INTRODUCTION TO GASIFICATION

Neal Richter
What is Gasification?

- Where does it come from?
- What is it good for?
- and why should anyone care?
Gasification Process

Gasification is a process that produces mixtures of Hydrogen and Carbon Monoxide (synthesis gas or syngas) from carbonaceous materials.
Starting in 1790, there have been many processes called Gasification. The GTC and EPA have made further, significant additions to the definition to describe today’s commercial operations:

Gasification operates under slagging conditions at a minimum temperature of 2300°F.
Processes meeting these conditions are called “second generation gasifiers”.

As a result of these conditions they are efficient, fuel flexible and meet stringent environmental regulations.
Gasification Process

The Texaco Gasification Process, and the processes of other GTC members, are second generation processes developed for the “alternate energy” and synthetic chemical industries.
Partial Oxidation (POX) – Reaction with a Limited Amount of Oxygen results in a highly reducing atmosphere:

- \[ \text{CxHy} + \frac{x}{2} \text{O}_2 \Rightarrow x \text{CO} + \frac{y}{2} \text{H}_2 + (\text{heat}) \]
  - non-catalytic
  - reducing atmosphere (no oxygen) limits products
Gasification Process

- High Pressure, refractory lined reactor – up to 1200 psi.
- High Temperature – inorganic material is melted. Organics, except trace methane, destroyed.
- Entrained flow reactor – all feeds flow co-currently from top.
- Short residence time - seconds.
- High purity oxygen preferred.
Gasification Process

**Feedstock** + **Oxidant**

\[
\text{CHSNOAsh} + O_2 + H_2O \rightarrow \text{Products}
\]

- **(major)**
  - CO
  - H\(_2\)
  - CO\(_2\)
  - H\(_2\)O

- **(minor)**
  - H\(_2\)S
  - N\(_2\)
  - CH\(_4\)

- **(trace)**
  - NH\(_3\)
  - COS
  - HCN

- **Slag**

- High carbon conversion – small amounts of solid carbon produced that can be recycled
- Wide range of feeds – any carbonaceous material
## Gasification vs. Combustion

<table>
<thead>
<tr>
<th>Gasification</th>
<th></th>
<th>Combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>←</td>
<td>C</td>
</tr>
<tr>
<td>H₂</td>
<td>←</td>
<td>H</td>
</tr>
<tr>
<td>N₂</td>
<td>←</td>
<td>N</td>
</tr>
<tr>
<td>H₂S</td>
<td>←</td>
<td>S</td>
</tr>
<tr>
<td>O</td>
<td></td>
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</tbody>
</table>
## Gasification is Not Incineration

<table>
<thead>
<tr>
<th>GASIFICATION</th>
<th>INCINERATION</th>
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</thead>
<tbody>
<tr>
<td><strong>Purpose:</strong> Creation of valuable, usable products</td>
<td><strong>Purpose:</strong> Destruction of waste materials</td>
</tr>
<tr>
<td><strong>Chemical conversion using limited amounts of oxygen:</strong></td>
<td><strong>Complete combustion using excess air:</strong></td>
</tr>
<tr>
<td>C to CO</td>
<td>C to CO2</td>
</tr>
<tr>
<td>H to H2</td>
<td>H to H2O</td>
</tr>
<tr>
<td>S to H2S, then pure S</td>
<td>S to SO2</td>
</tr>
<tr>
<td>N to N2</td>
<td>N to NOx</td>
</tr>
<tr>
<td><strong>High temps (2300-2700 F) and high pressure</strong></td>
<td><strong>Lower temps (1500-1800 F) and atmospheric pressure (0 psig)</strong></td>
</tr>
</tbody>
</table>
Texaco Gasification Process

**Feeds**
- Oxygen

**Gasification**
- Alternatives:
  - Petroleum Coke
  - Coal
  - Heavy Oil/Residuals/Tar
  - Refinery Sludges

**Gas Refining**
- Sulfur Recovery
- Sulfur Removal
- H₂S

**End-products**
- Combustion Turbine
- HRSG
- Electricity
- Steam
- Chemicals:
  - Hydrogen
  - Ammonia
  - Methanol
- Co-products:
  - Sulfur
  - Solids

Chemicals

Recovery

Evolution

Syngas
Gasification Process

What are the consequences of the Texaco Gasification Process mode of operation and very severe conditions?

♦ Small, high capacity reactor

♦ Can use essentially any carbonaceous material solid/liquid/gas, ash, S, mixtures, variable, no reactivity concern HIGHLY FLEXIBLE

♦ Many uses for product VERY VERSATILE.

♦ ENVIRONMENTALLY CLEAN!!
Gasification Process

FEEDSTOCKS:
- Natural Gas
- Oil
- Petroleum
- Coke
- Coal
- Recycled Products
- Low Value Materials
- Secondary Materials

RAW SYNGAS:

PRODUCT SYNGAS:
- Methanol
- Oxo-Chemicals
- Liquid Fuels
- Acetic Acid
- Ammonia
- Refinery Products
- Hydrogen
- Electric Power
- Iron Ore
- Reduction Fuel Cells

PURIFICATION AND REFINING

PRODUCTION OF SYNGAS (H2 + CO)
Feedstocks Gasified

- **PETROLEUM**: full range, natural gas to asphalt. All types of crudes. Orimulsion®

- **COAL**: all ranks, anthracite to lignite, caking and non-caking, high & low ash, high & low sulfur (over 50 different coals)

- **COAL LIQUEFACTION RESIDUES**:

- **PETROLEUM COKE**: delayed and fluid (over 30 different cokes)

- **BY-PRODUCTS AND SECONDARY MATERIALS**: petrochemical and refinery by-products, sewage sludge, plastics, tires
## Environmental Impact Summary

- No gaseous emissions from the gasifier, only from the process using syngas for fuel or chemical synthesis.
- Sulfur emissions can meet requirements, sulfur a product.
- No NOx in syngas. IGCC NOx production relatively low compared to other coal using processes.
- Particulates emissions below standards.
- Organics, including TCDD, undetected, or below limits.
- Most coal ash in glassy, carbon free particles, the rest in fines with char. Both normally pass TCLP. Inorganic matter can be recovered.
- Mercury can be contained.
DIOXIN AND FURAN MEASUREMENTS: Only amounts near detection limits have been found in some samples (50-100 pico g/m³ - 10 parts/quadrillion). Results of the same magnitude as analytical blanks and probably not statistically significant. In no case has TCDD (tetrachloro dibenzo-p-dioxin) been found.

FORMATION & THEORY: Dioxins and Furans are formed by reaction of hydrocarbons and chlorine, in the presence of metals, particularly copper, and oxygen, in the temperature range of 200-600°C. This combination of conditions/factors does not occur at any point in the ChevronTexaco Gasification Process, therefore, the negligible concentrations found are expected.
API Energia, Italy IGCC Example
Refinery Environmental Improvement

Total Refinery Emissions (mg/Nm³)

- Refinery - Before Gasification
- New EEC Refinery Limits
- Refinery - After Texaco Gasification

SOx: 2400, 1700, 507
NOx: 375, 500, 97
CO: 190, 250, 41
Particulate: 85, 80, 14

ChevronTexaco
Texaco Gasification Operating Plants

72 Facilities: Operating (60), Construction / Engineering (12)
125 Gasifiers: Operating (102), Construction/Engineering (23)
154,200,000 Nm3/Day: Syngas (H2/CO) Nominal Capacity

Europe - 23
USA - 23
U.K. - 8
France - 5
Germany - 8
Spain - 5
Italy - 5
Sweden - 1
Oldest Plant: 1958

Asia - 26
China - 14
Japan - 6
Singapore - 2
India - 1
South Korea - 1
Taiwan - 1
Australia - 1
Oldest Plant: 1961

Oldest Plant: 1958