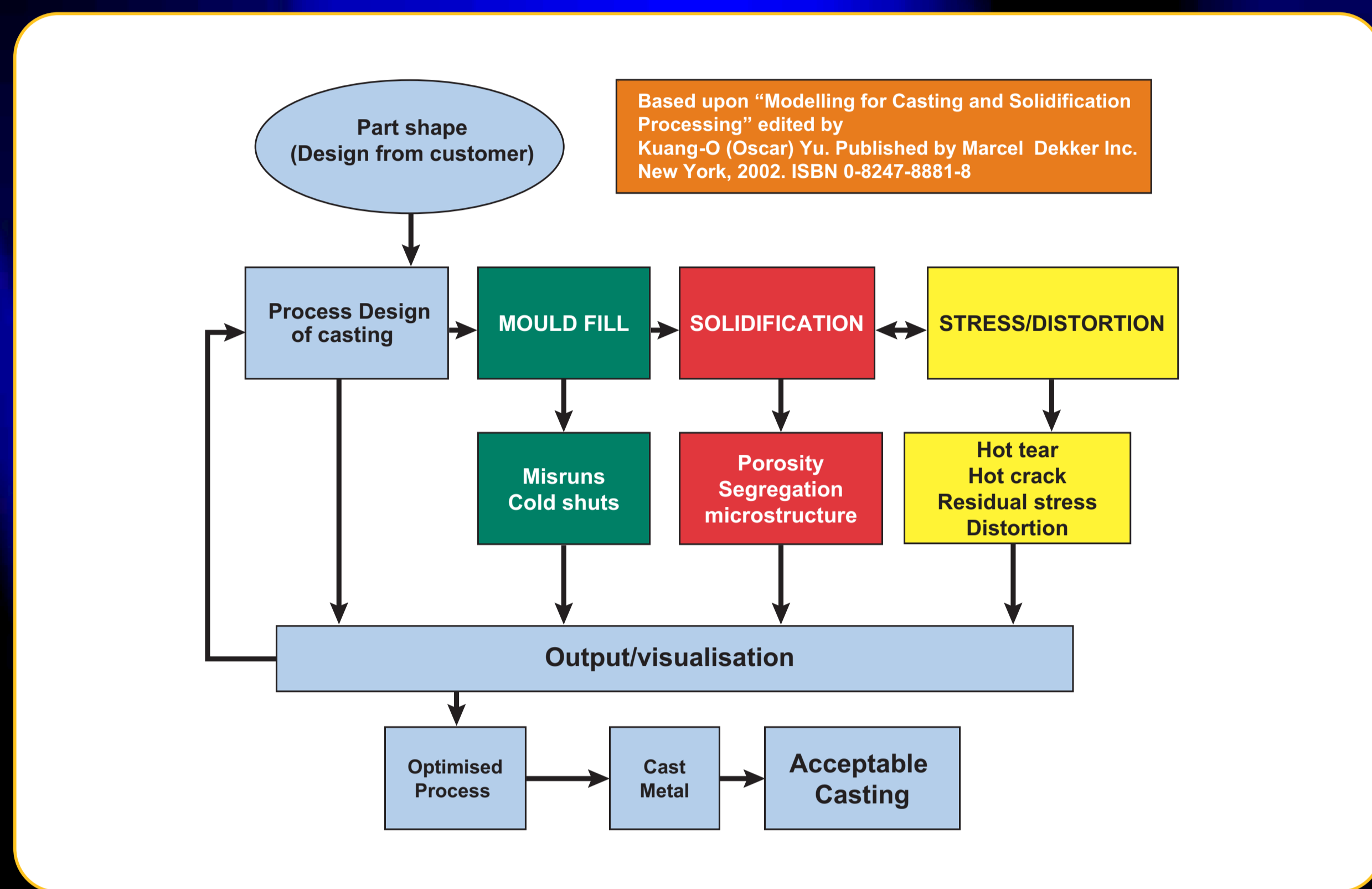


## Introduction: The Need for Data

There is an increasing use of physically based simulation modelling of processes, to improve productivity through lower energy costs, lower scrap, improved quality and greater product consistency. An element in the success of these models depends on the quality of the thermophysical property data. In order to fill the knowledge gaps NPL with the University of Swansea and other partners have developed several methods of measuring the relevant properties.

Measurement of thermophysical properties for solidification and mechanical models are difficult because of the high temperatures required and the reactivity of samples with containers and atmosphere conditions.

## Mould Fill

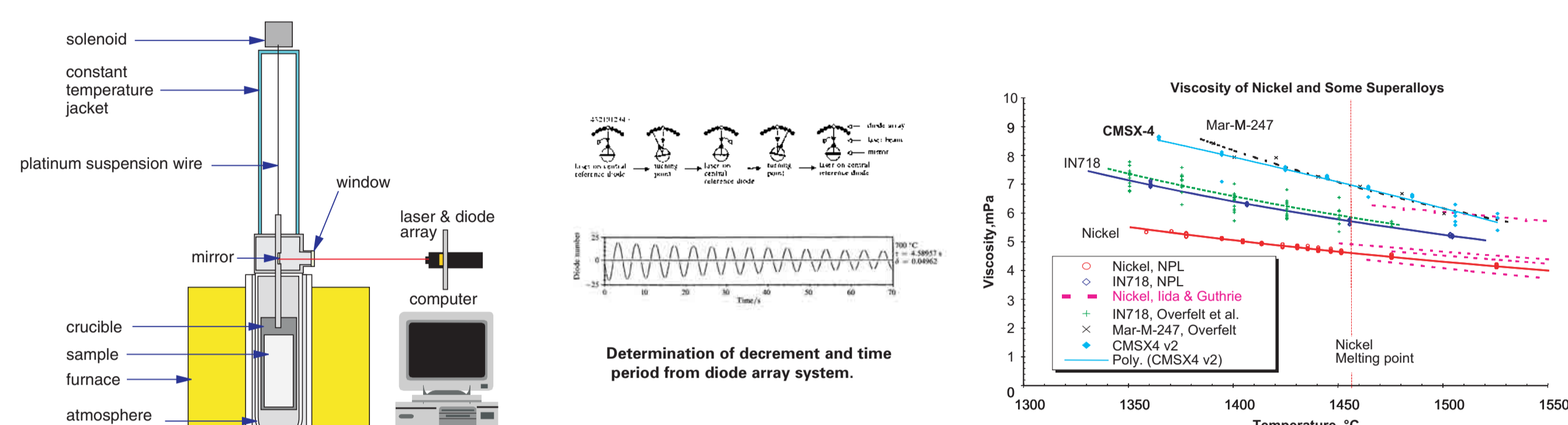


### Viscosity

A variety of methods are available for measuring viscosity.

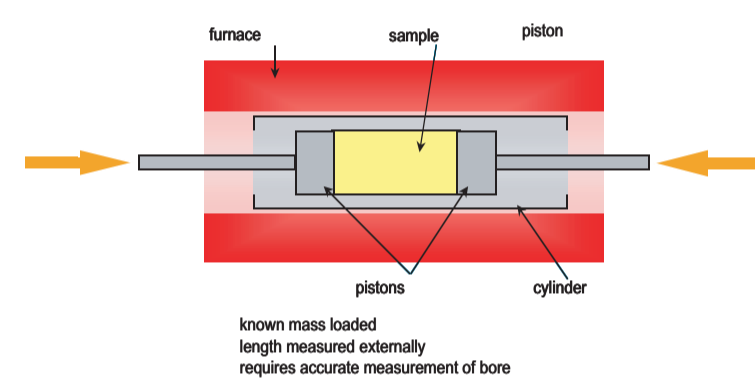
At NPL a rotating bob viscometer is available for measuring higher viscosity materials, e.g. slags, glasses, oils or an oscillating crucible (cup) viscometer is the most common method used for liquid metal measurements.

Rob Brooks, NPL

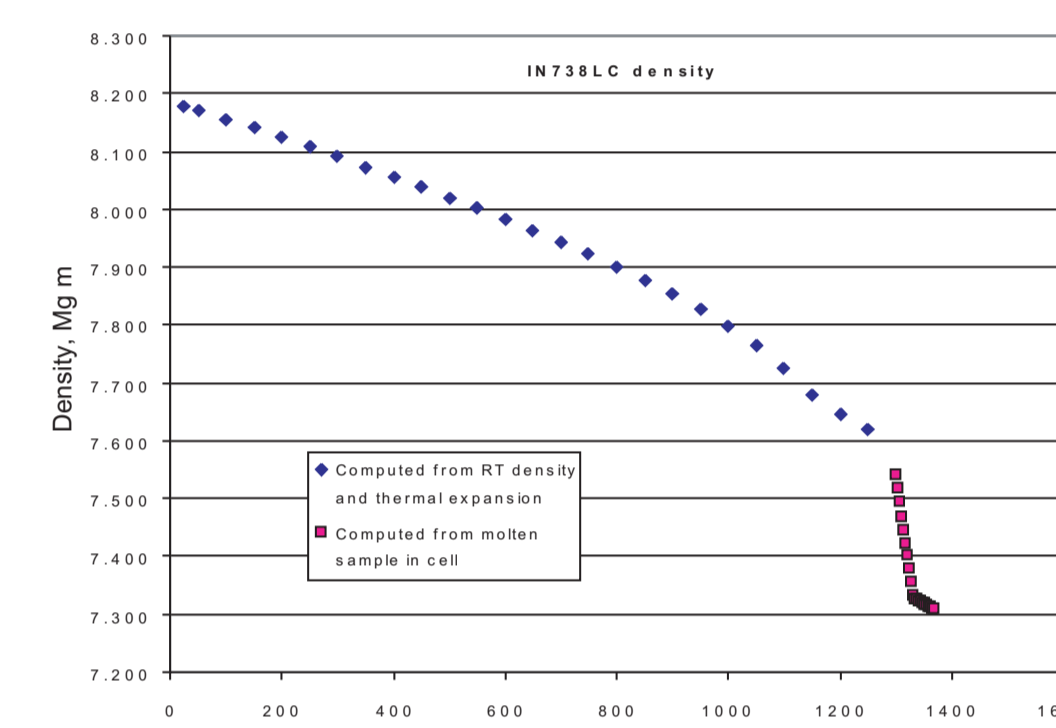


### Density

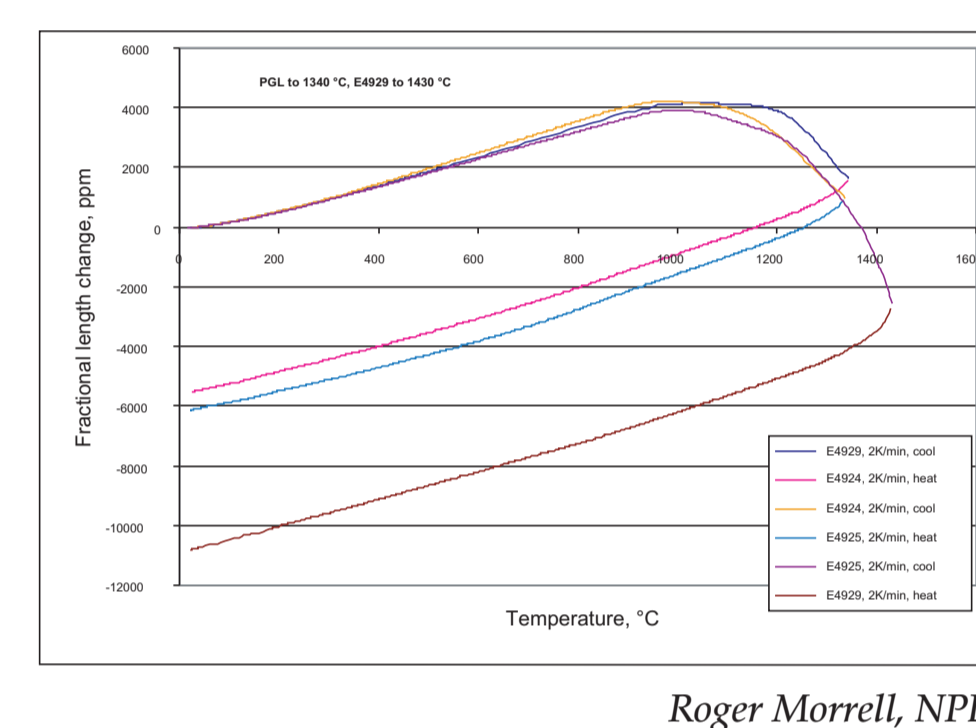
A number of methods have been used to determine density but the focus here is on Push Rod Dilatometry as method of obtaining both Density and Thermal Expansion for alloys and mould materials.



Density of Nickel Based Superalloy

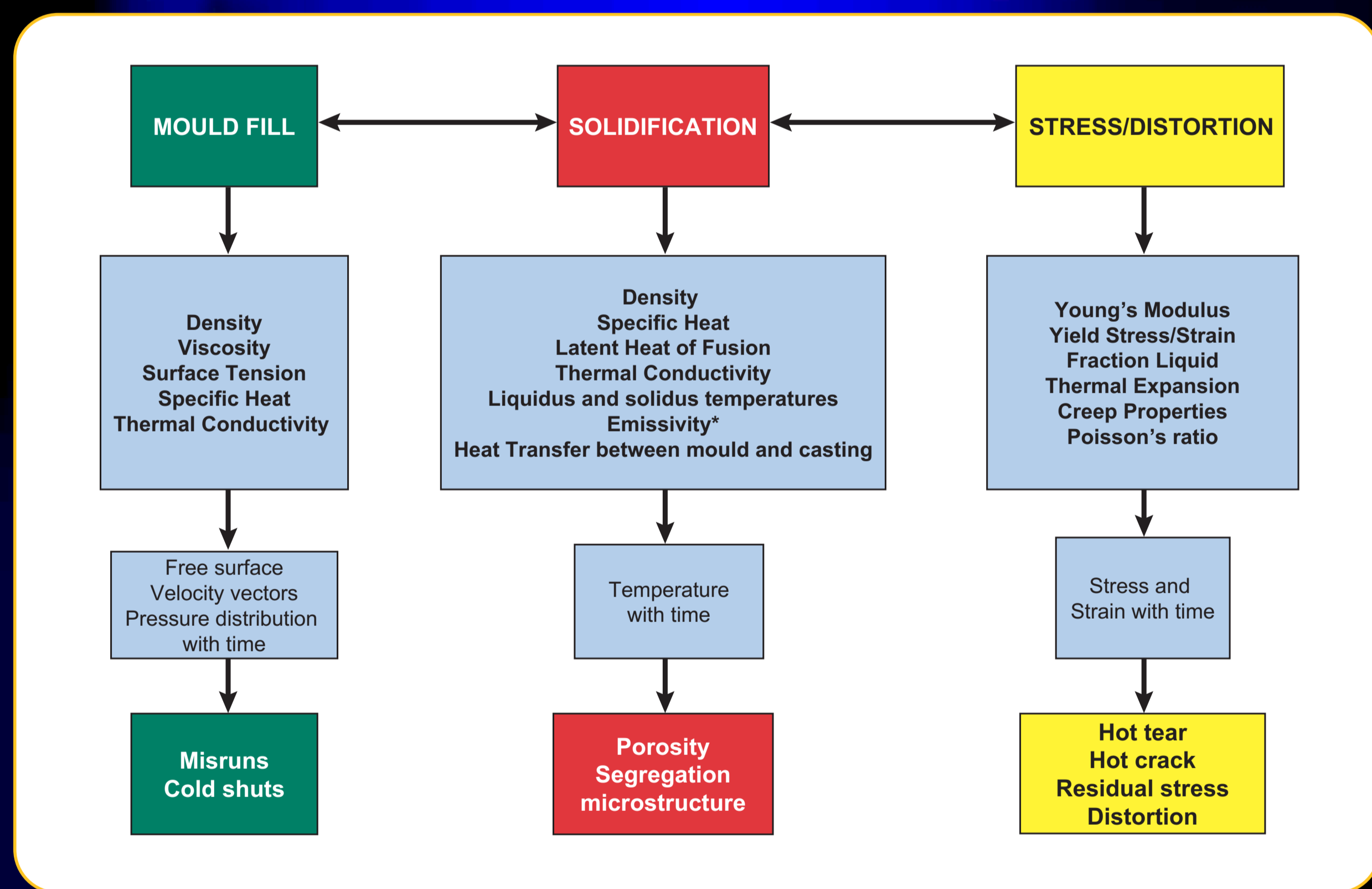


Thermal Expansion of Mould Materials

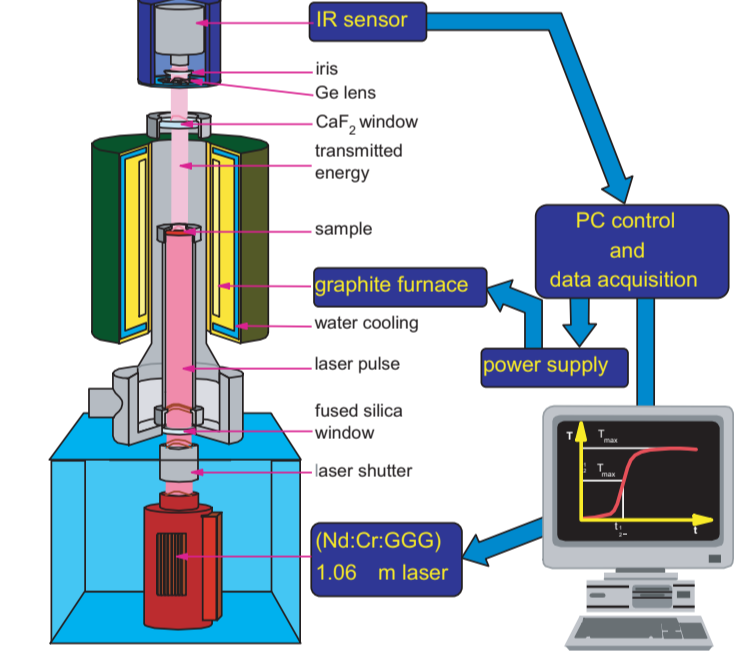


Roger Morrell, NPL

## Solidification



### Laser Flash Apparatus

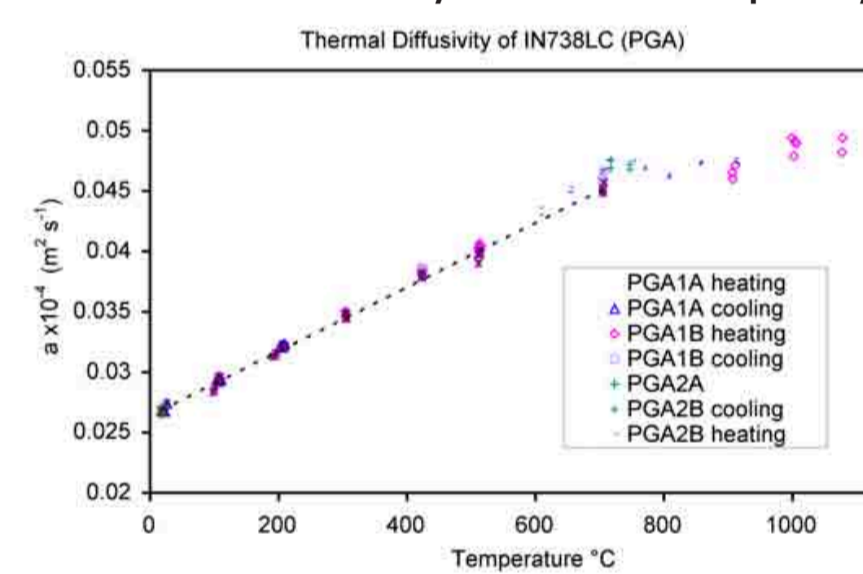


Lindsay Chapman, NPL

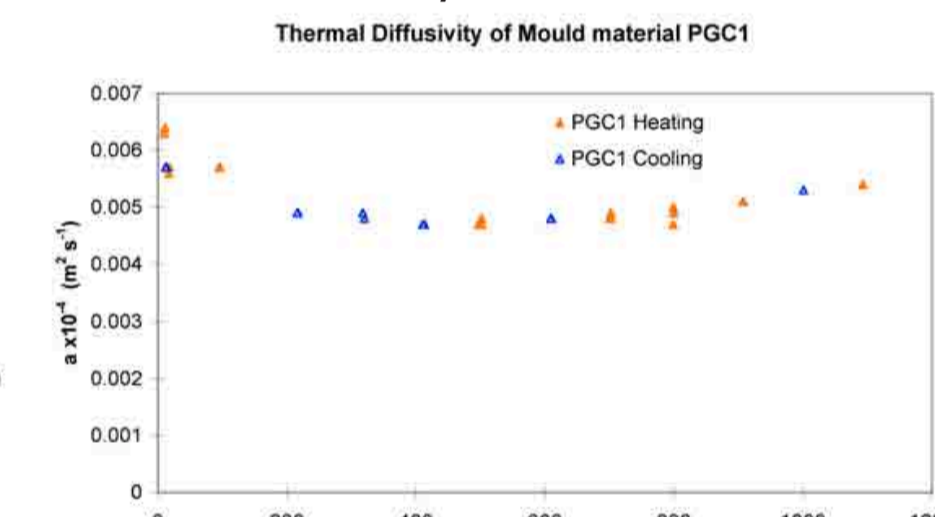
### Thermal Diffusivity

The Laser Flash apparatus is used to measure thermal diffusivity, a parameter which is itself used in models and also for the calculation of thermal conductivity. NPL is one of the few places where liquid diffusivity of industrial alloys can be measured.

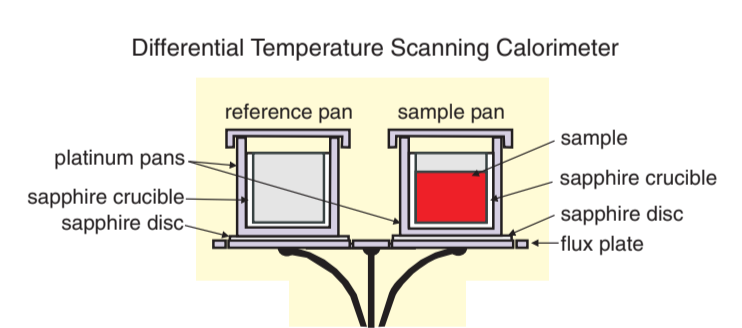
Thermal Diffusivity of Nickel Based Superalloy



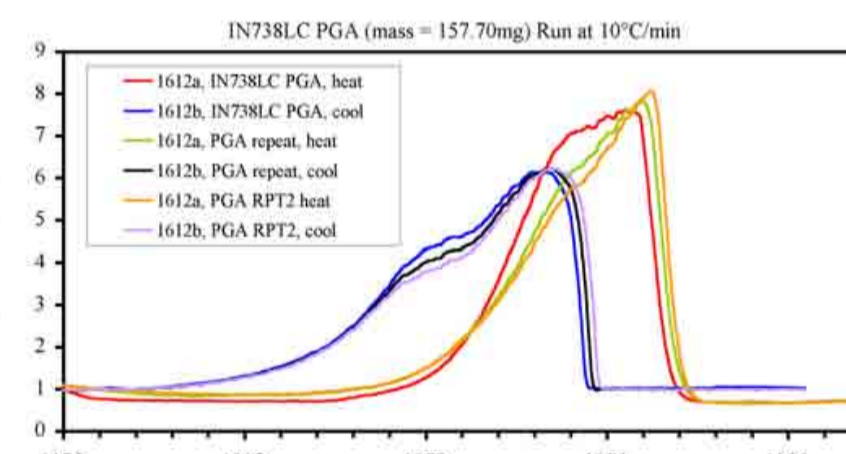
Thermal Diffusivity of Mould Material



The method of Differential Scanning Calorimetry is used to measure Specific Heat, Enthalpy and solidus and liquidus temperatures.

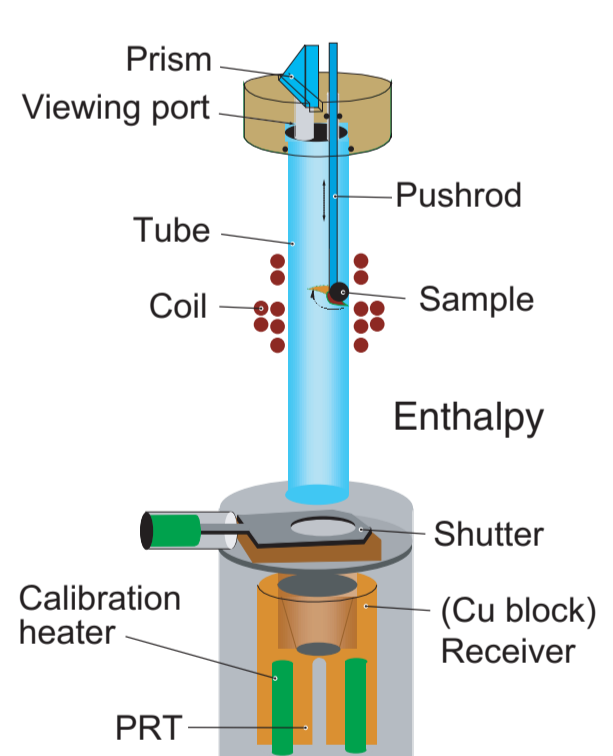


Lindsay Chapman, NPL



### Levitation Methods

Most measurements by levitation are performed on metals. Enthalpy values may be obtained by Drop calorimetry, and measurements of thermal expansion, density, and surface tension may also be made. However the accurate temperature measurement by pyrometry is a major challenge.



Rob Brooks, NPL

## Conclusions

There is a need for thermophysical data of industrially important materials for simulation models which include solidification. Data has been shown to improve predictions of simulation models, and there has been a dramatic increase in the quality of this data during the last ten years. Further Improvements could be made to the estimation of properties of alloys in the solid/liquid region improvement in the uncertainties of measurement (thermal diffusivity; density) An understanding of properties of moulding materials. The implications of Surface and interfacial properties Improved Mechanical properties at relevant temperatures.

## Acknowledgements

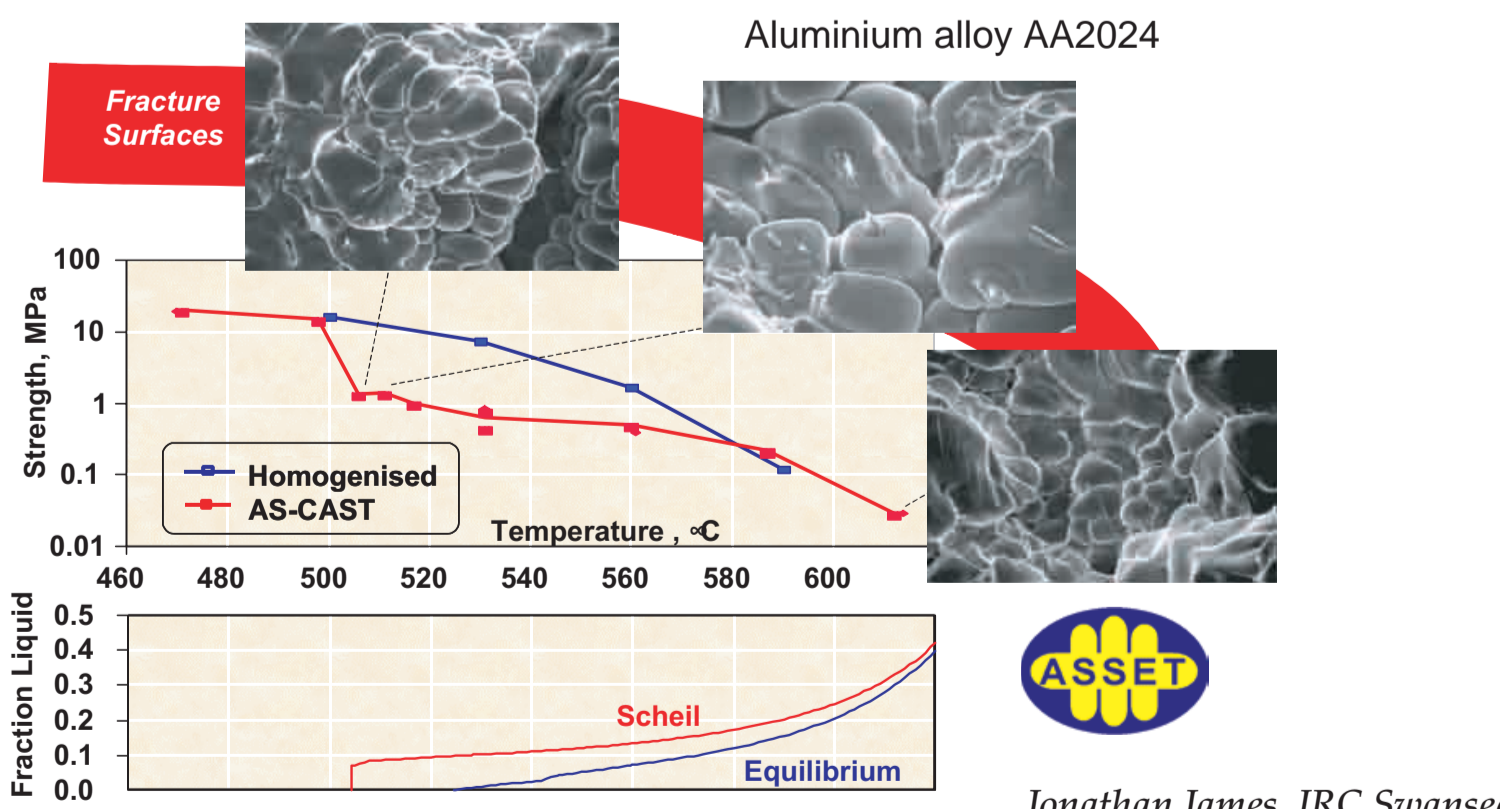
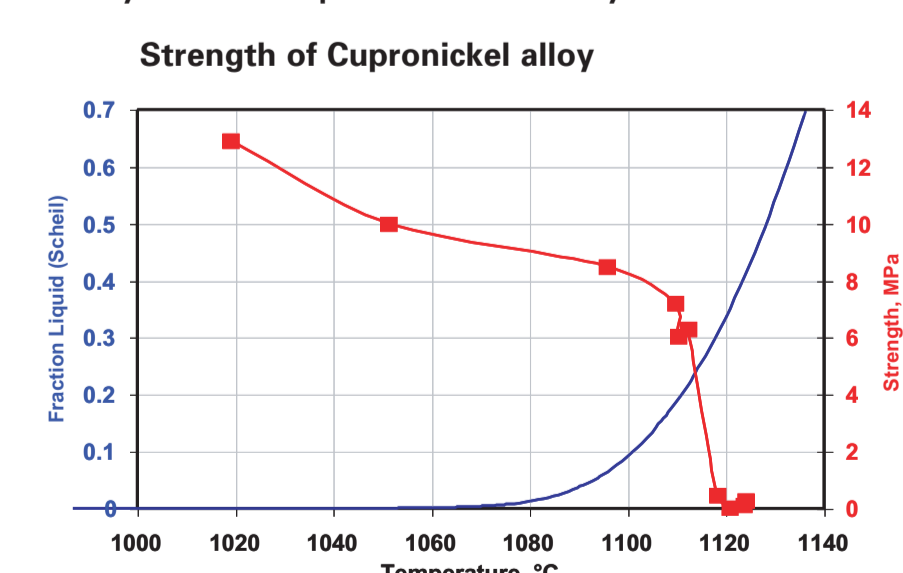
NPL acknowledges the UK's Department of Trade and Industry for funding projects in this area as part of their "Measurement for Processability" Programme. Thanks also to a wide range of industrial sponsors for their financial support.

Technical input and discussions have come from a wide range of sources including colleagues at NPL; various European Laboratories and industrialists who formed the Industrial Advisory Group associated with the projects.

## Stress Distortion

### Strength

The ASSET facility at the IRC Swansea is used to measure the strength of alloys at temperatures very close to the solidus.



Jonathan James, IRC Swansea

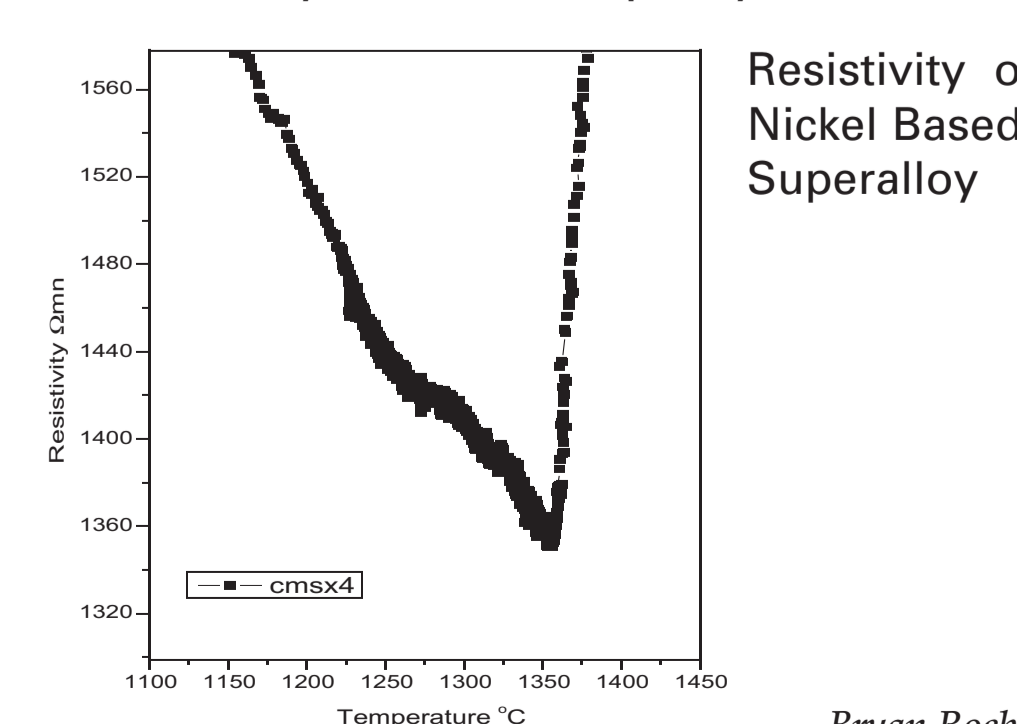
### Strain

Accelerated test methods promise to provide useful data that can support reliable predictive modelling of the processing of industrial components. NPL has developed a new desk-top miniature multi-property test system that can be used for this purpose - the ETMT.



Testpieces can be loaded monotonically in tension or compression or fatigue. The testpiece is heated using a computer controlled DC current. Resistance changes are used to calculate strain.

Resistivity of Nickel Based Superalloy



Bryan Roebuck, NPL