THyGA

Testing **Hy**drogen admixture for **G**as **A**pplications

Questions & Answers from the Webinar "Impact of hydrogen admixture on combustion processes –Part I: Theory"

30th of October 2020, 10-12 am

Organisation	WP2, GWI
Host of the day and speakers	Jörg Leicher & Johannes Schaffert, GWI Stéphane Carpentier, ENGIE Maximilien Merieux, GERG
Notes	Jörg Leicher & Stéphane Carpentier
ID	THY_WP2_023_Q&A Webinar Combustion

The THyGA project has received funding from the Fuel Cells and Hydrogen Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

1. Questions answered during the webinar

[10:27] Salvador Ochoa (BSH)
Were relative density and GCV change % interchanged in the graph explanation?
[10:28] Brown, Martin John
Yes, they were - but the changes are correct
Jörg Leicher: Sorry about that, I fixed it for the upload version of the slides.

[10:56] Salati, Eugenio
Hasn't Methane gas an LEL of 4.4%, not 5%?
[10:58] CARPENTIER Stephane (ENGIE SA)
according to ISO/IEC 80079-20-1:2017, it is 4.4%. but I have seen 5% elsewhere (however, I don't have the reference at hand)
[10:59] Garry-Madden, Mark [COMRES/TOD/WIG]
ISO sets it at 5%
[11:29] DUBOST Jacques (ENGIE SA)
LFL of methane is given as:

- 4,4 % in IEC 6007920-1:2010 'Explosive atmospheres – Part 20-1: Material characteristics for gas and vapor classification – Test methods and data' (cancelled in 2017, while still valid as EN 60079-20-1:2010)
- and as 5 % in ISO 10156:2017 'Gas cylinders — Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets.

[11:35] Dave Lander
Google: " The limiting oxygen concentration and flammability limits of gases and gas mixtures by Isaac A. Zlochower" for a good discussion of differences between US and Europe in LFL/UFL
In ISO 10156:2017 standard, the lower inflammability limit of CH4 in air is 4.4% (not 5%), as in IEC 6007920-1:2010. The 5%-15% flammability limits interval probably originates from the USA standards ASTM E 681 and E 918. However, I do not have access to these standards to check the values.,
Anyway, it should be reminded that flammability limits are strongly dependent on the experimental setup and test conditions used. As an example of the diversity of values, you can have a look to the values listed in the publication of Miao & al. (https://doi.org/10.1016/j.ijhydene.2011.02.126).

[11:12] Hössel, Markus
will the function of the control systems in the further project be estimated?
[11:13] CARPENTIER Stephane (ENGIE SA)
Yes, we will test boilers with combustion control

2. Other questions

[10:44] Essen, Martijn van
Are you going to compare the different methane number methods?
[10:44] Patrick Milin
no, sorry, we don't focus much more on methane number in the rest of the presentation
[10:46] Essen, Martijn van
Ah ok, but in the project, you will use the MWM (EN 16723) method? If needed I can provide you with the PKI MN method for comparison
Jörg Leicher: In the project, we will be working with well-defined test gases, so the value of the MN does not matter that much for us, since we prescribe the actual composition of the fuel gases. The different ways how MN can be calculated is out of the scope of this project.

[11:17] Mário Paulo Ribeiro
1- How can it be guaranteed that the percentage of mixture of gas + H2 is maintained all over the distribution system or at least without significant changes. Is the process of mixing H2 with gas reliable?
[11:19] Jean Schweitzer
In principle where there is injection; the % of H2 will vary from 0 to max allowed; depending of H2 production capacity.
Jörg Leicher: constant H2 concentrations probably cannot be guaranteed, especially if there is a significant deployment of PtG units to convert renewable electricity. But even if there was a constant H2 concentration, the impact on a specific combustion process is also dependent on the composition of the natural gas that H2 is admixed to 20 vol.-% H2 in Russian H-gas may very well have a different effect than 20 % H2 in North Sea H or a LNG.

2- What are the best mixing systems?
[11:19] Maurizio Beghi
Mixture speed and flame speed at burner ports are the critical factors and burners - as you said - are designed for best performance with a given set of gases and flow rates. The fixed geometry of the burner system (injector/venturi and flame port design) is the main limiting factor for the resilience of burners to high % in gas change. With high H2 injection, we are asking the burner to be more flexible where actually it cannot: its geometry.
Jörg Leicher: I agree with Maurizio's explanations. Nevertheless, burners in residential systems are designed for operation with rather high air excess ratios (compared to industrial burners, for example), which gives them a safety margin. But we need to keep in mind in this discussion that a) H2 is a very different fuel from natural gas and b) all the systems in the field were never designed with hydrogen in mind. This is why the THyGA project is so important.

[11:23] Enzo Alfonsetti (Guest)
Will the shortening of the flame due to increased H2 at some point result in higher levels of CO as the flame sits closer to the burner head and is quenched?
[11:26] CARPENTIER Stephane (ENGIE SA)
From what I have read in the literature, adding H2 tends to decrease CO levels on domestic appliances
Jörg Leicher: I agree with Stéphane, usually H2 admixture should lead to lower CO levels (as long as you run with a reasonable lambda). Quenching should, in my opinion, not be a concern. What

could happen is that due to H2 admixture, the stoichiometry of the combustion process shifts too far into the super-stoichiometric regime, resulting in an unstable flame, and hence, increased CO formation. This would be very much dependent on the actual burner and is something that we will have to look for in the experiments.

[11:28] Enzo Alfonsetti (Guest)
Yes, Stephane I agree however is there a critical point at which the CO can increase?
[11:30] CARPENTIER Stephane (ENGIE SA)
Enzo: if the flame is closer to the burner, the burner surface temperature will also increase (thus reducing quenching of the flame), but only test results of the THyGA project will enable us to check that.
Jörg Leicher: CO oxidation requires temperatures of 600 °C or higher. I doubt that increased heat transfer into the burner will lower local temperatures this much. Local overheating of the burner might be a more serious concern here. But we will see what the experiments say.

[11:25] Miklós Ferenc Fazakas
What happens to NOx if the power of the appliance is kept constant?
[11:48] N. MOSTEFAOUI (CETIAT)
The reduction of NO is caused by the double impact of increase of lambda and the reduction of the heat input when adding H2 (decrease of flame temperature). Also, the reduction of NO produced by the prompt process in the flame front due to the reduction of CH radicals
Jörg Leicher: I'd expect NOx emissions to go up with higher levels of hydrogen if the firing rate is increased (provided lambda stays constant). Hydrogen admixture leads to higher combustion temperatures and hence stronger NOx formation as long as lambda remains constant. If lambda can change, then it depends whether the burner is a non-premixed or a premixed burner. In a premixed burner, the shifting lambda will likely lead to a reduction in flame temperature and hence NO. In a non-premixed burner (where the majority of the combustion reactions occur at a local lambda = 1), H2 admixture causes higher NO emissions.
There have already been experiments with industrial non-premixed forced draught burners which show this. As always, NOx emissions are highly dependent on the actual burner design, so there is no generally valid answer.

[11:26] Cindy Devacht Brux env
Can you tell the impact of adding H2 on the overall efficiency of a residential condensation boiler?
Jörg Leicher: It depends. From a purely combustion point of view, the combustion efficiency will increase slightly with higher levels of H_2 (at constant air excess ratios…otherwise it will go down). Also, there is more water vapor to be used. If this translates into an overall efficiency gain will probably depend on the application but should be a result of the experiments.

[*11:27] N. MOSTEFAOUI (CETIAT)*
slide 36: Does it mean that the useful heat could increase and the useful efficiency may go about theoretical 111% of condensing boilers
[11:28] Jean Schweitzer
The efficiency for boilers is slightly impacted: more flue gas loss but also more condensate heat recovery with increase of %H2
Jörg Leicher: see above.

[11:32] Dennis van Stratum
Could a difference in reaction speed of hydrogen with oxygen and methane with oxygen also cause an increased concentration of carbon monoxide in the flue gases? Or perhaps the cooling of the flame due to the creation of more water vapor at a higher hydrogen concentration has an effect on the concentration of carbon monoxide as well as nitrogen oxides?
Jörg Leicher: I doubt that the difference in reaction speeds between CH4 and H2 will make an appreciable difference in CO formation, as long as there is sufficient oxygen available. Both oxidation processes are very fast, and exponentially dependent on temperature (which will be high in the flame). The calculation of adiabatic combustion temperatures already takes the increased water formation into account, but still results in overall higher temperatures with higher levels of H2.

[11:33] Essen, Martijn van
are you planning to test the cooking hob with different turn down ratio's or a fixed one (how fast you turn off the cooking hob)?
Patrick Milin: we didn't have thoughts about this specific aspect of the test protocol, but we will have a look.

[11:33] Polidoro.DOMENICO.PESERICO
Did you make some tests related to the impact on the efficiency?
[11:35] Jean Schweitzer
Answer to (Polidoro) yes, we are measuring efficiency variations with H2

[11:33] Prencipe, Massimo
In case of variable H2% injected in the gas line, CO_2 setting in the field by the service, without knowing the gas composition could be a risk?
Jörg Leicher: it will definitely lead to a situation where you don't really know to which lambda you have adjusted your appliance. Adjustment via excess O_2 is far less sensitive here (see bonus slide). In a worst case scenario, you'd have adjusted to a CO_2 value in a situation where you have a lot of H_2 in the fuel gas, and then, local gas composition shifts back to a mix with little or no H_2. This could lead to a situation where you may produce more CO because lambda gets too close to 1. However, residential appliances are usually set to high air excess ratios, so the change would have to quite significant to be safety-relevant. This can be calculated quite easily.

[11:34] Garry-Madden, Mark [COMRES/TOD/WIG]
Will you be covering standard ionization flame detection and the impact of adding H2 to CH4?
[11:40] Hristina Cigarida
An answer to Garry-Madden, Mark, yes, we do measure the ionization signal at Qmin and Qmax. with different H2 levels.

[11:36] Paul Glanville
With respect to standard premix burner designs (flame holder specifically, screens/perf. plates/etc.), any practical generalization on quench distance/diameter?
Jörg Leicher: There are some theoretical considerations on quenching diameters in the D2.2. report.

[11:36] David Hughes (Guest)
Thank you. Great presentation. Delivered energy impact / impact on the efficiency could have customer reaction?
Jörg Leicher. See above, and thank you 😊

[11:39] Tyler Mason (Guest)
Can you confirm my understanding of your usage of the term premixed burner with a combustion control to be a system where the combustion air is altered (You noted a flame ionization measurement system) to maintain burner output? I ask, as there are premixed burner systems that utilize a zero-governor/regulator or gas/air ration controller - where the modulation of the incoming combustion air is performed by the incoming gas pressure or volume flow (Where H2% would be expected significantly alter lambda)
Jörg Leicher: in the context of this presentation, combustion control means that the volume flow of air is adjusted to maintain a set air excess ratio, based on some kind of input (e.g. from a flame ionization detector or maybe a CO/O_2 sensor in the flue gas). This does not mean that the burner firing rate remains constant, it doesn't. In order to maintain a constant firing rate, you'd need to increase nozzle pressure to push more fuel through the nozzle, which is not done in residential appliances.
I am familiar with industrial burner systems where there is a fixed ratio of gas and air volume flows set in some kind of control system, to maintain a constant lambda if the firing rate changes. Such a system implies that the minimum air requirement or CARI do not change, which, in the case of H_2 admixture, is obviously incorrect. In such a system, the global stoichiometry would shift.

[11:39] Essen, Martijn van
I disagree with the remark regarding the methane numbers: there are differences between AVL/MW and PKI MN which are important for engines maybe we could have a discussion outside this meeting?
Jörg Leicher: I agree that there are differences between the different calculation methods, but these differences are not of great relevance for the THyGA project. I'd be happy to discuss this further.

[11:41] Ben Greeneklee
In, say, the context of a residential gas hob, NG flame is a light blue, my understanding is that a H_2 flame is much less colored. For safety and public perception, has there been any study of luminosity / color of flame as H2 added to NG?
Jörg Leicher: Flame color and luminosity are topics that are difficult to tackle from a theoretical perspective. We will need to see what the experiments show.

[11:43] Wesenbeeck van P.J.M.M. (Peter)
As stated, appliances are not designed/certified for use with natural gas / hydrogen mixtures but seems to function well at lower levels of hydrogen in practice. How do you think to solve this regulatory problem of missing certification for (older) appliances? Is it for example possible to perform a general risk analysis for different types of appliances to demonstrate their suitability?
Jörg Leicher: The THyGA project has one work package dedicated to matters of certification, headed by Kris de Wit (gas.be). I think this issue is best addressed there.

[11:45] Enzo Alfonsetti
Will there be a study on the effect of H_2 on surface combustion burners?
Patrick Milin: Yes, surface burners will be tested in WP3 but there won't be dedicated study, on different designs for example.

[11:50] Polidoro.DOMENICO.PESERICO
Did you make some measurements on the appliance efficiency changing the percentage CH4 vs H2?
Jörg Leicher: see above.