-UN ESCAP
"FGD Technology in Coal-fired Power Plants", (Tokyo, Dec 17, 2008)

KC Cottrell

FGD Technologies for

Korean Coal Firing Power Station

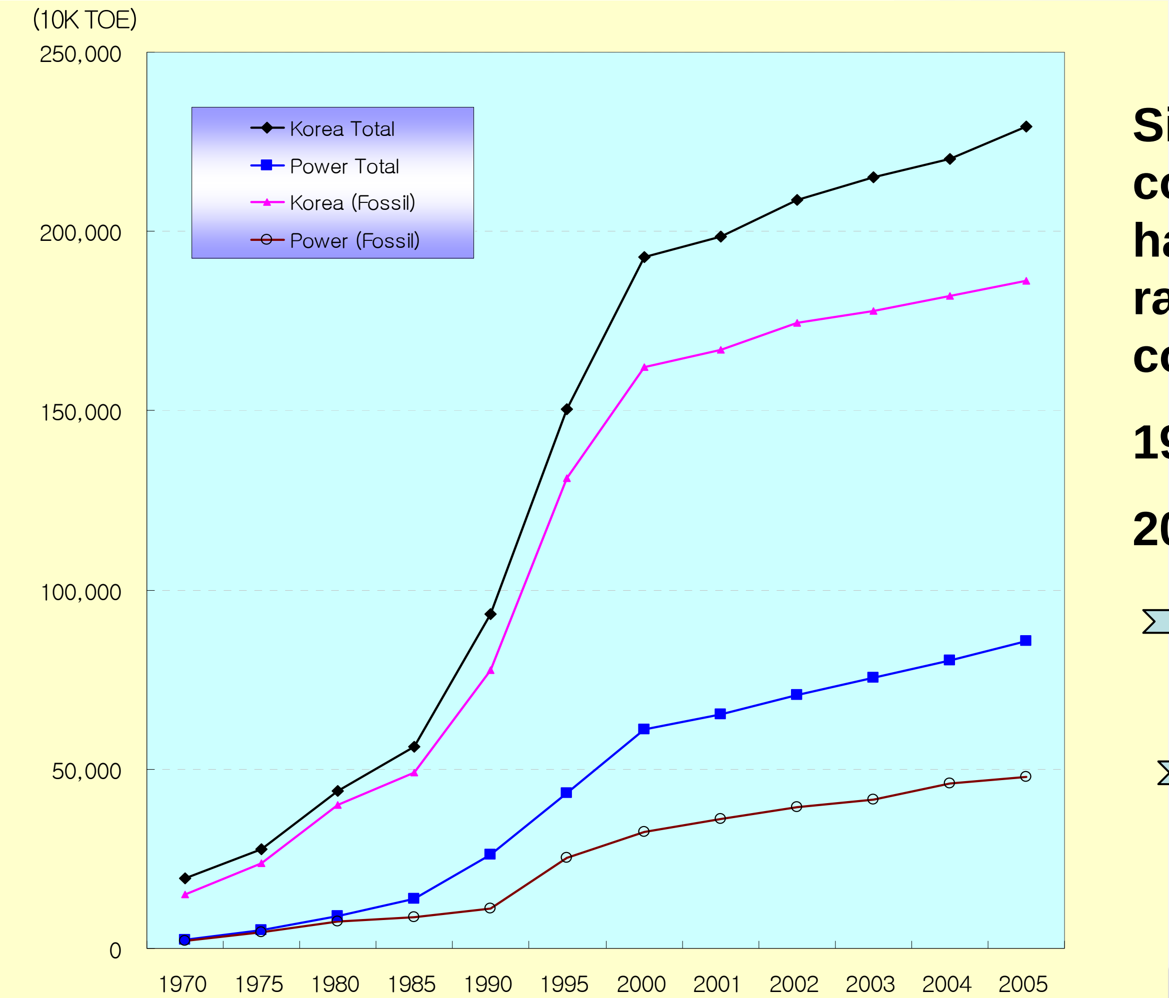
Ki Suh Park / CTO

KC Cottrell Co., Ltd.
Homepage: www.kc-cottrell.com
Phone +82-2-320-6231
e-mail : kisuh@kc-cottrell.com

KC Cottrell

Status of General Korean FGD Market

Domestic Energy Portfolio



Since 1960s, overall energy consumption of the country has been increased very rapidly. Electric power consumption has risen too.

1970: 9,167 GWh

2005: 349,743 GWh

➔ more than 38 times

➔ App 30% of energy for Power Generation

Amounts of Air Pollutant from Power Stations

Unit: 10K ton

	Total Amount			Power Sector		
	SOx	NOx	Dust	SOx	NOx	Dust
1980	154.0	88.9	36.9			
1985	135.2	72.3	34.2			
1990	161.1	92.6	42.0	19.4 (12.0%)	9.0 (9.7%)	0.8 (1.9%)
1995	153.2	115.3	40.6	33.0 (21.5%)	18.3 (15.9%)	1.1 (2.7%)
2000	53.1	100.4	8.9	11.7 (22.1%)	13.9 (13.9%)	0.9 (10.2%)
2003	49.9	116.7	9.1	11.4 (22.8%)	16.1 (13.8%)	0.5 (6.7%)

In general, approximately 15 % of the air pollutants are accounted by power industry at present. In spite of the increased power capacity, volume of SOx emission has decreased by 66% from year 1995 to year 2003.

Air Pollution Regulation History for Korean Power Stations

	Power Stations			1991	1995	1999	2005	2007
SOx (ppm)	Coal	Anthracite Coal		1200 ~1650		150	150	
		Bituminous Coal		700	500	150~270	100(70~270)	
	Heavy Oil			1200	1200	70~150		
NOx (ppm)	Coal	Local Coal		350	350	350	350	
			Upto 1990				350	
			Since 1990				250	150
	Heavy Oil			250	250	250	70 ~ 250	
	Gas	Gas		400	400	400	150	
		Combined Cycle		1400	1400	950	150 ~ 300	
Dust (mg/Nm^3)	Coal			250	100	50	40 ~ 50	
	Heavy Oil			100	60	40	40	

Air Pollution Regulation for Power Stations

Air Pollution Regulation Limits (Since 2007)			
SOx	Exisitng Power Station		
	Coal	100	ppm
	Oil	150	ppm
	New Power Station		
	Coal	80	ppm
	Oil	70	ppm
NOx	Exisitng Coal (before 1990)	350	ppm
	Exisintg Coal (afer 1990)	150	ppm
	New Coal	80	ppm
	Exisitng Oil	250	ppm
	New Oil	70	ppm
Dust	Exisitng Coal	40	mg/Nm3
	New Coal	20	mg/Nm3

From 2010, Mercury Control will be implemented. 0.1 mg/Nm^3

Even tough agreement with Local Government

<table>
<tr><th rowspan="2"></th><th rowspan="2" colspan="2">Type of Facility</th><th colspan="2">Local Gov.(NOx)</th><th colspan="2">Youngheung Thermal</th></tr>
<tr><th>Seoul (1999)</th><th>Incheon/Kyungki (2001, 2003)</th><th>Yr 1997</th><th>Yr 2002</th></tr>
<tr><td rowspan="4">Power</td><td rowspan="2">Coal</td><td>Existing</td><td></td><td>70</td><td rowspan="6">◇ SOx : 70
◇ NOx : 70
◇ Dust : 30</td><td rowspan="6">◇ SOx
#1-2 : 45
#3-4 : 25
◇ NOx
#1-2 : 55
#3-4 : 15
◇ Dust
#1-2 : 20
#3-4 : 10</td></tr>
<tr><td>New</td><td></td><td>50</td></tr>
<tr><td rowspan="2">Gas</td><td>Existing</td><td rowspan="2">50</td><td>50 ~ 80</td></tr>
<tr><td>New</td><td>50</td></tr>
<tr><td rowspan="2">Gas Turbine</td><td rowspan="2">Gas</td><td>Existing</td><td rowspan="2">100</td><td>100</td></tr>
<tr><td>New</td><td>50</td></tr>
</table>

Comparison with Germany

KC Cottrell

	German National Regulations		
	old, since 1983	existing- /new plants new, since 20.07.2004	
Emission-Limits (EL)	EL daily average value	EL daily average value	EL 1/2 h - average value
	• No daily average value > EL plus • No 1/2 h average value > 2 x EL plus • 97% of 1/2 h average values ≤ 1.2 x EL	• No daily average value > EL	• No 1/2 h average value > 2 x EL
Emission Limits (EL)	mg/m³ i.N. dry, 5/6% O_2	mg/m³ i.N. dry, 6% O_2	
• Dust	50	20 / 20	60 / 40
• NOx	200	200 / 200	400 / 400
• SO2	400	300 / 200	600 / 400
• Hg	-	0.03	0.05

SO2 Emission regulation is app 100 ppm /70 ppm for existing/new large power plant respectively in Germany. Also under this new regulation, flue gas downstream of FGD is not necessarily reheated. Therefore wet stack/cooling tower discharge become more common way of FGD discharge.

KC Cottrell

How does Korean Government encourage the power stations?

- Maintain the SOx emission less than 60% of legal limit
- Maintain NOx emission less than 70% of legal limit
- Maintain Dust emission less than 50% of legal limit

Korea Government recognizes the company as "Environmentally Friendly Company" with some benefits.

But most power stations have its own tighter regulatory standard. They understand the importance of environment management.

Dangjin Coal Firing Power Station

- 500MW coal firing station with 8 units (4,000MW total)

Legal Limit

- SOx 100 ppm
- NOx 150 ppm
- Dust 40 mg/Nm^3

Internal Guideline

- SOx 45 ppm
- NOx 50 ppm
- Dust 12 mg/Nm^3

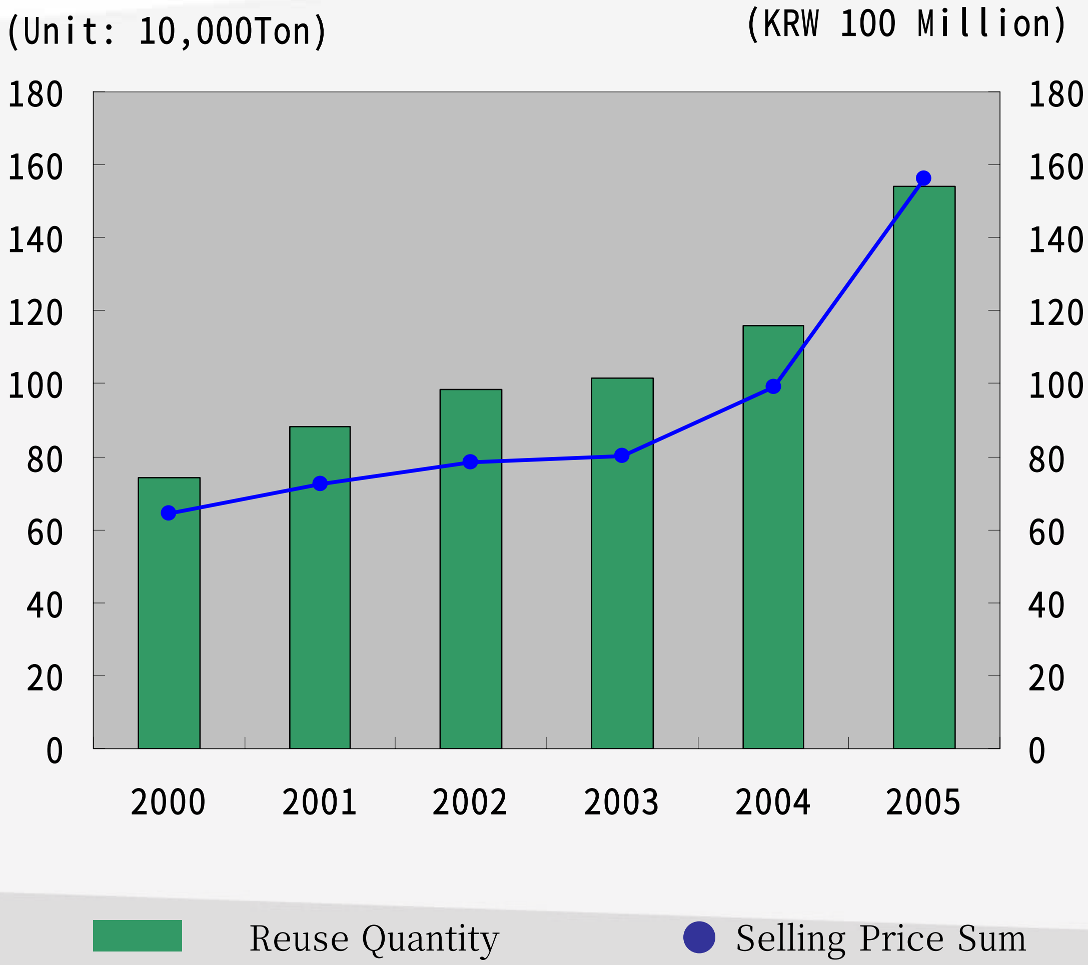
Current Emission Level

- SOx 30~50 ppm
- NOx 40~50 ppm
- Dust 5~10 mg/Nm^3

FGD Systems for Existing Korean Power Stations

		Number of Units			Generating Capacity (MW)	Name of Station
		1997 ～2000	2001 ～2002	2003 ～2005		
Coal	Local Coal	4			725	Yongdong#1-2, Seocheon #1-2
	Bituminous Coal	16	4	6	13,840	Poryng#3-6,Taean#1-6 Hadong#1-6,Dangjin#1-4 Yongheung#1-2 Samcheonpo#1-4
	Sub Total	30			14,565	
Oil		7		5	3,540	Ulsan#4-6, Yosu#1-2 Yongnam#1-2, Pyungtaek#1-4 Jeju Internal #1 (NaOH Scrubber)
Total		42			18,105	

Status of FGD Gypsum Reuse in Korea



Mainly FGD gypsum is reused for wall board or cement production.

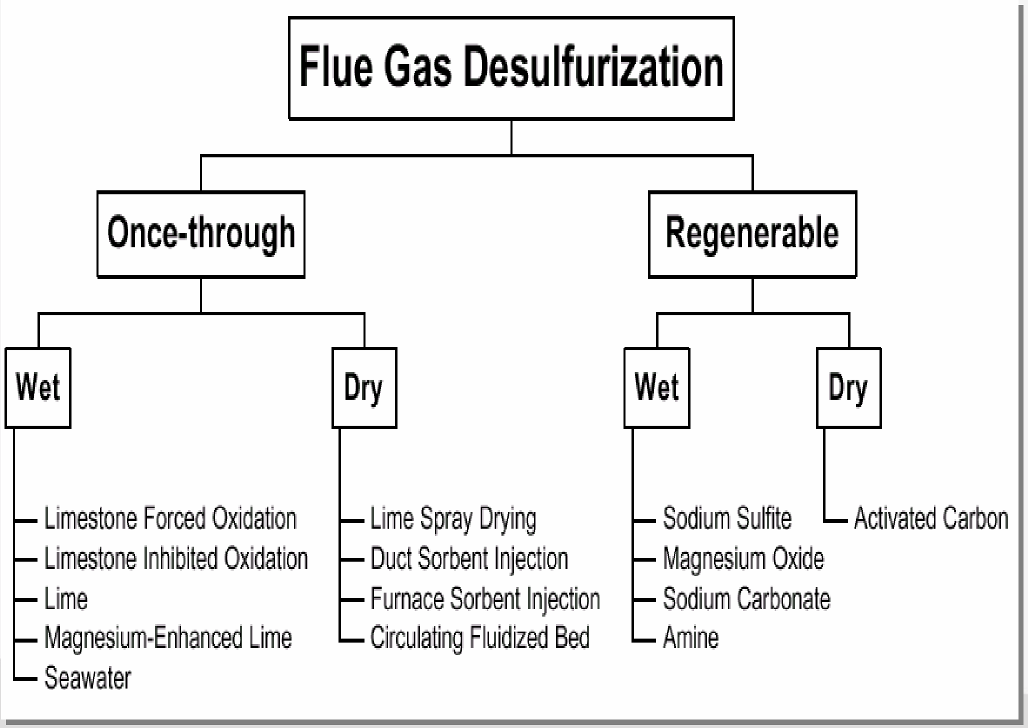
No landfill at all!!

General Understanding of FGD technologies

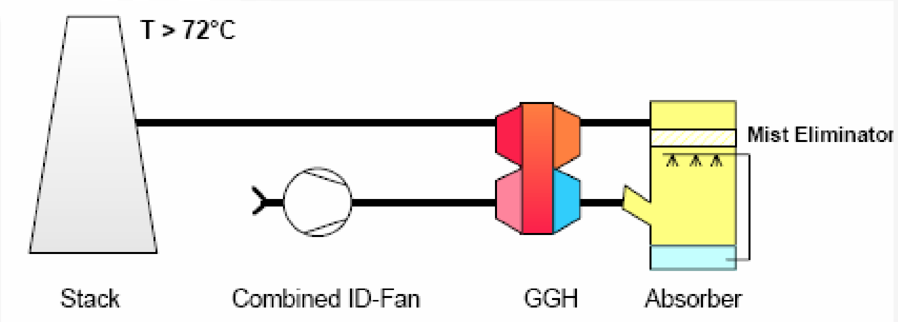
KC Cottrell

FGD technologies
: General

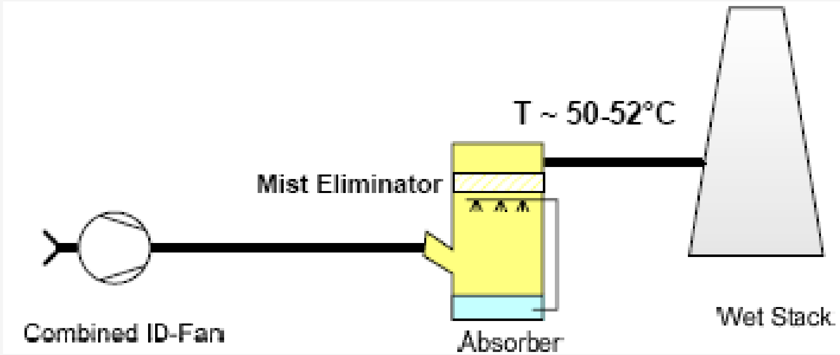
- **Classification of FGD Technologies**
  - Wet Process :
    - Once-through (throw-away) process,
    - Gypsum by-product process
  - Dry Process :
    - Spray Drying
    - Sorbent Injection(Duct or Furnace)
    - Circulating Fludized Bed
    - Activated Carbon
  - Other Technologies :
    - Regenerable processes :
      - Wellman-Lord,
      - SNOX
      - NOXSO
    - Combined SOx/NOx



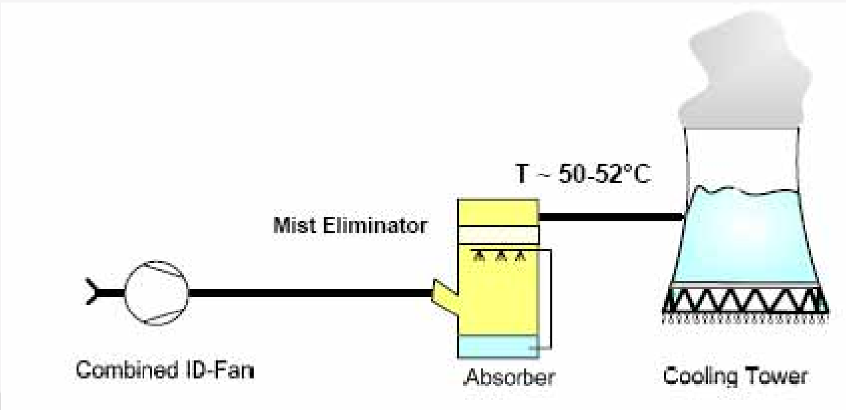
Wet FGD Discharge Arrangement



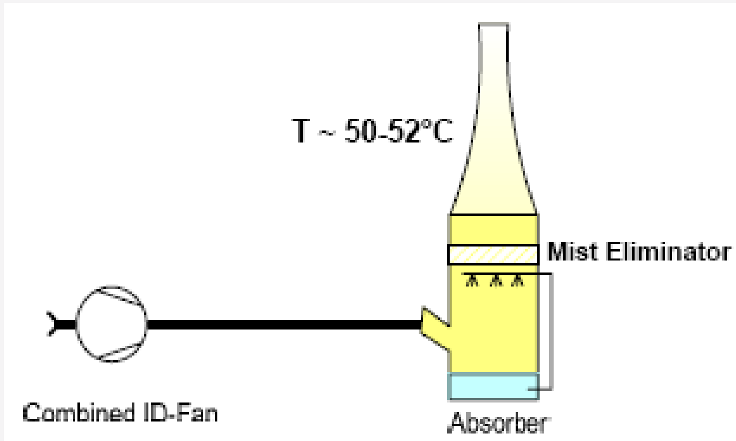
Dry Stack



Wet Stack



Cooling Tower Discharge



Self sustaining wet Stack

Recent Trend in Wet FGD Technology Worldwide

- **More FGDs from Dry Stack to Wet Stack or Cooling Tower Discharge**
- **Higher Superficial Gas Velocity due to the larger boiler unit**
- **High SO_2 Removal Efficiency**
  - Inner Ring or ALRD
  - Improved liquid-gas mixing
  - New Demister Arrangement
- **More practical Material Selection**
  - More FRP & PPs
  - Widened metal available for absorber
  - Rubber Lining
- others

For the Korean Power Stations …..

- SO_2 Removal (Wet) vs SO_2 & NOx (Dry)
  - Activated Carbon Process has not been applied for power station but steel mill.
- Absorbent Choices
  - Limestone
  - Ammonia
  - Sea Water ← **Potentially for East Sea side**
  - Mg(OH) ← **Potentially for Smaller oil firing units**
- Wet Stack vs Dry Stack ← **But this is not yet well accepted by residents!**

Key Consideration Factors for FGD System of Existing Power Stations

KC Cottrell

- Remaining Plant Life Time
- Available Area Footage
- Acceptable SO_2 removal Efficiency
- Applicable Budgets for FGD System
- Balance of Water & other Energy Source
- others

But Economy.. Economy… and Economy!!!!

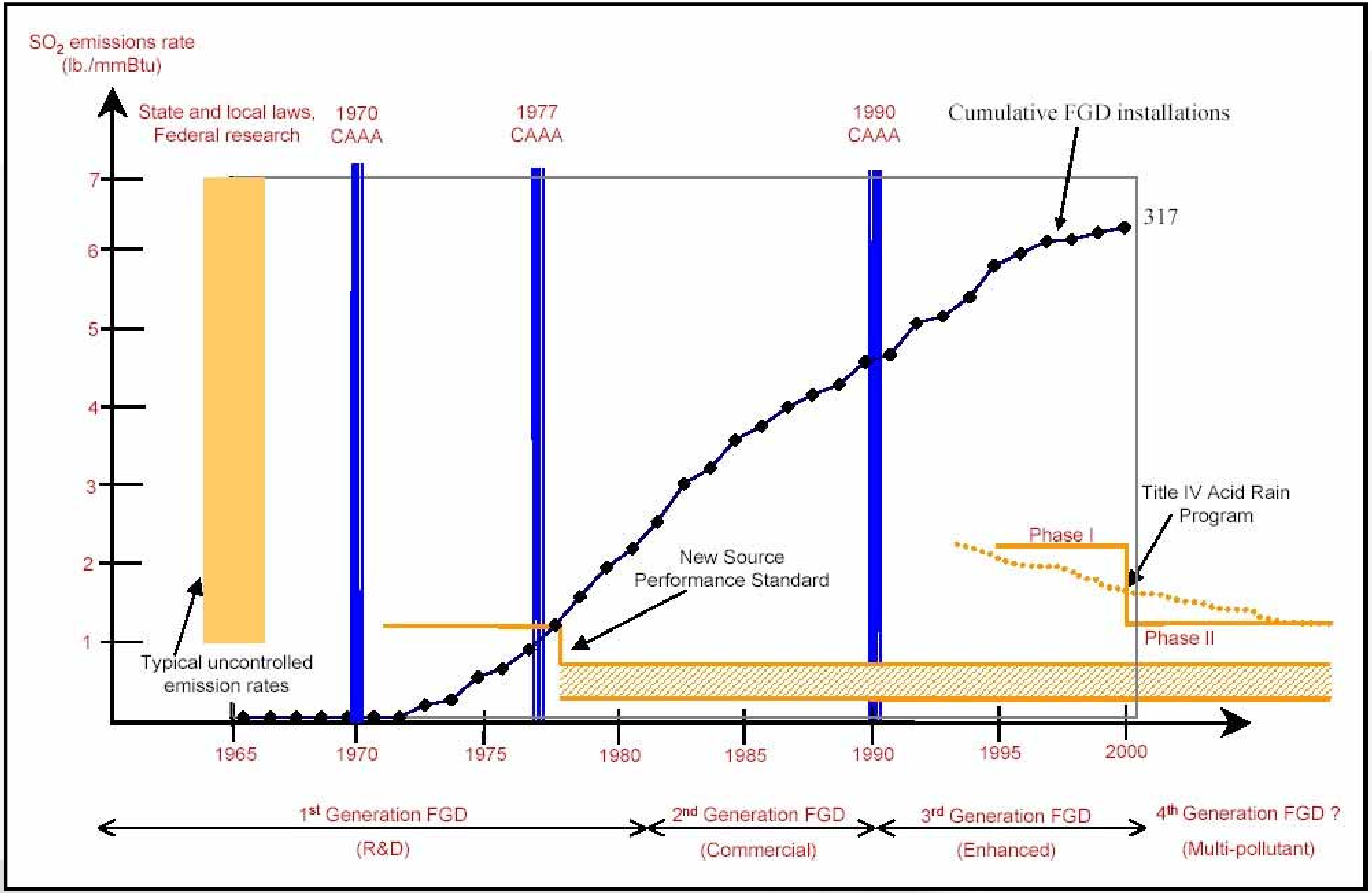
KC Cottrell

Basic Comparison of FGD System

System	Efficiency	Ca/S	Investment (West European basis)
Dry	80 - 90 %	< 2	65 - 78 US$/$KW_{el}$ (50 – 60 €/KW_{el})
Semi-Dry	90 - 97 %	1.2 -1.5	65 - 78 US$/$KW_{el}$ (50 – 60 €/KW_{el})
Wet	90 - 99 %	1.05	85 - 115 US$/$KW_{el}$ (75 – 90 €/KW_{el})

- Wet-system if:
  - High S-content in coal
  - Gypsum can be sold
  - Landfill cost for product of semi dry process
  - Cost benefit for high flue gas throughput
  - Water resources are sufficient
- Semi dry-system if:
  - Lower desulphurization efficiency is asked for
  - Product has to be landfilled
  - Water resources are insufficient

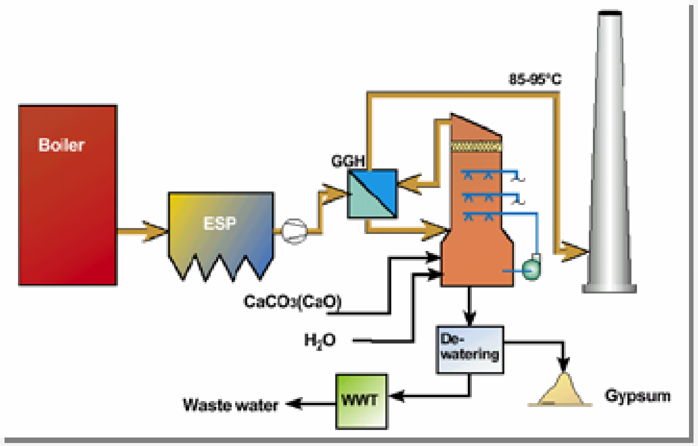
Timeline of U.S. SO_2 policy and FGD technology



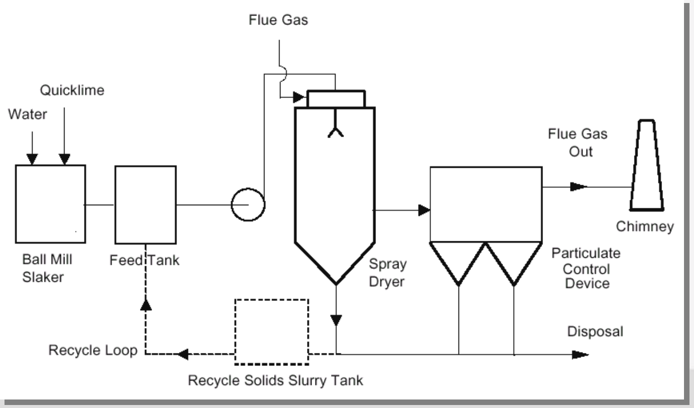
Source : "Environmental Regulation and Technological Innovation", A. E. Farrell, Management Options Information Seminar, Calgary, Alberta, Sep. 17, 2002

First generation FGD technologies
: Wet

- History of FGD Technologies
  - The first demonstrations of modern wet FGD technology
    - In the U.S. in the mid-1960s
  - Dry FGD technology :
    - In both the U.S. and Europe in the mid-1970s

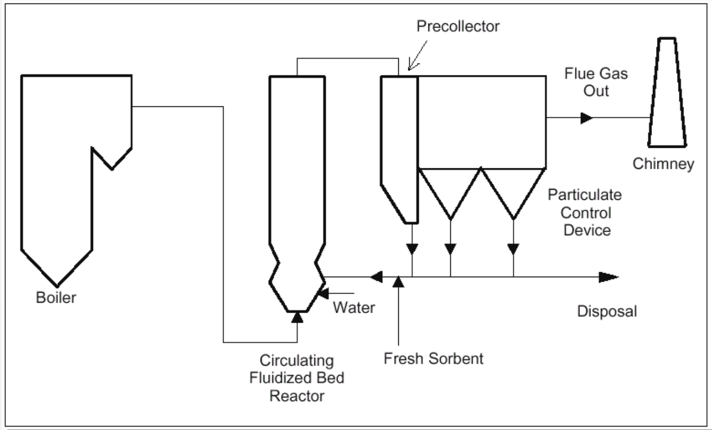


- Features of early FGD technologies
  - Relatively high capital and operating costs
    - Poor reliability due to scaling and fouling by solids
  - Built with a high level of spare equipment, including spare absorber
    - Disposal of solid byproduct(Throw-away processes)
    - Additional operating costs

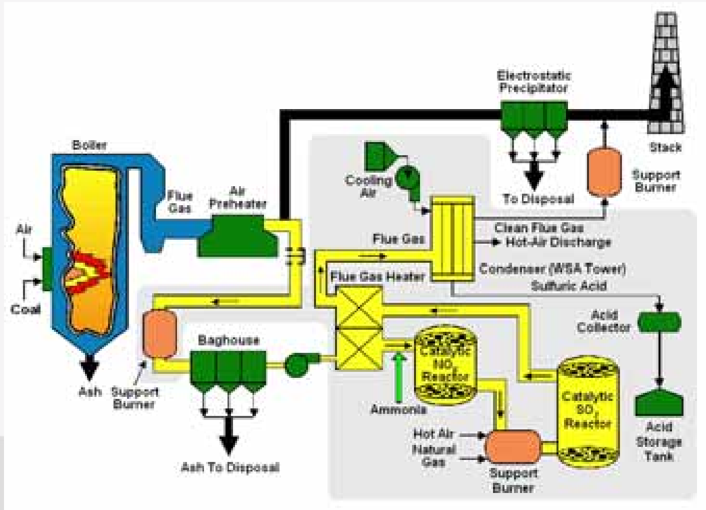


First generation FGD technologies
: Others

- **CFB processes**
  - Contacting of a dry sorbent, normally limestone, with humidified flue gas in a CFB boiler
  - Particulates including the reaction products are removed in the particulate control device



- **Regenerable wet processes**
  - Wellman-Lord : Sodium sulfite, sodium carbonate
  - Dual-alkali : sodium carbonate and lime reagent
  - Abandoned for use by electric generating facilities owing to the significantly higher operating costs that result from the high cost of the reagents.



KC Cottrell

Second generation FGD technologies

Second generation FGD technologies
: Wet FGD

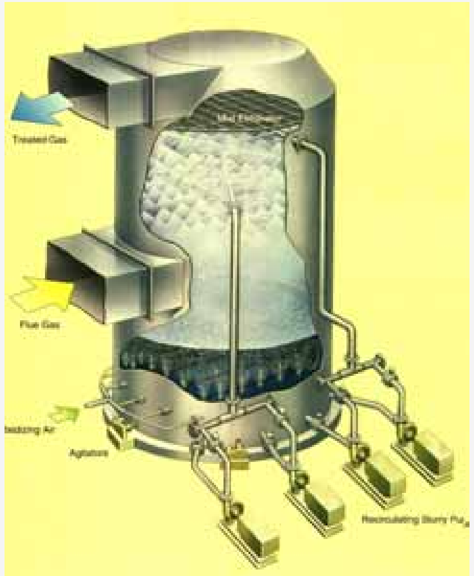
- **Applying Oxidation Method**
  - First significant advancements in FGD technology is oxidation :
  - Improving system reliability and reducing operating costs
  - Severe gypsum scaling
    - Limited system reliability and greatly increased maintenance costs

- **Inhibited oxidation**
  - Absorbed SO_2 is oxidized to a very low level by addition of an additive to inhibit oxidation
  - Most common additives : Thiosulfate or elemental sulfur

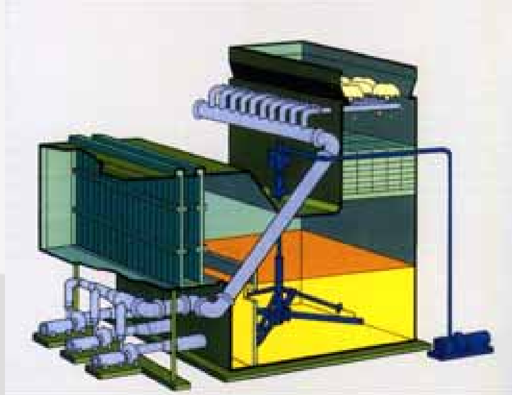
Second generation FGD technologies
: Wet FGD

- **Forced oxidization**
  - Sparging air into the reaction or hold-tank of the system or agitator oxidation
  - Maintaining high and near-complete oxidation of absorbed SO_2
  - Saleable gypsum is produced

- **Advantages of oxidation process**
  - Greater simplicity, improved operability, lower capital costs, and lower operating costs
  - High removal performance(>90%), greatly improved reliability



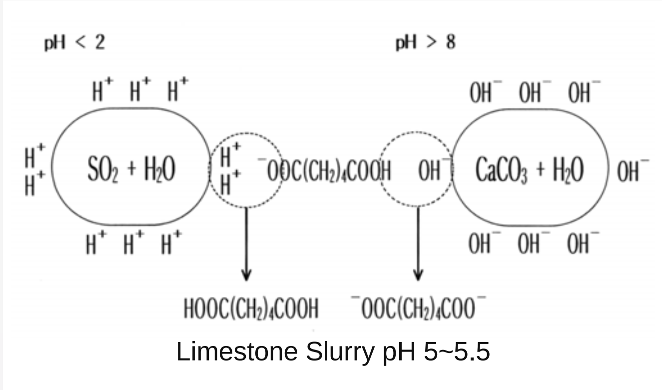
MHI's Grid-Packed Absorber



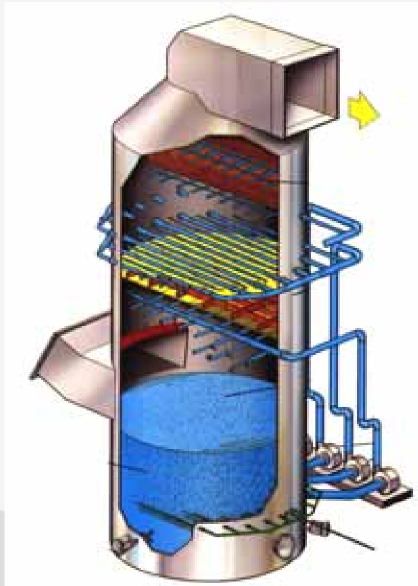
Second generation FGD technologies

: Wet FGD

- **Applying Additives**
  - Development of organic acid additives to improve SO_2 removal efficiency
  - Additives : adipic acid. di-basic acids(DBA), formic acid or sodium formate
  - Enhance removal by increasing the liquid alkalinity of a scrubber
  - Improves the mass transfer characteristics of the system
  - To achieve very high (95% to 99%) removal efficiency at a lower liquid-to-gas ratio (L/G) ⇒ lower capital costs.



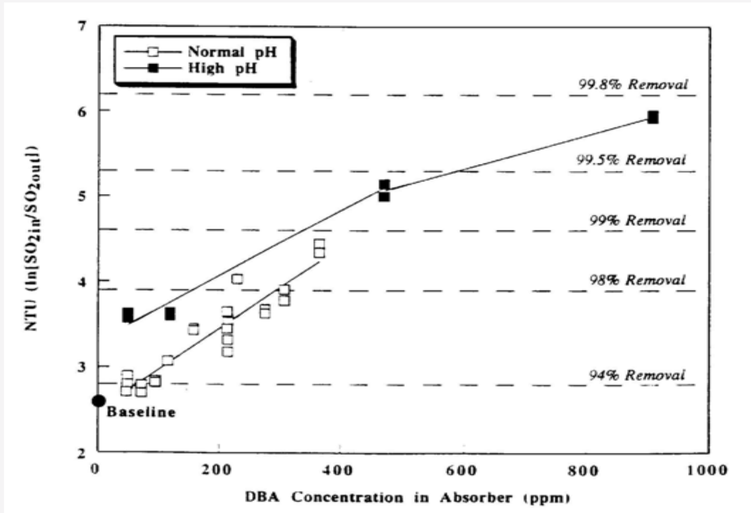
- **Applying Trays in Absorber**
  - Dual-flow or sieve trays improve the mass transfer characteristics of the scrubber by "holding up" the slurry
  - Formation of froth and allowing more contact time between the liquid and the gas.
  - Lower capital and operating costs due to lower L/G



Case Study of Additive Dosing

KC Cottrell

- Background
  - Big Bend Plant : Tampa Electrical Company(TECo), Florida, USA
  - Capacity : 1,800 MW
  - FGD Operation : 486MW(FGD 4 unit, each unit : 160MW), from Feb. 1985
  - Limestone-Gypsum process
  - Test to get SO_2 removal efficiency more than 98% by DOE
- Testing Results
  - High pH(6.1-6.2) : DBA 900ppm
  - Maximum SO_2 removal efficiency : 99.7%
  - Normal pH(5.6-5.8) : DBA 400ppm
  - SO_2 removal efficiency : 98.5%
  - Increased more than 5%(pH 5.6-5.8)



Second generation other FGD technologies

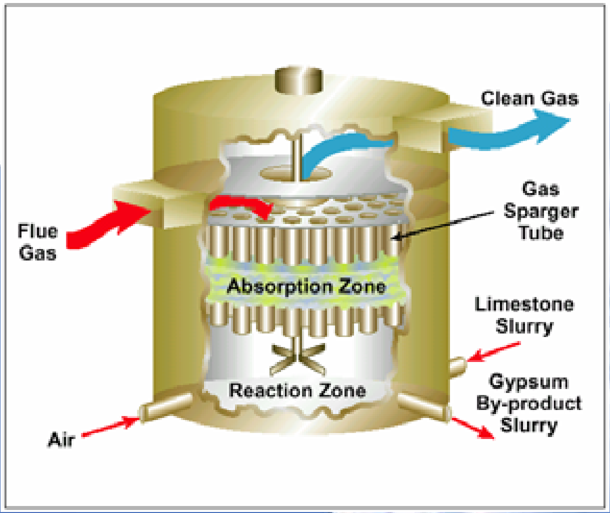
• Features of CT-121

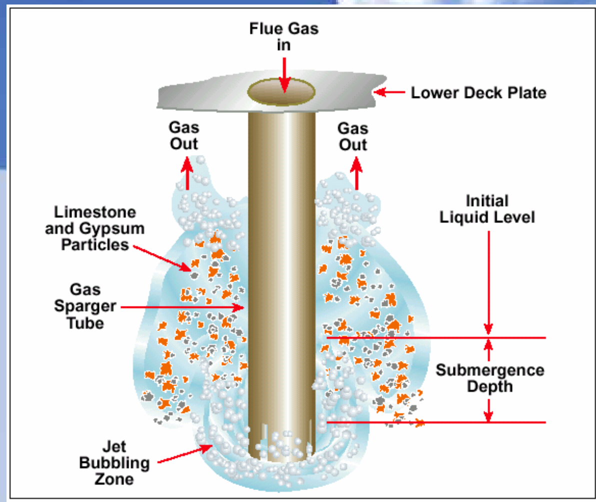
– Project was supported by DOE

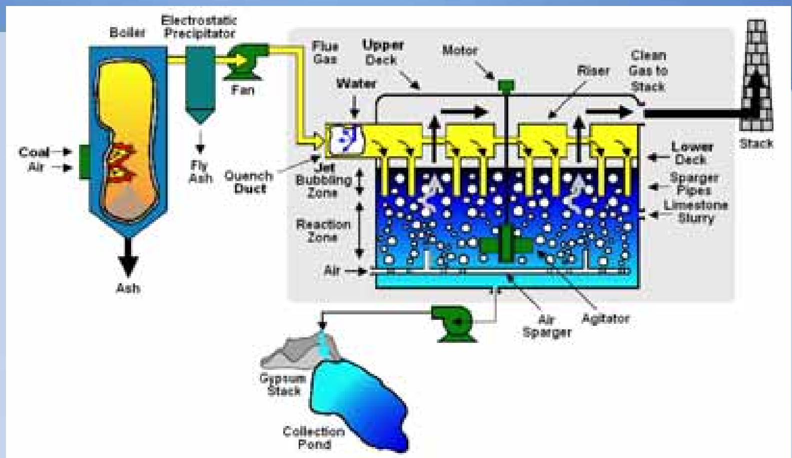
– Over 90% SO_2 removal efficiency was achieved at SO_2 inlet concentrations of 1,000-3,500 ppm with limestone utilization over 97%.

– JBR achieved particulate removal efficiencies of 97.7-99.3%

– Gypsum stacking proved effective for producing wallboard/cement-grade gypsum.







Source : Clean Coal Technology, Topical Report Number 12, U.S. DOE, June 1999

Second generation other FGD technologies

KC Cottrell

- Features of AFGD
  - – AFGD design enabled a single 600-MWe absorber module without spares to remove 95%
  - – Wallboard-grade gypsum was produced
  - – The wastewater evaporation system (WES) mitigated expected increases in wastewater generation

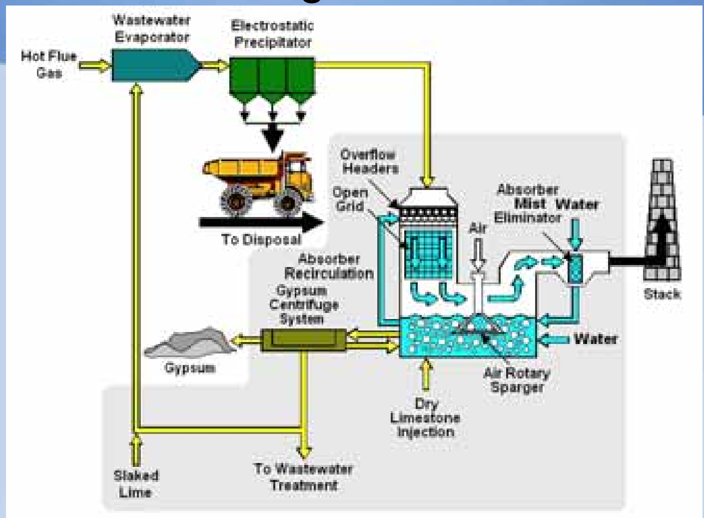


Exhibit 8
Estimated Costs for an AFGD System
(1995 Current Dollars)

Cases:	1	2	3	4	5	6	7	8	9
Plant size (MWe)	100	100	100	300	300	300	500	500	500
Coal sulfur content (%)	1.5	3.0	4.5	1.5	3.0	4.5	1.5	3.0	4.5
Capital cost ($/kW)	193	210	227	111	121	131	86	94	101
Levelized cost ($/ton SO_2)									
15-year life	1,518	840	603	720	401	294	536	302	223
20-year life	1,527	846	607	716	399	294	531	300	223
Levelized cost (mills/kWh)									
15-year life	16.39	18.15	19.55	7.78	8.65	9.54	5.79	6.52	7.24
20-year life	16.49	18.28	19.68	7.73	8.62	9.52	5.74	6.48	7.21

Source : Clean Coal Technology, Topical Report Number 12, U.S. DOE, June 1999

Recent FGD technologies

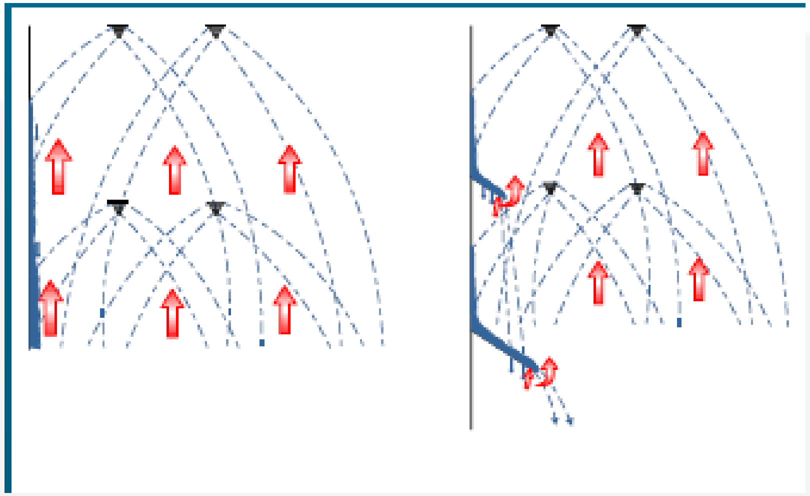
Recent FGD technologies : Wet FGD

- Features
  - Diversified FGD Designs
  - Improving the system reliability
  - Development of large capacity absorber modules
  - Improving the SO_2 absorption rate as a result of increased turbulence
  - Achieving the high performance and high mist collection efficiency of mist eliminator
  - Reducing the size of the scrubber by higher flue gas velocities
    - Smaller absorbers
    - Significant capital savings, estimated to be in excess of 35%

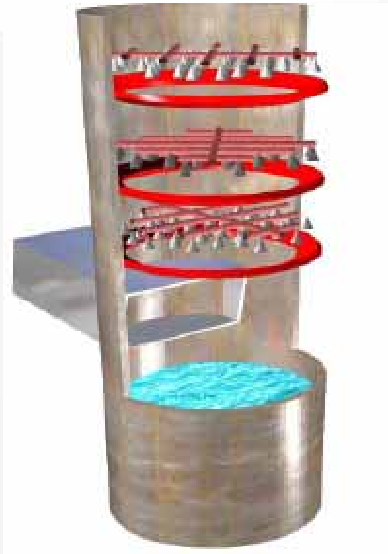
Option	Approach
Design	large capacity modules
	increased flue gas velocity in scrubber
	concurrent flow
	improved mist eliminator
	improved hydraulics
	superior materials of construction
	low-energy spray nozzles
Sorbent	organic acid buffering
	ultrafine limestone grind
Process	wet stack
	in-situ oxidation
	ex-situ oxidation with MEL
	wastewater evaporation system
	gypsum stacking for final disposal

"CONTROLLING SO2 EMISSIONS: A REVIEW OF TECHNOLOGIES, EPA/600/R-00/093, Nov. 2000

Wall Slip Phenomenon



(Marsulex's ALRD Design)



- dramatic improvement in removal performance
- preventing gas sneakage
- redirect the gas flow along walls toward the middle of the tower

- With regard to open spray tower design, ALRD or inner Ring design for absorber received more favorable acceptance due to the better SO_2 removal efficiency and less SO_3 slip through absorber wall.
  - ALRD by Marsulex
  - Other Simple Ring Designs

Recent FGD technologies : Absorber Design

- Improving gas and liquid distribution by designing nozzle configuration and layout
  - Dual Orifice Nozzle for Open Spray Tower
  - Double Contact Flow Scrubber (DCFS) System for modified Co-current Flow FGD System
- Computer Based Inlet Gas Distribution Design
  - Less Gas Sneakage
  - Less Slurry Scale Build-up

KC Cottrell

Dual Orifice Nozzle Design

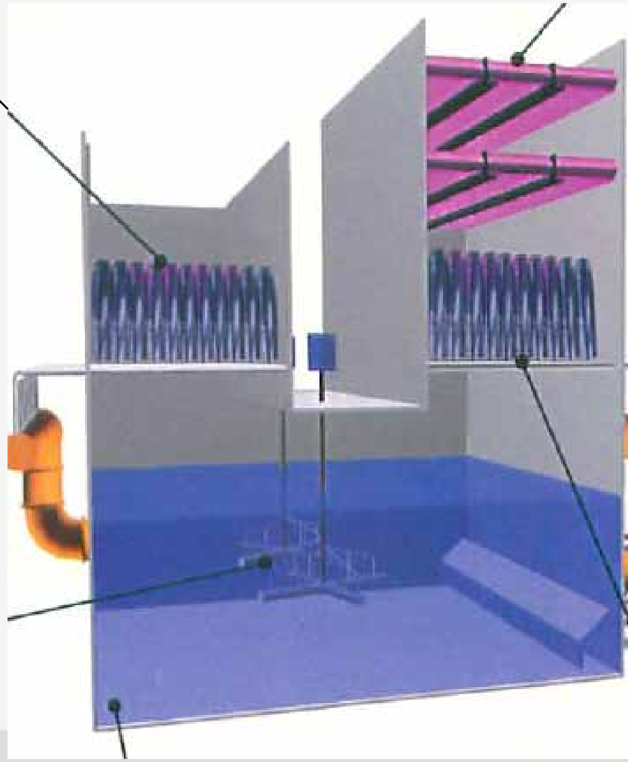
Dual orifice nozzle has been more widely used for the open spray tower design FGD.

-Any spray bank but the highest bank to avoid the mist entrainment to the treated gas stream

- More careful approach for the spray bank design to avoid the erosion issue (in combination with single orifice nozzle)

Double Contact Flow Scrubber (MHI Design)

Multiple Fountain Design

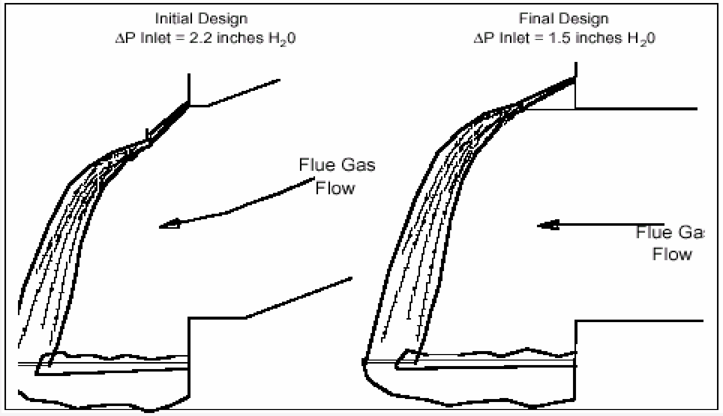


Spray Nozzle

Single always-operating Spray level

Recent FGD technologies :

- Three-dimensional computational fluid dynamic(CFD) modeling
  - Provides information concerning the gas and liquid velocity and pressure profiles in the absorber
  - Important for the design and evaluation of counter-current, open spray towers
  - Evaluate the location and placement of gas inlet and outlet ducts, number and location of spray headers
  - Evaluate gas and liquid distribution
- Stringent Mist Entrainment (PM2.5 associated issue)
  - 3 Stage Mist Eliminator Design
  - Wet ESP
- Mercury Control with FGD System

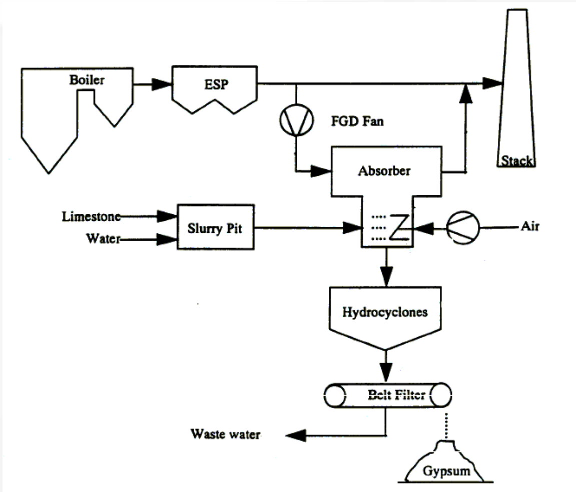


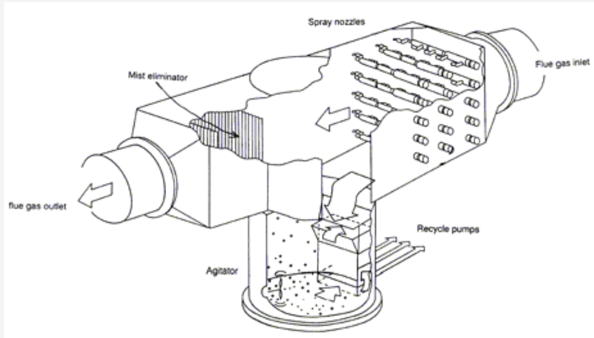
Recent FGD technologies : Examples

Simplified FGD System : Babcock-Hitachi

KC Cottrell

- Features
  - Designed to achieve 80% removal vs. 95% in current-generation wet FGD systems.
  - Design goal is 50% capital and 60% of the total cost of conventional wet FGD.
  - Differs from the conventional wet limestone with forced oxidation (LSFO) process mainly in equipment design
  - Uses a high gas velocity horizontal absorber
  - Only application is a demonstration project in China Special Features
- Commercial Status
  - Demo on 2/3 of a 310 MW unit
  - Conducted 3-year program at the Taiyuan Power Plant in Shanxi Province starting in 1996
  - Plant operated open-loop - liquid-phase Cl = 1000mg/l
  - Limestone is 95% pure with about 2% mud.
  - Inlet particulate loadings range from 20-30mg/Nm^3 to >300 mg/Nm^3 on a daily basis.
  - Outlet particulate loadings are <40 mg/Nm^3.

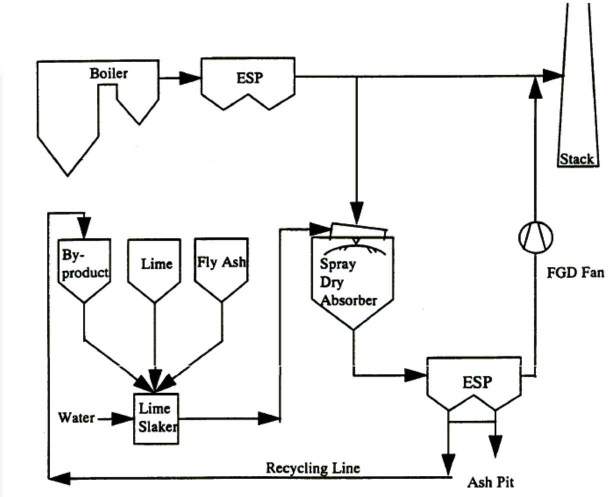


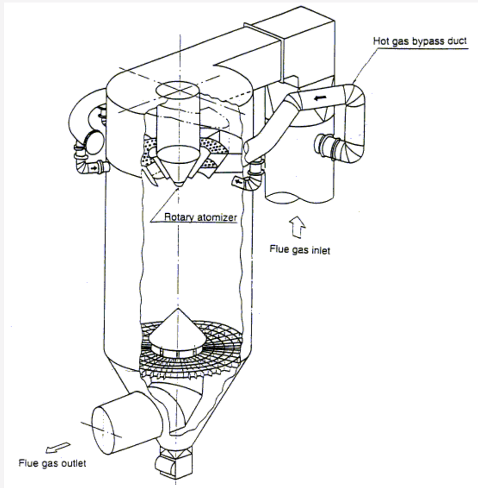


Simplified Spray Drying :
MHI of Japan

KC Cottrell

- Features
  - Modification of the conventional lime spray drying system.
  - Major difference is in alkali processing where the Lively Intensified Lime-Ash Compound (LILAC) process is used.
  - Fly ash, lime, and by-product are mixed in a hot water curing process.
  - Forms reactive amorphous compound of SiO_2 , Al_2O_3, $Ca(OH)_2$ and $CaSO_4$.
  - Silicates formed result in a more reactive alkali compared to slaked lime
  - Only application a demonstration in China
- Commercial Status
  - Demonstration treats 100 MW of flue gas
  - Plant Startup of the was in 1994 and the demonstration was completed in 1998.
  - The inlet SO_2 ranged from 1000-2000ppm.
  - Inlet gas temperature is 150C (302F). Outlet was 65-70C(149-158F).
  - Plant reported that the spray dryer consistently met its goal of 80% SO_2 removal.





Stack Integrated FGD System : MHI

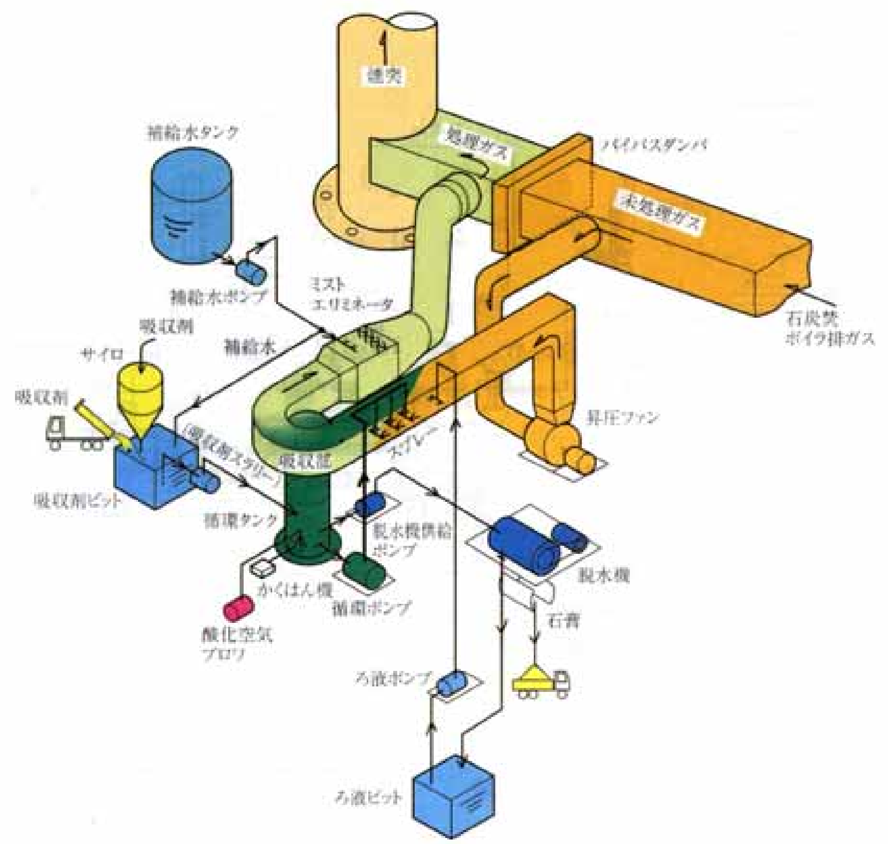
- Purpose
  - Less expensive investment
  - Operation cost employing highly effective and reliable wet limestone gypsum process
  - Using Double-Contact-Flow-Scrubber(DCFS)
  - To apply to the industrially developing countries
- Special Features
  - Independent stack is unnecessary.
  - Desulfurization Efficiency : 70~90%
  - Dedusting Efficiency : Equivalent to conventional system with quencher,
  - Low FGD Pressure Loss : Enables elimination of FGD boost-up fan.Special Features
- Experience
  - Weifang Chemical Plant in People's Republic of China

Weifang Chemical Plant

In-line Type FGD system :
IHI of Japan

KC Cottrell

- Background
  - Demonstration projects of “Green Aid Plan” from Japanese Gov.(1997-98)
- Features
  - No absorber : Spray in the duct
  - Smaller installation area : Less capital cost
  - Simple system : Easy operation and lower operating cost
- Application
  - Thai Union Paper Public Co.
  - Boiler Type: Lignite-fired stoker type
  - Steam Generation: 35 ton/hr
  - SO_2 concentration (inlet): 1,200 ppm (dry)
  - SO_2 removal efficiency: 70%
  - Absorbent: Lime mud or limestone (waste from paper production)
  - Byproduct: Gypsum

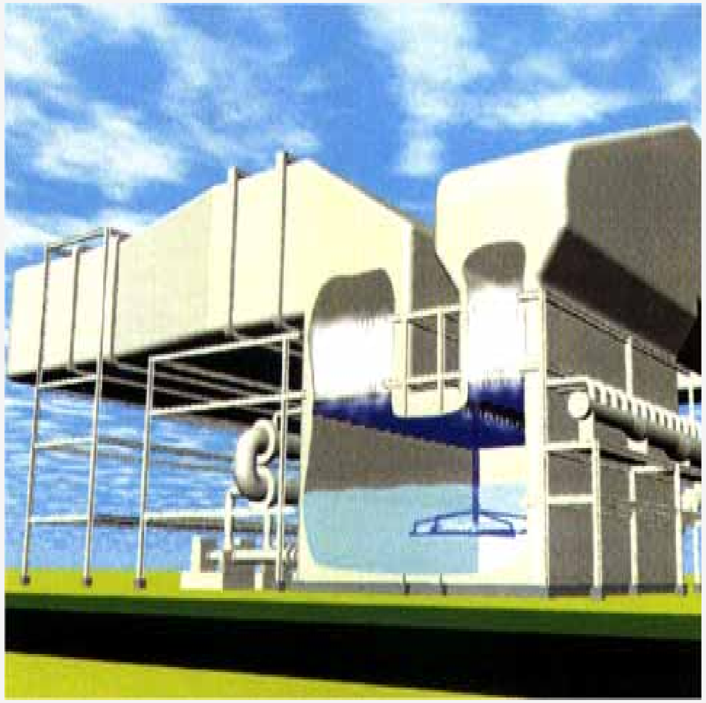


IHI’s In-line Type FGD system

Double-Contact-Flow Scrubber FGD : MHI

KC Cottrell

- Purpose
  - Simple and compact type absorber
- Performance
  - Desulfurization Efficiency : 90 ~ 98 %
  - Dedusting Efficiency : Above 80 %
  - Gypsum Purity : Above 95 %
- Special Features
  - Stable desulfurization, dedusting and oxidation performance
  - Recoverable high purity and high grade gypsum
  - Simply structured for easy maintenance
  - Economical with low power consumption and compact designs
- Experience
  - Supply experience of FGD plants
    - FGD plants for Japanese utilities : 61units
    - FGD facility for Japanese domestic industrial plants : 15units
    - Exported FGD plants : 55units



MHI's DCFS System

KC Cottrell's experience

Key References for Fossil Power Station
Wet Limestone-Gypsum Process

KC Cottrell

Dangjin Power Station
- **500MW * 4 units (#1,2,3 &4)**
- **Bituminous Coal**

Chungju District Heat
- **Oil Firing Boiler (CHP & HB)**

Samcheonpo Thermal Power Station
- **560MW * 4 units (#1,2,3 & 4)**
- **Bituminous Coal**

Hadong Power Station
- **500MW * 2 units (#7 & 8)**
- **Bituminous Coal**

Hsinta Power Station FGD Retrofit Work in Taiwan
- **600MW * 2 units**
- **Bituminous Coal**

Yongnam Thermal Power Station FGD Modification
- **Oil to Orimulsion Conversion**

… and many others

KC Cottrell

Plant Name	Customer	Location	Capacity	Fuel	Type	Absorbant	Additive	Removal Efficiency(%)	Start-up
Tang Jin Power Plant #1~4 unit	Korea Electric Power Corp.	TangJin, Korea	500MW × 4	Bituminous coal	Wet Scrbbing Open Spray Tower	Limestone pebble	N	90	2001
Cheong Ju Energy Supply, CHP Boiler	Korea District Heating Corp.	Cheong Ju, Korea	260 ton/hr	B-C Oil	Wet Scrbbing Open Spray Tower	Limestone powder	N	91.7	2001
Cheong Ju Energy Supply, HOB Boiler×2	Korea District Heating Corp.	Cheong Ju, Korea	150 ton/hr	B-C Oil	Wet Scrbbing Open Spray Tower	Limestone powder	N	91.7	2001
Youngnam Thermal Power Plant #1	Korea Southern Power Corp.	Ulsan, Korea	200MW	Orimulsion	Wet Scrbbing Open Spray Tower	Limestone pebble	DBA	94.8	2002
Youngnam Thermal Power Plant #2	Korea Southern Power Corp.	Ulsan, Korea	180MW	Orimulsion	Wet Scrbbing Open Spray Tower	Limestone pebble	DBA	94.8	2002
Taegu Dyeing Industry Complex Corp.	Hanwha Corporation	Taegu, Korea	50MW	Bituminous coal	Wet Scrbbing Packing Tower	Alkali Waste Water	N	92.5	2004

Plant Name	Customer	Location	Capacity	Fuel	Type	Absorbant	Additive	Removal Efficiency(%)	Start-up
Samcheonpo Thermal Power Plant #1~4	Korea South-East Power Corp.	Samcheonpo, Korea	500MW × 4	Bituminous coal	Wet Scrbbing Open Spray Tower	Limestone pebble	N	91	2004
Bridgestone Carbon Black Thailand Ltd.	Fujikasui Engineering Co., Ltd.	Bridgestone, Thailand	-						
Thai Tokai Carbon Product co., Ltd.	Fujikasui Engineering Co., Ltd.	Tokai, Thailand	-						
Jeju Thermal Power Diesel Power Station	Korea Midland Power Corp.	Jeju, Korea	40MW × 1						
BLCP Power Plant Thailand Ltd.	Fujikasui Engineering Co., Ltd.	Thailand	-						
Kwangyang #1~4 Sinter Plant	Pohang Iron & Steel Co., Ltd.	Kwangyang, Korea	-	-	Dry Injection	NaHCO3	N	80	2006
Hadong Thermal Power Plant #7~8	Korea Southern Power Corp.	Hadong, Korea	500MW × 2	Bituminous coal	Wet Scrbbing Open Spray Tower	Limestone pebble	N	93.5	2008

Dangjin #1~#4 FGD System
4 Units, 500MW each

First Full Scale FGD

Reliable Material Selection

Detail of Project
Dangjin Power Station

- **Fuel : Bituminous coal (2% sulfur coal)**
- **Process : Wet Limestone-Gypsum FGD**
- **SO2 Removal efficiency : >95%**
- **FGD commercial operation : since 1997**
- **Scope : Turn-key FGD project including**
  - Limestone slurry preparation
  - Gypsum dewatering plant
  - FGD Waste water treatment
  - Stack Inner flue basic design

KC Cottrell

Project Brief
Case of Yongnam thermal Power Station

SCR System

FGD System

Oil to Orimulsion Conversion Project

-SCR

-ESP Modification

-FGD Upgrade

Project Brief
Case of Samcheonpo Power Station

Detail of Project
Samcheonpo Power Station

- Bituminous Coal Firing Power Station
- 560MW * 4 Units
- Wet Limestone-Gypsum FGD absorber
- 91% SO2 Removal efficiency
- 1.05% Sulfur Coal / Design base
- Turnkey FGD Project including Limestone & Gypsum Handling System , FGD Waste water treatment
- Limestone slurry preparation with Wet Ball Mill
- Gypsum dewatering plant with Hydrocyclone & Vacuum Belt Filter
- Stack Inner flue basic design & modification
- Material concept absorber : C276, 4.5%Mo etc

Project Brief
Case of Bridgestone Carbon Black in Thailand

Self sustained wet stack type FGD for Oil Firing Boiler Application

Project Brief
Case of Hadong Thermal Power Station #7 & #8

Detail of Project
Hadong Power Station

KC Cottrell

- 2 units of 500MW New Power Station
- Dry Stack FGD
- Project Cost: app. KRW 80 Billion
- Project Period:
  - Signing of Project: June 2006
  - Commercial Operation of both Units: June 2009
- Major Scope of Work
  - Absorber
  - Ball Mill
  - Vacuum Belt Filter
- Total Steel Weight: app.6000~7000 ton

Project Brief
Case of Tokai Carbon in Thailand

Flue Gas bypass-reheating without GGH

•Wet Limestone – Gypsum FGD Process
• Absorbent: Powered Limestone
• Centrifuge for Dewatering
•High SO2 Removal Efficiency (≥90%)
•Commercial grade of gypsum quality (≥92%)

Project Brief
Case of Chungju District Heat Plant

- Combined Heating Power Boiler
  (260t/hr – 61,400KW × 1unit)
- Heat Only Boiler(150t/hr × 2units)
- Wet Limestone-Gypsum FGD Process
- 90% SO_2 Removal efficiency
- B –C Oil (Sulfur content) / Design base
- Powdered Limestone slurry preparation
- Gypsum dewatering plant with Centrifuge
- Less than one year for whole works!

Single Rec. Pump for three Spray Banks

Project Brief
Case of Cheju Internal Combustion Power Station

- Contract Amount:
  - Unit #1 10 Billion KRW
  - Unit #2 13 Billion KRW
    - Even common facility of waste water treatment, ash silo and absorbent preparation system was not included.
- Construction Periods; 13 Months (unit 1)
  - Signing of Contract May 2004
  - Commercial Operation June 2005
  - For Unit #2, project period is even shorter. Less than 1 year!

Cheju Power Station

- 40MW Internal Combustion / One Unit
- Fuel 0.3% Sulfur BC Oil
- Key Air Pollution Control System
  - Electrostatic Precipitator
  - FGD Scrubber
    - Type of Absorber: Internal Tray Perforated Type
    - Absorbent 50% NaOH
    - Type of Discharge Dry Stack
  - Waste Water Treatment Facility
    - Zero Liquid Discharge

      : Thermal Vapor Recompression (TVR) System

Details about Unit #1 Project

- Client : Korea Midland Power Co.,Ltd,(KOMIPO)
- Low Speed Diesel generator Facilities
- (600,979 A㎥/hr Temp: 261℃)
- Providing Basic & Detail Engineering and Major Facilities (ESP/Ash Handling/FGD/WWT)
- NaOH as Absorbent of SOx
- High SO2 Removal Efficiency (≥75%) on Low Sulfur Oil
- Waste water treatment system
- – Evaporizing Concentration Type
- Flue Gas Reheating with GGH(115℃)

Key Consideration

- High SO_2 removal Efficiency
- Minimum material Flow between Main land and Cheju Island
- Minimum Water Discharge

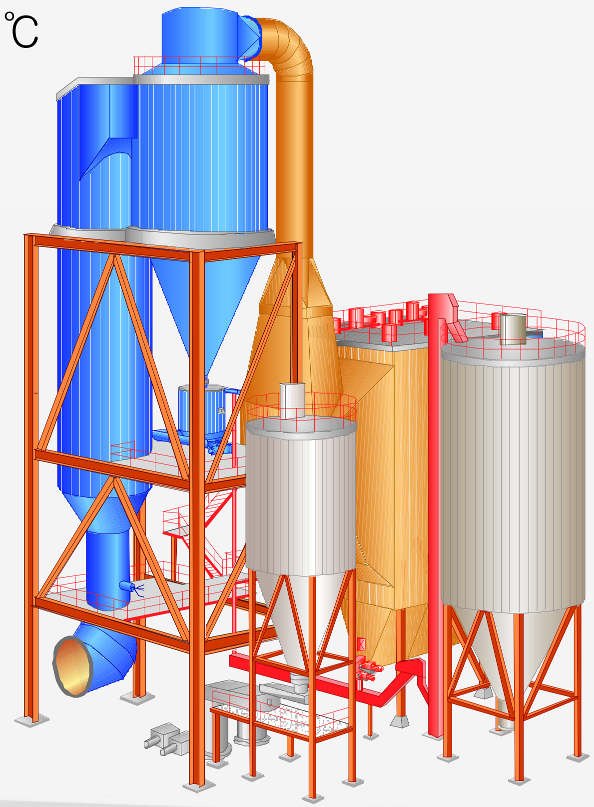
Actual Performance Data of unit #1

• Removal Efficiency	90.25 ~ 94.9 %
• SOx Concentration at Stack	6.21 ~ 14.29 ppm
• Mist Content at Absorber outlet	20.6 mg/Nm^3
• Dust Emission at Stack	1.557 mg/Nm^3
• Flue Gas Temperature	138 ℃
• Consumed NaOH S.R.	1.106
• Waste Water Discharge from Absorber	0.48 m^3/Hr

KC Cottrell

Project Brief
Point Comfort Plant in Texas

- Fuel: Coal and/or Petcoke
- Gas Volume: app 550,000Nm^3/Hr @ 150℃
- Performance Guarantee
  - SOx 91.5% / 34 ppm Guarantee
    400 ppm Inlet Concentration
  - Dust Inlet 30 g/Nm^3
    Outlet 44 mg/Nm^3
- Air Pollution Control System
  - GAS with Fabric Filter
  - Ca(OH)2 Powder Injection
  - No Waste Water
  - Relatively Simple and Reliable



Details of Project

• Project Amount:	USD 13 Million
• Period:	Total 10 Months
– Contract	April. 2007
– Engineering	6 Months
– Material Delivery	Feb. 2008

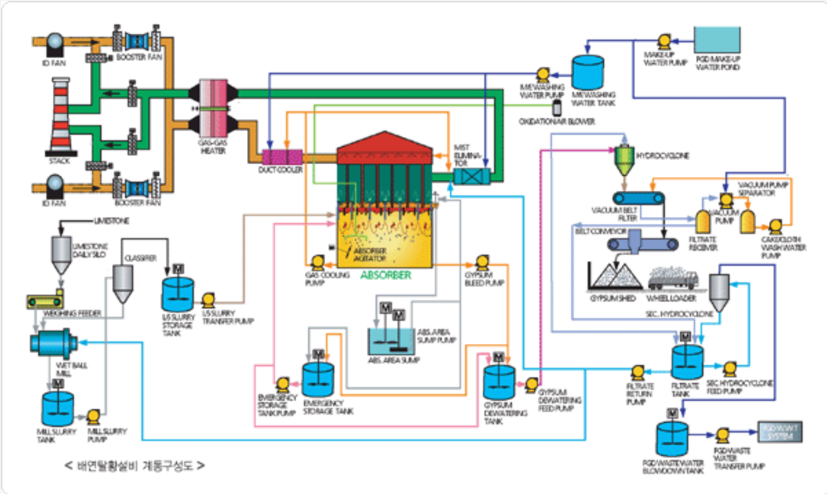
- Key Scope of Supply
  - GAS Reactor
  - Fabric Filter
  - Flue Gas System
  - Reagent Preparation
  - Commissioning

KC Cottrell

R&D Activities in Korea

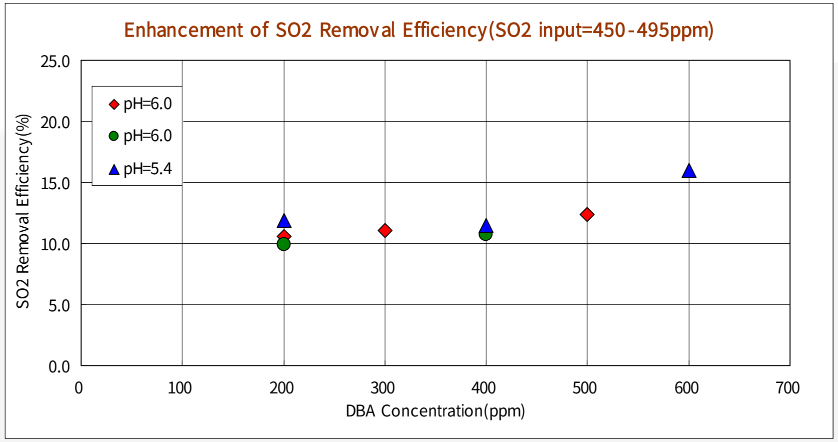
Major FGD R&D Companies in Korea

- Korea Institute of Energy Research (KIER)
  - Fundamental FGD R&D
  - Lab Scale FGD Facility
- Korea Electric Power Research Institute
  - Subsidiary of Korea Electric Power
- Korea Power Engineering Company
  - Subsidiary of Korea Electric Power for plant engineering
  - Co-developed its own FGD absorber design named “KEPAR” (Korea Electric Power Absorption Reactor)
- Korea Institute of Machinery & Metals



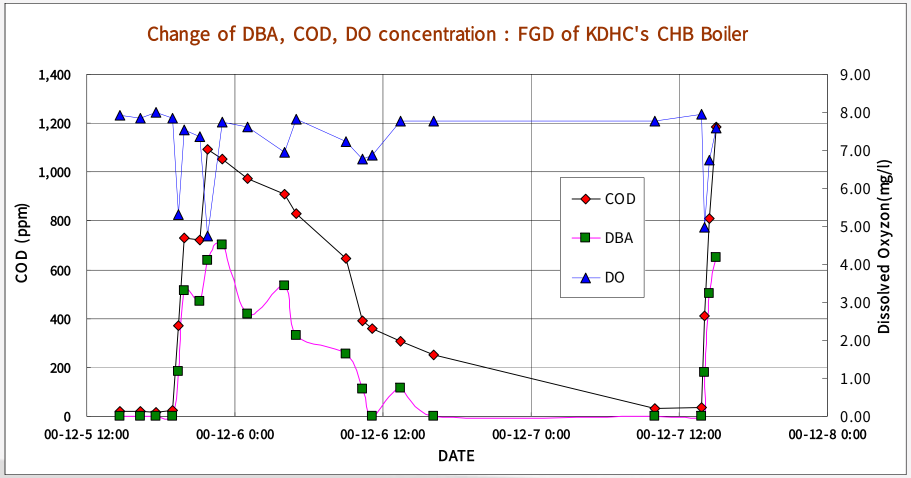
Performance test of DBA at KDHC(Daegu)

KC Cottrell



Absorber(Upper)

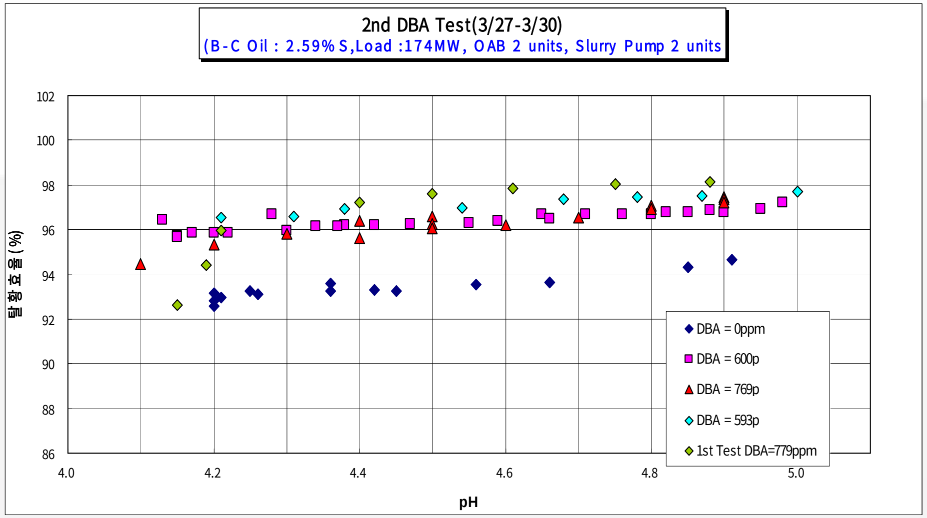
Absorber(Lower)

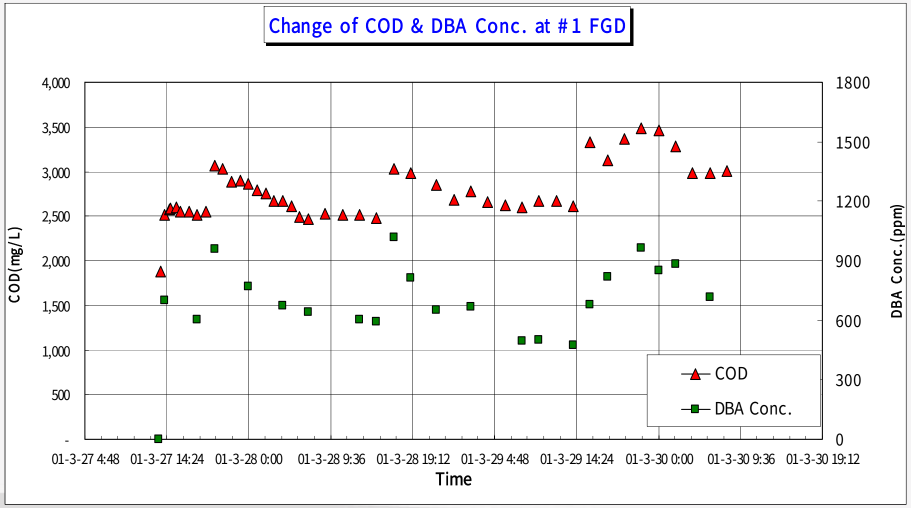


DBA Supplying System

Performance test of DBA at Korea Power Plant at Youngnam

KC Cottrell





흡수탑 전면

DBA 공급시스템

Design of 3MW Scale KIER $Mg(OH)_2$ FGD Process

Lab Scale Bubbling Reactor

Bench Scale Wet FGD

Wetted Wall Column

3MW Pilot Plant

Data Collecting From Industries

FGD Upgrade/Maintenance Works in Korea Power Industry

KC Cottrell

- Performance Upgrade Works
  - "Y" Oil Firing Thermal Power Station
    - DBA Injection System due to the fuel conversion
  - "DG" District Heat Company
    - DBA Injection System for improved efficiency
  - "T" Coal Firing Thermal Power Station
    - ALRD (Absorber Liquid Redistribution Device) System was installed for SO_2 removal efficiency.
  - "D" Coal Firing Power Station
    - Absorber Gas Flow Model Study due to the slurry deposit
- Major Maintenance Works
  - Mainly for the GGH heat element replacement
  - Etc
- Operation Test in conjunction with newly installed SCR
  - Study on Corrosion Potential by increased SO_3

KC Cottrell

Thank You !