



Kiewit



Circulating Dry FGD



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Major Types of Dry FGD

- ❑ Spray dryer absorber (SDA)
 - SDA have been in commercial operation for over 30 years
 - Slurry is atomized and dry in the hot flue gas
- ❑ Dry Circulating FGD
 - Newer technology: ≈20 years old
 - Solid lime and recirculated byproduct are injected dry
 - Water is injected independently

Dry Circulating FGD Technologies

Supplier	Technology Name	Acronym
Foster Wheeler / Graf Wulff	Circulating Fluidized Bed Scrubber	CFBS
Babcock Power Environmental (BPEI)	Turbosorp	Turbosorp
Andritz Environmental Solutions (formerly Allied)	Circulating Fluid Bed Scrubber	CFB
Babcock & Wilcox (B&W)	Circulating Dry Scrubber	CDS
Clyde Bergemann Power Group (CBPG)	Circulating Dry Scrubber	CDS
Marsulex Environmental Technologies (MET)	Circulating Dry Scrubber	CDS
KC Cottrell	Gas Suspension Absorber	GSA
Dustex	Circulating Fluid Bed Scrubber	CFB
Alstom	Novel Integrated Desulfurization (formerly Flash dryer absorber)	NID
Mitsubishi Hitachi Power Systems America	Enhanced All-Dry	EAD

Two Major Types of Circulating Dry FGD

	CDS or CFB	Wetted Solids Absorbers
Development	Originated by Graf Wulff / Lurgi	NID: Alstom developed EAD: Solios / Procedair
Suppliers	<ul style="list-style-type: none"> Foster Wheeler / Graf Wulff CFBS BPEI Turbosorp Andritz CFB B&W CDS CBPG CDS KC Cottrell GSA Dustex CFB MET CDS 	<ul style="list-style-type: none"> Alstom NID Hitachi EAD
Reagent	Ca(OH) ₂ into absorber	NID: CaO EAD: Ca(OH) ₂
Water Injection	Into bottom of absorber	Into byproduct mixer
Stoichiometric Ratio*	1.3 to 1.8	1.5 to 1.8
Pressure Drop	12 to 16 in. w.g. (excluding GSA's cyclone)	13 to 15 in. w.g.

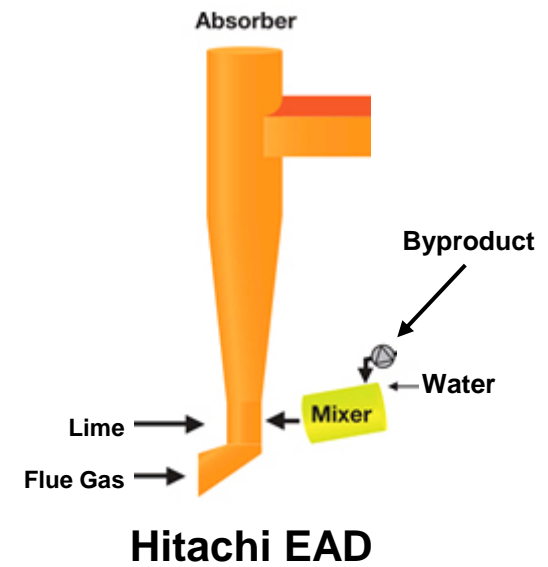
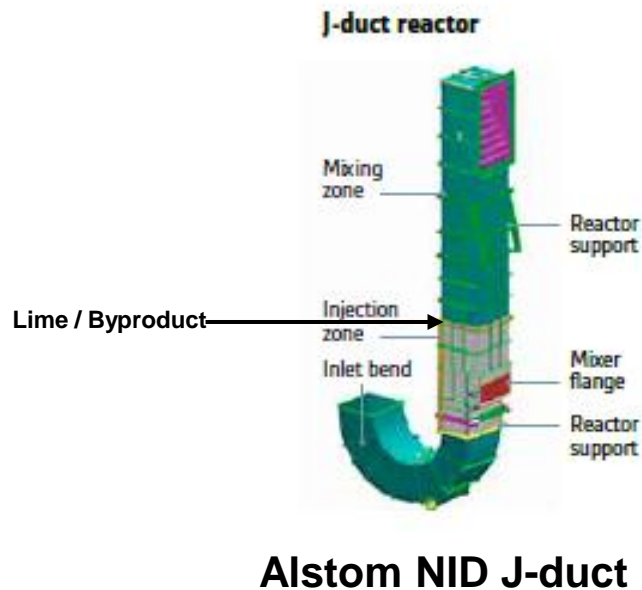
* For medium sulfur bituminous coal. SR in moles calcium per mole of sulfur at the absorber inlet.

Comparison of CFB / CDS FGD

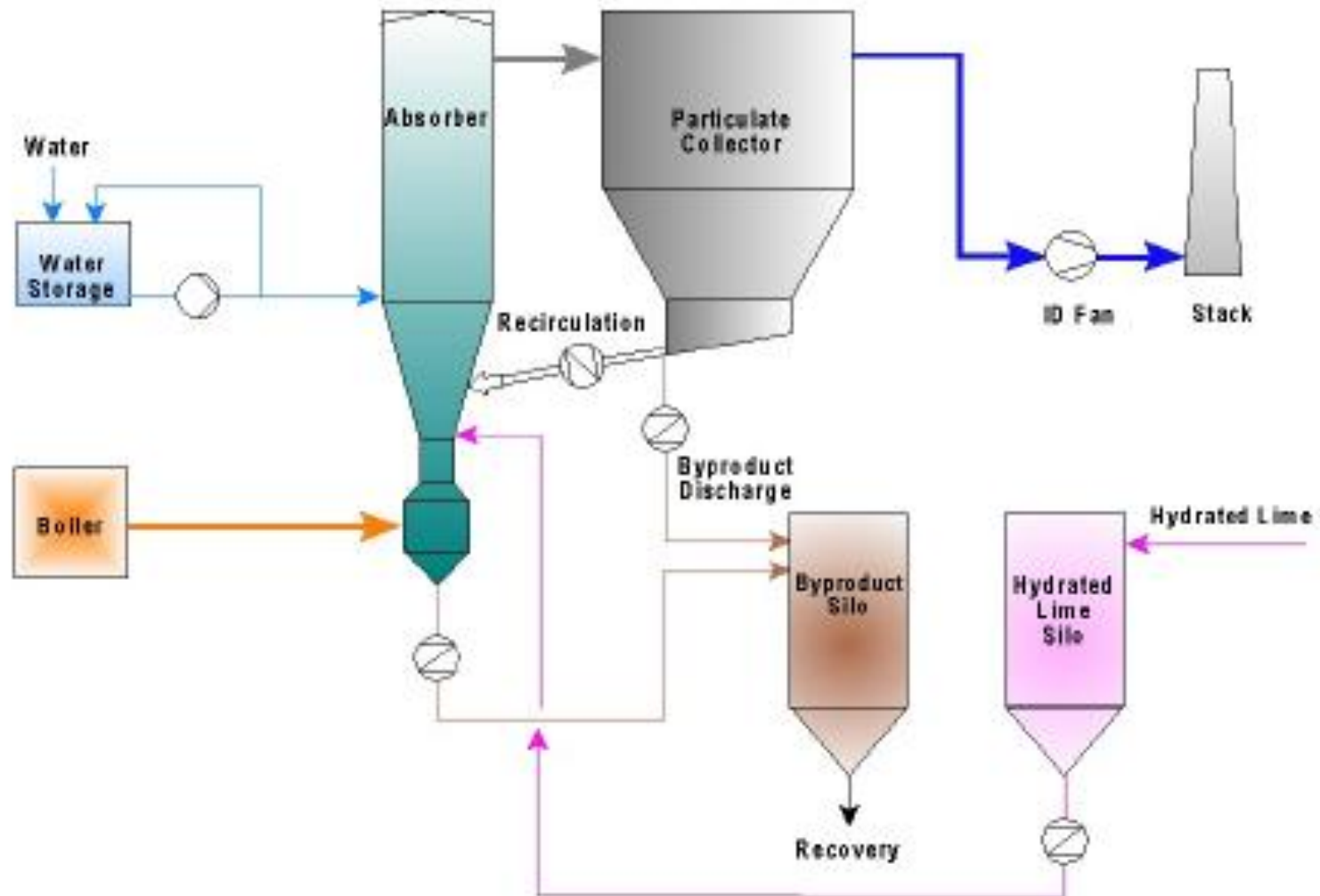
	Lime Injection	Other Features
Graf Wulff	Ca(OH) ₂ Below Venturi	Integrated Fabric Filter
Andritz	Ca(OH) ₂ Below Venturi	
B&W	Ca(OH) ₂ Below Venturi	
CBPG	Ca(OH) ₂ Above Venturi	
BPEI Turbosorp	Ca(OH) ₂ Above Venturi	
MET	Ca(OH) ₂ Above Venturi	2-stage humidification
KC Cottrell GSA	Ca(OH) ₂ Above Venturi or as slurry from slaked quicklime, CaO	Cyclone

Comparison of Wetted Solids Absorbers

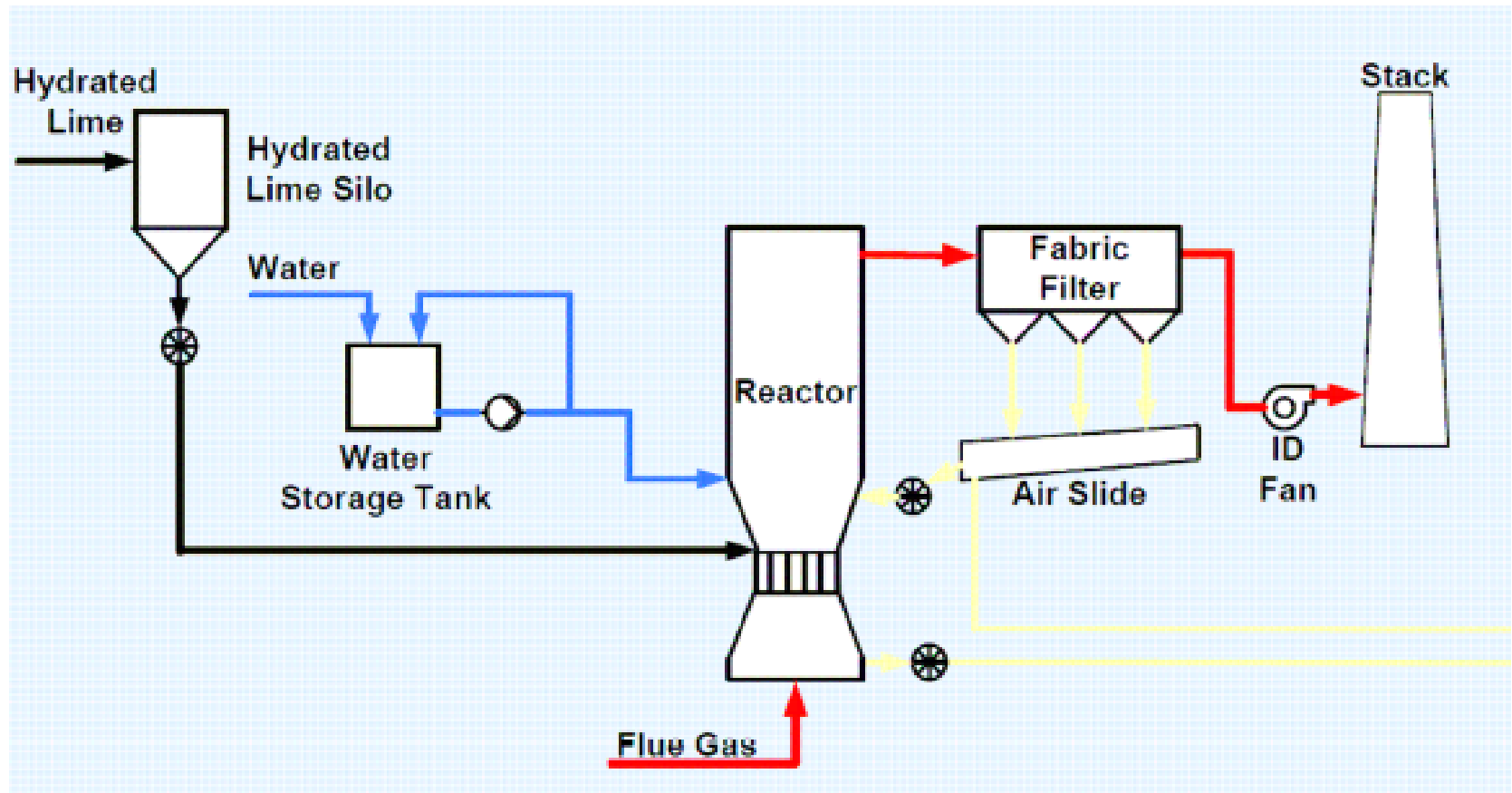
	Lime Injection	Other Features
Alstom NID	Above bend of the J	J-duct reactor close coupled to Fabric Filter
Hitachi EAD	Bottom of absorber / separate from recirculated byproduct	Venturi absorber



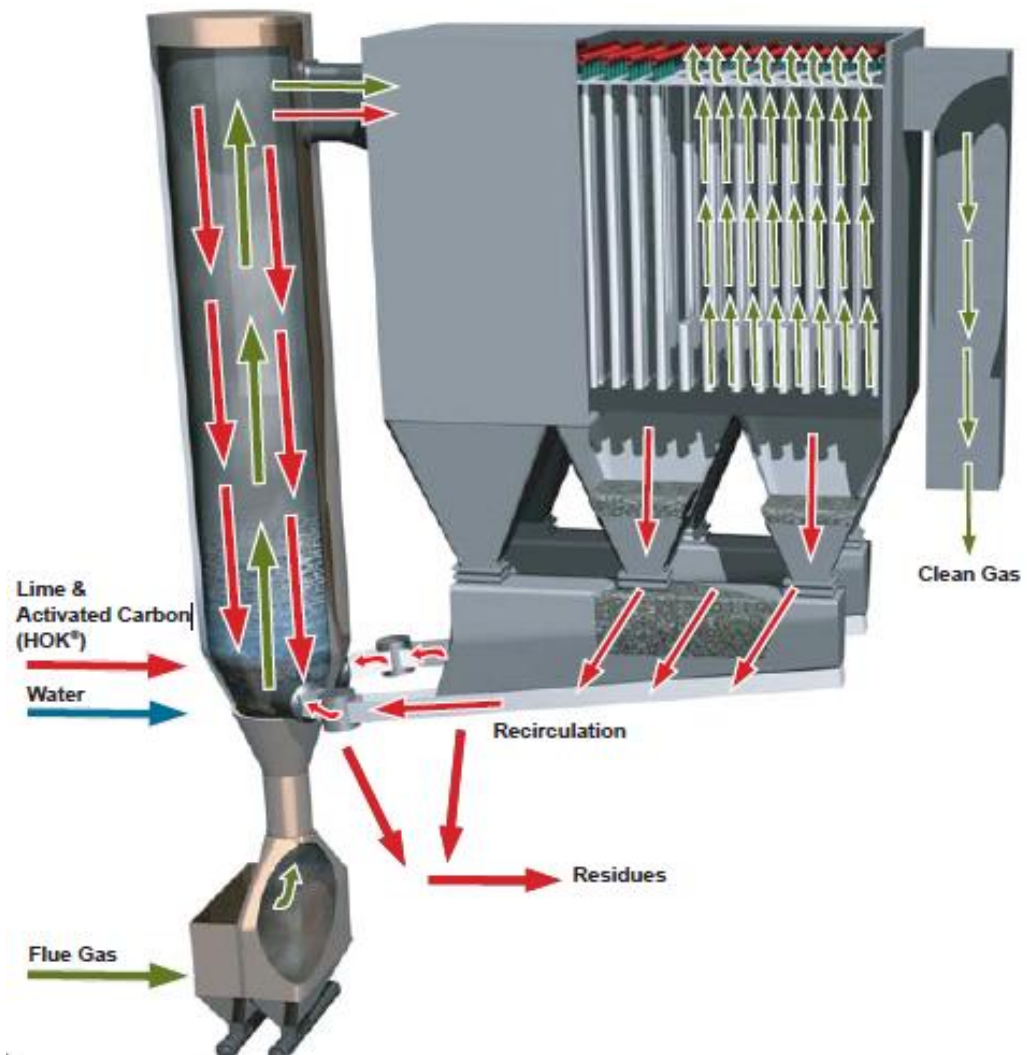
Graf-Wulff Circulating Fluid Bed Scrubbing (CFBS)



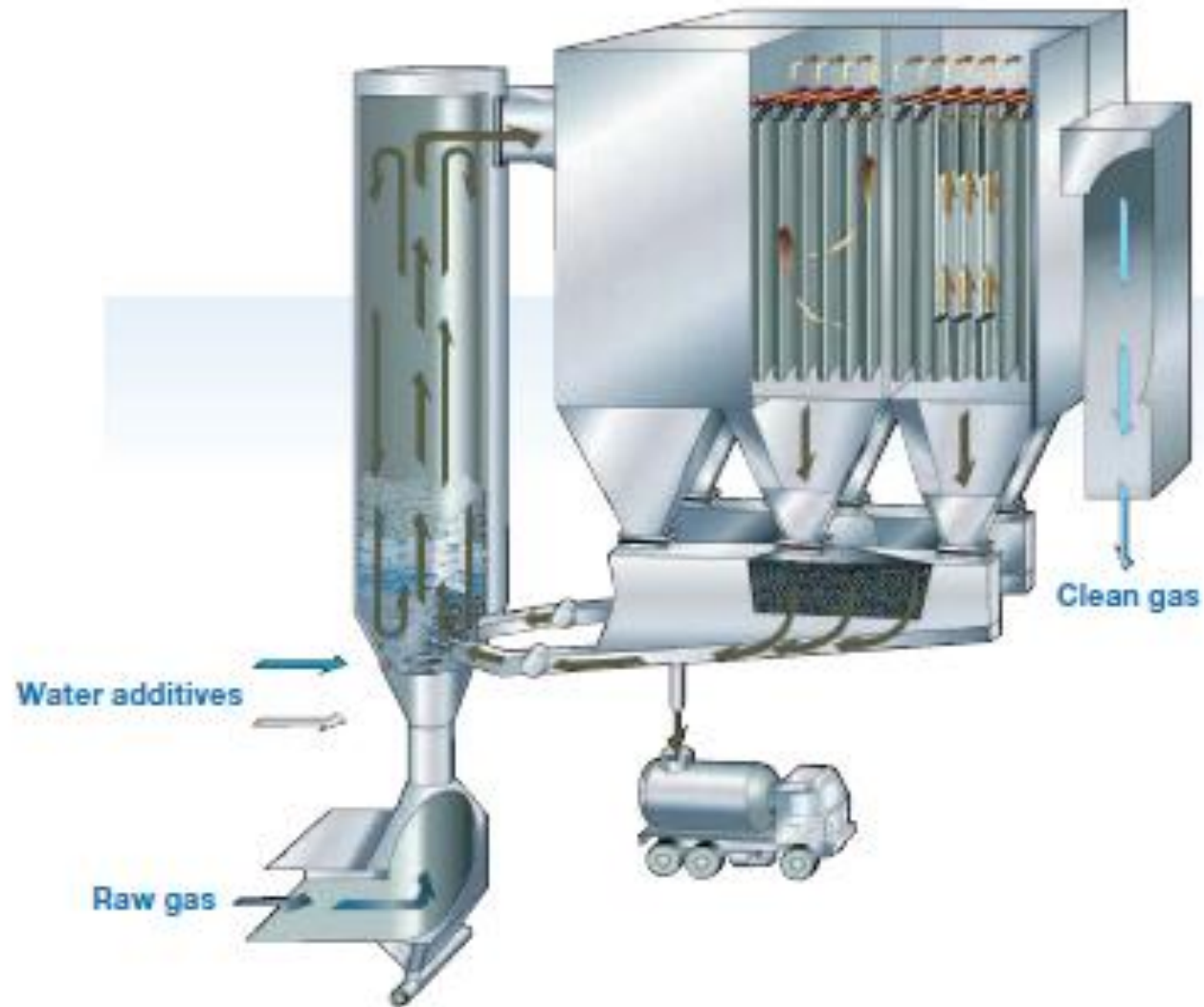
BPEI Turbosorp



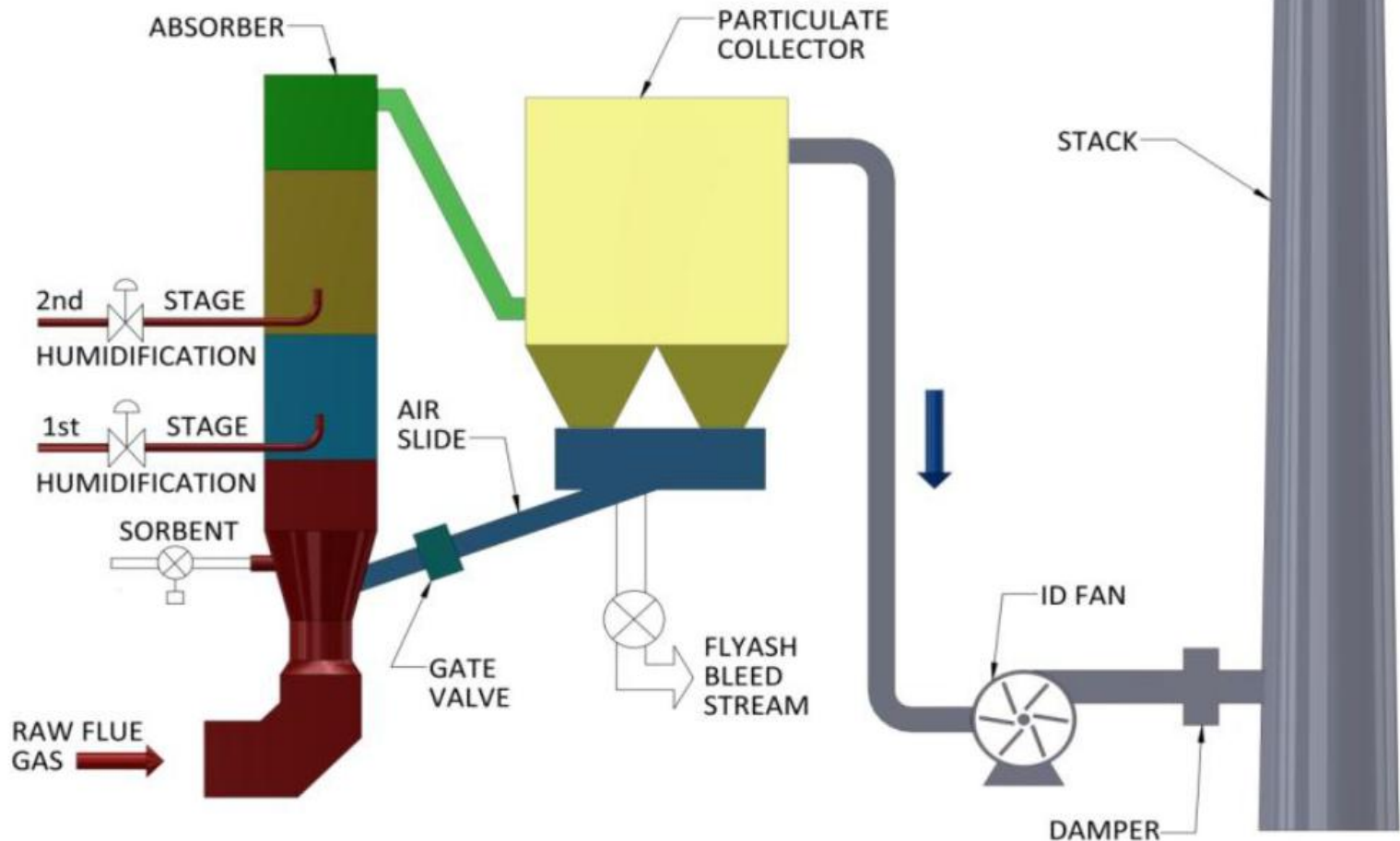
BPEI Turbosorp



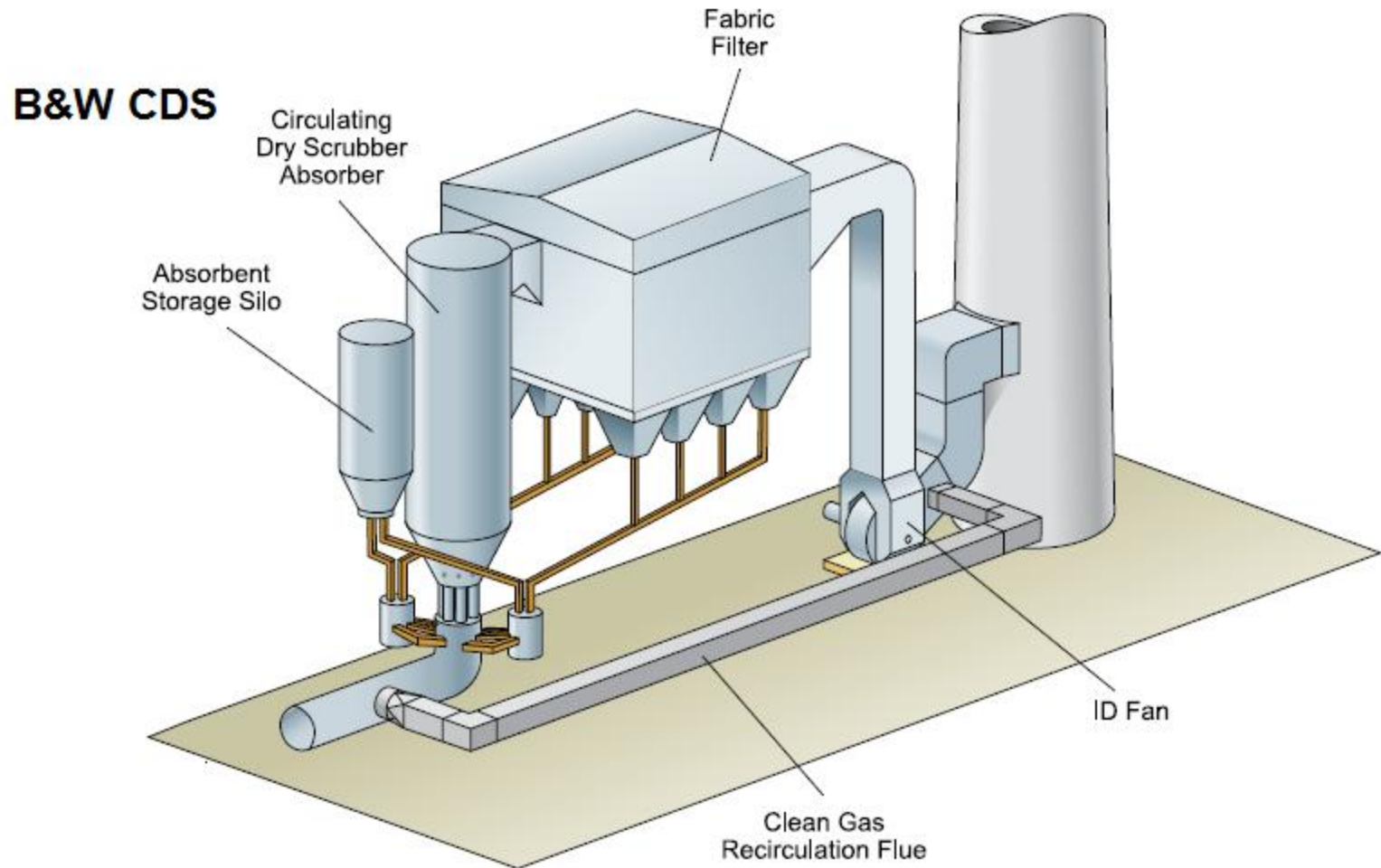
Andritz



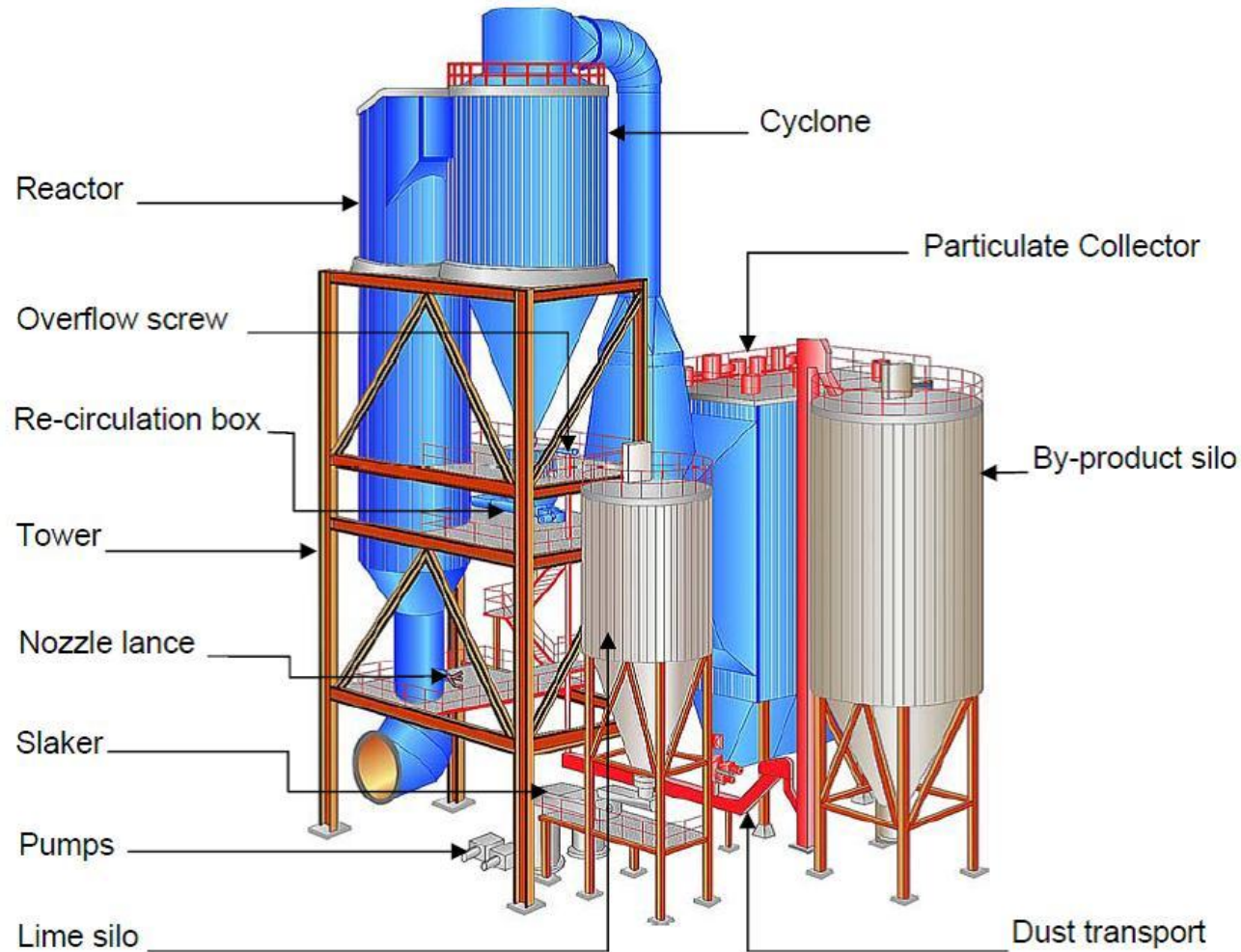
MET CDS FGD



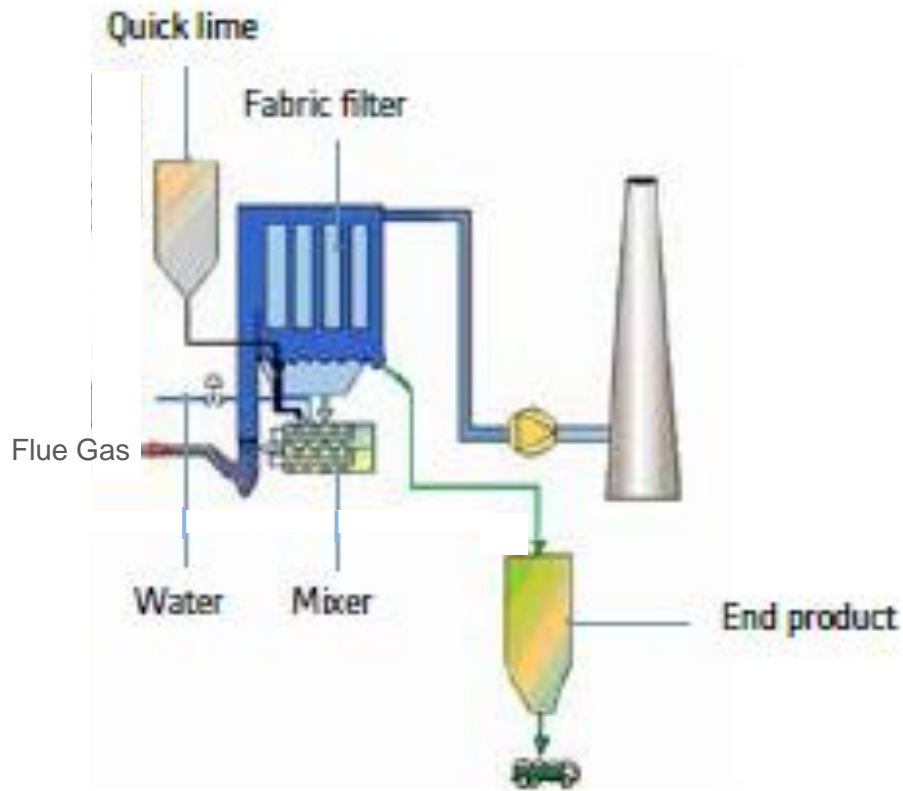
B&W CDS



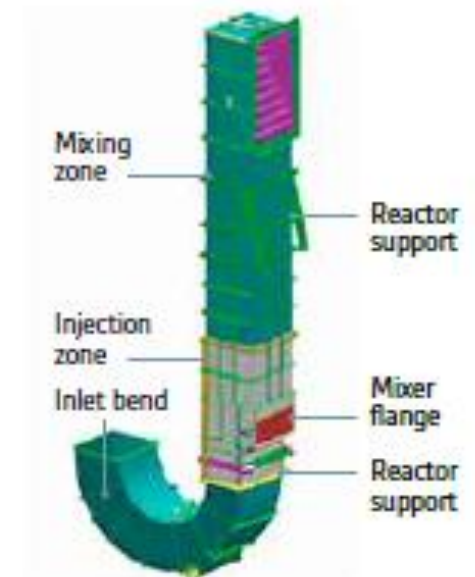
KC Cottrell GSA (Gas Suspension Absorber) Technology



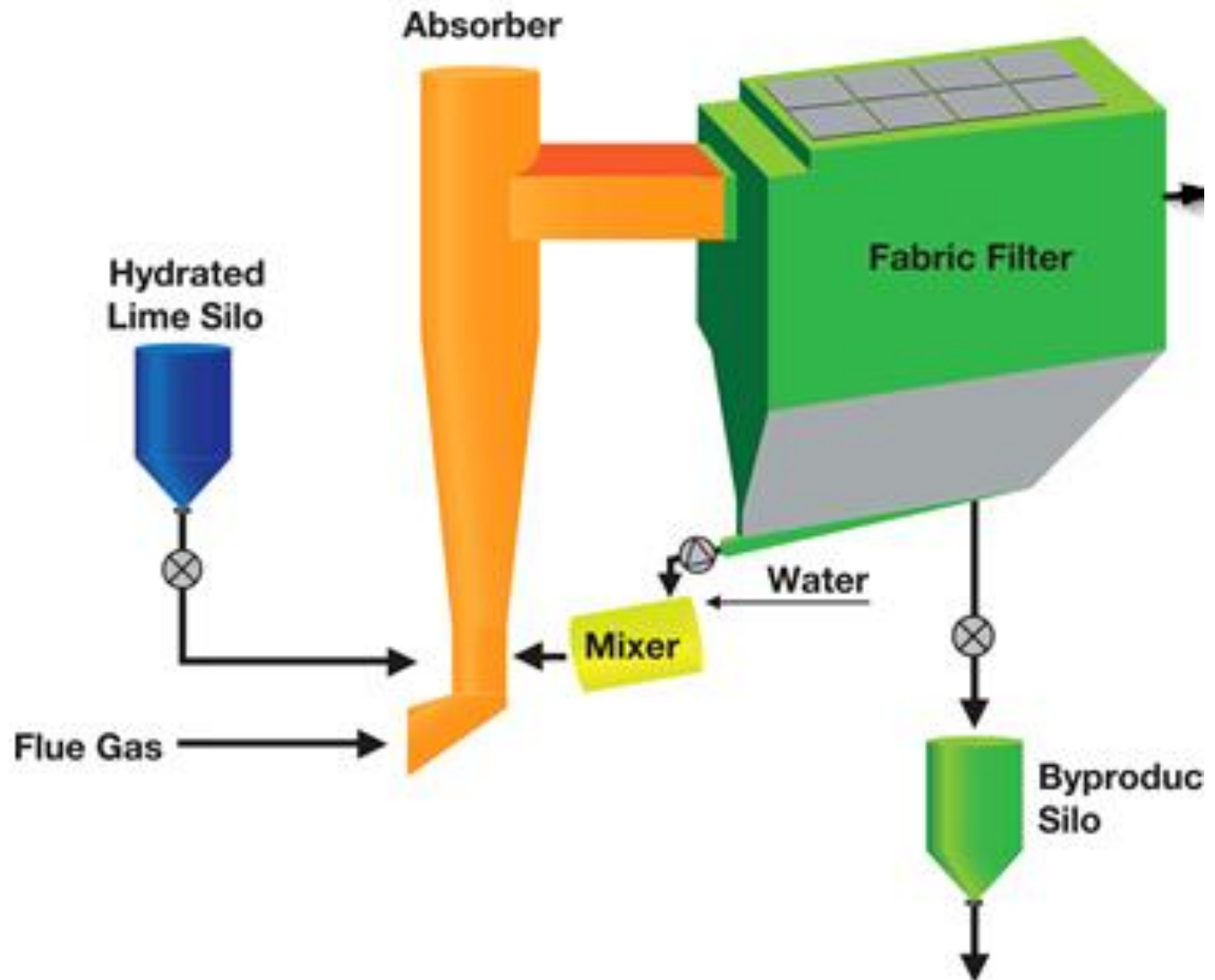
Alstom NID



J-duct reactor



Mitsubishi Hitachi EAD



Foster Wheeler / Graf Wulff Experience

80 Total Units Operating Across 3 Continents

- Utility, Industrial, Heating, and CHP Applications
- Wide Fuel Experience
- Both ESP and Baghouse Configurations

Foster Wheeler / Graf Wulff Sample Projects

Customer	Station	Location	Fuel Type	Unit Capacity	Start-up Date
Shell Deutschland Oil GmbH	Refinery	Wesseling, Germany	Heavy Fuel Oil	2 x 59 MWe (equivalent)	2012
Basin Electric	Dry Fork Station	Gillette, WY	PRB Coal	420 MW	2011
MVV Gersthofen	Gersthofen	Germany	Waste – RDF	13 MWe (equivalent)	2009
Wuhan Kaidi Electric Power Environmental Co., Ltd	Hengyun II - Guangdong	China	Bituminous Coal	2 x 300 MW	2007
EVI Europark	EVI Europark	Germany	Municipal Waste	2 x 27 MWe (equivalent)	2008

Andritz (Allied) – US Experience

Client Location Country	Application	Gas Volume ACFM	Start-up
Black Hills Power & Light Gillette, Wyoming, USA	Coal-fired Boiler	1 x 440,000	1995
Roanoke Valley Energy Facility Weldon, North Carolina, USA	Coal-fired Boiler	1 x 170,000	1995
AES Guayama, Puerto Rico	Coal-fired CFB Boiler	2 x 911,600	2002
Georgia Pacific Port Hudson, Louisiana USA	Pet Coke & Coal CFB Boiler	1x 440,000	2007
CLECO Lena, Louisiana USA	Pet Coke & Coal CFB Boiler	2 x 935,000	2009
Texas Utilities Milam County, Texas, USA	Lignite	2 x 1,045,000	2009
City Utilities of Springfield Springfield, Missouri USA	Coal-fired	1 x 983,000	2010
PPGA, Whelan Energy Hastings, Nebraska, USA	Coal-fired	1 x 874,000	2010
Dominion Energy Virginia City Hybrid Energy Center Virginia City, Virginia USA	Waste Coal & Biomass	2 x 1,046,000	2011
East Kentucky Power Cooperative Somerset, KY USA	Coal-fired Boiler	1 x 940,000	2012
Otter Tail Power Big Stone City, SD USA	Coal-fired Boiler	2 x 1,163,500 (1 x 495MW w/ 2 DFGD Trains)	2015
Empire District Electric Company Asbury, MO, USA	Coal-fired Boiler	1 x 917,800	2014

Babcock Power Environmental – Experience

Systems have been operating since 1994

- 60 CDS systems in Europe, 34 units on coal
- 14 CDS projects in China
- 24 CDS projects in the U.S.
- Five Turbosorp® CDS Coal-fired Systems in the U.S.

Babcock Power Environmental – US Experience					
Customer	Station	Location	Fuel Type	Unit Capacity	Start-Up
AES	Greenridge Unit 1	Dresden, NY	Bituminous	85 MW	2006
	Roquette CFB Boiler	Keokuk, IA	Coal+ pet coke	80 MW	2007
AES	Westover Unit 1	Johnson City, NY	Bituminous	90 MW	2008
First Light	Mt. Tom Unit 1	Holyoke, MA	Bituminous	155 MW	2009
Gainesville Regional Utilities	Deerhaven	Gainesville, FL	Bituminous	238 MW	2009

Alstom – US Experience

Customer	Station	Location	Fuel Type	Unit Capacity	Start-Up Date
Reliant Energy	Seward	New Florence, PA	Bituminous	2 x 285 MW	2004
East Kentucky Power Cooperative	Gilbert Unit 3	Maysville, KY	Bituminous	300 MW	2005
East Kentucky Power Cooperative	Spurlock Unit 4	Maysville, KY	Bituminous	300 MW	2008
Indian River Power LLC (NRG)	Indian River Unit 4	Dillboro, DE	Bituminous	436 MW	2011
Dominion Energy	Brayton Point Unit 3	Somerset, MA	Bituminous	630 MW	2013
Jingmen P.P.	Jingmen Unit 4	China		200 MW	2004

Alstom – Non-US Experience

Customer	Station	Location	Fuel Type	Unit Capacity	Start-Up Date
Elektrownia Laziska	Laziska Units 1 and 2	Laziska, Poland		2 x 120 MW	1996
Wärtsilä Diesel Oy	Vaasa	Vaasa, Finland		37 MW	1998
EWAG	Sandreuth Unit 3	Nuremberg, Germany		53 MW	1999
AES Corporation	Fifoots Units 1,2 and 3	Fifoots Point, UK		3 x 125 MW	2000
Juhua Group Co.	Zhejiang Unit 8	China		70 MW	2000
Formosa Heavy Industries	Mai Liao RF-1	Taiwan		2 x 150 MW	2001
Hailong Paper Co.	Dong Guan Unit 5	China		70 MW	2003
Jiangyin Binjiang TPP	Binjiang Thermal	China		12.5 MW	2003
Jiangyin TPP	Jiangying Thermal Unit 3	China		70 MW	2003
Jiulong (Taicang) Paper Co.	Taicang	China		135 MW	2003
Heimeng Hudian	Baotou #2 TPP#1	China		200 MW	2004
Hua Ying Shan Power Plant	Hua Ying Shan Unit 4	China		100 MW	2004

Alstom – Non-US Experience (Continued)

Customer	Station	Location	Fuel Type	Unit Capacity	Start-Up Date
JCS Lithuanian Power Station	Elekternai Unit 8	Lithuania		150 MW	2004
Jiangying Xinyan TPP Co. Ltd	Xinyuan Thermal Unit 3	China		25 MW	2004
Jingmen P.P.	Jingmen Unit 4	China		200 MW	2004
Jiulong Paper Co.	Dong Guan	China		210 MW	2004
Liwen paper Co.	Liwen Units 1 and 2	China		2 x 30 MW	2004
Sanfangxiang TPP	Sanfangxiang Thermal Unit 1 and 2	China		2 x 25 MW	2004
Customer	Station	Location	Fuel Type	Unit Capacity	Start-Up Date
Shengyang TPP	Shengyang Thermal Unit 3	China		50 MW	2004
Wuxi TPP	Wuxi Thermal	China		25 MW	2004
Xinwang P.P.	Xinwang Units 1 and 2	China		2 x 135 MW	2004
Mondi Paper Merebank Mill	Mondi Units 1 and 2	Mondi, South Africa		2 x 35 MW	2004 / 2005
Jiulong Paper Co.	Dong Guan Unit 6	Guangdong, China		210 MW	2005
QiLu Power Plant	Zibo Units 7 and 8	China		2 x 100 MW	2005
SPDC	Mindanao IPP Units 1 and 2	Philippines		2 x 105 MW	2005
Hemei Group	Heibi Unit 1	Henan, China		2 x 135 MW	2006
Juhong TPP	Juhong	Zhejiang, China		135 MW	2006
Taizhou P.P.	Taizhou Unit 6	Zhejiang, China		135 MW	2006
Kaidi Electric Power	Yima	Henan, China		78 MW	2006
Shenhai Cogen	Shenhai	Shenyang, China		200 MW	2006
VKG Energia OU	Kolta-Jarve	Estonia		50 MW	2008
Zilinska Teplarenska A.S.	Zilina	Slovakia		200 MW	2009
AS Narva Elektriijaamad	Esti Power	Estonia		2 x 200 MW	2011
Technoprom Export	Cherepetskaya	Russia		2 x 225 MW	2011
Soda Polska CIECH	Janikowo	Poland		80 MW	2012

Hitachi / Solios – US Experience

Customer	Station	Location	Fuel Type	Start-Up Date
Johns Manville	Glass melting furnace	Waterville, OH	-	1991
Wisconsin Electric Power Company	Light weight aggregate kiln for paper mill / sewage	Milwaukee, WI	-	1994
General Shale	Coal-fired brick tunnel kiln	Fairdale, KY	Coal	1996
Virginia Tech	Virginia Tech Power Plant	Blacksburg, VA	Bituminous	1999
Redland Brick	Brick tunnel kiln	Cheswick, PA	-	2001
General Shale	Brick tunnel kiln	Fairdale, KY	Coal	2005
Virginia Tech	Virginia Tech Power Plant	Blacksburg, VA	Bituminous	2006
Graymont Lime	Calcinating kiln	Pleasant Gap, PA	-	2008
Saint-Gobain Proppants	Calcinating kilns	Fort Smith, AR	-	2010
Saint-Gobain Proppants	Calcinating kilns	Bryant, AR	-	2012

Hitachi / Solios – Non-US Experience

Customer	Station	Location	Fuel Type	Start-Up Date
City of Gardanne	Provence	Gardanne, France	Coal	1986
Remetal	Secondary aluminum smelting	Russia	-	-
Remetal	Secondary aluminum smelting	St. Petersburg, Russia	-	-
Ecotechnic	Indirect combustion oven for soil remediation	Holland	-	1992
NBM	Indirect combustion oven for soil remediation	Schiedam, Holland	-	1993
Elm Energy	Tire incinerators	Wolverhampton, UK	-	1993
Prisma	Diesel engines	Madrid, Spain	Diesel	1995

KC Cottrell – US Experience

Customer	Station	Location	Fuel Type	Start-Up Date
Wasatch	Household Waste	USA	Waste	2002
Red Wing	Household Waste	USA	Waste	2002
Harding Lawson	Coal-fired boiler	USA	Coal	2002
Formosa Heavy Industries Corp.	Coal-fired boilers	USA	Coal	2011

KC Cottrell – Non-US Experience

Customer	Station	Location	Fuel Type	Start-Up Date
Cleveland	Household & Industrial Waste	UK	Waste	1997
Tuntex	Coal-fired boiler	Thailand	Coal	1998
Valene	Household & Industrial Waste	France	Waste	1998
Glanford	Meat & bone meal	UK	-	1999
REFA, Nykabing F.	Household & Industrial Waste	Denmark	Waste	1999
Elean	Biomass	UK	Biomass	2000
Xiaolong Tan	Coal-fired boiler	China	Coal	2000
Isles of Sicily	Household & Industrial Waste	UK	Waste	2001
Yan Tian	Household Waste	China	Waste	2002
Hongwon Paper Mfg. Co.	Oil burner	South Korea	Oil	2003
LKAB Malmberget	Metals	Sweden	-	2004
PCIC	Coal-fired boiler	Kuwait	Coal	2005
Formosa Heavy Industries Corp.	Coal-fired boilers	China	Coal	2008
Cheng Loong Corporation	Coal-fired boiler	Taiwan	Coal	2012
Formosa Heavy Industries Corp.	Coal-fired boilers	Petron Bataan Refinery, Philippines	Coal	2012
Formosa Heavy Industries Corp.	Coal-fired boilers	Petron Bataan Refinery, Philippines	Coal	2013