Air Products Slurry Gasification Technology: Petcoke & Coal

Presentation by

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Agenda

- Air Products Slurry Gasification Technology
- Slurry Gasification Design Options
- Petcoke & Coal Experience
- Licensed Plants – a Summary
- Air Products Syngas Solutions Offering

Air Products Slurry Gasification Technology

- AP Slurry Gasification is based on Entrained bed, Slurry feed, Slagging mode, Refractory walled reactor with direct water quench and heat recovery options
- Gasification technology leader since 1948 with 100+ commercial plants in operation with 80+ licenses worldwide
  - First Oil Gasification plant in 1959
  - First Coal Gasification plant in 1978
  - First Petcoke Gasification plant in 1984

Reliable and Proven Gasification Technology with Worldwide Experience

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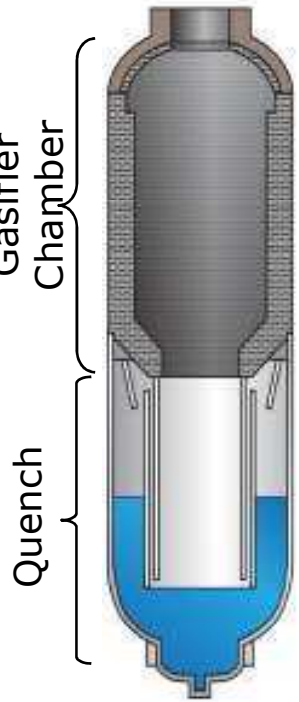
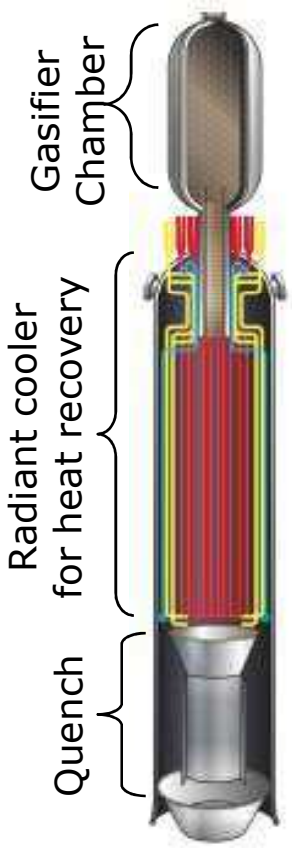
Solids Feed - Two Configurations

Quench



- Hot syngas immediately quenched by direct water contact
- Syngas is warm and saturated with water… ideal for sour CO shift
- Pressures up to 87 bar
- Proven gasifier sizes up to nominal 900 ft^3; 1800ft^3 under design
- Typical applications: chemicals, hydrogen, refinery polygen
- Lower capital cost than RSC

Radiant Syngas Cooler



- Hot syngas first cooled by radiant cooling before quenching
- Generates high pressure steam to up to 138 bar
- Pressures up to 87 bar
- Proven up to nominal 1800 ft^3
- Typical applications: power generation, chemicals, hydrogen, refinery polygen
- Better efficiency than quench due to heat recovery

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Air Products Slurry Gasification Experience - Petcoke

- 1960s – Early R&D, Pilot testing and Semi commercial test began
- 1980s – First commercial Petcoke application at Eastman/ Ube
- Further Industrial applications in Coffeyville Urea/ Refinery H_2
- 100+ years commercial gasification operating experience on petroleum coke and coke/coal blends
- Have plant sending 100% of CO_2 to EOR, so no emissions in normal operation
- Low cost gasifier sparing can provide consistent syngas availability over 98-99%

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China Plant Startup History

- Team has started up over 50 Gasification plants in China since 1993
- Improved Time to maturity and quicker commercial production in different product plants
- Simpler gasification process design facilitated highest localization of process equipment fabrication
- Best in class Technical services and Startup support while enabling seamless coordination among DEC, EPC & Vendors
- Growing Experienced Operator base leveraging industry lessons learnt and building successful gasification plants.

Plant	Contract to Mechanical Completion	Gasifier Configuration	1st Year Availability
A	31 months	2+1 900 ft³ @ 65 bar	91.9%
B	18 months	2+0 450 ft³ @ 65 bar	92.5%
C	31 months	2+1 900 ft³ @ 65 bar	91.5%
D	35 months	2+1 900 ft³ @ 65 bar	91.4%
E	32 months	5+2 900 ft³ @ 65 bar	95.0%
F	24 months	2+1 900 ft³ @ 50 bar	92.0%
G	32 months	2+1 900 ft³ @ 65 bar	91.5%
H	43 months	2+1 900 ft³ @ 65 bar	92.1%
I	18 months	4+2 900 ft³ @ 87 bar	91.8%
J	36 months	2+1 900 ft³ @ 40 bar	92.0%
K	40 months	2+1 450 ft³ @ 65 bar	91.8%
L	18 months	2+1 450 ft³ @ 45 bar	93.1%
M	45 months	10+4 900 ft³ @ 65 bar	91.3%
N	39 months	5+2 900 ft³ @ 65 bar	90.5%

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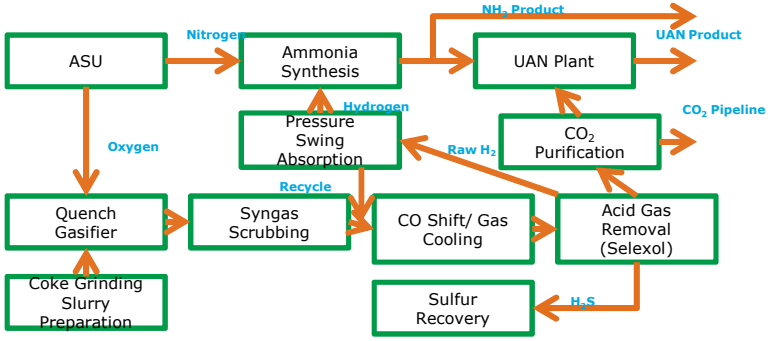
Coffeyville Resources Nitrogen Fertilizers LLC



- ✓ Licensee/Owner : Coffeyville Resources
- ✓ Operator : Coffeyville Resources
- ✓ Location : Coffeyville, Kansas, USA
- ✓ Startup : 2000
- ✓ Feedstock: Petroleum Coke
- ✓ Design Capacity: 1,300 STPD (per gasifier)
- ✓ Operation Pressure: 620 psig (43 bar)
- ✓ Gasifier Config : 2 Quench gasifier train
- ✓ EPC Contractor: Black & Veatch

On-stream factors for gasification and ammonia production from CVR Annual report

	Gasification	Ammonia
2015	99.9%	97.7%
2014	98.2%	94.3%
2013	99.5%	98.9%

LCVR's Annual Form 10K 2016 report weblink: Pg 101
http://investors.cvrenergy.com/static-files/c7e04ba5-db2d-4888-be54-e5c1e6415deb

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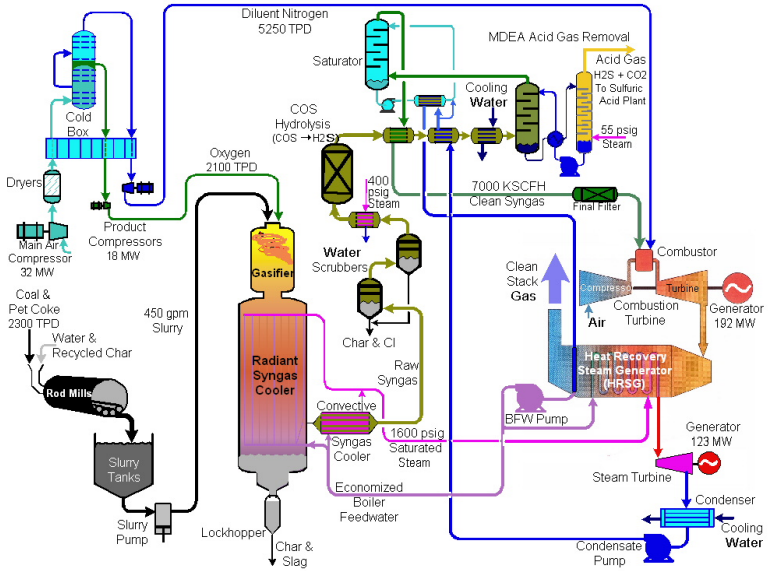
TECO Polk Power Station



- ✓ Single 1,800 ft³ gasifier operating at 375 psig, 123 MMSCFD of H_2+CO to power one 7FA GE Gas turbine
- ✓ 2,500 ton per day Original designed 100% coal ran 85% coke, 15% coal for last 11 years of operation
- ✓ Slag screening & 100% fines recycle
- ✓ 250 MW (net) Power to grid

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Case Study: ZTHC Zhongtian Reached/Sustained Capacity Quickly

Started : 2016
Gasifiers : 900 cu ft, 10op+4sp
Pressure : 65 bar g
Products : 3.6 MMTPA MeOH

One of the Largest gasification plants in world

- 14.7 hrs from start-up until standard MeOH produced
  - ✓ 23rd Sep, 2016 first fire of first gasifier
  - ✓ 24th Sep, 2016 On spec MeOH production starts
- 65 Days from start to full production of first series of 5op+2sp gasifiers
  - ✓ On 28th Nov, 2016 Plant achieve 110% of designed MeOH production

World record for slurry gasification scale/speed

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Case Study: Pucheng Gasification Project
Savings from High Pressure

Started : 2014
Gasifiers : 900 cuft, 4op + 2sp
Pressure : 86 bar g
Products : 1.8MMPTA MeOH, MTO

- ✓ High pressure configuration eliminated one gasifier train and associated equipment
- ✓ 60% MeOH Synthesis Compressor energy saving,
- ✓ 50% AGR energy saving
- ✓ Less fouling in HP grey water system
- ✓ Performance

Single train	Unit	NOC	Operation
Pressure	Bar g	86	81
Syngas output	kNm^3/hr	139	144.3
$(CO+H_2)$	%	78	80 - 83

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Air Products offer SOG and Licensing

SOG (Sale of Gas)

- ✓ Air Products offers complete turnkey gasification complex where AP builds, finances, owns and operate the syngas production facility
- ✓ Offers a best cost efficiency enabling customers to focus valuable capital, management and personnel on their primary value added products

Licensing or SOE (Sale of Equipment)

- ✓ This option offer legacy licensing business model, process design package and sale of proprietary equipment
- ✓ Also offers, technical services, commissioning, start up and performance testing to customer

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Thank you
tell me more

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http://www.airproducts.com/Microsites/syngassolutions.aspx

Slurry Licensed Petcoke, Coal blend reference list

Location (Country)	Startup	Primary Feedstock	Size, cu.ft	# of Gasifiers (Op+Sp)	Operating Pressure, barG	H_2+CO, MMSCFD (kNm^3/hr)	End Product	Mode	Project Status
Japan	1984	Petcoke	450	3 + 0	38	78.9 (88.1)	Ammonia	Quench	Operating
USA	1996	Coal/Petcoke	1800	1 + 0	26.2	123 (137.3)	Power	RSC+CSC	Operating
USA	2000	Petcoke	900	1 + 1	43	86 (96)	Ammonia	Quench	Operating
USA	2001	Petcoke	900	2 + 0	66.9	138.9 (155)	Steam, Power	Quench	Shutdown
China	2005	Coal/Petcoke	900	2 + 1	40	122.7 (137)	Ammonia/ Hydrogen	Quench	Operating
China	2006	Coal/Petcoke	900	1 + 1	85	78.4 (87.5)	Ammonia/Urea	Quench	Operating
China	2008	Coal/Petcoke	450	2 + 1	58	89.5 (99.9)	Oxochemicals	Quench	Operating
China	2014	Coal/Petcoke	900	2 + 1	65	190.8 (213)	Hydrogen	Quench	Operating
China	2020	Petcoke	900	4 + 2	65	403.1 (450)	Hydrogen	Quench	Construction
USA	2023	Petcoke	1800	3 + 1	67.2	441 (492)	MeOH/ Hydrogen	Quench	Design/ EPC

50 Coal feed gasification plants are licensed and 35 plants are currently operating and seven in various EPC stages

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