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Experiences from the first 5 years of operation in Chalmers gasifier

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Göteborg Energi · CHALMERS · SP · VOLVO · e.on · Swedish Energy Agency · metso · AKADEMISKA HUS

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Chalmers Gasifier

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Commercialization

~50 Persons research activity at Chalmers, GU, SP, MiUN are devoted to support the development

Chalmers lab reactor

Chalmers
2-4 MW Raw Gas
Demonstration Plant

13 Million SEK

GoBiGas Phase 1 Hisingen
20 MW Biomethane Pilot Plant
Göteborg Energi

1400 Million SEK

GoBiGas fas 2 Hisingen
80-100 MW Biomethane
Commercial Plant
Göteborg Energi

3500 Million SEK

2008 → 2013 → 2017

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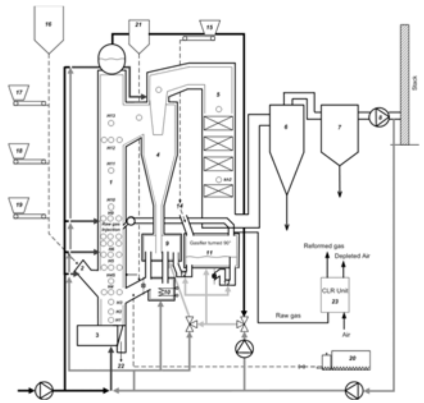
Chalmers Gasification Infrastructure

- Boiler designed for 12 MW_{th} operated typically at 6-8 MW_{th}
  - Operated continuously November to the beginning of April ~ 4000h/year
- Gasifier 2-4 MW
  - optional operation
  - Dual bed operation since start ~15000 h
  - where of ~2500 h with fuel to gasifier



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Specification of Chalmers Gasifier

Variation possibilities

- Fuel load 0 – 4 MW (0 - 1 ton/h)
  - (tested: 0-2.3 MW)
- Optional fluidization media
  - Steam
  - Flue gases
  - Air (not yet tested)
- Temperature in Gasifier 550-900 °C (tested 725 - 860 °C)
- Residence time
  - Adjustable solid flux
  - Adjustable bed height
- Fuel
  - Dry pellets (tested: Wood and Bark)
  - Wet biomass (tested: Wood chips)
- Bed material (tested: silica sand, silica sand/Illmunite bauxite, olivine)

Measurements

- Product gas composition and mass flow
- Solid flux
- Fuel feed
- Temperatures
- Pressures
- In plant gas and bed sampling
- Extraction of gas slip flow

Accumulated Time of Operation

with fuel ~2500 h without fuel ~12000 h

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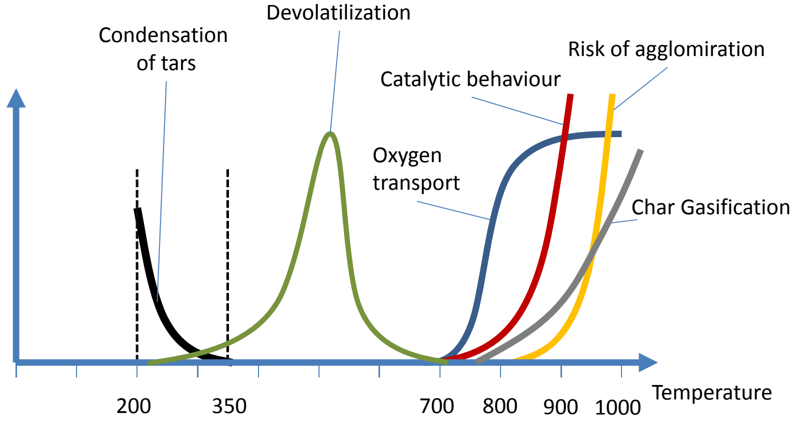
Processes to Consider



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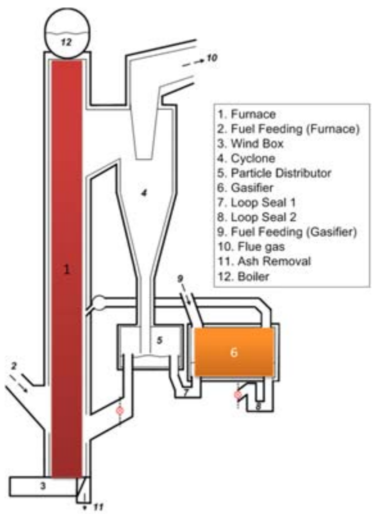
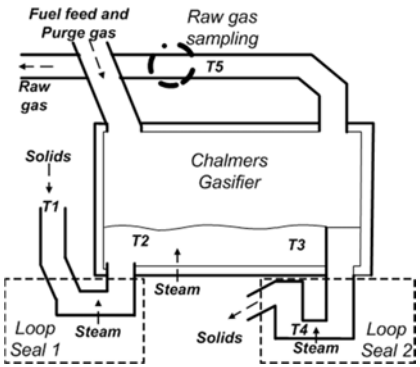
Experimental

Chalmers System





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Experimental

Gasification

Control room

Gas cooling and cleaning

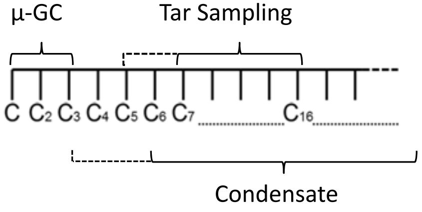
Bed Sampling

Fuel tracking

Gas analysis

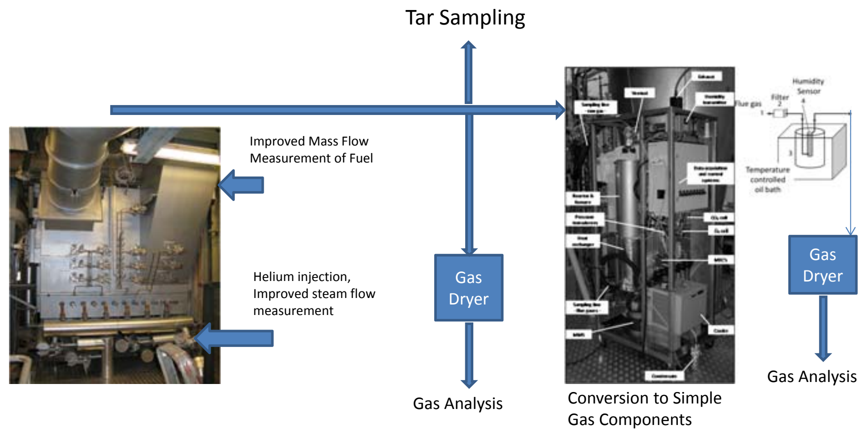
Gas Analysis

Raw Gas Contains:
H_2,CO,CO_2,H_2O,(N_2) and a large variety of organic compounds

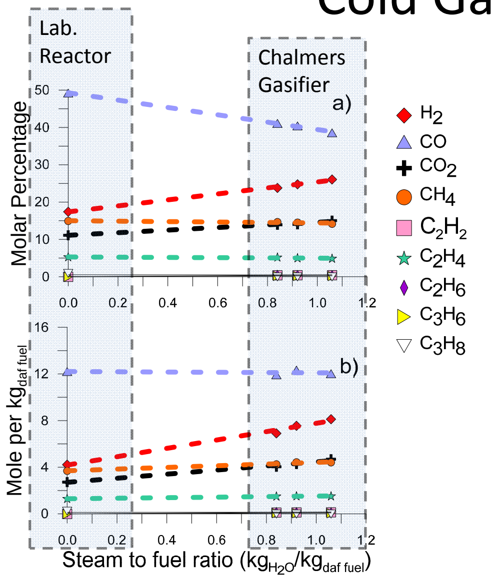


Cold Gas Contains:
H_2,CO,CO_2, (N_2) and C_1,C_2,(C_3) organic compounds

Gas Analysis



Cold Gas



Constant temperature (830˚C) and solids flow.

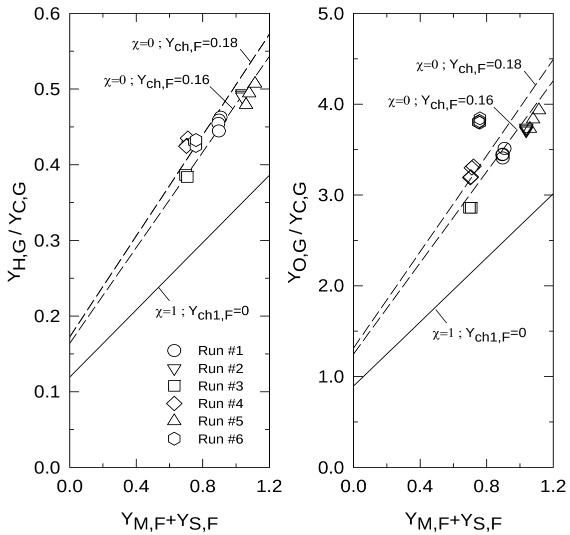
Change in Steam-to-fuel ratio

Over all reactions in Gasifier

1) C + 2H2O -> CO2 + 2H2

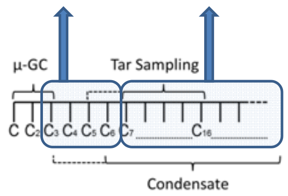
2) CxHyOz (+ aH2O) -> bCO2 + cH2

Elemental Composition of Raw Gas

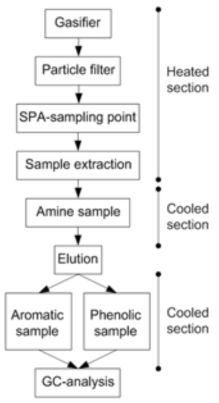


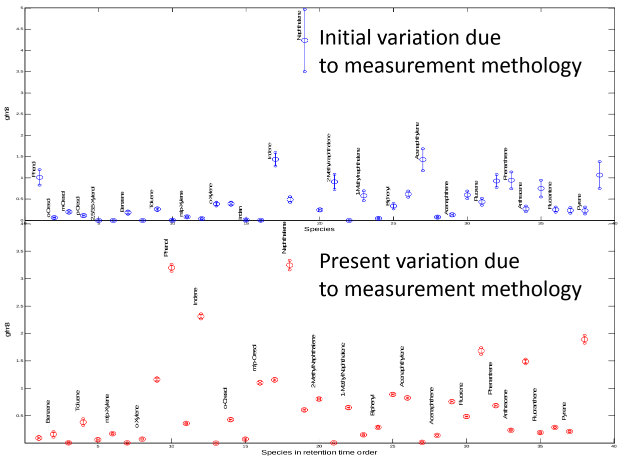
Comparison between Carbon Balance and Tar measurements show that:

Mass C3-C6 ≈ Mass Tars

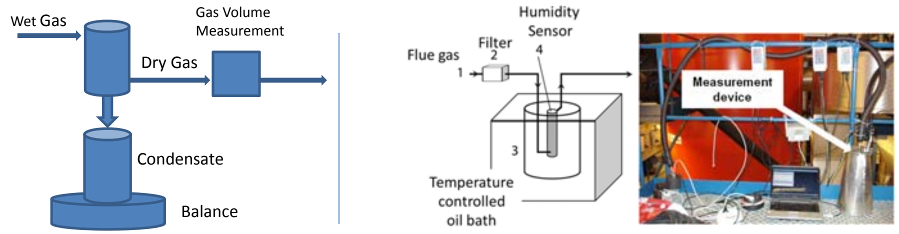


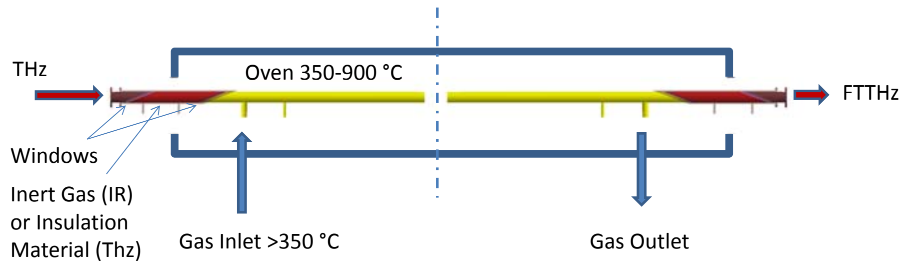
Development of Representative Tar Measurements



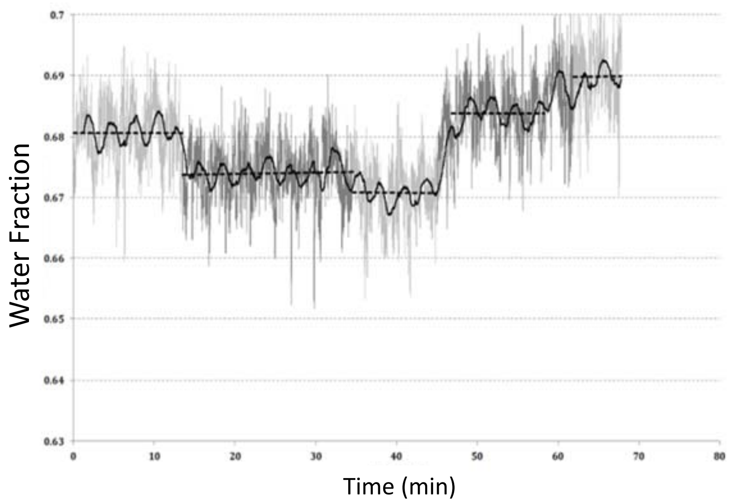


Water Concentration Measurements

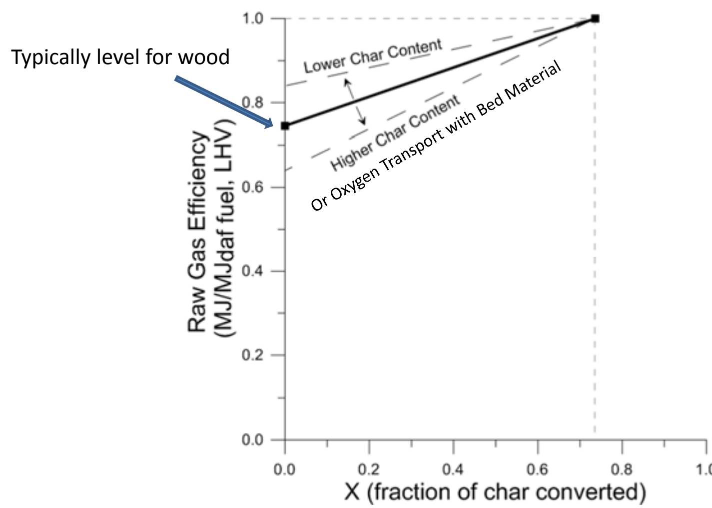




Water Concentration Measurements with THz

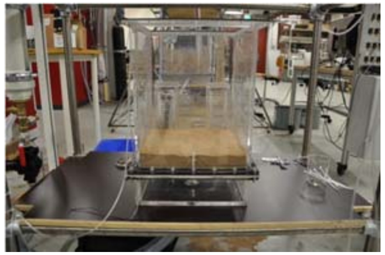


Raw Gas efficiency as Function of Char Gasification and Oxygen Transport

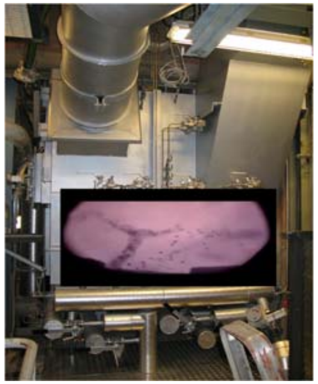


Residence time of Fuel in the Gasifier

Cold flow model



Gasifier

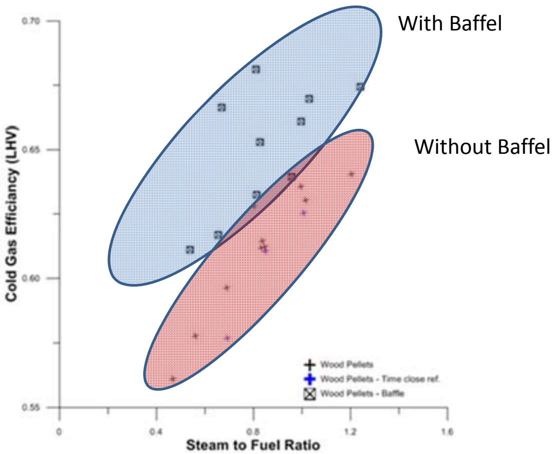


Fuel Tracking

Low Steam Flow

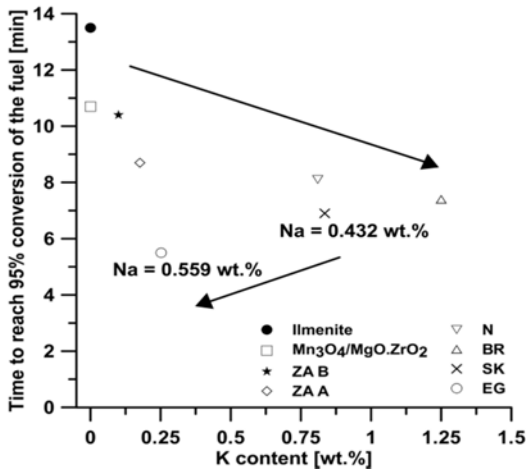
High Steam Flow

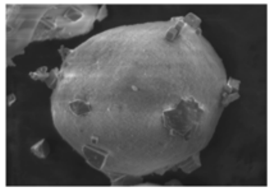
Separate of Bed Circulation and Fuel Transport



Bed Materials influence on Char Gasification

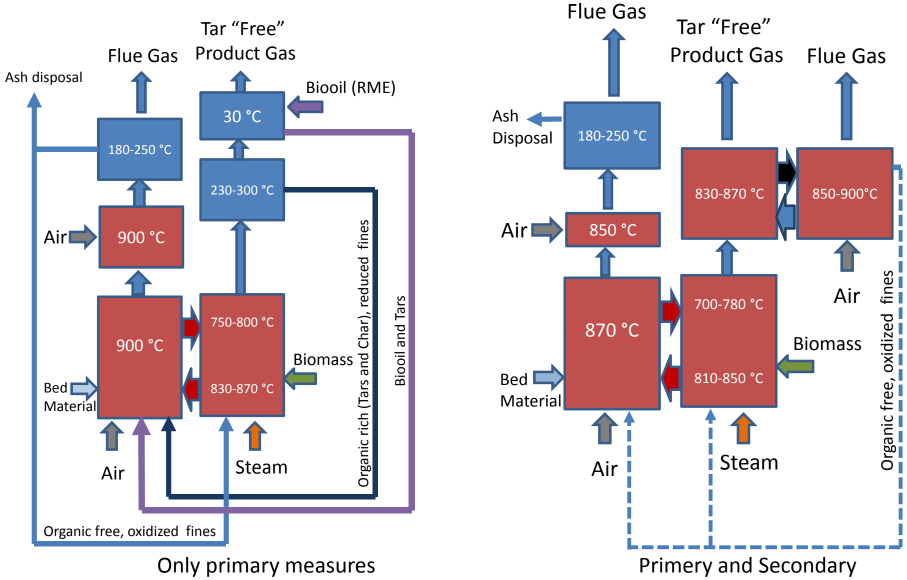
(Silica sand ~25 min)



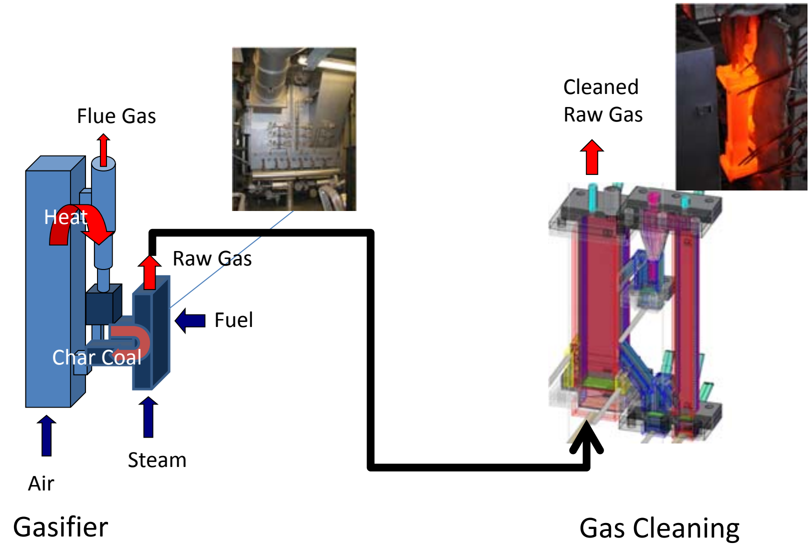


Can Ash deposits give the same effect?

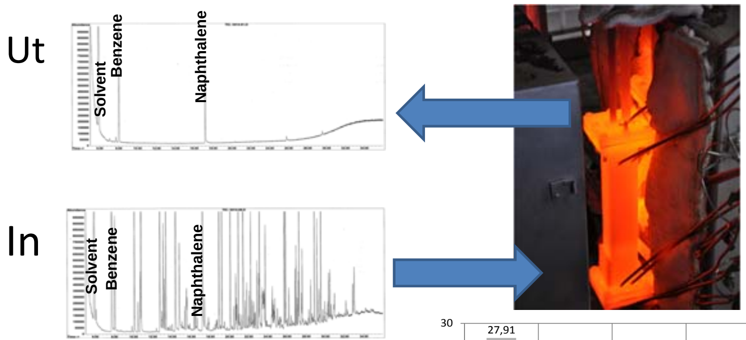
Catalytic Cracking of Tars

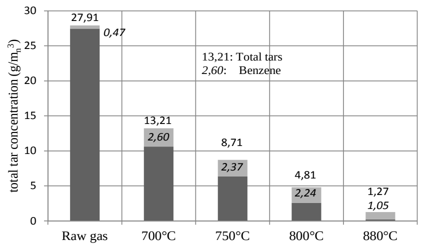


Primary and Secundary measuremnt



Exemple of Results





General Conclusion

- Raw gas produced by the devolatilzation in a dual fluidized bed is enough for all proposed biofuel processes
- Future plants with higher biofuel to biomass ratio needs that some of the Char is gasified
- Introduction of an known amount of inert gas (e.g. Helium) with the fluidization gas make it possible relate the measured gas components to converting fuel
- To enable a closure of the mass balance the raw gas need to be converted to a few simple gas components, for example, CO_2 and H_2O by combustion with an known amount of oxygen
- A closure of the mass balance reveal that standard analysis of cold gas and tars miss hydrocarbons in the range C3 to C6, which in amount will be of the same order as the measured Tars
- Catalytic material used for Primary reduction of Tars transport in most cases oxygen in a dual fluidized bed gasification system => need for gasification of Char

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General Conclusion (cont.)

- Bed material transport also other species between the reactor, for example, when using silca sand as bed material “all” sulfur is released as H2S in the gasifier independent in which reactor it is initially release
- Measurement of the water concentration in the raw gas can be done with a high frequency with THz waves and revile the characteristics of the process
- By controlling the fluidization and introducing baffles the residence time of fuel in the gasifier can be disconnected from the circulating bed material
- Potassium combined with certain bed materials can increase rate of char gasification in steam with a factor 10
- By dividing the dual fluidized gasifier into two consecutive dual fluidized beds the management of heat and oxygen transfer can be arranged so it is possible to convert all hydrocarbons to CO and H2