Reliance
Industries Limited

# Coal/Petcoke Gasification

# And

# Reliance's Jamnagar Gasification Project

by

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- CENTRE OF EXCELLENCE FOR GASIFICATION

# WHAT IS GASIFICATION?

- **Conversion of any carbonaceous fuel to a gaseous product with a useable heating value.**

- **The feed for Gasification can be**
  - **Gas** **(e.g., Natural gas)**
  - **Liquid** **(e.g., Light or Heavy oils)**
  - **Solid** **(e.g., Coal, Petroleum Coke, Lignite or Biomass)**

# HISTORY OF GASIFICATION

| PERIOD | TECHNOLOGY |
|---|---|
| Before 1700 | Major fuels were Wood and Charcoal |
| 1700-1750 | Industrial revolution – Coal as fuel |
| 1800-1900 | Coal Pyrolysis – Town gas supply<br>Water gas, Producer Gas |
| 1920 | Cryogenic air separation – Oxygen replaces air |
| 1926 | Winkler Fluidized Bed Gasifier |
| 1931 | Lurgi Moving Bed Gasifier |
| 1940 | Koppers-Totzek Entrained Flow Gasifier |

# HISTORY OF GASIFICATION (Cont….)

| PERIOD | TECHNOLOGY |
|---|---|
| 1950s | Texaco and Shell develop Oil Gasification |
| 1970s | Oil crisis |
| 1973 | Texaco develops Slurry Process for Coal Gasification |
| 1974 | Shell and Koppers-Totzek Pressure Gasification JV |
| 1981 | High Temperature Winkler Gasification |
| 1984 | Lurgi Slagging Gasifier (together with British Gas) |
| 1999 | Shell/Krupp-Uhde develops Pressurised Entrained Flow (PRENFLO) Gasifier |

# GASIFICATION – INDIAN CONTEXT

| PERIOD | TECHNOLOGY | FEED | LOCATION |
|---|---|---|---|
| 1940s | Wood Gasification | Wood | FACT - Cochin |
| 1945-1950 | Lurgi Fixed Bed | Coal | Sindri |
| 1960s | Winkler Fluidized Bed | Lignite | Neyveli |
| 1960s | Texaco | Naphtha | FACT - Cochin |
| 1970s | Krupp-Koppers Entrained Bed Atm. | Coal | Ramagundam Talcher |
| 1970s | Shell | Fuel oil | Sindri |
| 1980s | Shell | Fuel oil | NFL - Bhatinda, Panipat, Nangal |
| 1980s | Texaco | Fuel oil | GNFC - Bharuch |

# Gasification Theory

# GASIFICATION Vs. COMBUSTION

- **Partial oxidation**
- **Higher temperature, often high pressure**
- **Purpose - Get Fuel-rich gas & not High temperature gas**
- **Product gases ($CO$, $H_2$, $CH_4$, $CO_2$, $H_2O$) have fuel value**
- **Oxygen as feed instead of air**
- **Intermediate scrubbing of gas**
- **Char reaction rate is slower**

# GENERAL REACTIONS

$CH + O_2 + H_2O \rightarrow CO + H_2 + CO_2 + H_2O + CH_4$

$H_2 + S = H_2S$

$C + \frac{1}{2} H_2 + \frac{1}{2} N_2 = HCN$

$\frac{1}{2} N_2 + \frac{3}{2} H_2 = NH_3$

$C + S + \frac{1}{2} O_2 = COS$

$\frac{1}{2} H_2 + \frac{1}{2} Cl_2 = HCl$

ASH $\rightarrow$ SLAG + FLY ASH

# GENERAL REACTIONS

| | | $\Delta H$ (+ Endothermic / - Exothermic) |
|---|---|---|
| **Combustion reactions** | | |
| $C + \frac{1}{2} O_2$ | $= CO$ | - 111 MJ/kmol |
| $CO + \frac{1}{2} O_2$ | $= CO_2$ | - 283 MJ/kmol |
| $C + O_2$ | $= CO_2$ | - 394 MJ/kmol |
| $H_2 + \frac{1}{2} O_2$ | $= H_2O$ | - 242 MJ/kmol |
| **Boudouard reaction** | | |
| $C + CO_2$ | $\leftrightarrows 2\ CO$ | + 172 MJ/kmol |
| **Water gas reaction** | | |
| $C + H_2O$ | $\leftrightarrows CO + H_2$ | + 131 MJ/kmol |

# GENERAL REACTIONS

**ΔH**

**(+ Endothermic / - Exothermic)**

**Methanation reaction**

| | | |
|---|---|---|
| $C + 2\,H_2 \leftrightarrows CH_4$ | | - 75 MJ/kmol |
| $CO + 3\,H_2 \leftrightarrows CH_4 + H_2O$ | | - 206 MJ/kmol |
| $CO_2 + 4\,H_2 \leftrightarrows CH_4 + 2\,H_2O$ | | - 165 MJ/kmol |

**The reverse Steam-reforming reactions are endothermic**

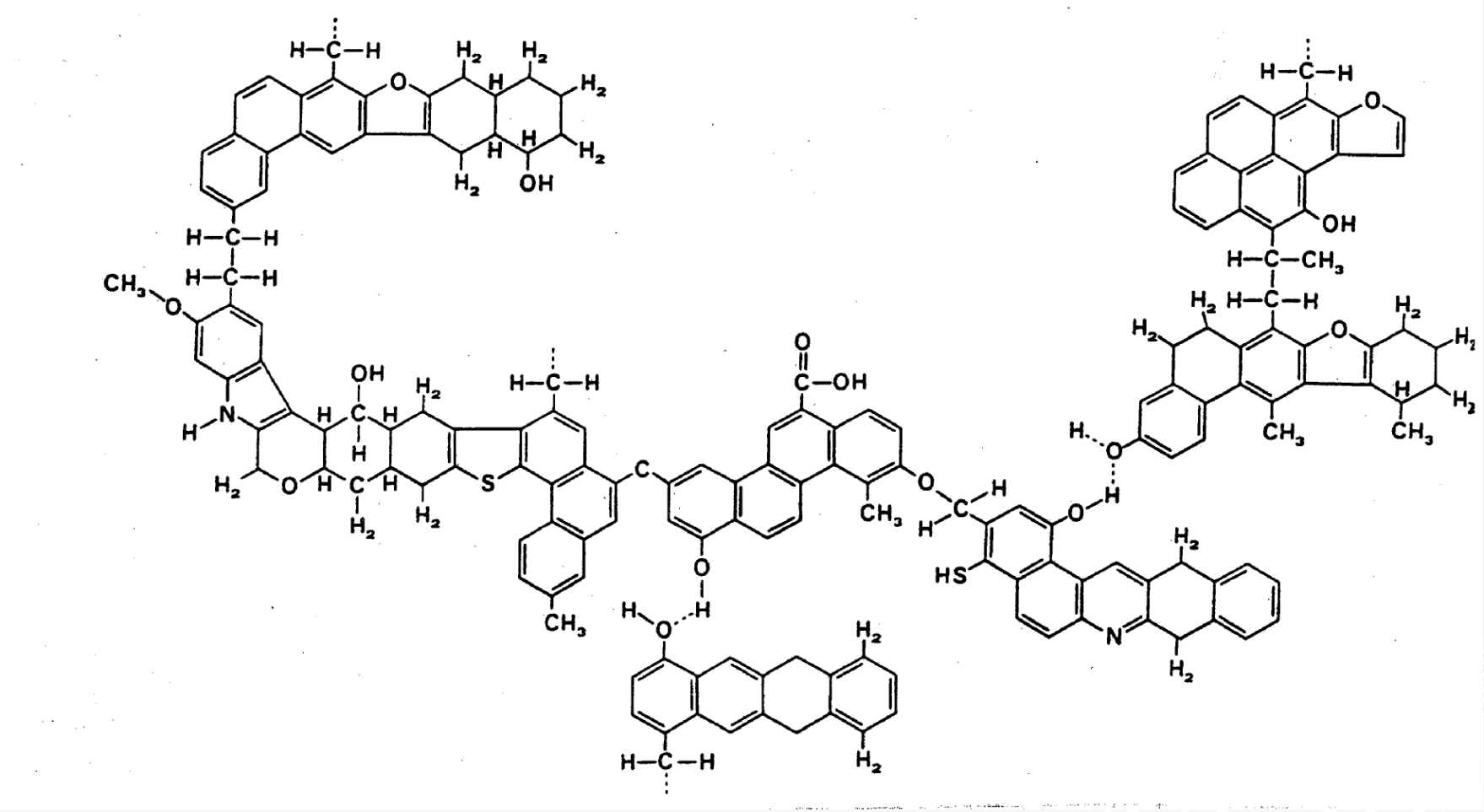
**CO shift reaction**

| | | |
|---|---|---|
| $CO + H_2O \leftrightarrows CO_2 + H_2$ | | - 41 MJ/kmol |

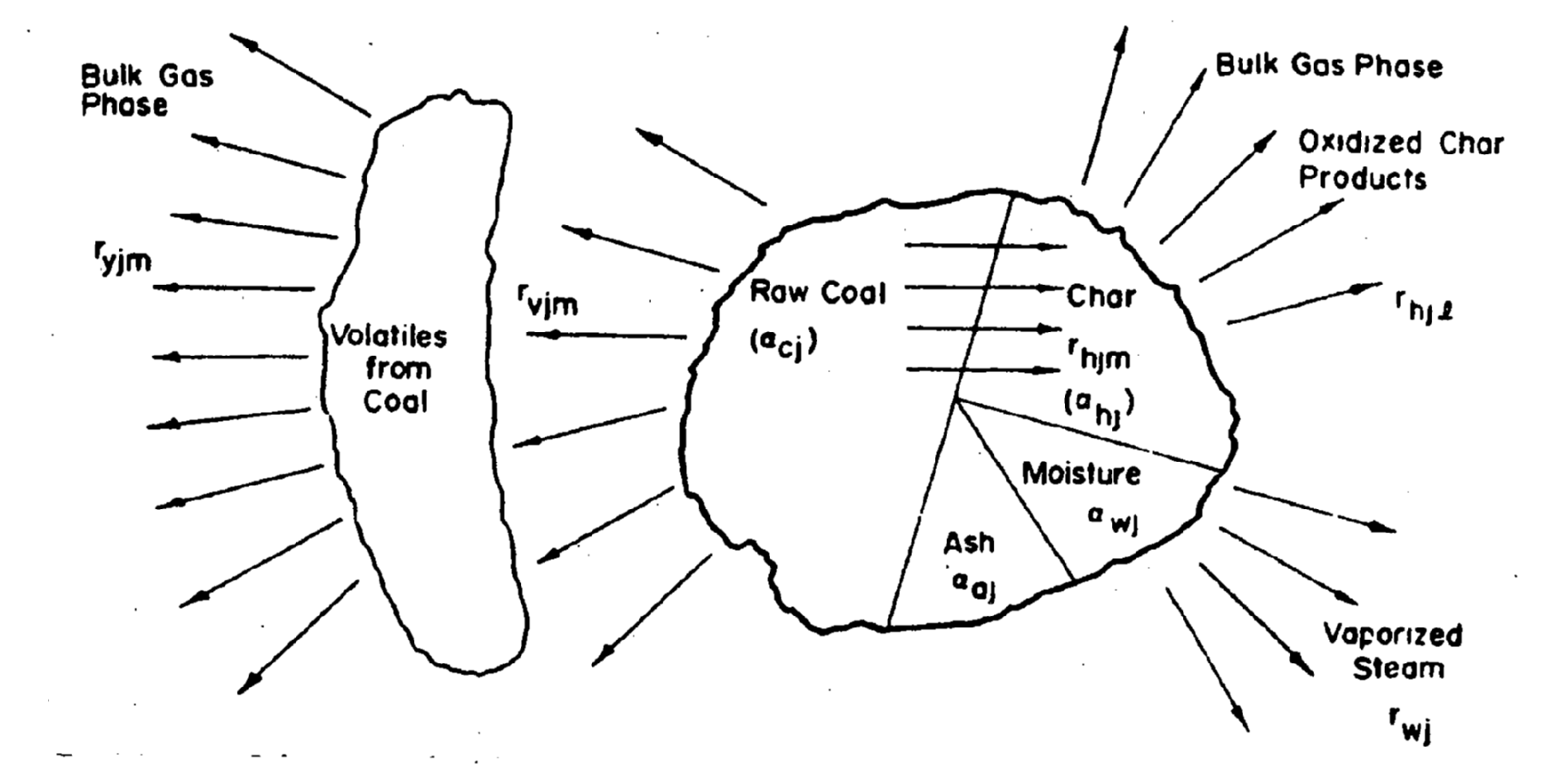
**Gasification Reaction – Summary**

$$CH + O_2 + H_2O \rightarrow CO + H_2 + CO_2 + H_2O + CH_4$$

# PICTURE OF A HYPOTHETICAL COAL MOLECULE



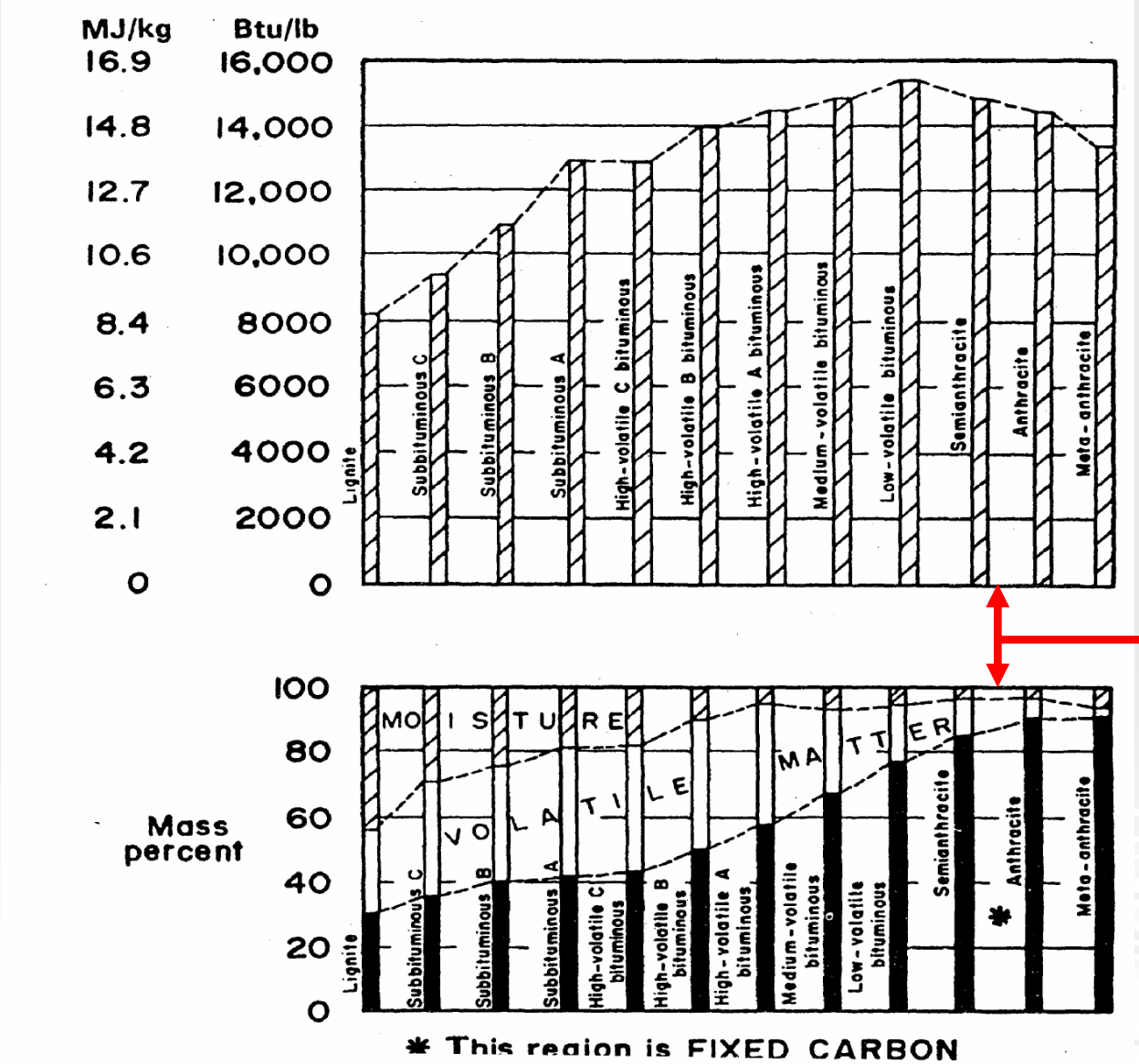
# What Happens to a Coal Particle?




**Coal reactions are generally divided into two distinct components**

- **Devolatilization of the raw coal**
- **Oxidation of the residual char**

# ENERGY CONTENT AND COMPOSITION OF COALS




Petcoke

# COAL ANALYSIS

- **PROXIMATE ANALYSIS**

  **Water**
  **Volatile matter**
  **Fixed carbon**
  **Ash**
  **Calorific value**

- **ULTIMATE ANALYSIS**

  **Carbon**
  **Hydrogen**
  **Oxygen**
  **Nitrogen**
  **Sulphur**
  **Chlorine**
  **Metals**

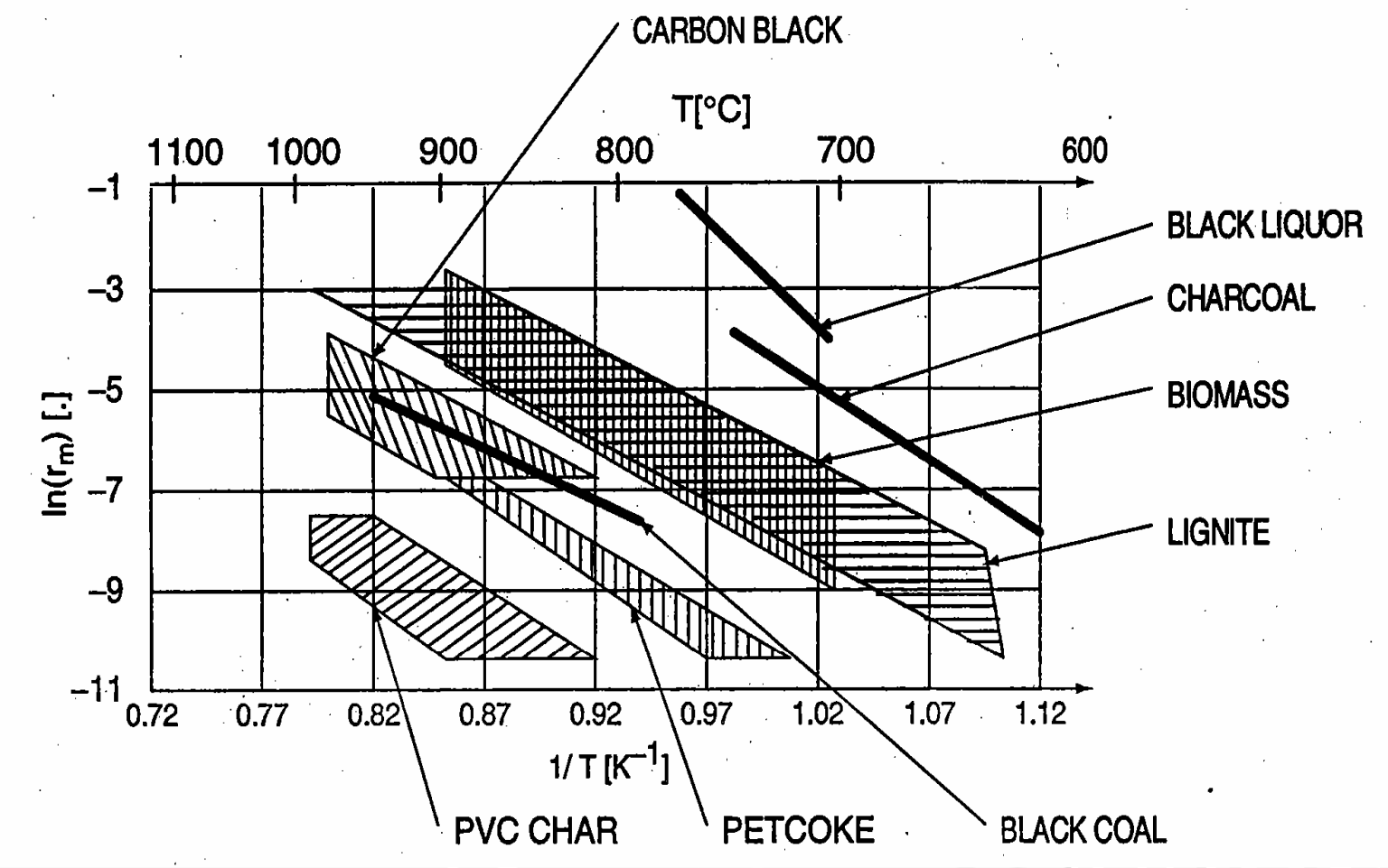
- **ASH ANALYSIS**

  **Metal oxides**

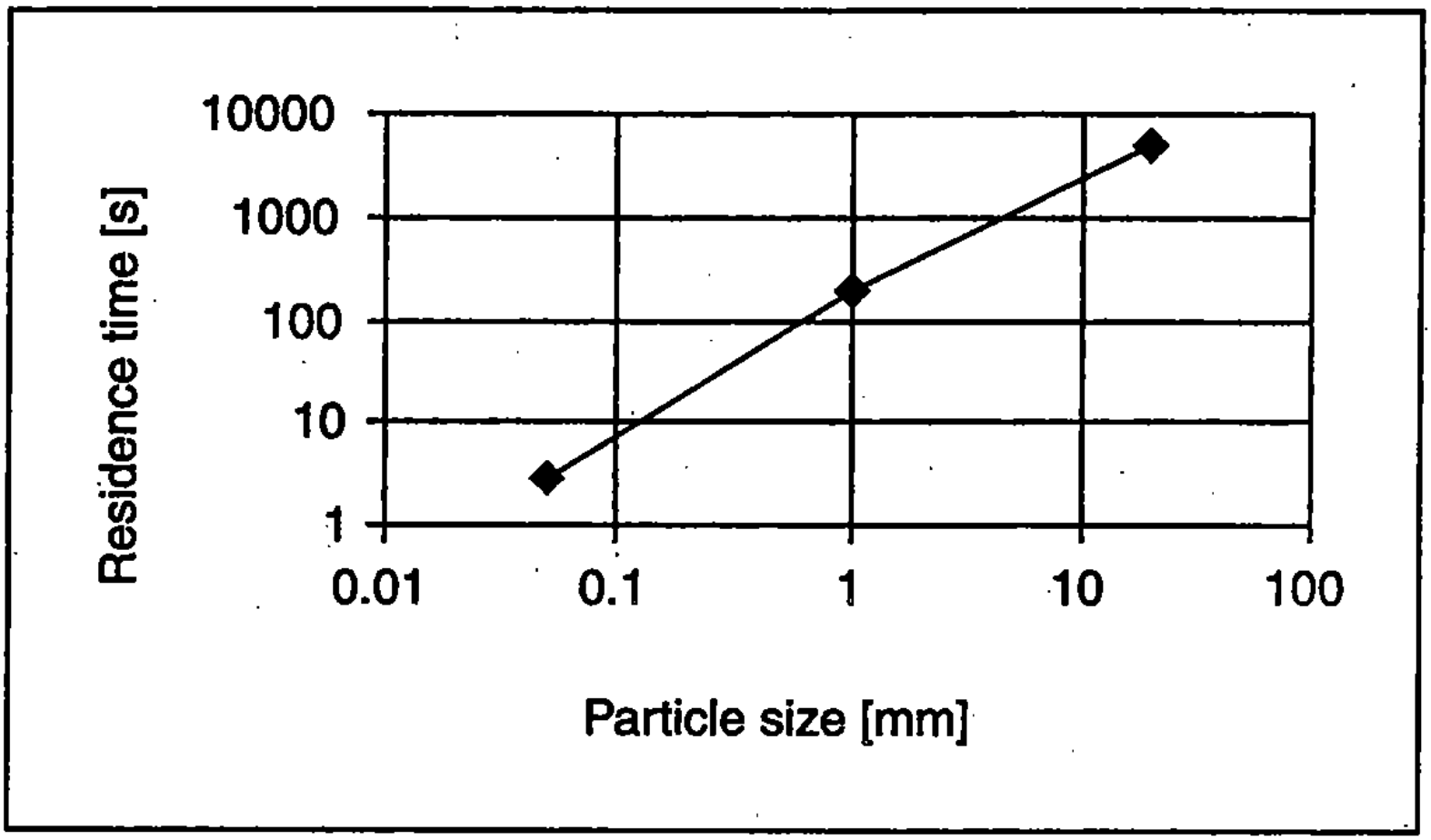
- **ASH FUSION TEMPERATURE**

  **Ash melting point**
  **Initial Deformation Temperature**
  **Hemispherical Point**
  **Flow Point**

# REACTIVITY OF FUELS AS FUNCTION OF TEMPERATURE



# RESIDENCE TIME AS FUNCTION OF PARTICLE SIZE



# ASH BEHAVIOR

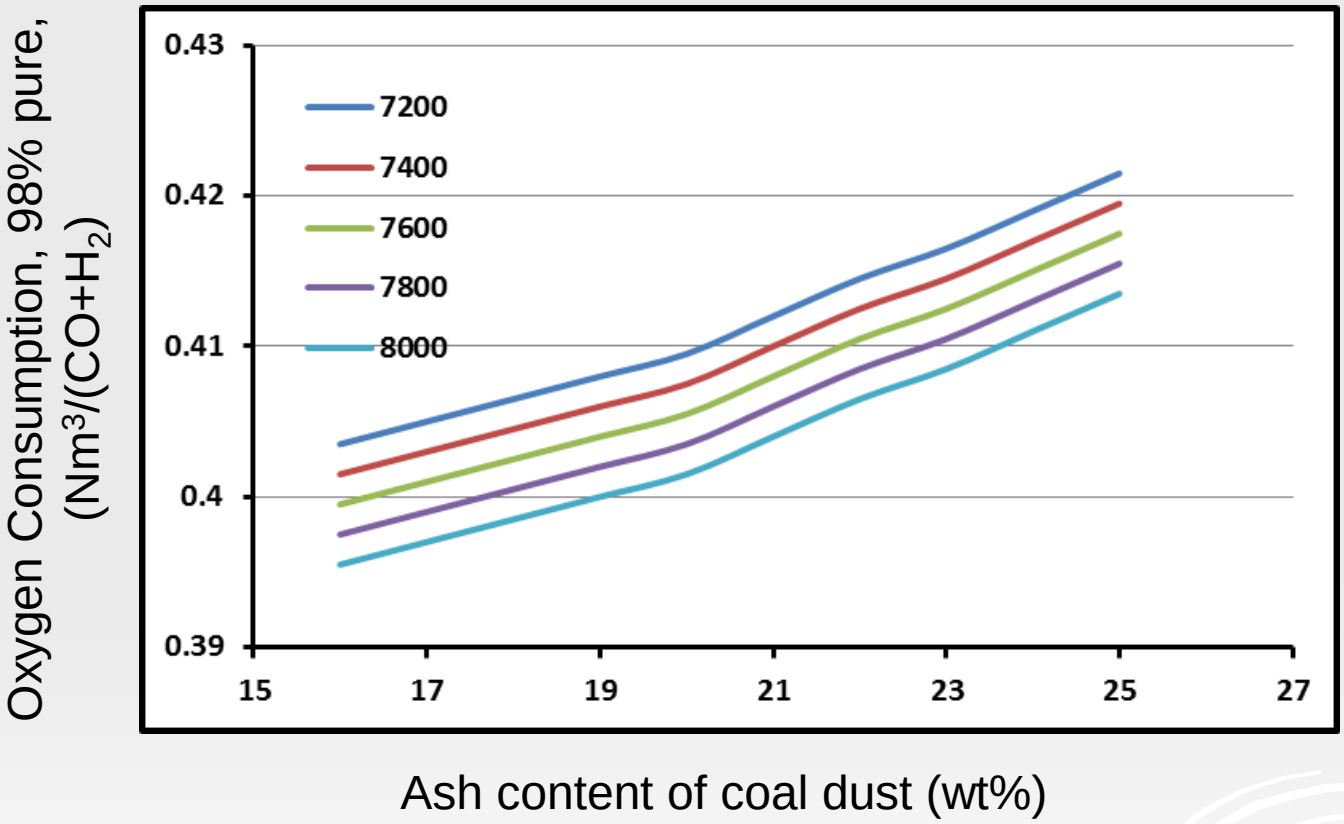
- The relationship between ash-melting characteristics and composition is a complicated one and is dependent largely on the quaternary $SiO_2$-$Al_2O_3$-CaO-FeO.

- In general, slags that are high in $SiO_2$ and/or $Al_2O_3$ will have high ash melting points, but this is reduced by the presence of both CaO and FeO.

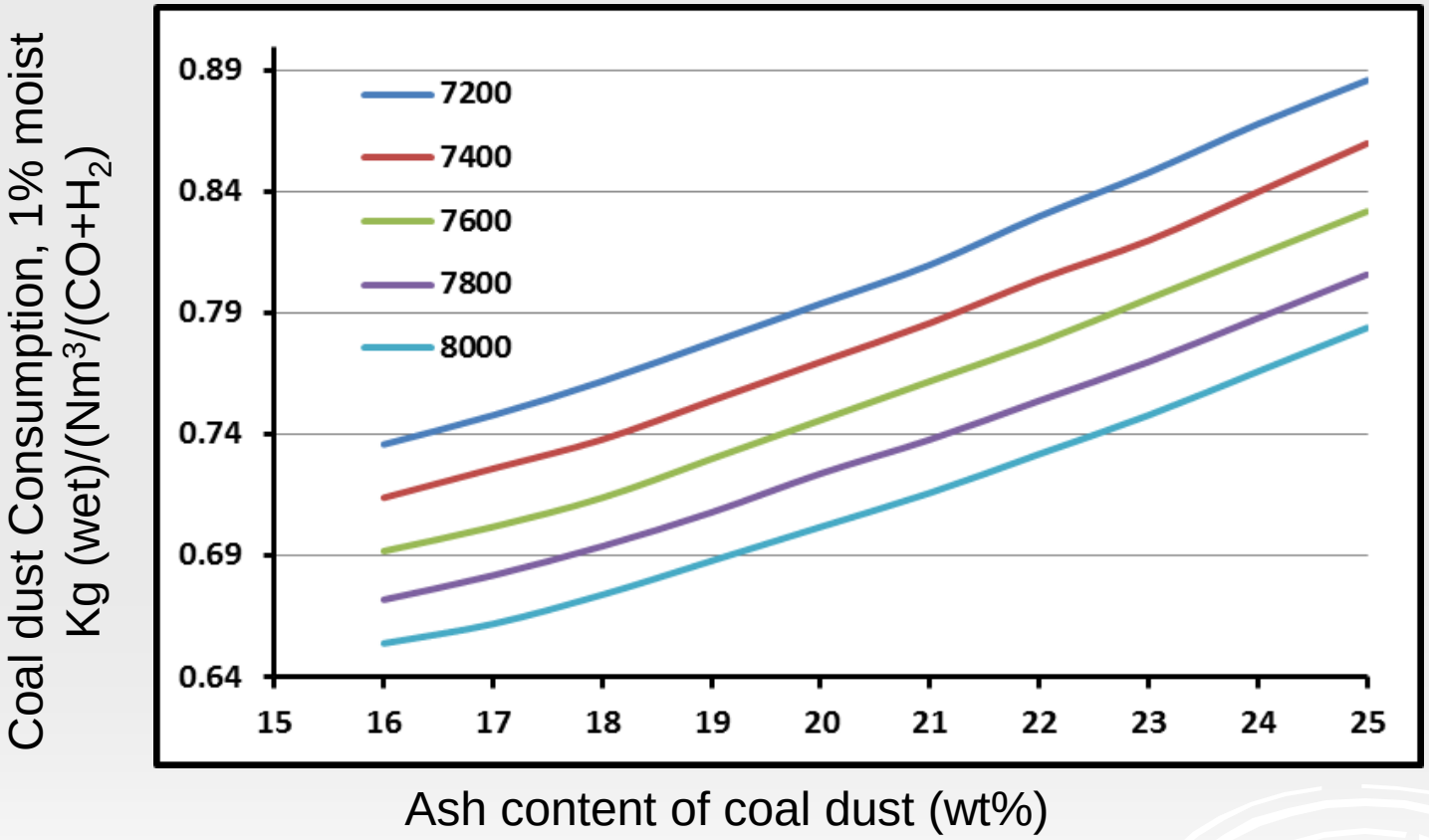
- The $SiO_2/Al_2O_3$ ratio is also important – where the Calcium content is already high, $SiO_2$ addition can lower the ash melting point.

- Slag is very different from ash as it has been molten and is in fact a fusion-cast material similar to glass.

# O2 consumption depending on Ash content and CV



# Coal dust consumption depending on Ash content and CV



# EFFECT OF PRESSURE

**Synthesis gas composition changes with pressure**

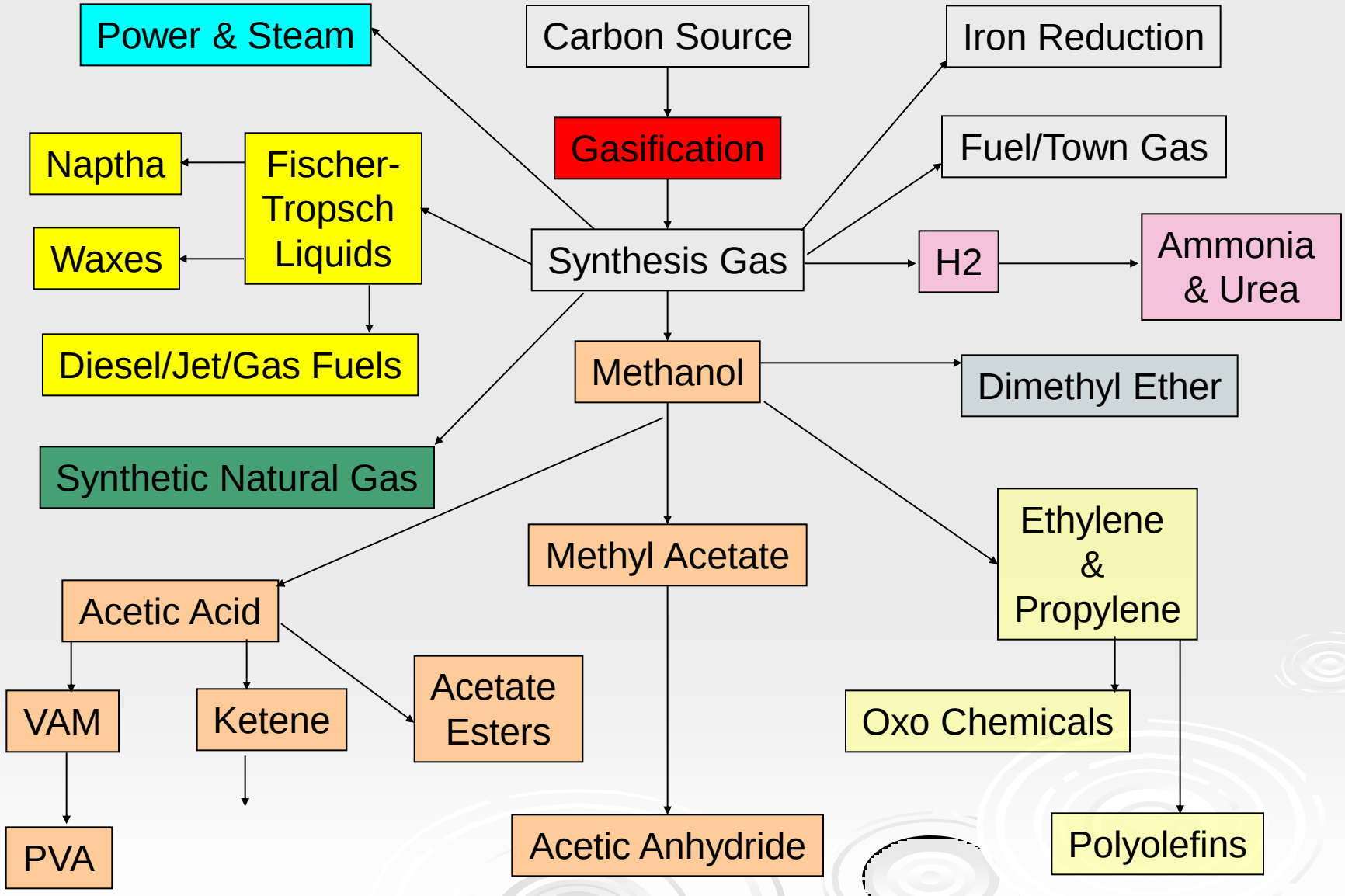
- Methane and $CO_2$ content go up with increasing pressure
- $H_2$ and CO content go down
- However, at high temperatures (1500 deg C), the change in gas composition with pressure is negligible.

# EFFECT OF TEMPERATURE

- Below the ash softening point for fluidized bed and dry ash moving bed Gasifiers
- Above the ash melting point for slagging (entrained bed) Gasifiers
- Flux may be required to be added for coal/coke having very high ash melting point
- CO content goes up while $H_2$ content goes down with increasing temperature
- CO + $H_2$ yield goes through a mild maximum between 1200 and 1300 deg C
- Methane content goes down with increasing temperature
- Oxygen demand is more at high temperatures

# Application of Gasification Process

# APPLICATIONS OF GASIFICATION PROCESS



# Types of Gasifiers

# TYPES OF GASIFIERS

1) **Moving/Fixed bed** — **Lurgi/BGL**

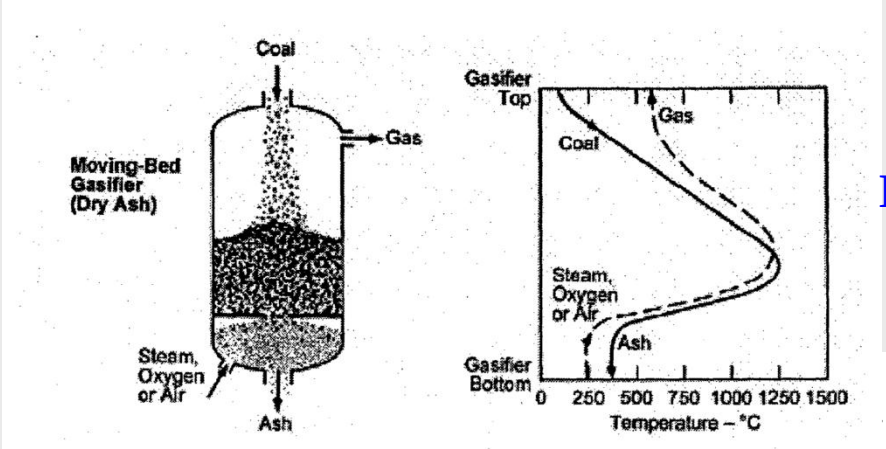
   Counter-current
   Co-current

2) **Fluidized bed** — **Winkler/KBR etc**

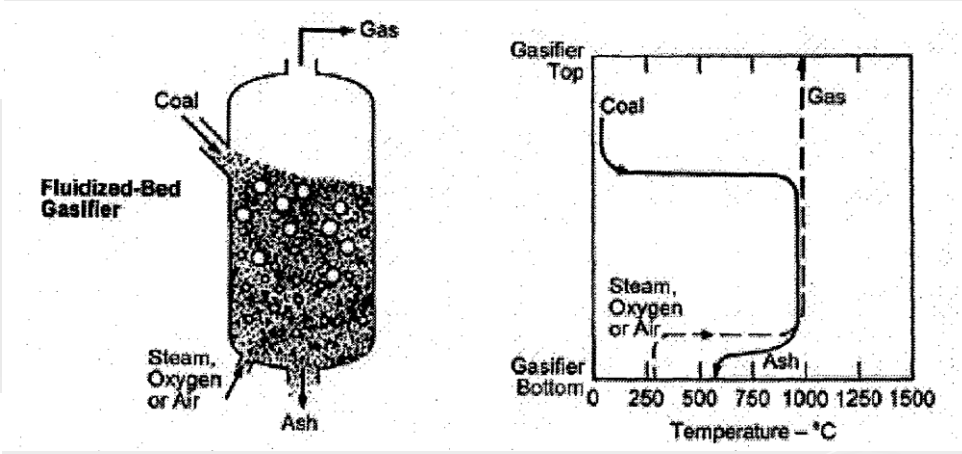
3) **Entrained flow** — **GE/Shell/Conoco/Siemens/Uhde**

   Dry pulverized solid fuel
   Fuel slurry
   Atomized liquid fuel

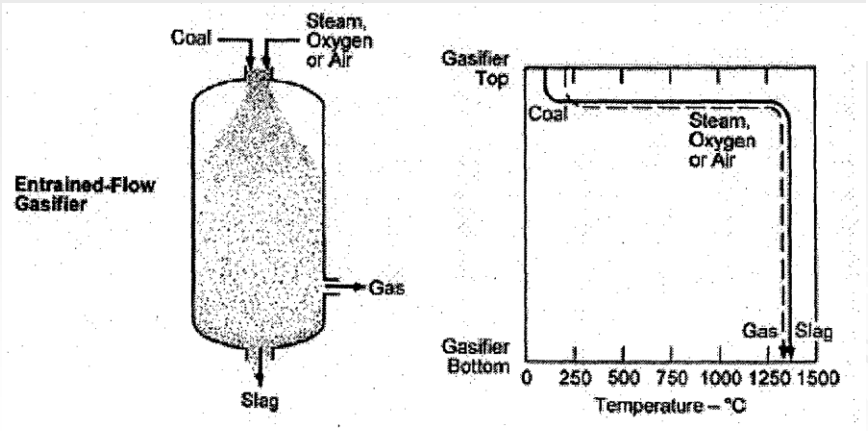
# TYPES OF GASIFIERS




MOVING BED GASIFIER




FLUIDIZED BED GASIFIER

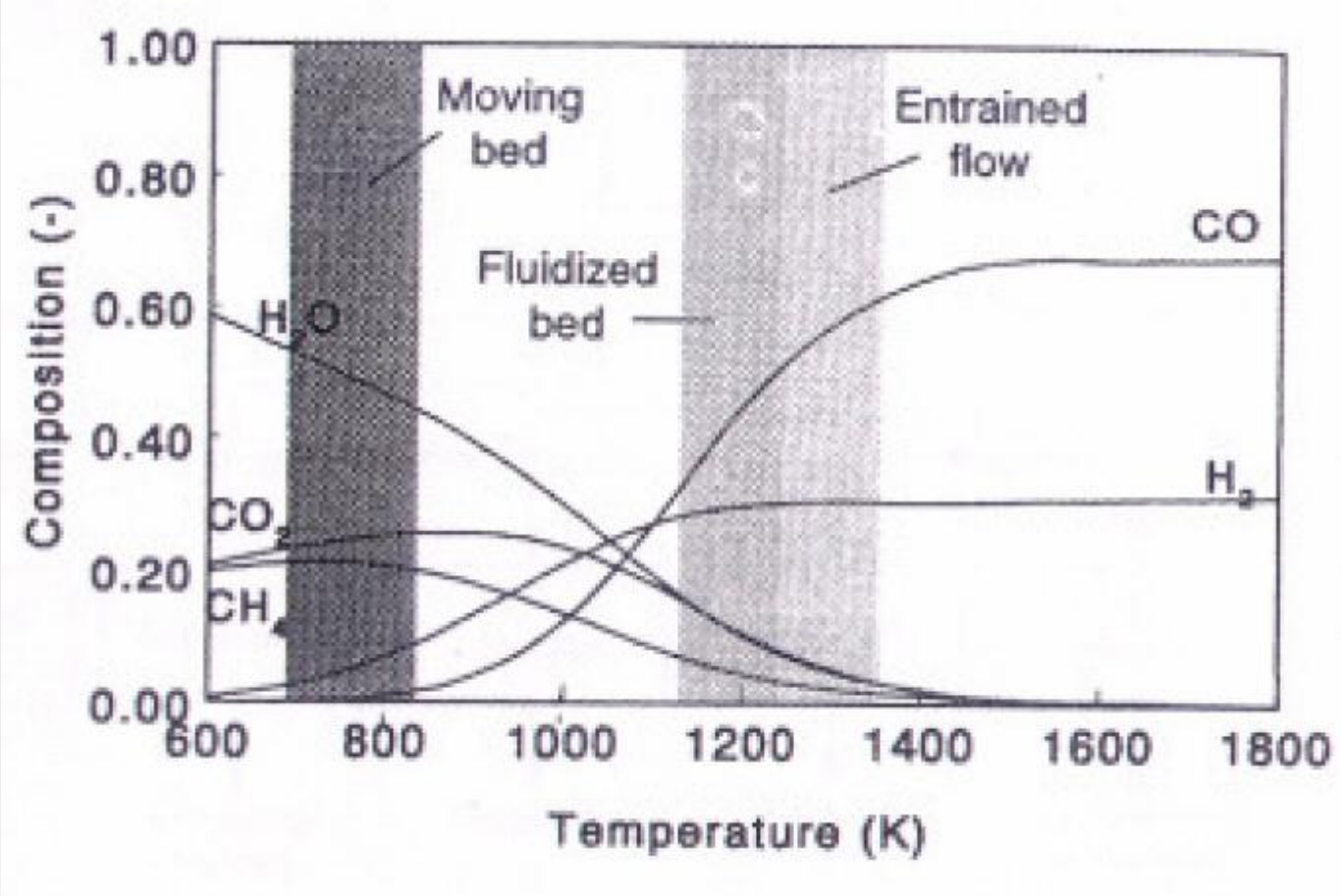



ENTRAINED FLOW GASIFIER

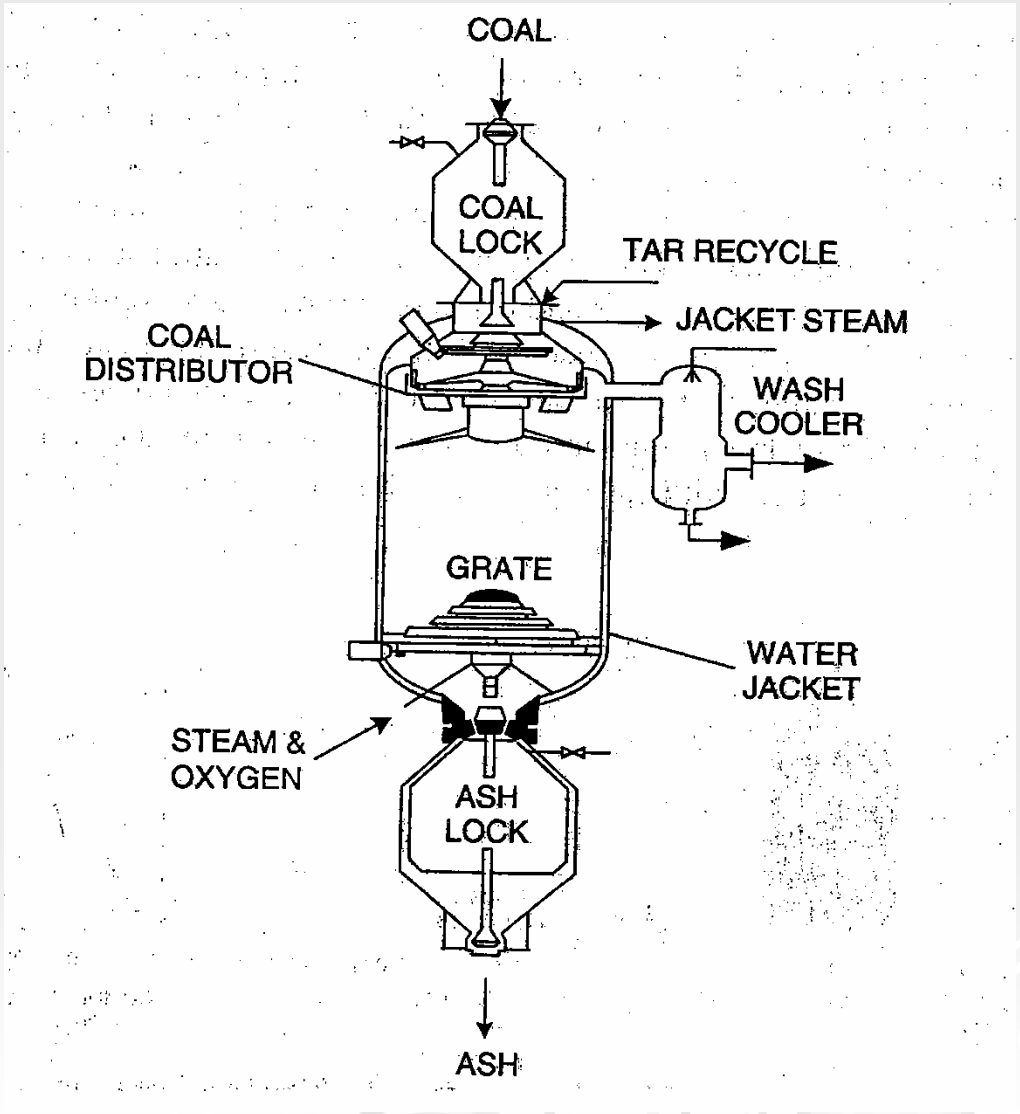
# TYPES OF GASIFIERS

| | Fixed bed | Fluidized bed | Entrained bed |
|---|---|---|---|
| Residence time | 1-3 hr | 20-150 min | 0.4-2 s |
| Coal size | 6-50 mm | 6-10 mm | < 100 microns |
| $O_2$/Coal | 0.14-0.81 | 0.25-0.97 | 0.28-1.17 |
| Steam/Coal | 0.28-3.09 | 0.11-1.93 | 0.10-1.20 |
| Coal type | Most types - No fines | Non-caking coals | All types |
| Temperature range (°C) | 420-650 | 900-1050 | 1250-1600 |
| Pressure range (Atm) | 1-10 | 10-30 | 30-80 |
| Product gases (Mol%) | | | |
| $CO + H_2$ | 40-70 | 60-80 | 65-95 |
| $CH_4$ | 5-15 | 3-5 | 0.1-2 |
| HHV (BTU/SCF) | 250-320 | 300-400 | 300-550 |
| Efficiency | Low | Medium | High |

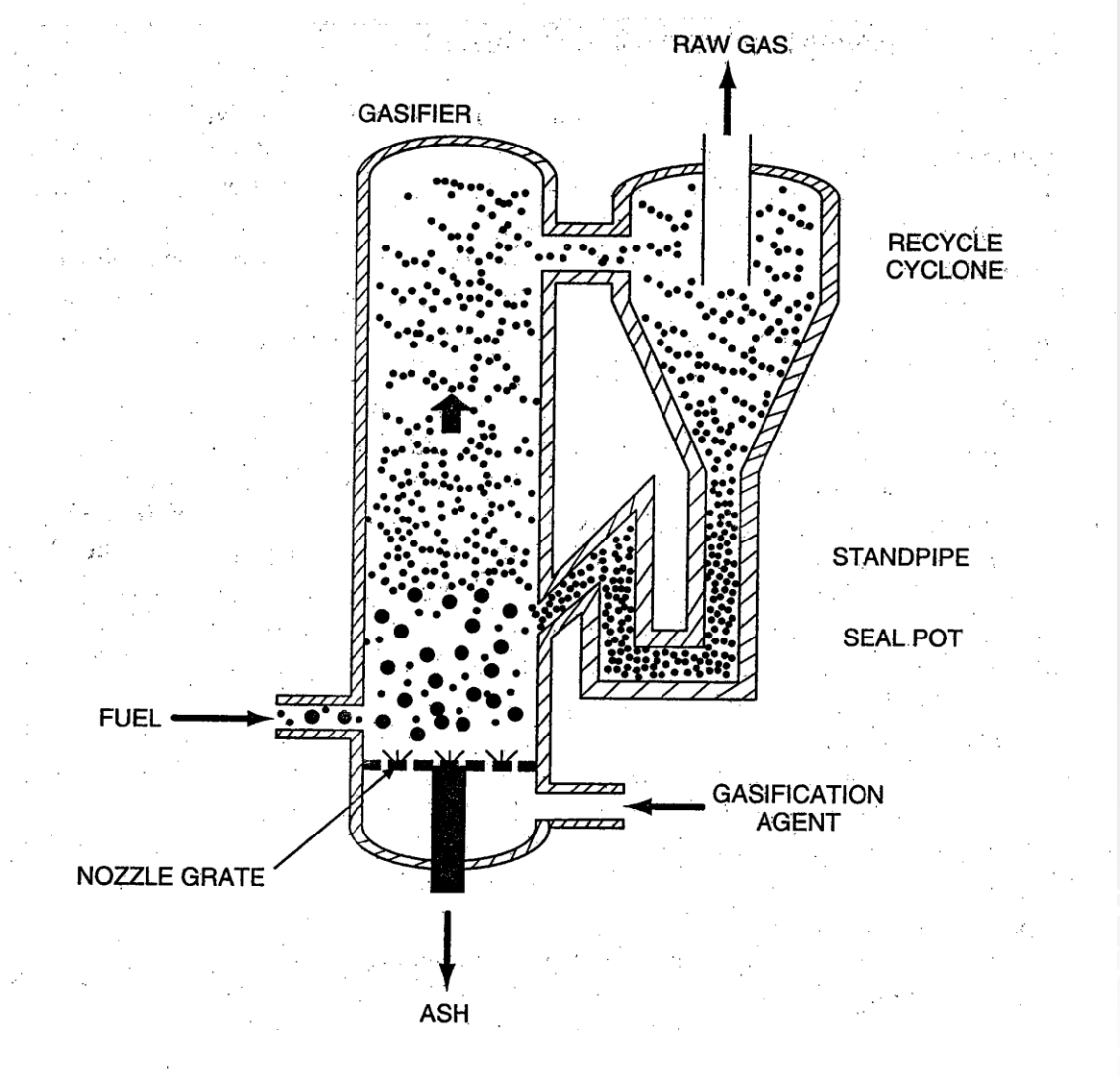
# EQUILIBRIUM EXIT GAS COMPOSITION



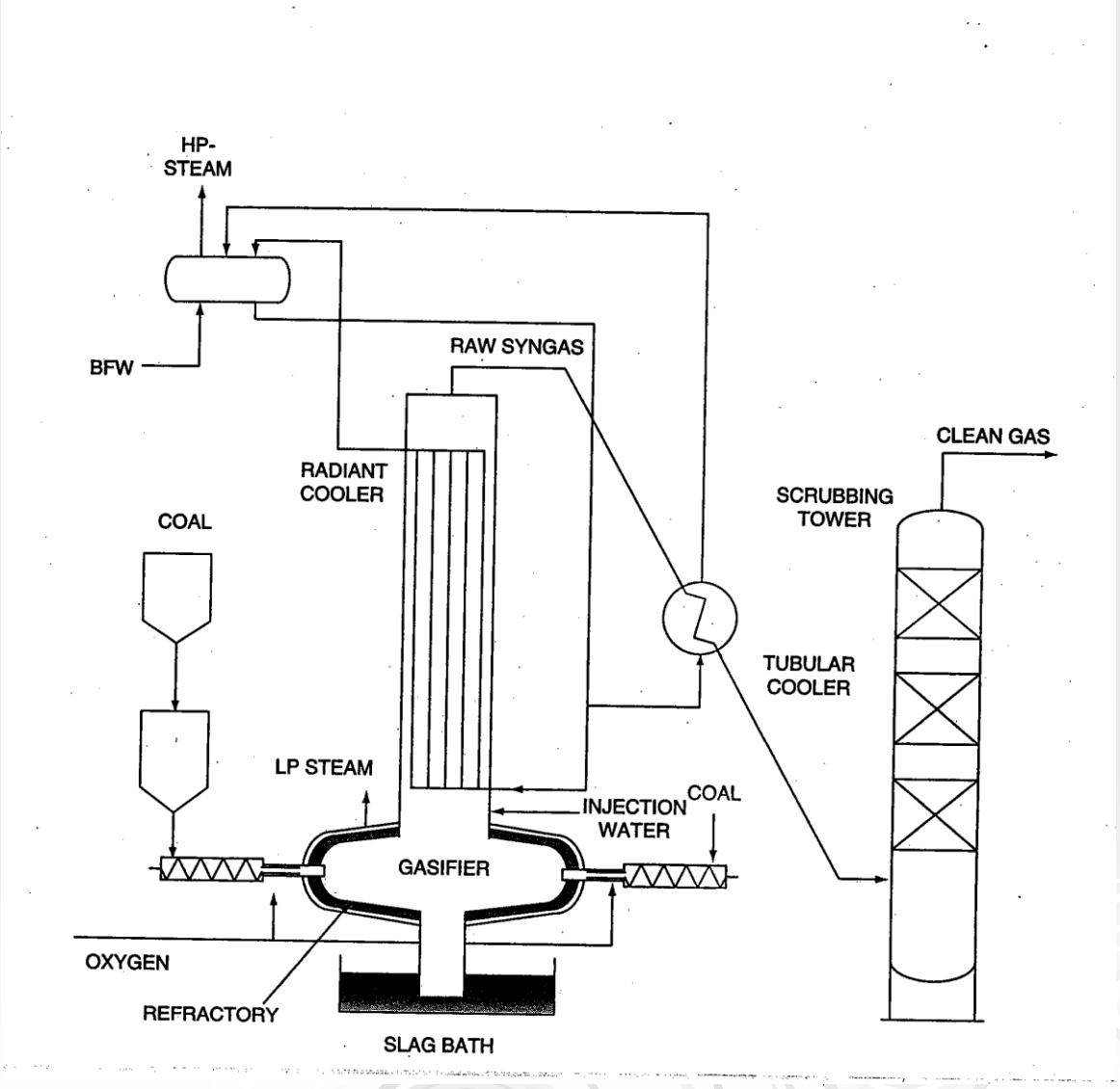
# LURGI DRY ASH GASIFIER – MOVING BED



# LURGI CIRCULATING GASIFIER – FLUIDIZED BED



# KOPPERS-TOTZEK GASIFIER – ENTRAINED BED



# WHY ENTRAINED FLOW GASIFIER?

- **Ability to handle variety of solid fuels**
- **High throughput because of high reaction rates/temperature**
- **High carbon conversion**
- **Syngas free of oils and tars**
- **Low methane production**

# Gasification Technology Development

# GE GASIFICATION PROCESS DEVELOPMENT

Texaco -1953
TGP License

Texaco -1959
Las Palmas, Spain

Texaco -1960
Lisbon, Portugal

Texaco -1971
Lavera, France

Texaco -1971
Rhodes, Australia

TCGP – 1973
Development

TCGP-1978
Demo Holten, D

TCGP – 1986
Oberhausen, D

Texaco -1991
Oberhausen, D

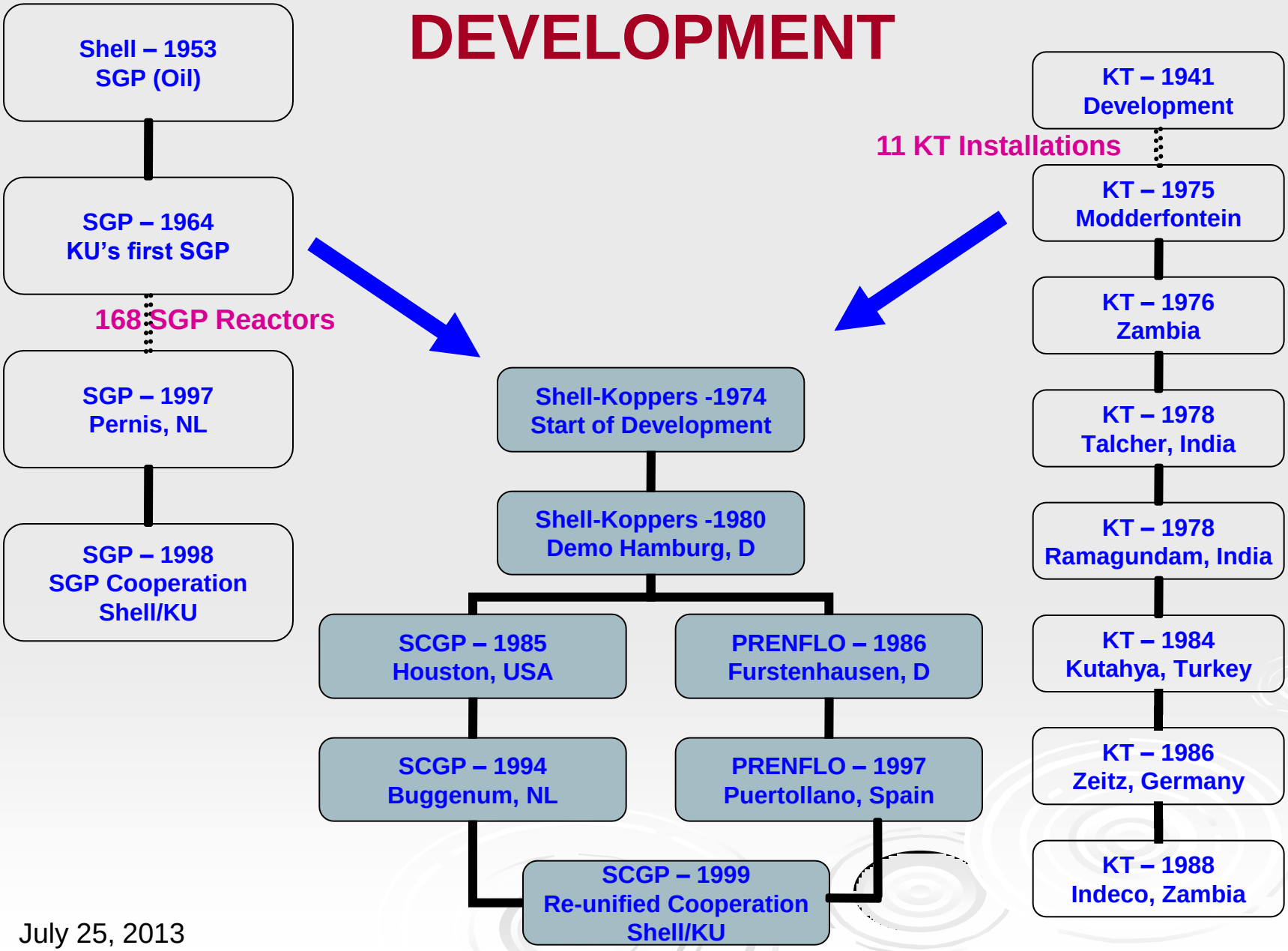
Texaco - 1998
Bharuch, India

Chevron takes over
Texaco - 2001

GE takes over Texaco
Technology - 2004

| No. of installations | Solid | Liquid | Gas |
|---|---|---|---|
| | 14 | 27 | 21 |

# SHELL GASIFICATION PROCESS DEVELOPMENT

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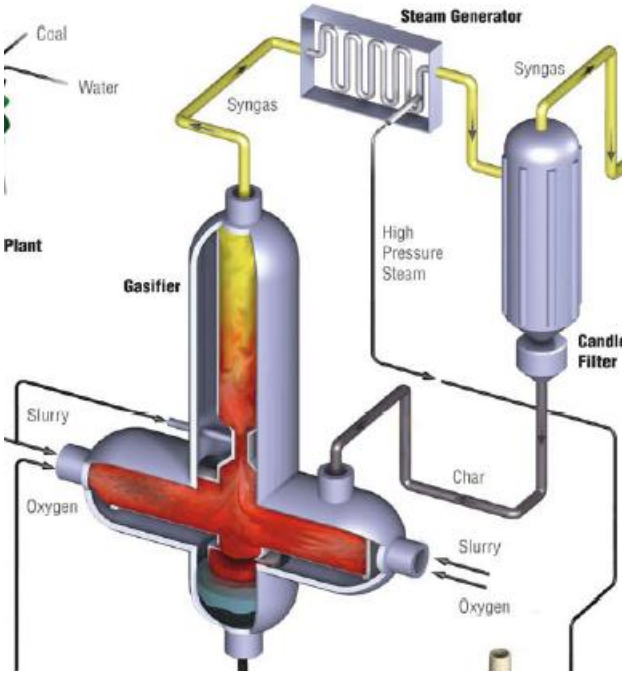
# Conoco Philips E-GAS – Two stage gasifier




DOW (LGTI)

↓

DESTEC

↓

CONOCOPHILLIPS

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P 66

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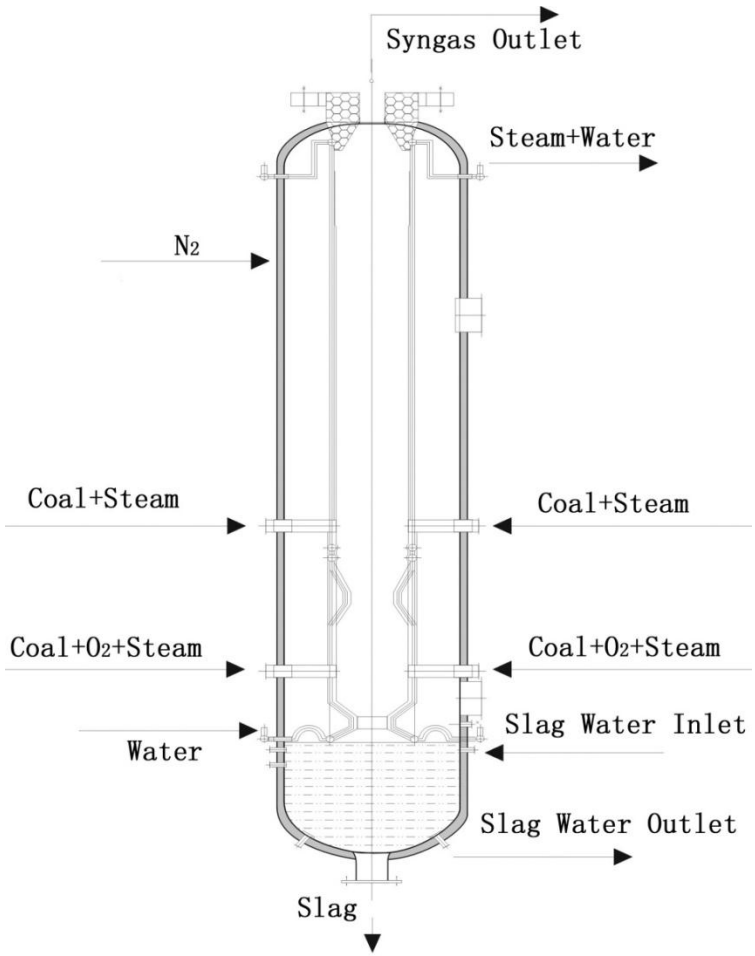
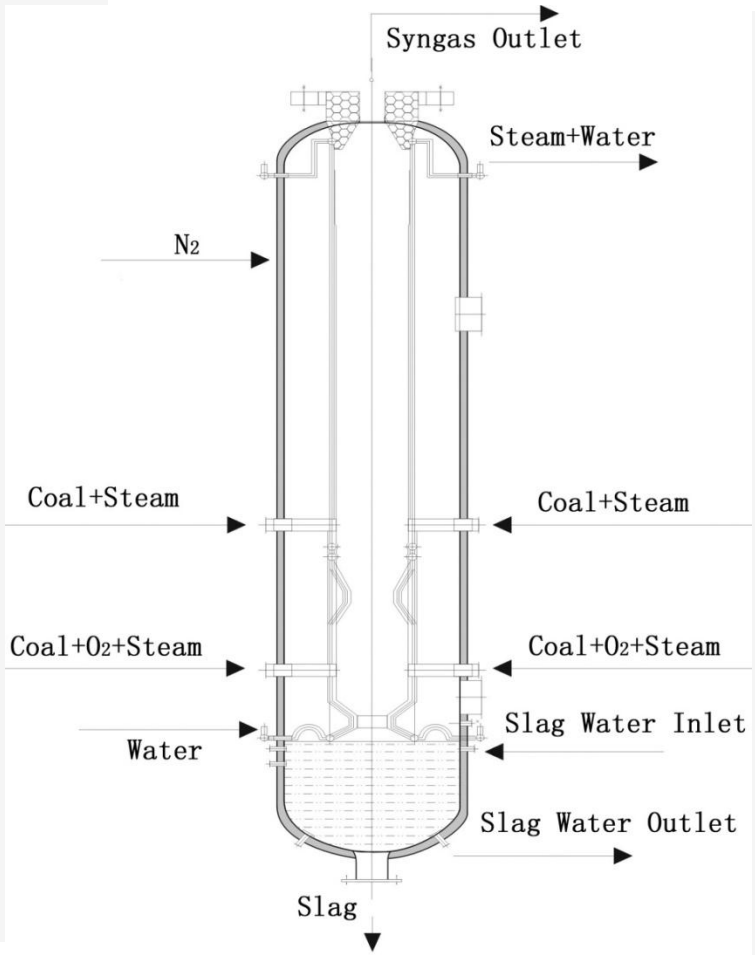
CB & I

# TPRI/Future Fuels Generic Gasifier Design

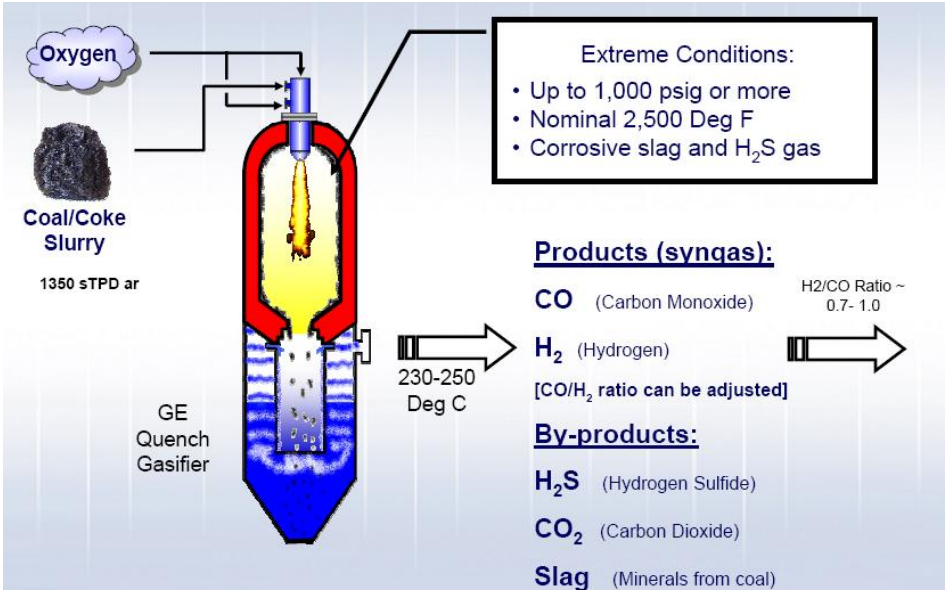


TPRI Syngas Cooler Gasifier (SCG)

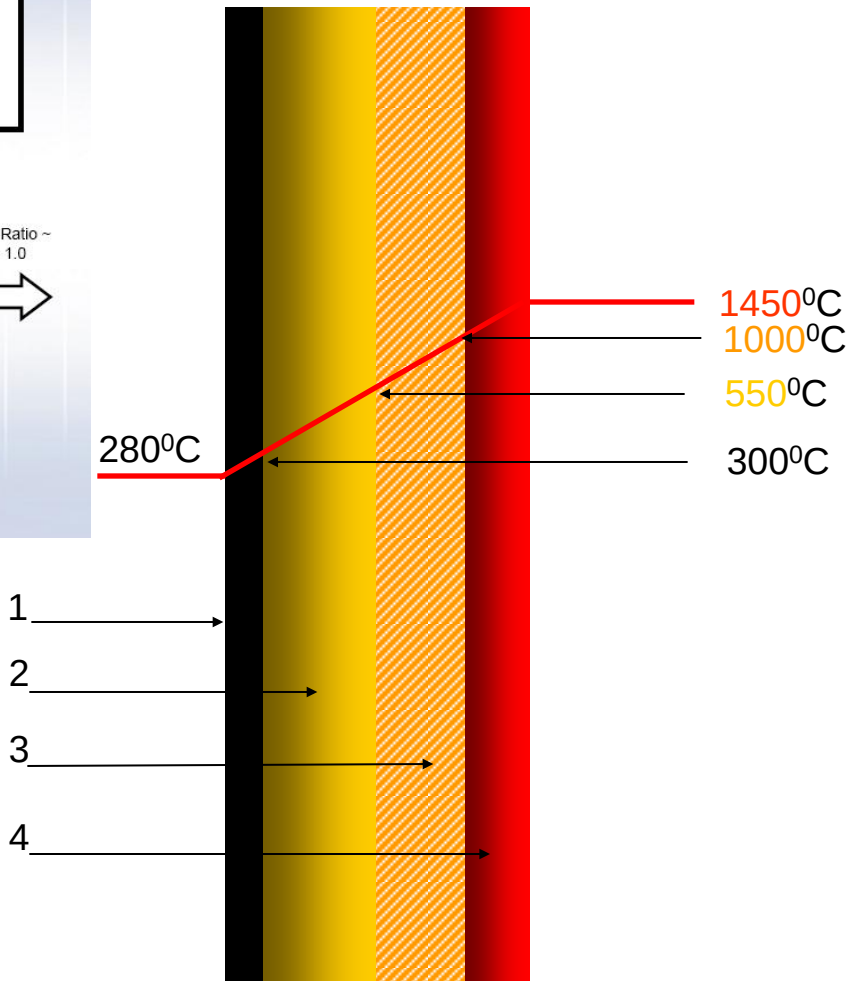



TPRI Syngas Quench Gasifier (SQG)

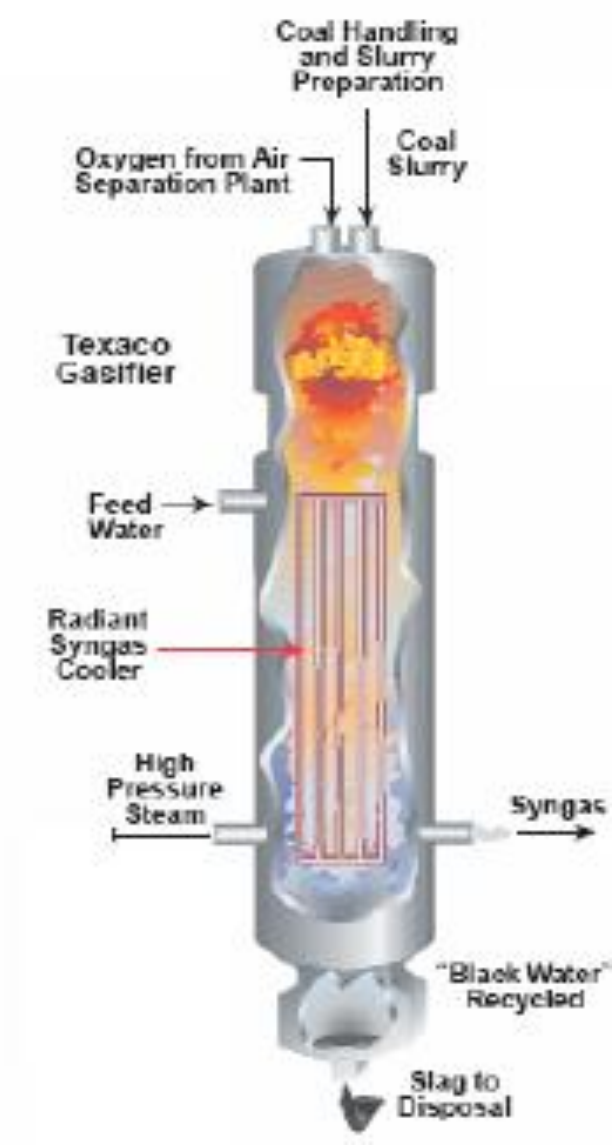
# General Electric: Quench Gasifier



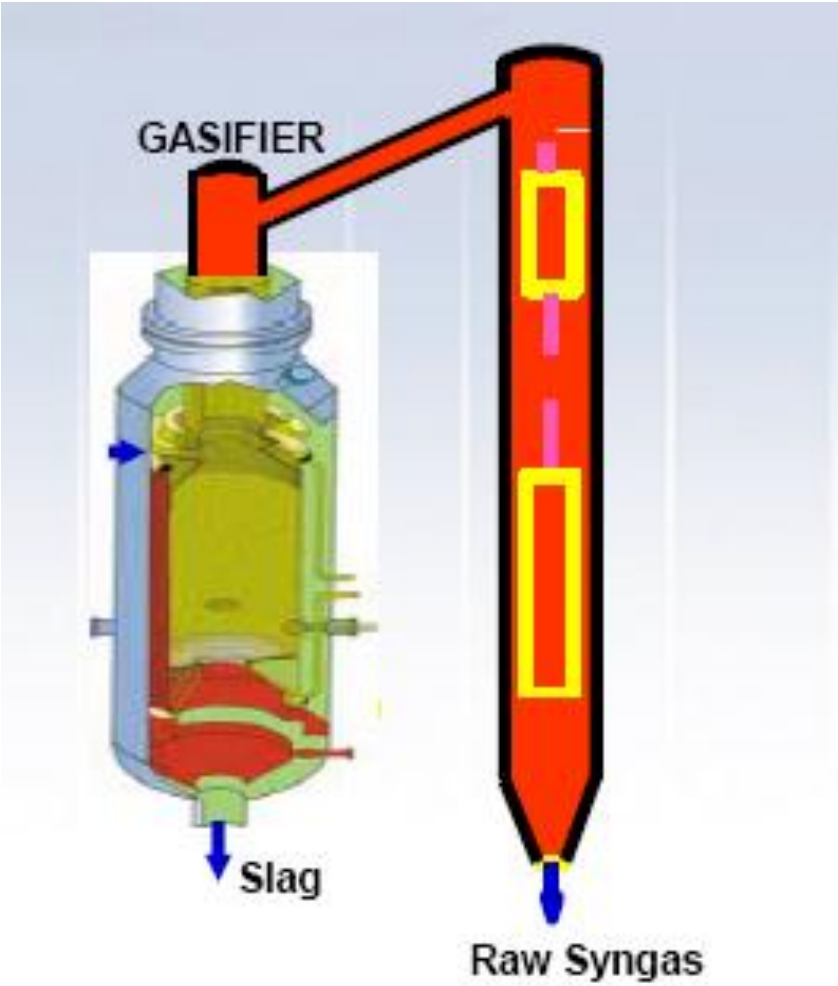

1. Steel Pressure Shell
2. Insulation Layer
3. Castable Layer
4. Hot-face Refractory



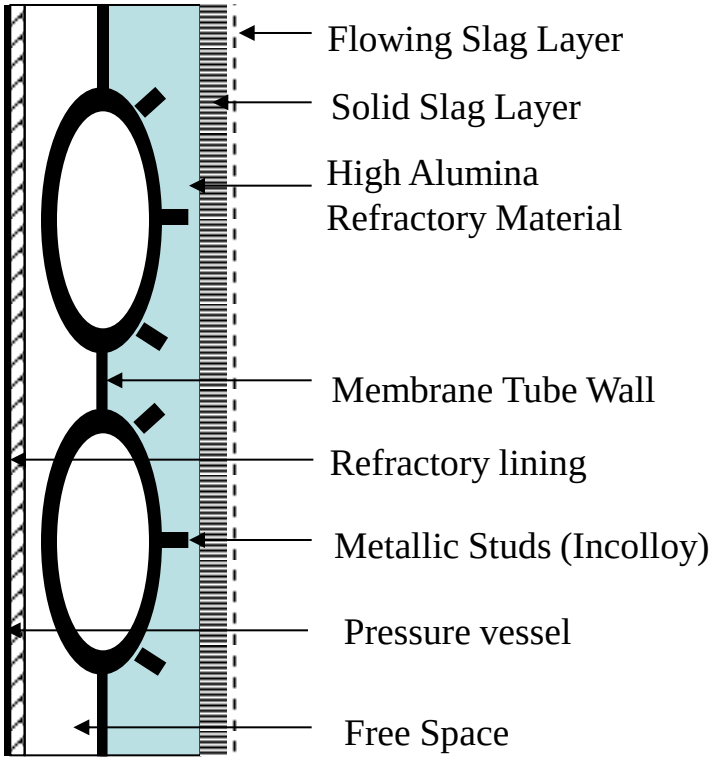
# General Electric: PHR Gasifier

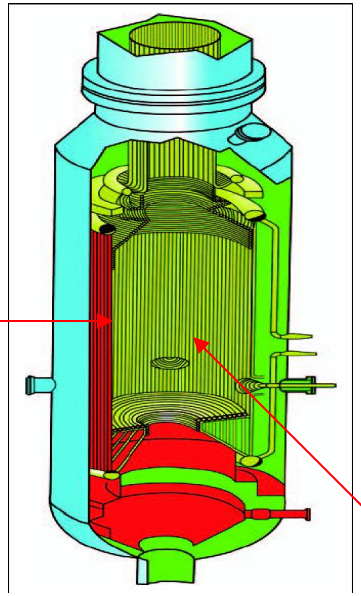


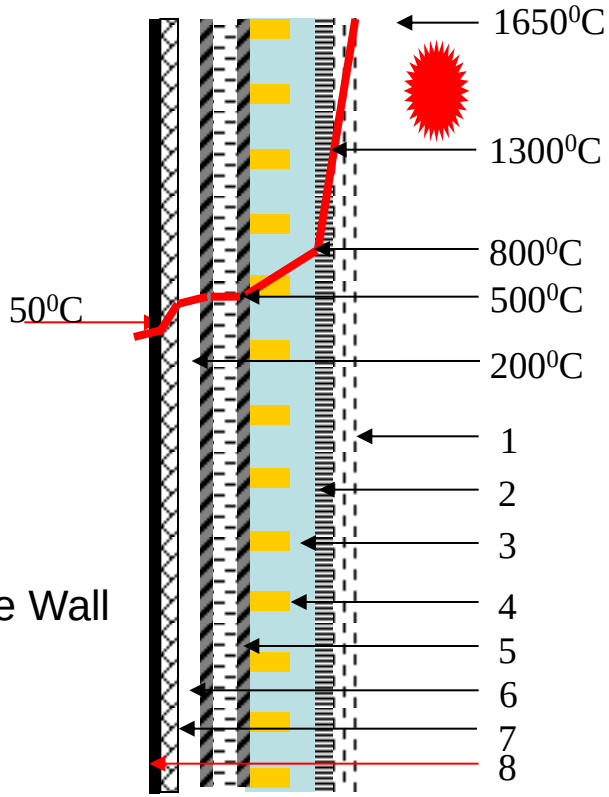
# Shell Gasifier



# Shell Gasifier

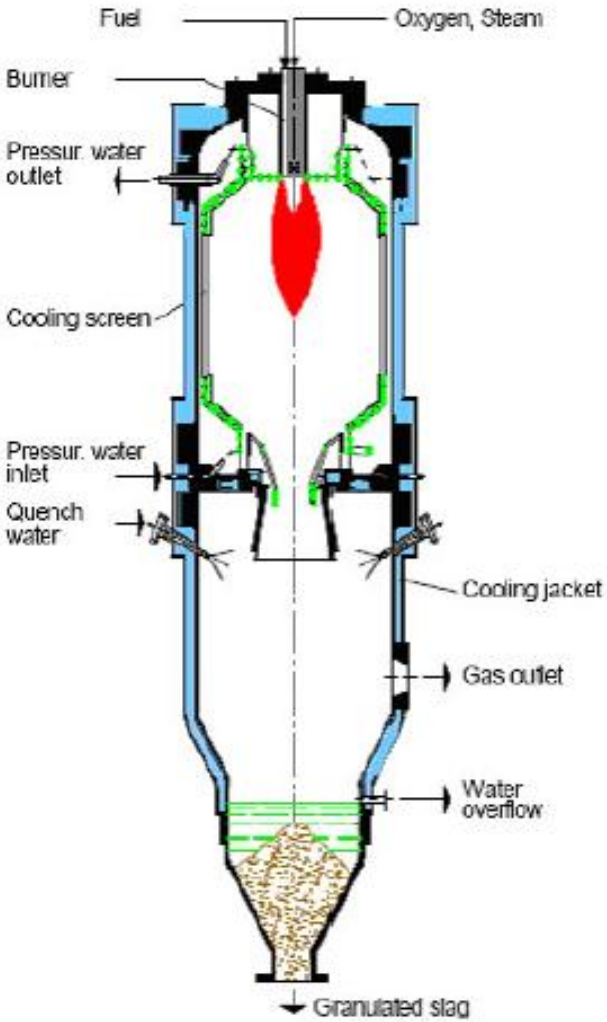


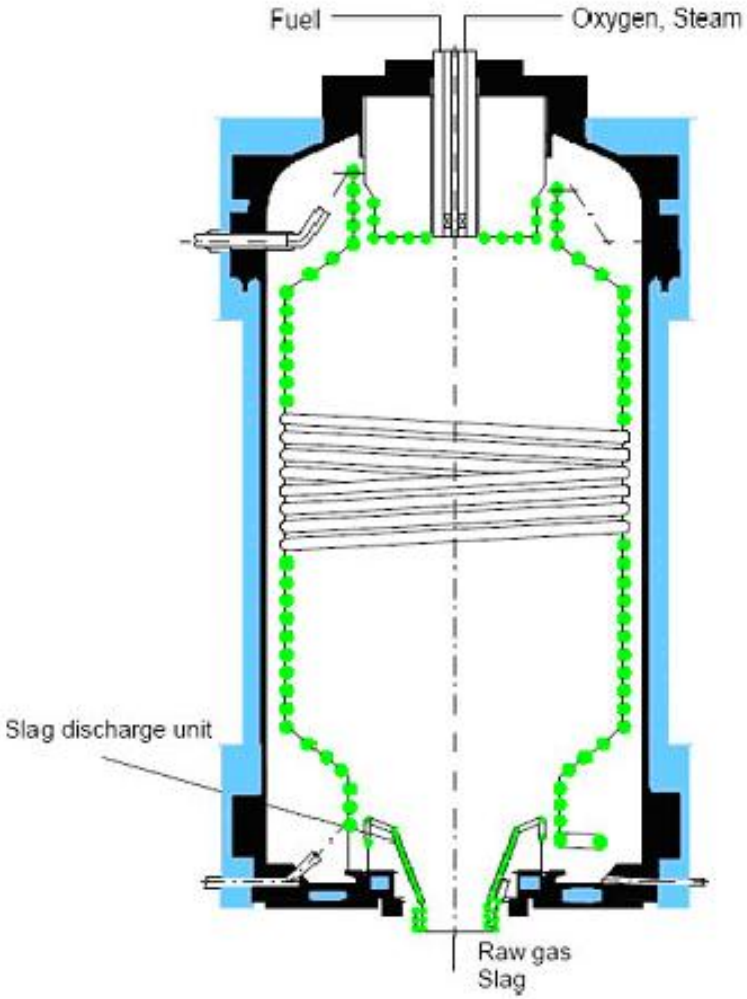




1. Flowing Slag Layer
2. Solid Slag Layer
3. High Alumina Refractory Material
4. Metallic Studs (Incolloy)
5. Membrane Tube Wall
6. Free Space
7. Refractory Lining on Pressure Vessel
8. Pressure Vessel

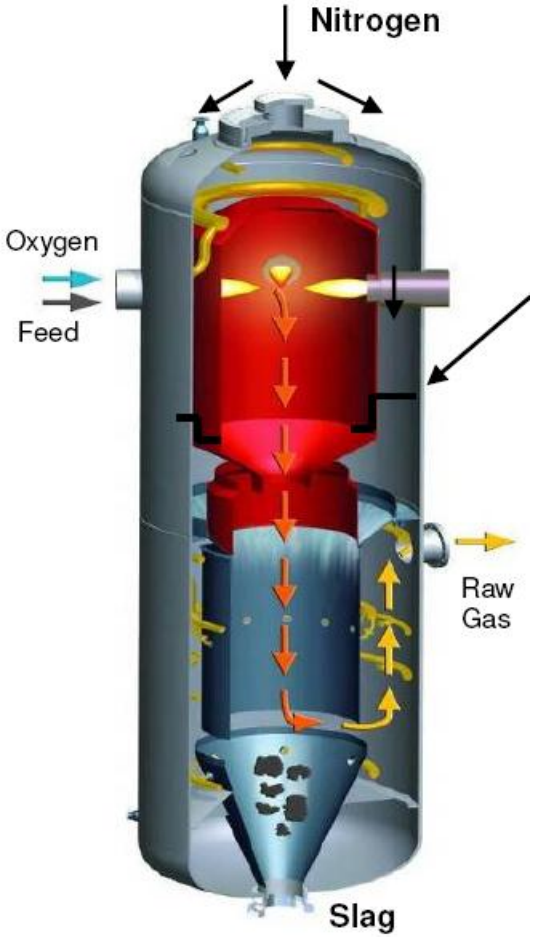
# Siemens Gasifier



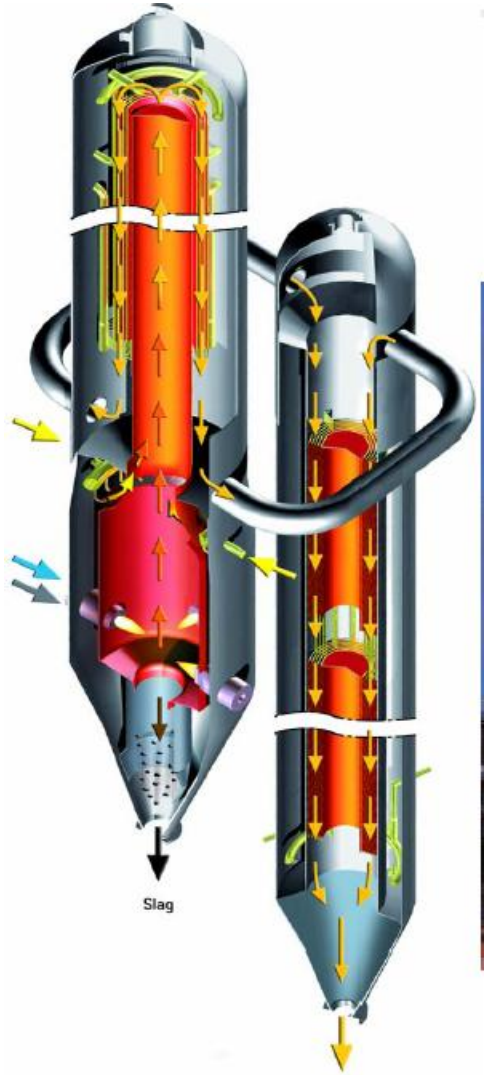




Source: Siemens

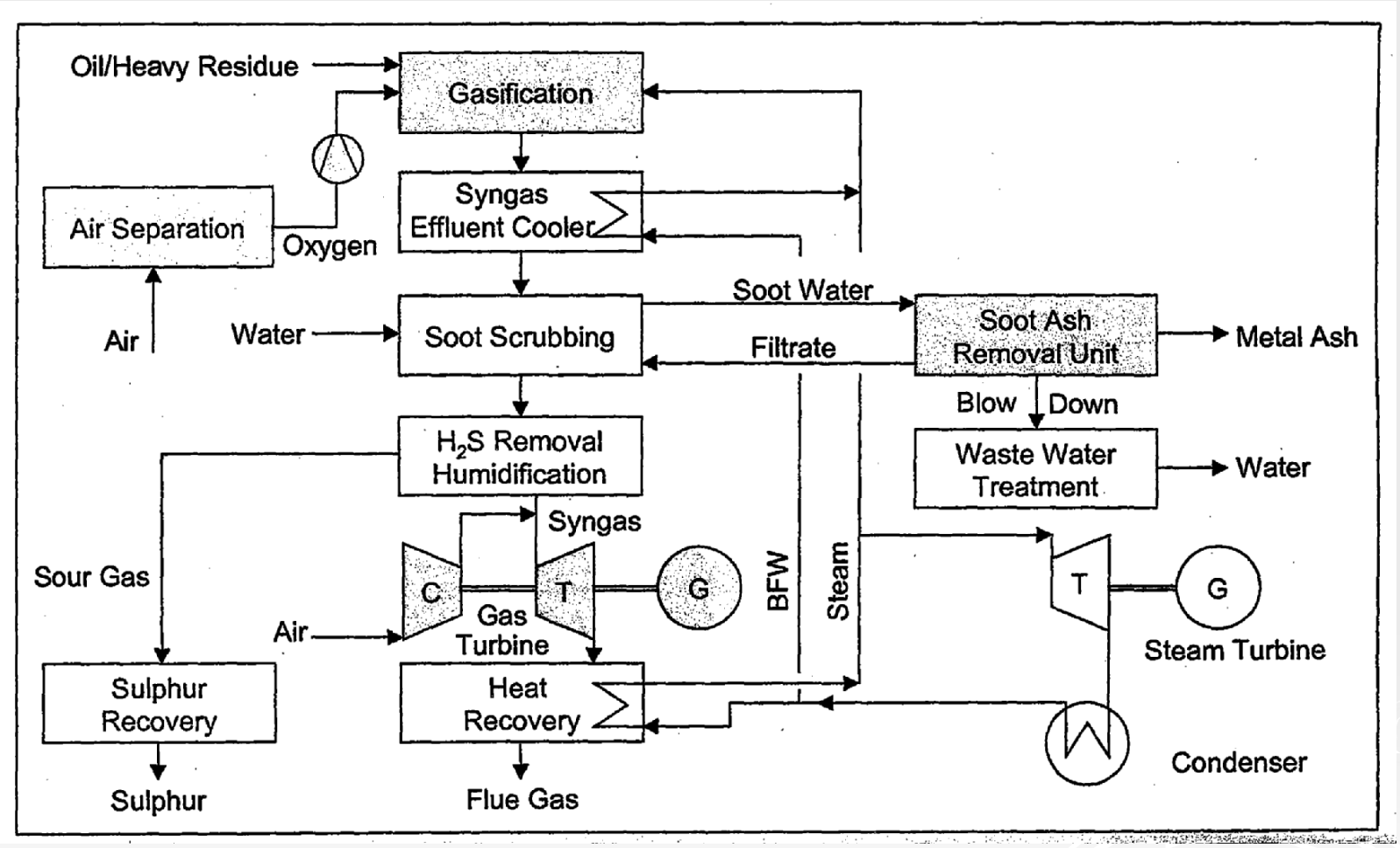
Uhde: Prenflo Direct Quench



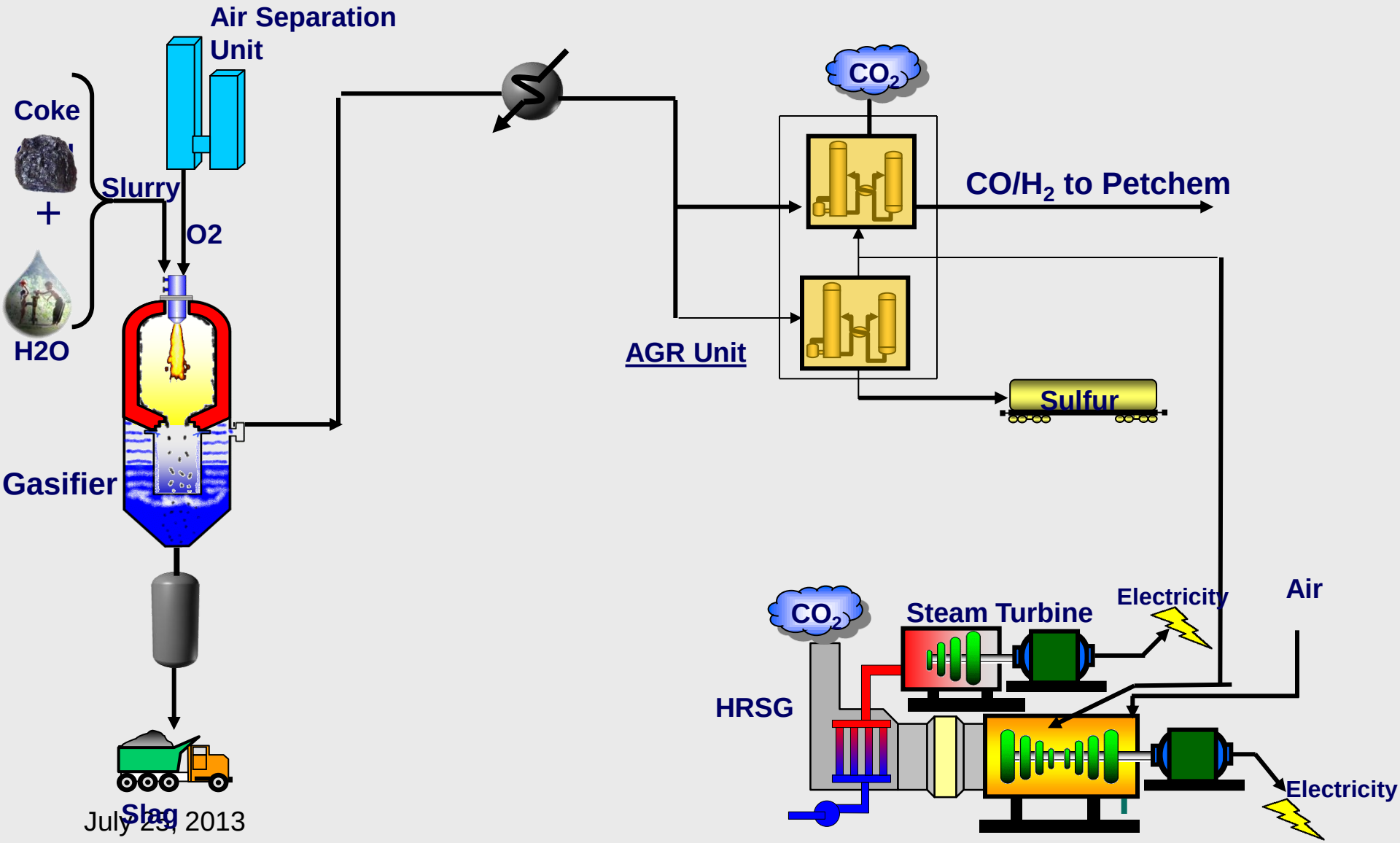

Uhde: Prenflo Steam Generator



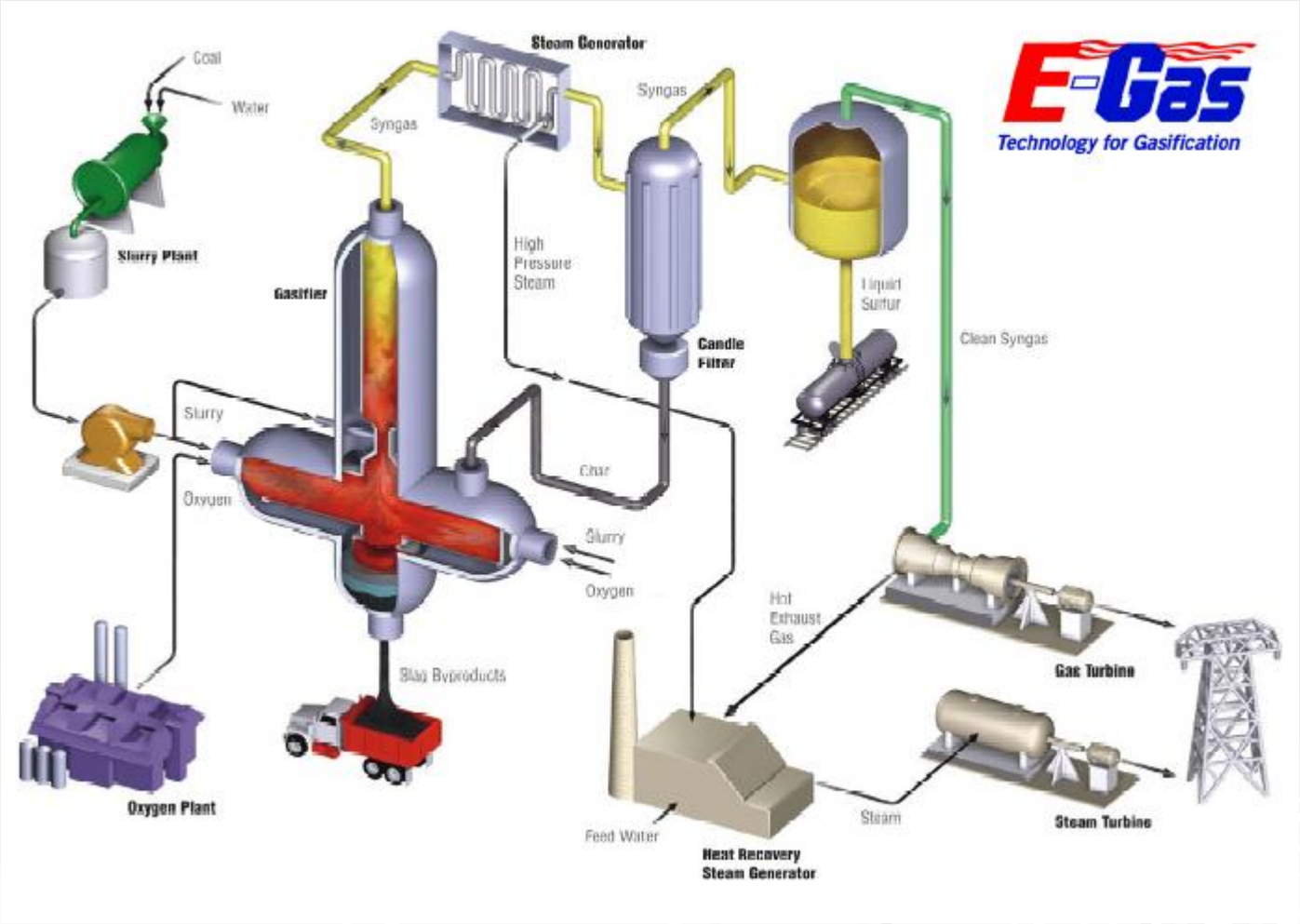
# IGCC POWER STATION BASED ON SHELL TECHNOLOGY



# GE QUENCH GASIFIER FLOW SHEET



# CONOCO-PHILIPS GASIFICATION FLOW SHEET

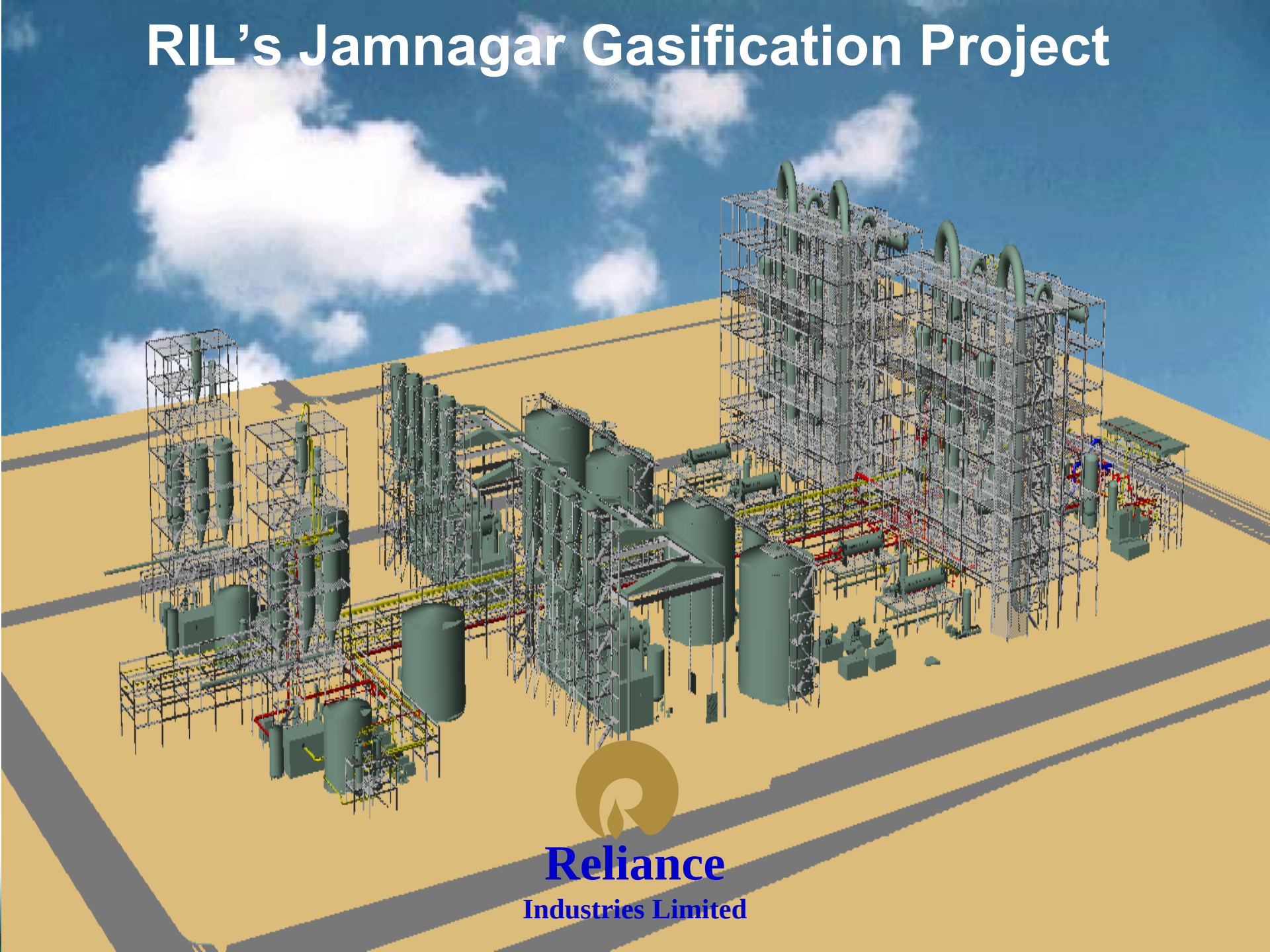



July 25, 2013

# COMMERCIAL SCALE IGCC PLANTS

| TECHNOLOGY SUPPLIER | SOLID FUEL FEED TYPE | INSTALLATIONS |
|---|---|---|
| GE Technology | Water Slurry | 1. Tampa Electric IGCC Plant, (250 MW)<br>2. Cool Water IGCC Plant (100 MW)<br>3. Eastman Chemical, Kingsport |
| Conoco Philips<br>E-GAS | Water Slurry | 1. Wabash River IGCC Plant (262 MW) |
| SHELL (SCGP) | $N_2$ Carrier/Dry | 1. Demkolec IGCC plant, (Buggenum Netherlands) (253 MW)<br>2. SHELL-Pernis IGCC Plant (Netherlands), Hamburg |
| PRENFLO / Uhde | $N_2$ Carrier/Dry | 1. Elcogas, Puertollano IGCC Plant (Spain) (298 MW) |

# RIL's Jamnagar Gasification Project



Reliance
Industries Limited

# Options for Petcoke Usage

- First Refinery at Jamnagar started up in Q4'99. Petcoke production ~ 8500 TPD

- During project engineering phase several options for petcoke usage were discussed:

  - Thermal power plant – CFBC Boiler + STG

  - Petcoke gasification to generate $H_2$ for refinery. Back up of coal feed during start up

  - Storage of petcoke during intervening period between start up of refinery and proposed units above

  - Focused effort for marketing of petcoke – National + International Customers

- Marketing efforts were so successful, that RIL didn't pursue any of the other options.

# Petcoke Analysis

| Property | Wt% (dry basis) | Comments |
|---|---|---|
| Carbon | 89.1 | - |
| Hydrogen | 2.8 | Volatile matter |
| Sulfur | 7.5 | High S crude dependent |
| Ash | 0.6 | Contains metals |
| Nitrogen | 500 ppm | - |
| Oxygen | 100 ppm | - |
| Hard grove index (HGI) | 30 - 35 | Hard coke |
| Moisture | 8.0 | As delivered |
| Gross calorific value | 8350 kcal/kg | As measured |

# Indian Petcoke Scenario

- Second Refinery at Jamnagar started up in Q4’08
- Petcoke production: ~9500 TPD
- Total Reliance petcoke generation: ~6.4 MMTPA
- Total petcoke generation in India: ~ 12 MMTPA
- Expected additional generation of petcoke in India by 2016: ~10 MMTPA
- Surplus petcoke will be available
- Reliance considers petcoke gasification as opportunity for value addition

# Business Drivers

- Transform “Jamnagar” into “bottomless” refinery
- Exploit price delta between natural gas and petcoke/coal
- Insulate the Jamnagar refinery from future energy cost escalation
- Utilize H2 to maximize refinery performance
- Recover C2+C3 from RFG for advantage petrochem feed
- Recover CO for acetyl chemicals
- Pursue reduction in GHG through possible CO2 capture and sequestration or effective utilization

# Integration with Refinery

| | |
|---|---|
| Refinery | • 1.35 mmbbl/d crude, w/ 12.6 Nelson complexity |
| Coker | • 340 kb/d, 2 trains, world's largest<br>• 18300 tpd of petcoke production |
| CPP fuel* | • Power + steam, MW = 1510 (cogen)<br>• Repower by syngas |
| $H_2$ | • Demand = 1300 t/d (on-purpose)<br>• Recovery from syngas |
| RFG* | • Demand = 3500 Gcal/hr (fired heters)<br>• From syngas via SNG |

**Integration: Refinery + petrochem + utilities/power + port/terminal**

* CPP: Captive Power Plant * RFG : Refinery Fuel Gas

**Stepping stone for Gasification**

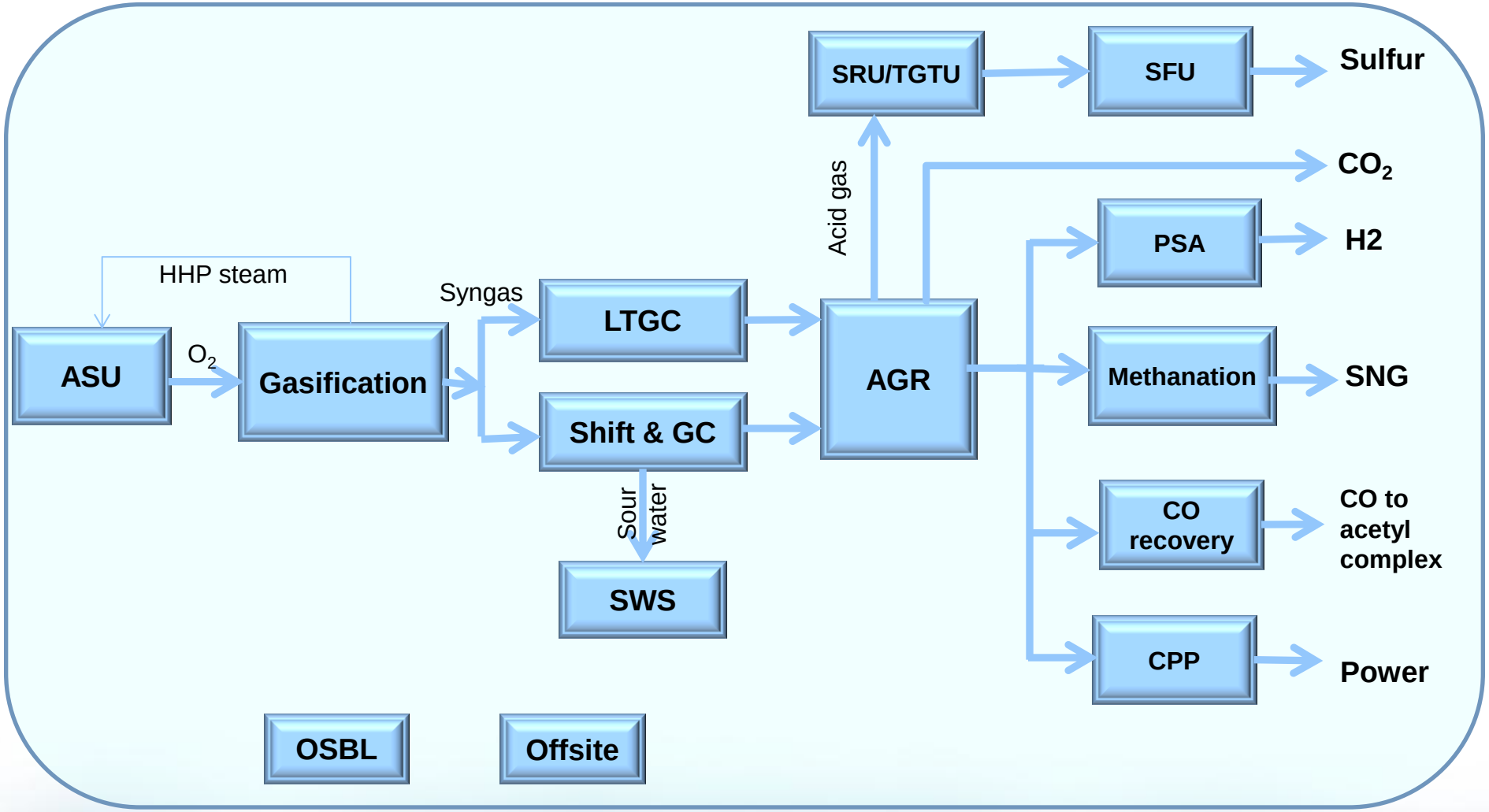
# Gasification Overview

- Modular design
- Flexible feed : petcoke or blend of coal and petcoke
- Implementation in two phases
  - Phase I
    - 4 modules, 2 gasifiers per module
    - 4 ASUs, 1 per gasifier module
  - Phase II
    - 2 more modules
    - 2 more ASUs
- Gasifier capacity:
  - ~2900 tpd petcoke per gasifier
  - ~272 KNm3/hr syngas production per gasifier (2.35 MMSCMD NG eqv.)
- World's largest ASU
  - 5250 tpd $O_2$ per ASU
  - 99% pure $O_2$ product
- Other units
  - AGR, PSA, SNG, CO Recovery, SRU/TGTU & SFU
- Open art design
  - LTGC, shift with gas cooling & Sour water strippers

ASU : Air Separation Unit AGR: Acid Gas Removal Unit SNG : Synthetic Natural Gas LTGC : Low Temperature Gas Cooling
SRU: Sulfur Recovery Unit SFU : Sulfur Forming Unit

**World's Largest gasification complex**

# Configuration

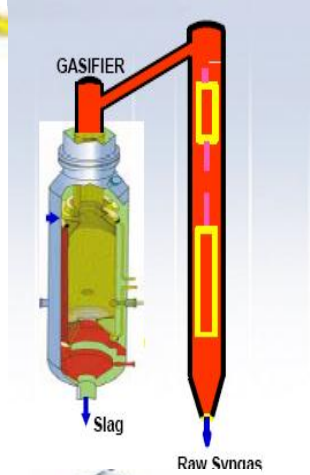


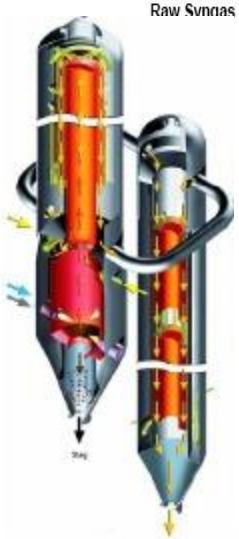

Optimized Design

# Technology Selection

## Entrained flow gasifiers:

- Type: Up flow or down flow
- Operate above ash melting point
- Feed: Slurry or dry feed
- High per pass carbon conversion
- High pressure & throughputs
- Short residence time
- Suitable for wide range of coals, including petcoke





**Selected for Jamnagar**

# Gasification Technology Ranking Matrix

**Gasification Technology Licensors considered:**

**EmberClear-TPRI, GE, CB&I, Shell, Siemens, Uhde**

| Design | Risk | FRAME | Performance | Financials |
|---|---|---|---|---|
| Gasifier design | Experience | Availability | Cold gas η | Capex |
| Operating conditions | Scale-up | Feeding system | Thermal η | Opex |
| Heat recovery system | | Gasifier | Carbon η | Life cycle cost |
| Syngas & slag flow | | Syngas cooling system | Useful gas η | |
| | | Maintenance schedule | $O_2$/feed | |

**CB & I selected for Jamnagar**

# Technology suppliers for Downstream units

| Unit | Technology Licensor |
|---|---|
| ASU | Air Liquide, Air Products, **Linde**, Praxair |
| AGR | Air Liquide, **Linde**, UOP/Technip |
| PSA | **Linde**, UOP |
| SNG | BASF, Haldor Topsoe, Johnson Matthey |
| Shift Catalyst | Haldor Topsoe, Johnson Matthey, Sudchemie |
| Shift/LTGC/SWS | Open art design by Fluor |
| SRU | Black & Veatch, Lurgi, **Worley Parsons-Linde** |
| SFU | **Enersul**, Brimrock, Sandvick, Devco |

SWS: Sour water stripping Unit

**Technology selection almost completed**

# Status update

- **Licensor Selection**
  - Gasification licensor : CB & I
  - E&P contractor : Fluor
  - Construction mgmt. : Reliance
- **Gasification updates**
  - Kickoff : May 2012
  - PFD review : June 2012
  - P&ID review : October 2012
  - PDP delivered: November 2012
  - Equipment : RFQ issued / Bid evaluation
- **ASU updates**
  - HAZOP in progress
- **OGBL updates**
  - Package units : Licensors selected
  - Open art unit : Design in progress/RFQ issued
- **OSBL/Offplot**
  - Issue RFQ & bid evaluation
- **Start-up**
  - Q2 2015

* ASU : Air Separation Unit *OGBL: Outside Gasification Battery Limit * OSBL : Outside Battery Limit

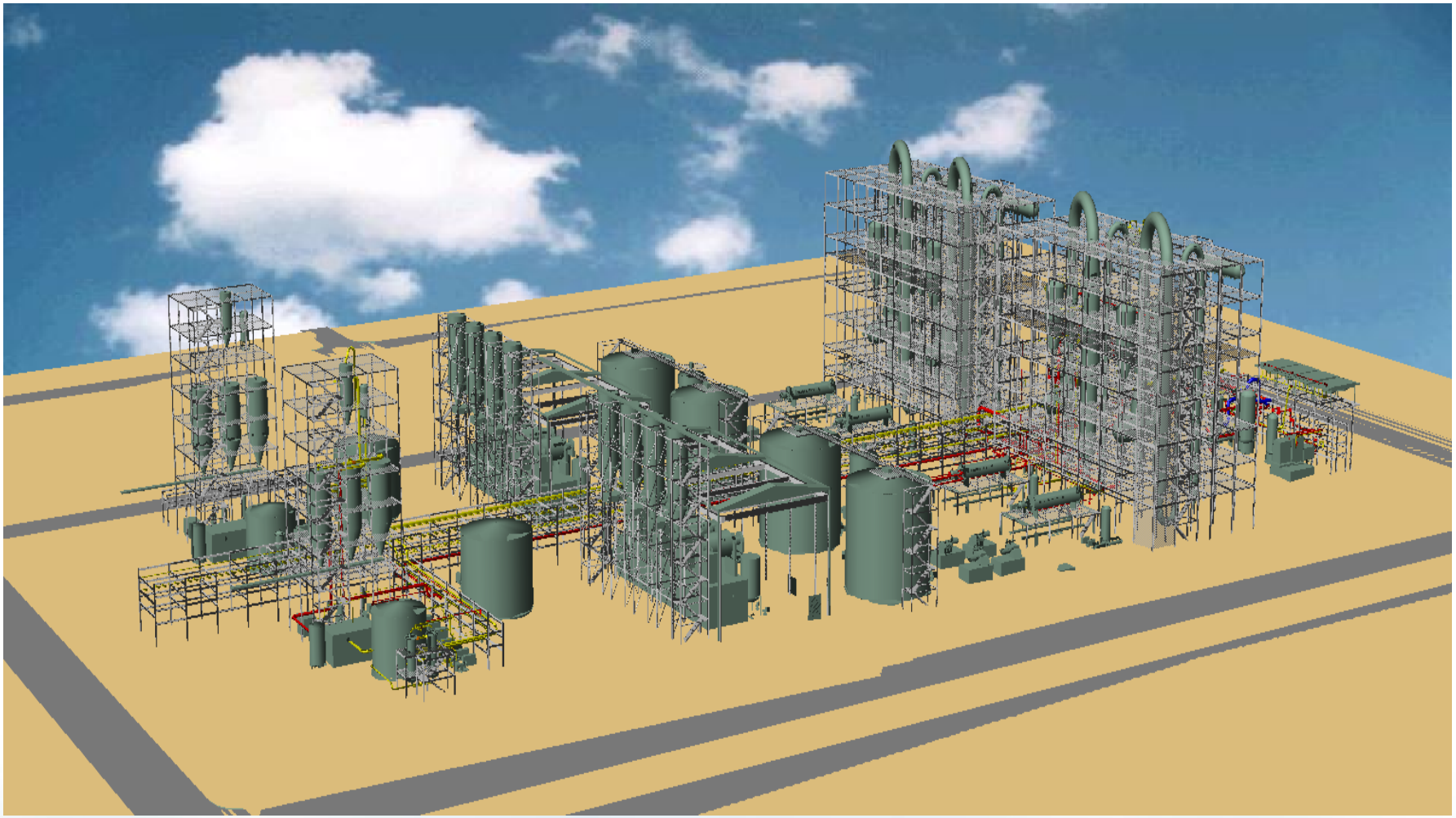
**Site preparation complete**

# Project Status

- Selected Gasification Licensor - Phillips 66 now CB&I
- Selected PMC & EP - Fluor
- Kick off - May 2012
- PDP completed - November 12
- Selected ASU & AGR Licensor - Linde
- Selected SRU Licensor - Linde/Worley Parsons
- Start-up - 36 months post kick-off

**Typical Reliance Aggressive Project Schedule**

# Jamnagar at 2015



# Centre of Excellence (CoE) for Gasification

- ✓ Acquiring knowledge of:
  - All existing and emerging gasification technologies
  - All downstream and auxiliary process technologies
  - Suitability of different feedstocks
- ✓ Understanding economics of all processes
- ✓ Develop expertise on modeling of gasification processes
- ✓ Explore opportunities for development of own technology

# Centre of Excellence (CoE) for Gasification

- ✓ Creation of knowledge repository:
  - Gasification portal
  - Keeping abreast with gasification-related activities globally
- ✓ Techno-economic evaluation of:
  - Existing & emerging gasification technologies
  - Downstream products & processes
- ✓ Pilot plant studies with technical / commercial collaboration for:
  - Characterization of feedstocks (coal, lignite, petcoke, biomass)
  - Understanding reaction kinetics
  - Building capability for gasifier design
  - Developing Gasification Technology for high ash content Indian Coal

# Centre of Excellence for Gasification

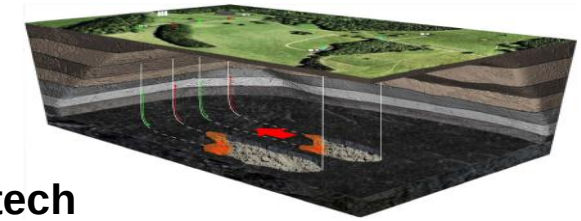
- Jamnagar Petcoke/Coal gasification Project: Under Implementation
- Coal Bed Methane – Commercial pilot
- Underground Coal Gasification – Business case prepared
- Direct Coal Liquefaction – Pilot tests performed
- Hybrid Coal Liquefaction – Business case prepared
- Microbial Coal Conversion – Prefeasibility in progress
- Creating Centre of Excellence for Gasification

Reliance sees coal business as a strategic growth sector

# Microbial Coal Conversion

**Technology being developed to efficiently convert in-ground and extracted low rank coal to gas**

- In-situ Bioconversion-
  - Low cost chemicals (bio-stimulants) are injected into coal seams to stimulate microbes to convert coal to methane.
  - Technology may also be used to enhance or generate methane from fully depleted CBM wells
- Ex-situ Bioconversion-
  - Low grade coal converted by chemical solubilization and anaerobic fermentation
  - Does not produce $CO_2$ and hazardous waste



**<u>Technology providers:</u>**
**Luca, Ciris, Next fuel, Synthetic Genome Institute, MicGas-Arctech**

**Proposal for feasibility study in Progress**

# Challenges for Clean Coal

- **Complex projects**
- **High cost of new technology**
- **Need to strengthen research environment**
- **Expensive & high risk investment for any single industry player**
- **Need collaborations with emerging technology providers**
- **Needs strong support from Indian Government**
- **Need Public/ Private partnerships and partnership with technologically advanced players**

**Access to technology & stronger national/ international partnerships needed**

# Progressive policy needed to accelerate improved coal utilization

- **Accelerate opening up of Coal sector for private sector investments**
- **Develop clear policy on bidding and allotment of coal blocks**
- **Open new coal blocks for bidding**
- **Expedite clearances for new projects**
- **Strengthening of coal supply chain**
- **Promote consortia (private + public) for pre competitive technology development with financial support**
- **Policy concessions and economic incentives for development and deployment of new technologies in India**
- **Coal pricing to be market linked**

**Government's proactive role in building technical & operational capabilities is crucial**

# Innovation Led Growth

## Growth is Life

# THANK YOU