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Redesigning Dalhousie's Boiler System to Run on Catalytic Hydrogen Combustion Technology

Introduction

- Dalhousie uses natural gas and heating oil to fuel the boiler system. Natural gas combustion emits both greenhouse gases (GHG) and nitrous oxides (NOx) that contribute to global warming.
- Hydrogen offers a more environmentally friendly fuel source that eliminates carbon emissions.
- Catalysts are used to reduce activation energy and reduce the overall rection temperature. This further reduces the formation of NOx.

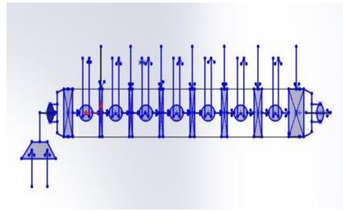
Design Process

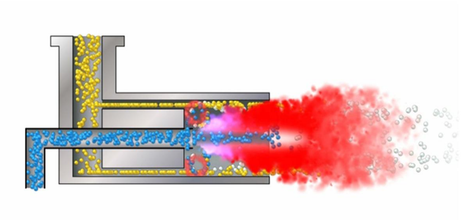
- Catalytic combustion burner designs were researched. Aspen HYSYS was used to simulate heat transfer and reaction kinetics
- Cantera Python was used to model the premixed flame and design the secondary burner.
- NOx formation kinetics were then investigated to model emissions from the burner
- Existing boiler designs were researched. Mathematical modelling used for radiative heat transfer calculations. Aspen Exchanger Rating and Design software used for convective transfer sections.
- Flue gas recovery system was researched and modeled using a direct contact condenser with inspiration taken from the FLU-ACE design
- P&ID was created with all safety features and control systems.

Details of Design

Catalytic Hydrogen Ignition System

The catalytic ignition system heats the hydrogen to it's autoignition temperature of 585 °C. This is done using a series of intercooled packed bed reactors to partially combust the hydrogen under rich combustion conditions



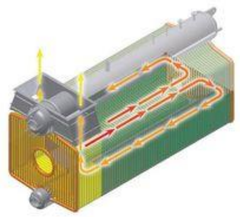


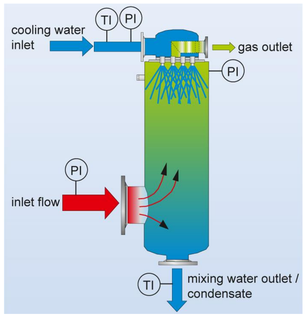
Secondary Burner

The secondary combustion burner ignites and fully combusts the remaining hydrogen by injecting air into the fuel rich mixture at autoignition temperature. This produces a premixed flame used to heat the boiler.

Boiler

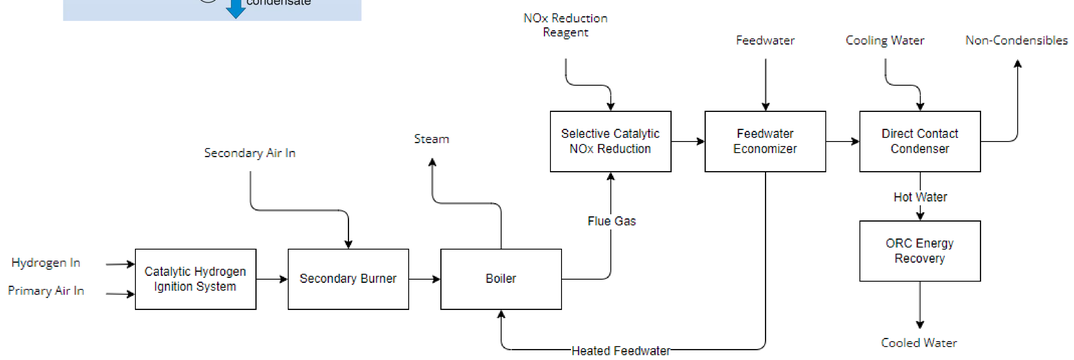
Dual pass, O-type water tube boiler. Designed to produce 36,000 kg/hr of saturated steam at 9 bar.





Flue Gas Recovery System

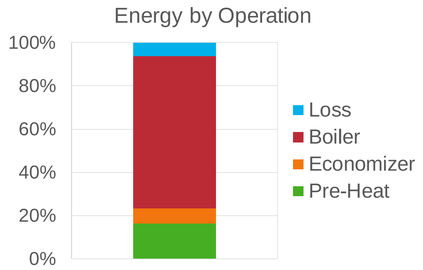
Flue gas heat is recovered using a dry feedwater economizer, direct contact condenser and organic Rankine cycle heat exchanger. These units combine to maximize efficiency and recover waste heat.



Economics and Energy

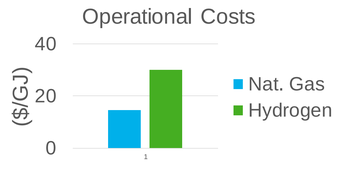
Energy

- Net efficiency of 93%
- 108 GJ/hr max firing rate
- 2:1 turndown ratio



Economics

- CAPEX costs are roughly double vs. natural gas
- Sustainable hydrogen is very costly to use as fuel



Conclusions and Recommendations

Conclusions

- Hydrogen fueled boiler is not economically feasible
- Reduces Dal's CO2 equivalence by 30%
- Process requires a $20M investment per boiler

Recommendations

- Investigate the use of natural gas-hydrogen mixtures in existing boilers
- Investigate catalyst regeneration

References

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