석탄가스화 기술

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http://www.coal.or.kr

전세계 석탄 자원의 사용 가능량

❑ **2002년말 확인된 전세계 지역별 석탄매장량 (백만톤)**

	Hard Coal	Brown Coal	Total
OECD Europe	22 420	17 041	39 461
OECD North America	218 818	35 614	254 432
OECD Pacific	39 677	38 033	77 710
OECD	**280 915**	**90 688**	**371 603**
Transition economies	**208 762**	**38 872**	**247 634**
of which Russia	*146 560*	*10 450*	*157 010*
China	95 900	18 600	114 500
East Asia	3 053	4 330	7 383
South Asia	90 146	5 350	95 496
of which India	*90 085*	*2 360*	*92 445*
Latin America	19 769	124	19 893
of which Brazil	*10 113*	–	*10 113*
Africa	50 333	3	50 336
Middle East	419	–	419
World	**749 297**	**157 967**	**907 264**

Source: World Energy Council (2003).

❑ **전세계 2002년 사용량과 2030년도 예측 석탄 필요량 및 발전에 사용되는 비중 (백만톤)**

	2002		2030		Average annual rate of growth in demand, 2002-2030 %
	Million tonnes	Coal's share of electricity generation %	Million tonnes	Coal's share of electricity generation %	
OECD North America	1 051	46	1 222	40	0.5
OECD Europe	822	29	816	24	0.0
OECD Pacific	364	36	423	29	0.5
OECD	**2 237**	**38**	**2 461**	**33**	**0.3**
Russia	220	19	244	15	0.4
Other transition economies	249	27	340	18	1.1
Transition economies	**469**	**22**	**584**	**16**	**0.8**
China	1 308	77	2 402	72	2.2
East Asia	160	28	456	49	3.8
South Asia	396	60	773	54	2.4
Latin America	30	4	66	5	2.8
Middle East	15	6	23	5	1.6
Africa	174	47	264	29	1.5
Developing countries	**2 085**	**45**	**3 984**	**47**	**2.3**
World	**4 791**	**39**	**7 029**	**38**	**1.4**
European Union	*767*	*31*	*716*	*25*	*-0.2*

* Including hard coal (steam coal and coking coal), brown coal and peat.

❑ 사용 가능 **Year : 907,264 / 4,791 = 189.4년**

(2002년말 확인 가채매장량 /2002년 사용량 기준)

Ref. : World Energy Outlook 2004, International Energy Agency.

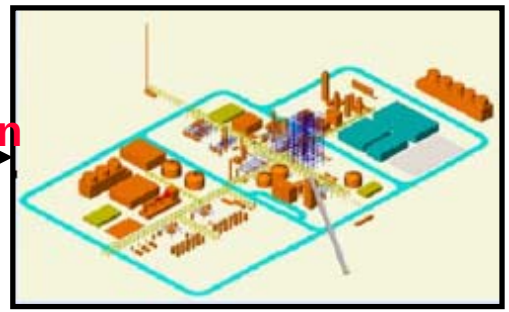
석탄의 고부가가치화 활용

($30/ton)

Combustion

Gasification

Gasification



Electric Power production

2 MWh Electricity	$70.0
Total	$70.0

FT Fuels and Power

0.41 MWh Electricity	$14.0
0.34 bbl Naphtha	$15.0
1.36 bbl Diesel fuel	$95.0
Total	$124.0

Fertilizer, FT Fuels and Power

0.007 MWh Electricity	$ 0.23
0.017 bbl Naphtha	$ 8.00
0.078 bbl Diesel fuel	$54.00
0.25 tons of ammonia	$87.00
Total	$149.00

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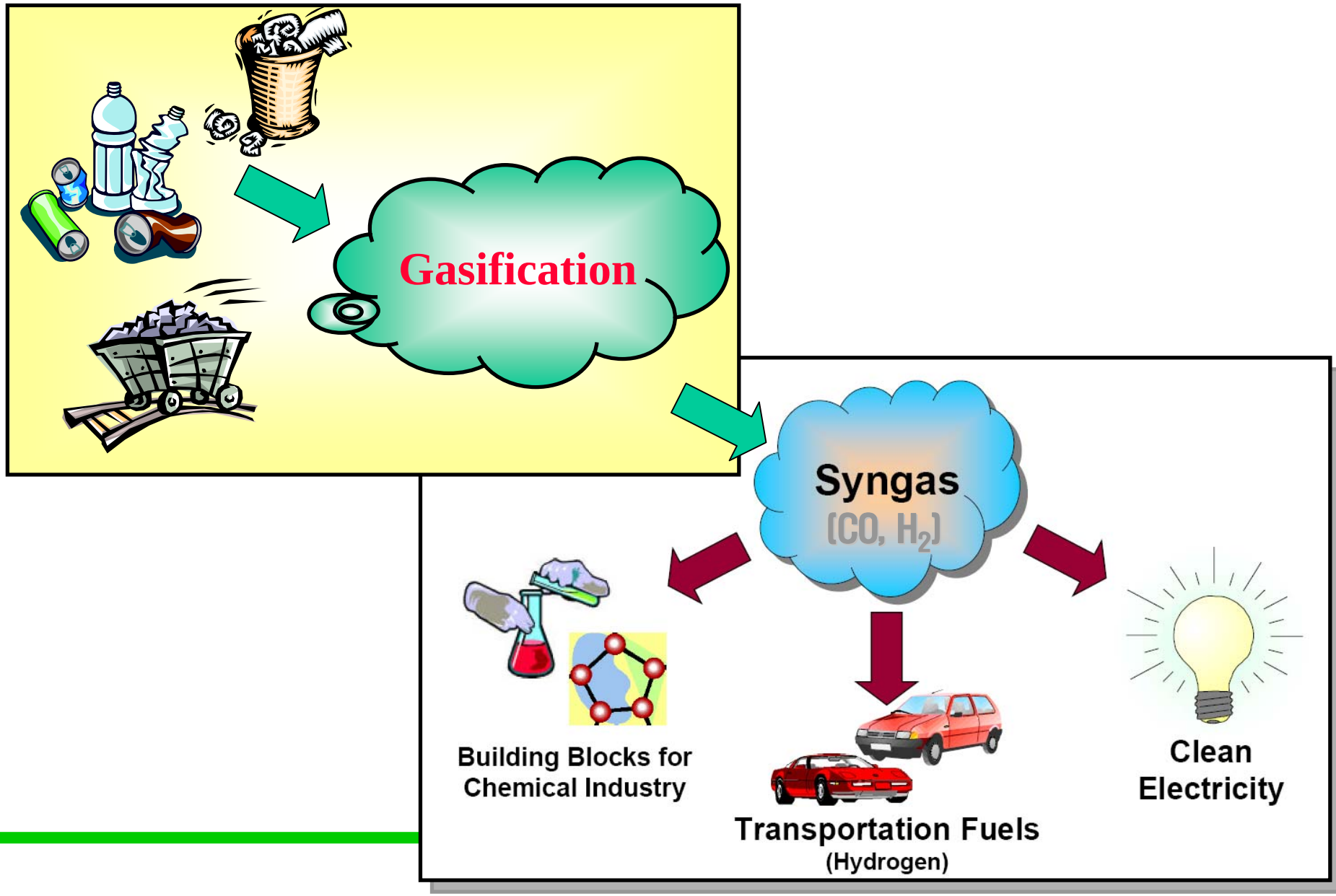
가스화 (Gasification) ?



합성가스(syngas) 활용의 형태 및 장점

❑발전
- ✓저급의 석탄이나 폐기물을 연료로 사용
- ✓가장 낮은 SOx, NOx 배출
- ✓고효율에 따른 CO_2 배출량 저감
- ✓용융에 따른 고형 폐기물의 거의 zero 배출

❑화학원료 제조
- ✓정유공장의 공정 폐기물을 연료로 사용
- ✓타 설비 및 공정과의 연계

❑수송 연료 제조
- ✓고급 수송 연료 생산이 가능
  (Fischer-Tropsch diesel : 세탄가 70 이상,
  황 함량 10 ppm 이하)

❑ 합성가스 정제/분리한 대량 수소 제조

경제성 확보
Synergy 효과

Integration
+
Flexibility

Polygeneration

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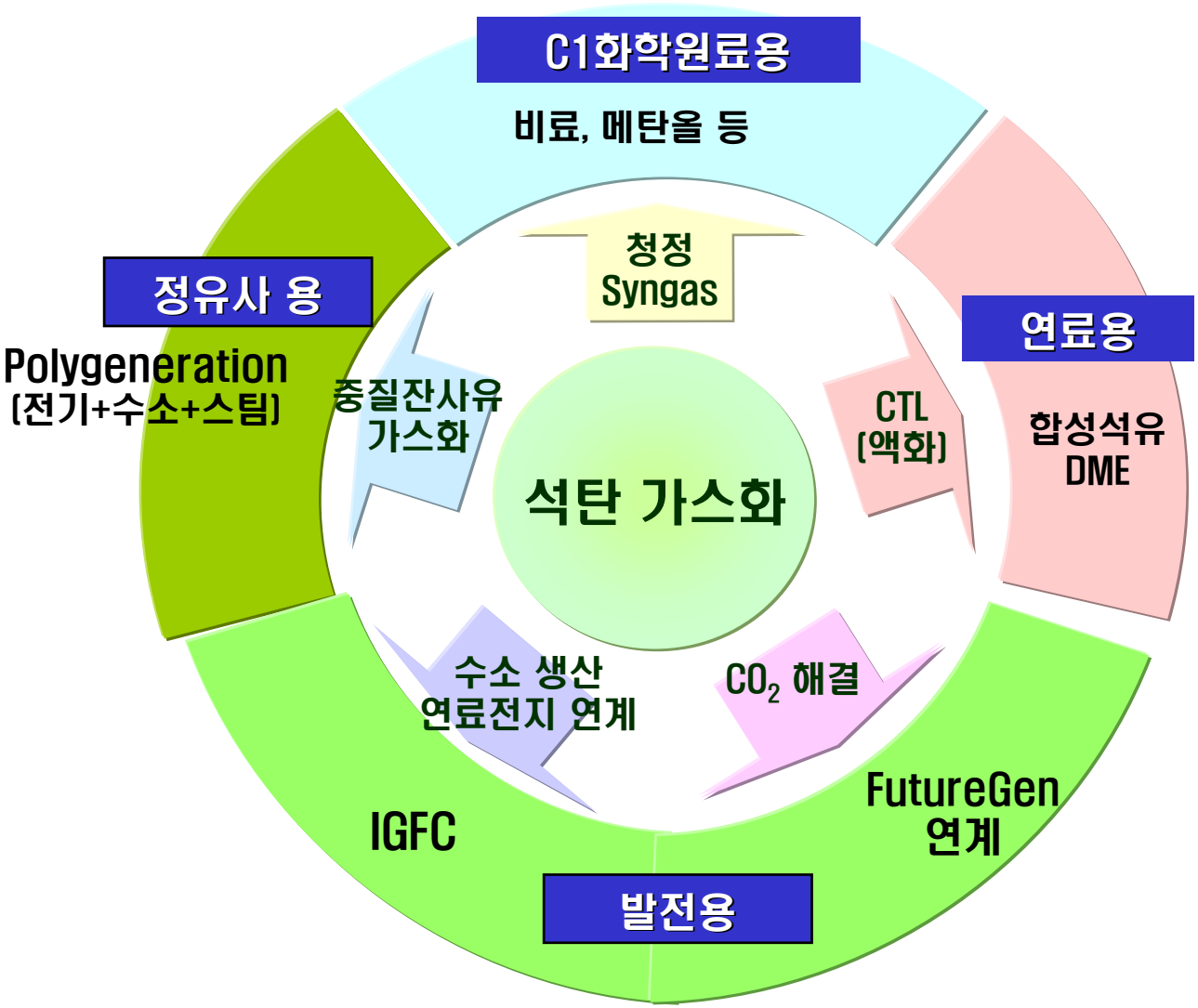
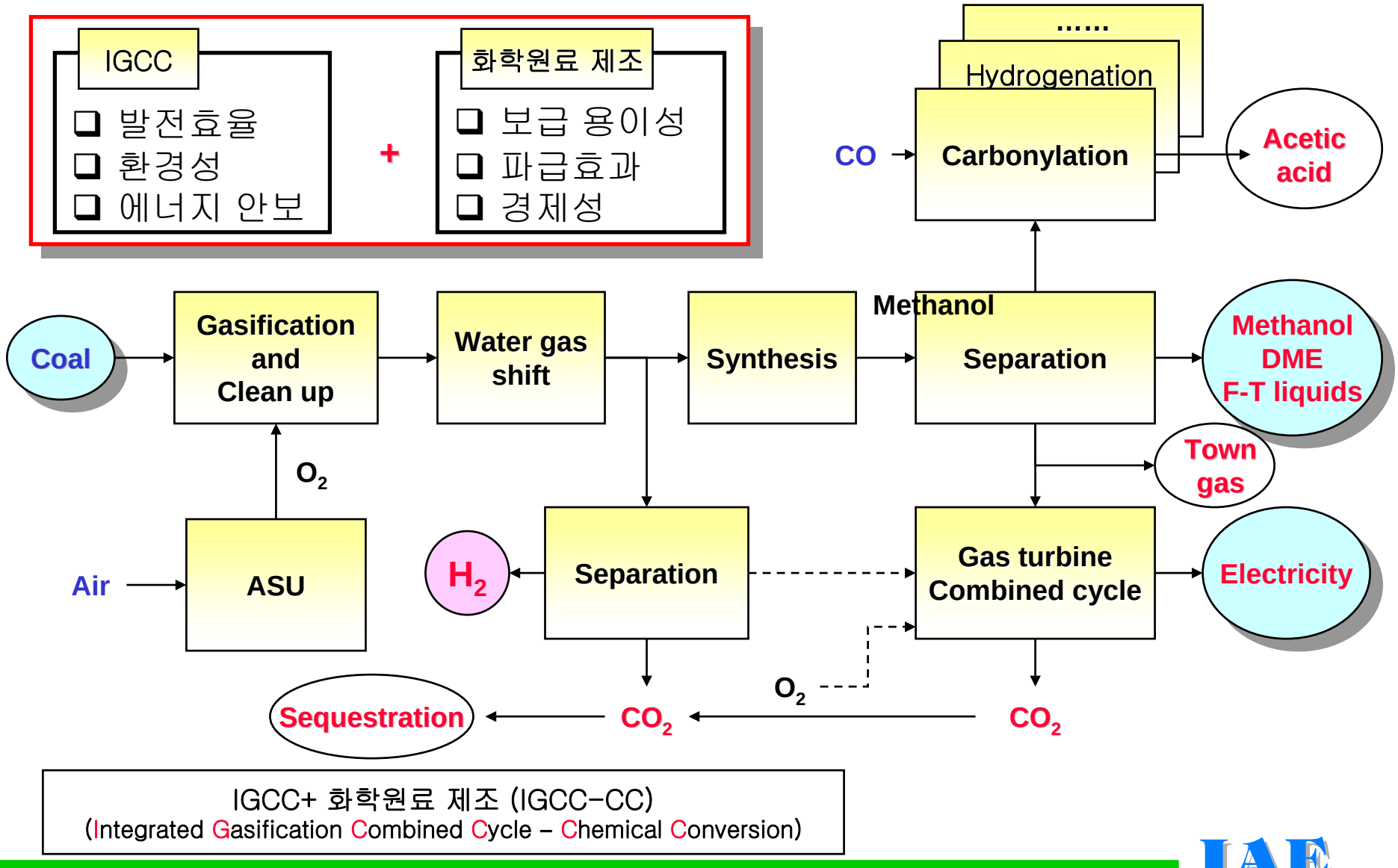
석탄가스화 합성가스 활용 Route

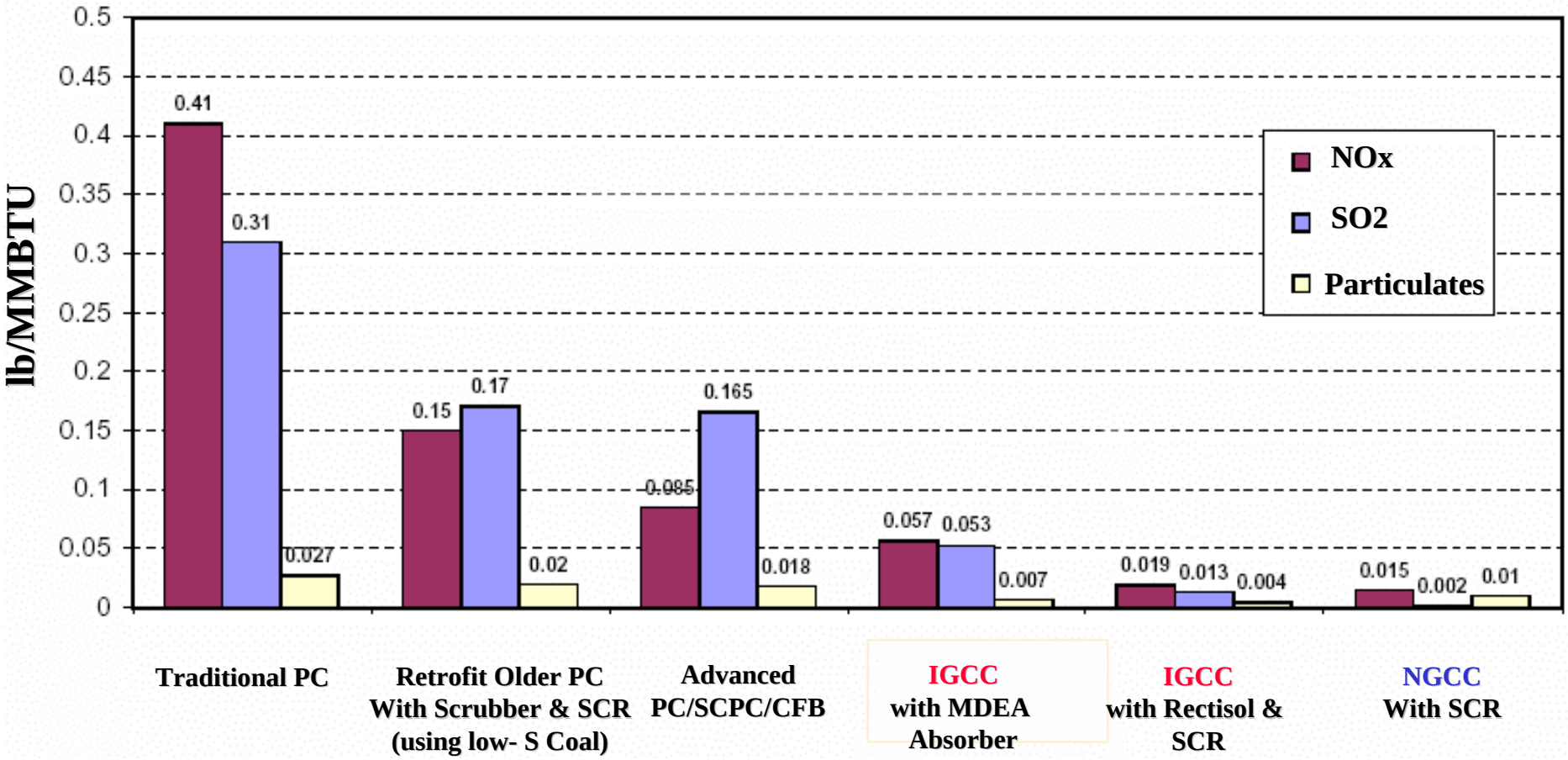


석탄 가스화를 이용한 다양한 polygeneration 예



IGCC+ 화학원료 제조 (IGCC-CC)
(Integrated Gasification Combined Cycle – Chemical Conversion)

대표적인 화력발전 기술별 공해물질 배출량의 비교

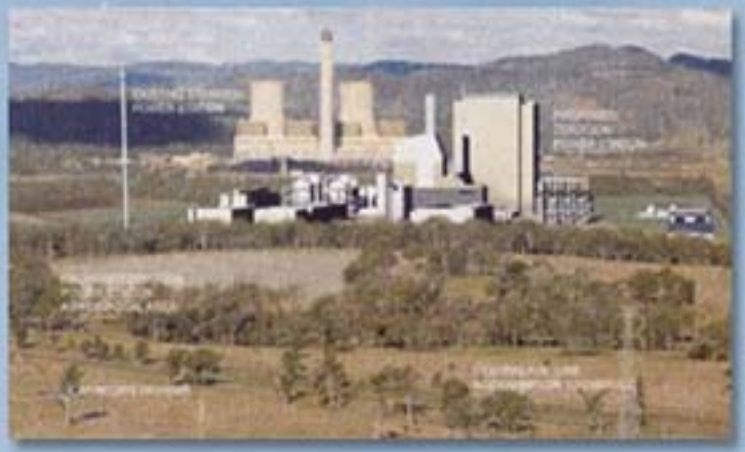


해외 석탄 IGCC 현황

미국 FutureGen 프로젝트
(석탄 IGCC 275MW + CCS +수소)

중국 GreenGen 프로젝트
(석탄 IGCC 200MW + CCS)

호주 ZeroGen 프로젝트
(석탄 IGCC 100MW + CCS)



인도 : 석탄 IGCC 100 MW 자체기술로 건설

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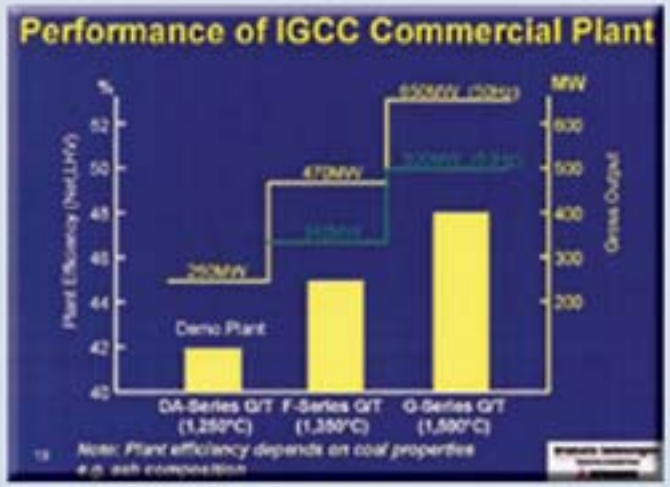
CCS : Carbon Capture & Sequestration

일본 석탄 IGCC 현황

- 일본정부와 미쯔비시중공업 주도로 250 MW 실증사업 운전과 병행, 자체기술로 340~500 MW급 석탄IGCC 2012년부터 운전 계획
- 공기사용 아시아시장 대상, 저가 대용량 IGCC 기술개발에 주력

일본 250 MW 석탄IGCC 실증플랜트



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일본 석탄가스화 연료전지 연계 EAGLE 플랜트

- 석탄 150톤/일 사용
- 1995-2006 기간
- 2002-2006년 운전중
- 2004년 예산: 10.5억엔

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- EAGLE : Coal Energy Application for Gas, Liquid and Electricity

중국 Dongting 2,000톤/일급 석탄가스화 플랜트

2000년 이후 해외 석탄 가스화 플랜트 건설 추세

최종 생산물 특징

❖ 선진국은 전기 생산, 인조석유 생산 시작단계.
❖ 중국은 화학원료 생산이 주 품목

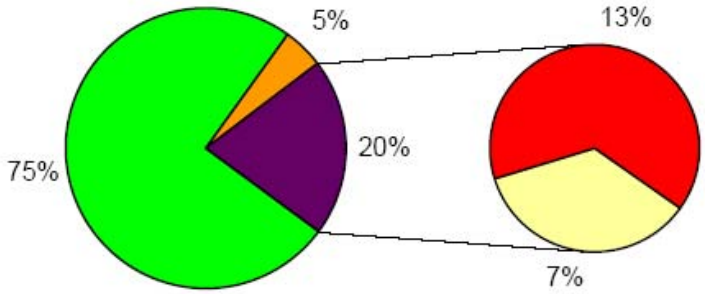
Plant Name	Year	Region	Country	Technology Name	Main Product	Feed Class
Puyang Ammonia Plant	2000	Asia/Australia	China	Sasol Lurgi Dry Ash Gasification Process	Chemicals	Coal
Sanghi IGCC Plant	2002	Asia/Australia	India	GTI(IGT) U-GAS Gasification Process	Power	Coal
Hefei City Ammonia Plant	2000	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
Sulcis IGCC Project	2006	Europe	Italy	Shell Gasification Process	Power	Coal
Thermoselece Vresova	2005	Europe	Czech Republic	GSP Gasification Process	Power	Coal
Dong Ting Ammonia Plant	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
Hubei Ammonia Plant	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
Mesaba Energy Project	2009	North America	United States	E-GAS (Destec/Dow) Gasification Process	Power	Coal
Steelhead Energy	2010	North America	United States	E-GAS (Destec/Dow) Gasification Process	Power	Coal
Rentech & Royster Clark	2009	North America	United States	E-GAS (Destec/Dow) Gasification Process	FT liquids	Coal
[no name]	2001	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2005	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2006	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2006	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2006	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
[no name]	2006	Asia/Australia	China	Shell Gasification Process		Coal
[no name]	2007	Asia/Australia	China	Shell Gasification Process	Chemicals	Coal
China 1	2005	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
China 2	2005	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
China 5	2006	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
Jinling	2005	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
China 4	2005	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
China 3	2005	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal
Haolianghe Ammonia Plant	2004	Asia/Australia	China	GE Gasification Technology	Chemicals	Coal

(Ref.: 미국 EPRI 2006년 data)

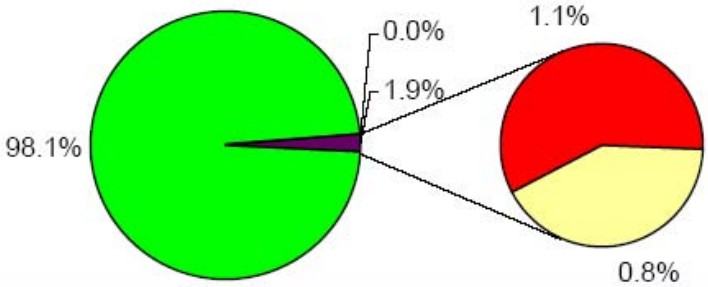
습식 석탄 IGCC 플랜트 설비 배치
(GE Energy, Tampa IGCC 예)

현재 운영중인 상용급 석탄 IGCC 플랜트 Reliability 현황

Plant A (스페인 Puertollano IGCC)



Plant B
(미국 Wabash IGCC)



- On stream
- Not required/despatched
- Planned outage
- Unplanned outage

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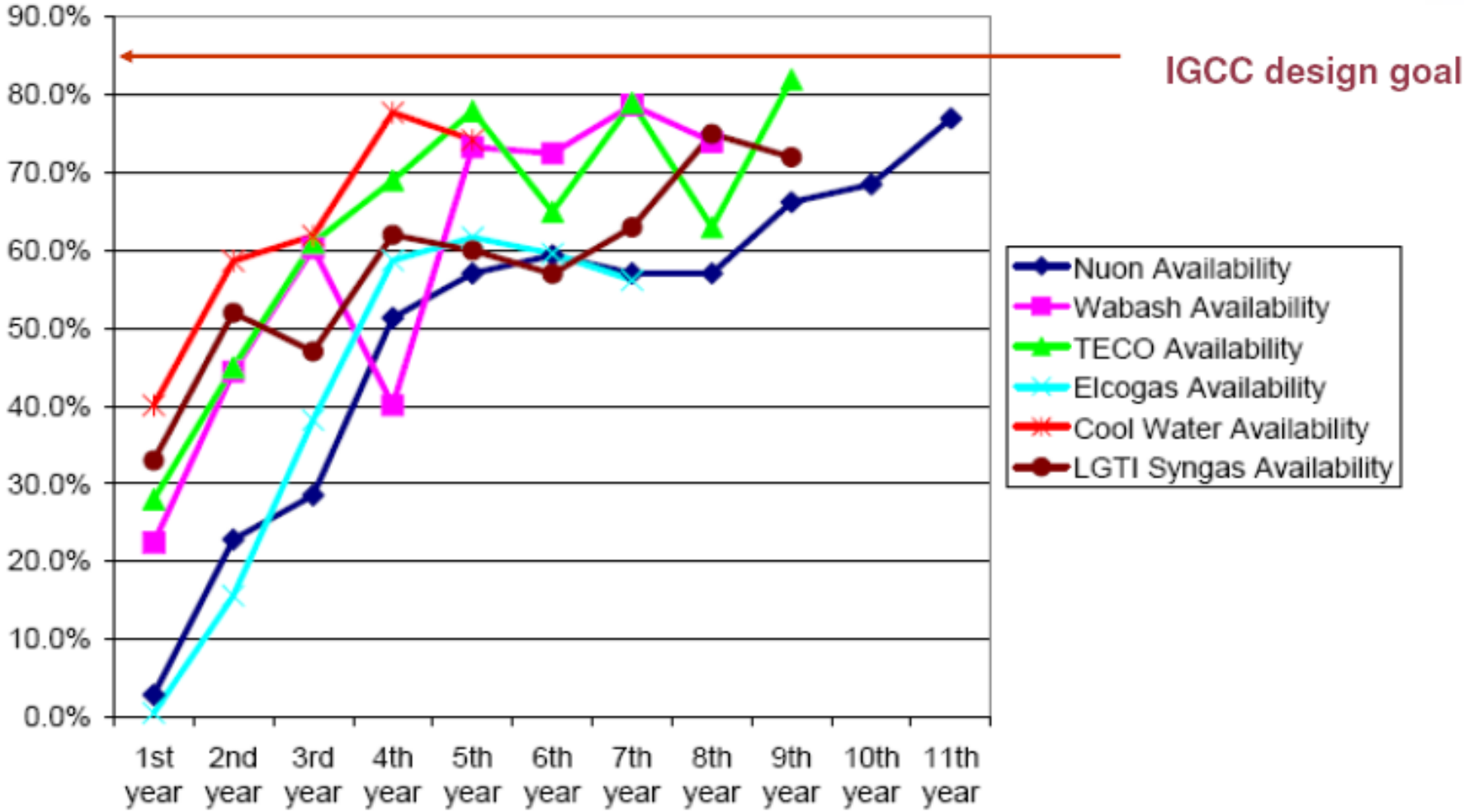
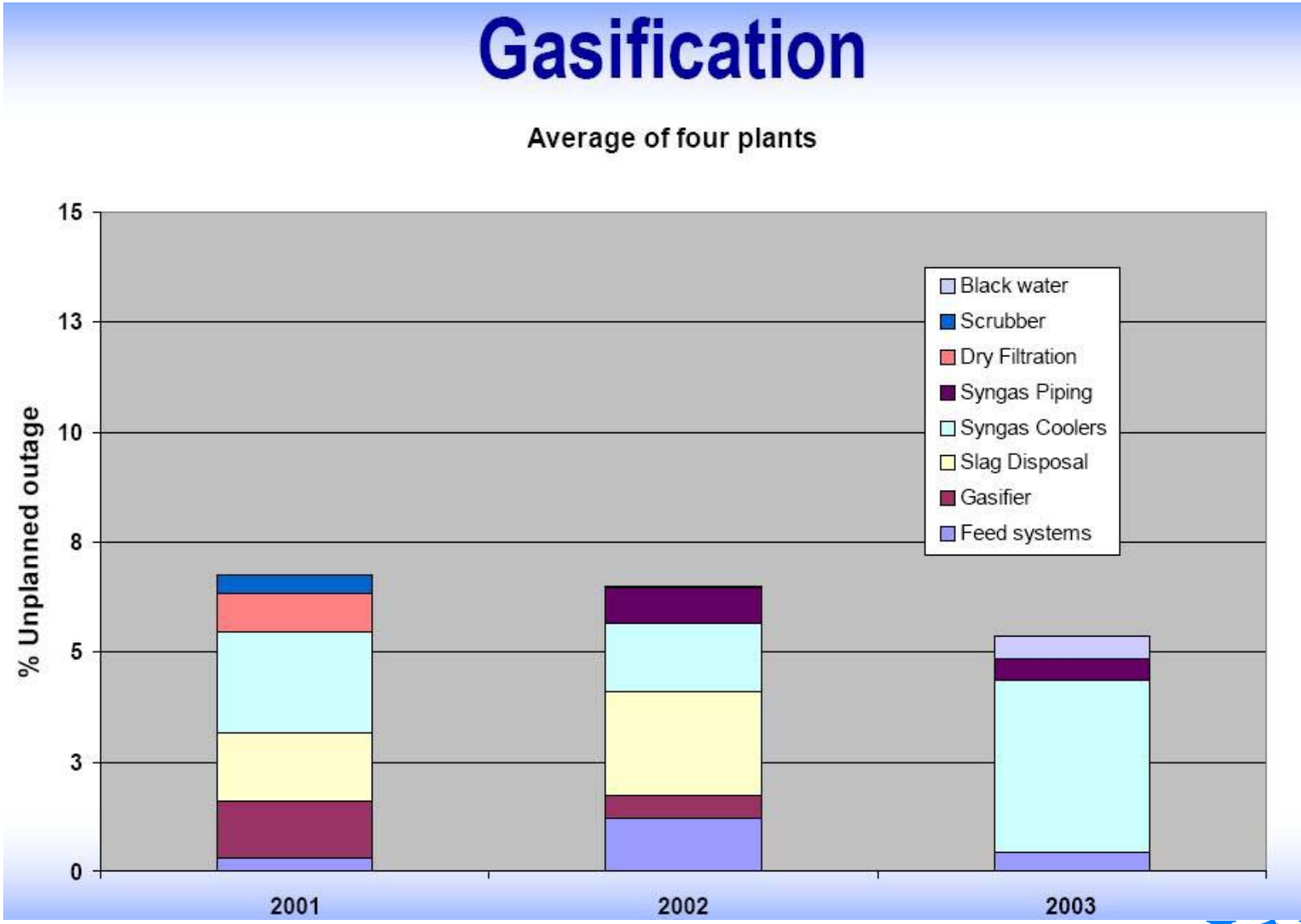
- Ref.: C. Higman, et.al., “Reliability of IGCC Power Plants,” Gasification Technologies Conf., 2005/10/11.

IGCC 플랜트 Availability 이력
(Back-up 연료 사용 운전기간 제외 경우)

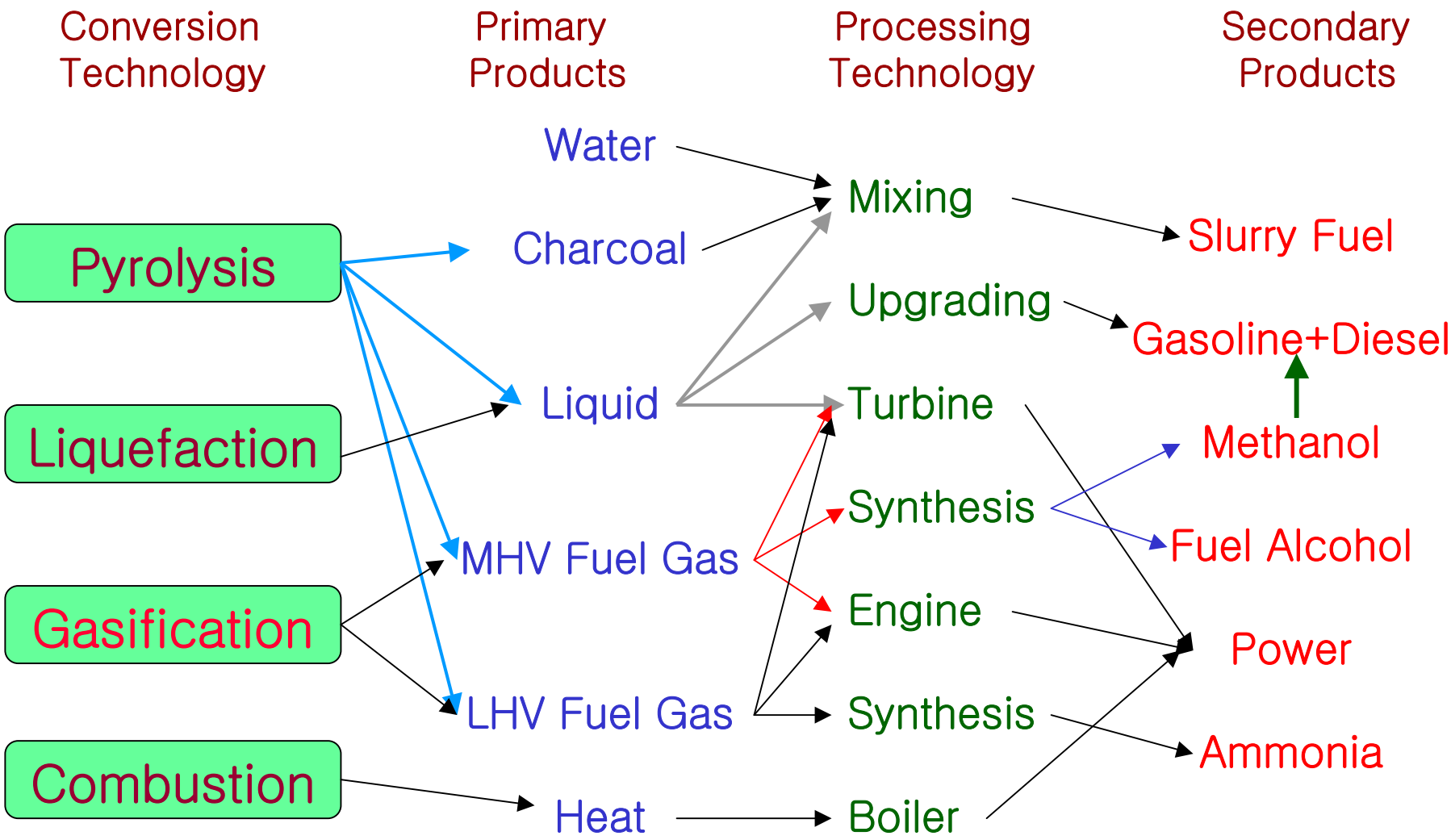


Ref.: Steve Jenkins, “Fundamentals of Gasification,” 2007 Gasification Technologies Workshop, Denver, USA, 2007/3/14.

석탄가스화 부분의 Reliability



Thermochemical Conversion



Ref.: A.V. Bridgwater and G. Grassi, Biomass Pyrolysis Liquids Upgrading and Utilization, Elsevier Applied Science, 1991.

원료 내 함유수분의 소각(연소),가스화 과정에서의 역할 차이

- 소각 (연소) : 수분은 에너지 소모 대상

- 가스화 : 수분은 가스화반응 원료

$C + H_2O \rightarrow CO + H_2$

$CO + H_2O \rightarrow CO_2 + H_2$

- 일반적인 상용 가스화 공정에서의 공급 수분량

석탄 : 5-10% steam/feed (wt/wt)

중질잔사유 : 30-50% steam/feed (wt/wt)

(cf. 국내 생활폐기물 함유 수분 : 15-50%)

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냉가스효율 (Cold Gas Efficiency)의 정의

- 정 의
  - 냉가스효율 = $\dfrac{\text{생성가스 유량 } (m^3/h) \times \text{생성가스 발열량 } (kcal/m^3)}{\text{가스화용 투입시료량 } (kg/h) \times \text{시료발열량 } (kcal/kg)}$

- 석탄가스화 경우 : **75-85% 범위**
- 생활폐기물 가스화 경우 :
  - 경남 **Y**시 생활폐기물 (고위발열량 기준)
    - Input energy: (113 kg/h x 2,167 kcal/kg) + (15 Nm^3/h x 23,684 $kcal/m^3$)
    - Output energy: 210 Nm^3/h x (3021x0.25+3050x0.25)
    - 냉가스효율 53.1%
  - 경기 **S**시 생활폐기물 (고위발열량 기준)
    - CO 32%, 수소 30% 발생
    - 냉가스효율 65.8%

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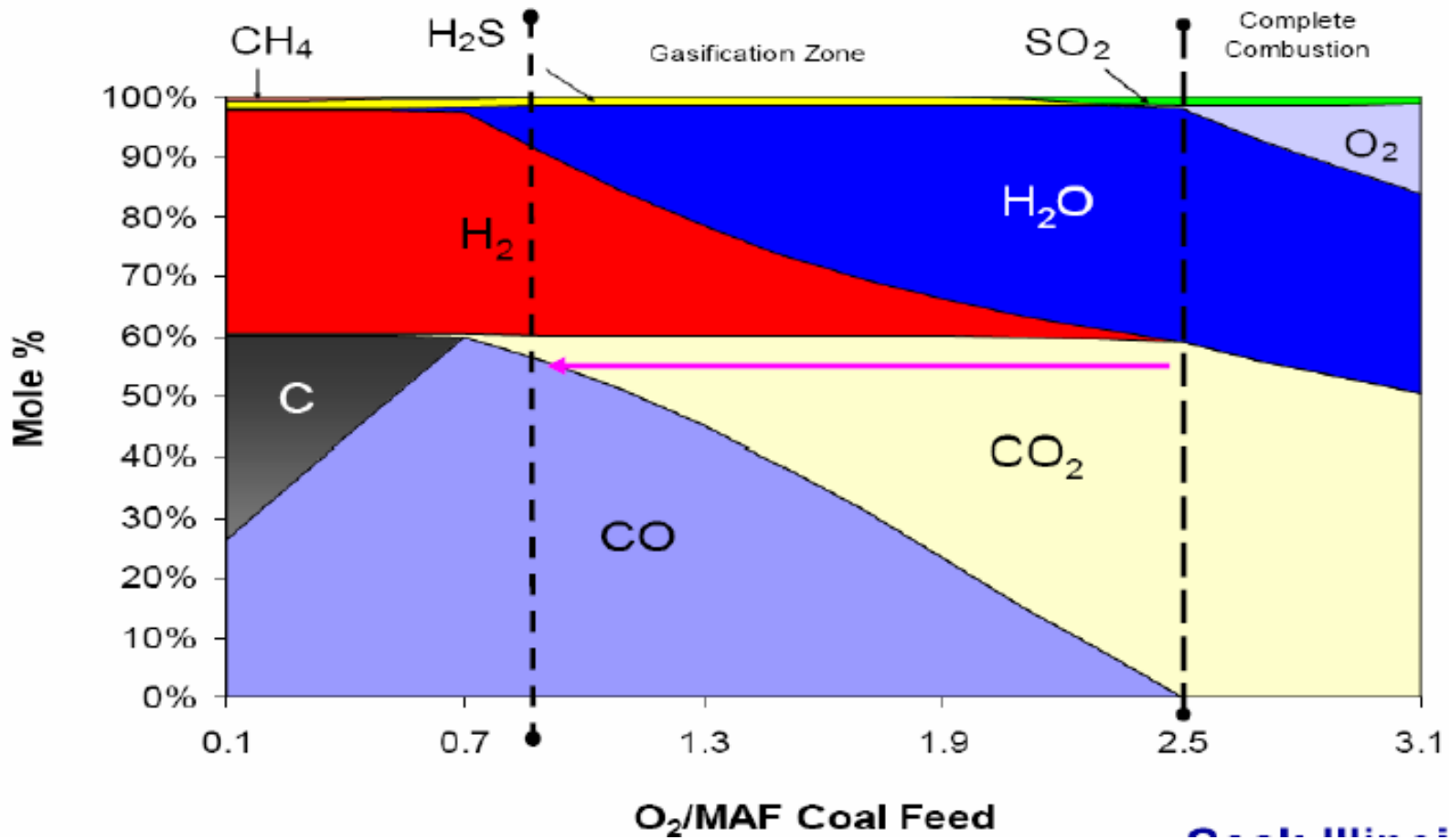
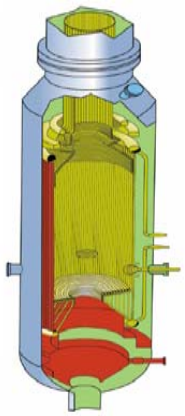
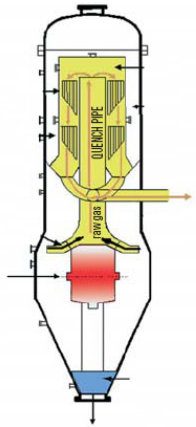
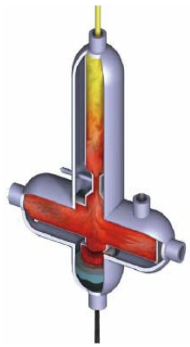
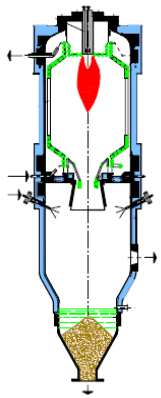
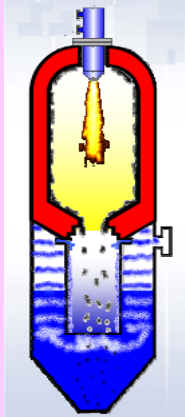
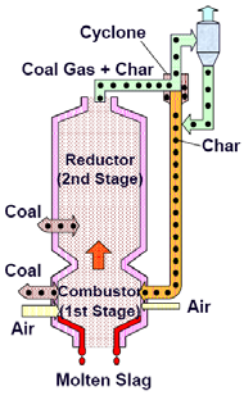
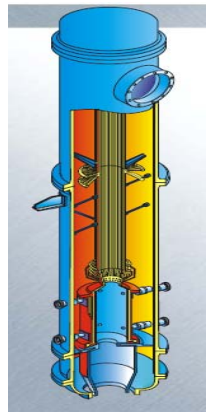
열역학 평형계산에 의한 합성가스 조성



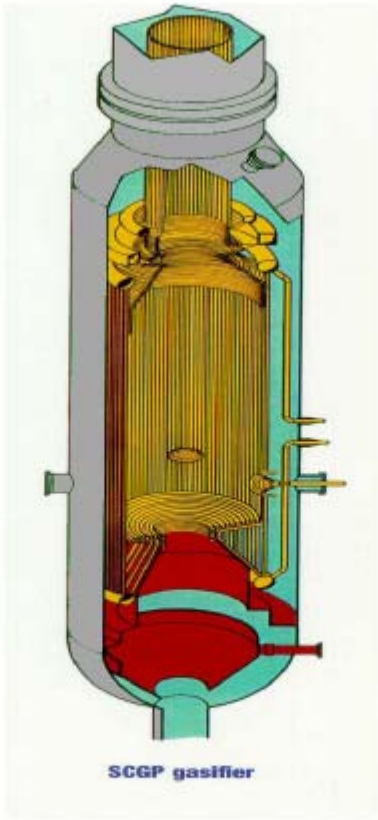
Ref.: 2005년도 EPRI 자료.

석탄 가스화기의 종류

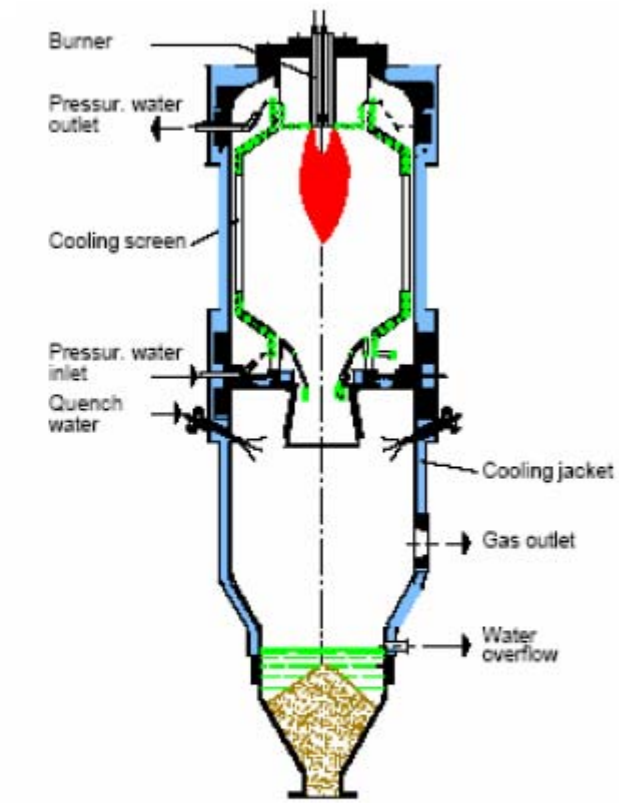
	Shell	Prenflo (Shell과 합병)	Conoco (E-gas)	GSP	GE Energy (Texaco)	CRIEPI/MHI	HITACHI (EAGLE)
형식							
석탄 공급	건식	건식	습식	건식	습식	건식	건식
가스화제							
공급							
버너							
Wall	Membrane	Membrane	Refractory	Membrane	Refractory	Membrane	Membrane
개념도							

-중국: 일본기술 copy 개발 중. -호주: Shell기술도입 건설예정. -대만: IAE형태 파일롯설비 운영중.

GE
Direct Quench

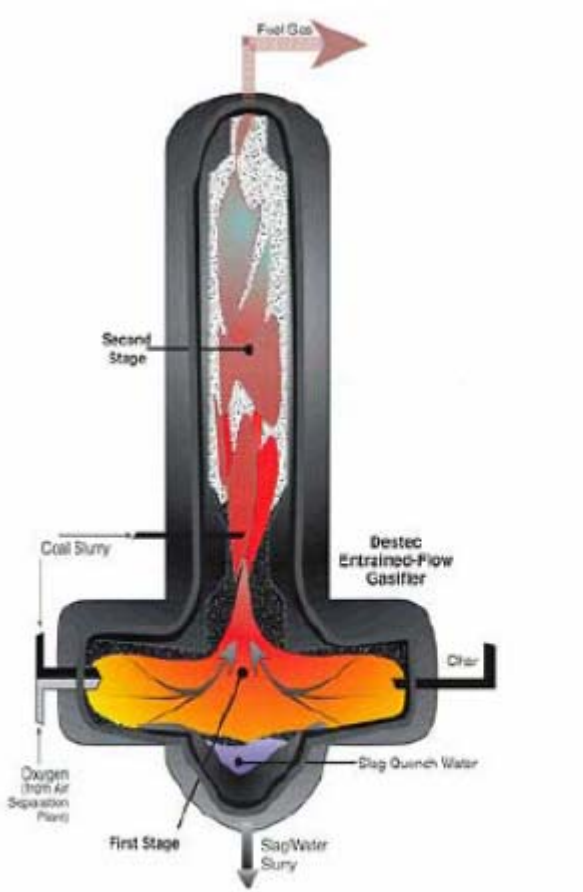


Shell

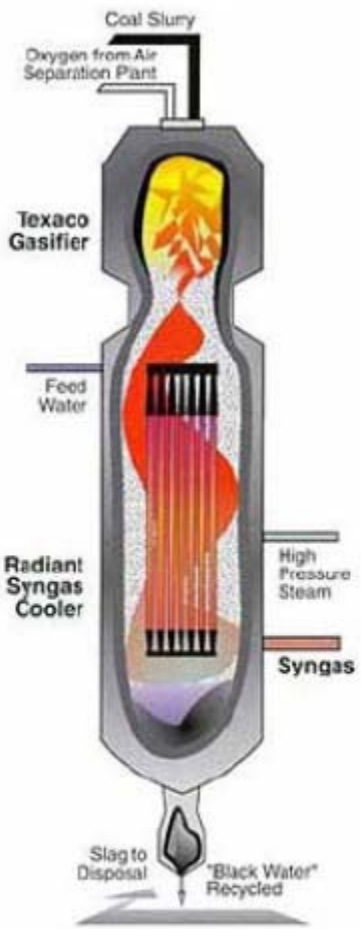


Siemens

Ref.: John Henley, “Coal Gasification in China,” 2007 GTC Congressional Roundtable Discussion, 2007/3/23.



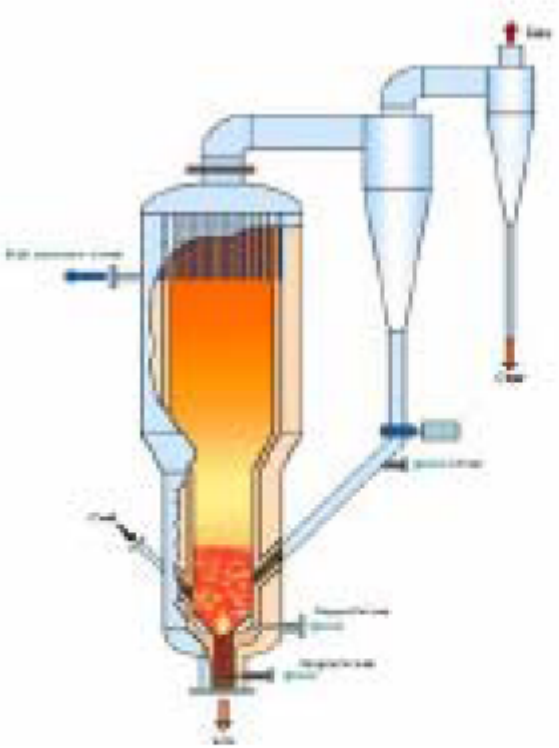
ConocoPhillips
E-Gas



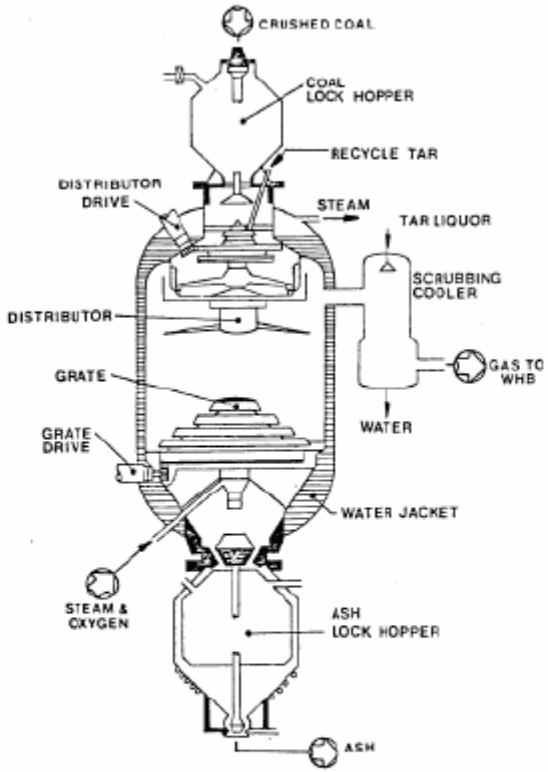
GE
Radiant Boiler

East China University
of Science and Technology

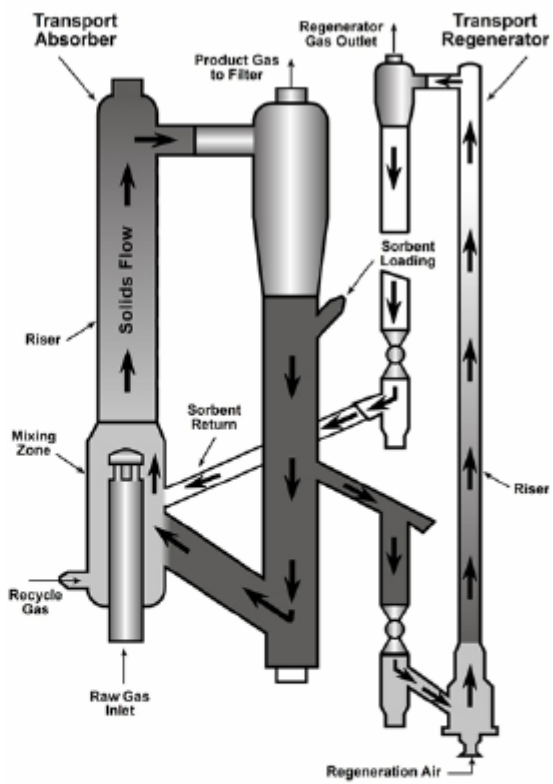
Ref.: John Henley, "Coal Gasification in China," 2007 GTC Congressional Roundtable Discussion, 2007/3/23.



SES U-Gas
Fluid Bed



Lurgi Moving Bed



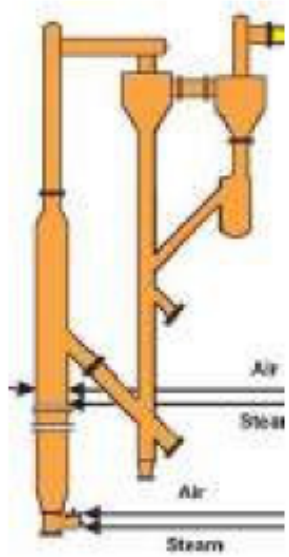
KBR/Southern
Transport
Gasifier

Ref.: John Henley, “Coal Gasification in China,” 2007 GTC Congressional Roundtable Discussion, 2007/3/23.

순환유동층 개념 석탄가스화기

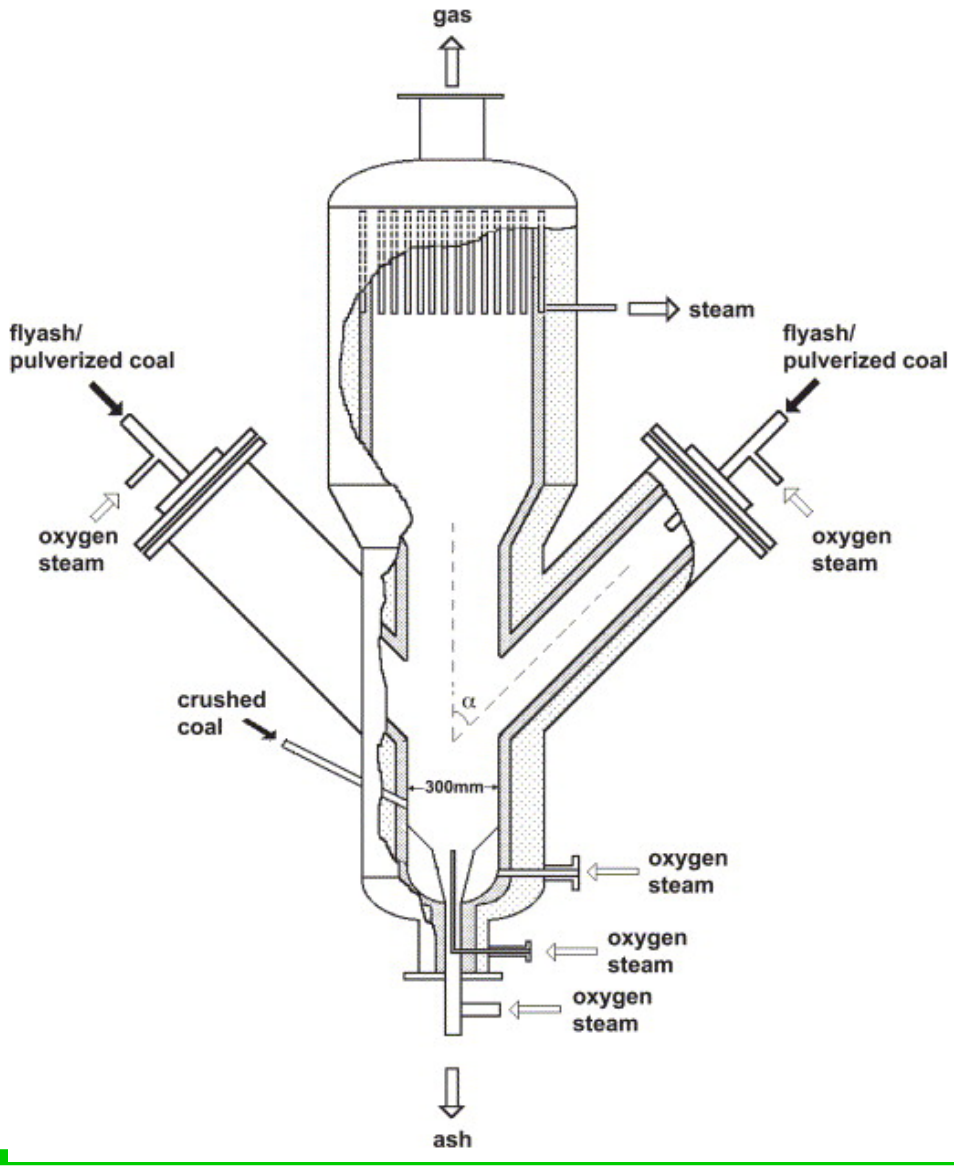
Kellogg Brown & Root (KBR)

- Transport Gasifier
- Air-blown
- Based on catalytic cracker technology from refinery industry
- Pilot tested on wide range of coals at Power Systems Development Facility in Alabama
- Best on low-rank coals, i.e. PRB and lignite
- To be demonstrated by Orlando Utilities and Southern Power



Ref.: Steve Jenkins, “Fundamentals of Gasification,” 2007 Gasification Technologies Workshop, Denver, USA, 2007/3/14.

중국 Institute of Coal Chemistry 개발중인 석탄가스화기 형태

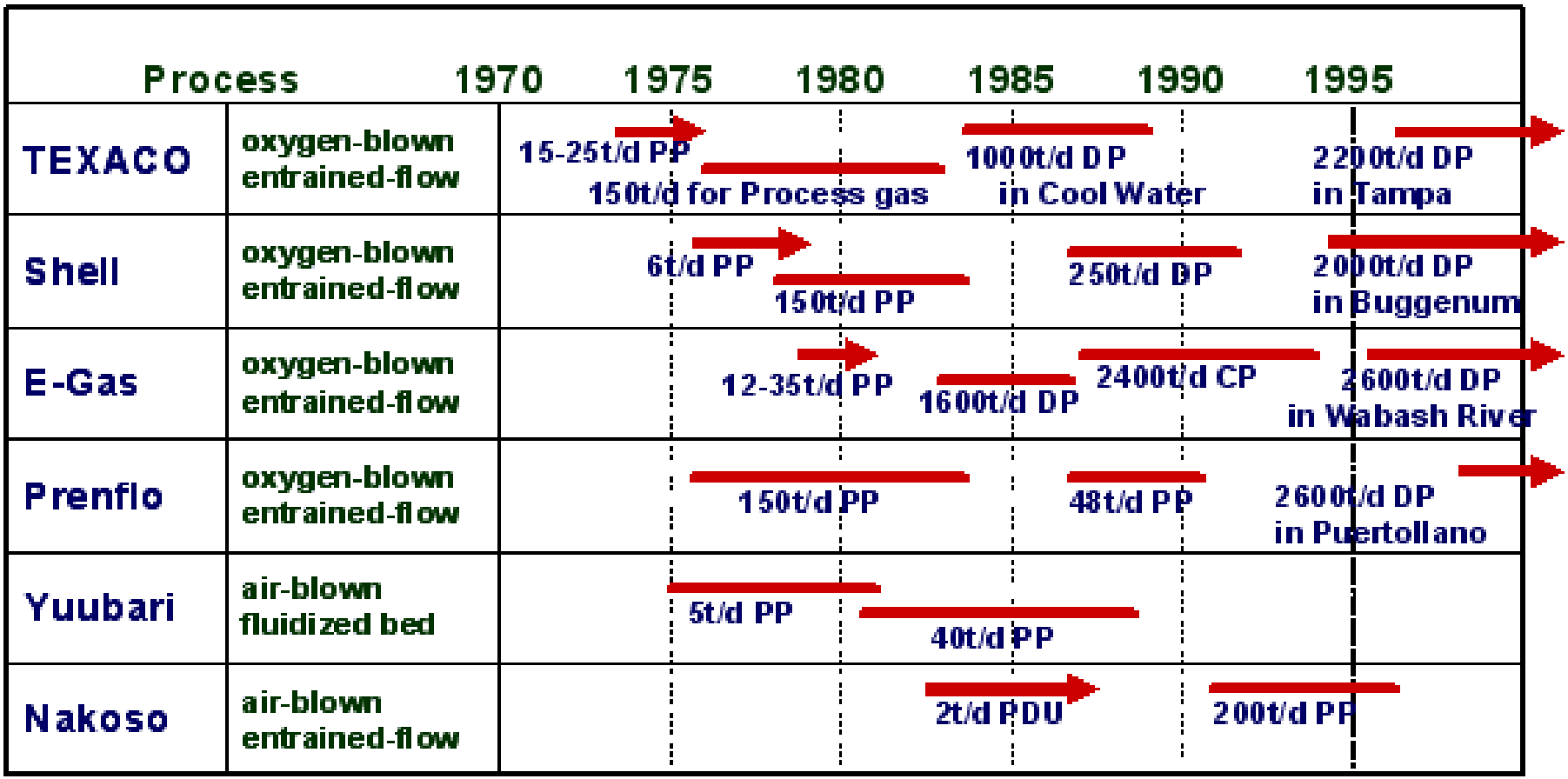


Ref.: J. Wu et al., *Fuel Processing Technology*, 68(3), 261-266 (2004).

석탄가스화기 설계 options

- **건식 vs. 습식**
  - ✓ 습식가스화기는 유연탄만 사용 가능.
  - ✓ 아역청탄/갈탄은 가스화 적용 곤란.
  - ✓ 건식가스화기가 더 고효율
- **분류층 vs. 유동층 vs. 고정층**
- **Top-feeding vs. Side-feeding**
- **운전 압력 :** 가스터빈 압축비가 주요 인자
- **가스화에 유리한 석탄 :**
  - ✓ 회분함량이 수% 함유, 10% 이내로 높지 않은 석탄.
  - ✓ 휘발분 함량이 높을 수록 반응성 측면에서 유리함.

개발 석탄가스화기 형태 및 단계별 Scale-up



상업용 석탄 IGCC플랜트 가스화기 운전압력

Wabash	Destec	습식공정	22 bar
Tampa	Taxaco	습식공정	24 bar
Buggenum	Shell	건식공정	27.2 bar
Puertollano	Prenflo	건식공정	23.1 bar
			(Siemens G/T에 적합 압력)
GEC	Alsthom air-blown FBC		22 bar

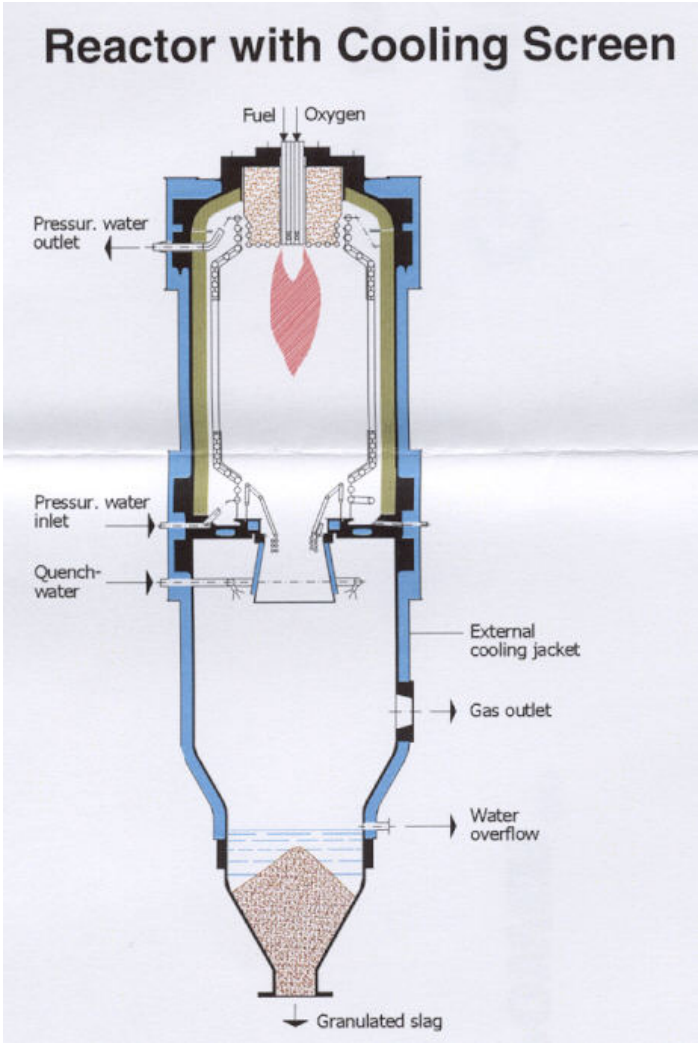
석탄가스화기 vendor별 석탄사용 실적

High Ash Coals	Lignite	Sub-Bituminous	Bituminous Illinois Basin	Bituminous Appalachian	Anthracite & Other Bitum	Petcoke
			Allied Syngas BGL			
			ConocoPhillips E-Gas			
			General Electric			
			KBR Transport			
			Mitsubishi			
			Pratt & Whitney			
			Sasol – Lurgi			
			Shell			
			Siemens SFG			
			Synthesis Energy Systems U-Gas			

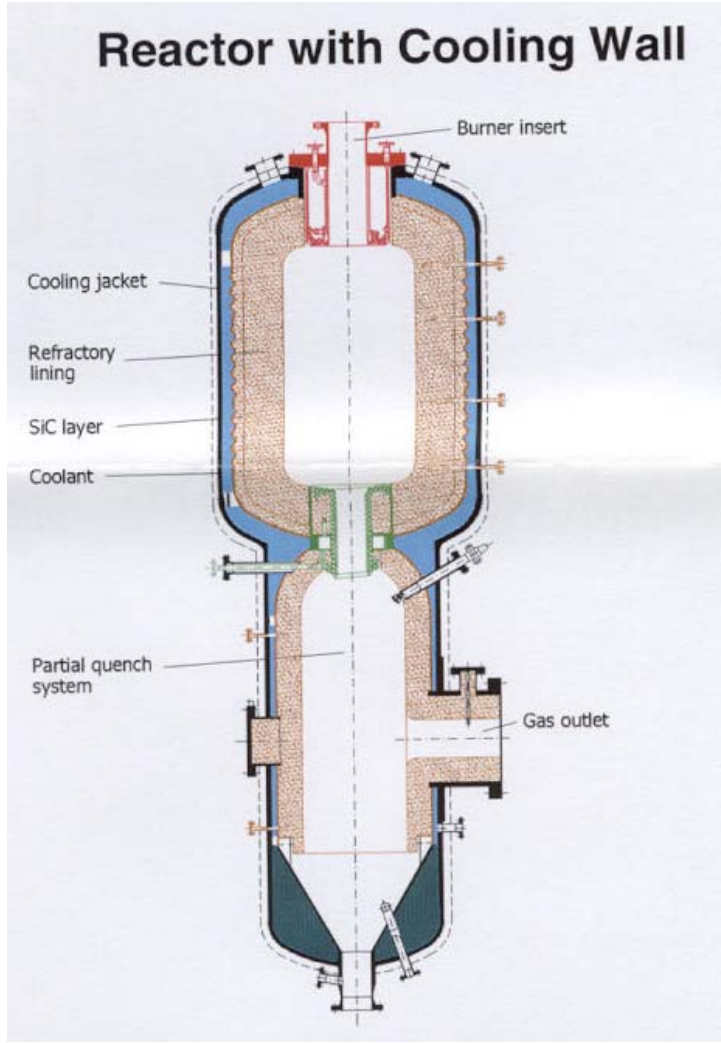
Tested			Blended
Demonstrated (500 TPD or more)			
Million Tons Operation			

Ref.: Phil Amick, “Experience with Gasification of Low-Rank Coals,” 2007 Gasification Technologies Workshop, Denver, USA, 2007/3/14.

분류층 Top-Feeding 가스화기 개념도
(Siemens (구 Future Genergy) 기술 경우)

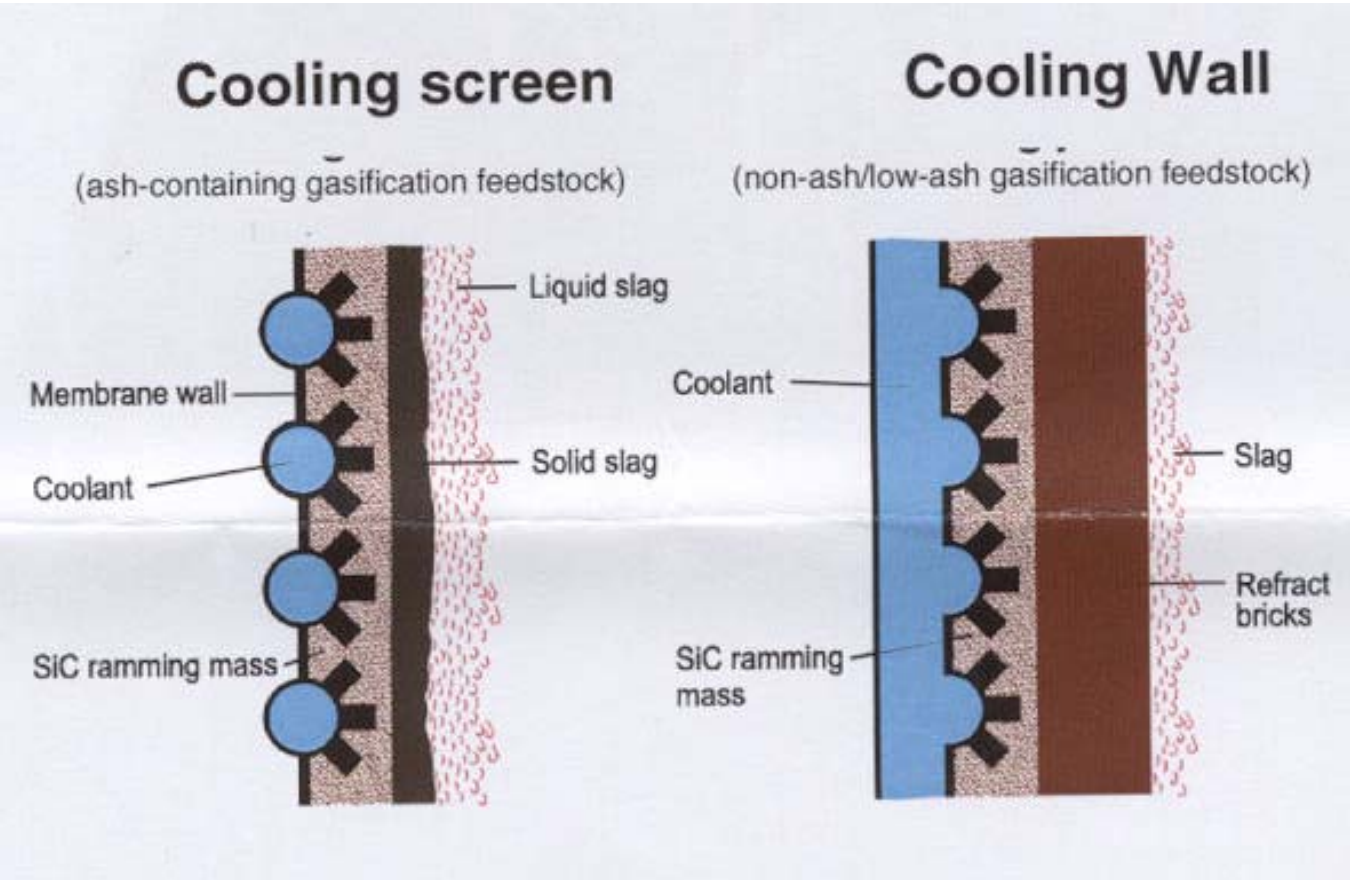


Ash-containing Fuel 적용



Non-ash, Low-ash Fuels 적용

가스화기 벽면 기본구조 options
(Siemens (구 Future Genergy) 기술 경우)



VS. 단순 내화물 구조 (미국 쪽 습식가스화기 경우)

Shell사의 석탄가스화기

Shell사 가스화기 버너 부근 Membrane Wall

Ref.: Ross Fava, “Shell Gasification Update,” 2007 COALGEN Gasification Session, 2007/8/3.

Fixed-Bed (고정층) Gasifier Concepts

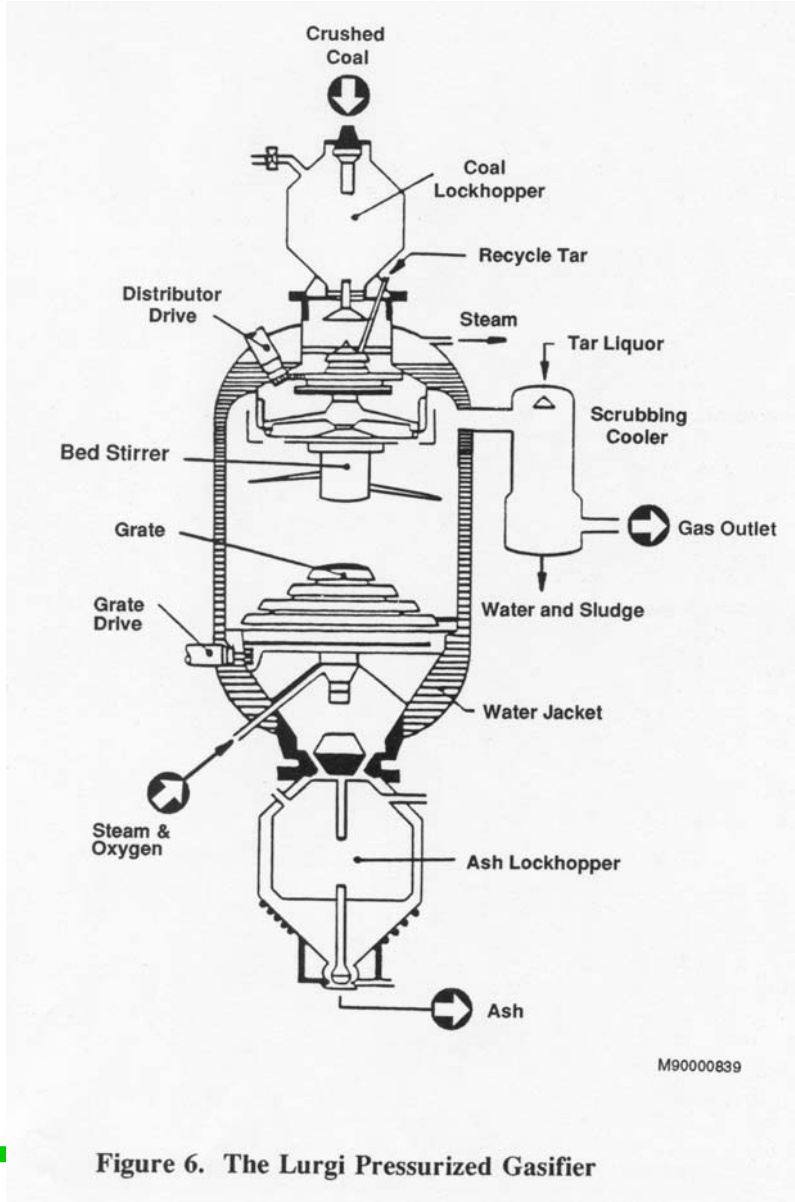


Figure 6. The Lurgi Pressurized Gasifier

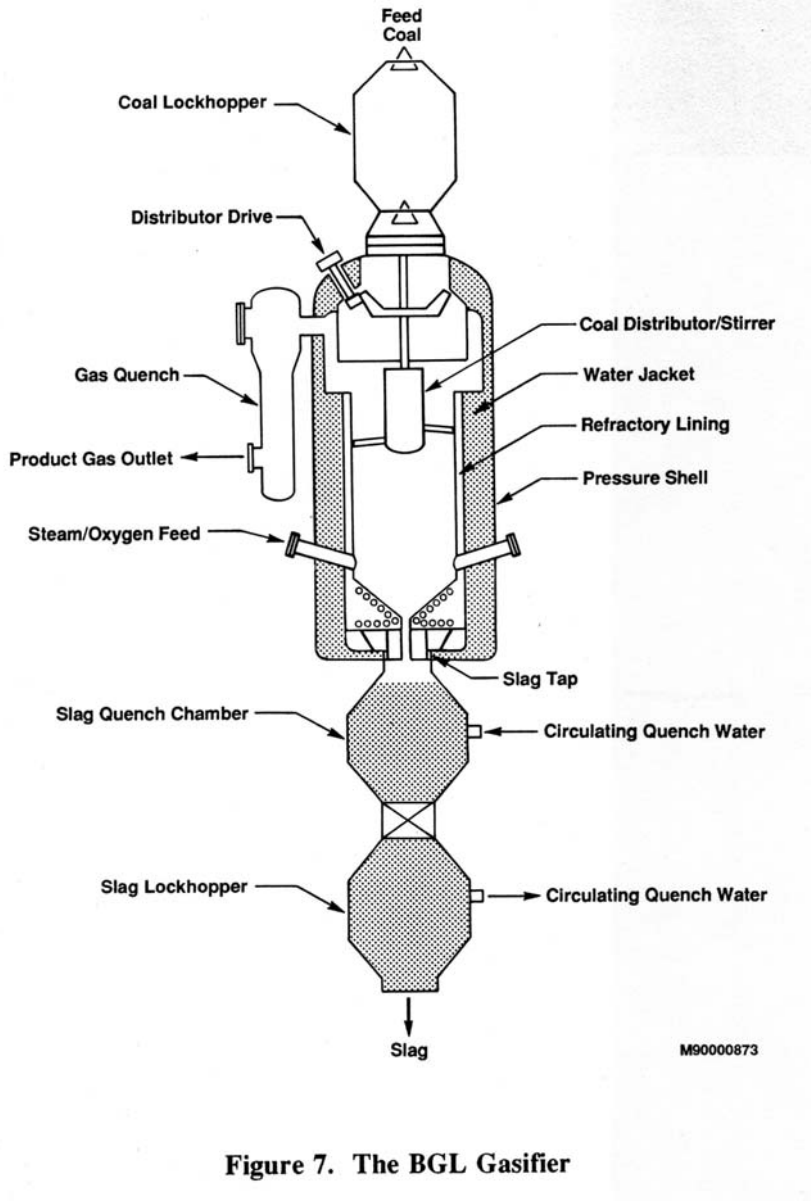


Figure 7. The BGL Gasifier

Fixed–Bed Gasifier Example 3

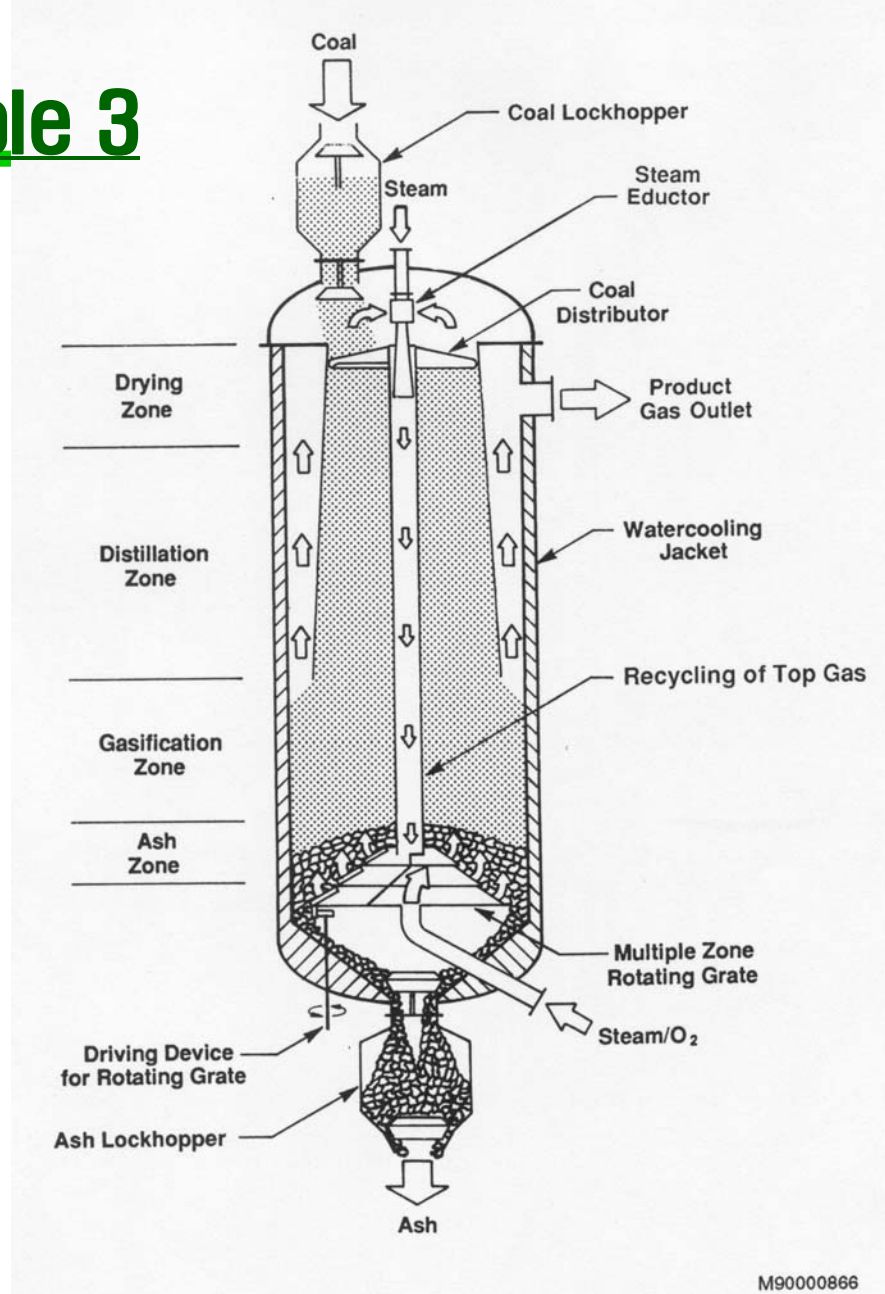


Figure 9. The KGN Fixed-Bed Gasifier

Fixed–Bed Gasifier Example 4

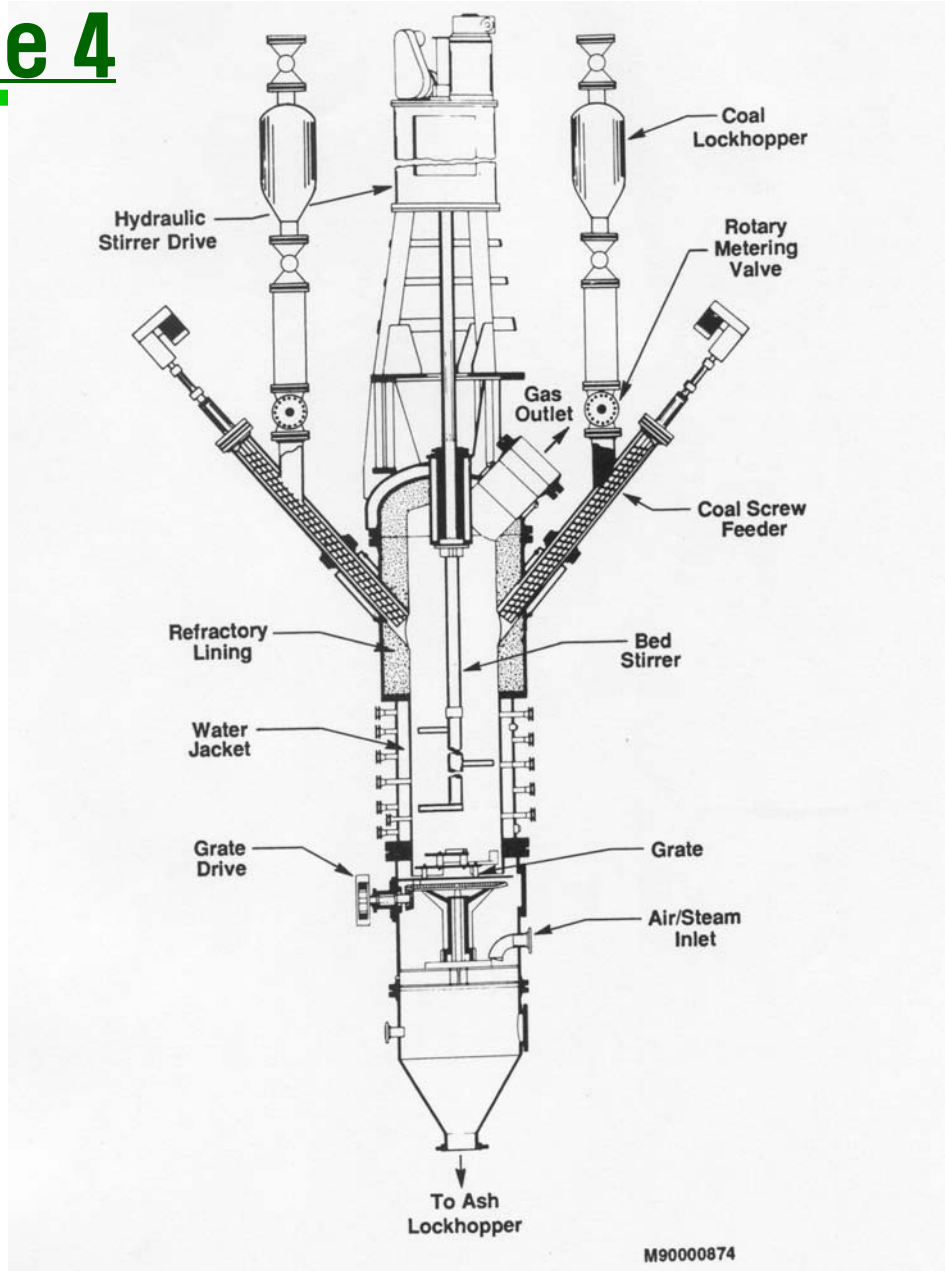


Figure 11. Sectional View of the Current METC Fixed-Bed Gasifier

Fixed–Bed Gasifier Example 5

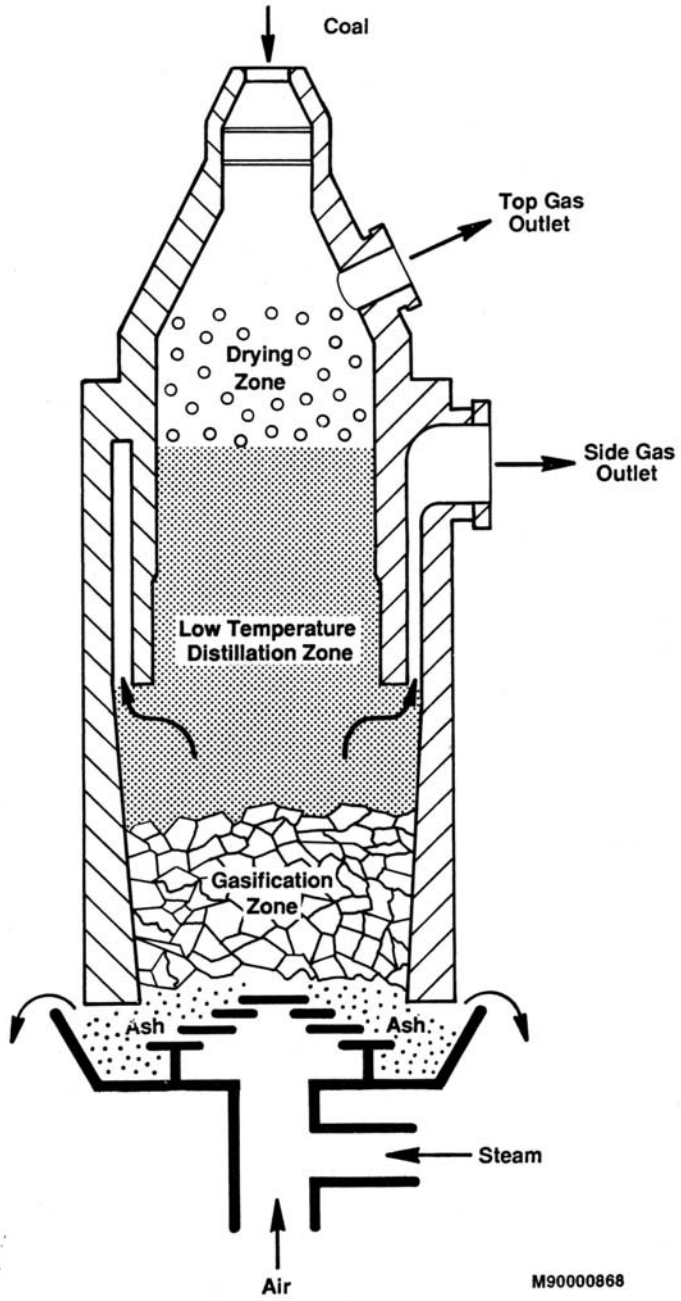


Figure 8. The Woodall-Duckham Gasifier

고정층 석탄 가스화기 다른 형태의 예

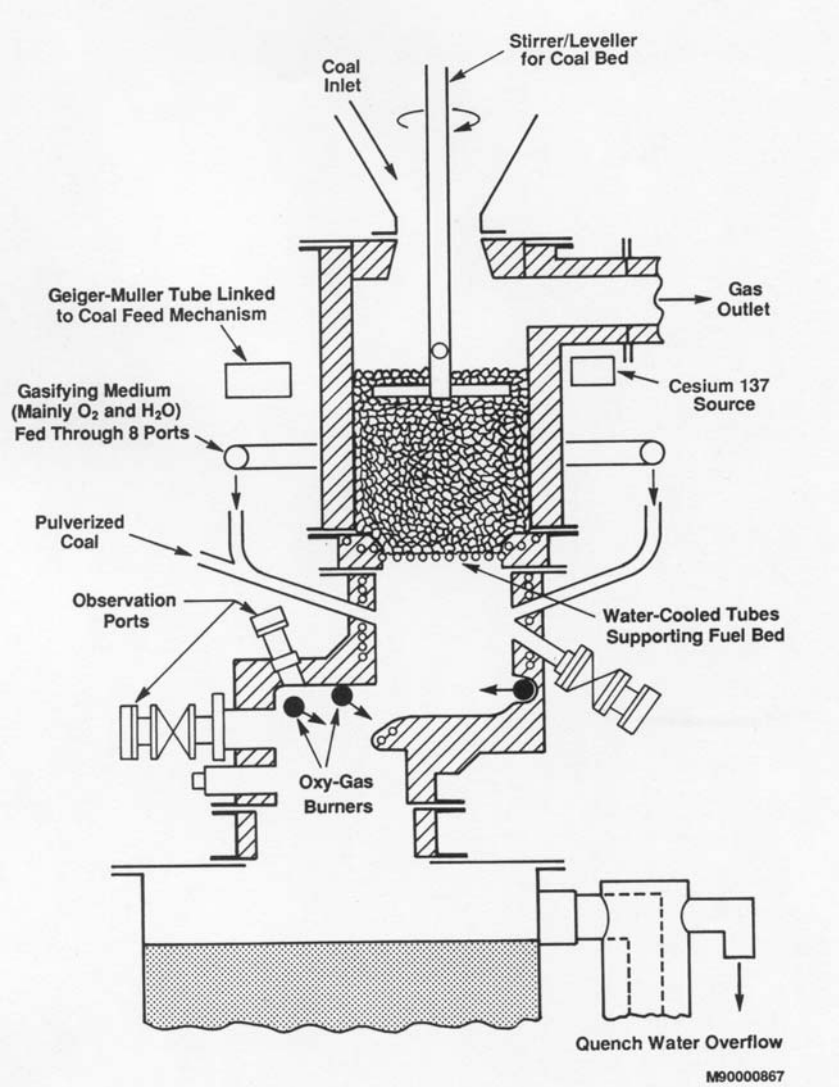


Figure 12. NCB/CURL Experimental Composite Slagging Gasifier

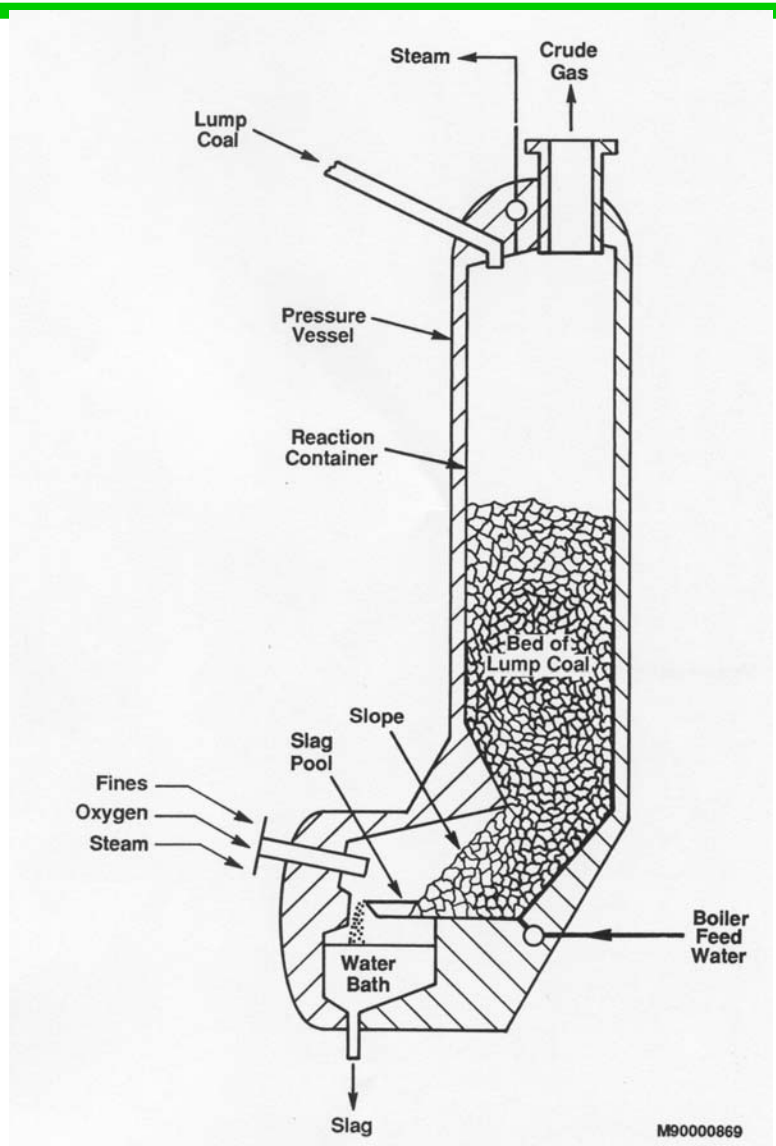


Figure 10. The Voest-Alpine Gasification Reactor

석탄가스화 생성 슬랙 및 석탄 합성가스 연소 화염

생성 슬랙

석탄 합성가스 연소화염

IAE