EFFECTS OF HYDROGEN COMBUSTION

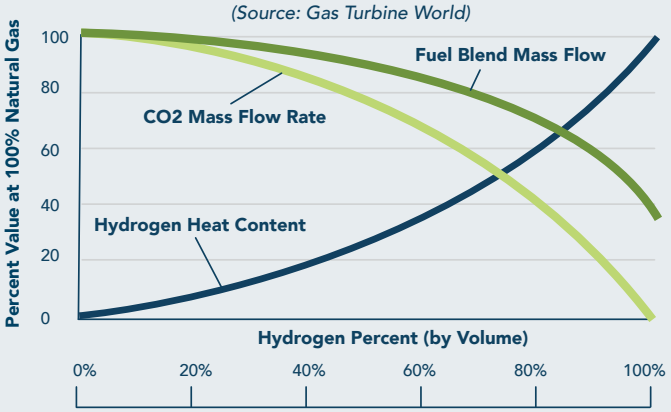
Hydrogen has been identified as a clean alternative to traditional fuels like natural gas, as it can reduce greenhouse gas emissions. Ongoing research seeks to understand what, if any, impacts on criteria pollutants result from increased hydrogen use.

HYDROGEN COMBUSTION AND CRITERIA POLLUTANTS

- Hydrogen combustion does not produce carbon monoxide (CO) or carbon dioxide (CO_2)
- When combusting a hydrogen-natural gas blend, onsite carbon emissions are reduced compared to 100% natural gas fuel
- As the amount of hydrogen is increased, carbon dioxide (CO_2) emissions are reduced
- With higher combustion temperatures (i.e., from blending more than 30% hydrogen), nitrogen molecules separate from the air and combine with oxygen more easily to create higher concentrations of nitrogen oxide pollutants[1]

Hydrogen Blend Effects

(Source: Gas Turbine World)

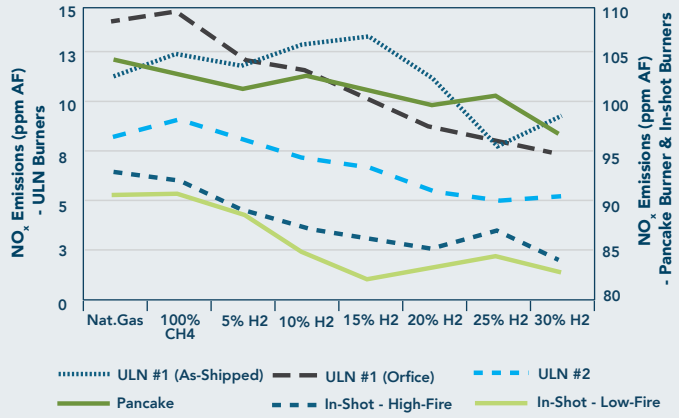


HYDROGEN BLENDS AND NITROGEN OXIDE (NO_X) EMISSIONS

- A 2022 study conducted by the Gas Technology Institute (GTI) concluded that the concentration of NO_X emissions remains relatively stable or decreases slightly up to a 30% hydrogen blend by volume[2]
- GTI tests confirmed that there are no significant increases in NO_X or CO emissions at end-use applications such as water heating and furnace burners[3]
- In addition, up to a 15% hydrogen-by-volume fuel blend was tested successfully on appliances manufactured between 1950-2021 with no increases in NO_X production[4]

Impact of Hydrogen Blends up to 30% on ULN, Pancake, and In-shot Burners

(Source: Gas Technology Institute, 2022)



IMPACTS OF HYDROGEN BLENDS

- Hydrogen-natural gas blends exceeding 30% hydrogen by volume tend to result in significantly higher levels of NO_X emissions if no control measures are applied[5]
- Natural gas operators have limited hydrogen blends to the 20-30% range while they continue to study the impacts of higher blend percentages to both natural gas infrastructure and end-use appliances
- A 2022 demonstration of up to a 44% hydrogen-by-volume fuel blend at a power generating plant indicated a nearly 14% reduction in CO_2 and an 88% reduction in CO while NO_X emissions while keeping within acceptable limits using selective catalytic reduction control system[6]

100% HYDROGEN COMBUSTION

- Manufacturers have started developing and testing HVAC appliances specifically designed for 100% pure hydrogen fuel[6,7]
- Mitigation methods for end-use applications are being tested to ensure NO_X emissions are kept within the allowable limits[8]
- These developments will help ensure net zero goals are achieved in the coming years as more emphasis is placed on replacing natural gas and other traditional combustion fuels with a cleaner alternative, hydrogen

1. Ambient conditions impact CO and NOx emissions: part II (digitalrefining.com)
2. Gas Technology Institute (GTI)
3. Angela Serrano de Rivera - AEE WORLD | Energy Conference & Expo
4. 2023-AEE-World-Proceedings.pdf (aeecenter.org)
5. Mehmen, S. (2017). Investigations on performance and emission characteristics of an industrial low swirl burner while burning natural gas, methane, hydrogen-enriched natural gas and hydrogen as fuels. (ResearchGate.net)
6. HydrogenReady SmartBurner for Heat Treatment Furnaces | Tenova
7. Combustion | Hy-Ductflam™ - Hydrogen duct burner - Fives Group
8. Gersen, S. (2020). Domestic hydrogen boilers in practice: enabling the use of hydrogen in the built environment (ResearchGate.net)