

# Hot Gas Filtration & Pyrolysis / Gasification Processes

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# Gasification and Pyrolysis 1

## ⇒ Fuels

- Coal and similar fossil fuels
- Wood and biomass derived materials
- Municipal and other types of waste

## ⇒ Conventional Combustion Processes

- *Hot gases raise steam for turbine*
- Power Generation
  - ⇒ Fuel combustion, to generate hot gas
  - ⇒ Steam raising in a boiler
  - ⇒ Power generation via a steam turbine
  - ⇒ Gas treatment and discharge to atmosphere
- Incineration
  - ⇒ Primary combustion, to make the ash inert and safe
  - ⇒ Secondary combustion, to complete the combustion of the gas
  - ⇒ Steam raising, for power, as far compatible with off-gas treatment
  - ⇒ Gas treatment, to allow products of combustion to be discharged

# Gasification and Pyrolysis 2

- ⇒ Gasification & pyrolysis processes
  - *Create fuel gases for direct use in an engine*
  - Gasification
    - ⇒ Partial combustion of fuel due to insufficient air
    - ⇒ Heat generated volatilises other hydrocarbons
    - ⇒ Hydrocarbons plus products of combustion are a fuel gas
    - ⇒ Fuel gas is used to drive an engine
      - » Reciprocating engine for small units
      - » Gas turbines for larger capacities
  - Pyrolysis
    - ⇒ Indirect heating of fuel
    - ⇒ Heating cracks and volatilises hydrocarbons
    - ⇒ Hydrocarbon vapours are a high fuel content gas
    - ⇒ Fuel gas can be used in an engine
    - ⇒ Or it can be condensed to create a liquid fuel

# Why Use Gasification or Pyrolysis

## ⇒ Gasification

- Improved Efficiency
  - ⇒ Better conversion of chemical to electrical energy
  - ⇒ Reduced cooling requirement
  - ⇒ Easier control of emissions
  - ⇒ Reduced environmental impact
- Lower Capital Cost
  - ⇒ Gas turbine vs boiler / steam turbine
  - ⇒ Reduced pollution abatement equipment
  - ⇒ Smaller units are feasible

## ⇒ Pyrolysis

- All of the above reasons
- Possibility of producing a liquid fuel
  - ⇒ Use for transport
  - ⇒ Fuel can be stored

# Fuel Gas Filtration

- ⇒ Fuel Gases are Dirty
  - Ash carryover
  - Carbon (soot) entrainment
  - Desublimation
  
- ⇒ Engines Need Clean Gas
  - Erosion
  - Friction
  
- ⇒ Fuel Gases are Hot
  - Use hot for increased efficiency
  - Gas cooling causes problems
    - ⇒ Tars
    - ⇒ Fouling
  
- ⇒ Hot Gas Filtration
  - Allows choice of filtration temperature
  - Is very effective at removing solids
  - With sorbents can also remove gaseous components

# Hot Gas Filtration

## ⇒ Hot Gas Filters

- Generally operate at >250 degC
- Filtration media are normally rigid
- Reverse pulse cleaning for on-line solids removal

## ⇒ Ceramic Media

- Granular
  - ⇒ SiC + surface coating e.g. Dia-Schumalith
- Vacuum Formed Fibres
  - ⇒ Alumino-silicate e.g. Cerafil
  - ⇒ Calcium silicate e.g. Firefly

## ⇒ Metal Media

- Metal fibre felts

## ⇒ Filter Vessels

- Vertical elements suspended from header plate
- Solids discharge from hopper at base

# Potential Hot Gas Filter Problems

- ⇒ Process Gas Is Combustible
  - Compressed air cannot be used for reverse pulse cleaning
  - Leaks, in or out, are not acceptable
  - Solids discharge may be problematic
  
- ⇒ Process Gas May Be Condensable
  - Reverse pulse can condense process gas within elements
  - Cold spots can condense liquids
    - ⇒ Reverse pulse valves and exposed tube ends
    - ⇒ Solids discharge system
  
- ⇒ Solids May Be Sticky
  - Blinding of elements
  - Solids discharge problems
  
- ⇒ Solids May Be Combustible
  - Discharged solids could catch fire
  - Solids inside filter vessel could ignite on shutdown or process upset
  
- ⇒ Process Gas May Be Reactive

# Potential Solutions 1

*Gasification / Pyrolysis Processes Vary Considerably*

## ⇒ Obtain Comprehensive Data

### ➤ Gas Composition

- ⇒ Dewpoints
- ⇒ Acid gas components
- ⇒ HEL & LEL
- ⇒ Process upset conditions

### ➤ Solids Composition

- ⇒ Stickiness
- ⇒ Combustibility
- ⇒ Proportion condensing from vapour

## ⇒ Choose Operating Temperature With Care

### ➤ Operating considerations

- ⇒ High enough to avoid gas condensation
- ⇒ Low enough to ensure that all inorganics have already condensed

### ➤ Cost considerations

- ⇒ Valves to operate above ca 250 degC are expensive
- ⇒ Lower temperature filters are smaller
- ⇒ Alloy construction at >400 degC is more expensive

# Possible Solutions 2

## ⇒ Reverse Pulse Cleaning

*To avoid explosion hazard*

- Use bought-in inert gas e.g. N<sub>2</sub>
  - ⇒ Can be expensive over long term
- Use nitrogen generator
  - ⇒ Some residual O<sub>2</sub>
  - ⇒ Substantial capital costs
- Use compressed process gas
  - ⇒ Compressor manufacturers reluctant to specify
- Use mechanical cleaning
  - ⇒ May not be effective

*To avoid process gas condensation*

- Heat the pulse cleaning gas
  - ⇒ High temperature reverse pulse valves are expensive
  - ⇒ Reservoir pressure control requires careful engineering
- Purge reverse pulse tubes
  - ⇒ Prevent diffusion of process gas along tube to cold region
- Again, consider mechanical cleaning

# Possible Solutions 3

## ⇒ Filter Vessel

*To avoid damage by fires etc*

- Design to process equipment standards
  - ⇒ Material thickness >5mm
  - ⇒ Thick header plate reinforced with deep ribs
  - ⇒ Proper flanges and high temperature gaskets
  - ⇒ Heavy duty insulation with trace heating if required
  - ⇒ Specify QC procedures
  - ⇒ Remember, it's not a bag filter
- Build to process equipment standards
  - ⇒ Laser cut sheets to drawing templates
  - ⇒ Observe QC procedures

## ⇒ Solids Discharge System

*To avoid gas leakage / solids combustion*

- Use ball valves with filled PTFE or metal seats
- Discharge into sealed drum

# Further Reading

## *Coal Processes*

- ⇒ Schneibner & Wolters: *Schumacher Hot Gas Filter Long-term Operating Experience in the Nuon Power Buggenum IGCC Power Plant*,  
<http://www.netl.doe.gov/publications/proceedings/02/GasCleaning/1.05paper.pdf>
- ⇒ Westerheide et al: *Effect of Combustion Properties on Properties of Ceramic Hot Gas Filters*.  
[http://www.iwm.fraunhofer.de/arbeitsgebiet/lb/thema\\_lb11/CocoaBeach.pdf](http://www.iwm.fraunhofer.de/arbeitsgebiet/lb/thema_lb11/CocoaBeach.pdf)
- ⇒ M. Davidson et al: *Power Systems Development Facility – Filter Element Evaluation*:  
[http://psdf.southernco.com/tech\\_papers/0999\\_Karlsruhe\\_Paper\\_HH.pdf](http://psdf.southernco.com/tech_papers/0999_Karlsruhe_Paper_HH.pdf)

## *Biomass & Waste*

- ⇒ Supported project listing: <http://www.care.demon.co.uk/>
- ⇒ Suresh P. Babu: *Status of and Prospects for Biomass Gasification*:  
<http://www.gastechnology.org/webroot/downloads/en/IEA/IEASTCBC804.pdf>
- ⇒ De Jong et al: *Biomass and fossil fuel etc*: <http://bioproducts-bioenergy.gov/pdfs/bcota/abstracts/27/z107.pdf>
- ⇒ Equipment Manufacturer: <http://www.primenergy.com/Default.htm>