

Project objectives:

- 1- Identifying principles governing highly accurate and durable temperature measurement
- 2- Developing and testing mitigation strategies and production of design guidelines

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What was the challenge?

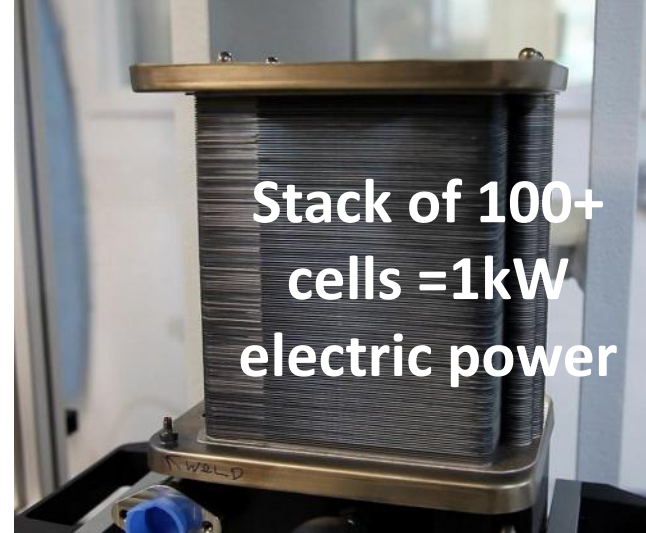
Accuracy of SOFC thermometry system plays an important role in achieving higher efficiency, better thermal management, longer product life and lower environmental impact. One challenge in developing low cost products was in understanding the principles governing accurate and durable temperature measurement which would allow them to achieve highly accurate temperature control. The KTP in thermometry aimed to measure temperature accurately and reliably at the required product cost point, inside the system.

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Ceres Steel Cell



We believe that the Steel Cell is one of the most cost effective and robust fuel cells ever developed.



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CeresPower

Ceres Power Holdings PLC is a world leading developer of low cost, next generation **fuel cell** technology.

Available thermometry systems

- Thermocouples (TC)
- Resistance thermometer
- Nuclear quadrupole
- Fiber optics system
- Photoluminescence thermometry
- Acoustic thermometry systems
- Radiative thermometry system
- Laser based

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Literature and patent review

As a **researcher** I did a thorough literature review to identify all the available thermometry systems regardless of their costs and limitations. Also learned about physics behind each systems.

As an **engineer** I reviewed various patents and learned how inventors tackled similar thermometry issues

As a **project manager** at this stage I used this information to scope the project and refine the deliverables. I did Customer and Stakeholder analyses to identify requirements and manage the stakeholder expectations.

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KTP Residential module

Attending KTP residential modules have improved my interpersonal skills and management skills. They have improved my business skills and enabled me to be a better leader. Moreover, I had a great time there and made many friends!

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Six Sigma training

What is Six Sigma: It is a disciplined, data-driven approach and methodology for eliminating defects in any process – from manufacturing to transactional and from product to service. This training helped me improve my engineering skills to improve products or process.

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Identifying variables

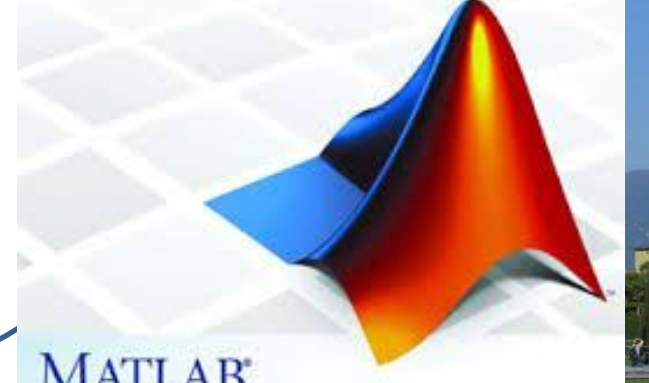
As a **researcher** I numerically solved a **mathematically model** of a thermocouple in a pipe to estimate possible errors.

As an **engineer** I used various **Six Sigma** tools to identify variable such as part-to-part variation, assembly tolerance, contamination, etc which researchers do not addressed in their papers.

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Conference in Pisa

I combined the modelling data and **Design of Experiment (DOE)** method to identify critical variables. DOE method helped me to identify the statistically significant variable that affected the thermometry system. I wrote a paper and presented in UIT Heat Transfer Conference in Pisa. Conference paper was published in Journal of Physics and can be accessed by scanning this QR:



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Critical variables

Six Sigma tools such as FMEA and Cause and Effect diagram helped me to identify variables affecting the systems in a complex systems. I managed to combining both modelling data and these methods to identify critical variables and reduce the number of test runs.

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KTP conference (2014)

Mathematical Model and numerical solution was presented at KTP conference in Brighton University.

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Design the test piece

After critical variables identified I designed a test piece to validate the modelling and FMEA results. During this task I have developed many essential engineering knowledge and project management skills which will help me to run engineering or research projects.

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Engineering skills

Improved my CAD skills by model the test piece. Learned how to design for different tolerances. Learned about various stainless steel properties and how to select them. **Cost Estimation technique** to estimate the build cost and time. Conducting Risk and COSHH assessment. Defining test requirements and selecting components to deliver the requirements. Liaising with manufacturing team to review the final design. Moreover, I liaised with test team to make sure the design will fit the test stand and test stand capable of delivering all test points.

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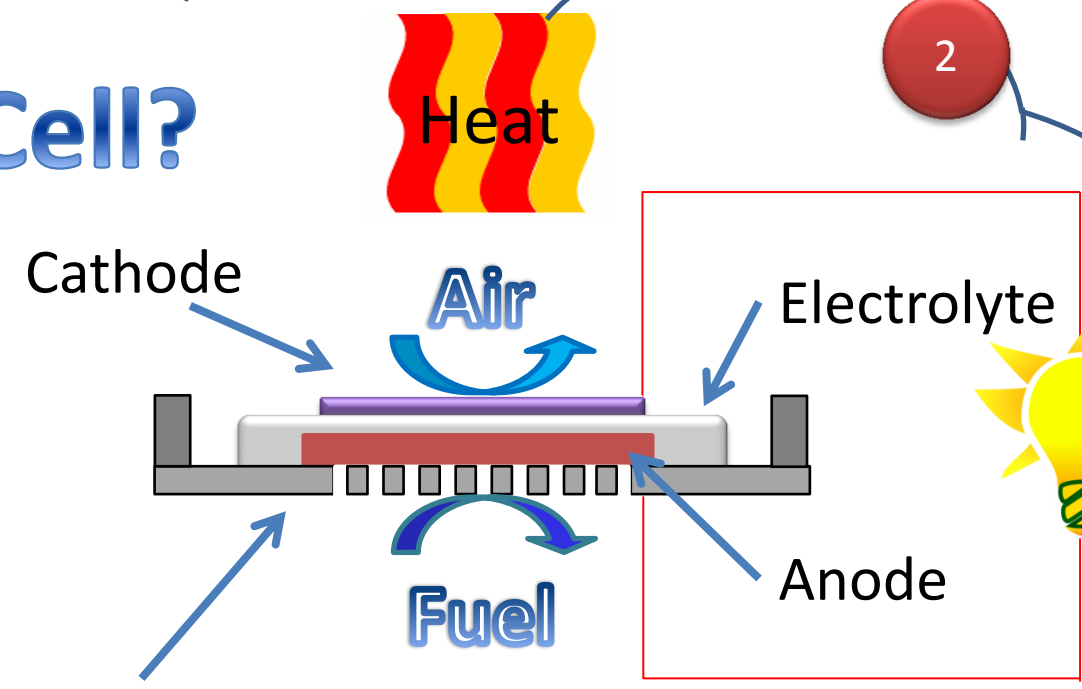
Attended **Introduction to Cost Estimation** training ran by IMechE

What is Fuel Cell?

A fuel cell is the most efficient way of converting fuel energy into electricity.

Fuel cells convert fuel and air directly into **power** and **heat** in a chemical reaction.

Stainless steel support



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Follow the numbers!

My KTP journey...

BEING A RESEARCHER ENGINEER AND PROJECT MANAGER

Developing mitigation method

After combining all the data one of the mitigation method was selected based on various factors. The mitigation method was analysed to evaluate its robustness. To do this I had to consider many factors such as system performance at the start of product life and after X years in service, how it performs at different environment or altitude, how about sub-systems interaction and many other possible scenarios which were predicted by FMEA analysis and team brainstorming. The selected method has passed the analysis and it will be tested on our latest product.

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Patenting the design

Following the success of this invention, we are on the process of having discussion with patent lawyers to patent the invention. It has been a great experience for me and I have learned patenting process.

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Disseminating the knowledge

I have delivered several presentations to our relevant colleagues about the project findings and best practice for accurate temperature measurement. I'm writing a detailed final report to document all findings. Alongside the final report I'm writing a design guidelines for our design and engineering team. I've also worked with our modelling team to add my model to our SOFC model to improve the modelling results

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Heat transfer conference 2015

accurately and reliably at the required product cost point, inside the system.

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KTP conference 2015

This poster will be presented at Glasgow 2015 KTP conference. It demonstrates the outcome of this successful KTP project for the KTP associates, Ceres Power and university of Brighton.

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Running tests and Analysing data

After running initial tests and tuned the controllers, 60 tests were conducted to study the variables, test the mitigation strategies and estimating tests errors and uncertainties. Each run had 24 temperature set points and five flow rates set point. Temperature was measured at 15 different locations. For each set point 600 data were logged. In other word I had to analysed **64,800,000 DATA!** In order to do this I wrote several Matlab codes to automatically analyse the data and generate graphs and required results. **Dr Robert Morgan**, my university supervisor, support and guidance were critical to delivering this task.

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Dr Robert Morgan, my university supervisor

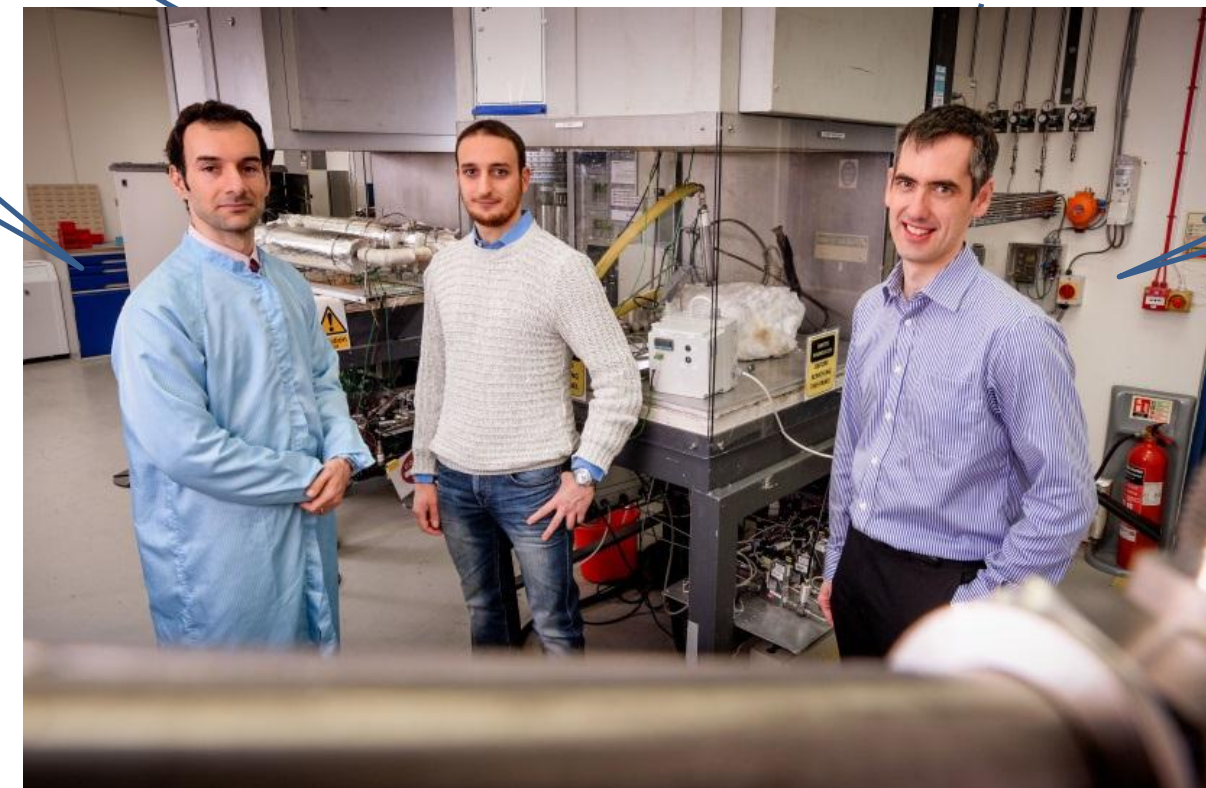


CFD modelling

Mr Elios Ferrauto, a master student from University of Naples, join the project and I supervised him to produce computer simulations through computational fluid dynamics modelling which extrapolate the test data across many more points than it is possible to physically test on the rig.

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Mr Paul Barnard my industry supervisor



NPL and UKAS seminar

I attend two days seminar about temperature measurement which greatly enhanced my thermometry knowledge. I was lucky to see the most accurate thermometer in the world and his designer Dr Michael de Podesta.

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Networking with NPL

After the seminar I and both my supervisors had a meeting with Dr Jonathan Pierce about thermocouple drift and how to minimise it. (Thermocouples operating at high temperature drift and reduce product efficiency)

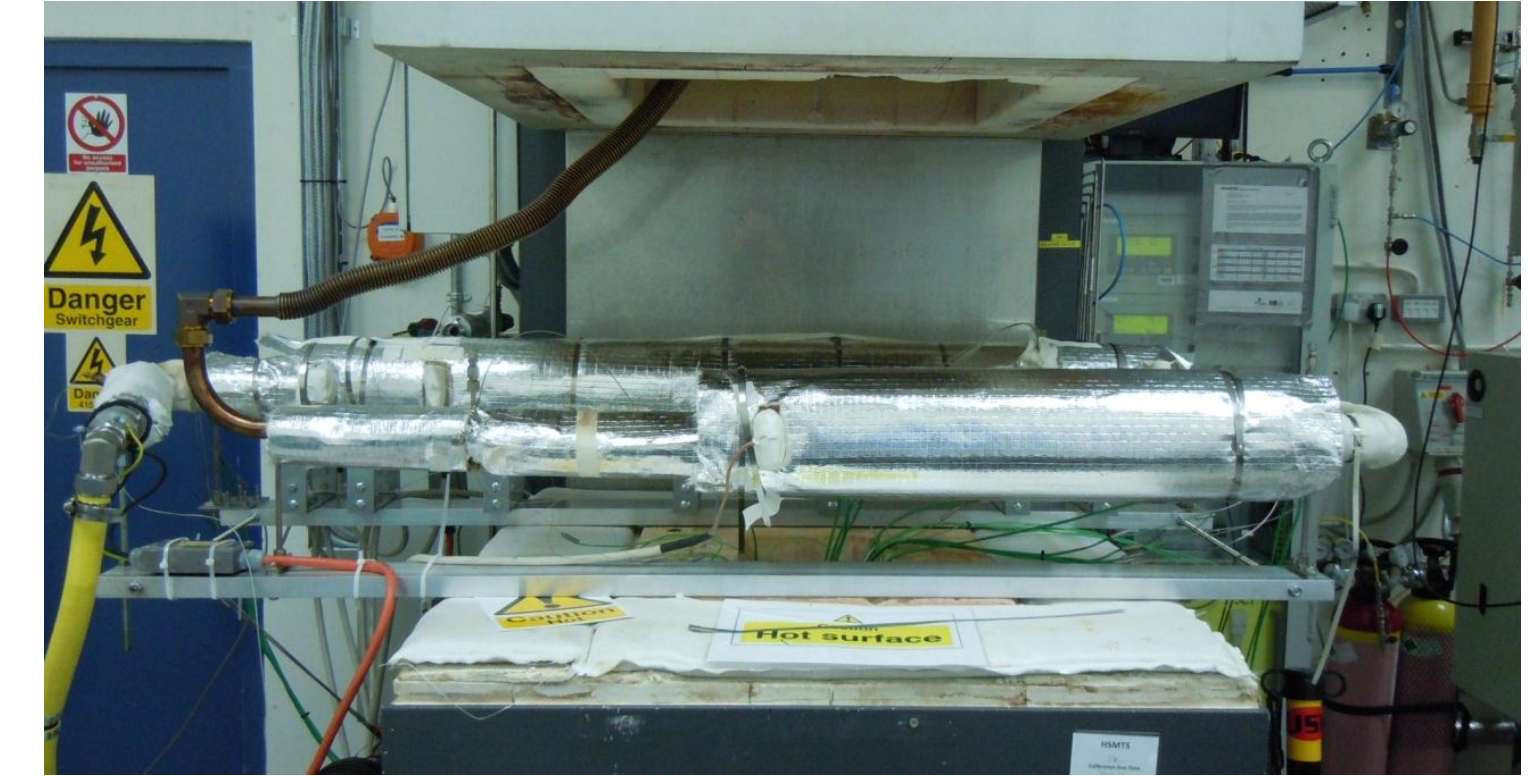
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Dr Michael de Podesta and world's most accurate thermometer. I



Test piece mounted on the test stand



University of Brighton

Innovate UK
Technology Strategy Board

Knowledge
Transfer
Partnerships