the Energy to Lead

Experiences supporting the IBR (integrated biorefinery) TIGAS project

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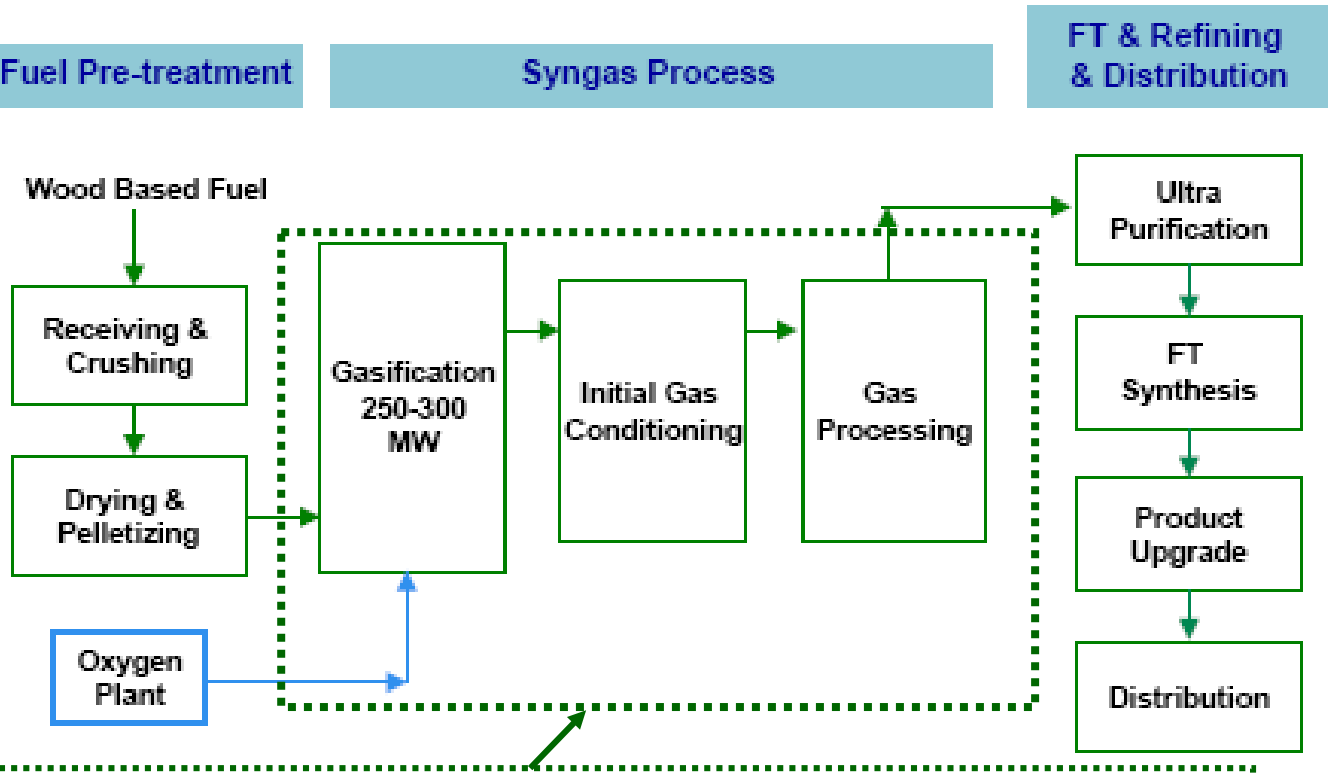
UPM-KYMMENE BIODIESEL PROCESS

ANDRITZ Carbona Projects:

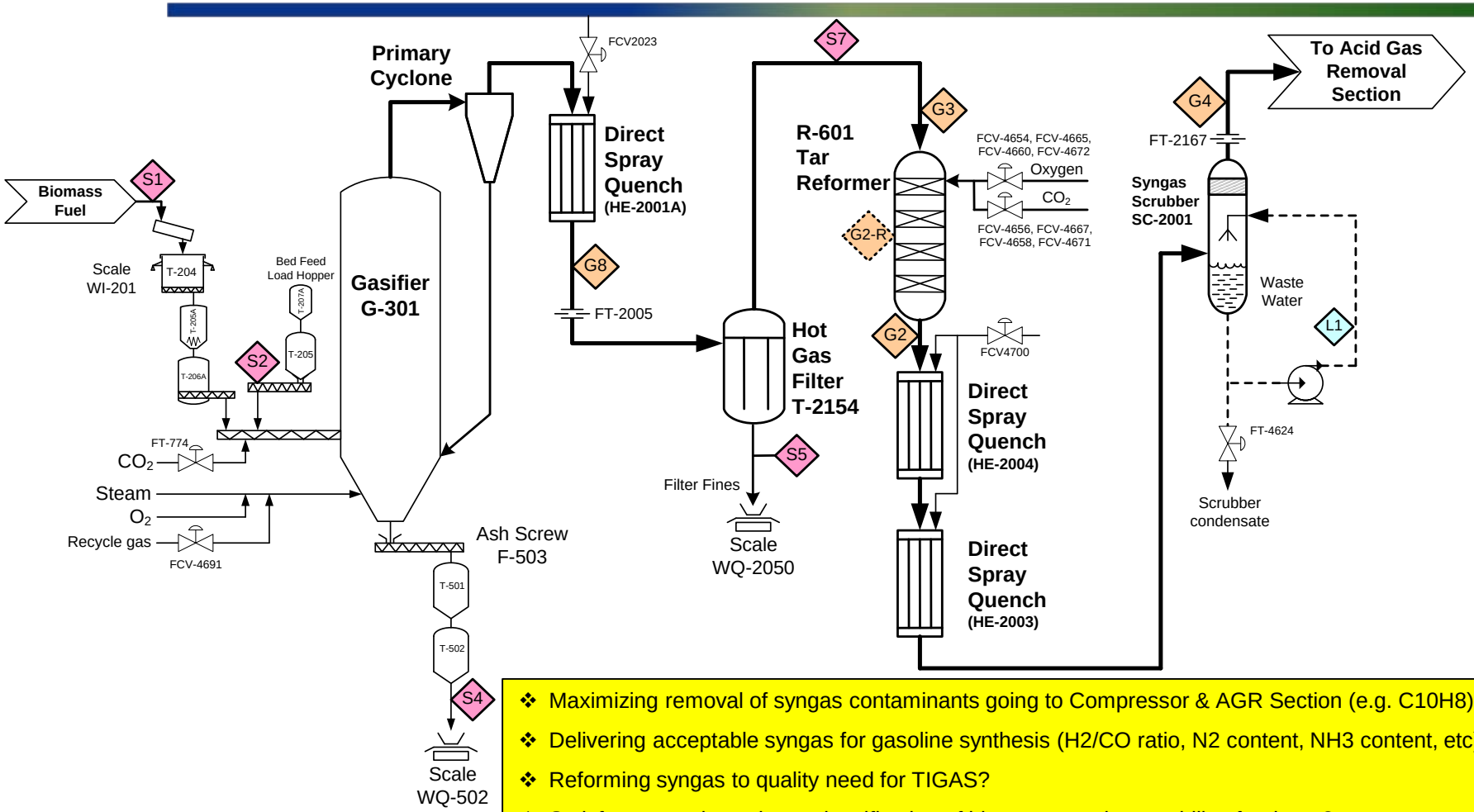
- Biodiesel with UPM-Kymmene, Finland
- SNG with E.ON, Sweden
- Wood-to-Gasoline (US DOE Recovery Act, multiple partners)



> GTI's involvement (R & D support):

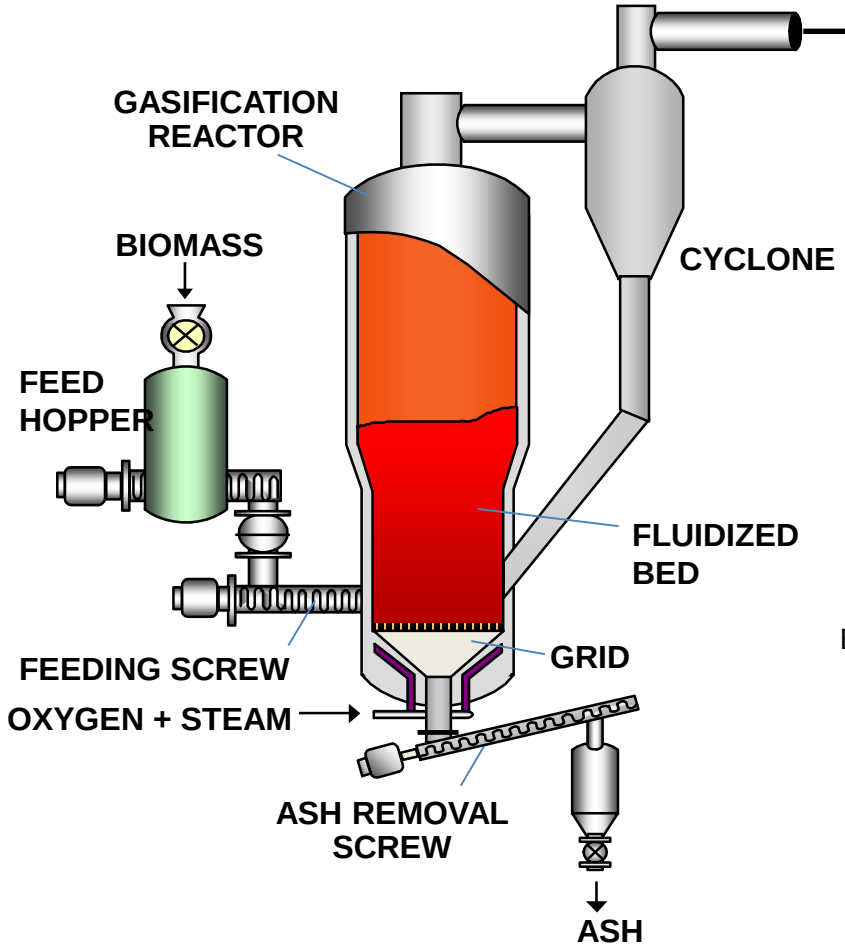
- > Further develop pressurized oxygen/steam gasification of biomass
- > Develop efficient tar reforming at higher pressure and other syngas cleanup for BTL (and SNG) applications
- > Develop design data for process scale up & integration; confirm simulation data
- > Generate data for EIS & other BTL process steps

GASIFICATION Section: Gasifier, Hot Gas Filter, Tar Reformer, Scrubber

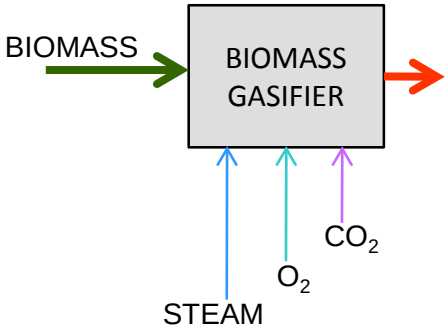


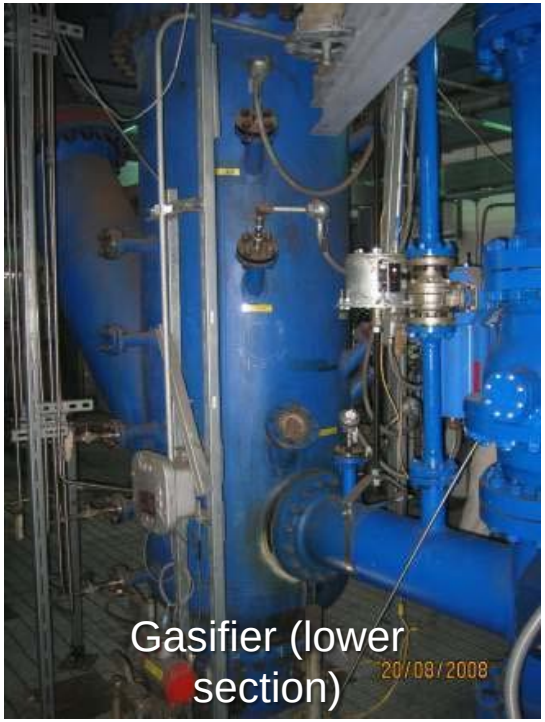
- Maximizing removal of syngas contaminants going to Compressor & AGR Section (e.g. C10H8)?
- Delivering acceptable syngas for gasoline synthesis (H2/CO ratio, N2 content, NH3 content, etc)?
- Reforming syngas to quality need for TIGAS?
- Satisfactory and consistent densification of biomass supply to stabilize feed rate?

Gasification (Andritz-Carbona)

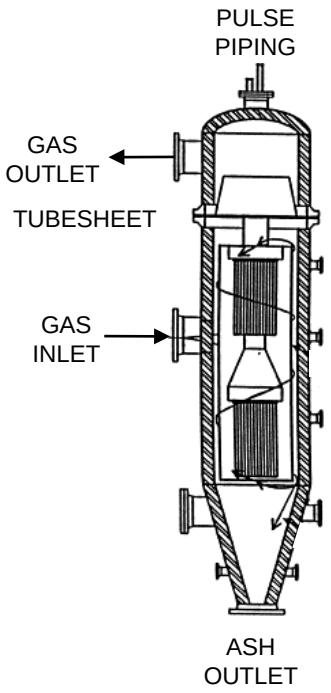


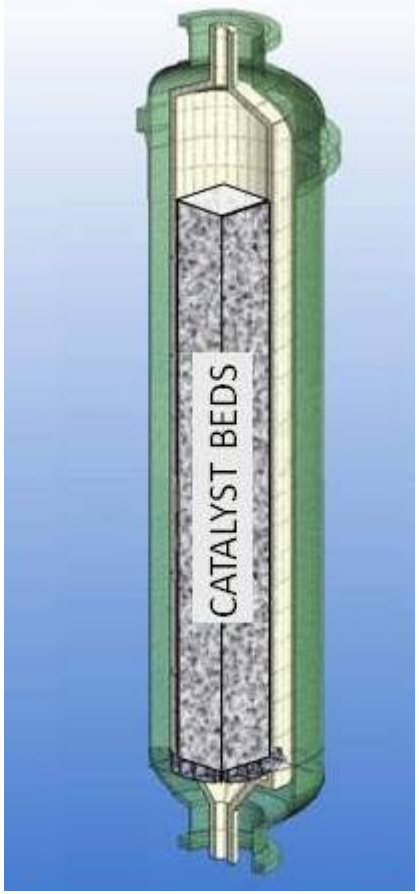
- > Oxygen-blown
- > Bubbling bed
- > High conversion efficiency (>95%)
- > Low syngas tar contamination



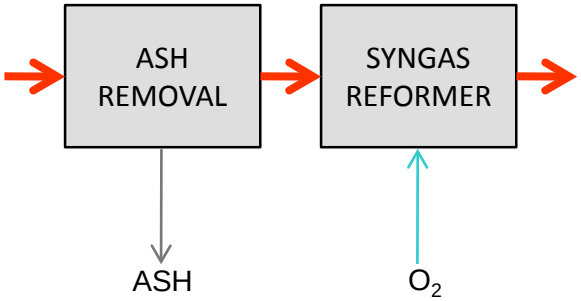


Syngas Cleanup (Andritz-Carbona & Haldor Topsoe)





- > Hot particulate filter
- > Catalytic syngas reformer
- > Converts C_{6+} tars and CH_4 to CO and H_2



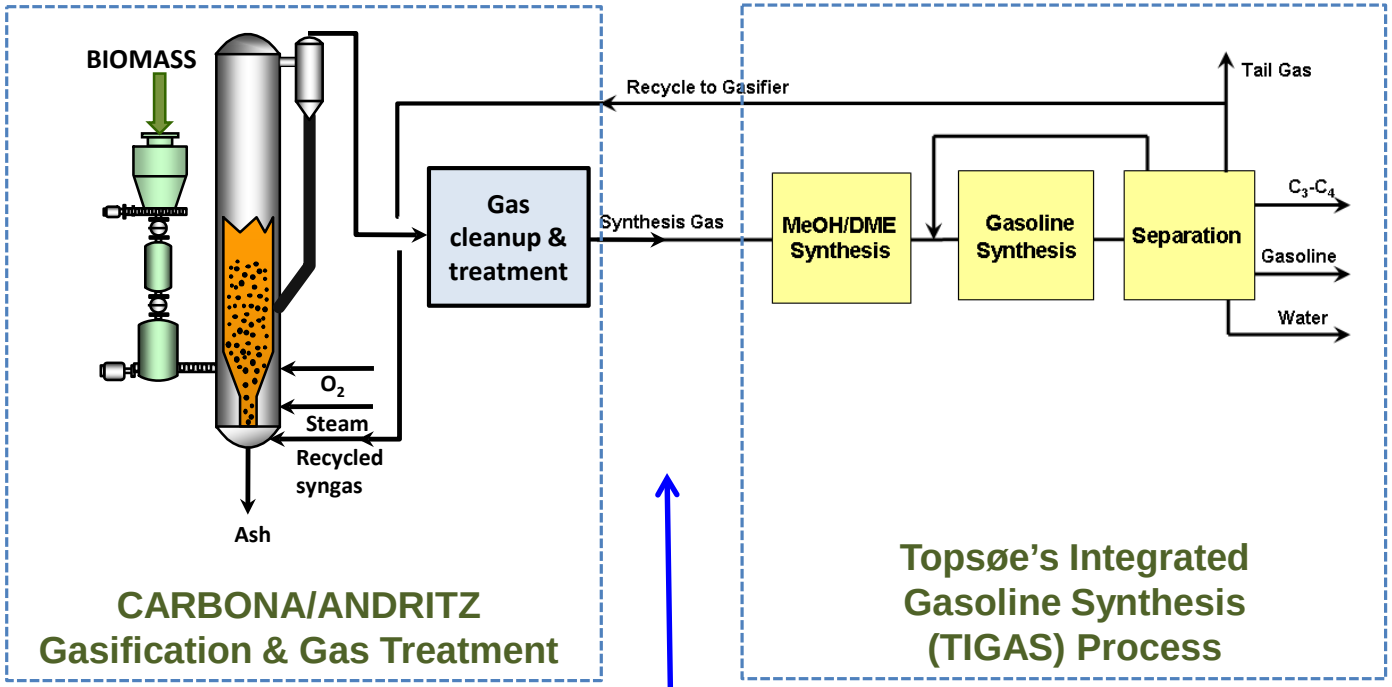
Database on numerous biomass fuels has been developed under wide ranges of operating conditions

- Empirical correlations on key parameters developed:
  - Water-Gas-Shift equilibrium approach
  - Methane make
  - Light HCs and tars yield
  - Carbon conversion
- Development of a proprietary model
  - Empirical correlations
  - Useful tool throughout project life
    - Test planning and execution
    - Data analysis
    - Scale up/process design package

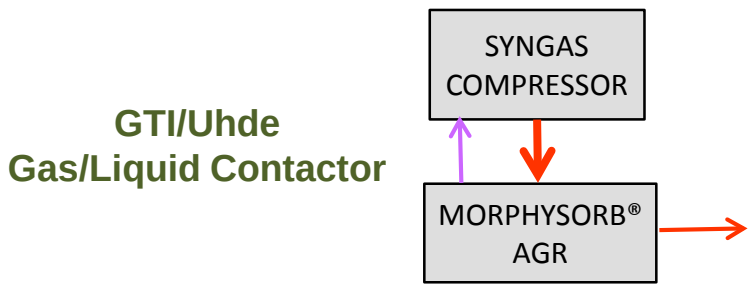
Development Highlights:

- Over 1000 hours of Gasification Section operation
- Generated complete data packages to support detailed study of over 30 stable operating periods or steady states (from several hours to over 10 days in duration)
- Tested various fuels (bark, forest residue, stump, etc.)
- Tested different gasifier bed materials
- Tested different reformer catalysts

IBR: Integrate Gasification & Gas Treatment (CARBONA-UPM test configuration) / Acid Gas Removal / TIGAS



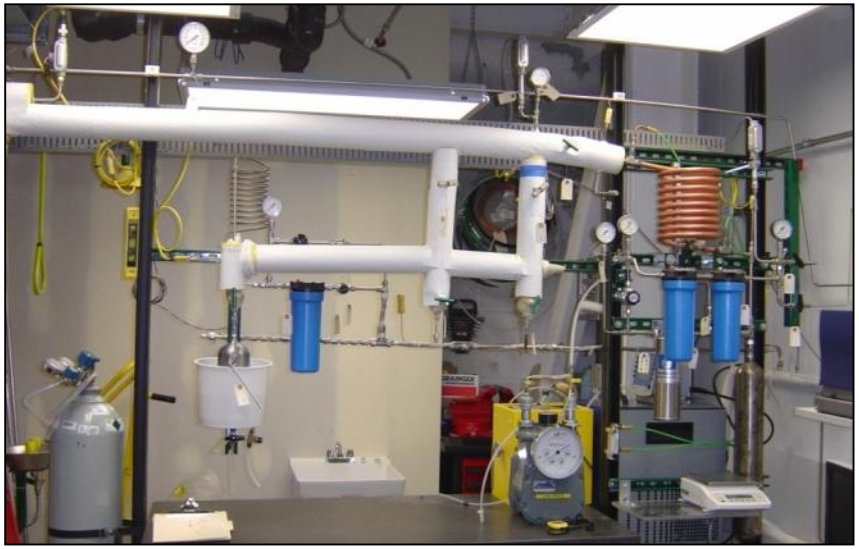
Pilot unit feeds **21** tons/day of pelletized woody biomass (mixed wood waste) to produce **23** bbl/day of gasoline blendstock

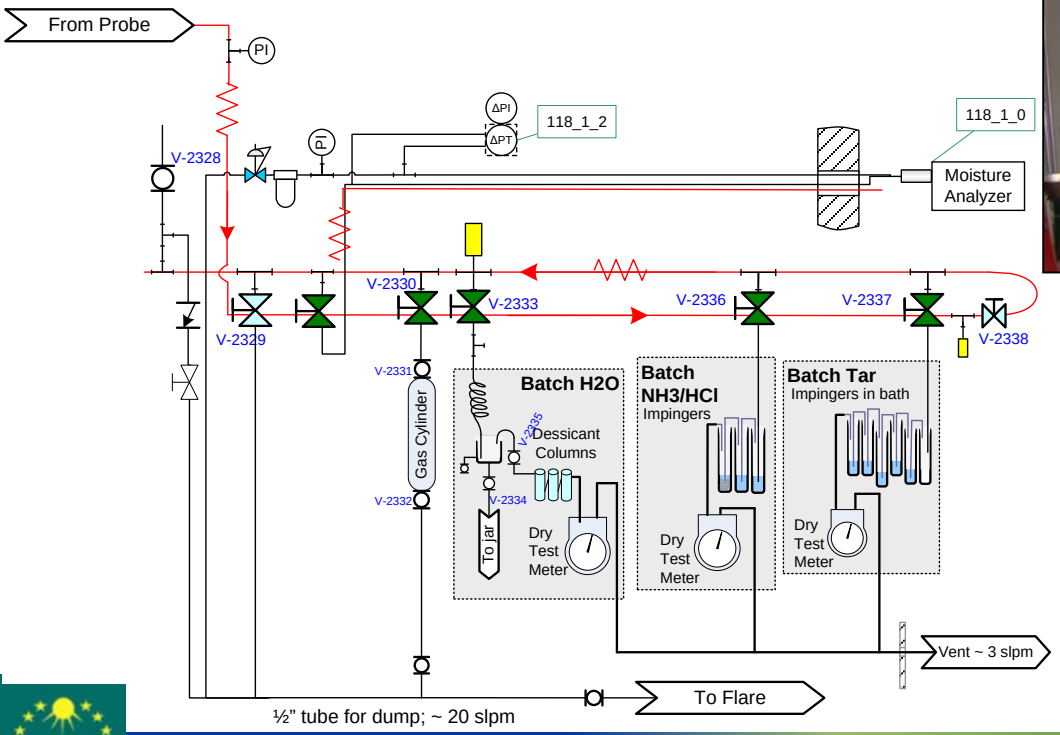


Batch Sampling Systems/offline analyses to confirm & complement online measurements

> Modified European Tar Protocol

> Moisture (gravimetric)





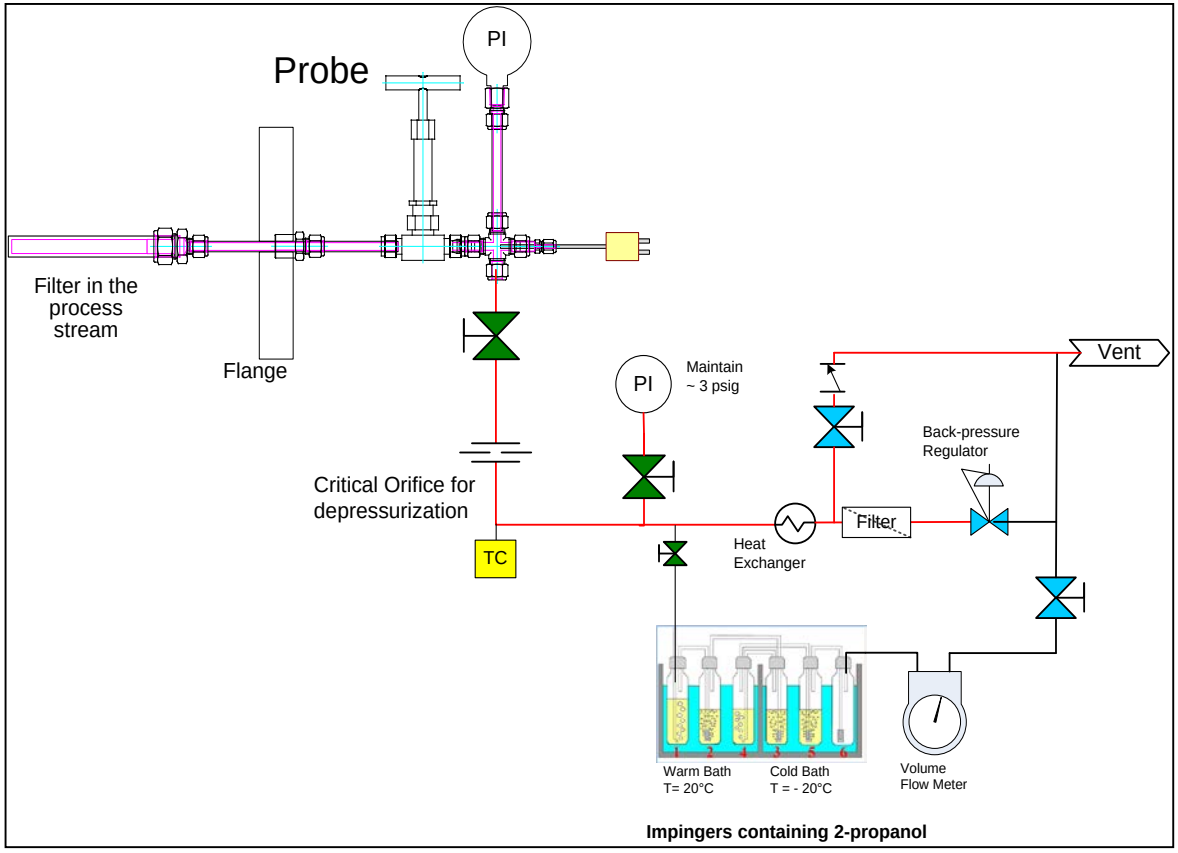
> HCl/Ammonia/Alkali

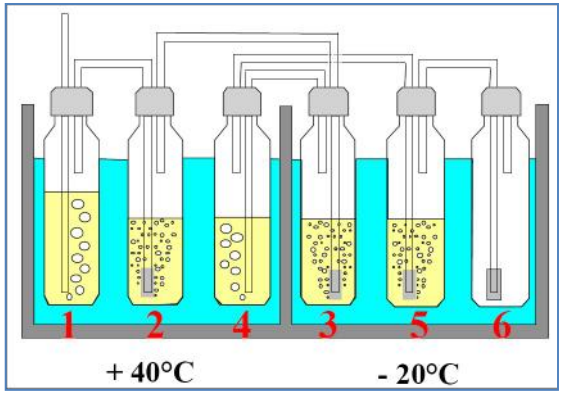
> HCN

> Trace Elements (As, Cd, Se, etc.)

> Mercury

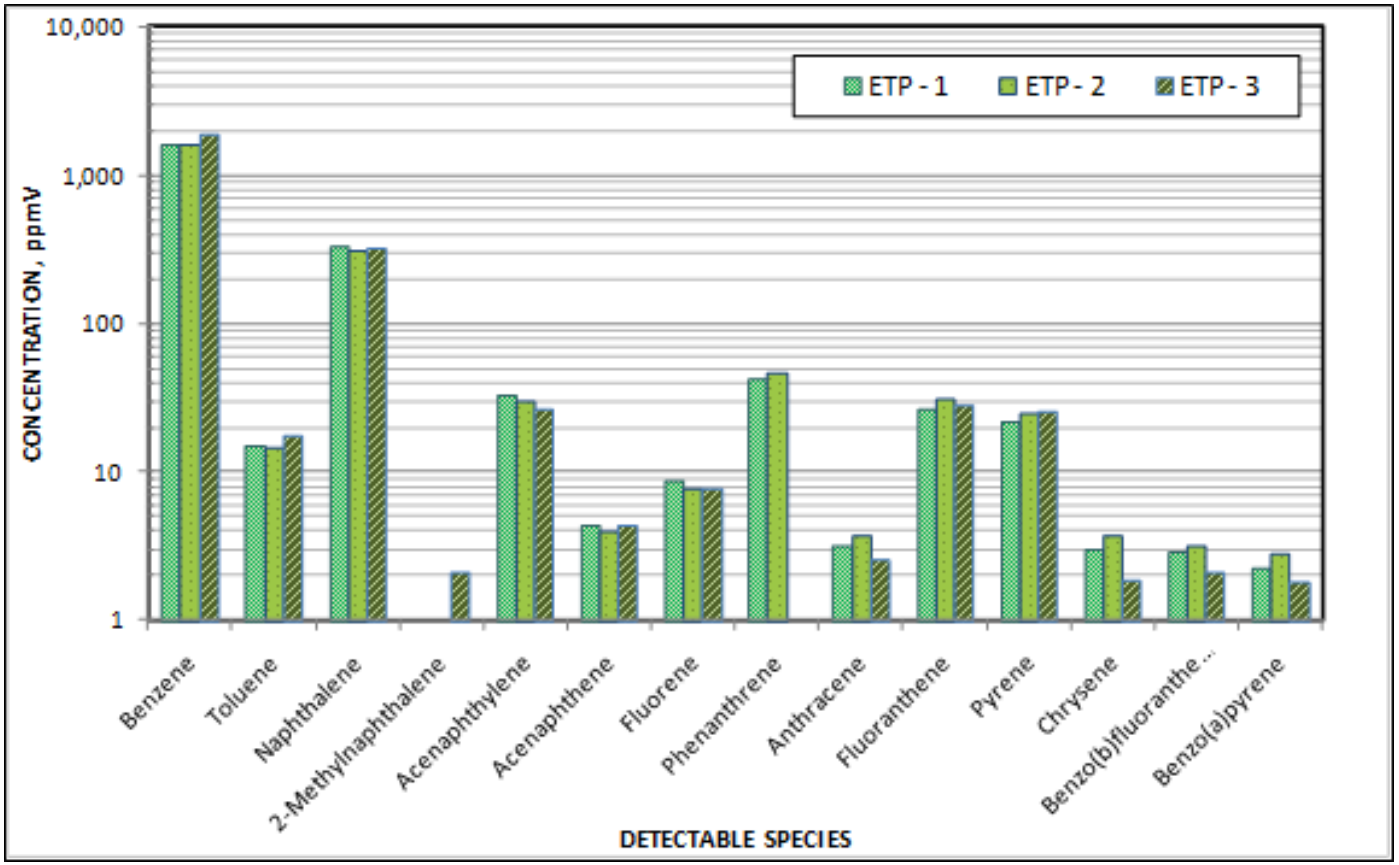
Details of the GTI-Modified ETP (off-line benchmark: CEN/TS 15439)



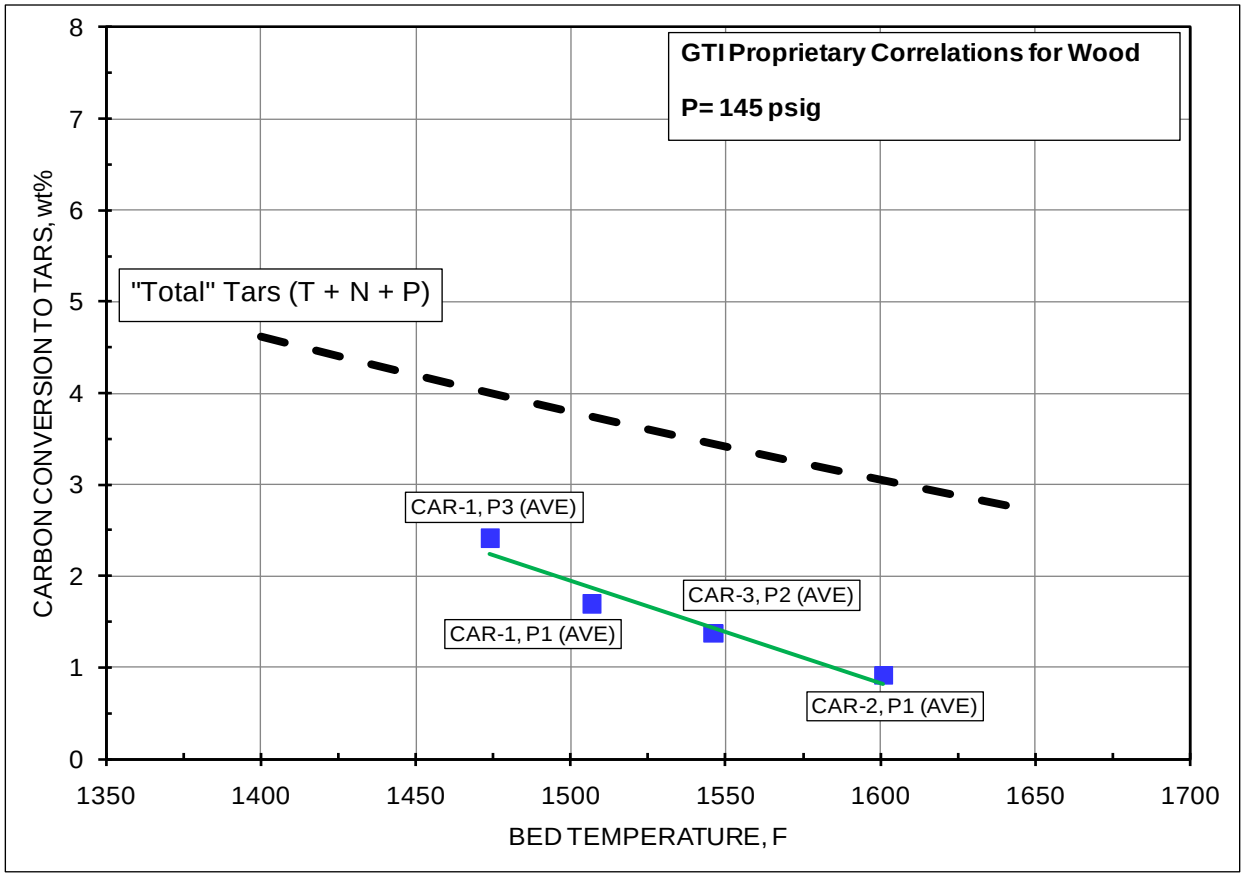


Ensure consistency: Preparation, recovery, and GC/MS analysis by GTI's in-house analytical lab

Consistency of test results



U-GAS® Model correlations for model tar compounds vs test data

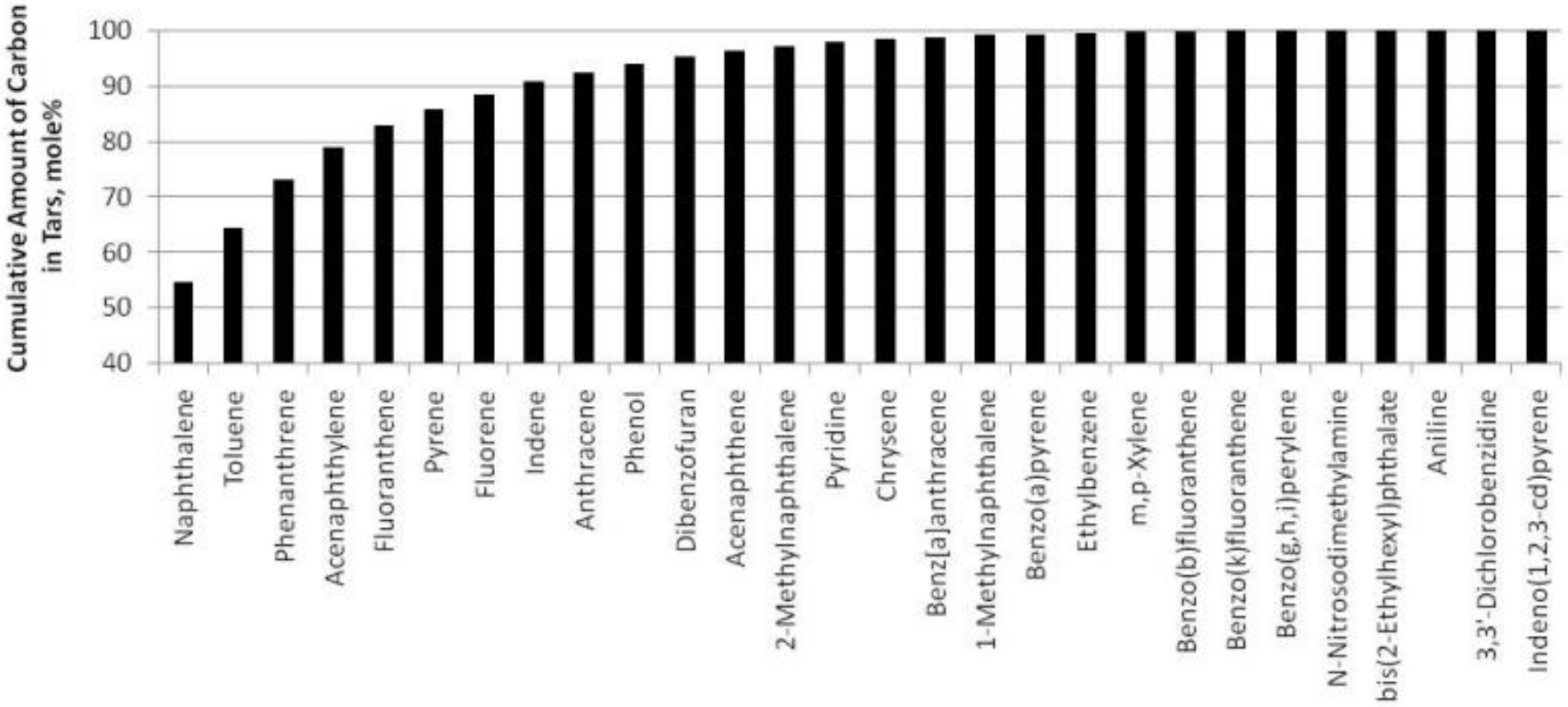


Model is a good tool for test data assessment:

✓Trend of tars yield with increasing temperature consistent with expectation

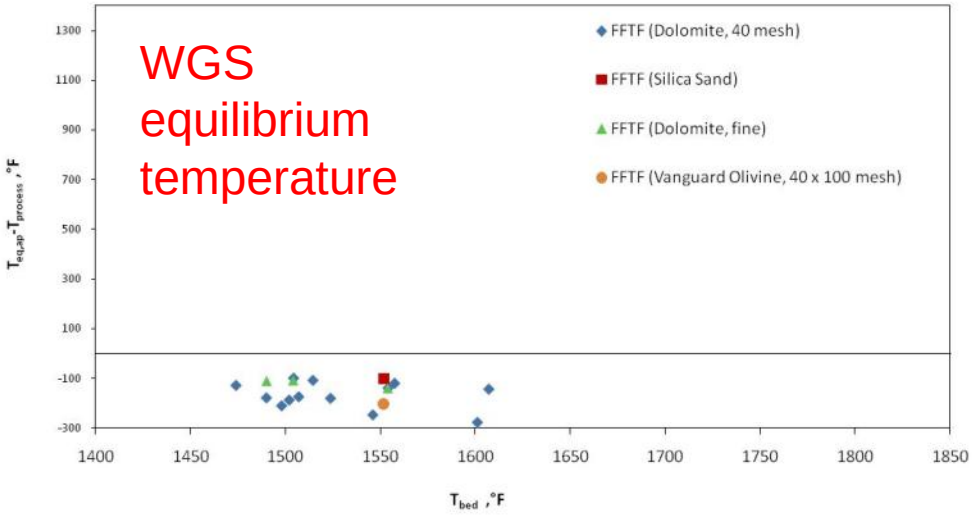
✓Contribution of somewhat active bed material to in-situ reforming of tars evident

Tars Yield & Speciation

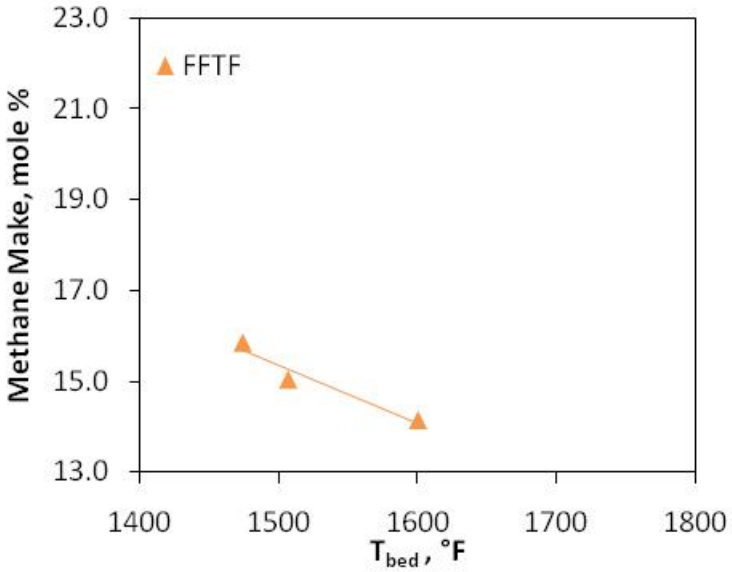


Data on other key gasifier performance parameters

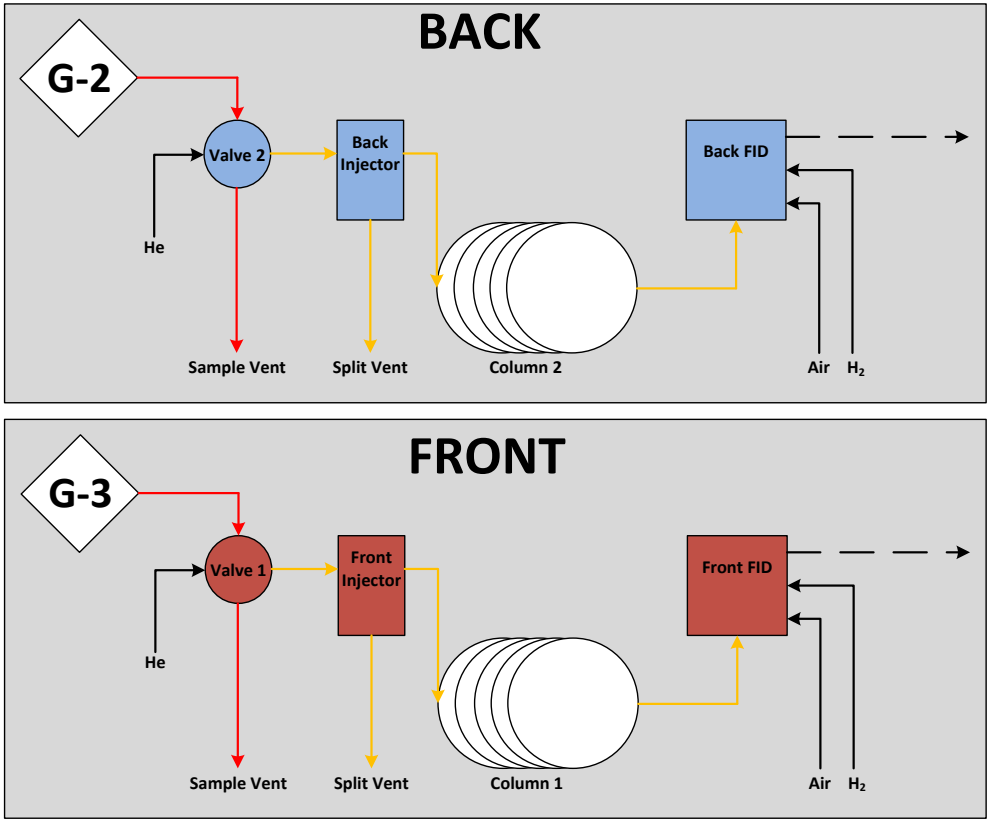
WGS equilibrium temperature



Methane make

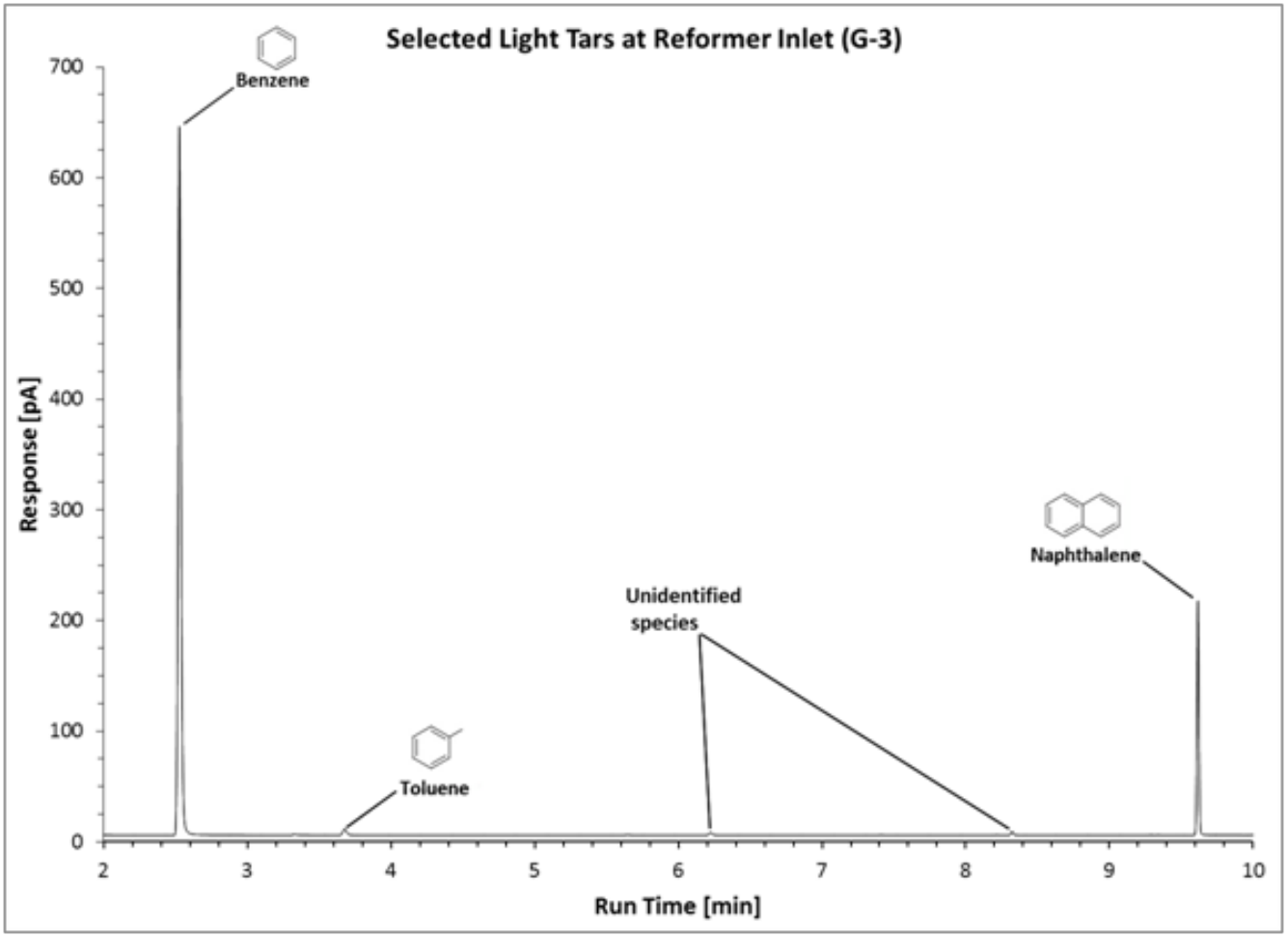


Key Instruments - Agilent® 7890A GC



- Dual channel GC-FID. Has two sets of sampling valves, injectors, columns, detectors (FID)
- Can do simultaneous analysis of two sample points using the same analysis method

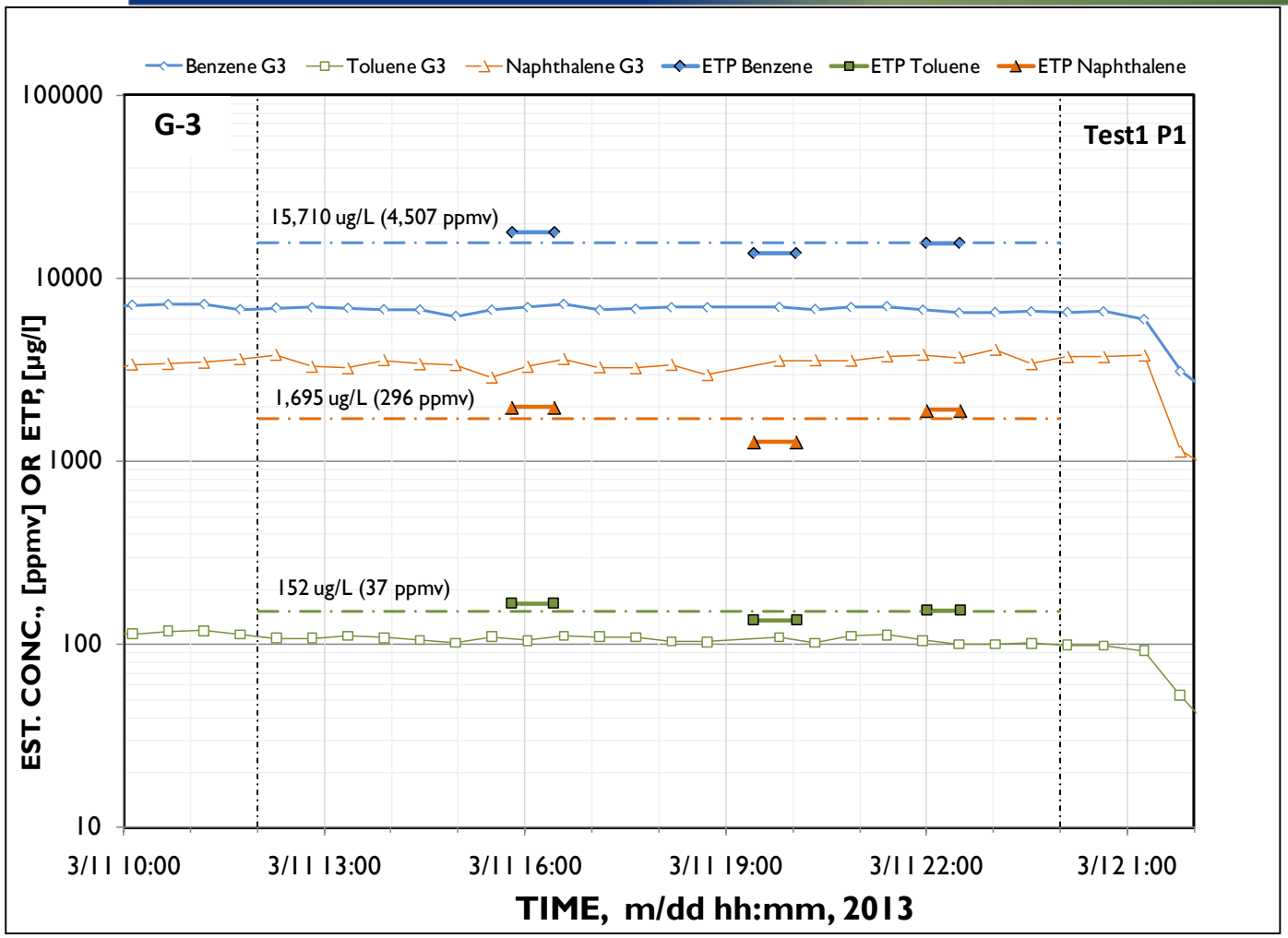
A typical G-3 chromatogram showing analytes of interest



Current:

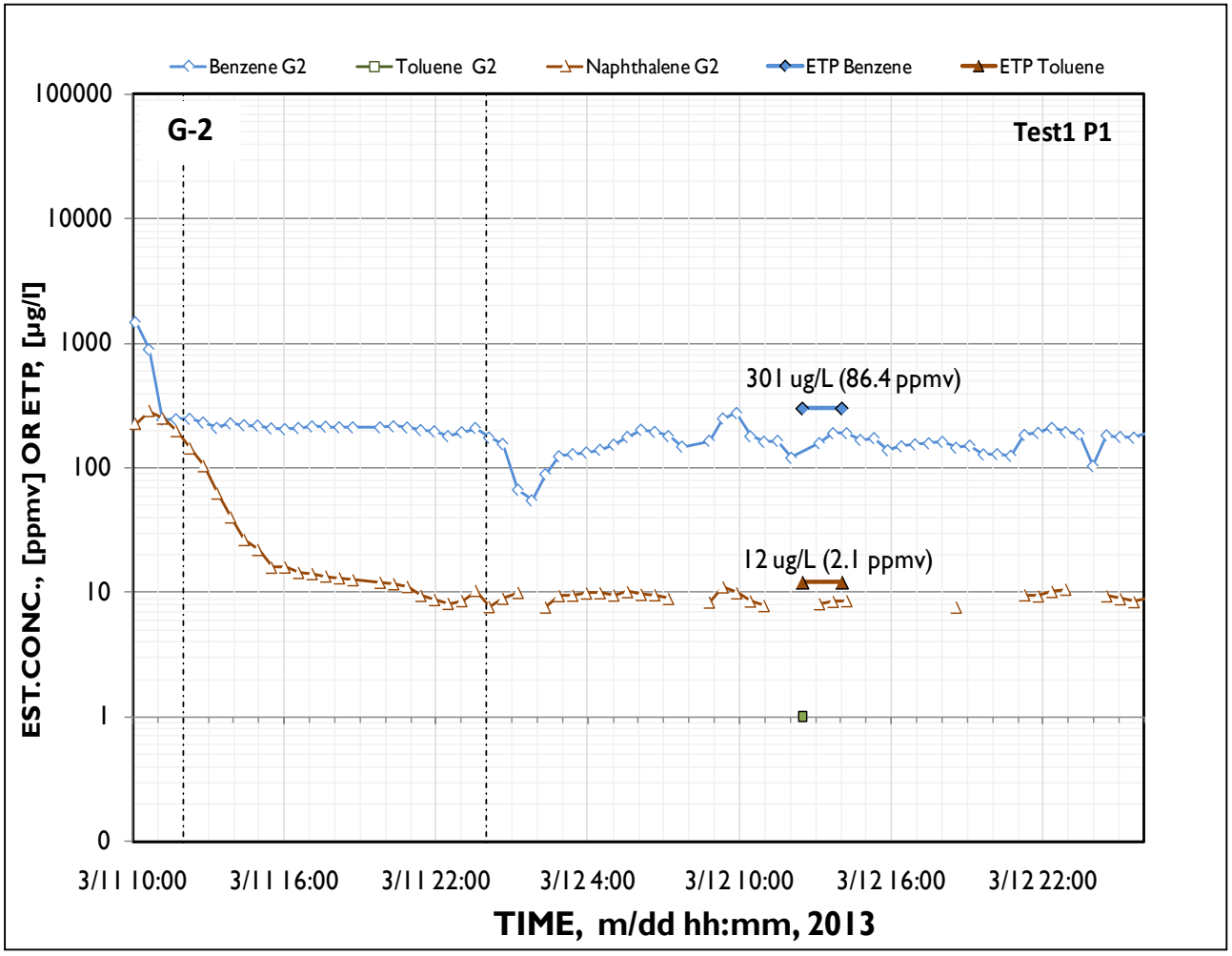
- Benzene
- Naphthalene
- Toluene

Online measurements of selected tars from hot, undiluted, continuous syngas streams at Tar Reformer inlet

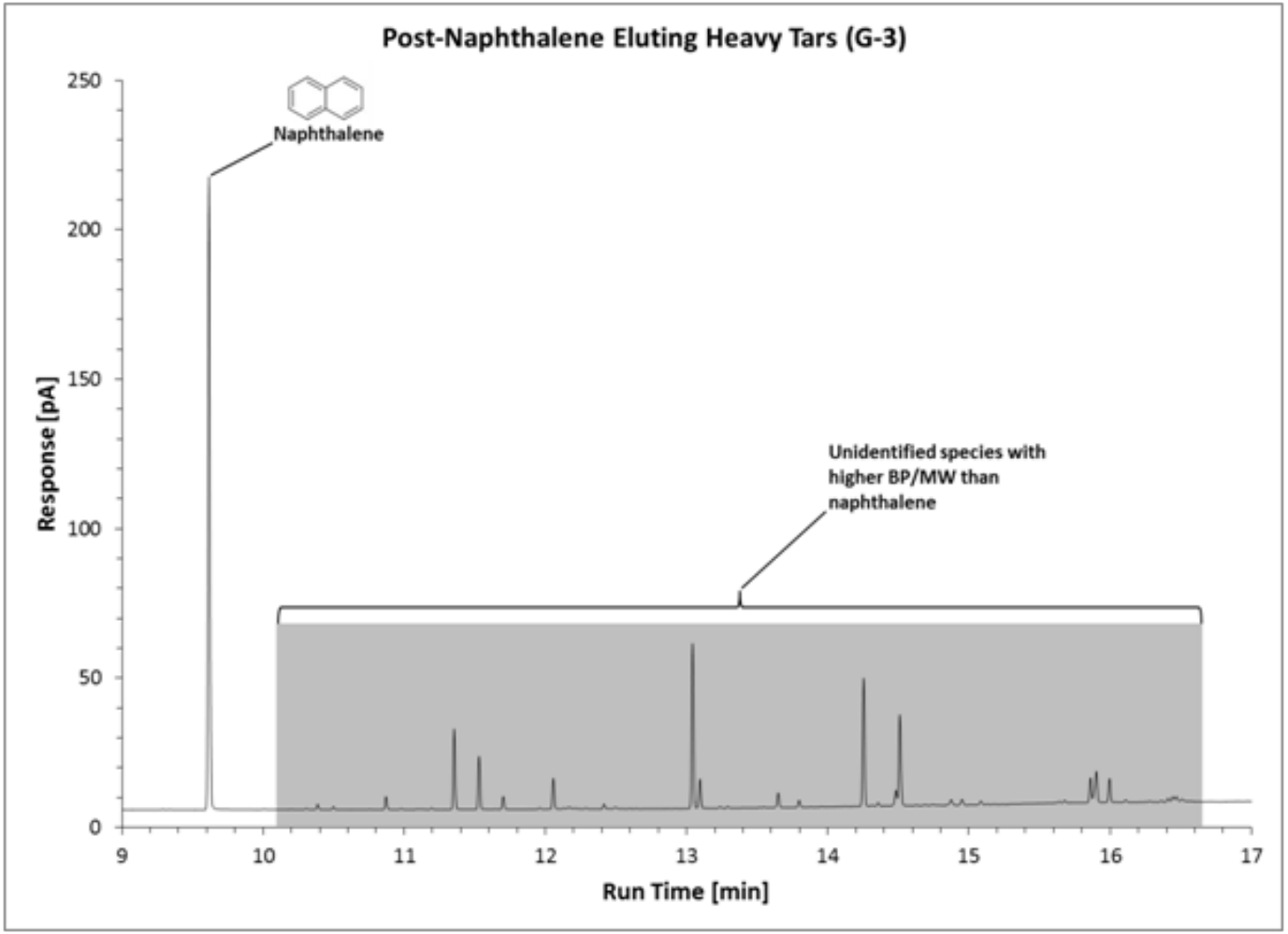


- Pre-test calibration using liquid standards
- Limited number of ETPs taken during testing
- GC output refined post-test

Online measurements of selected tars from hot, undiluted, continuous syngas streams at Tar Reformer outlet



Post-naphthalene chromatogram highlighting unidentified tar species



Future:

- Acenaphthylene
- Phenanthrene
- Pyrene
- Acenaphthene
- Fluoranthene
- Fluorene
- Anthracene
- Dibenzofuran