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SHOULD WE ADD HYDROGEN TO THE NATURAL GAS GRID TO REDUCE CO_2-EMISSIONS?

(CONSEQUENCES FOR GAS UTILIZATION EQUIPMENT)

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Acknowledgement

1. INTRODUCTION

Why use Hydrogen (H_2)?

- CO_2 Reduction (Kyoto)
- H_2 possible from renewable sources

  e.g. Solar, Wind, Biomass

Why H_2 in natural gas ?

- Smooth introduction towards **sustainable energy** possible_ using the existing natural gas infrastructure

Why Research/Knowledge/Experience needed ?

- **End user:**

  H_2 has different combustion properties than natural gas

  ➔ possible negative consequences for combustion equipment
- **Grid**

2. CO_2 REDUCTION (by H_2 addition)

Natural Gas: $CH_4 + 2O_2 \rightarrow$ **CO_2** $+ 2H_2O$

(mainly CH_4 [methane])

Hydrogen: $2H_2 + O_2 \rightarrow 2H_2O$ **(No CO_2)**

Low heating value of H_2:

e.g. replacing natural gas by 50% $H_2 \rightarrow CO_2$ emission decreased by only 25%!

(per unit of energy [kg CO_2/MJ])

This "reduced" decrease of CO_2 emission must be weighed against the other consequences of hydrogen addition

3. CHANGES IN COMBUSTION PROPERTIES

(by H_2 addition)

Gross Calorific Value:

~ 3x more H_2 needed for same thermal input

Wobbe Index, W:

thermal input proportional to WI at constant pressure drop

H_2: ~ 3x flow rate of Natural Gas at same Wobbe Index (48 MJ/m^3)

Stoichiometric Air Requirement (SAR):

H_2 requires 25% of the O_2 of Natural Gas per mole of gas

➔ flame temperature higher: 2382K vs 2226K → important for NO_x

Ignition Properties:

H_2 knocks easier than natural gas; engine at risk ?

Burning Velocity, Su:

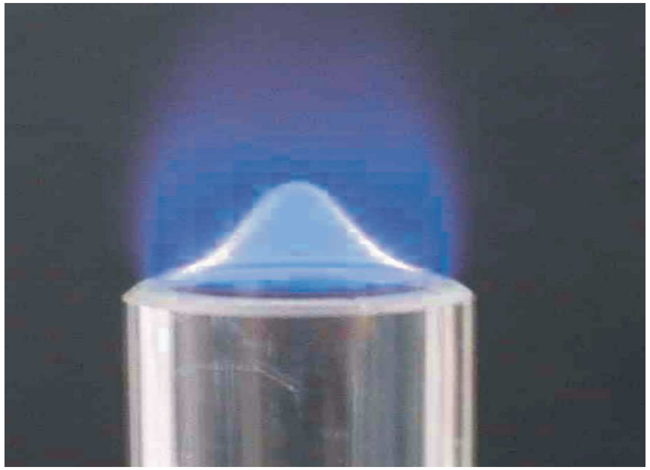
Propagation velocity; closely related to stability:

Su higher than exit velocity → flash-back

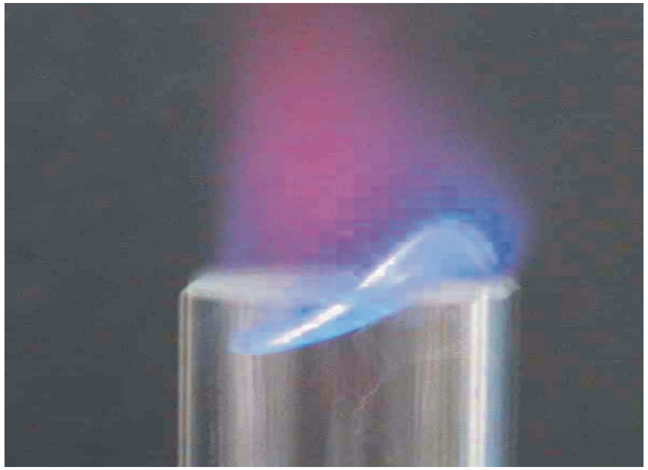
Su H_2 ~ 6x higher than methane, *will flash-back occur?*

4. RESPONSE TO H_2 ADDITION OF:
Domestic Appliances

Of the domestic appliances the **Partially Premixed Burner** ("cooking burner") is most prone to flashback



Bunsen experiments: Normal Flame



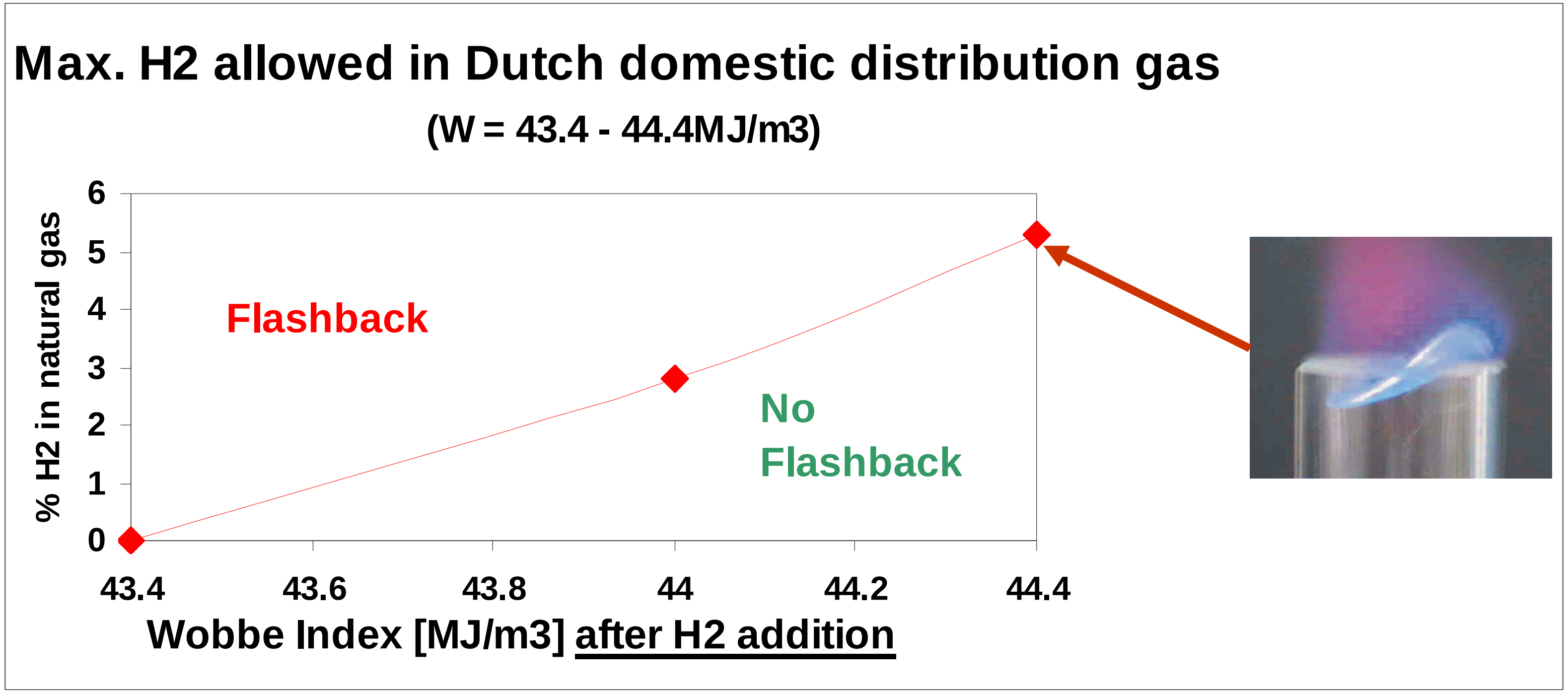
(Incipient) Flashback

Requirement:

Natural Gas/H_2 mixture may not flashback easier than any gas distributed in the past

Flame speed increases at decreasing Wobbe Index ➔ Lowest Wobbe Index distributed is most sensitive to flashback

4. RESPONSE TO H_2 ADDITION OF:
Domestic Appliances



Only 5% H_2 allowed at Upper Wobbe Limit

If the Wobbe Index is allowed to fluctuate the allowable H_2 addition becomes even lower

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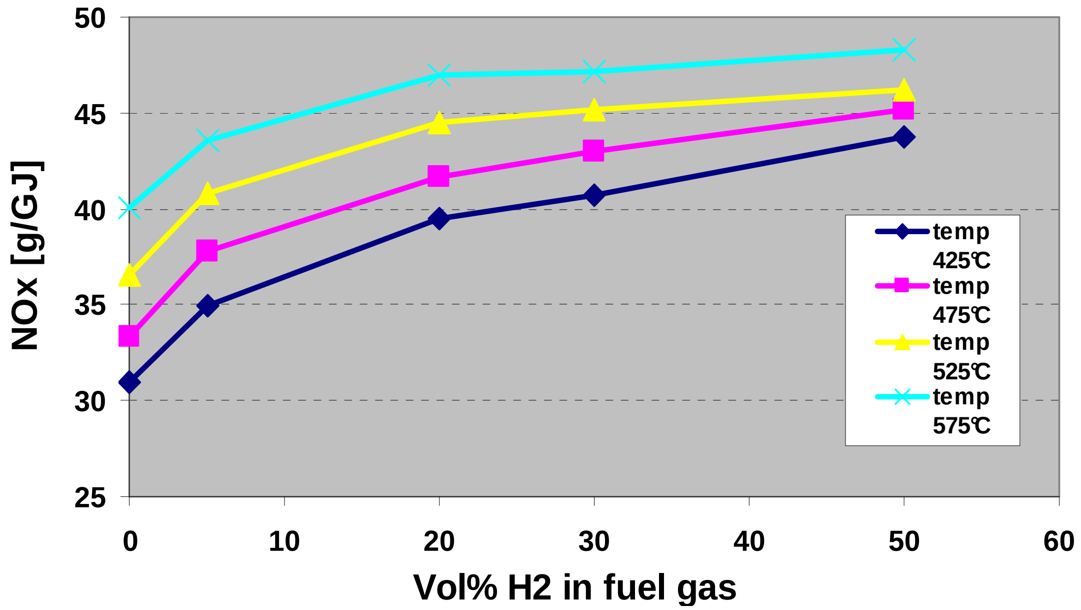
4. RESPONSE TO H_2 ADDITION OF:
Industrial Burners

Conventional Process-Burner

- Nozzle-mix ➔ No flashback
- Flame closer to burner ➔ Overheating a risk ?
- Higher flame temp. ➔ More NO_x ?

NO_x formation for different H_2 concentrations in natural gas at different test furnace temperatures

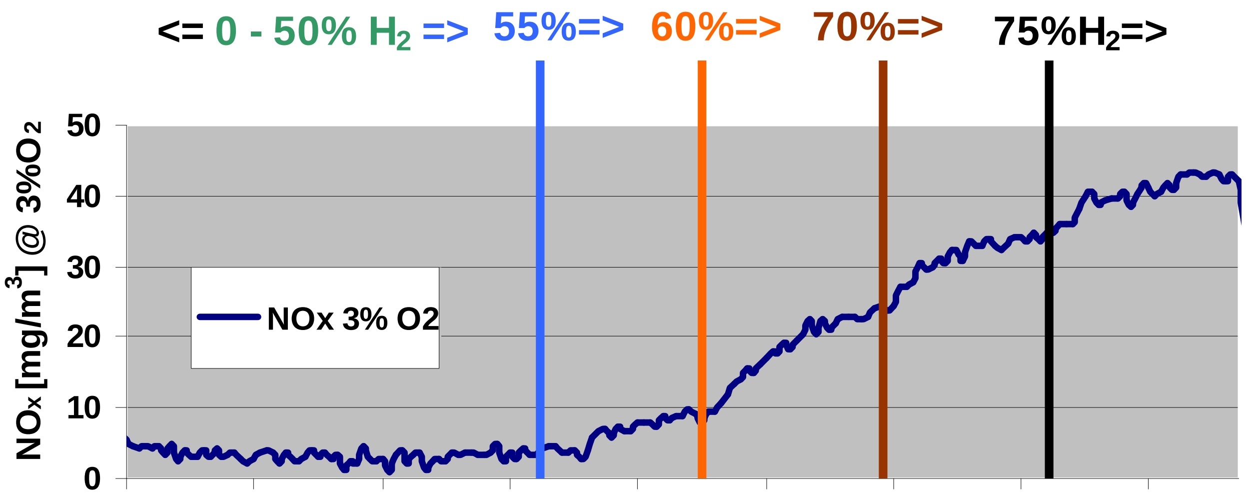


H_2 addition increases NO_x emission

4. RESPONSE TO H_2 ADDITION OF:
Industrial Burners

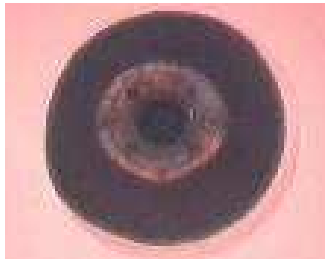
Prototype Flameless -Burner

NO_x-emissions with increasing H_2-addition



Flameless mode (H_2 < 55 %):

- Very low NO_x
- No visible flame



More H_2 (>55%):

- More NO_x
- Blue flame

H_2 ruins working principle of burner

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4. RESPONSE TO H_2 ADDITION OF:
Spark-Ignition Engines

H_2 increases the burning velocity of natural gas:

Experiments showed (lean-burn engine):

20% of H_2 added ➔ efficiency + 3%

due to:

- Shorter ignition lag period
- Faster combustion

At constant air-fuel ratio the NO_x-emission can double at 20% H_2 !

H_2 spontaneously ignites much easier than methane:

➔ engine knock is a risk !

Engine knock:

= autoignition of unburned fuel gas (unwanted)

Engine can be damaged rapidly !   (in seconds)

4. RESPONSE TO H_2 ADDITION OF:
Gas Turbines

Lean-premixed (Low NO_x) gas turbines are extremely sensitive to variations in gas composition:

- Spontaneous ignition before reaching the burner
- Flashback of the flame into the burner
- Flame blow-off
- Partial flame lift ➔ Acoustic instabilities

Generally:

- <10% H_2 addition allowed by manufacturers
- Little *fluctuation* in H_2 content is tolerated

5. CONCLUSIONS

Hydrogen addition to natural gas has some benefits:

– CO_2 reduction (but limited)

– Possible from renewable sources

But also some specific "consequences" for each class of end-use equipment with respect to safety and environmental impact, such as:

– **Domestic Appliances:** flashback

– **Industrial Burners:** increased NO_x-formation

– **SI Engines:** engine knock and increased NO_x-formation

– **Gasturbines:** flashback and acoustic instabilities

The decrease of CO_2 emission must be weighed against the other consequences of hydrogen addition

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