Synthesis Gas from Methane by using Plasma Assisted GlidArc Catalytic Partial Oxidation Reactor

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Out line of Presentation

- **Aim**
- **Introduction**
- **Materials and Methods**
- **Results and Discussion**
- **Conclusions**

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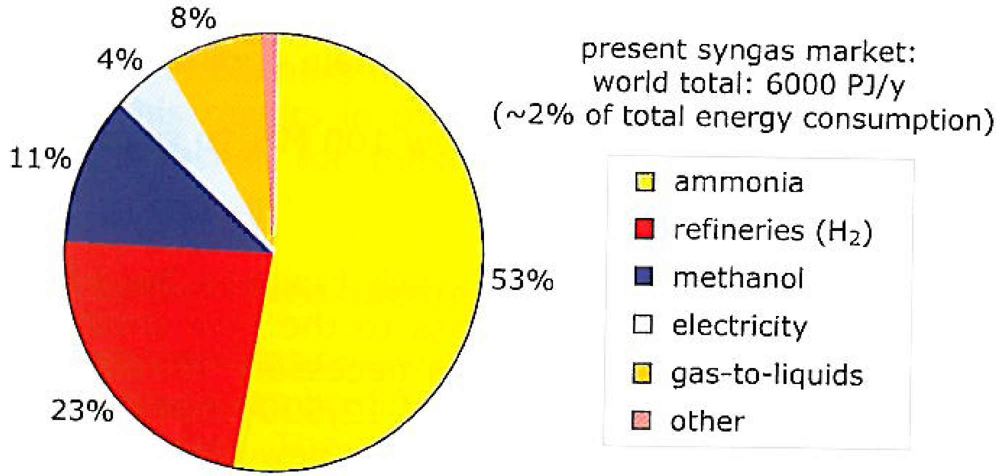
Aim of this study is to convert 2.64g/min of methane to syngas by using normal air and enriched air (N_2/O_2=60/40) for a single tube cobalt based Fischer-Tropsch reactor with special emphasis on H_2/CO Ratio.

WORLD SYNGAS MARKET



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SYNTHESIS GAS PRODUCTION PROCESSES

- Steam Reforming (SMR)

$$CH_4 + H_2O \rightarrow CO + 3H_2 \qquad \Delta H^0_{298} = 206\frac{KJ}{mole}$$

Method of producing hydrogen in the pressence of Ni Catalyst.

- Autothermal Reforming (ATR)

Uses oxygen and carbon dioxide or steam in a reaction with methane to form syngas.

$$2CH_4 + O_2 + CO_2 \rightarrow 3H_2 + 3CO + H_2O + \text{Heat}$$

$$2CH_4 + O_2 + H_2O \rightarrow 5H_2 + 2CO$$

The advantage of ATR is that the H_2/CO ratio can be varied, this is particularly useful for producing certain second generation biofuels.

- Partial Oxidation (POX)

Combusting substoichiometric fuel-air mixture in a reformer to produce hydrogen-rich syngas.

$$CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2 \qquad \Delta H^0_{298} = -38\frac{KJ}{mole}$$

- Dry Reforming or Combined Dry and Steam Reforming

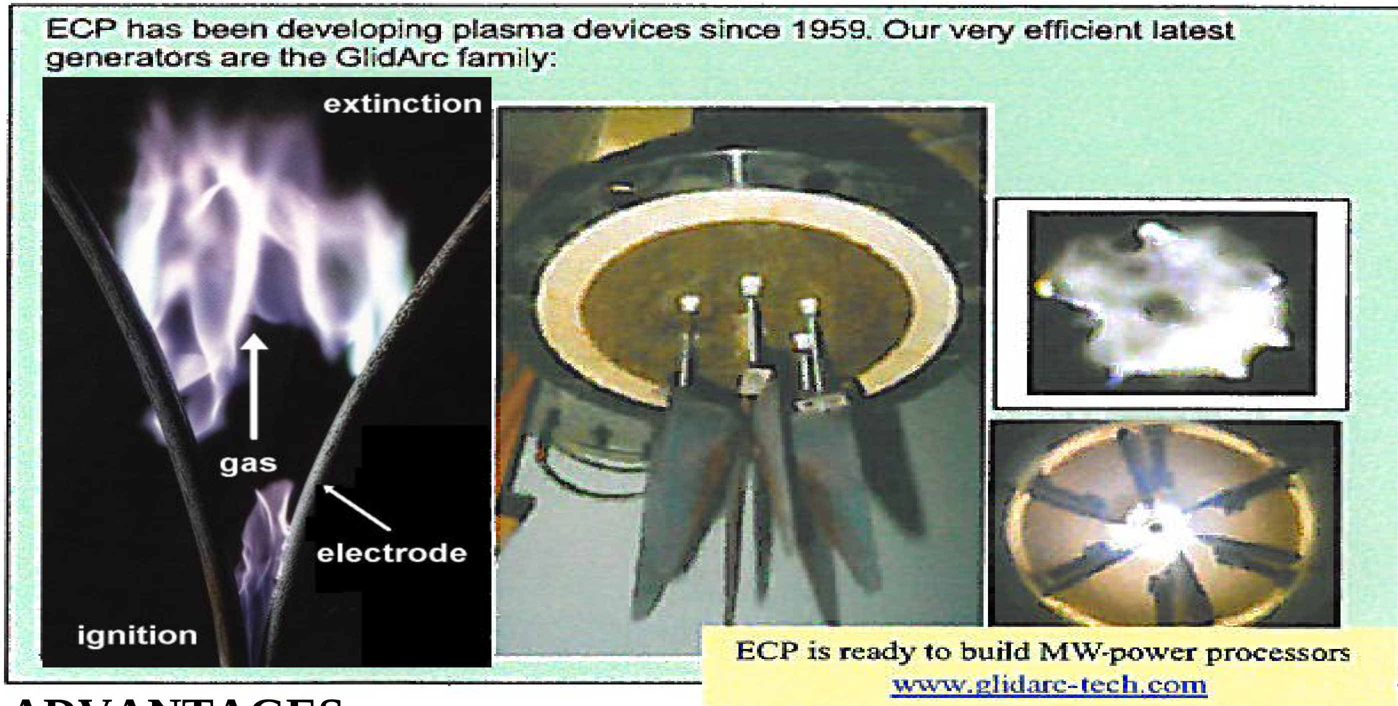
Production of hydrogen from carbon dioxide reforming of methane becomes more attractive way to utilize carbondioxide.

$$CH_4 + CO_2 \rightarrow 2CO + 2H_2 \qquad \Delta H^0_{298} = 247\frac{KJ}{mole}$$

GLIDARC PLASMA REFORMING

DEFINITION

- An electrically assisted reforming of hydrocarbons where the electric energy is dissipated directly in the processed gas through specific high-voltage discharges.



ADVANTAGES

- Electric energy consumption for non-catalytic reformer is less than 2% of the Lower Heating Value (LHV) power of produced syngas (H_2+CO).
- Frequent start-up or drastic changes of the output flow rate and composition can be done in few seconds.
- No soot formation.
- Insensitive to sulphur content in the feed gas.

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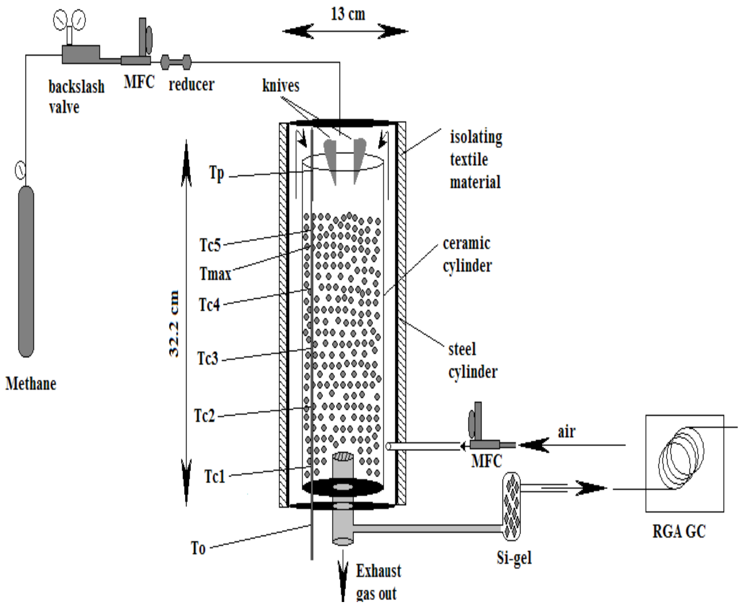
EXPERIMENTAL SETUP

- Double mantle with inner silicon carbide (SiC) ceramic cylinder filled with Nickel based catalyst
- Reactor dimensions (L × D) 32.2cm×5.9cm
- Length of knives=6.1 cm
- Distance b/w knives and catalyst top surface =1.3 cm



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EXPERIMENTAL SETUP

PLASMA

- The electrical arc formed between the two high-voltage diverging electrodes (knives) is powered by a single phase transformer. The high-voltage (10kV, 60mA) self-maintained discharges strike directly across the methane and air .
- The electrodes are not cooled so all the electrical energy is directly and totally transferred to the processed gas.

GAS CHROMATOGRAPH

- Commercial Rapid Gas Analyzer (RGA) Gas Chromatograph (GC) are used to analyze the exhaust gas. Gas is directly injected into the steel loop of the RGA GC with a special gas syringe.
- The concentration of the components detected is estimated using standard gas and the amount of oxygen is measured by considering that the composition of air is 21% O_2 and 78% N_2.

RUNNING THE GLIDARC REFORMER

- CH_4 Flow is kept Constant (i.e. 2.64 g/min).
- GlidArc is operated with different flow rate of normal air and enriched air to find the optimal H_2/CO ratio.

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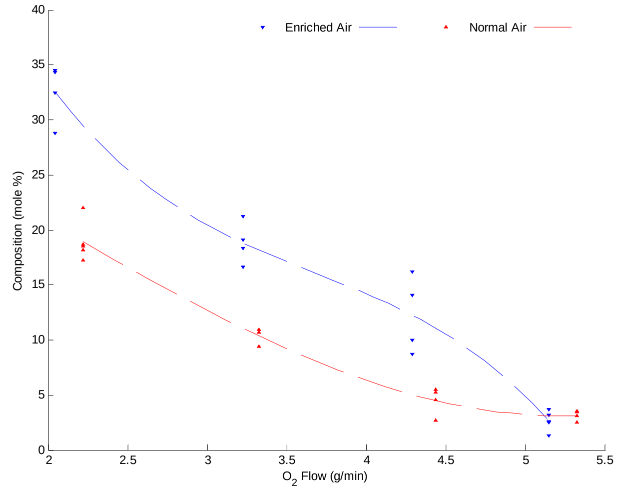
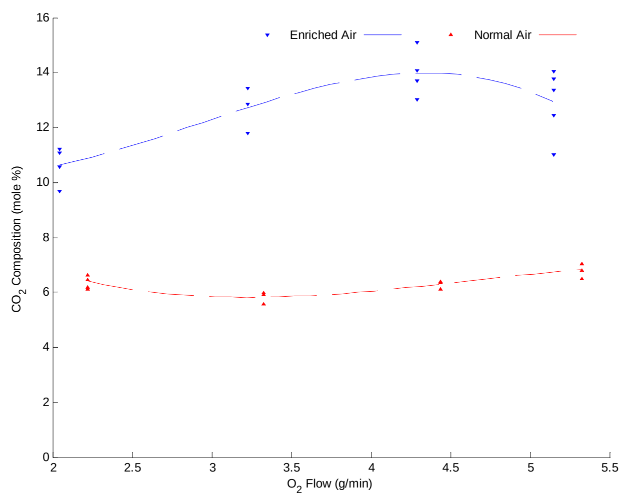
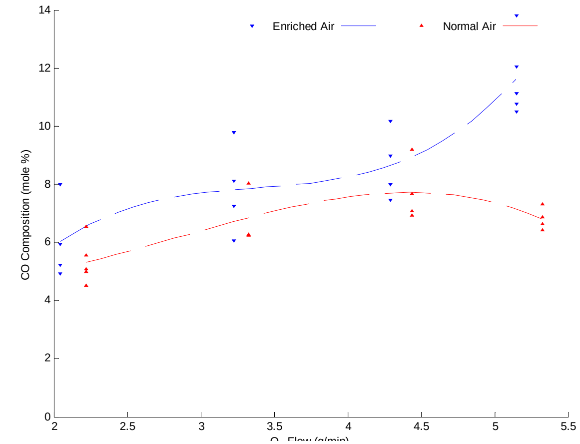
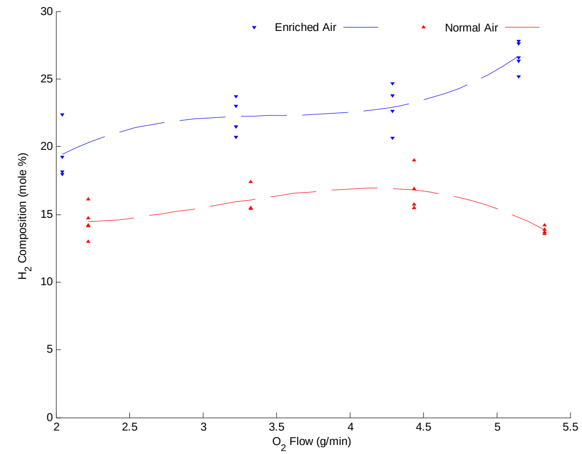
EFFECT OF O_2 FLOW

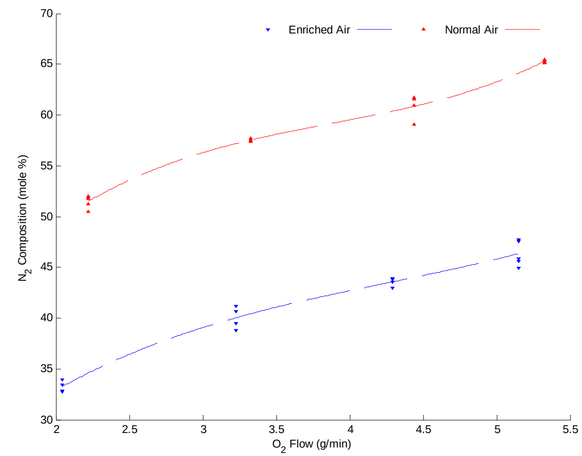
Product Gas Composition (Dry Basis)











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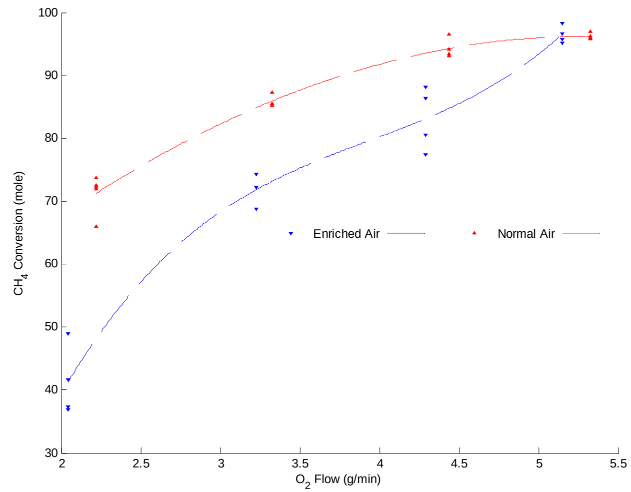
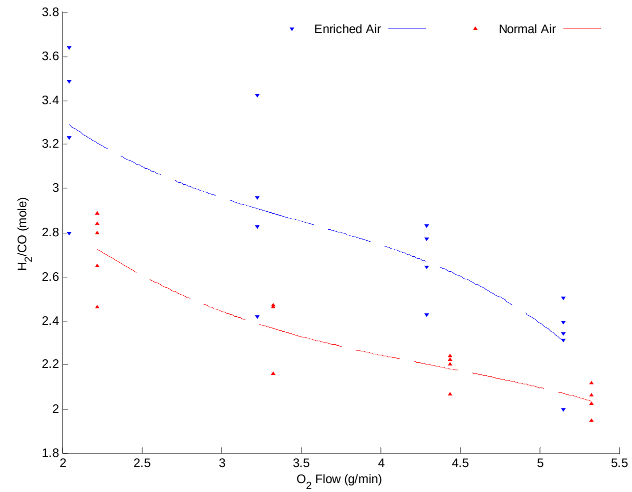
EFFECT OF O_2 FLOW

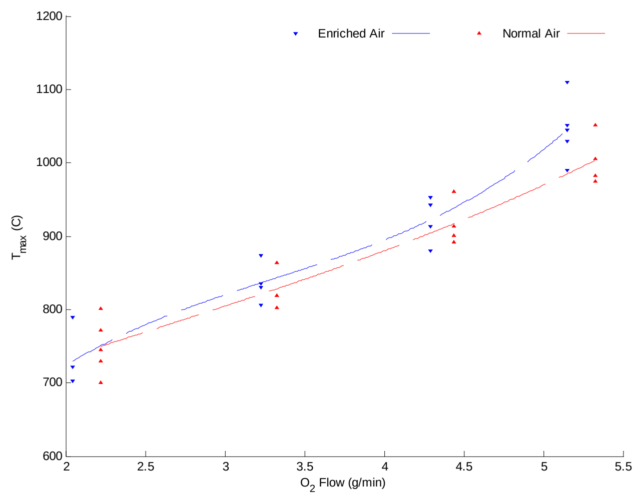
CH_4 Conversion



H_2/CO Ratio



T_{max}



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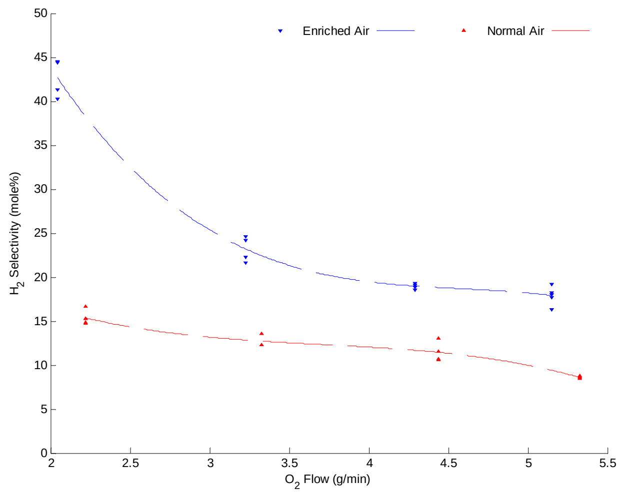
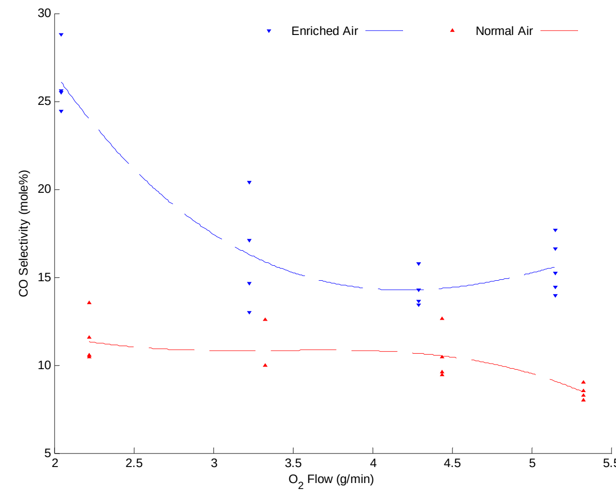
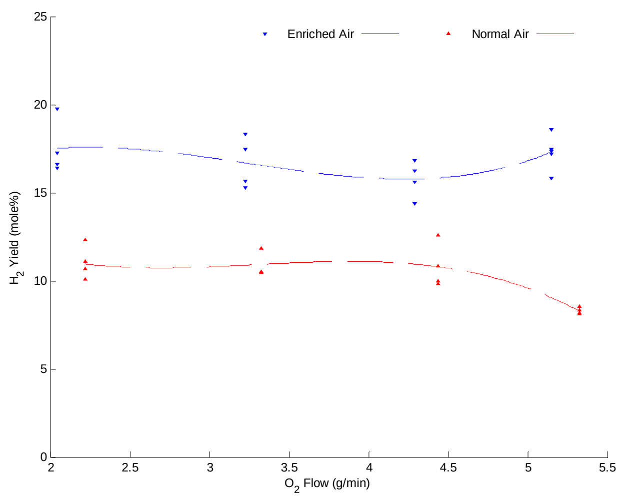
H_2 Selectivity



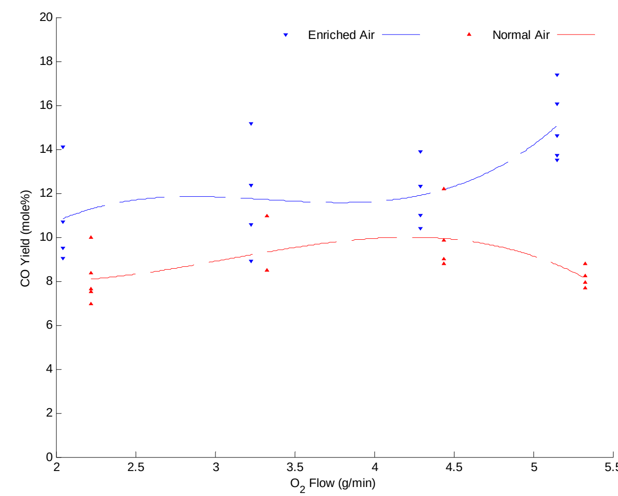
CO Selectivity



H_2 Yield



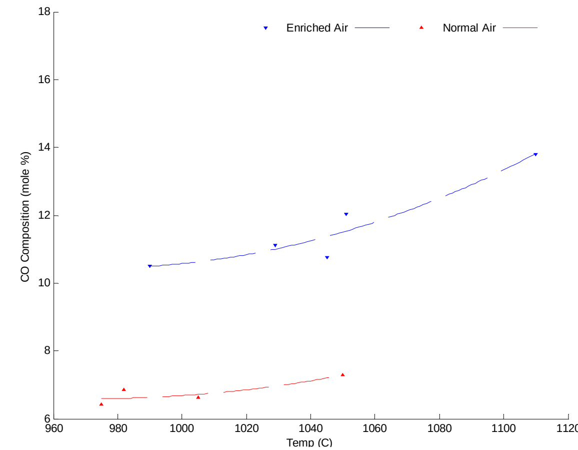
CO Yield

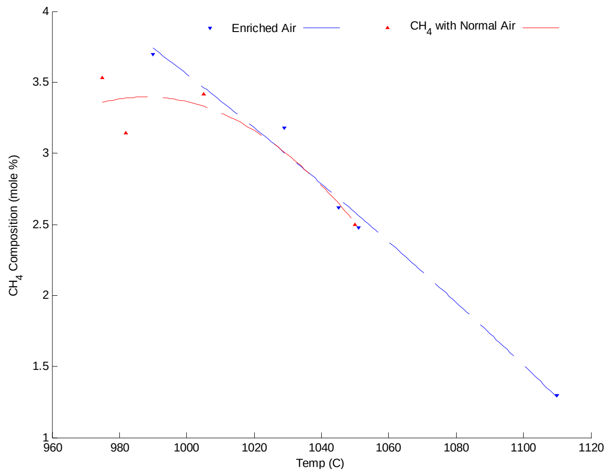


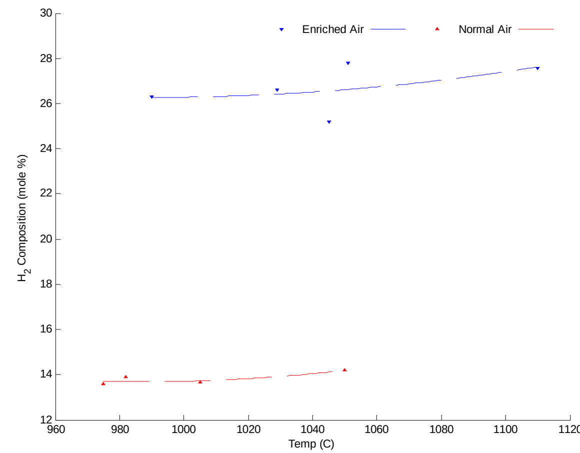
EFFECT OF TEMPERATURE

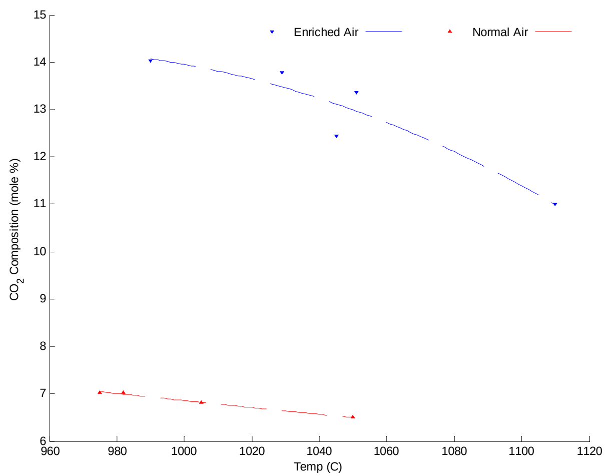
PRODUCT GAS COMPOSITION

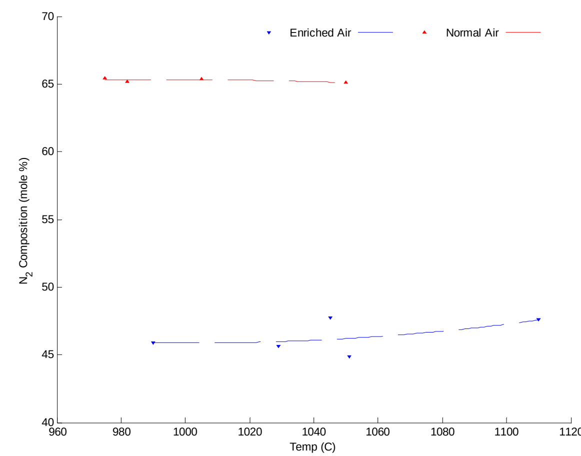
Flow rate of O_2 in normal air	=5.32 g/min
Flow rate of O_2 in enriched air	=5.15 g/min
CH_4/O_2 molar ratio	=1.0











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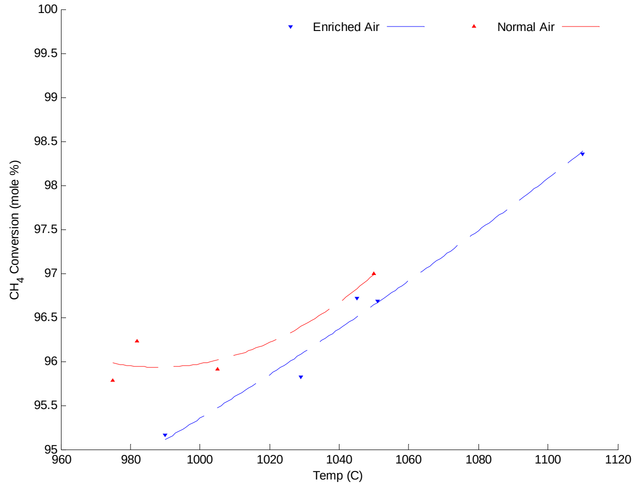
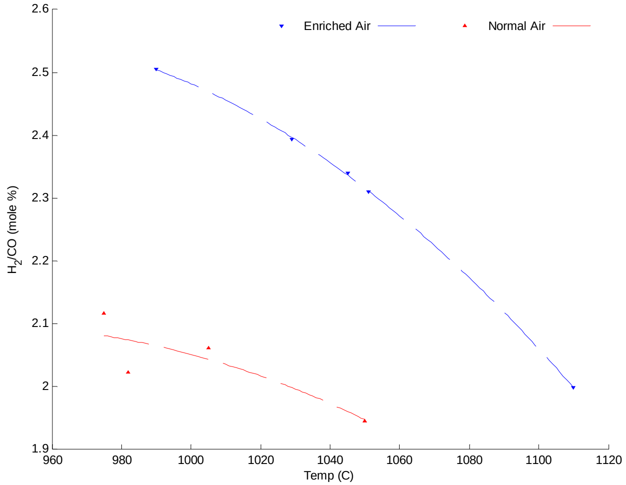
Flow rate of O_2 in normal air	=5.32 g/min
Flow rate of O_2 in enriched air	=5.15 g/min
CH_4/O_2 molar ratio	=1.0

CH_4 Conversion



H_2/CO Ratio



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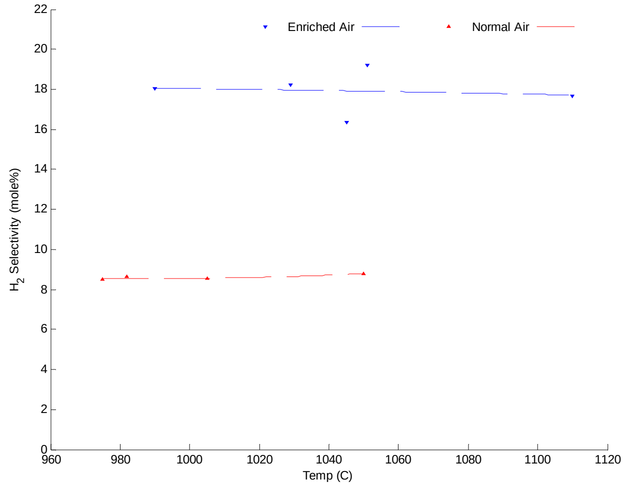
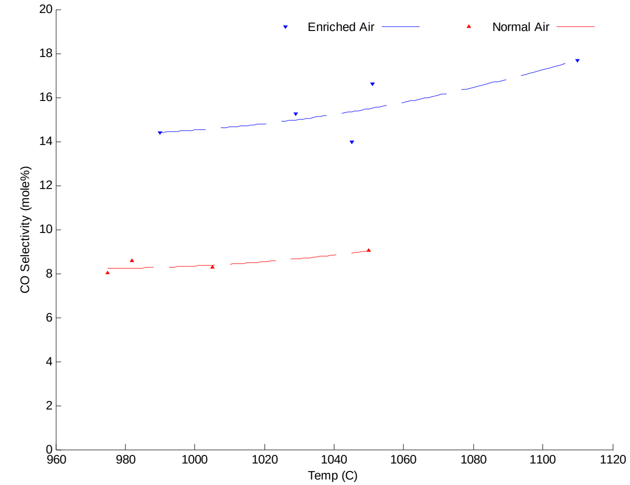
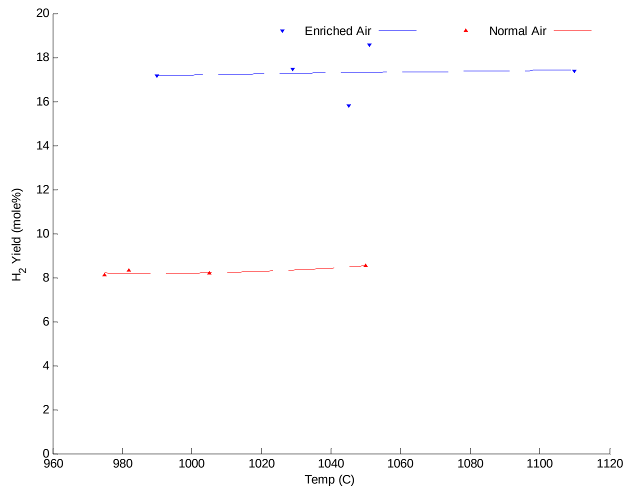
H_2 Selectivity



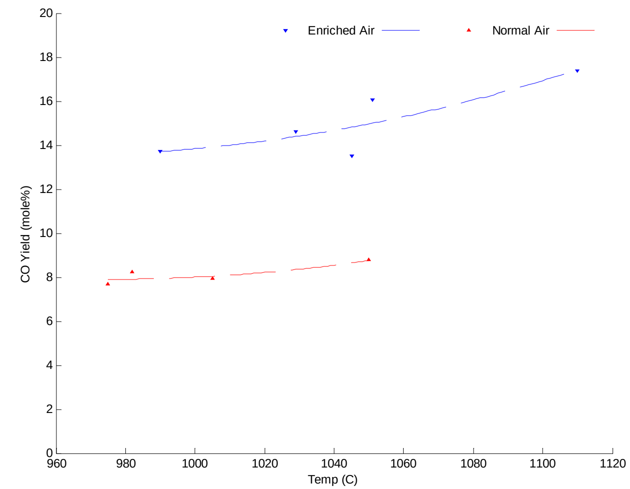
CO Selectivity



H_2 Yield



CO Yield



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RESULTS

Parameters	Normal Air	Enriched Air
CH_4 Flow (g/min)	2.64	2.64
Air Flow (g/min)	22.68	11.9
O_2 Flow (g/min)	5.32	5.15
Syngas Composition (Dry Vol %)		
CH_4	2.8	1.3
CO	7.1	13.8
CO_2	6.7	11
H_2	14.2	27.58
N_2	65.2	46.5
H_2/CO Ratio (mole basis)	2	1.99
CH_4 Conversion (mole basis)	96.5	98.36
T_{max}	1050	1110
H_2 Selectivity (mole basis)	8.7	17.67
CO Selectivity (mole basis)	8.5	17.68
H_2 Yield (mole basis)	8.5	17.38
CO Yield (mole basis)	8.4	17.39

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CONCLUSIONS

- Parametric studies are achieved to determine reforming characteristics in the GlidArc reformer with both normal air and enriched air.
- CH_4 conversion and Tmax increases, whereas H_2/CO ratio and syngas selectivity decreases with the increase of O_2 flow for both normal and enriched air.
- The temperature along the reformer varies significantly at constant CH_4 and air flow, so the chemical composition of the syngas is strongly affected.
- CH_4 conversion increases, syngas selectivity and yield slightly increases, whereas H_2/CO ratio decreases with the increase of T_{max} at constant flow of both normal and enriched air.
- The GlidArc reactor is stabilized after several hours . The temperature of the catalyst, especially in the lower part of the reformer increases slowly by time.
- The continuous electrical discharge is essential during the whole process. At higher CH_4 and air flows the outer mantle should be reconstructed to withstand higher temperature and pressure.

THANK YOU!!