Production of Syngas: Generation of Power and DME Synthesis

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Abstract

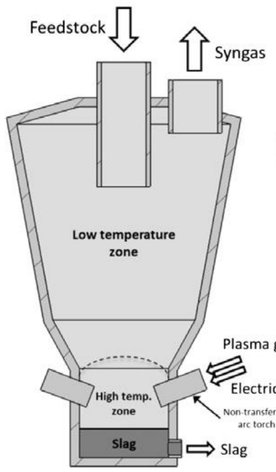
Refuse Derived Fuel (RDF) from municipal solid waste was used as the feedstock into a Plasma Gasifier in a two-step production process. Syngas, produced by the gasifier, was used as an energy source in a steam turbine that produced electricity. After losing heat, the syngas was then sent into a one-step synthesis process where it was converted into Methanol and Dimethyl Ether (DME) for sale. DME is used as an alternative to diesel fuel and Methanol is often used as a source for other products.

Feedstock Composition and Analysis

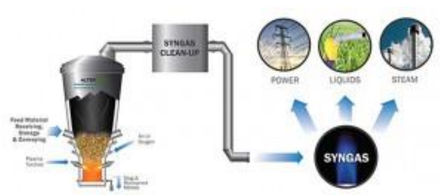
Component	Weight Percent (%)
Paper	50.0
Sawdust	3.0
Wood	11.0
Vegetation	3.7
Cloth	5.5
Plastics	10.0
Rubber	3.5
Resins	1.0
Electronics	3.0
Debris	4.5
Glass	4.0

Component	Dry Basis Mole Fraction (%)
Carbon	50.5
Hydrogen	5.6
Oxygen	30.7
Nitrogen	1.1
Chlorine	<0.1
Sulfur	0.3

Plasma Gasifier Diagram



Source: http://www.alternrg.com/waste_to_energy/



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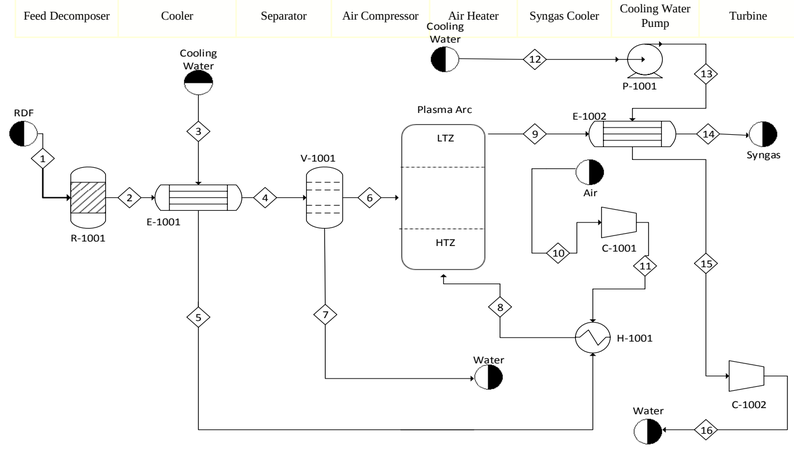
1. Plasma Gasifier

R-1001	E-1001	V-1001	C-1001	H-1001	E-1002	P-1001	C-1002
Feed Decomposer	Cooler	Separator	Air Compressor	Air Heater	Syngas Cooler	Cooling Water Pump	Turbine



Reactor Models

One-Step Synthesis Reactions:
[Bifunctional Catalyst] $CuO\text{-}ZnO\text{-}Al_2O_3 \cdot \gamma\text{–}Al_2O_3$

$CO + 2H_2 \leftrightarrow CH_3OH$ (Methanol Synthesis)

$CO_2 + 3H_2 \leftrightarrow CH_3OH + H_2O$ (Methanol Synthesis)

$2CH_3OH \leftrightarrow CH_3OCH_3 + H_2O$ (Dehydration)

$CO + H_2O \leftrightarrow CO_2 + H_2$ (Water-Gas Shift)

LHHW Kinetic Model (*K_1-K_7 Constants)

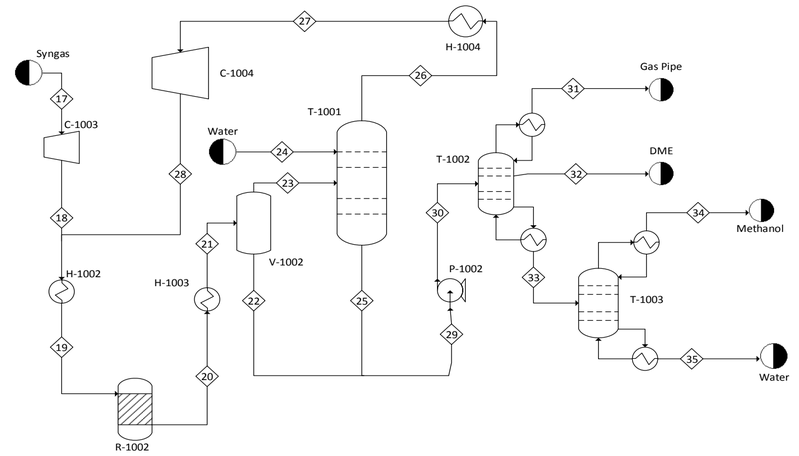
$$R_{Hydrogenation} = \frac{K_4\left[\frac{P_{CO2}P_{H2}}{1} - \frac{P_{CH3OH}P_{H2O}}{K_{E1}PH2^2}\right]}{\left[1 + K_3\left(\frac{P_{H2O}}{P_{H2}}\right) + K_1 P_{H2}{}^{0.5} + K_2 P_{H2O}\right]^3}$$

$$R_{Dehydration} = \frac{K5\left[\frac{P_{CO2}}{1} - \frac{P_{CO}P_{H2O}}{K_{E2}PH_2}\right]}{\left[1 + K_3\left(\frac{P_{H2O}}{P_{H2}}\right) + K_1 P_{H2}{}^{0.5} + K_2 P_{H2O}\right]}$$

$$R_{Water\text{-}Gas\ Shift} = \frac{K_3\left[\frac{P_{CH3OH}}{1} - \frac{P_{DME}P_{H2O}}{K_3 P_{CH3OH}}\right]}{\left[1 + K_7 P_{CH3OH} + \frac{P_{H2O}}{K_6}\right]}$$

2. DME Synthesis

C-1003	H-1002	R-1002	H-1003	V-1002	T-1001	P-1002	T-1002	T-1003	H-1004	C-1004
Syngas Compressor	Syngas Pre-Heater	Reactor (CSTR)	Condenser	Knock Out Drum	Absorber	Quench Pump	DME Column	Methanol Column	Rec. Heater	Recovery Comp.



Stream Summary

Stream	Temp. (C)	Pressure (Bar)	*Stream Cont.*	Temp. (C)	Pressure (Bar)
1	25	1	***17***	270	30
2	300	1	***19***	250	50
6	80	1	***20***	260	50
8	4000	32	***23***	40	30.4
9	1600	1	***31***	184	30
14	250	1	***32***	199	33
15	1476	150	***34***	180	10
16	570	1	***35***	180	10

Product Composition, Purity, and Power

Syngas (Mol Fraction)	
H_2O	0.055
H_2	0.517
CO	0.411
N_2	0.005
S	0.001
CO_2	0.011

Steam Turbine: Net Power
6.1 MW

Product	Purity
Methanol	99.7
DME	99.91

References

[1]Bouallou, Chakib and Everton Simoes Van-Dal. "Design and Siml=ulation of a Methanol Production Plant From Hydrogenation." *Journal of Cleaner Production* (2013): 38-45. Web. <https://www.researchgate.net/c/o41jjb/javascript/lib/pdfjs/web/viewer.html?file=https%3A%2F%2Fwww.researchgate.net%2Fprofile%2FChakib_Bouallou%2Fpublication%2F273855580_Design_and_simulation_of_a_methanol_production_plant_from_CO2_hydrogenation%2Flinks%2F>. [2]Galeno, G, M Minutilla and A Perna. "From waste to electricity through integrated plasma gasification/fuel cell (IPGFC) system." *International Journal of Hydrogen Energy* (2011): 1692-1701. Webpage. October 2015. <http://www.sciencedirect.com.portal.lib.fit.edu/science/article/pii/S0360319910022160>. [3]Janareh, Isam, Syed Shabbar Raza and Arnar Snaer Valmunsson. "Plasma Gasification Process: Modeling, Simulation and Comparison with Conventional Air Gasification." *Energy Conversion and Management* (2012). Web. [4]Jett, Paul Michael. *A Comparison of Two Modeled Syngas Cleanup Systems and Their Integration with Selected Fuel Synthesis Processes*. Thesis. Raliegh: University of North Carolina, 2011. Web. <http://repository.lib.ncsu.edu/ir/bitstream/1840.16/6851/1/etd.pdf>. [5]Westinghouse Plasma Corporation. *Converting the World's Waste into Clean Energy*. Annual Meeting Presentation. Washington DC: USEA, 2013. Powerpoint. <http://www.usea.org/sites/default/files/event-/Westinghouse_Walter_Howard.pdf>. [6]Yuanyuan, et al. "Modeling and Simulation of Production Process on Dimethyl Ether Synthesized from Coal-Based Syngas by One-Step Method." *Chinese Journal of Chemical Engineering* (2014): 108-112. Webpage. [7]Zhang, Qinglin, et al. "Gasification of Municipal Solid Waste in the Plasma Gasification Melting Process." *Applied Energy* (2011). Web.

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