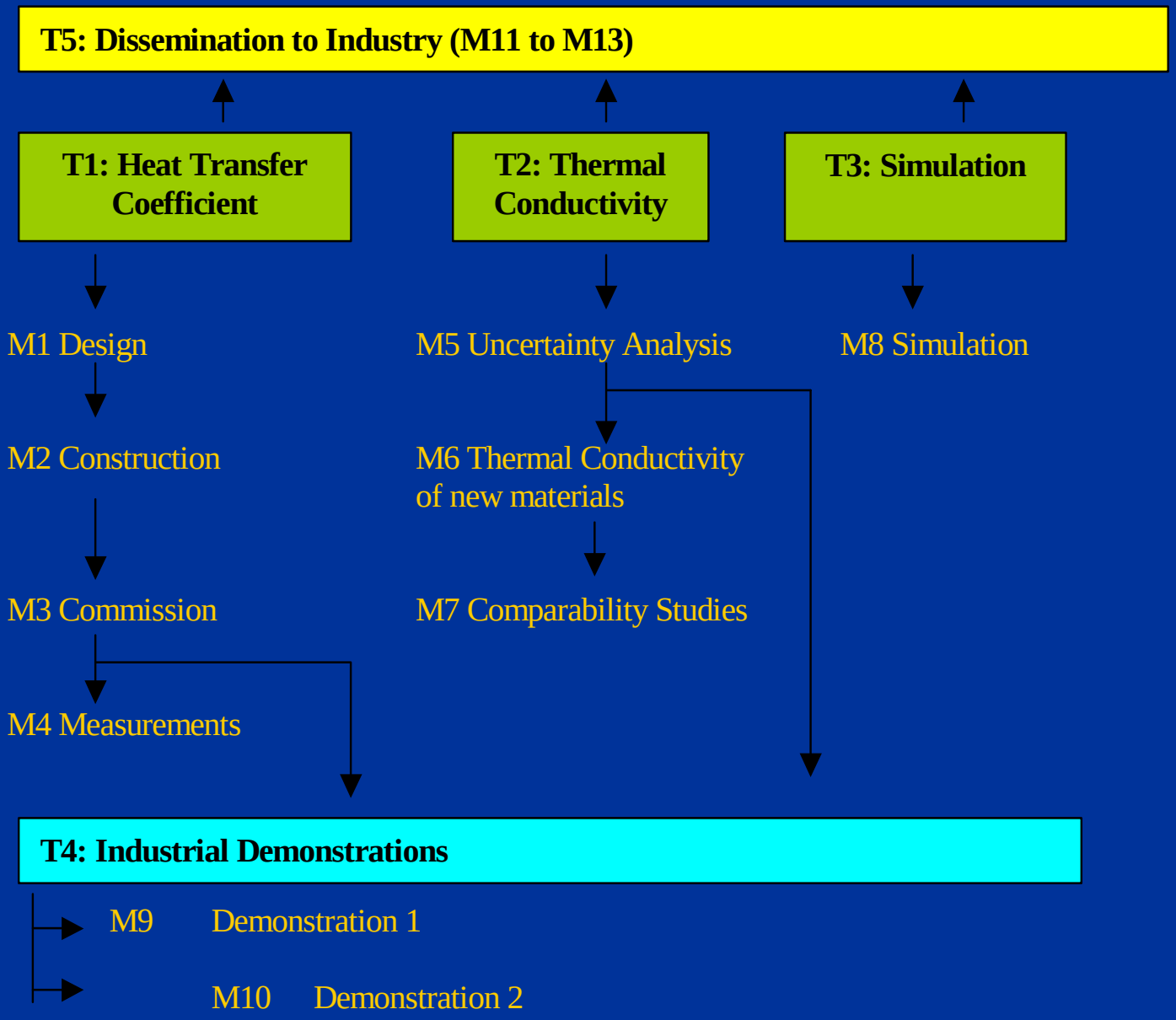
Project Plan



Simulation

- Aims to establish the commercial implications of uncertainties in heat transfer measurements
- On a real industrial product
  - To illustrate practical importance of accurate measurement
- And on a simple geometry
  - To investigate how thickness may change the relative importance of the parameters

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Simulation

- In the previous project:
- thermal conductivity value measured at the correct temperature and pressure
- Compared with literature value
- Cooling times predicted under a variety of processing conditions

- *In this project:*
- *Uncertainties in all thermal parameters (thermal conductivity, heat transfer coefficient, specific heat, density)*
- *how does thickness change the relative importance of the parameters*

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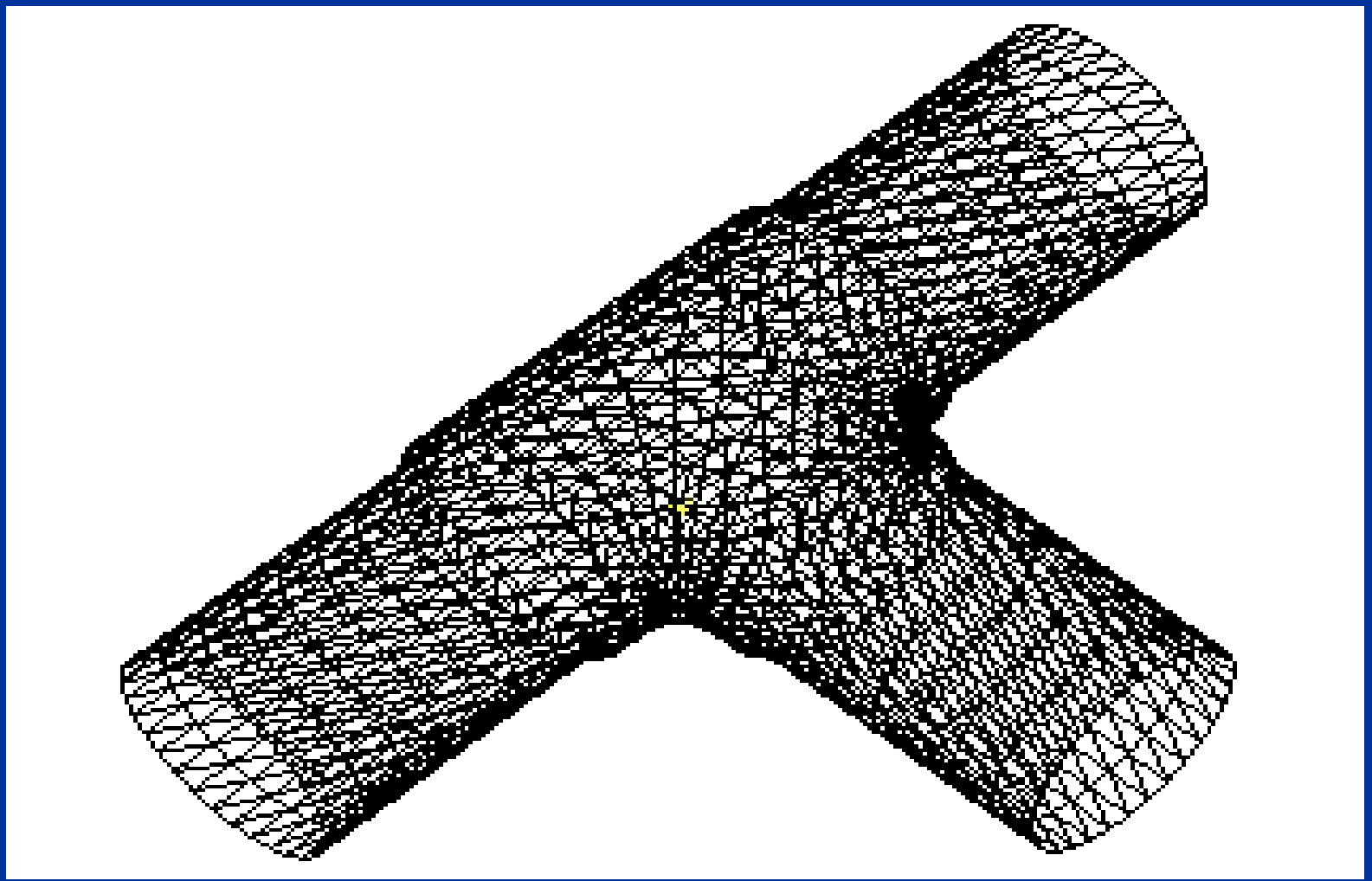
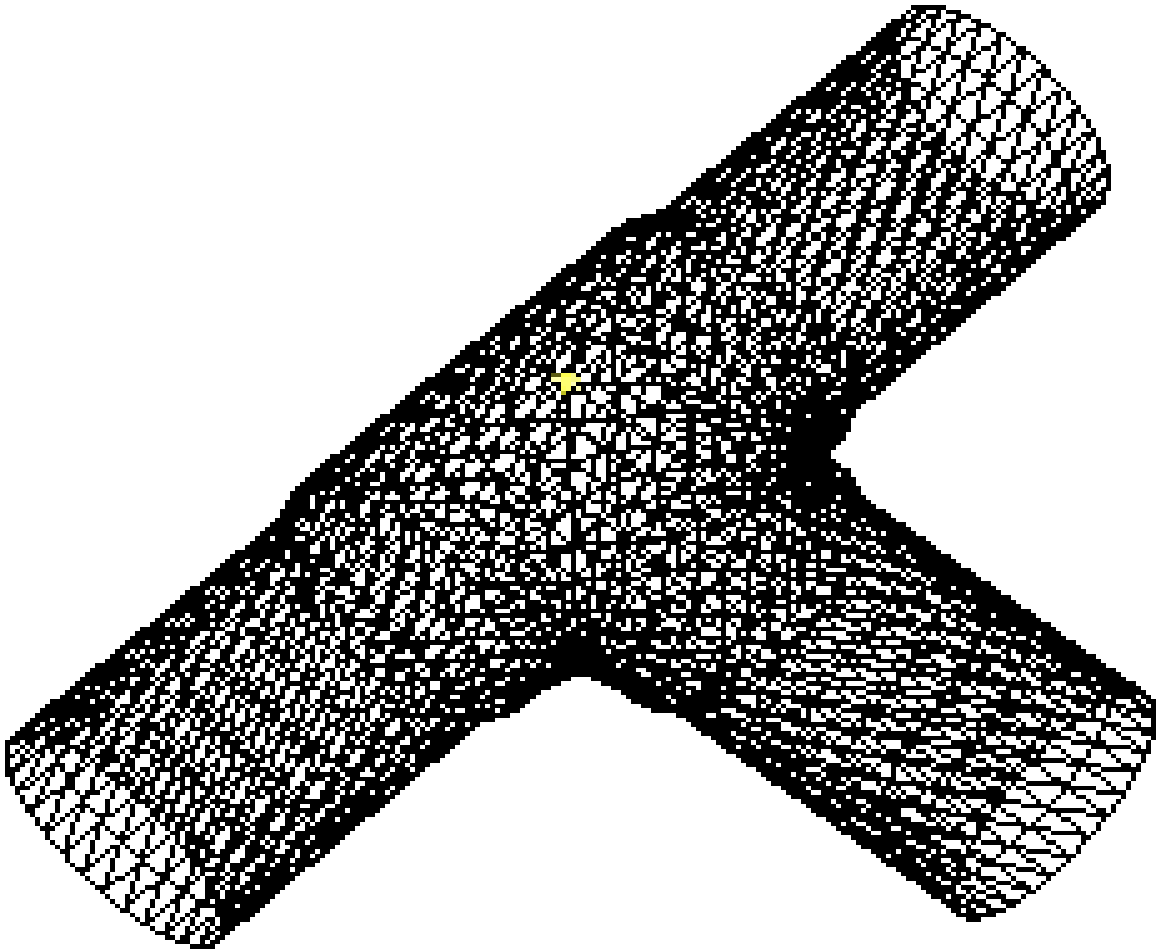
Example of process simulation from the previous project



Temperature change during cooling



Simulation Geometries

1. Simple disc

2. Engine mount from Avon Rubber

   or

   Tee piece from previous project

Outputs to date

- Paper at Interplas seminar
- Project Summary document
- First IAG minutes
- Specification of heat transfer coefficient apparatus

- *Brief document presenting outcomes of the previous project*

Next steps

- Complete the design of the heat transfer coefficient apparatus
- Uncertainty statement for thermal conductivity of polymer melts
- Thermal conductivity of six new materials
- Simulation studies
- Start industrial demonstrations
- Start Eureka project
- Web feature

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Summary

- Heat transfer coefficient design well under way
- Offers received from companies
  - Industrial demonstrations
  - Samples for measurements
- Documents available

… and we will soon be able to cook the perfect pancake

… and you will be able to produce the perfect product with astonishing productivity rates

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