Small-Scale Engineered High Flexibility Gasifier

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Crosscutting Research, Rare Earth Elements, Gasification Systems and Transformative Power Generation

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Project Team

SOUTHERN RESEARCH

REACTION ENGINEERING INTERNATIONAL

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Project Goals

- Develop a fuel flexible and modular/shop fabricated oxygen-blown small-scale coal gasifier to produce medium BTU syngas with a low tar content
- Demonstrate gasifier performance to meet target at bench-scale (10-50 lb/h)
- Optimization of bench scale gasifier to a pilot scale module; techno-economic evaluation (TEA) for syngas conversion to liquids (fuels, chemicals)

Project Tasks

Computational modeling to optimize gasifier design	Done-2019 presentation
Laboratory testing to obtain model input parameters	Done-2020 presentation
Design and construct gasification rig	This presentation
Commission & test & HAZOP review of gasification rig	This presentation
Demonstrate performance	Underway
Optimization of 1-5MW energy conversion system	Underway

Bituminous Coal Selected for Modeling and Testing

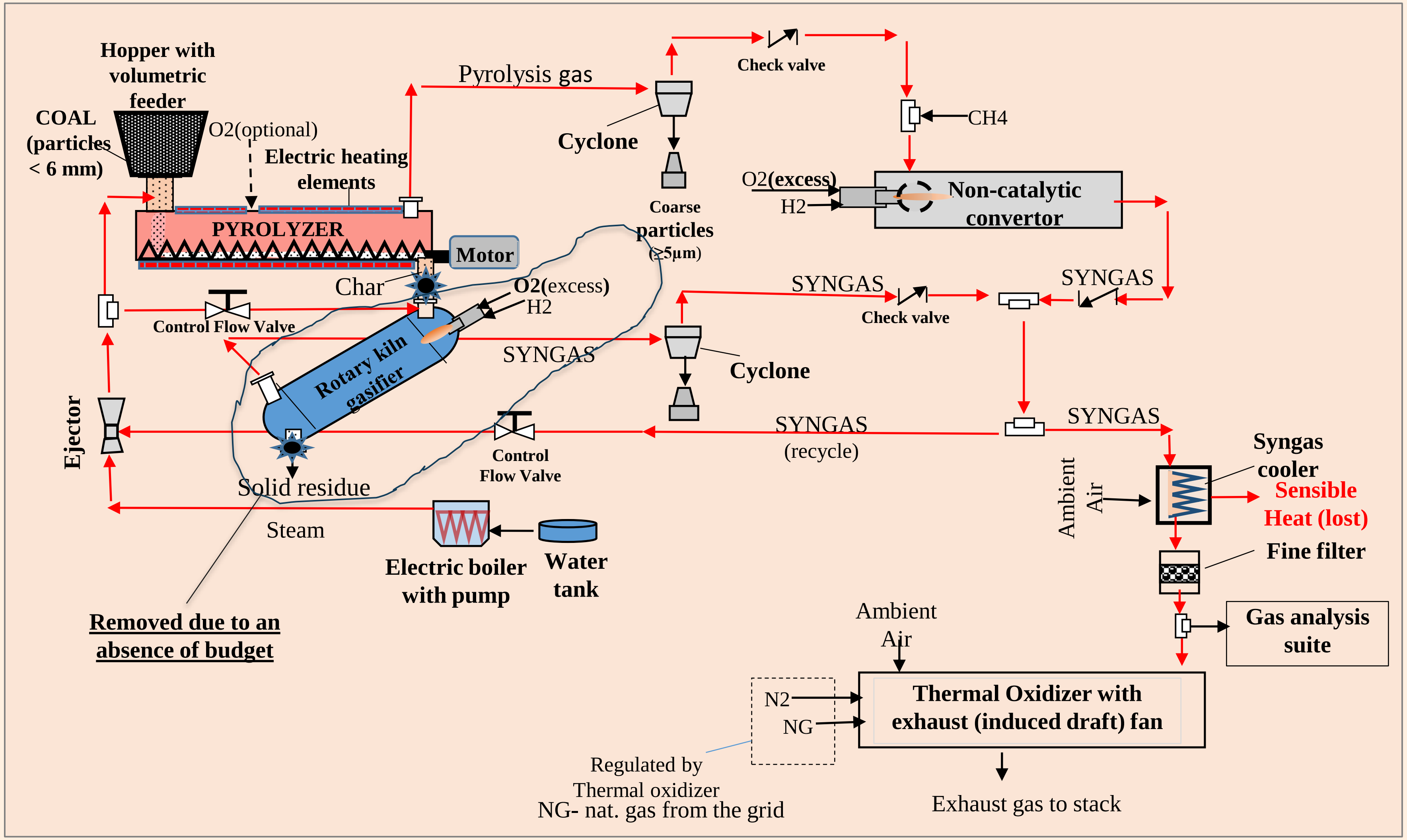
Ultimate analysis

Element	Wt.,%
C	84.7
H	4.8
N	1.0
O	3.7
S	0.8
Ash	5.0
Total	100

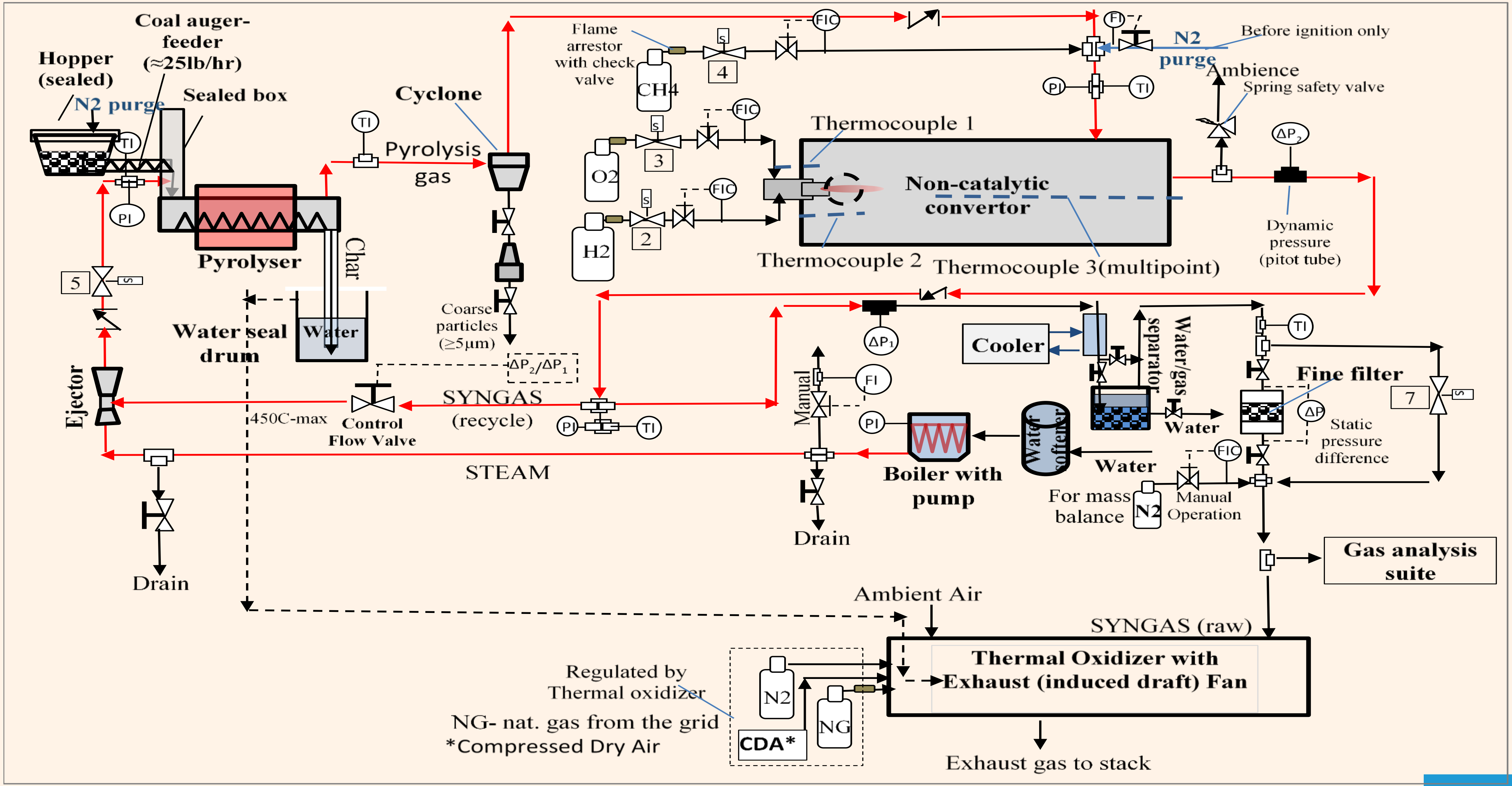
Proximate analysis

Component	Weight, %
Moisture	12.0
Volatile matter	26.2
Fixed Carbon	57.4
Ash	4.4

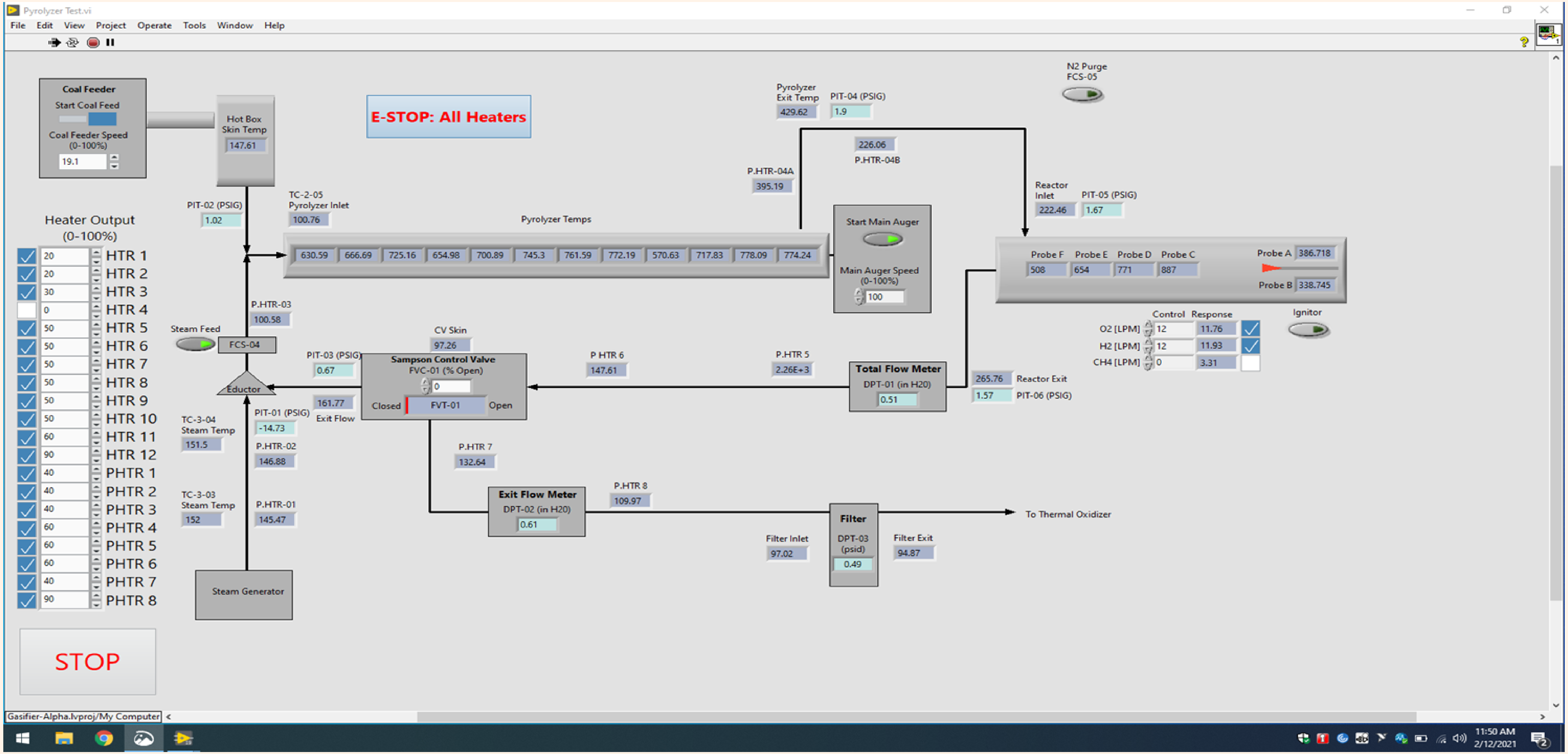
Process flow diagram of small-scale gasification skid
Modular structure of gasification process allows feedstock flexibility (coal, biomass, natural gas)



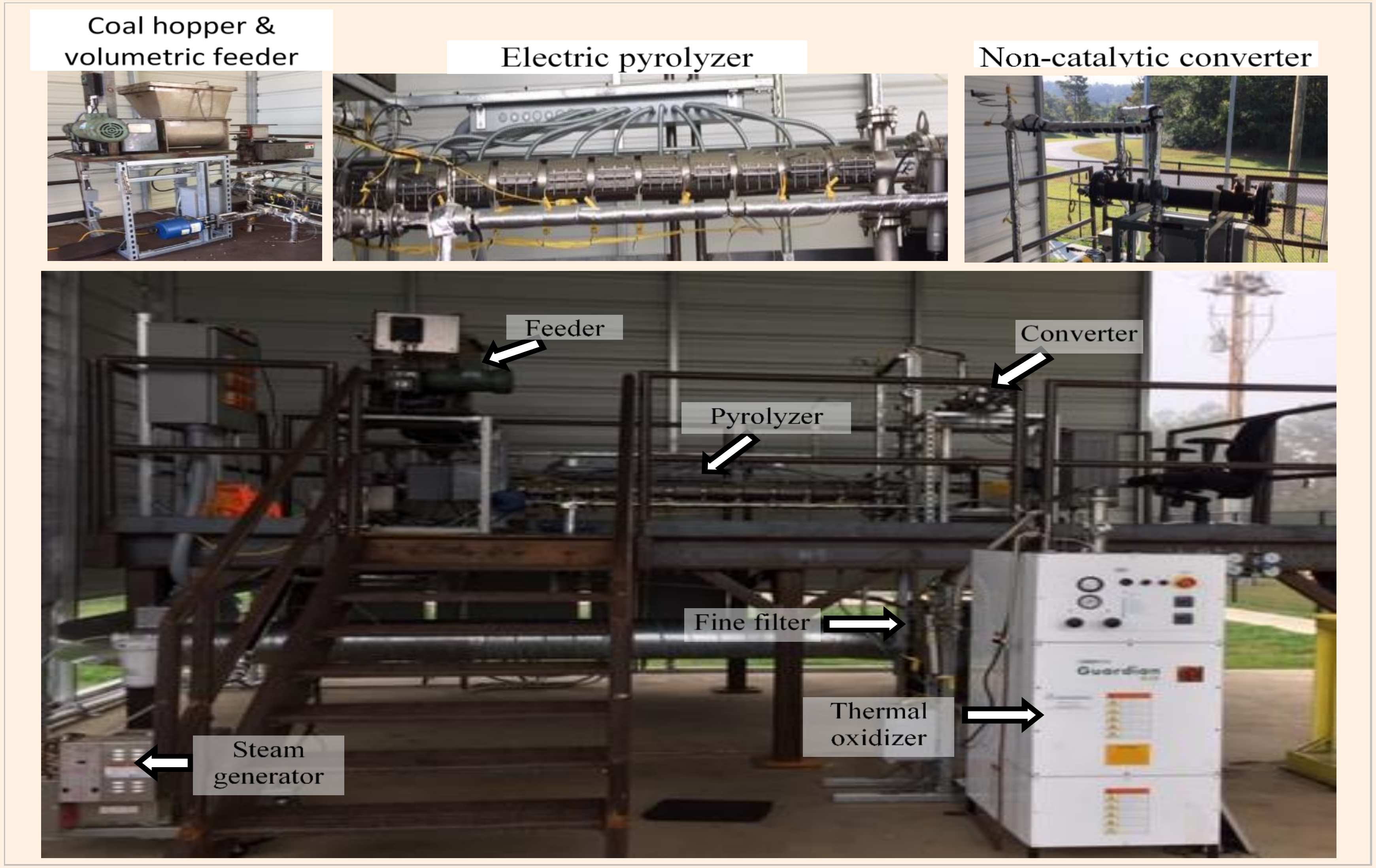
Current P&ID diagram of gasification skid



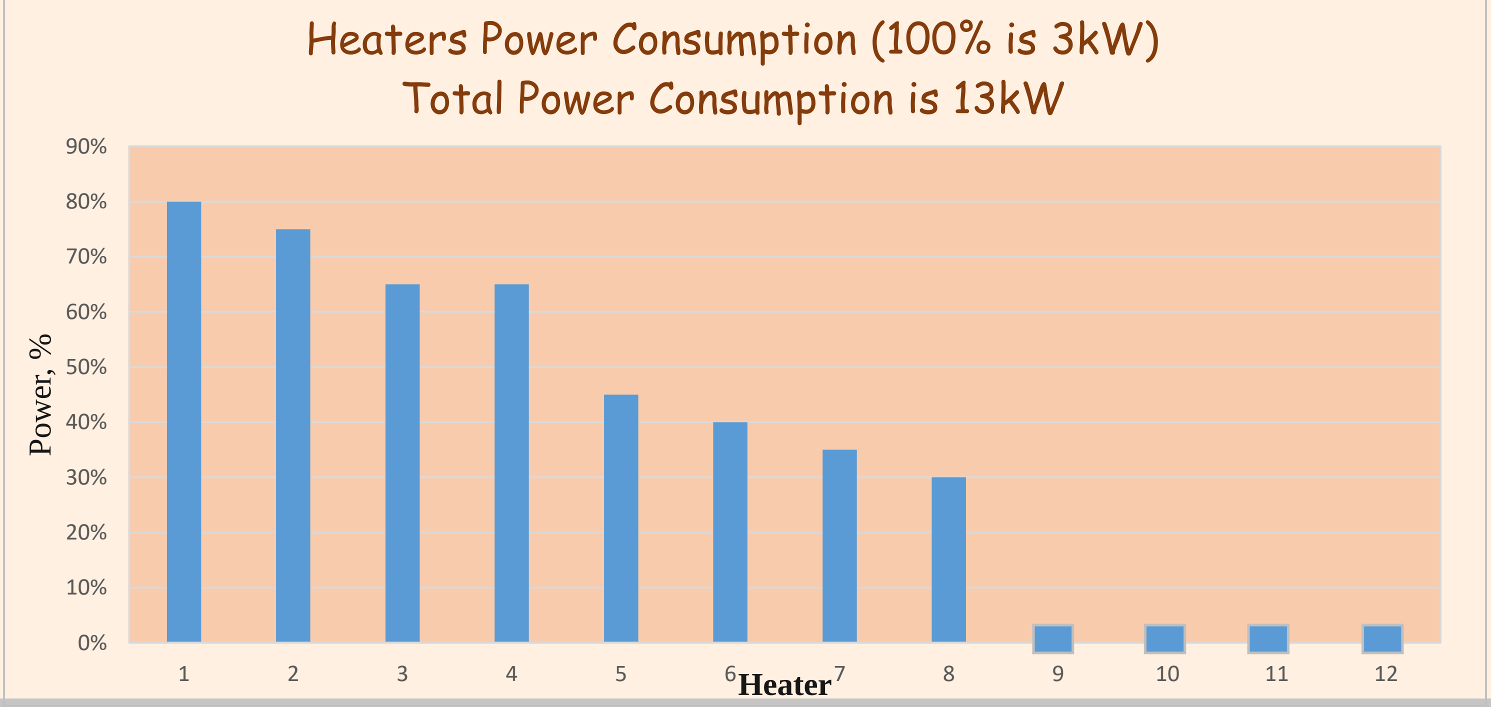
Lab-View Screen to run gasification skid



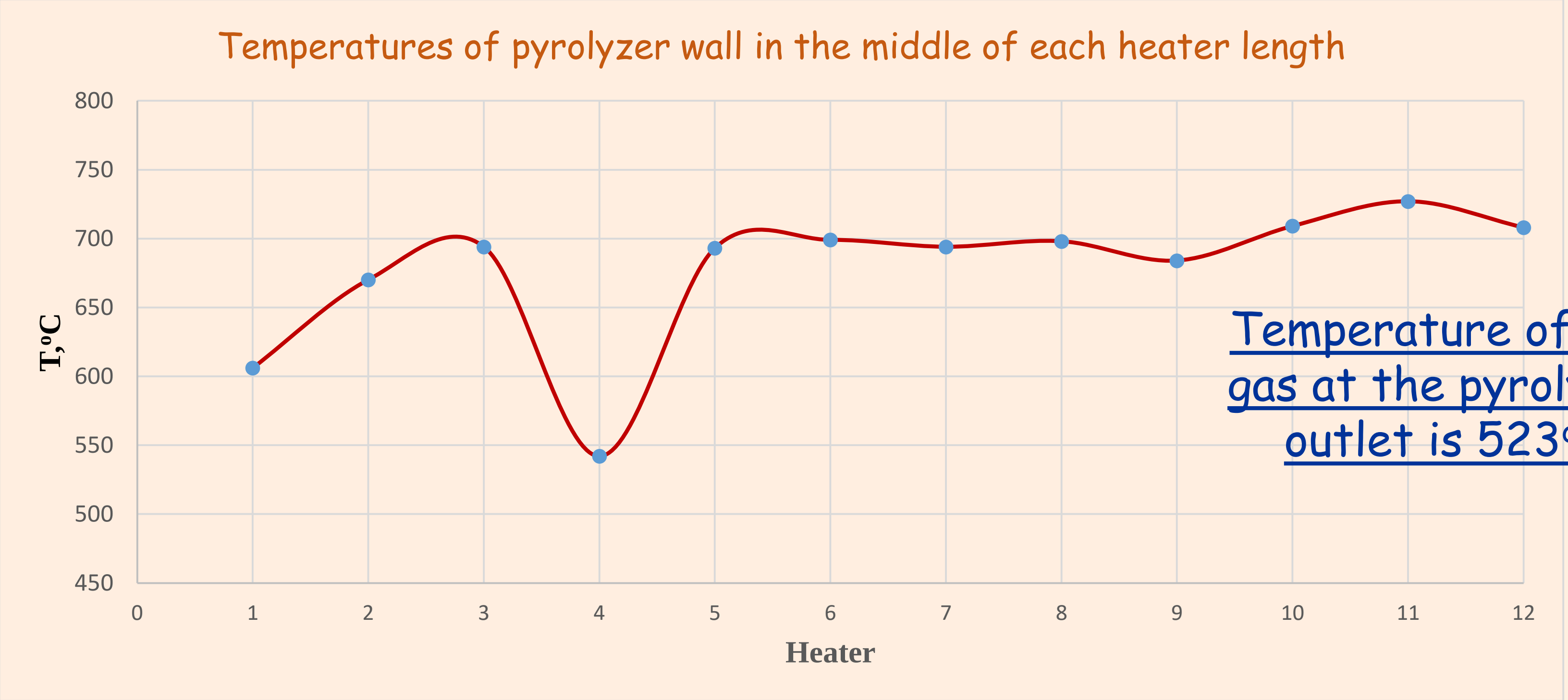
Current picture of gasification skid



Testing of electric pyrolyzer (at 15 lb/hr of coal; 35 lb/hr of superheated steam at 120-130°C)

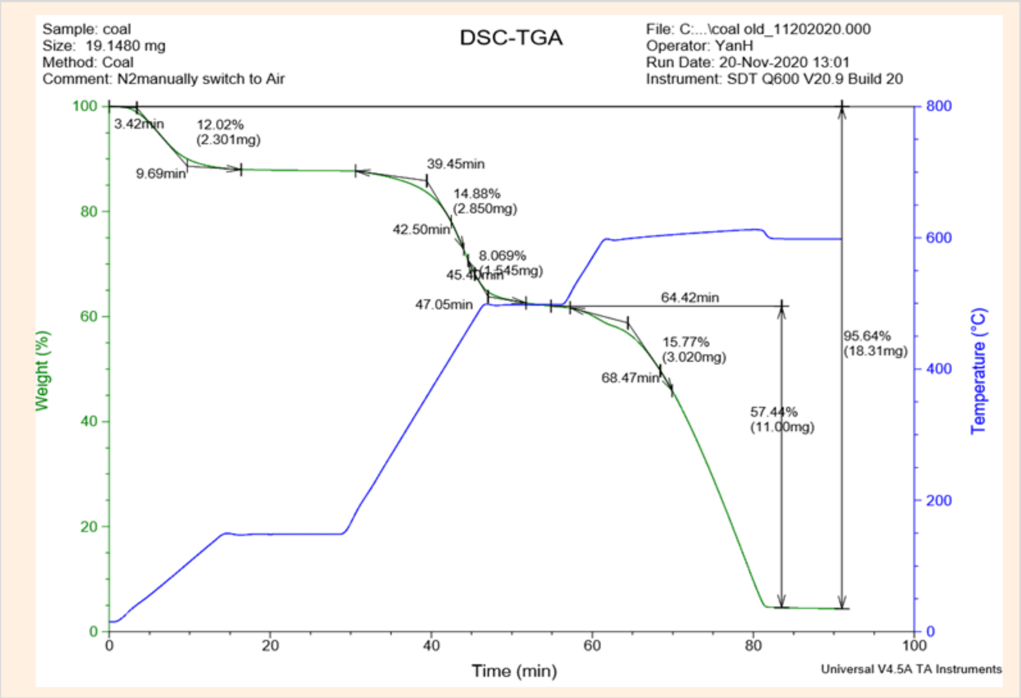


Testing of electric pyrolyzer (at 15 lb/hr of coal; 35 lb/hr of steam; residence time about 6 min.)

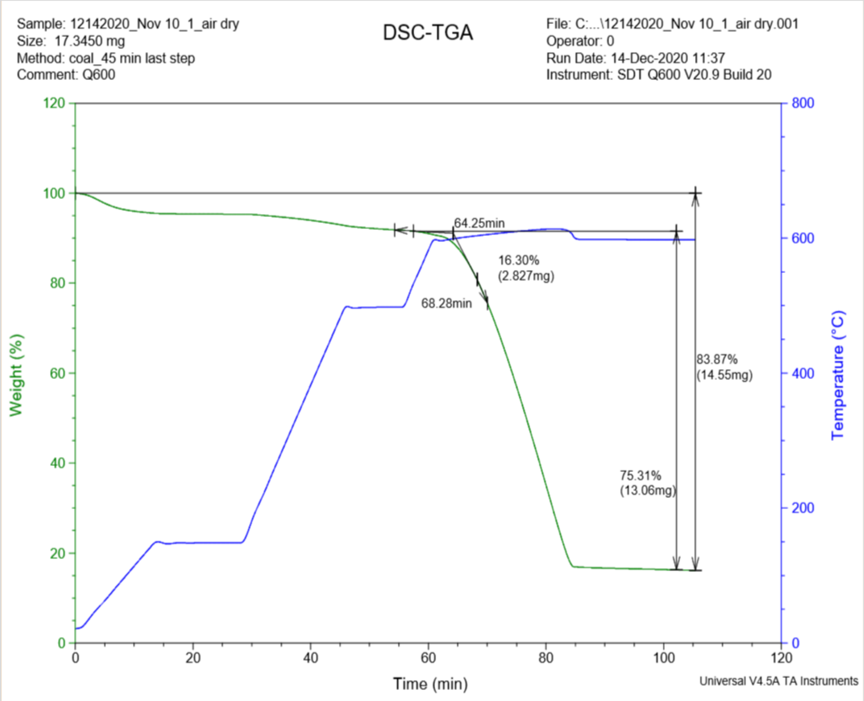


Efficiency of pyrolysis

Raw coal



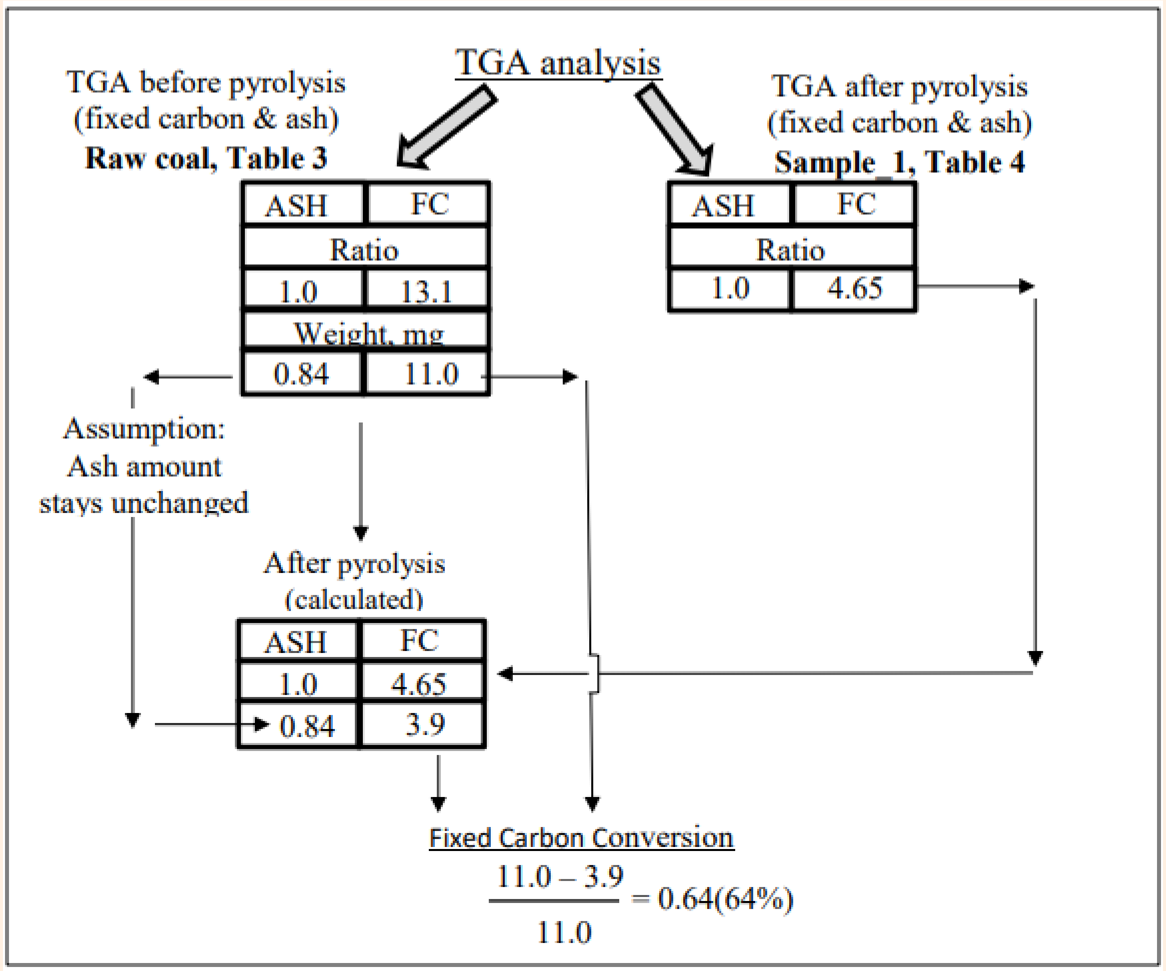
Char coal



Moisture, %wt.	Volatiles, %wt.	Fixed Carbon, %wt.	Ash, %wt.	Fixed carbon, mg	Ash, mg.
12.0	26.2	57.4	4.4	11.0	0.84
Without moisture					
Moisture, %wt.	Volatiles, %wt.	Fixed Carbon, %wt.	Ash, %wt.	Fixed Carbon/Ash	
0	29.8	65.2	5.0	13.1	

Fixed Carbon, %wt.	Ash, wt%	Fixed carbon, mg	Ash, mg.	FC/ASh
Oven dried				
71.5	15.6	15.6	3.4	4.6
Air dried				
75.3	16.13	13.1	2.8	4.7
			Average	4.65

Performance indicators of coal pyrolysis (steam:coal ≈2:1)



Coal Mass reduction: $\frac{19.15-(3.9+0.84)}{19.15}$ = 75%

≈73% of total carbon reduction (calculated)

LHV with raw coal: 26.1MJ/kg * 7kg/hr = 182.7MJ/hr

LHV in char = 6.7 MJ/kg-input *7 kg/hr=46.9 MJ/hr

Electricity is not converted into heating value of pyrolysis gas

LHV in pyrolysis gas = 182.7-46.9 = 135.8 MJ/hr

74% of heating value was recovered in Pyrolysis gas

Electricity is converted into heating value of pyrolysis gas

Accounting for 64% of C is converted $C+H_2O \rightarrow CO+H_2$

LHV in pyrolysis gas = 182.7-46.9+28.0 = 163.8 MJ/hr

90% of heating value was recovered in Pyrolysis gas

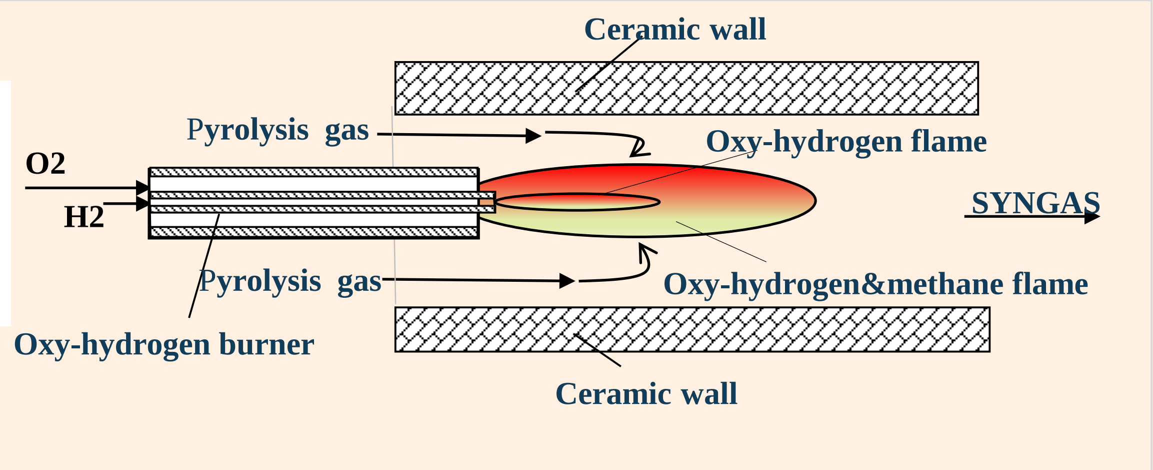
Electricity_pyrolyzer : 13kW *3600s = 46.8 MJ/hr

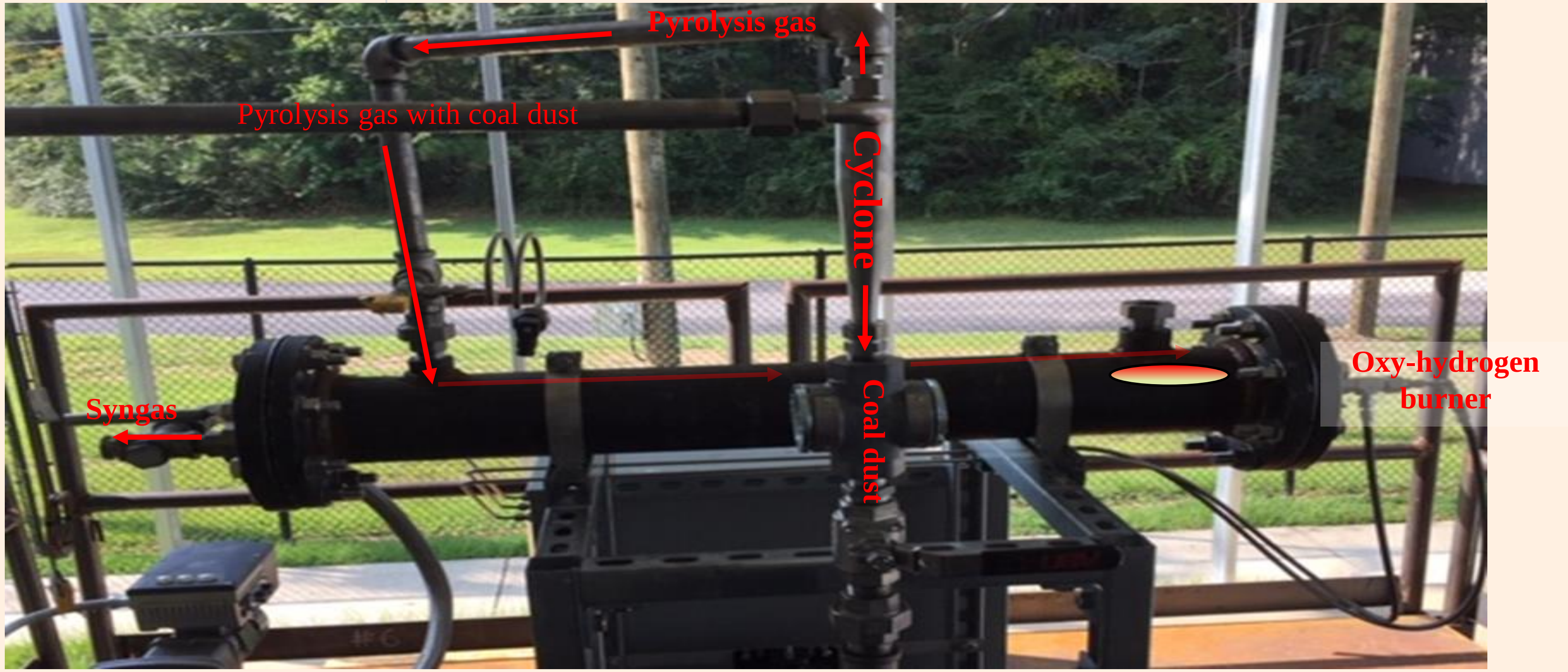
Electricity boiler : 10 kW *3600s = 36 MJ/hr

Thermal efficiency of Pyrolysis≈50%

Non-catalytic convertor

Oxygen is taken in an excess to stoichiometric amount to burn H2 to allow partial oxidation of hydrocarbons





Testing of the pilot-scale non-catalytic convertor

H_2,L/min	O_2,L/min	CH_4,L/min	Steam
10	15	20	-----

Non-stoichiometric oxy-hydrogen burner

$$H2 + 0.5\ O2 \rightarrow H2O\ (10\ L/min\ O2\ left)$$

L/min 10 15(5+10) 10

Stoichiometric ratio between CH4 and O2

$$CH4 + 0.5\ O2 \rightarrow CO + 2H2$$

L/min 20 10 20 40

Test results

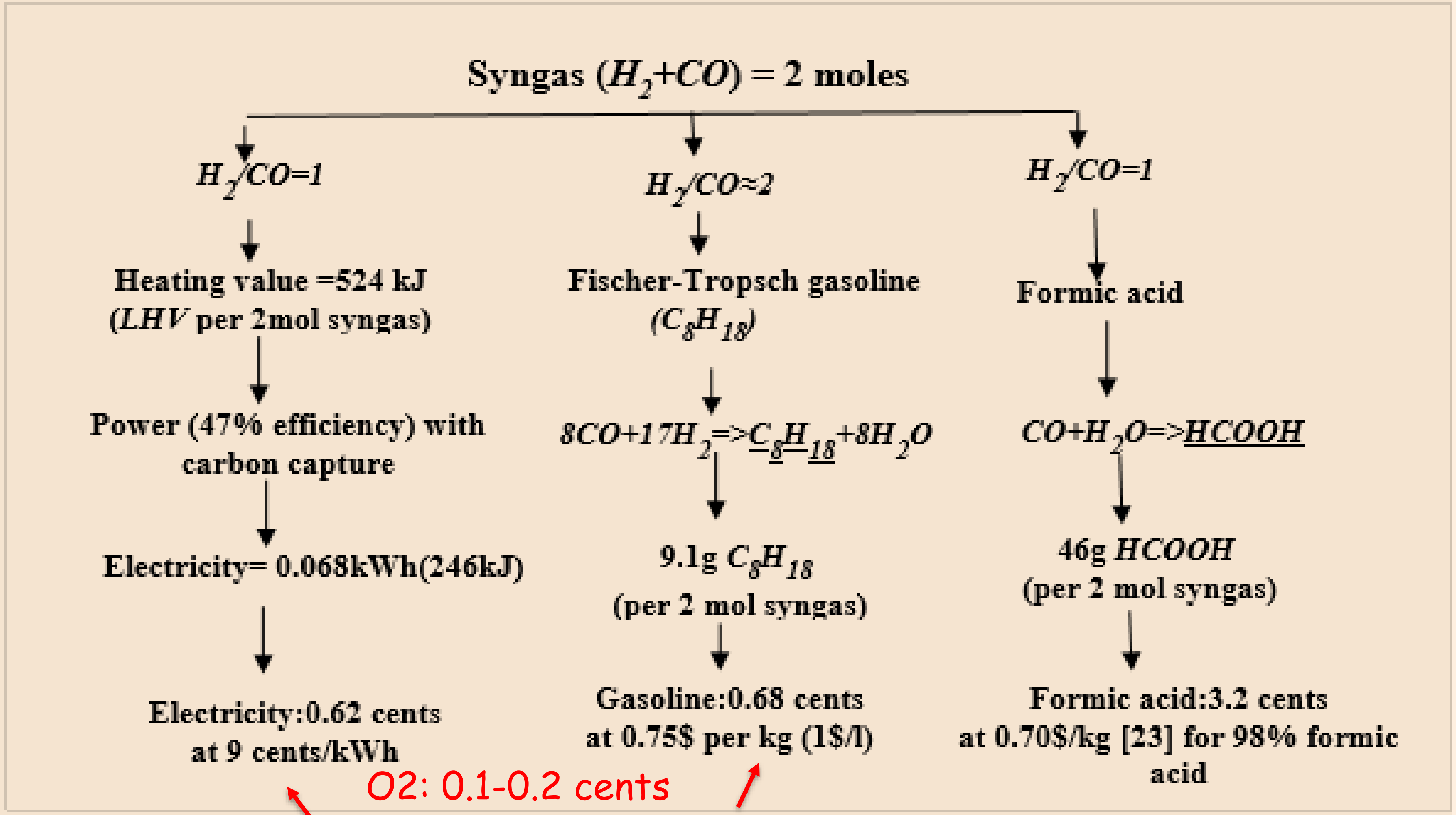
Units	H2	O2	N2	CH4	CO	CO2	C2H2
%, Vol.	56.7	0	2.8	11.9	30	5.03	1.05
L/min	23.1	0	1.14	4.85	12.2	2.05	0.43

$$\text{Methane Conversion} = \frac{20-4.85}{20} \approx 75\%$$

Efficiency of 75% of methane conversion into syngas (CO+H2)

$$\text{Methane-to-syngas efficiency} = \frac{23.1+12.2}{(20*3)*0.75} \approx 80\%$$

A commercial success depends on a syngas utilization technology



A significant relative decrease if O2 is used instead of air

(23) Chua, W.; Cunha, S.; Rangaiah, G.; Hidajat, K. Design and optimization of Kemira-Leonard process for formic acid production. *Chemical Engineering Science:X* **2019**, *2*, 1-16

Conclusions and Future Work

- Pyrolyzer was tested at 15 lb/hr of coal; steam:coal=2:1 ratio;
- Pyrolysis of bituminous coal with steam allows conversion of about 73% of carbon into pyrolysis gas
- A proprietary pilot-scale non-catalytic reactor was tested with methane with encouraging results
- The full experiment with conversion of pyrolysis gases into syngas is underway (after HAZOP analysis)

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Thanks for Listening! Questions?

SR

SOUTHERN RESEARCH

Solving the world's hardest problems.