Industrial Perspective on Hot Gas Cleanup

Presentation at the
5th International Symposium on Gas Cleaning at High Temperatures
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U. S. DOE National Energy Technology Laboratory
Morgantown, West Virginia

by
Dale Simbeck
SFA Pacific, Inc.

Presentation Overview

Background

• SFA Pacific
• Commercial gasification trends

Objective of the recently completed SFA Pacific analysis of gas treating for commercial gasification for NETL

• Emphasis was commercial gas cleanup, however NETL requested that SFA Pacific add an objective overview of hot gas cleanup

Results relative to hot gas cleanup

• Limited interest in & success of hot gas cleanup
• Many issues working against hot gas cleanup
• Challenges hot gas cleanup must overcome

Conclusions
SFA Pacific Background

Founded in 1980

Performs technical, economic & market assessments for the major international energy & engineering companies

Principal work involves residual oil upgrading, electric power generation, syngas generation & emissions control

Niche is objective outside opinion and comparative analysis before companies make major decisions or investments

Unique perspective as we have no vested interest in E&C, resources, technologies, R&D or project development

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### Representative SFA Pacific Clients

<table>
<thead>
<tr>
<th>UTILITIES</th>
<th>INDUSTRIALS</th>
<th>MANUFACTURERS + E&amp;C</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Gas</td>
<td>BHP</td>
<td>ABB/Alstom</td>
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<tr>
<td>CEA (Canada)</td>
<td>BP (Amoco Arco Veba Oil)</td>
<td>Babcock &amp; Wilcox</td>
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<tr>
<td>EdF</td>
<td>Chevron Texaco</td>
<td>Black &amp; Veatch</td>
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<tr>
<td>Electrabel</td>
<td>Chinese Petroleum</td>
<td>Bechtel</td>
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<tr>
<td>EPDC (Japan)</td>
<td>Dow/Destec</td>
<td>Chiyoda</td>
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<td>EPRI</td>
<td>DuPont/Conoco</td>
<td>Cummins</td>
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<td>Eskom</td>
<td>ENI</td>
<td>Fluor Daniel</td>
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<td>GRI</td>
<td>Exxon Mobil</td>
<td>Ford</td>
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<td>National Power</td>
<td>PDVSA</td>
<td>Foster Wheeler</td>
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<td>Power Gen</td>
<td>Rio Tinto Kennecott Energy</td>
<td>General Electric</td>
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<td>RWE/Rheinbraun</td>
<td>Saudi Aramco</td>
<td>General Motors</td>
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<td>Tokyo Electric Power</td>
<td>Shell International</td>
<td>Kellogg Brown &amp; Root</td>
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<td>Tokyo Gas</td>
<td>Statoil</td>
<td>MHI</td>
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<tr>
<td>TransAlta</td>
<td>Total Fina Elf</td>
<td>Siemens/Westinghouse</td>
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<tr>
<td>Vattenfall</td>
<td>Weyerhaeuser</td>
<td>Snamprogetti</td>
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Summary of Gasification Trends

Large capacity & increasing growth rate the last few years

- Over 43,000 MW\textsubscript{th} syngas (24,000 MW\textsubscript{e} IGCC equivalent) real installed capacity + annual growth rates of 4,000 to 5,000 MW\textsubscript{th} syngas or 10%

Growth application: GCC power generation,

- However, not highly integrated GCC of coal in central power plants
- Mostly simple non-integrated designs in oil refinery polygeneration with large export power to the grid plus cogen steam & syngas - H\textsubscript{2}
- Principal fuels are low value “opportunity” fuels such as high sulfur, nitrogen & metals pitch & especially petroleum coke

Growth areas: Western Europe, North America & Asia

Gasification offers maximum flexibility for an uncertain future

- Natural gas replacement, electric deregulation, the hydrogen economy & stringent emissions, especially carbon management

Cumulative Worldwide Gasification Capacity in MW\textsubscript{th} Synthesis Gas Output

Source: SFA Pacific, Inc. for the U.S. Department of Energy
Gasification by Application

Source: SFA Pacific, Inc. for the U.S. Department of Energy

Gasification by Geographic Region

Source: SFA Pacific, Inc. for the U.S. Department of Energy
Gasification by Country

Top 10 Commercial Gasification Projects
### Gasification Projects Without Subsidies

<table>
<thead>
<tr>
<th>Chemicals from coal or pet coke</th>
<th>MW&lt;sub&gt;th&lt;/sub&gt;, syngas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ube Ammonia - Japan</td>
<td>294</td>
</tr>
<tr>
<td>Farmland - Kansas, USA</td>
<td>293</td>
</tr>
<tr>
<td>Eastman Chemicals - Tennessee, USA</td>
<td>219</td>
</tr>
</tbody>
</table>

### Oil refinery polygeneration from pitch or pet coke

<table>
<thead>
<tr>
<th>Location</th>
<th>MW&lt;sub&gt;th&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Arthur*, Texas - USA</td>
<td>2,029</td>
</tr>
<tr>
<td>Repsol*, Spain</td>
<td>1,654</td>
</tr>
<tr>
<td>Lake Charles*, Louisiana - USA</td>
<td>1,407</td>
</tr>
<tr>
<td>Deer Park*, Texas - USA</td>
<td>1,400</td>
</tr>
<tr>
<td>Total/Texaco - France</td>
<td>1,043</td>
</tr>
<tr>
<td>Nippon Oil - Japan</td>
<td>793</td>
</tr>
<tr>
<td>Exxon - Texas, USA &amp; Singapore</td>
<td>711</td>
</tr>
<tr>
<td>Shell - the Netherlands</td>
<td>637</td>
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</tbody>
</table>

* Planned

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**Farmland - Commercial (no subsidizes) Coke to Ammonia Gasification Plant at Coffeyville, Kansas**
Polygeneration

Defined as gasification to make synthesis gas (H₂ & CO) for GT-based cogen steam/power + syngas chemicals & fuels

Shell Oil Pernis refinery in the Netherlands is a good example, no subsidies & high availability without a spare gasifier

- Pitch gasification - 3 units total 640 MWth with 2 gasifiers for oil refinery H₂ & 1 gasifier for GCC cogeneration with NG as GT back-up

Great potential for polygeneration in the future due to ongoing deregulation of electric power generation

- Use of low value “opportunity fuels” high in metals, nitrogen & sulfur
- Offers greater flexibility than traditional power plant relative to fuels, products, revenues, emissions, efficiency & annual capacity factors
- Low marginal costs for CO₂ capture (will likely be added at Pernis)

Gasification Technology Trends

Texaco - about 75% of the market the last 5 years

- Simple direct water quench designs well suited for polygeneration
- Aggressive marketing including equity participation in 6 projects
- Extensive successful operating experience on various feedstocks
- Texaco is the most aggressive in reducing capital costs by working with GE & Praxair on improved standardized GT integrated designs
- Innovative H₂-CGCC with CO₂ capture design by Texaco/GE/Jacobs

Challengers to Texaco - mostly entrained slagging processes

- Simple, flexible & clean - any feedstock to just: syngas, sulfur & slag
- Shell - now taking equity positions: Sinopec coal to ammonia project
- E-Gas (Destec) - operation with pet coke & “over-the-fence” syngas
- Lurgi MPG & Noell BBP - operations with “nasty” waste fuels
Recent Analysis of Gas Cleanup in Gasification for NETL

Update of an original analysis by SFA Pacific for EPRI in 1987 (AP-5505)

- Gasification Technology Council (GTC) members found the original analysis quite useful & wanted the update
- Recently completed for NETL but not yet published

Objective:

- Review performance of gas treating processes that are applicable to IGCC under current & proposed U. S. emission standards
- Focus was on commercial technologies & applications used in current & proposed gasification projects
- In the course of the project, NETL requested adding an objective overview of hot & warm gas cleanup to the analysis

Why Hot Gas Cleanup

Avoid the high capital cost, energy losses & complexity of totally cooling the hot raw syngas leaving the gasifier

Avoids waste water & black/gray water slurry processing

Increases IGCC efficiency & capacity by increasing the mass flow & sensible energy into the gas turbine

Likely required for air-blown gasification to “make-it” due to the lower cold gas efficiency & larger, more expensive gasifiers of air-blown gasification relative of O₂-blown

- Large amount of sensible energy associated with the massive nitrogen heating into & cooling out of air-blown gasifiers
- For the same energy output, twice as many or twice as large gasifiers & gas cleanup vessels if air-blown
Industrial Views of Hot Gas Cleanup

Only commercial success has been warm gas particulate control via ceramic & sintered metal barrier filters

- This allows dry soot & char recycle thereby avoiding “black” water slurry processing or gasifier recycle of “black mud”
- Successful operation at several commercial scale IGCC facilities including Wabash River CCT demo in the U.S.

Failure of Piñon Pine - only air-blown & hot gas cleanup IGCC

- Including many problems with the hot gas desulfurization

Lack of use plus the embarrassingly large size of hot gas desulfurization unit at Polk County IGCC CCT demo

- Never used but would only process 10% of syngas with vessels as big as the conventional cold gas treating processing 100% syngas

Why the Limited Industrial Interest in Hot Gas Cleanup

Poor performance & limited use of hot gas cleanup (except warm particulate cleanup) in large gasification facilities

Increasingly stringent emission requirements

- NO\textsubscript{x}, SO\textsubscript{2} & especially trace components like Hg + other HAP & PBT

Ultra clean syngas requirements of gas turbines & fuel cells

Poor availability & lack of growth in highly integrated GCC

- Better availability & growth in polygeneration & syngas chemicals requiring O\textsubscript{2} gasification + super clean & CO shifted syngas

Increasing interest in CO\textsubscript{2} capture & storage

- Favors O\textsubscript{2} gasification, H\textsubscript{2}O + CO shifting & CO\textsubscript{2} capture from syngas
Challenges Hot Gas Cleanup Must Overcome

Removal of key trace components
- NH$_3$ & HCN as they form NO$_x$ in gas turbines
- Hg, carbonyls, persistent bio-accumulated toxins (PBT), other hazardous air pollutants (HAP), and alkali metals

High cost of hot syngas control valves for gas turbines

Overall size and complexity of hot desulflurization systems

Overall sulfur reductions, including COS, of as high as 99.8% may be required if SCR is needed in the future

Lack of industrial interest in and applications for air-blown and highly integrated GCC for power only
- Natural gas replacement, polygeneration, CO shifting & CO2 capture clearly favor O2-blown gasification & direct water quench

Conclusions

Hot gas cleanup is not hot
- Should consider changing the name & focus of this conference to include gas cleanup systems at all temperatures
- Large hot cleanup demos have failed + questionable technical, economic & market potential for highly integrated air-blown GCC
- Unclear if hot gas cleanup can remove NH$_3$, HCN, Hg, HAP & PBT

However, warm gas cleanup may still hold lots of promise
- Keeping H$_2$O of raw syngas in the clean gas helps CO shifting & IGCC
- Better chance of meeting increasingly ultra clean syngas demands
- Interesting potential for advanced H$_2$ membranes & CO$_2$ capture

Consider advanced gas cleanup systems that are synergistic with H$_2$, CO$_2$ capture, syngas chemicals & polygeneration