The Hy4Heat Programme

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Background

The Climate Change Act 2008 (the Act) established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below 1990 levels by 2050. Heating and cooling in the UK accounts for nearly one half of primary energy consumption and one third of carbon emissions. Over 80% of homes and business are currently supplied by gas and the UK has one of the most comprehensive gas networks in the world with 282,000km of gas pipes feeding 22.7 million homes and businesses. Achieving the UK's legally binding 2050 climate change targets is likely to require the almost complete decarbonisation of heat in domestic and non-domestic buildings. The most cost effective way to decarbonise buildings on the gas grid on the scale required to meet our 2050 targets has yet to be determined. At this stage, it is not clear which technologies are likely to work best at scale and offer the most cost-effective, long term answer. Crucially, the costs and the barriers to the development of all the heat decarbonisation options are uncertain. For all options, further work on evidence, cost reduction, policy development and innovation is required to help de-risk them.

The hydrogen approach

To be able to inform any future assessment of the feasibility of the costs and benefits of undertaking a hydrogen conversion, a full understanding of issues from end-to end (production to use) of the gas chain will be required.

The hydrogen gas chain can be split into the following stages:

- Production (including plant and CO2 off-take, CO2 sequestration and hydrogen storage).
- Transmission network (involving the pipework that transports the gas under a pressure of between 7 and 85 bar).
- Distribution network down to the end user’s gas meter (involving pipework that transports the gas under a pressure of up to 7 bar).
- End-use (i.e. downstream of the meter). This innovation programme seeks to demonstrate and de-risk the technologies downstream of the meter

Hy4Heat Programme

The Department for Business, Energy and Industrial Strategy (BEIS) has appointed Arup+, a group of companies led by Ove Arup Ltd, as the Programme Management Contractor (PMC) to manage and successfully deliver Hy4Heat.

Hy4Heat is a programme to demonstrate and de-risk the use of hydrogen for heating in GB homes and businesses.

The Hy4Heat programme's aim is:

- **To establish if it is technically possible and safe to replace methane with hydrogen in commercial and residential buildings and gas appliances.**

This will enable the Government to determine whether to proceed to a community trial. a programme to demonstrate and de-risk the use of hydrogen for heating in GB homes and businesses.

The Hy4Heat programme's overall objective is:

- **To provide the technical, performance, usability and safety evidence to de-risk the use of hydrogen for heat in buildings whilst working with others to prepare for a potential future occupied trial.**

The programme's focus is on researching, developing, testing and demonstrating within the end-use stage of the gas chain. This will involve the gas appliance and equipment sectors as well as consumer research.

Safety

There is a perception in the public that hydrogen is not a safe fuel and will cause more explosions and deaths. This could kill hydrogen for energy if this eroneous view of the safety of hydrogen is allowed to dominate the debate.

All the evidence is that this is unlikely and people are ignoring the great safety benefits of hydrogen in not generating CO, no matter how the burner is operated or badly operated or badly installed.

The are 10 times the number of deaths from CO poisoning from NG appliances in houses than there is from explosions (~1.5 per year on average). Thus lives will be saved in converting to hydrogen.

Hydrogen leaks at 3 times the volumetric flow rate of NG, but you need to leak 4 times as much to reach the most reactive concentration. Also hydrogen is very buoyant and is only a risk if the leak is confined, where it sits on the ceiling. NG also rises to the ceiling, but at a slower rate than hydrogen. For ignition at the ceiling the downward propagation limit is most relevant and that is 6% for NG and 10% for H_2.

The Hy4Heat programme is aiming to demonstrate:

- **That safe, reliable, efficient and affordable end-use appliances and equipment can be developed for the lower pressure, below seven bar domestic sector.**
- **That hydrogen can be safely distributed to the end user appliances in existing buildings' pipework, downstream of the meter.**
- **Initial findings of what the consumer experience of a hydrogen fuelled home will be. This includes testing through unoccupied trials appliance suitability, as well as developing requirements and options for progressing to a potential community trial.**

Hy4Heat Mission

Heidi Genoni: Hy4Heat Programme Manager WP2 Launch presentation 2018.

To establish if it is technically possible, safe and convenient to replace methane with hydrogen in residential and commercial buildings and gas appliances. This will enable the government to determine whether to proceed to a community trial.

Note that the aim is to replace natural gas (NG), not methane, with hydrogen and NG is of variable composition and hydrogen should be pure at ~99.9% (not now the case).

The hydrogen will be manufactured from NG using gasification with the CO_2 captured and stored in salt caverns, as detailed in the Leeds H21 project.

Hy4Heat is based on 100% hydrogen in the gas supply. Lower volume proportions are not sensible as the mass and energy content of the hydrogen is low. Several countries are looking at 20% hydrogen but it is pointless as the CO_2 reduction is too not sufficient for 2050 target.

Take MW NG as 18 and GCV 50 MJ/kg (justified in our WP4 app.)

MW H_2 as 2 and GCV 142 MJ/kg

NG % Vol	H_2 % Vol x	H_2 % mass	H_2 % Energy	CO_2 % reduction
90	10	1.2	3.4	3.4
80	20	2.7	7.3	7.3
50	50	10	24.0	24.0
30	70	20.6	42.4	42.4
10	90	50	74.0	74.0
2	98	84.5	93.9	93.9
0.1	99.9	99.1	99.7	99.7

$H_2 / (CH_4 + H_2) = x$ volume

$1 /(CH_4/H_2 + 1) = x$

$[CH_4/H_2]_{mass} = [(1-x)/x]\ 18/2$

$H_{2\ mass} = 1/[1 + (CH_4/H_2)_{mass}]$

$H_{2\ Energy} = 1/\{1+ [(CH_4/H_2)_{mass}\ 50/142\}$

Hydrogen mixed with NG is pointless as it is a small part of the energy until there is >50% hydrogen. For major CO_2 reductions 100% hydrogen is required

Hy4Heat Programme Work Packages

WP1 Programme & technical management – ARUP + KIWA +
WP2 Hydrogen quality / standard – DNVGL/IGEM/BSI
WP3 Hydrogen Appliance Certification – BSI – IGEM
WP4 Domestic appliances (Leeds U. part of 3 contracts)
WP5 Commercial appliances (Leeds U. bidder – Phase 2)
WP6 Industrial appliances (Leeds U. bidder – Phase 2)
WP7 Safety & risk assessments (Bids just closed – April 12th)
WP8 Demonstration trial
WP9 Community trial preparation
(Leeds city council should bid for this)

WP2 Hydrogen Gas Quality - Contracts start July 2018

- Developing gas standards
- Assessing hydrogen purity
- Testing gas odorants
- Reviewing colourisation options

Work Package 2 – Objectives

- Assess current gas standards and their suitability for use with H_2
- Develop a H_2 gas standard (new or adoption of an existing standard)
- Develop and update the relevant IGEM standards for use with H_2
- Develop robust evidence through research and testing
- Obtain IGEM committee approval for the updated standards
- Communicate to the gas industry prior to commencing the trial.

Work Package 2 – Output

- To enable installers (supported by Gas Safe) to construct and commission the pipe work and appliances required
- Support an unoccupied trial and/or demonstration zone
- Put procedures in place for a potential occupied trial

To produce a package of standards that provide a level of safety equivalent to that of natural gas.

Gas Quality Standards

Jeremy Few

Hy4Heat Work Package Lead

Work Package 2 – IGEM

- Hy4Heat recognises the key role that IGEM standards have in achieving safe working practices in the gas industry
- Hy4Heat will work with IGEM to extend existing documentation
- Especially relating to gas purity, odorisation & colorant
- In collaboration with industry, including, H21, H100, the HHIC, BS installation committees and EN mirror committees, to produce holistic safety equivalent to natural gas

It is likely that the same odorant as for NG will be used.

Colour is a potential problem, but we find H_2 flames can be visible and orange with the appropriate burner design.
The hy4heat programme assumed invisible flames – why? Lean premixed hydrogen flames are not very visible – but no need to used this type of burner design.

WP2 Procurement Lots

Lot 1 (£200K) Co-ordination and technical development of a hydrogen gas standard and IGEM gas standards. (IGEM/BSI have this contract) May 2019 end date.

To support, coordinate and complete the updates to the IGEM gas standards in relation to hydrogen required for the Hy4Heat programme

Lot 2 (£150K) Research and development of purity, odorant and colourant (DNVGL, NPL and U. Loughborough have this contract) March 2019 end

Undertake research and testing studies to determine the optimum solutions for the key elements that need to be confirmed (purity, colourant, odorant)

Lot 2

1. Document the hydrogen production methods and purity levels produced in the UK
2. Identify the type and quantity of impurities found in each method for each purity
3. Obtain data on the likely impurities that hydrogen will pick up through the gas network (methane and hydrogen)
4. The implications on the purity level recommended on all downstream applications
5. Recommend the optimum purity level for the industry to adopt
6. Feasibility of producing hydrogen that is suitably clean for fuel cells without clean up
7. A cost vs benefit analysis of the various hydrogen purity levels
8. The potential gas clean up technologies available to meet all end use requirements

At the WP2 bidders meeting in 2018 H_2 was expected to be 99.9% or close to this as the production methods produced H_2 of this quality.

I was at a BSI meeting on testing standards for gas fires for hydrogen on Tuesday 9th April 2019. Here a verbal report on the WP3 hydrogen gas purity standard was given. The recommended standard was 98% hydrogen by volume, with 2% other gases, which were mainly air.

I was not happy with this and said so in no uncertain terms as it changes the Wobbe number and no gas fuel should have air in it.

$Air/(Air + H_2)_{vol} = 0.02 = (A/H_2) / (1 + A/H_2)_{vol}$

$0.02 (1 + A/H_2) = A/H_2$

$0.02 + 0.02 A/H_2 = A/H_2$

$0.98 A/H_2 = 0.02$ so $A/H_2 = 0.0204_{vol} = 0.0204 \times 29/2 = 0.296_{mass}$

Thus each kg of fuel will only have 0.703 kg of hydrogen and the GCV is reduced from 142 MJ/kg to 99.8 MJ/kg and NCV from 120 to 84.4 MJ/kg. This is an unacceptable reduction in energy flow.

The following slides show that 2% air in hydrogen decreases the Wobbe number by about a factor of 2 so that dual fuel fires are not possible.

The consortia that Leeds is part is funded to develop dual fuel domestic fires, with the anticipation that the purity of hydrogen would be 99.9%.

This specification for hydrogen needs to be changed or the benefits are more difficult to achieve.

The UK Gov. Web site on calculating your gas bill says the UK GCV is from 38 – 41 MJ/Nm^3

National Grid say the allowable GCV range is 37.5 – 43.0 MJ/Nm^3

ISO 15971:2008 says GCV range for NG is 30 – 45 MJ/Nm^3

The Wobbe Index for hydrogen (GCV 12.02 MJ/m^3) is $12.02/(2/29)^{0.5}$ = $12.02 / (0.069)^{0.5}$ = 45.8 MJ/m^3 on a Gross CV basis.

This is very close to the value for methane at 47.1 and only 6.53% below the above design value of 49 MJ/m^3 for NG. So the two fuels are interchangeable.

The MW for hydrogen is 2

The MW for hydrogen with 2% air by volume is 0.704 x 2 + 0.296 x 29 = 1.408 + 8.584 = 9.992

The density of hydrogen at 15°C and a std atmosphere is 0.0845 kg/m^3

The density of hydrogen with 2% air by volume is 0.422 kg/m^3

The Wobbe index for hydrogen with 2% air by volume on a GCV basis is 20.48 MJ/m^3

This is NOT interchangeable with NG, whereas 99.9% hydrogen is interchangeable.

At the BSI meeting on NG Domestic Heater standards 9.4.19 I think Keith Crowther of KIWA said that the new hydrogen specification would reduce the Wobbe number to 41 MJ/m^3.

He also said that oxygen would be <0.2% which implies only 1% air in NG

Wobbe number in mass units is:

$CV\rho_f^{0.5}$ = constant = Wobbe Number for CV in MJ/kg

This give the Wobbe Number for hydrogen with density = 0.0831 kg/m^3 as 40.93 MJ/m^3

However, the Wobbe Number for hydrogen with 2% air is 20.48 MJ/m^3

The Wobbe Number for methane with density = 0.665 kg/m^3 is 44.84 and the ratio of methane to hydrogen Wobbe number is 1.0955 and these fuels can use the same burner.

The Wobbe number ratio of Methane to H_2 with 2%air by vol. is 2.19 – these fuel cannot use the same burner.

In mass units the CV gross ratio methane to hydrogen = 55/142 GCV ratio or 0.387 of the mass of methane for hydrogen to deliver the same energy. This ratio is 55/99.8 = 0.551 for H_2 with 2% air by volume.

Methane GCV = 55 MJ/kg, H_2 GCV = 142 MJ/kg ratio= 2.58 (Inv. 0.388)

For NG GCV ~ 50 MJ/kg and H_2/NG ratio is 2.84 (inverse 0.352)

The density ratio of hydrogen to methane = 2/16 = 1/8 = 0.125

Wobbe number ratio for the same energy delivered = methane/hydrogen = 0.388 x $8^{0.5}$= 1.097

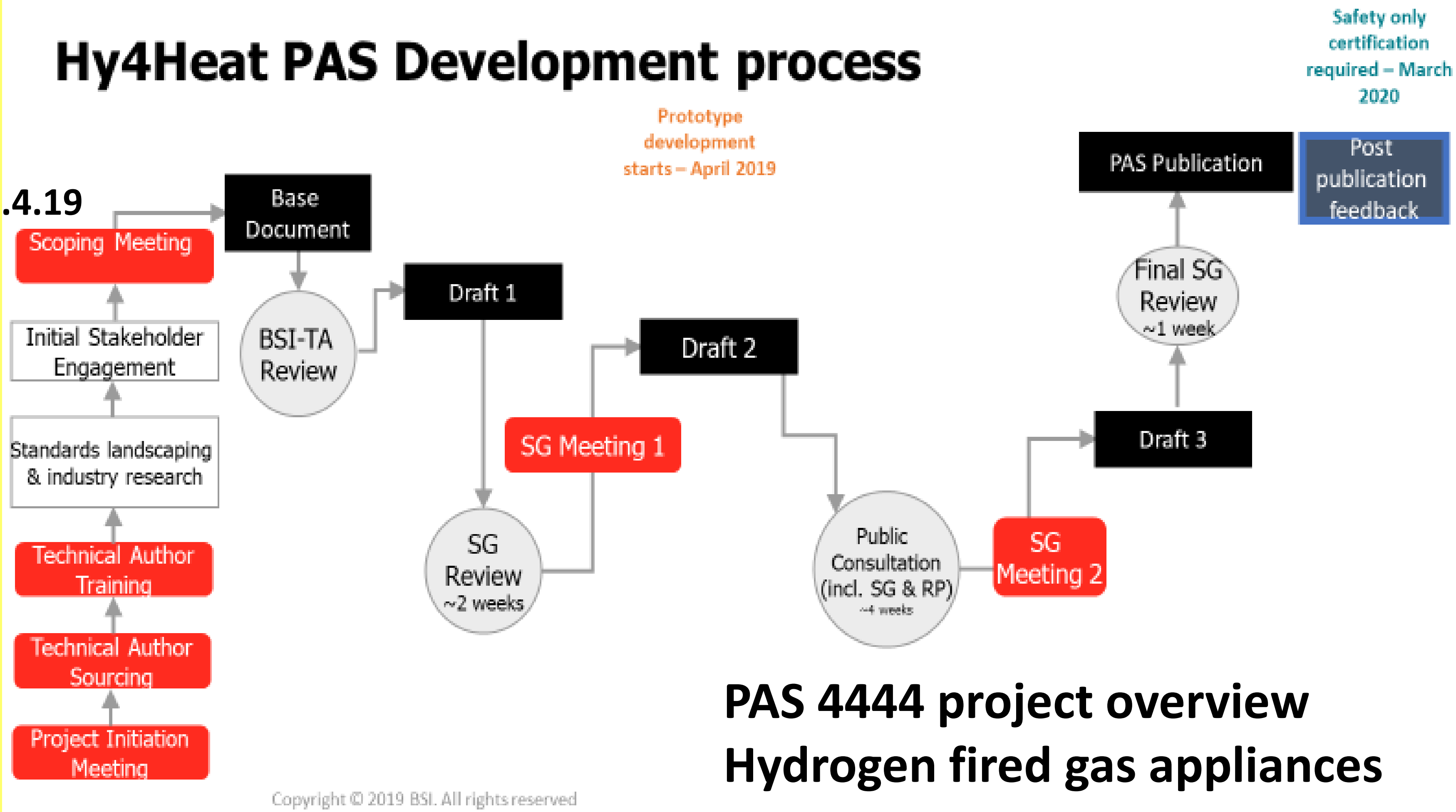
Thus in mass units for the same energy delivered methane requires 9.7% more mass flow than hydrogen. But for NG the CV is lower (50) and the MW higher (18) The GCV ratio is 0.333 and energy flow ratio is 0.333 x $(18/2)^{0.5}$= 0.999 or the same mass flow rate.

For hydrogen with 2% air by volume the GCV is 99.8 MJ/kg and the NG to hydrogen (2% air) ratio is 50/99.8 = 0.501 and the energy flow ratio is 0.501 x $(18/9.92)^{0.5}$ = 0.675 or nearly 1/3 less energy flow.

For pure hydrogen dual fuel is possible with NG, with no burner change. If there is 2% air by vol, in H_2 this is not possible. We are funded to develop dual fuel burners and there was a BEIS call for dual fuel burners. This fuel spec. prevents this happening.

WP3 Hydrogen appliance certification

9.4.19



PAS 4444 project overview
Hydrogen fired gas appliances

Aim

The PAS 4444 to be used primarily on the Hy4Heat programme, but the aim is that it can form the basis for wide-scale standardization of hydrogen-fuelled appliances.

The PAS will be providing principles to be followed by appliance manufacturers regarding functionality safety, installation, operating and servicing requirements for their hydrogen-fuelled and hydrogen/natural gas dual-fuelled or converted appliances, including: boilers; cookers; fires.

Once published, the PAS will made available on a dedicated online platform for a period of 6 months to facilitate continuous feedback on how the PAS is being implemented and therefore inform update options.

Draft Scope of PAS 4444

This PAS 4444 gives guidance on the development and construction of hydrogen-fired gas appliances which are either purpose-built to use hydrogen or might be converted to use hydrogen in the future.

Including thermal efficiency

The PAS covers the functional specification of the appliance, including specific advice on the demonstration of safety including worst case conditions to stress the appliance in excess of that it is likely to experience in normal service. It also covers the setting of limit (upper and lower) hydrogen supply pressures and limit voltages. It discusses the possible arrangement of fittings and devices that might help demonstrate compliance with the Gas Appliance Regulations.

The PAS also covers tests that manufacturers should consider adopting regarding both delayed ignition and unintended ignition of gas within the case of the appliance and/or its flue.

It also covers advice on manufacturer's instructions regarding installation of such appliances (including fluing) and their servicing requirements.

The PAS generally assumes that any default performance requirements (for example noise or pressure rating) align with those of an equivalent 2nd family gas appliance unless specifically stated otherwise.

This PAS is for use by the manufacturers of hydrogen fired gas appliances within the scope of the Gas Appliance Regulations and to manufacturers of conventional 2nd family gas appliances that might be converted to hydrogen at some date in the future.

The PAS is also of use to Notified Bodies.

WP4 Domestic appliances (Leeds U. part of 3 contracts)

Domestic Hydrogen Appliance Development Innovation SBRI Competition (Hy4Heat Work Package 4)

Appliance	Appliance Type	Target funds	Phase 2a %	Phse 2b %
Boiler	Combination	£720,000	75%	25%
Boiler	Regular/system	£720,000	75%	25%
Cooker	Stand alone hob	£170,000	75%	25%
Cooker	Stand alone cooker and grill	£270,000	75%	25%
Cooker	Integrated Free Standing cooker	£370,000	75%	25%
Fire	Open (Flue)	£370,000	75%	25%
Fire	Glass fronted Balanced flue	£370,000	75%	25%
Fire	Innovative	£370,000	75%	25%

Phase 1 – Solution design for a domestic hydrogen appliance. A maximum of £960k will be available in total for Phase 1 solution designs, up to a value of £30k per project. BEIS will be looking for a portfolio of appliance types and diversity of suppliers to support and encourage innovation. (Completed)

Phase 2a – Development of a first prototype (1.0) to be provided for demonstration trials. A maximum of £6.0m will be available in total for Phase 2a in accordance with the breakdown of target funds per project shown in the table below. (Awards announced and Contracts due) – Leeds University is in a funded consortia for all 3 fires.

Phase 2b – Further prototype development (2.0) and full certification. A maximum of £2m will be available in total for Phase 2b projects in accordance with the breakdown of target funds per project shown in the table below.

It is anticipated that between two and five projects per appliance type will be selected for Phase 1 and that two to three projects per appliance type will be selected to deliver Phases 2a and 2b. The number of projects funded will be dependent on the quality of applications and funding available within the value of the competition.

The Challenge

The aim of the Competition is to develop 'like for like' 3 appliances which can demonstrate the safe use of hydrogen as a fuel to meet domestic heat requirements.

Objectives The objectives of the Competition are to:

1. **Deliver prototype appliances which can demonstrate safe use of hydrogen as a fuel in providing domestic heating, hot water and cooking requirements;**
2. **Contribute to positive stakeholder engagement through use of the prototype appliances in unoccupied demonstrations;**
3. **Understand, and where feasible address, the challenges and risks associated with progressing the appliances to a volume manufacturing stage;**
4. **Understand the challenges and potential solutions for a transition to hydrogen, including products that simplify the switch-over process (e.g. 'dual fuel', 'hydrogen ready' or 'adaptable').**

The Leeds University Consortia for WP4 - Fires

Open Fires (Flued) – Clean Burner Systems (CBS) plc
(Jim Maxfield) – Consortia Lead
- Birmingham Burners (Chris McGlone)
- Focal Point Fires (Reference Fire)
- Leeds U. Team: Prof. Andrews, Prof. Tomlin, Dr. Dupont and Dr. Phylaktou

Glass Fronted Fires

Balanced Flue – As above but NOT Focal Point
- Legend Fires (Blackburn) Ref. Fire

Innovative Fires (Fan air supply in the Leeds design) – As above + extra Leeds U. staff:
Dr. Milne (Ceramic fibres) and
Dr. Taylor (Textile Design)
Legend Fires will provide the base enclosure

The Leeds University Consortia for WP4 - Fires

The technical design of the dual fuel burners for hydrogen and NG are the responsibility of the University of Leeds team. For the innovative fire several new burner design concepts are being investigated, including a fire compartment with heat transfer to give convective as well as radiant heat and to produce a condensing fire with the highest thermal efficiency on the market and lowest NO_x.

Clean Burner Systems (CBS) will mass produce the burners.

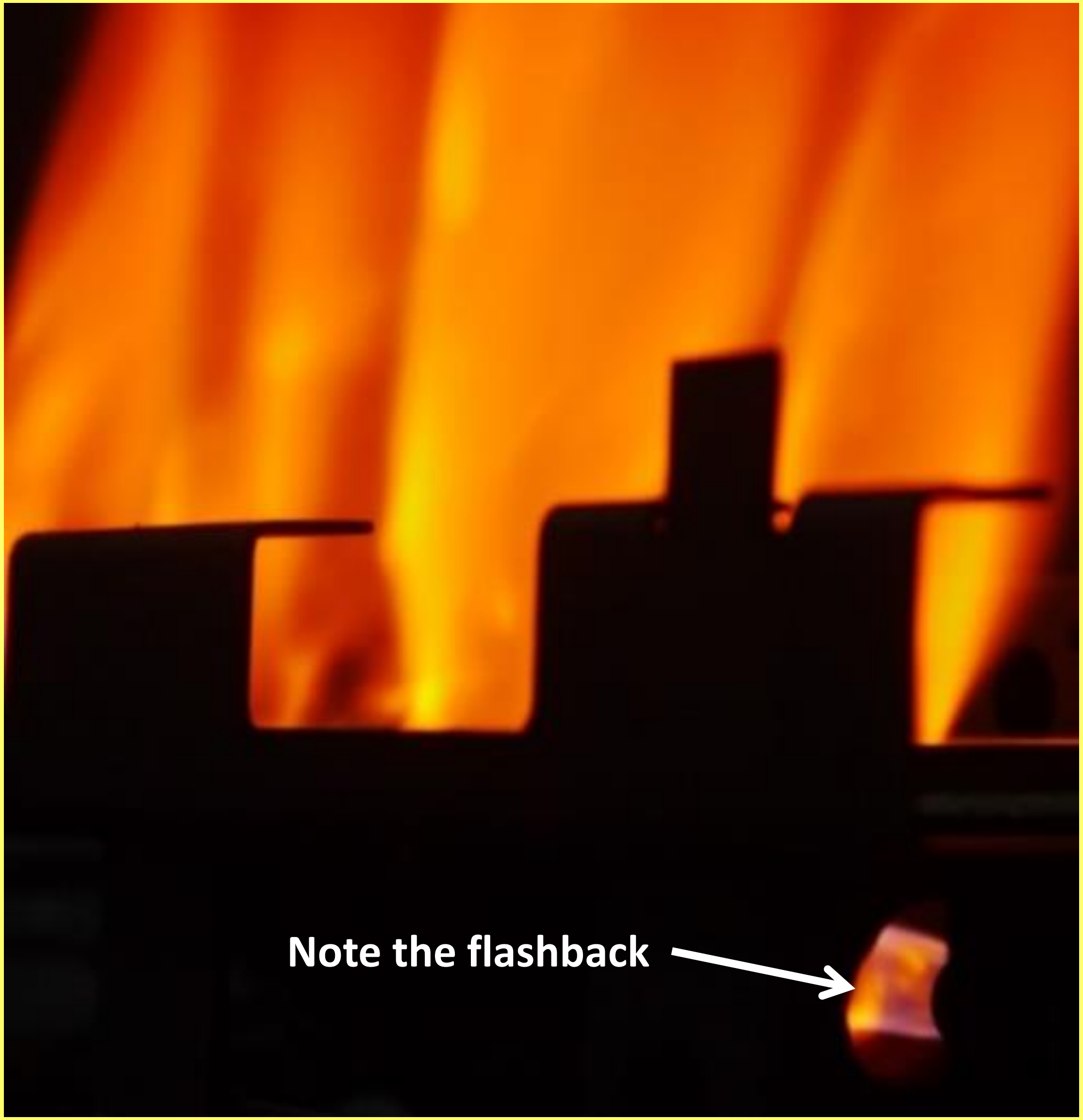
Birmingham Burners is the location for all the initial hydrogen and NG burner tests. They will also manufacturer all the prototype burner designs.

A laboratory for fire testing with full emissions measurement is being built at Leeds University as part of this work.

The companies providing the reference fires will build the final fires for product testing.

Standard Open Coal Effect Fire

Hydrogen Burner Design 2 on NG (left) and H_2 (right 2)
One of our new burner desings operated on NG and hydrogen.
Hydrogen burners can be designed to have colour.
Also with coal effect fires the flames heat the coals and these glow red hot and are visible.



The Reference Fire on hydrogen with no change in burner.
Note the flame has flashbacked to the metering hole.
Coals not in place.
Note also the strong orange colour.
There is no need for flame colour additives.
You just need a burner designed to give flame colour from its structure.

Glass Fronted Balance Flue Fires

NG fire at Legend Fires

Hydrogen fire for design 1.

The hydrogen burner can be used with NG with a good flame Appearance. Note that the hydrogen flame is visible.

Innovative Fires

Leeds University suggested that 'coal' and 'log' effect fires were old hat and new attractive flame designs were required as shown in the following slides for various burner design concepts.

A 7 jet 7 kW burner on hydrogen
Note that there is no problem with 'invisible flames'

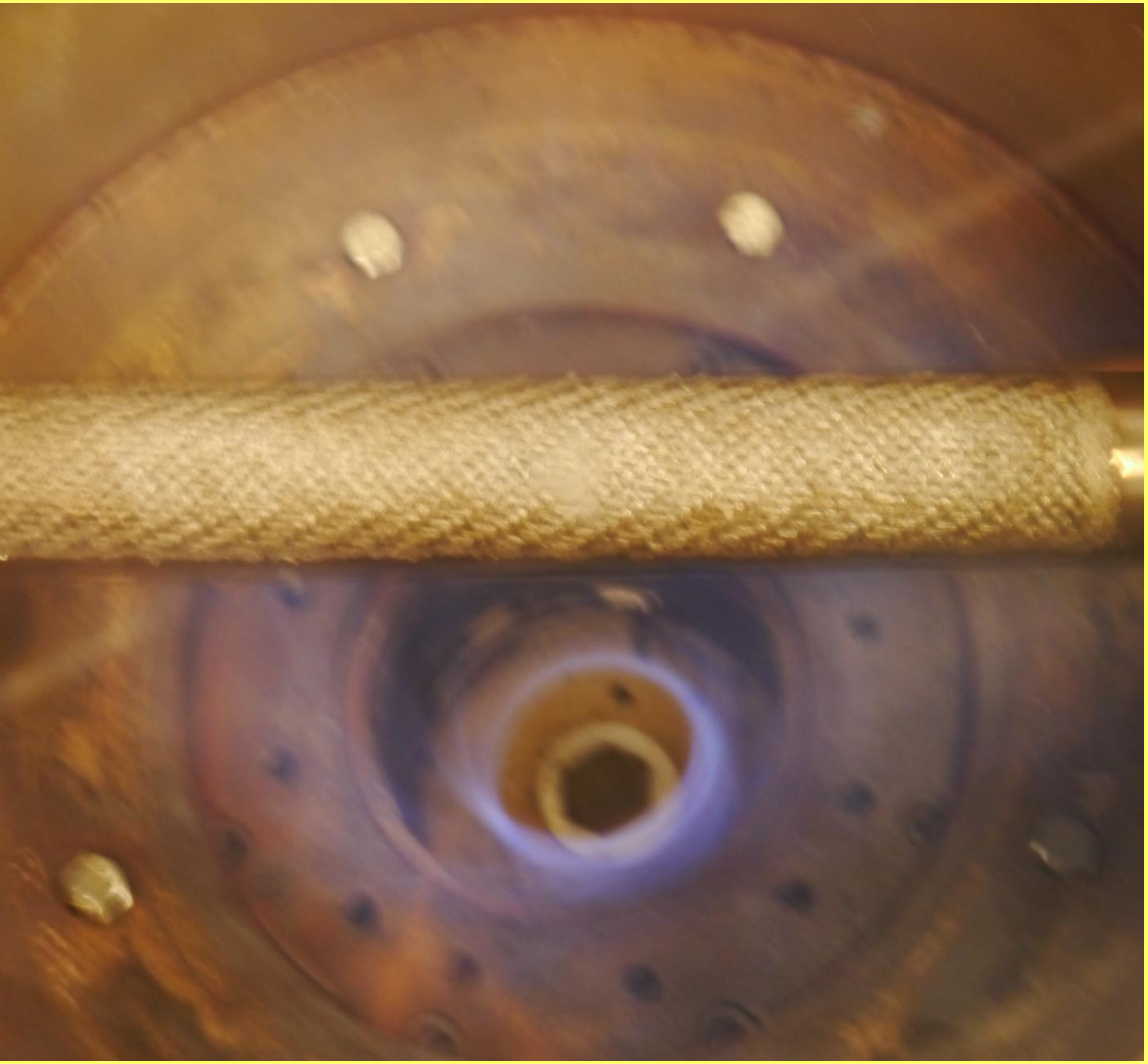
A 4 jet 4 kW burner on H_2

A baffle mixing hydrogen flame – 7 kW
Note the strong orange colour

Use of a porous metal flame impinger to give a good visual effect.

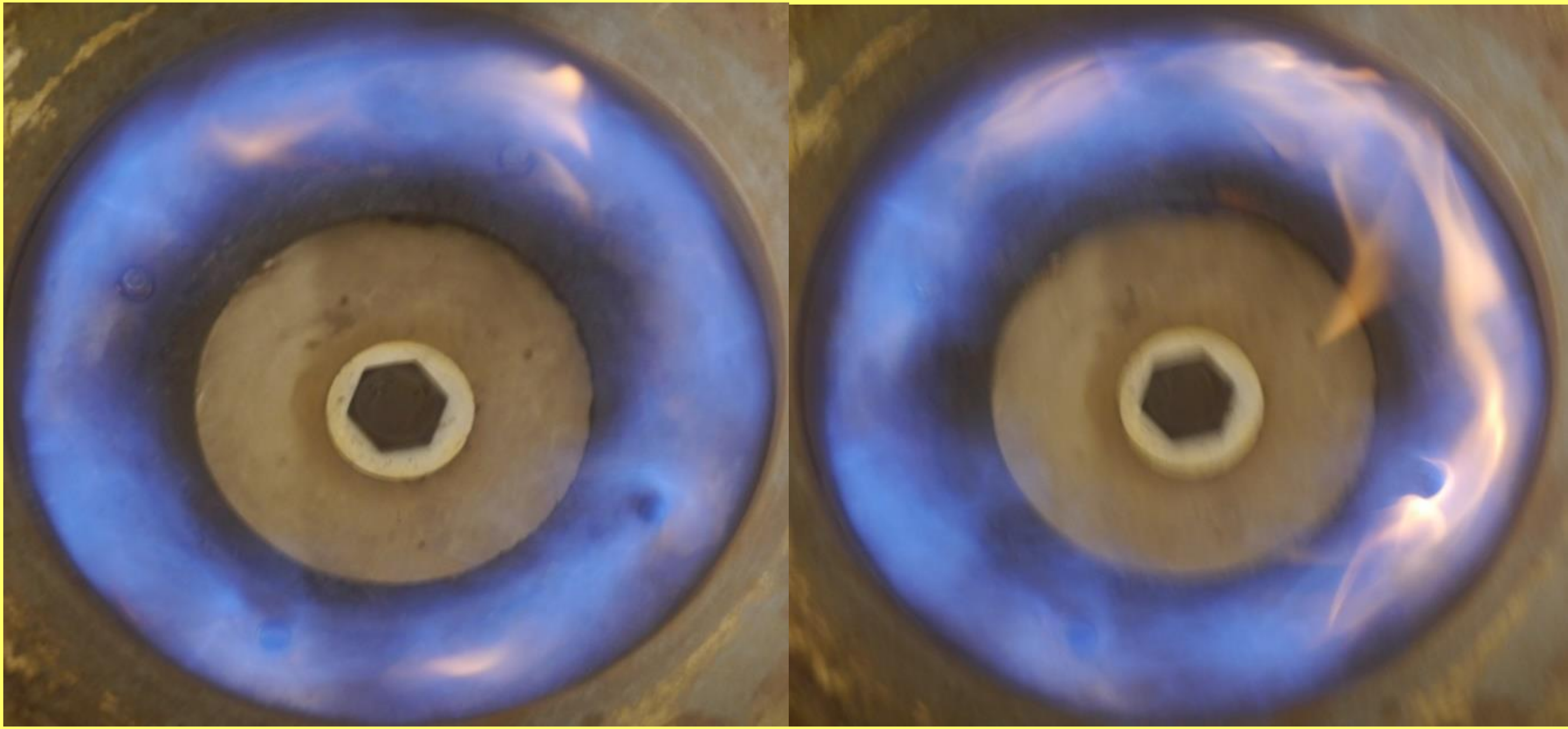
4 kW hydrogen flame against a ceramic wall.
Left – Flames fired up a ceramic wall: left injection between the real air jets and right in line with the rear air jets.
The offset position on the left gives very interesting flames that are fascinating to look at.

Porous metal flame burner on hydrogen (left) and NG (right) – 7kW The NG flame although attractive to look at would have a soot and NO_x problem, but the hydrogen flame looks good. This is an example where the performance on NG leads to a reject of the design.



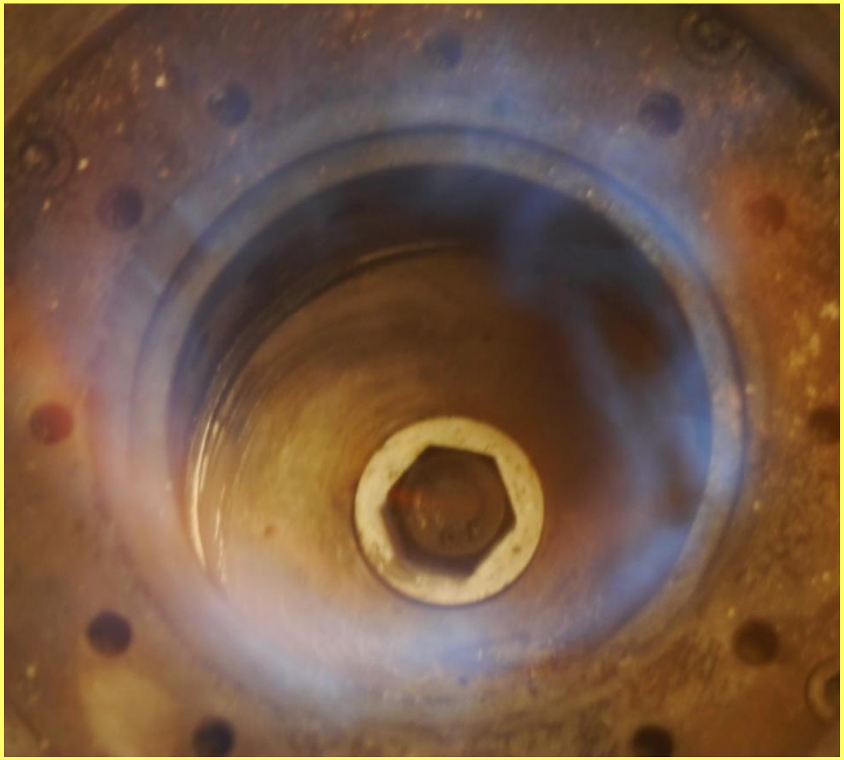
The same porous burner operated on NG with an air flow, has no flame Luminosity and a well mixing blue flame.

Operation at 10% excess air with 7kW thermal input.



Rapid mixing burner on NG with 60% excess air (left) and on hydrogen (right) 7 kW fuel input and the same air flow. Both flames are blue from OH radiation Some orange flickers in the hydrogen flame and yellow in the NG flame

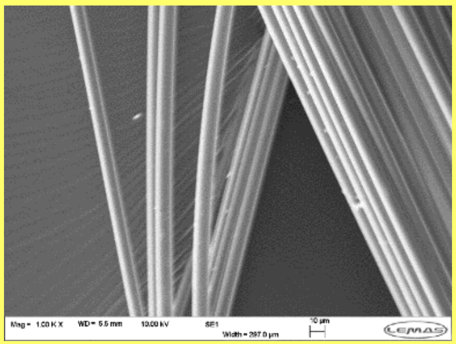
An alternative design of the rapid mixing burner on NG(left) and hydrogen (right). The hydrogen flame is nearly invisible.

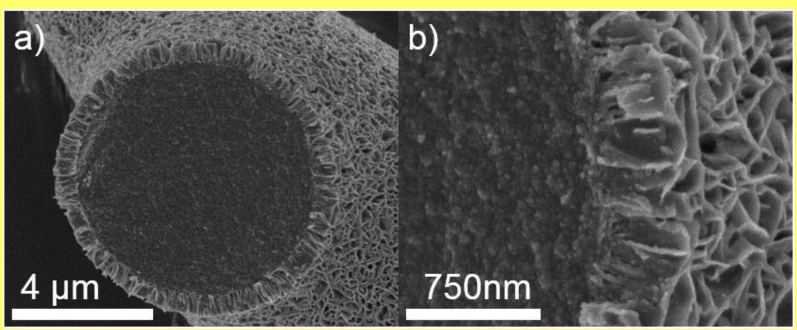


BB, 15.4.19, 15.13
7 kW NG
Ø ~ 1   941K exit Temp.

BB, 15.4.19, 15.41
7 kW H_2 Ø = 0.44
Near Invisible flame
839K exit temperature

Innovative Fires

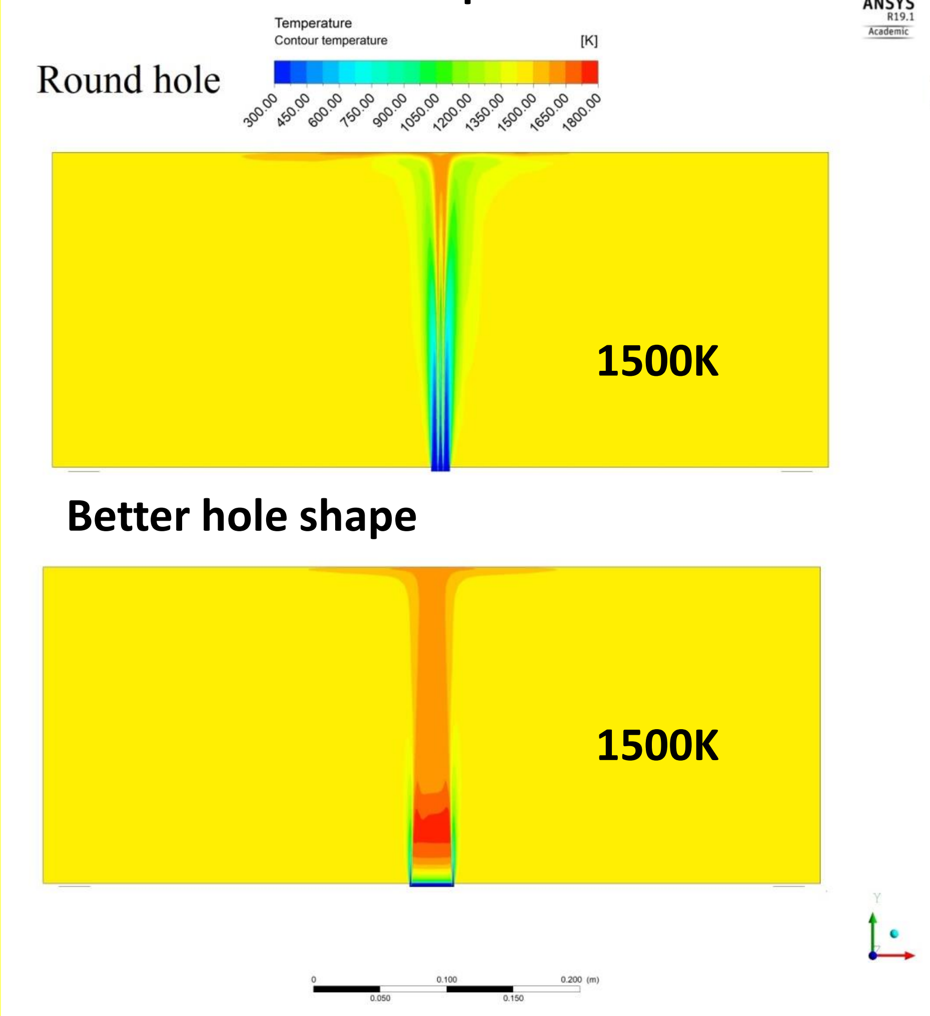


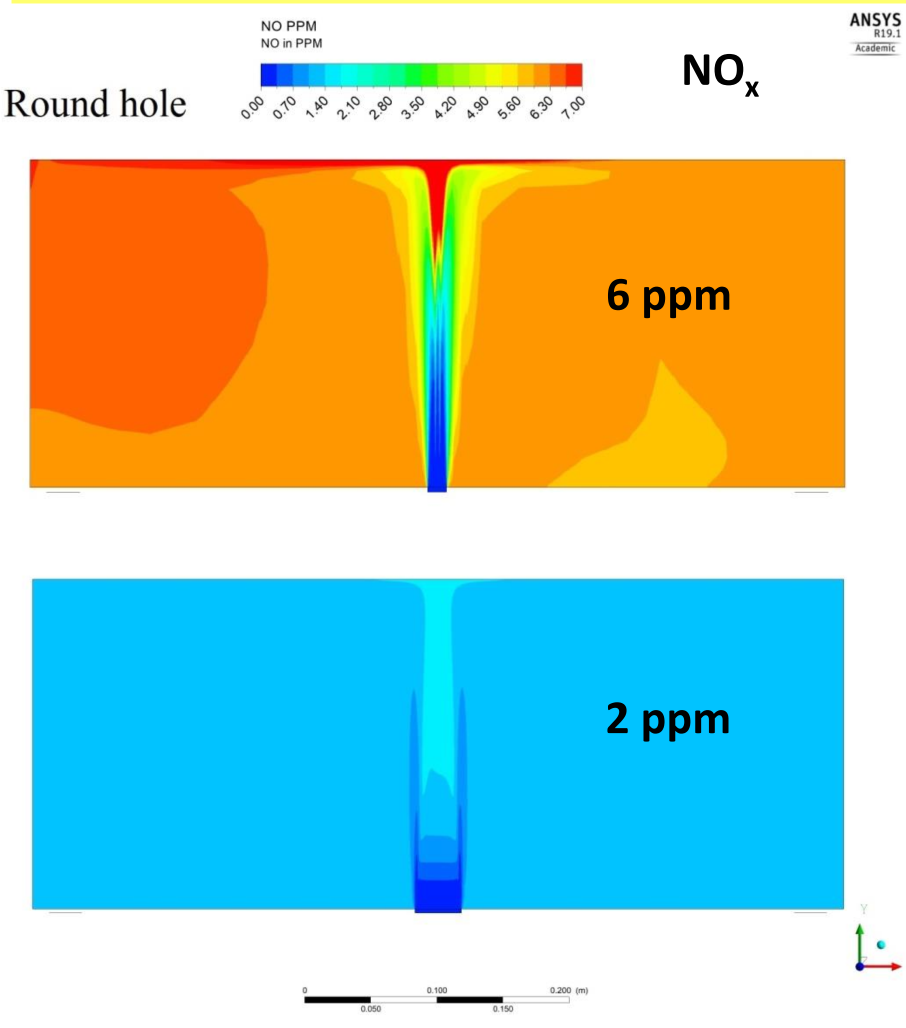


This shows the type of high end 3D-woven inserts we plan to secure by the burner ports to increase hydrogen flame radiance if needed, while also lowering flame temperature and hence reducing NOx further. 3D weaving requires threaded material, and threaded ceramics such as basalt (see above image) are currently commercially available in bobbins, enabling their mounting in the computer controlled 3D weaver housed at the unique 3D Weaving Innovation Centre at UoL (Taylor).

CFD work of some innovative burner designs. *Ramon Quinonez*

Flame Temperature





WP5 Commercial appliances (Leeds U. bidder – Lot 2)

BEIS intends to appoint a contractor(s) to deliver comprehensive research reports:

Lot 1 On the feasibility of converting commercial sector appliances.

Lot 2 Industrial heat generation (Lot 2) from natural gas to hydrogen (this is still to be awarded).

Lot 1 will require full characterisation of the market and identification of any knowledge gaps and barriers to conversion that may need to be addressed. They will inform consideration of whether further evidence, potentially in the form of practical testing, will be required to demonstrate that these sectors can be successfully converted as part of demonstrating and de-risking the use of hydrogen for heat in UK homes and businesses. This work is part of the Hy4Heat programme and will be managed and coordinated by Arup+, who have been appointed by BEIS as the programme management contractor for the Hy4Heat programme.

Estimated total value

Value excluding VAT: 380 000 GBP

Lot 1 was awarded to Element Energy, who are responsible for the hydrogen supply to the fuel cell buses of TfL. They know very little about burner design and cannot undertake Lot 2, which we hope to get. We were the next best bidders for Lot 1 and Lot 2

For Work Package (WP) 5, the focus is to:

1. understand the range of combustion equipment installed
2. estimate the overall installed market of this combustion equipment
3. identify the potential for conversion or retro-fit to enable hydrogen to be used rather than natural gas
4. identify barriers that might impact on any conversion potential
5. highlight future research and development that may be required to extend the opportunities for hydrogen in the commercial market sector

To enable BEIS to make judgements about the low-carbon heat requirement in the future, information on the applicability of hydrogen is required for the commercial market sector covering applications associated with:

space heating of buildings

heating of water (including sanitary uses and swimming pools)

catering

The range, type, scale and application of combustion systems in the commercial market sector is diverse, with some appliances resembling larger versions of domestic appliances whereas others are bespoke designs, such as those in some catering applications or large laundries.

Recognising this diversity, it is essential to contact equipment suppliers and end-users to understand the installed base of equipment, then follow this up through detailed technical evaluation to characterise the potential for hydrogen conversion or replacement options. In this way, the project will develop detailed, quantifiable, robust and defendable information on the commercial market sector to determine if it is theoretically possible to successfully convert this market sector to hydrogen.

WP6 Understanding industrial appliances for UK hydrogen for heat demonstration

Environment Resources Management submitted a proposal that was deemed to be the most economically advantageous bid overall.
We were the second best proposal.

For Work Package (WP) 6, the focus is to:

1. **understand the range of combustion equipment installed in the industrial sector**
2. **estimate the overall installed market of this combustion equipment**
3. **identify the potential for conversion or retro-fit to enable hydrogen to replace natural gas**
4. **identify the wider aspects (process atmospheres, heat transfer to stock, product finishing, product quality) relating to different industrial processes**
5. **identify barriers that might impact on any conversion opportunities**
6. **evaluate potential timescales for conversion and hydrogen utilisation**
7. **document knowledge gaps and highlight any bottlenecks that might arise with any hydrogen conversion activities**
8. **highlight future research and development that may be required to extend the opportunities for hydrogen in the industrial market sector**

WP6 Understanding industrial appliances for UK hydrogen for heat demonstration

To enable BEIS to make judgements about the low-carbon heat requirement in the future, information on the applicability of hydrogen is required for the industrial market sector covering applications associated with:

1. high temperature heating processes (for example metals, ceramics, glass)

2. medium temperature process heaters (for example petrochemicals)

3. steam boilers (cross sectoral coverage)

4. hot water boilers (cross sectoral coverage)

5. low temperature process heaters (for example drying, baking, curing)

This is the market that CBS and BB sell burners – most disappointed not to get this contract.

It appears that like the Ferry company that got a Brexit Ferry Contract even though they have no ferries, it seems that WP 5 and 6 can be done by companies that do not make burners and no member of their team makes burners.

It is our understanding that both WP 5 and 6 will have a future call for practical work to develop burners for hydrogen for this market.

I understand that this call is imminent and our consortia will be bidding for this.

It is also our understanding that in WP5 there was no bidder for the domestic cooker project and the one bidder for Phase 1 got funded for a market survey. They are not capable of developing burners for hydrogen.

This domestic cooker project will be combined with the commercial cooker project and we intend to bid for this.

Overall the feedback we have from BEIS indicates that they had hoped for more bidders, especially from elsewhere in Europe. But no European burner company bid for the contracts.

The Hy4Heat programme has been delayed and is behind schedule, it is a lot of work to do in a short time.

The End

Any questions?