Industrial Perspective on Hot Gas Cleanup

Presentation at the

5th International Symposium on Gas Cleaning at High Temperatures

September 18, 2002

U. S. DOE National Energy Technology Laboratory

Morgantown, West Virginia

by

Dale Simbeck

SFA Pacific, Inc.

444 Castro Street, Suite 720
Mountain View, California 94041
web home page: www.sfapacific.com

phone: 1-650-969-8876
fax: 1-650-969-1317
e-mail: simbeck@sfapacific.com

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, Inc.

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

SFA Pacific, Inc.

Representative SFA Pacific Clients

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

SFA Pacific, Inc.

Summary of Gasification Trends

Large capacity & increasing growth rate the last few years

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

Growth application: GCC power generation,

- **However, <u>not</u> 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_2**
- **Principal fuels are low value "opportunity" fuels such as high sulfur, nitrogen & metals pitch & especially petroleum coke**

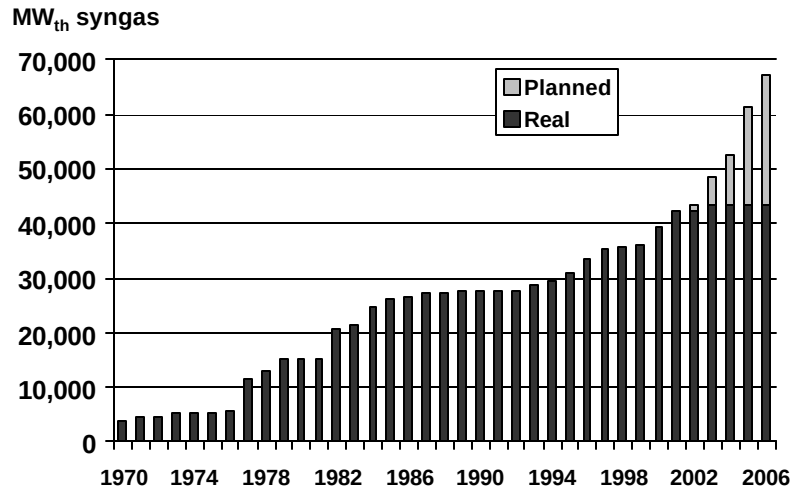
Growth areas: Western Europe, North America & Asia

Gasification offers maximum flexibility for an uncertain future

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

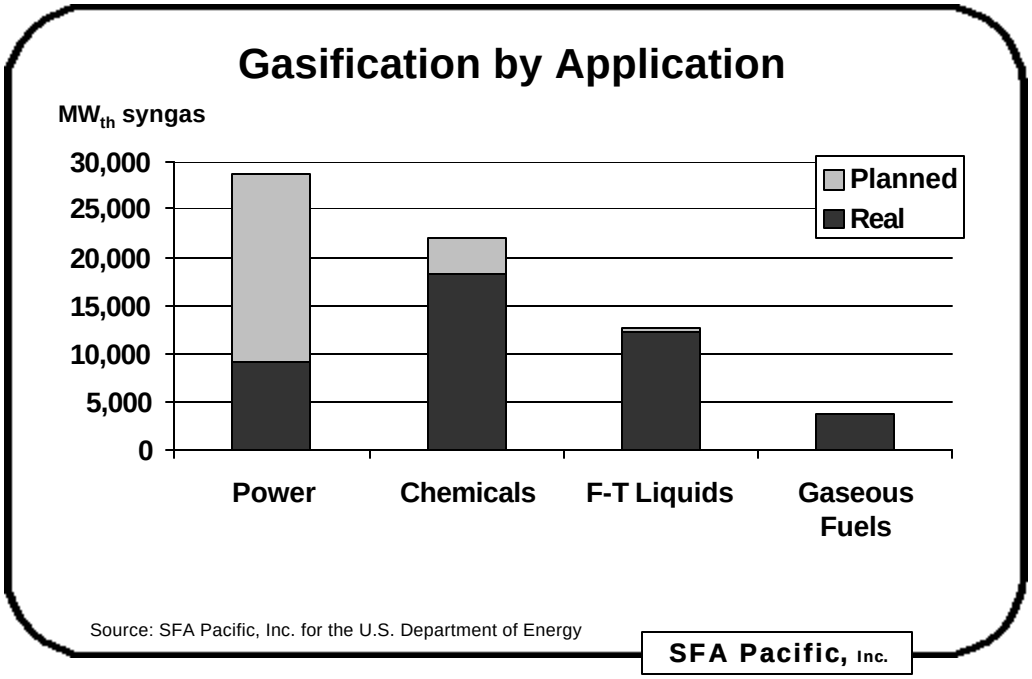
SFA Pacific, Inc.

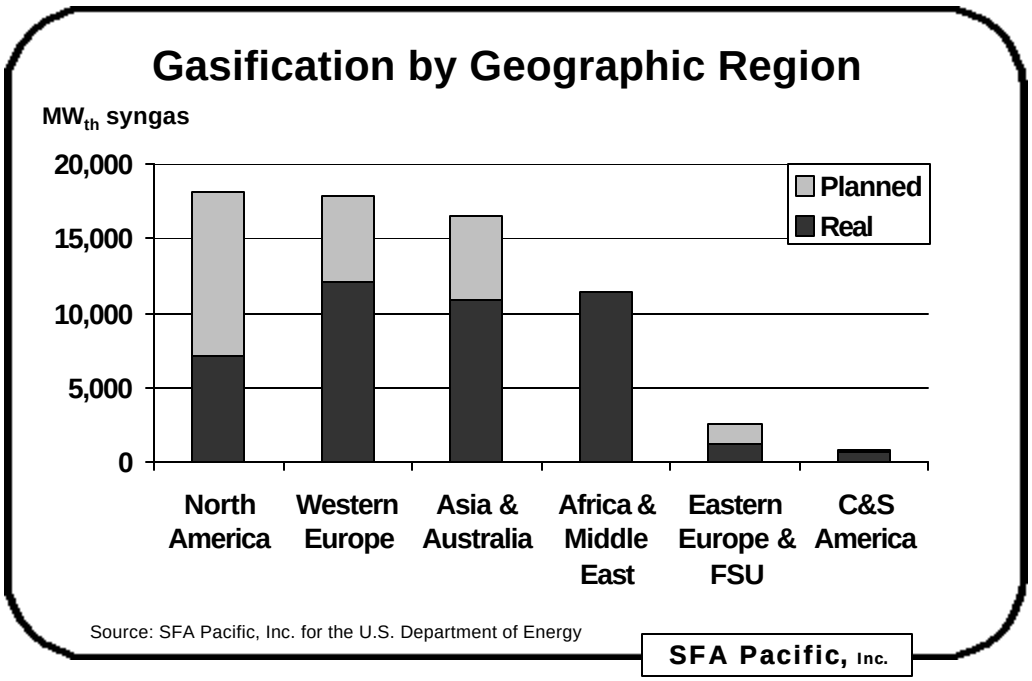
Cumulative Worldwide Gasification Capacity in MW_{th} Synthesis Gas Output



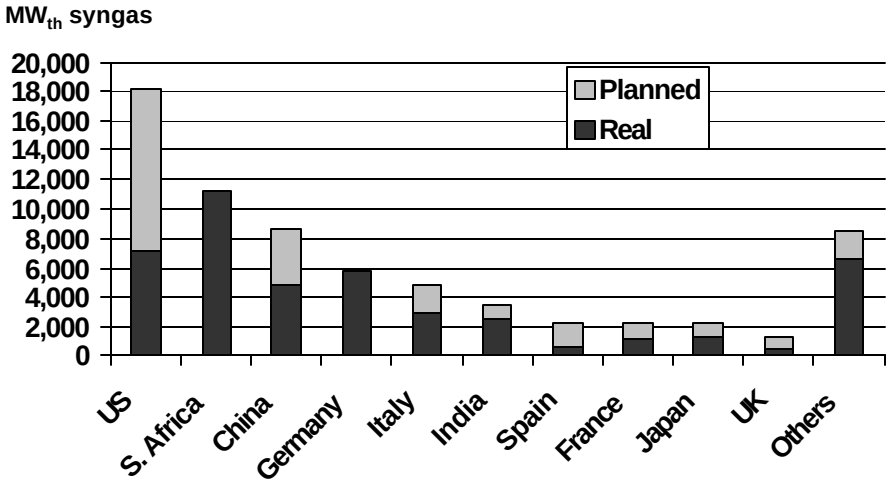
Source: SFA Pacific, Inc. for the U.S. Department of Energy

SFA Pacific, Inc.


Gasification by Application
MWth syngas
30,000
25,000
20,000
15,000
10,000
5,000
0
Planned
Real
Power
Chemicals
F-T Liquids
Gaseous Fuels
Source: SFA Pacific, Inc. for the U.S. Department of Energy
SFA Pacific, Inc.


Gasification by Geographic Region
MWth syngas
20,000
15,000
10,000
5,000
0
Planned
Real
North America
Western Europe
Asia & Australia
Africa & Middle East
Eastern Europe & FSU
C&S America
Source: SFA Pacific, Inc. for the U.S. Department of Energy
SFA Pacific, Inc.

Gasification by Country



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

SFA Pacific, Inc.

Top 10 Commercial Gasification Projects

Plants	Location	Gasifiers	MW_{th} syngas	Year	Feedstock / Products
Sasol-II	S. Africa	Lurgi	5,090	1977	coal / F-T liquids
Sasol-III	S. Africa	Lurgi	5,090	1982	coal / F-T liquids
Port Arthur*	USA	E-Gas	2,029	2005	coke / electric
Dakota	USA	Lurgi	1,900	1984	lignite / SNG
Repsol*	Spain	Texaco	1,654	2005	residue / polygen
Lake Charles*	USA	Texaco	1,407	2005	coke / polygen
Deer Park*	USA	Texaco	1,400	2006	coke / polygen
SARLUX	Italy	Texaco	1,217	2001	residue / polygen
Dong Ting*	China	Texaco	1,171	2006	coal / syngas chem.
Total/Texaco	France	Texaco	1,043	2005	residue / polygen

* Planned

SFA Pacific, Inc.

Gasification Projects Without Subsidies

Chemicals from coal or pet coke	MW_{th} syngas
• Ube Ammonia - Japan	294
• Farmland - Kansas, USA	293
• Eastman Chemicals - Tennessee, USA	219
Oil refinery polygeneration from pitch or pet coke	
• Port Arthur*, Texas - USA	2,029
• Repsol* - Spain	1,654
• Lake Charles*, Louisiana - USA	1,407
• Deer Park*, Texas - USA	1,400
• Total/Texaco - France	1,043
• Nippon Oil - Japan	793
• Exxon - Texas, USA & Singapore	711
• Shell - the Netherlands	637

* Planned

SFA Pacific, Inc.

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

Polygeneration

Defined as gasification to make synthesis gas (H_2 & 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 MW_{th} with 2 gasifiers for oil refinery H_2 & 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 CO_2 capture (will likely be added at Pernis)**

SFA Pacific, Inc.

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 H_2-CGCC with CO_2 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**

SFA Pacific, Inc.

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

SFA Pacific, Inc.

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 O_2-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

SFA Pacific, Inc.

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**

SFA Pacific, Inc.

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_x, SO_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_2 gasification + super clean & CO shifted syngas**

Increasing interest in CO_2 capture & storage

- **Favors O_2 gasification, H_2O + CO shifting & CO_2 capture from syngas**

SFA Pacific, Inc.

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 desuflurization 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**

SFA Pacific, Inc.

Conclusions

Hot gas cleanup is <u>not hot</u>

- **Should consider changing the name & focus of this conference to include gas cleanup systems at <u>all</u> 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_2O 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

SFA Pacific, Inc.