Wet limestone FGD absorber choices

Route Map and Summary Draft- Hot topic hour May 14, 2015

Absorber design for Limestone FGD

- The majority opinion is that laminar flow and optimum distribution of slurrly droplets is the ideal efficiency/power ratio
- A substantial minority contends that turbulent mixing provides better results
- The crucial comparison is total horsepower of the pump and the fan and not just one of the two.
- The turbulence approach is championed by Chiyoda in the jet bubbling reactor, B&W in the tray scrubber, and even those who are improving spray tower efficiency with incresed velocity

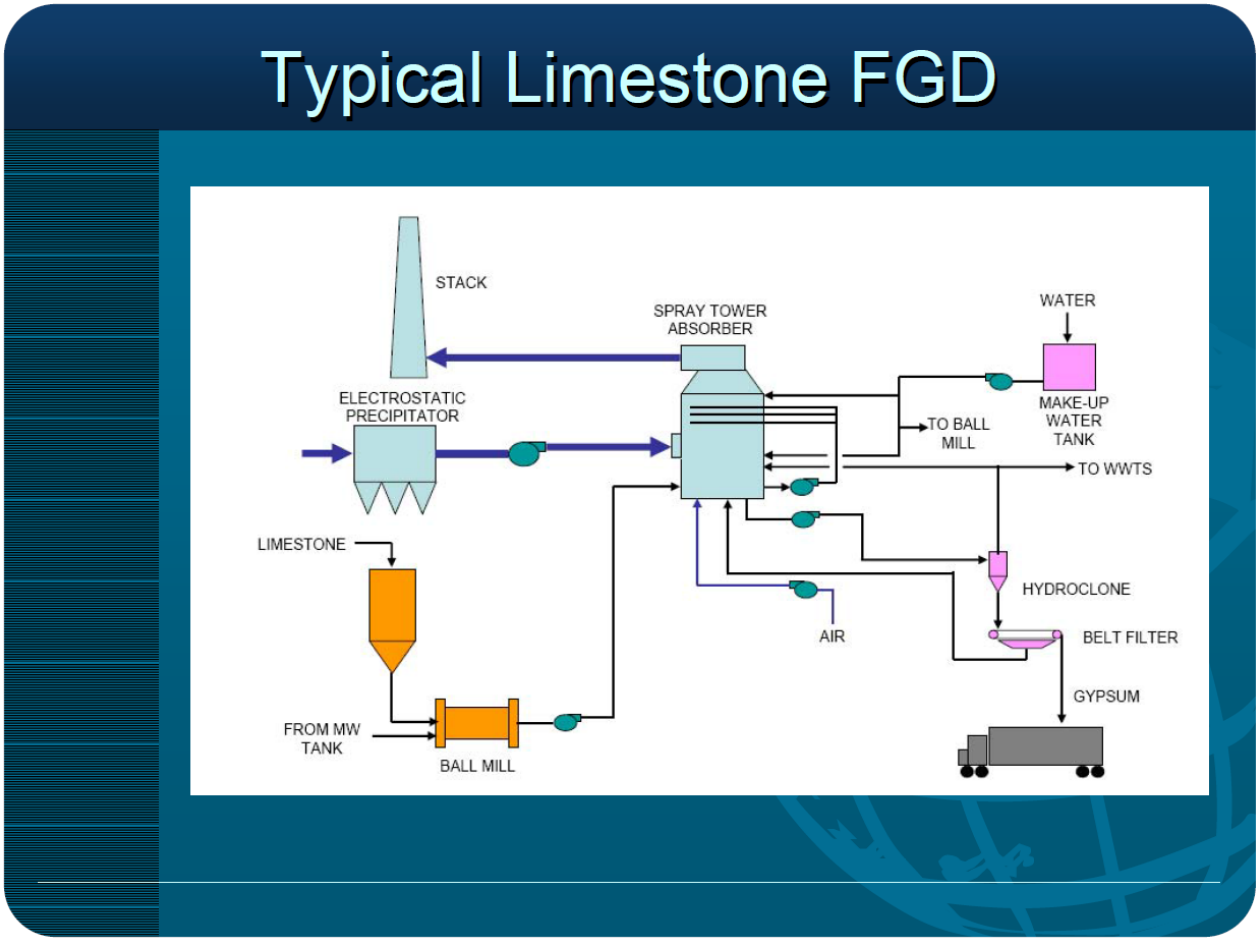
Role of components

- Mist eliminators can play a role particularly as the velocity is increased and more mist must be removed
- Mist eliminators also provide resistance and therefore additional fan horsepower
- Nozzles play an important role. They are crucial in the laminar flow approach and not significant in the turbulence approach
- Baffles and CFD flow optimization are important only in the laminar flow approach

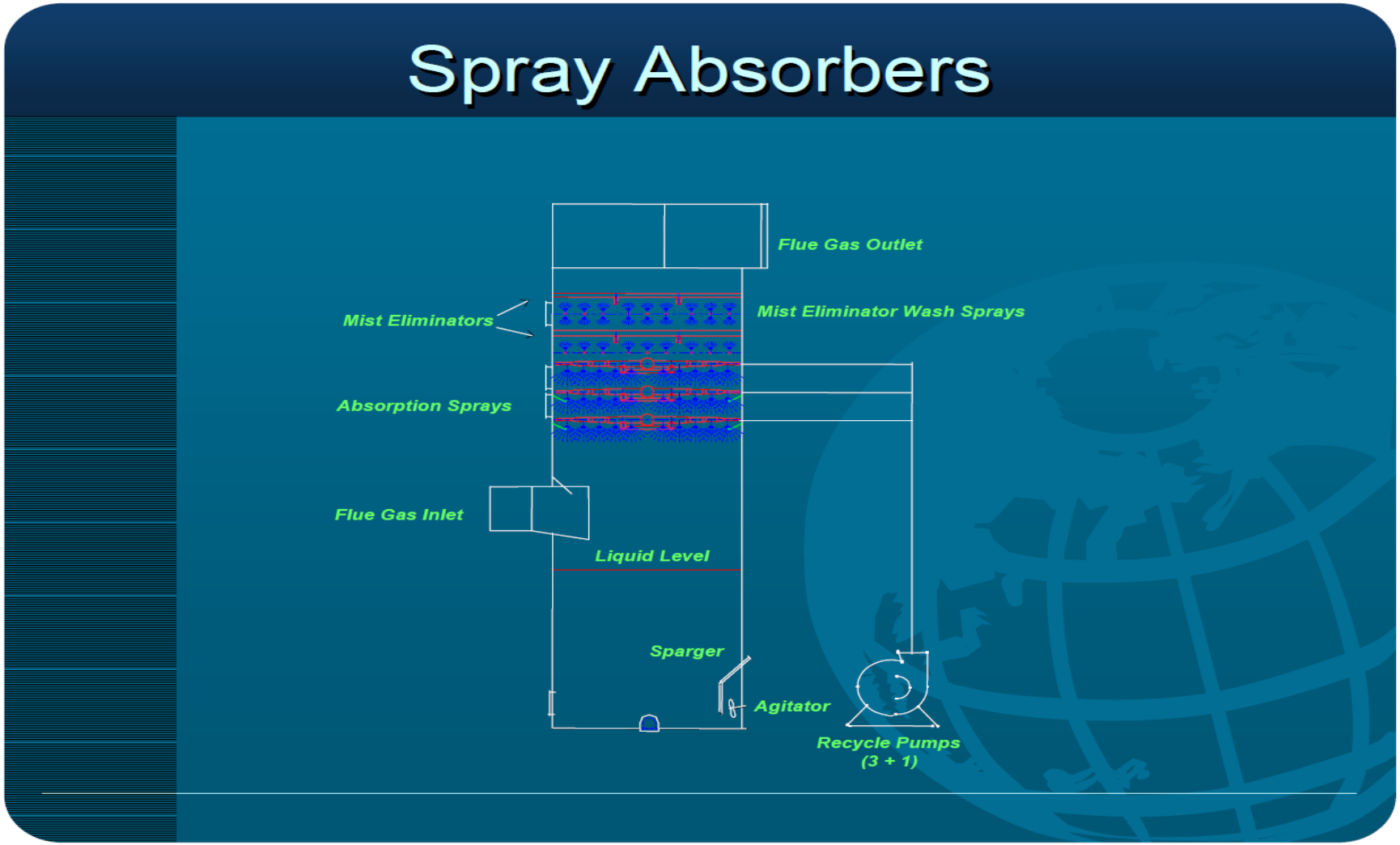
Absorber Options

Parameter	Tray	Spray	Sump
Pump Power	Medium	High	Low
Fan Power	Higher	Lower	Higher
Plugging Potential	Higher	Lower	Higher
Height	Lower	Higher	Lower
Experience Ranking	2nd	1st	3rd
Suppliers (Examples)	Babcock & Wilcox, Wheelabrator (FW)	Alstom Mitsubishi	Chiyoda Alstom
Particulate Removal	Higher	Lower	Higher
Biggest Concern	Tray Plugging	Nozzle Plugging	Level Control
Efficiency Increase Routes	2nd Tray	More Spray Banks	Higher Level Differentia

Spray tower system-Marsulex

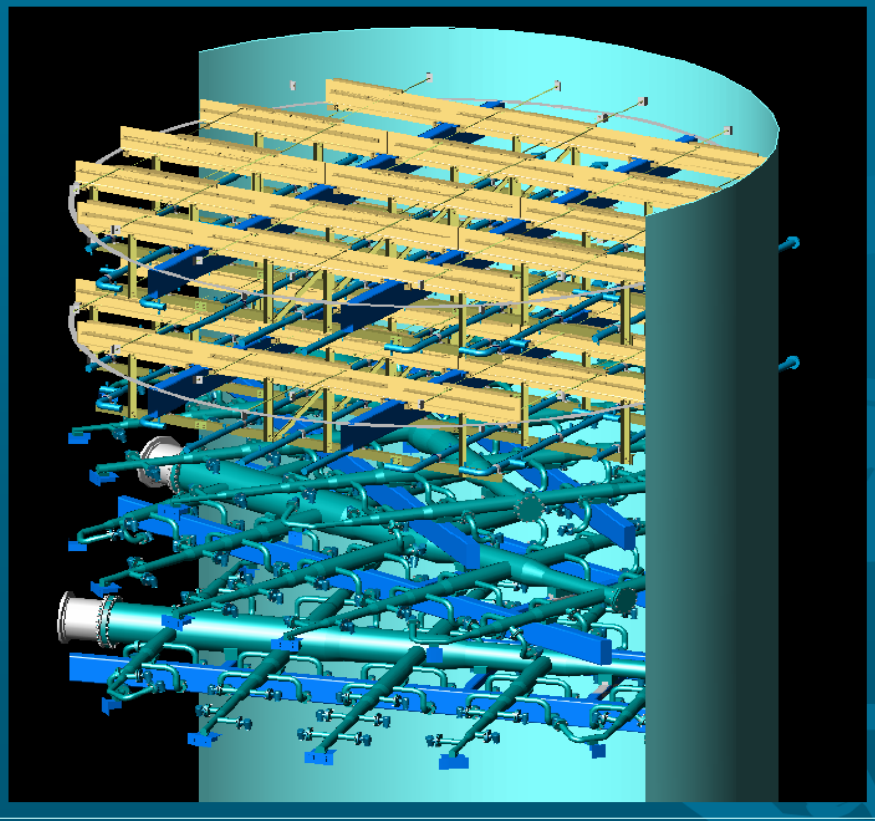


Spray tower internals

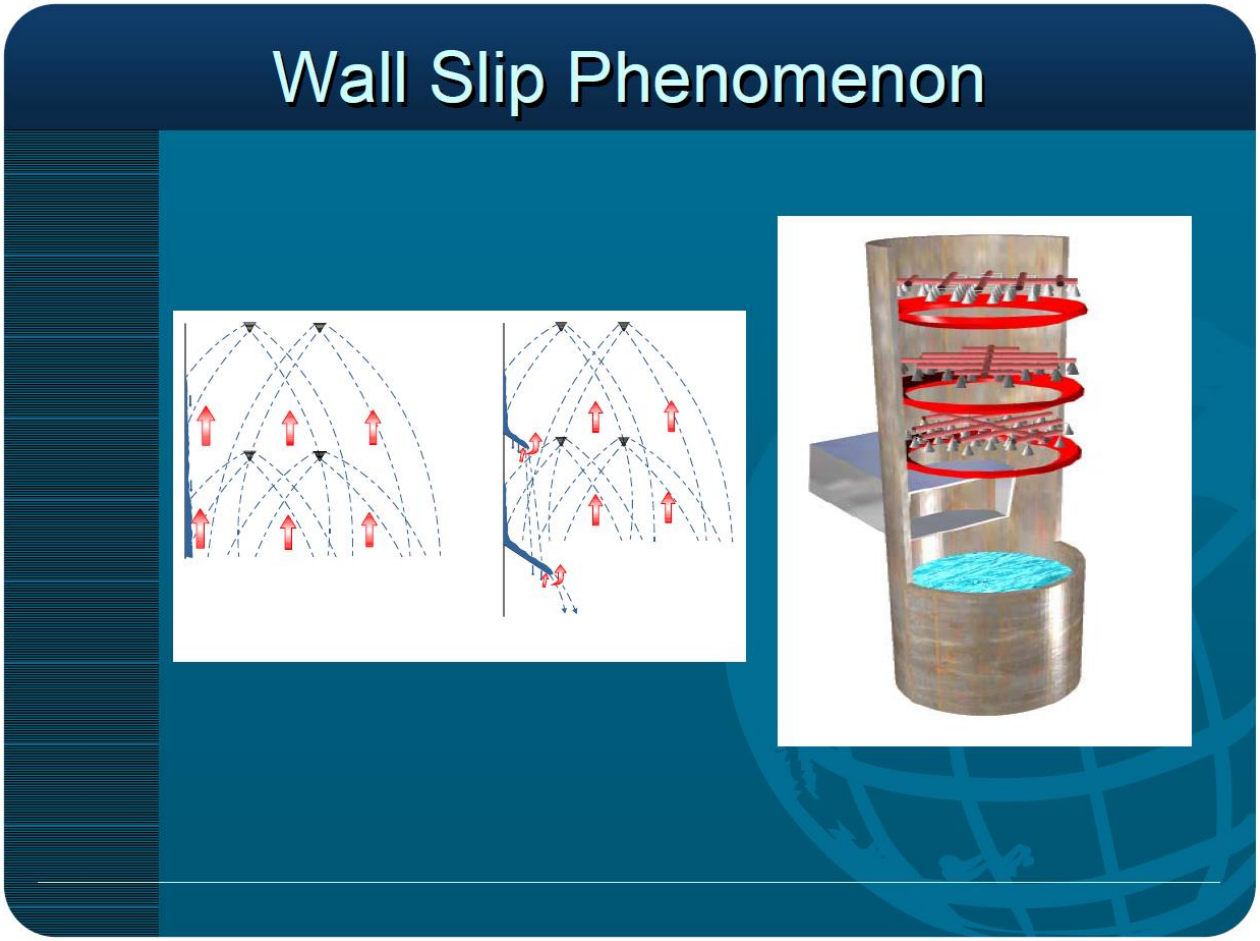


Nozzles and spray headers

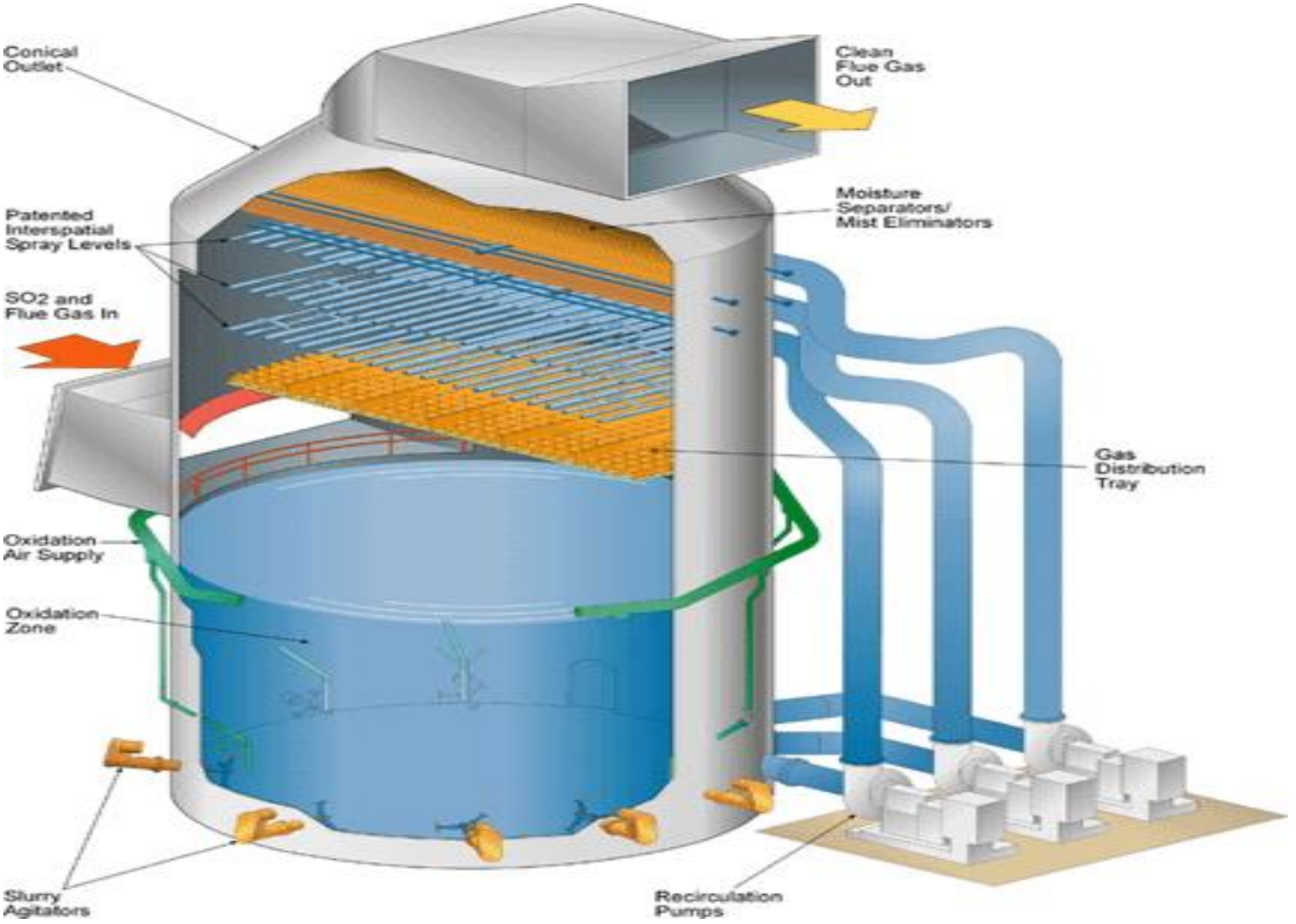
Isometric of “Open” Spray Tower



Baffles on walls counteract slip phenonemon

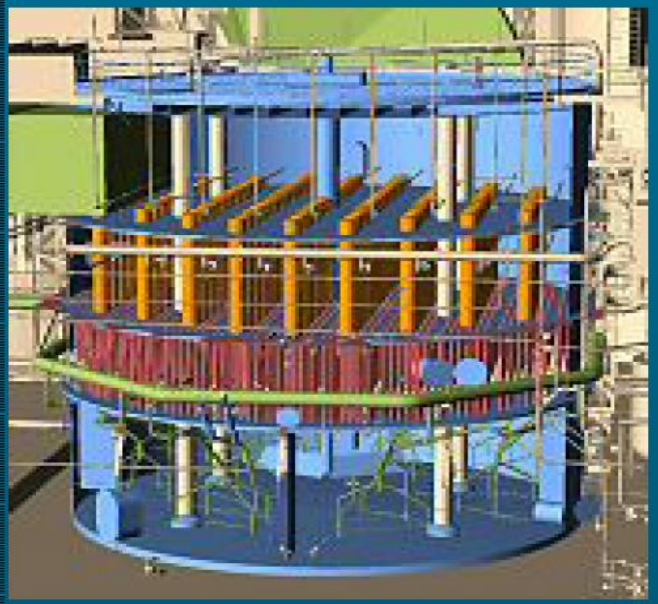


Tray scrubber-B&Q



Chiyoda JBR

Jet Bubbling Reactor

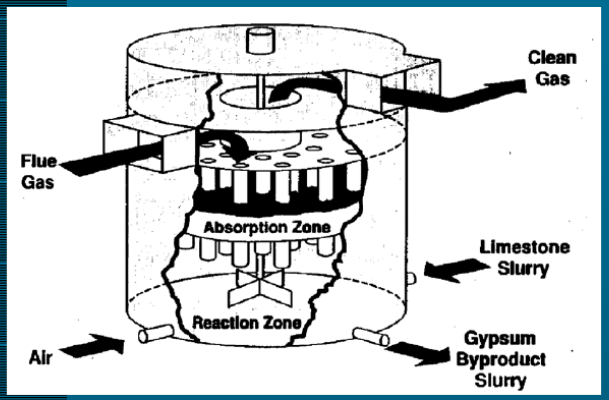


In one vessel combines concurrent chemical reactions of:

- limestone dissolution
- SO_2 absorption
- neutralization
- sulfite oxidation
- gypsum precipitation
- gypsum crystal growth

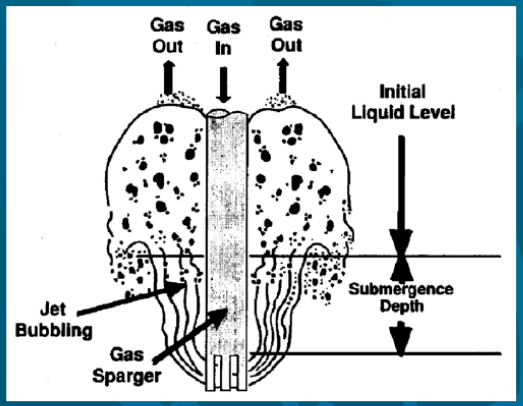
Flue gas creates bubble bath in JBR

Jet Bubbling Reactor



Cut-Away of JBR

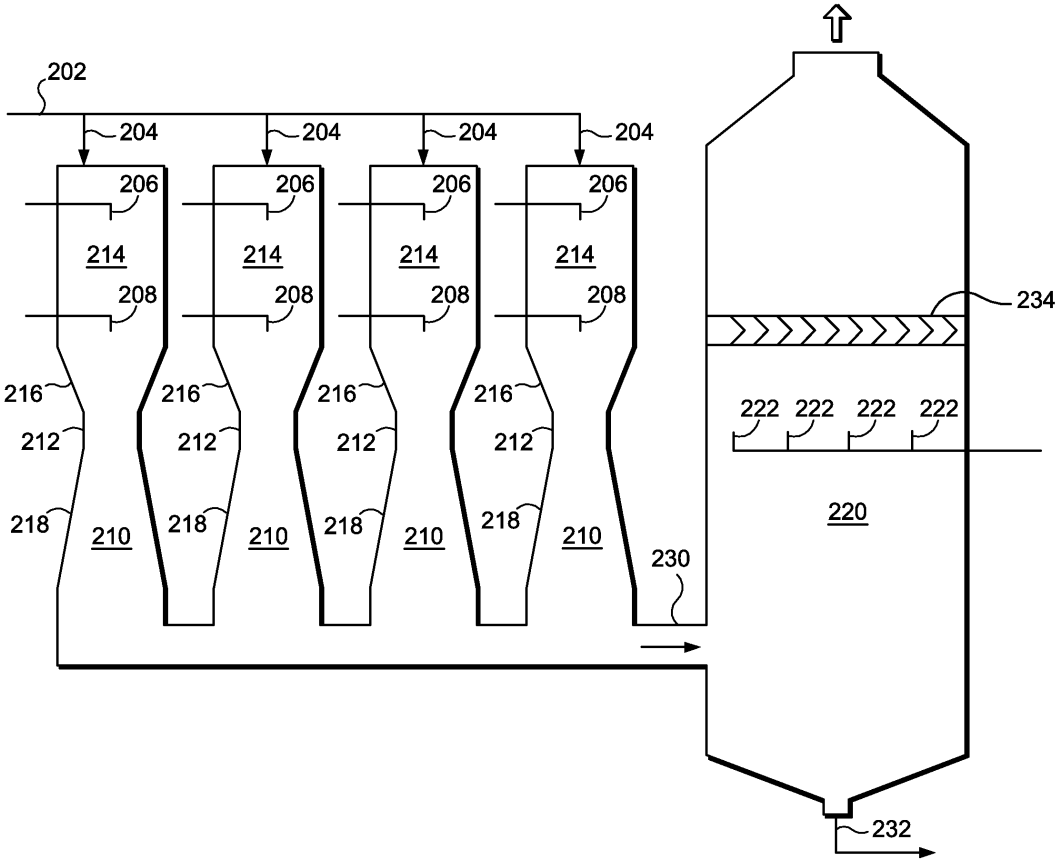
Gas Sparger Action



Andritz

- an open spraying tower that has been enhanced in recent years using computerized simulation techniques. Former AE&E has been conducting intensive development work in this field since
- During comparisons of simulator data with actual plant measurements, the flow and temperature profiles have verified our design parameters. The result is a scrubber that is characterized by minimum dimensions, adaptable scrubber entry and exit geometry, and the optimum layout of the spray nozzles and spray banks. This results in a uniform SO_2 profile in combination with the highest possible superficial velocity in the scrubber – removing the most pollutants and utilizing the least power.
- The scrubber also benefits from the use of the latest materials and construction methods. GRP absorbers and reinforced concrete absorbers with polypropylene linings are used in addition to the proven steel absorbers with a variety of inner linings or stainless steel.

Andritz recent patent



Mikropul rod scrubber

ikroPul's Multi Venturi Scrubber makes use of a venturi-rod deck consisting of a series of rods arranged to create a venturi effect between each rod. It offers higher efficiencies at lower pressure drops and liquid to gas ratios than conventional venturi scrubbers.

Operation

Dust laden gases are directed through the venturi-rod deck where atomized scrub water is introduced co-currently with the gas stream. The scrub water is sprayed through a series of low pressure, large orifice nozzles, distributing it evenly across the deck. The gas rapidly accelerates as it passes through the venturi-rods. This action creates smaller droplets, causing encapsulation of the particles and increasing the collection efficiency of submicron particles.

As the gases exit the venturi-rod area, velocity slows causing the larger particulate laden droplets to fall out of the stream. The scrubbed gasses are then directed toward a two-stage demisting zone by distribution baffles or turning vanes. Primary demisting and gas distribution occurs in the predemist area, which removes 90% of the water. The remaining free water droplets are removed by impingement on the final stage demist vanes. The scrub water collected prior to the demist section flows down the scrubber floor to the drain trough. Dewatered scrubbed gases are exhausted via the scrubber outlet.

Features

Up to 99%+ collection efficiency into submicron range

Wide range of pressure drops from 2.5 - 15 kPa (10 - 60 in. w.g.)

High performance at low pressure drops

Adjustable venturi rod deck (manual or automatic)

Compact, low profile design offers installation flexibility

Ideal for particulate scrubbing and gas absorption

INTRODUCTION

A milestone was achieved by Riley this summer with the start-up and performance ng of our first module of a new generation absorber known as the Ventri-Sorber™ at Duck Creek Station of Central Illinois Light Company. CILCO has contracted Riley ter for the design and procurement of a 400 MW flue gas desulfurization system using stone slurry as the scrubbing medium. The boiler as supplied by Riley is designed to n medium to high sulfur Illinois coal.

The heart of the flue gas desulfurization system is the second generation of absorbers gned by Environeering, a member of the Riley Stoker group. Since the success of an D system to a large extent depends on the performance of the absorber, CILCO's inal approach with the concurrence of Illinois EPA was to test and optimize the formance of a single absorber module capable of handling 300,000 ACFM of gas flow ivalent to a 100 MW prior to the design and start-up of an additional three modules. vever, the peripheral equipment of the system such as the limestone handling and ge disposal systems have been sized for a total of 400 MW.

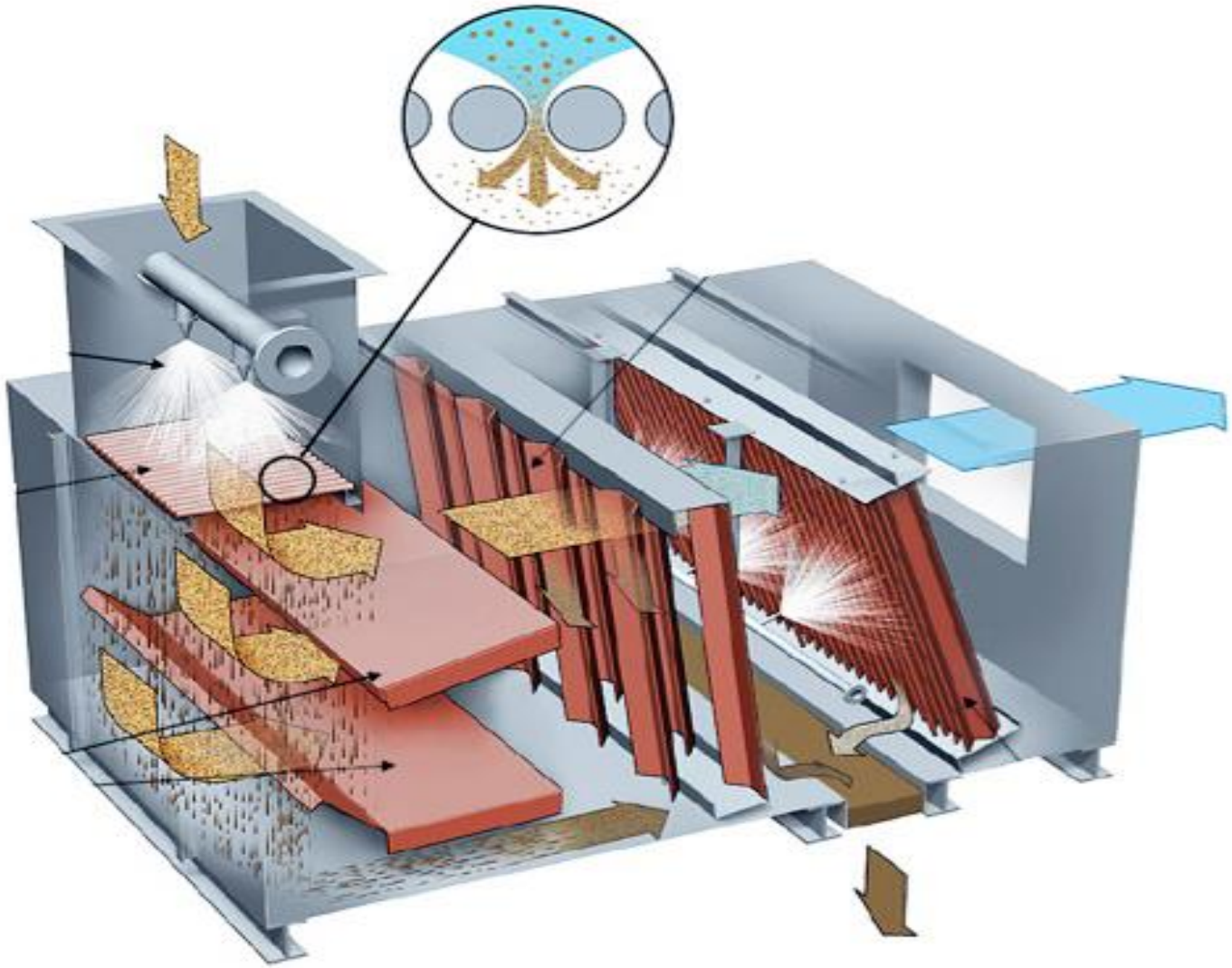
VENTRI-SORBER DESIGN

Riley Duck Creek 1977 rod scrubber performance

parameter	value
flow	300,000 cfm
l/g in gallons / thousand ACF	50
Pressure drop	8,5 “ w.g.
efficiency	91%

Multi Rod Deck Design

Downflow single rod deck



Mist eliminator considerations

- Chevron or non chevron
- Shape and number of turns
- Spacing between each chevron
- Number of mist eliminator stages
- Pressure drop vs efficiency

Mist Eliminator issues and options - Marsulex

Mist Elimination

- Important to remove entrained liquid droplets in order to avoid carryover of the liquid into downstream ducts and stack.
- Good performance of mist eliminators depends on:
  - Operation of absorber at flue gas velocities below critical velocity at which re-entrainment of mist occurs
  - Proper washing techniques

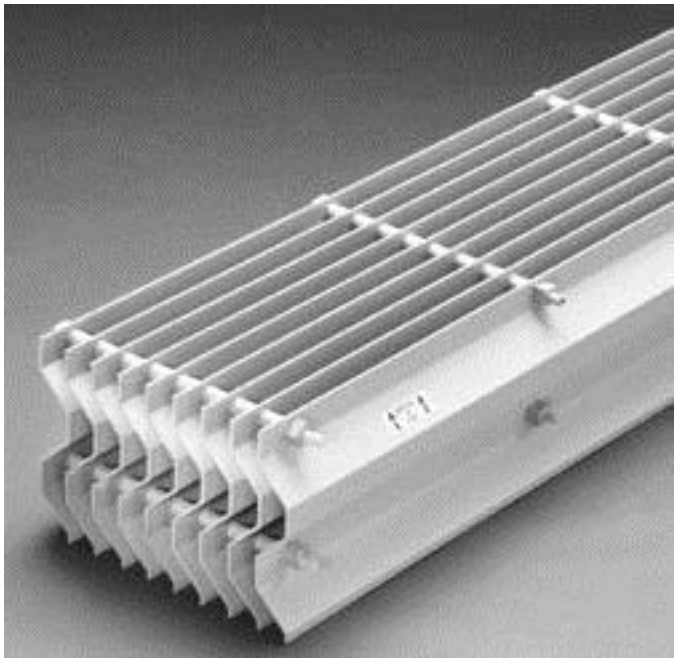
Mist eliminator water and nozzle issues and options

Mist Elimination

- Major parameters to be considered for proper mist eliminator washing include:
  - Wash water rate
  - Water quality
  - Timing sequence
  - Washing area coverage
  - Nozzle pressure
  - Nozzle spray angle

Koch Flexichevron VIII

- Processes for SO2 removal vary depending on the amount of SO2 involved, the solution used to absorb the SO2, and the particular equipment used in the absorption tower.
- Applications with lower SO2 levels may need only one chevron level because of lower L/G ratios or other unique tower geometries.
- The majority of applications use a mist elimination zone that contains two stages of mist eliminators.
-
- Koch-Glitsch offers many types of chevron mist eliminators for the numerous styles of absorbers and internal support arrangements.
- **FLEXICHEVRON® style VIII mist eliminators** are designed specifically for FGD absorbers, but also work well in a variety of other applications, such as evaporators and cooling towers.
- **FLEXICHEVRON® style XII/XIV mist eliminators** were developed for vertical up flow in high velocity absorber applications. This high capacity, two-stage design provides bulk removal by the first stage and fine removal by the second stage.



Anping Huilong Metal & Wire Mesh Product Co., Ltd. Mist Eliminator

Nozzles- side by side double hollow cone spray nozzles

- URS has upgraded existing FGD systems with side by side double hollow cone spray nozzles

- **New Technologies to Improve the Performance and Reliability of Older FGD Systems**
- This paper will describe and discuss the development and application of new technologies in upgrading older FGD systems.
- ***Revision Date:*** 8/18/2014
- ***Tags:*** URS Corp., Scrubber, FGD, Nozzle

Dual Flow down nozzles Babcock Power Upgrade

- At LGE recommended changes to dual flow down nozzles at some levels and up at others. Also recommended changing angle on some nozzles
- **Mill Creek FGD Performance Upgrade Study**
- Assess the feasibility of upgrading the Mill Creek Units 1 & 2 FGD's and upgrading the existing Mill Creek 4 FGD and utilizing it for Mill Creek Unit 3
- ***Revision Date:*** 7/23/2014
- ***Tags:*** Babcock Power, FGD, Scrubber, Upgrade

Hollow cone nozzles at Ameren

- Hitachi used Spraying systems silicon carbide hollow cone nozzles on 5 new systems
- **Recent Operating Results of the Five New Wet FGD Installations for Ameren**
- Hitachi Power Systems America, Ltd. has recently completed the Start-Up, Performance Testing and several months of operation on the five (5) Wet Limestone Forced Oxidation Scrubbers (WFGD) installed in Missouri and Illinois for Ameren. Ameren Corporation is the parent of utility companies that serve 2.4 million electric customers and 1 million natural gas customers in a 64,000 square-mile area of Missouri and Illinois. This paper will discuss the project backgrounds along with the design and operating performance of the advanced SO2 reduction technology that was implemented on these five units.
- ***Revision Date:*** 7/23/2014
- ***Tags:*** Hitachi Power Systems America, Ameren Services, FGD, Scrubber, Pollution Control

Lechler has variety of nozzle types

- TwinAbsorb technology provides uniform distribution and additional atomization through the counter-rotating swirl, support and improvement of the secondary atomization effect and the highly improved conditioning of the liquid for a more efficient mass transfer over conventional single orifice nozzles. This is achieved by higher velocity differences between the gas and injected liquid, higher turbulence within the droplets and maximizing the available surface area for absorption.
- Lechler can manufacture to customer exact specifications (flowrate, pressure, spray angle, connection type/size) or supply an existing design when delivery is critical. All o TwinAbsorb nozzles are built and manufactured in the United States.

Downflow hollow cone

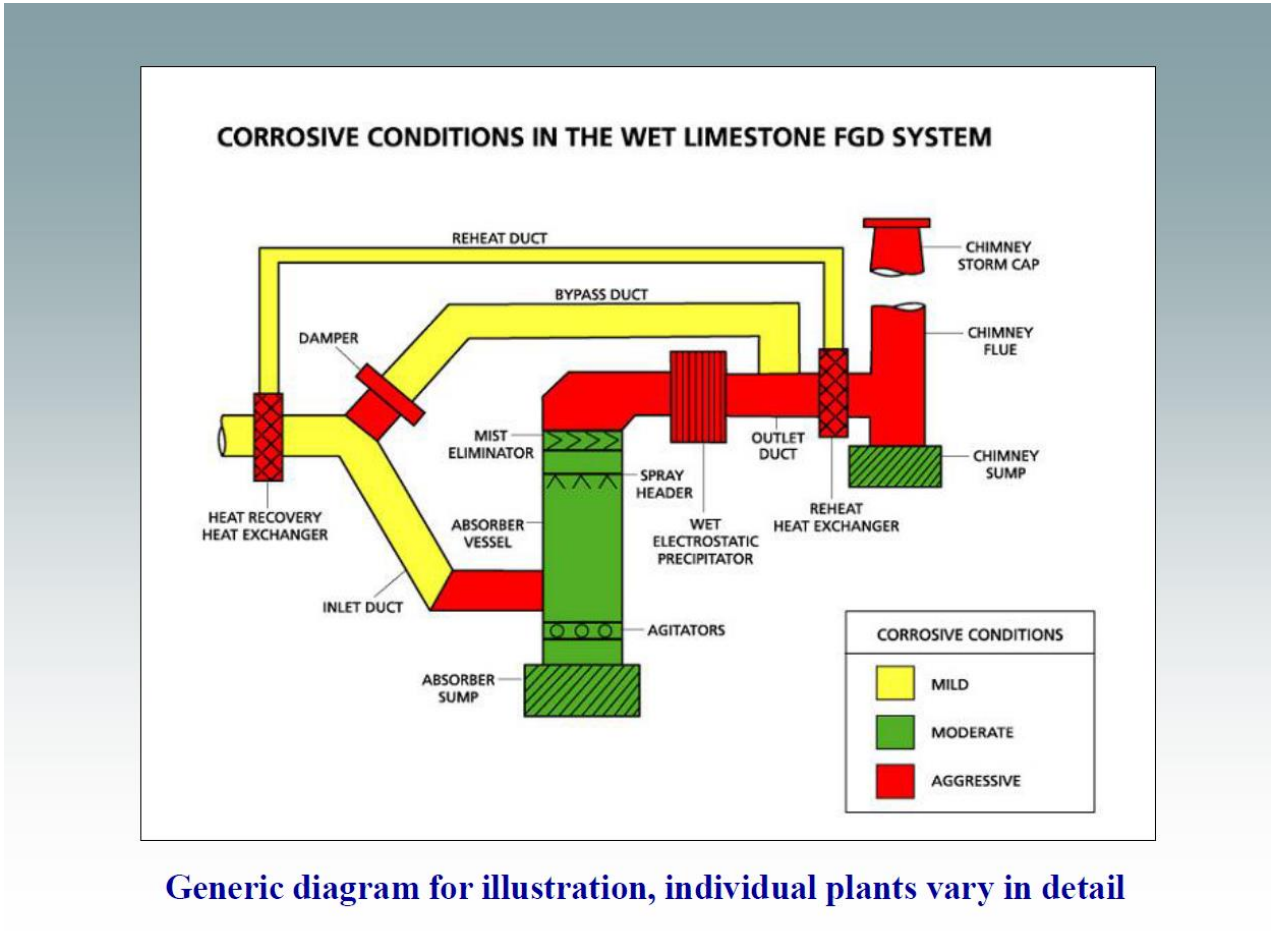
"Full cone and hollow cone up and down flow nozzles also available

Hollow cone nozzle-Spraying Systems

Spray Nozzles

Hollow Cone Spray Nozzle
(courtesy Spraying Systems Co.)

Areas of corrosion in scrubber systems



Generic diagram for illustration, individual plants vary in detail

Considerations for scrubber materials

- Scrubber inlet
- Scrubber shell
- Spray piping
- Baffles, trays
- Mist eliminators
- Recirculating tank
- Agitator
- Recycle pump
- Nozzles

- Plastic lining is used in china for scrubber shell
- Ceramic block, FRP, rubber, 276, and 2205 used in Europe and U.S.
- 276 often used in scrubber inlet due to heat and corrosion
- Lots of recent crevice corrosion problems

Wet limestone scrubber conditions

Conditions in FGD Systems

- Sulfuric / sulfurous acids - pH 5.5 to <1
- Temperature - 125°F to boiling
- Halides - chlorides & fluorides
- Wet / dry (boiling) interfaces
- Crevice formers - flyash, lime, gypsum
- Salts - oxidizing and reducing
- Traces of hydrochloric & nitric acids
- Solution may be much more corrosive under deposits

Marsulex materials selections

Materials of Construction

Absorber Reaction Tank

- *Carbon steel with flakeglass linings*
- *Carbon steel with rubber lining*
- *Stainless steels*
- *High Nickel alloys*
- *Carbon steel with C-276 alloy cladding*
- *Carbon steel with C-276 alloy wallpapering*
- *Concrete with Stebbins acid brick tile lining*
- *Fiberglass reinforced plastic*

Inlet Nozzle

- *Carbon steel with PennGuard block linings*
- *Stainless steels*
- *Carbon steel with C-276 alloy wallpaper*
- *C-276 / C22 alloy steels*

Spray Piping

- *Carbon steel with rubber lining*
- *Fiberglass reinforced plastic*
- *Stainless steel*
- *High Nickel alloys*

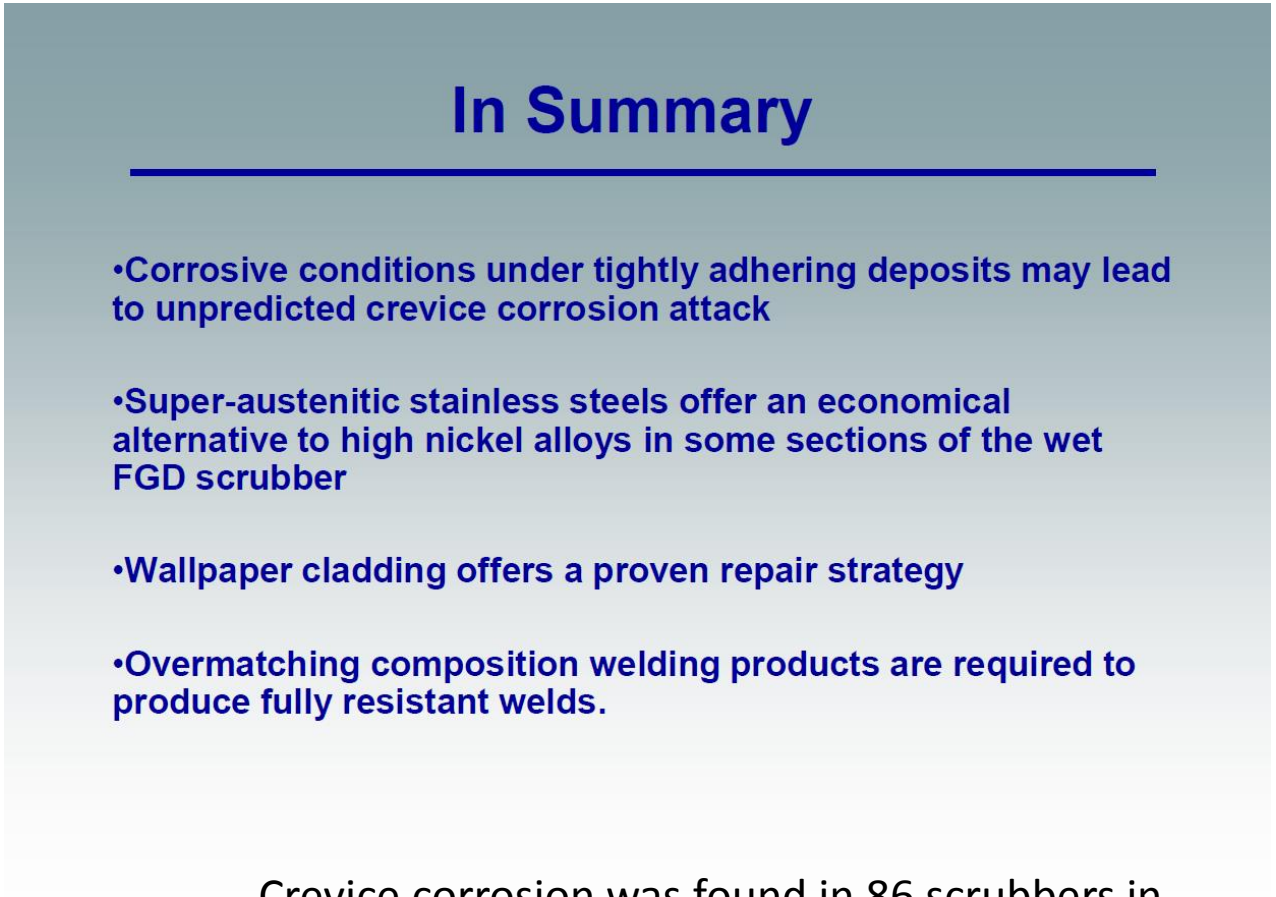
Spray Zones

- *Carbon steel with abrasion resistant flakeglass lining*
- *Carbon steel with rubber lining*
- *Stainless steels*
- *High Nickel alloys*
- *Carbon steel with C-276 alloy wallpaper*
- *Concrete with Stebbins acid brick tile lining*
- *Fiberglass reinforced plastic*

Outlet Duct

- *Carbon steel with flakeglass lining*
- *Carbon steel with PennGuard block*
- *Carbon steel with C-276 alloy wallpaper*
- *Fiberglass reinforced plastic*
- *Solid Alloy*

Special Metals solution to 2205 crevice corrosion



Crevice corrosion was found in 86 scrubbers in the U.S. with 2205 shells. Special Metals investigated the problem and offered solutions

Variety of nickel alloys and stainless for FGD- ATI

uct Line	Description	Products/ATI Company
Nickel Alloys	The Flue Gas Desulphurization (FGD) environment often requires resistance to both chlorides and sulfuric acid. flues, damper seals, etc. Nickel alloys are often required. The most commonly used alloys are listed on the right.	ATI 625™ ATI 22™ ATI 276™ ATI 59™
Stainless Steel	Resistance to chlorides is a requisite property of alloys used in FGD applications. The level of chlorides will be dependent on many	ATI 304L™ ATI 316L™ ATI 317L™ ATI 317LMN™ ATI 904L™ AL-6XN®

S31266 can be an option for scrubber shell- Industeel

- Many recently-constructed wet FGD systems that used the duplex alloy UNS S32205 or the austenitic grade S31726 and even more alloyed grades have experienced severe corrosion attack over the last few years. These issues were most often related to under-deposit/crevice corrosion. It is recognized that the primary cause of this crevice corrosion was the shift from natural oxidation to the forced air oxidation (FAO) system, which creates a highly-oxidizing environment inside the scrubber.
- Other parameters such as the presence of manganese oxide are also reported to have a detrimental impact on the crevice corrosion resistance of these stainless steels. The effect of calcium bromide on localized corrosion is arousing considerable interest since this compound is commonly being considered or being added to achieve mercury emission limits set by local regulations in North America.
- Industeel has conducted an extensive experimental program in order to highlight the influence of all these parameters on the localized corrosion resistance of several stainless steel materials. The results obtained confirm the detrimental impact of FAO. However, no significant influence of manganese oxide has been determined. The super-austenitic materials UNS S31266 is an interesting candidate material for FAO wet FGD systems showing excellent pitting and crevice corrosion resistance even when bromide irons are added. It’s crevice corrosion resistance is higher than that of the nickel base material UNS N06625

Bromine Corrosion is new problem due to mercury regulations-Analysis of LCRA

Balance-of-Plant Impact Concerns for Bromine-based Technologies

- Potential corrosion in bunkers, coal feeders
- Air heater basket corrosion
- **Increased pitting and/or crevice corrosion of wet FGD alloys of construction**
  - Station operates with zero liquid discharge
  - Units 1 and 2 FGD use mostly Stebbins Tile and C-276; some lesser alloys in wetted areas
    - Closed-loop water balance
  - Unit 3 FGD uses 316L with Potential Adjustment Protection, 317 LM, Alloy 2205
    - Relatively open-loop water balance
  - Large reclaim water system ties the FGD systems together
    - Cl^- purge water from Unit 3 used as makeup for Units 1 and 2

Recycle slurry pumps

courtesy of Marsulex

Pumps - Slurry

“Recycle Pump Selection

- Only a few pump companies make the very large limestone slurry recycle pumps
- KSB, Weir, and Duechting are capable of supplying individual pumps with more than 50,000 gpm
- Ceramic is becoming more popular as opposed to rubber lined or hard metal
- Steag/Evonik has experience with both and recommended the ceramic in a Mcilvaine 2008 hot topic hour. Is this still their opinion

Gate and Knife gate valves for size reduction and sulfite slurry recirculation

- Gate and knife gate valves

  Gate and knife gate valves can be used in many slurry services. With many gate valves, however, you must be willing to sacrifice tight shutoff in lime slurry service. Most gate valves force the gate into a wedge area to close the valve.

  Knife gate valves have a sharpened edge to improve the ability to cut through solid particles. In lime service, the seating area will be a spot for material accumulation. The lime will accumulate in this area, cause difficulties in valve operation and could prevent sealing the valve completely against the line pressure.

  The ideal knife gate valve for lime service features a hard-surfaced leading knife edge. For surfacing, stellite or some other material capable of protecting the softer steel blade is used. Actuator forces in knife gates also should be increased to give the valve the ability to cut through or close tightly against the lime buildup in the wedge.

  The knife of the knife gate will be exposed to scaling. The scale buildup on the knife most likely will result in packing problems in knife gates. The scale will accumulate on the valve's knife. As the knife is opened, the scale buildup will be dragged through the packing, requiring increased forces to open the valve. The packing also will be affected severely when this material is dragged across it. With most knife gates, you will experience significant packing leaks.

- If you are going to use knife gates in lime slurry service, you should incorporate a scraping packing material. This material would be a hardened substance that has the ability to scrape the knife clean with every operation. Also, the knife gate valve should have increased actuator forces capable of dragging this knife through the packing material.

Pinch valves are also used in FGD service

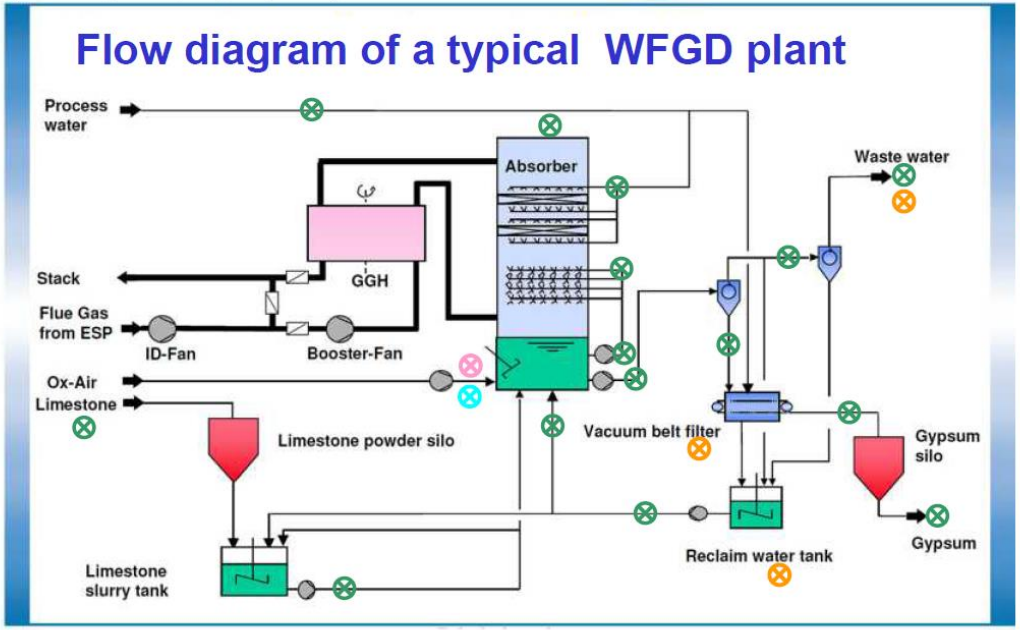
- Pinch valves are a good solution for lime slurry service because they have a straight-through design with no crevices or cavities for material collection. A pinch valve is a very effective device that has a self-cleaning effect on scaling materials.
- A rubber tube or sleeve is pinched by steel bars on the centerline of the valve to close. To close the pinch valve, you begin by stretching the rubber sleeve. As you stretch the rubber sleeve, the material or scale buildup begins to flake. As you continue to close the valve, the flaking becomes greater, but the fluid velocity increases substantially. Thus, the flaked material or scale is pressure washed from the elastic surface of the rubber sleeve.
- Pinch valves also address abrasion concerns. In abrasive flows, you have two options. The first is to make the ball, plug or gate valve and piping materials much harder. The second approach is to make the valve or piping material softer. Softer materials allow the abrasive particles to bounce off the surface without destroying it.
- For this reason, pinch valves have been used in mining applications on very coarse slurries for the past 30 years. With any mineral-based slurry, pinch valves are a very viable option for protecting against abrasion. A pinch valve also offers protection against clogging or jamming that can occur with other valves in lime slurry service. Many valves such as ball valves with stellite or harder coatings might be able to withstand the abrasiveness of lime slurry. However, they are subject to jamming or clogging because they have cavities that allow for material collection.
- Pinch valve selection must be performed very carefully and with due diligence. Stainless steel or carbon steel ball valves and plug valves do not vary greatly from one reputable manufacturer to another. As long as you use one of the "more reputable" ball or plug valves, you most likely will have a valve free from porosity or imperfections. In addition, some ball or plug valves have modified designs to enhance performance in difficult services.
- Pinch valves, however, can vary greatly from one another, and rubber quality and properties can differ drastically from one manufacturer to another. A good analogy is the purchase of automobile tires. Pretend you have the option to purchase either a 30,000-mile set of tires or an 80,000-mile set. Side by side, these tires look almost identical, but the 80,000-mile-rated tire certainly will cost more. For the extra money, it will give you two times the useful life of an inferior tire

Valve use in FGD-Crane

CRANE Energy Flow Solutions

Where to install

(Process systems, no gas systems)



- CenterLine RS (Bv)
- Saunders KB (IDV)
- XOMOX 108G
- HP / MS (Bv)

And ball valves

Total circa 300 – 650 different kind of valves

Butterfly valve issues and options

CRANE Energy Flow Solutions

Requirements

How should a Butterfly Valve designed in order to guarantee best protection against corrosion ?

a) **Minimization number of wetted parts**

b) **Material selection of wetted parts in accordance with Process Conditions**

c) **Avoidance of**
- **pitting corrosion**
- **contact corrosion**
- **stress corrosion**

Xcel experience with Pentair Clarkson knife gate

- Xcel Energy's Allen S. King power plant in Bayport, Minn., utilizes numerous 8-inch and 6-inch open spring return slurry Clarkson knife gate valves as well as 6-inch manual valves from Tyco Valves & Controls throughout its dry scrubber FGD system (Figure 2). Prior to the installation of Tyco knife gate products, plant engineers experienced continual difficulties with other valve equipment. These could not cope with the extreme conditions of the scrubber, where heavy buildup of recycled ash settled at the front of the seat ring, severely affecting performance and requiring frequent maintenance. Xcel Energy found that Tyco slurry knife gate valves worked well at another plant and decided to replace the existing valves at Bayport. The push-through/discharge design diverts the media away from the seat to prevent buildup, optimizing the valves' performance.

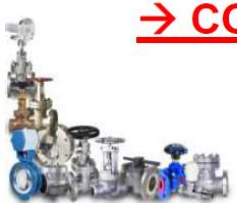
Materials , plastics or alloys?

CRANE Energy Flow Solutions

Hostalen GUR® jacketed disc, a Trend-setting material !

Con‘t

- **More than 15 years field experience in different services in WFGD systems**
- **Unique material vs Alloy castings in terms of chemical resistance for fluids with high Choride contents and low pH-values**
- **Due to continuous high material surcharges it gives a comepetitive edge to all other metal materials**
  → COSTSAVINGS



Elastomer sleeves are critical

- The elastomer sleeves are the crucial components within slurry knife gate valves, yet not all elastomers guarantee the same results. The key to producing high-performance sleeves within a slurry knife gate valve is the initial selection of ingredients that make up the rubber compound. High-quality ingredients are essential to achieve reliable and long-lasting slurry knife gate valve sleeves, while different compounds are necessary when dealing with different pressures and temperatures. Over time, the rubber in the valve sleeve can experience reduced mechanical performance, so it is vital that it have the correct properties to function when open or closed and guarantee zero-leakage performance.
- Tyco’s specialist team develops numerous rubber compounds and tests them extensively on-site to ensure that they meet the extremely high standards needed for FGD installations. It is impossible to mimic the blends of these elastomers, as the design not only requires the correct chemical composition but also the right curing and manufacturing setup.

Red Valve-control valves for lime slurry

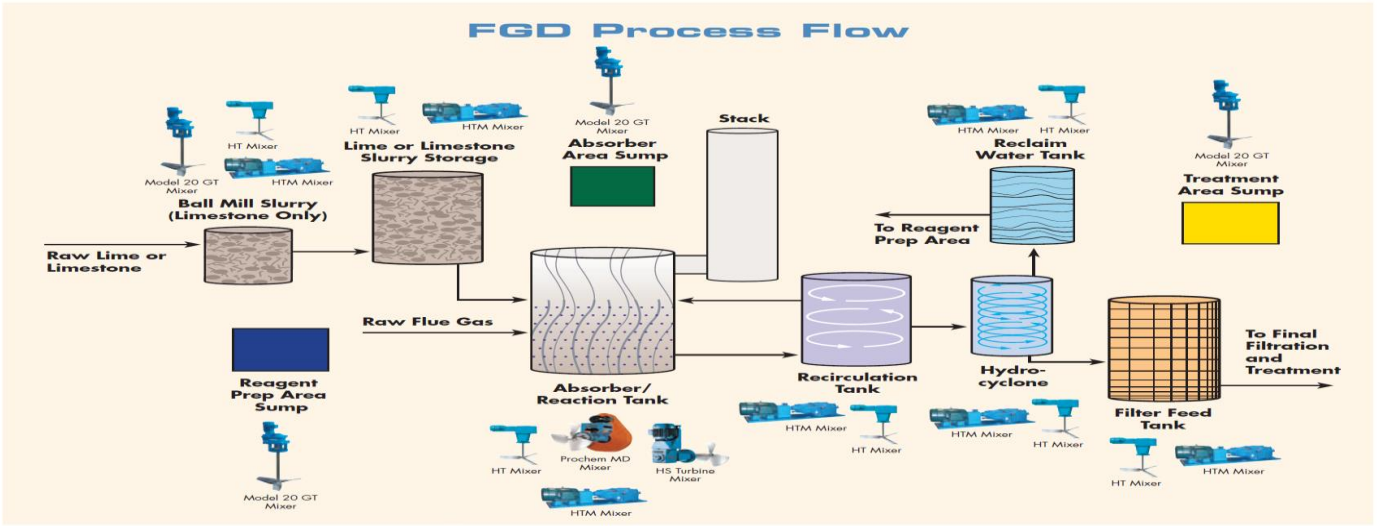
Oxidation options impacting blower design

Options	
Forced oxidation	Natural oxidation or inhibited
Limestone reagent	Lime reagent
Spray tower scrubber	Turbulent sump scrubber (Chiyoda)
Combination agitator and lance	Separate agitator and lance
Multi stage blowers	Lobe blowers or single stage compressors
Factors influencing blower choice	
Cost of energy	payback period
Specifications of design institute	Equipment already installed (inventory reduction for repair parts)
Continuous hours of operation needed	Amount of sulfur to be oxidized
Cost	Bundling all blowers in one purchase package
Engineering support	Maintenance and service
Voltage (medium or low)	Drive (direct?)

Chemineer agitators

Reliable FGD Mixing Solutions

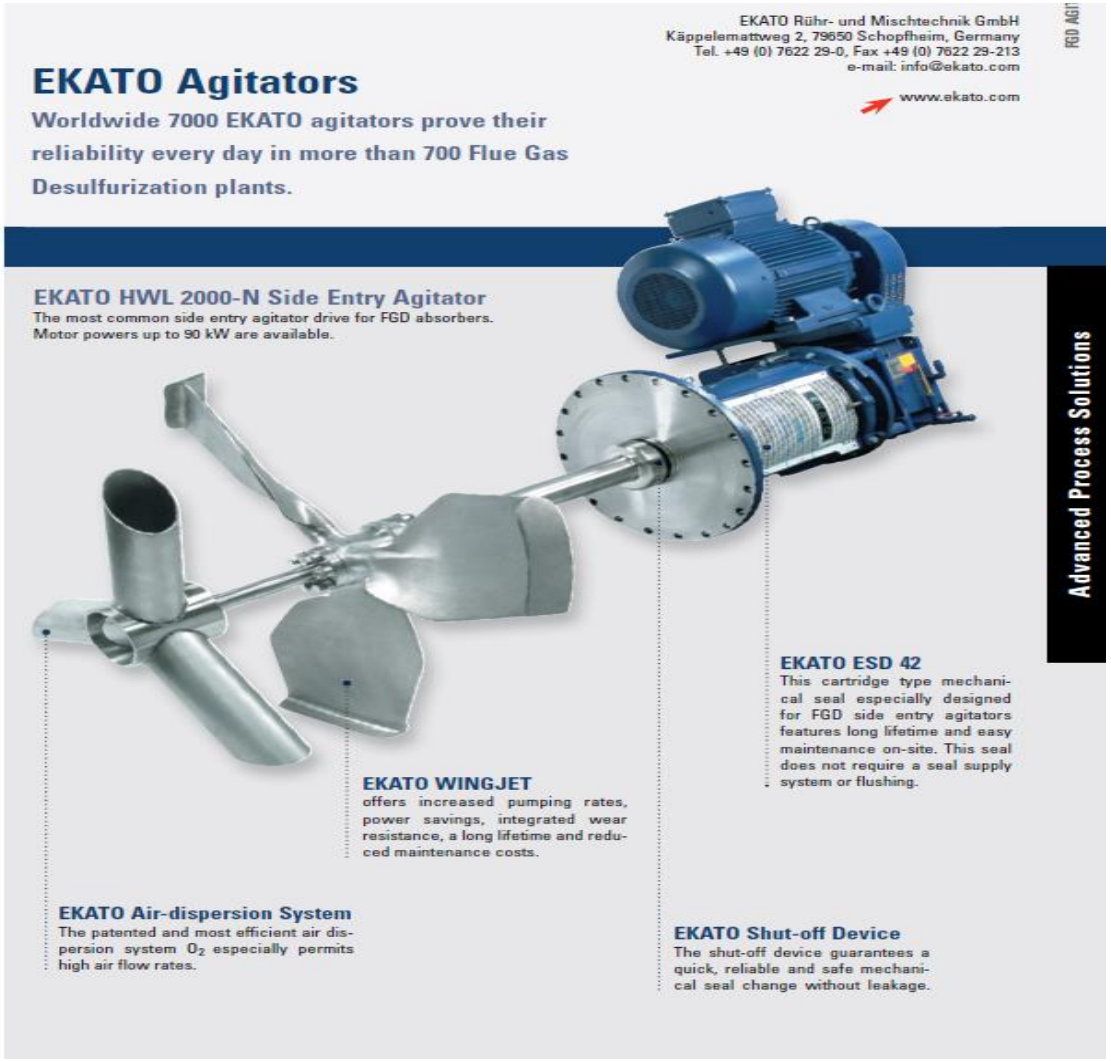
Chemineer is a leading supplier of mixing solutions and products for Flue Gas Desulfurization (FGD) systems throughout the world for over 60 years. By utilizing laboratory testing and industry-leading technology, Chemineer can design the ideal mixing system for your process. Chemineer distinguishes itself from the competition through the use of rugged agitators that are highly efficient and extremely reliable. Thousands of Chemineer agitators are currently operating in FGD service and many of these have been in service for decades. Chemineer's experience in evaluating FGD applications and supplying equipment specifically engineered for harsh FGD service ensures efficient plant operation and long, reliable service with minimal maintenance.



Chemineer-U.S

startup	plant name	unit id	utility name	state	reagent	process	size MW
2008	J M Stuart	1	Dayton Power & Light Co.	OH	limestone	wet	610
2008	J M Stuart	2	Dayton Power & Light Co.	OH	limestone	wet	610
2008	J M Stuart	3	Dayton Power & Light Co.	OH	limestone	wet	610
2008	J M Stuart	4	Dayton Power & Light Co.	OH	limestone	wet	610

EKATO Wing Jet



Ekato FGD Installations-U.S

startup	plant name	unit id	utility name	state	reagent	process	size MW
2005	Asheville	1	Duke Energy	NC	limestone	wet	207
2006	Asheville	2	Duke Energy	NC	limestone	wet	207
2008	Cholla	4	Arizona Public Service Co.	AZ	lime	wet	414
2011	Milton R Young	B1	Minnkota Power Coop Inc.	ND	lime	wet	257

Ekato Installations - China

startup	plant name	unit id	utility name	reagent	method	size MW
2006	Jiangyin Xiagang	1	Jiangyin Sulong Electric Power			
2006	Jiangyin Xiagang	2	Jiangyin Sulong Electric Power			
2006	Taicang	1	Huaneng Power International	limestone	wet	300
2006	Taicang	2	Huaneng Power International	limestone	wet	300
2006	Tianshenggang	1	Guodian Nantong Tianshenggang Power Plant	limestone	wet	330
2006	Tianshenggang	10	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2006	Tianshenggang	11	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2006	Tianshenggang	2	Guodian Nantong Tianshenggang Power Plant	limestone	wet	330
2006	Tianshenggang	8	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2006	Tianshenggang	9	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2007	Jianbi	9	Guodian Suyuan-Jianbi Power Generation Co.	limestone	wet	330
2007	Taicang	3	Huaneng Power International	limestone	wet	600
2007	Taicang	4	Huaneng Power International	limestone	wet	600

Mixing Solutions Comparison of Lance to combined lance/agitator

Research & Development Laboratory

Making the Unknowns - Known

Mixing Solutions Limited operates the largest, most comprehensive, full service industrial mixer laboratory in the world, including a 750,000 gallon test tank. In our R&D Lab we have the ability to model, design, test, and evaluate agitator configurations from scale model to full scale to meet your specific needs.

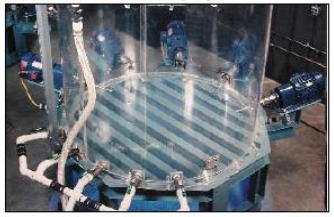
Make unknowns known without risk and remove any doubt. Using cutting edge technology and equipment we can accurately test and compare competing FGD solutions side by side.

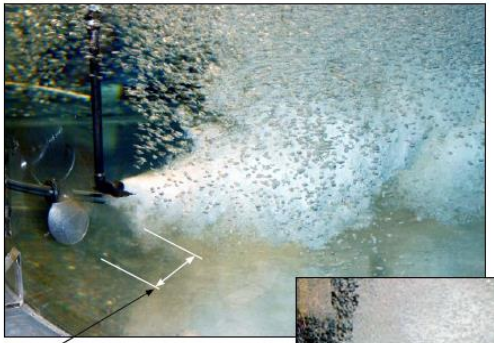
- **Analyze** solutions before they are installed in your facility.
- **Optimize** your process, maximize your profit, reduce chance of fines.
- **Eliminate** costly surprises, upset conditions, and "what ifs?"

Agitator Test Facility, scale-up lab with research & design analysis tank.

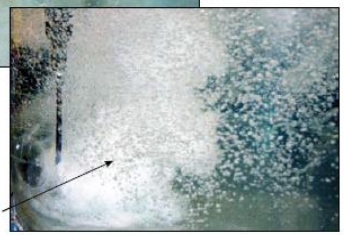
Shaft run-out test at bottom of 750,000 gallon test tank.

Comparative FGD impeller and O_2 delivery testing taking place.





AirWing™ undergoing comparative testing in the world's largest fluid mixing lab. Note the gap between impeller and air jetstream - no flooding is evident behind the impeller. This translates to less air required to fulfil your process.



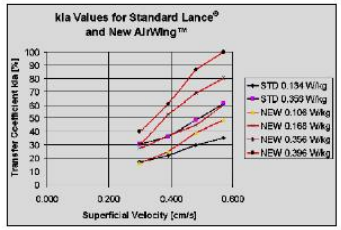
The same cannot be said for the standard air delivery lance. Significant flooding is evident here, resulting in process failure.

Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) Proven design.

Consistently outperforms the closest competitors' offerings in actual lab tests.

Actual Test Data Analysis proves that AirWing™ is the superior solution by up to 30%!

Revolutionary design demonstrates Mixing Solutions Limited's application understanding and expertise. Agitator Drive & Impeller combo make the Phoenix™ System your smart choice!



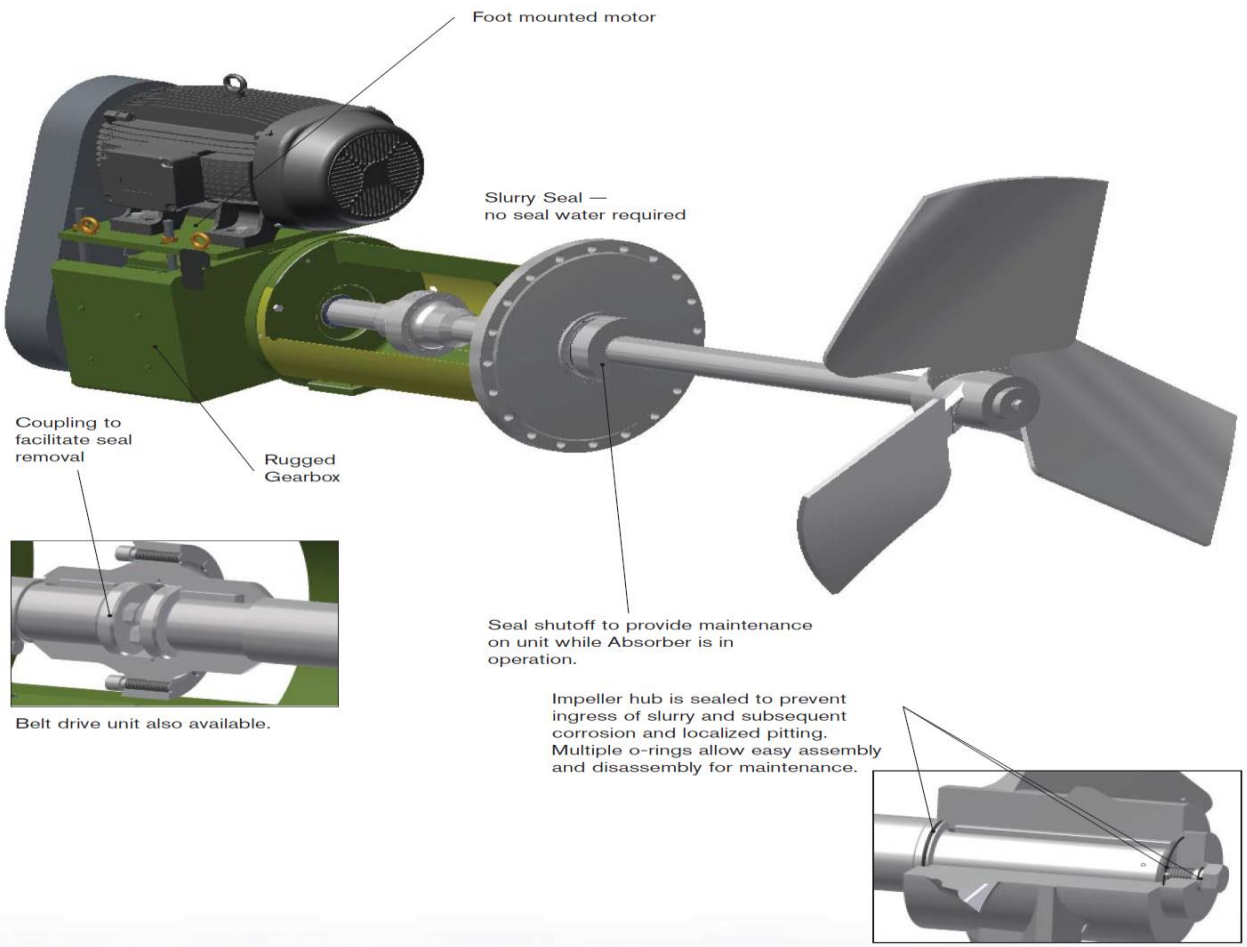
Philadephia Mixing Solutions-U.S

startup	plant name	unit id	utility name	state	reagent	process	size MW
2009	Coffeen	1	Ameren Illinois	IL	limestone	wet	390
2010	Coffeen	2	Ameren Illinois	IL	limestone	wet	617
2010	Oak Grove	2	Luminant Energy	TX	limestone	wet	796
2010	Sioux	1	Ameren Missiouri	MO	limestone	wet	549.8
2010	Sioux	2	Ameren Missiouri	MO	limestone	wet	549.8
2010	Oak Grove	1	Luminant Energy	TX	limestone	wet	796

SPX Lightnin mixer

THEORY OF OPERATION:

VSF Side-Entry Mixer Designed for FGD Absorber Service



Belt drive unit also available.

Zhejiang Great Wall Reducer Co.

BHEL teamed with MHPS-agitator spec for Indian market

BHEL: BAP: RANIPET

AGITATORS – TECHNICAL POINTS CONFIRMATION FROM VENDOR

Sl. No	Clause no.	Description	As per specification	Bidder to confirm
1.	**NUMBER OF AGITATORS**			
	3.4.0 (Table-1)	Limestone Slurry Tank	4 no's	
		Auxiliary Absorbent Tank	2 no's	
		Filtrate Tank	2 no's	
		Secondary Hydro cyclone Feed Tank	2 no's	
		Waste Water Tank	2 no's	
		Lime Feed Tank	2 no's	
		Absorber Drain Pit	6 no's	
		Ball Mill Area Drain pit	2 no's	
		Gypsum Area Drain pit	2 no's	
2.	**MATERIALS OF CONSTRUCTION**			
	3.8.0	Impeller Blade	Stainless steel or Nickel alloy. If Bidder offers rubber lining, the minimum life of rubber lining shall be 2 years.	
		Impeller Hub	D2B, ASTM A-439 or similar corrosion resistant material with rubber lining.	
	3.8.2	Shaft	Stainless steel or Nickel alloy.	
	3.8.3	Shaft Sleeve	Duplex Stainless steel CD4MCu or ASTM A-743 or 940L type nickel alloy with a minimum hardness of 240BHN	
	3.8.1	Seal	Stuffing box or any proven equivalent or superior sealing type.	
3.	**DYNAMICS**			
	3.10.0	**Critical Speed**		
		Operating speed of the Agitator motor shall be at least 25% below the first critical speed		
4.	**SPECIFICATION OF MOTOR**			
	6.0.0	**Degree of Protection**		
		Degree of protection for various enclosures shall be as follows:		
		a) Outdoor motors	IP 55	

5 new Hitachi Systems with separate lance and agitator

HITACHI
Inspire the Next

Figure 7 shows two spray header levels with nozzles trussed together with direct bonding of the SiC spray nozzles. Figure 8 displays the overlapping high density spray patterns resulting in the generation of fine droplets.

Fig. 7 Typical Spray Headers

Fig. 8 Overlapping High Density Spray Patterns

The design of the absorber reaction tank is also important when coupled with in-situ forced oxidation employing side mounted agitators and air lances. The result being a high level of solids for enhanced SO_2 removal and better dewatering coupled with sufficient residence time to ensure good gypsum crystal growth. Figure 9 shows a typical agitator and air lance arrangement which are spaced at the appropriate locations around the tank, while Figure 10 displays the dispersion of air bubbles.

Fig. 9 Agitator and Air Lance

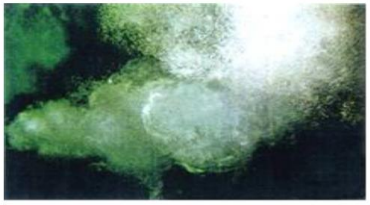
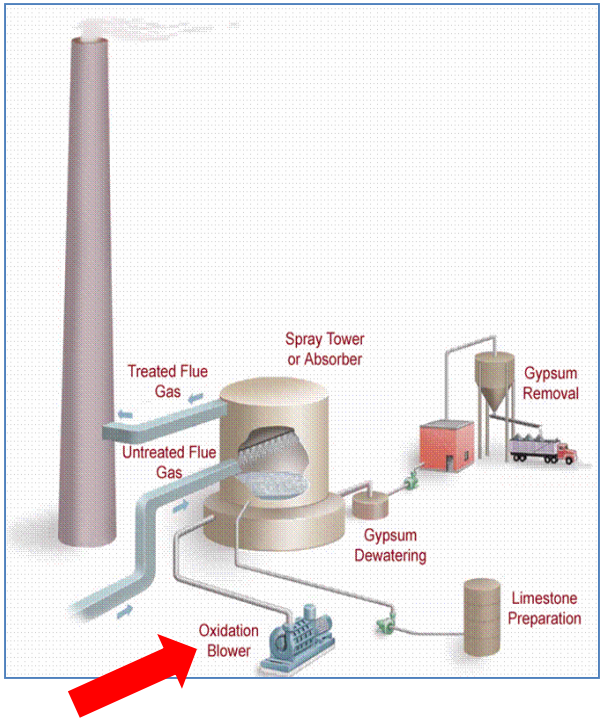


Fig. 10 Dispersion of Air Bubbles to Allow Forced Oxidation

Major Blower Technologies



PD Roots Lobe Blower: Lowest efficiency (45-65%), lowest capital cost

Single Stage Centrifugal: Highest efficiency, (70-80%), highest capital cost

Multistage Centrifugal Blower: Higher efficiency (50-70%), higher capital cost

One of three Siemens Turblex KA44-GL315 flue gas desulfurization oxidation air compressors, each 18,000 scfm, 30 psig, 2500hp.

Model	KA2	KA5	KA10	KA22
Flow (cfm)	500 - 2150	1800 - 6000	4500 - 9000	8000 - 14000
Pressure (psig)	4 - 22	4 - 28	4 - 25	4 - 23
HP	50 - 200	100 - 600	150 - 1000	200 - 1500
Model	KA44	KA66	KA80	KA100
Flow (cfm)	13000 - 21000	18000 - 33000	22000 - 44000	30000 - 70000
Pressure (psig)	4 - 23	4 - 23	4 - 20	4 - 17
HP	300 - 2000	450 - 3000	600 - 4000	800 - 5000

Siemens Turbo installations in U.S.

startup	plant name	unit id	utility name	state	reagent	process	size MW
2007	Roxboro	4A	Duke Energy	NC	limestone	wet	745
2008	Mountaineer	1	American Electric Power	WV	limestone	wet	1300
2008	Winyah	1	Santee Cooper	SC	limestone	wet	315
2008	Winyah	2	Santee Cooper	SC	limestone	wet	280
2009	Brunner Island	1	PP&L Inc.	PA	limestone	wet	363
2009	Brunner Island	2	PP&L Inc.	PA	limestone	wet	405
2009	Brunner Island	3	PP&L Inc.	PA	limestone	wet	790
2009	Cross	4	Santee Cooper	SC	limestone	wet	600
2009	Montour	1	PP&L Inc.	PA	limestone	wet	806
2009	Montour	2	PP&L Inc.	PA	limestone	wet	819
2009	Roxboro	1	Duke Energy	NC	limestone	wet	411
2010	Oak Creek (Elm Road)	1	We Energies	WI	limestone	wet	600
2010	Oak Creek (Elm Road)	2	We Energies	WI	limestone	wet	600

Siemens-China

startup	plant name	unit id	utility name	reagent	method	size MW
2006	Tianshenggang	1	Guodian Nantong Tianshenggang Power Plant	limestone	wet	330
2006	Tianshenggang	10	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2006	Tianshenggang	11	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2006	Tianshenggang	2	Guodian Nantong Tianshenggang Power Plant	limestone	wet	330
2006	Tianshenggang	8	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2006	Tianshenggang	9	Guodian Nantong Tianshenggang Power Plant	limestone	wet	137.5
2007	Jianbi	9	Guodian Suyuan-Jianbi Power Generation Co.	limestone	wet	330
2007	Taicang	3	Huaneng Power International	limestone	wet	600

Siemens ROW

startup	plant name	unit id	utility name	country	reagent	method	size MW
2000	Tangjin	3,4		South Korea	limestone	wet	1000
2001	Avedore	2	SK Energi	Denmark	limestone	wet	325
2001	Sostanj	5	ELES	Slovenia	limestone	wet	335
2002	Yongnam	1,2	Korea Electric Power Corp.	South Korea	limestone	wet	380
2004	Eggborough	4	British Energy	United Kingdom	limestone	wet	450
2004	Eggborough	3	British Energy	United Kingdom	limestone	wet	450
2005	Voerde	4	STEAG	Germany	limestone	wet	760
2005	Voerde	3	STEAG	Germany	limestone	wet	760

Ingersoll Rand-Hibon multi stage blowers at Tanjunglati Indonesia

- Two units of Hibon Multistage Centrifugal Blowers Model 450.06
- Flow: 15000 Nm3/h
- DifferentialPressure: 850 mbarg
- Motorsize: 700kW
- Customer: Babcock&Wilcox

Unique technical analysis –Gardner Denver presentation in Mcilvaine webinar

Single vs. Multistage

	GDI Multistage	Single Stage
Capital Cost	Moderate	More Expensive
Installation Cost	Low	Higher due to subsystems
Design Efficiency*	79%	79%
Operating Speed	3600 RPM Direct	>8,000 RMP
Tip Speed	<600 fps	>1000 fps
Bearings	(2) Ball: Field Changeable	(5) Sleeve: Not Field Changeable
Gear Increaser	None	Yes – Vertical Split Casing
Other Utilities	None	Cooling Water
Instrumentation	Simple	Complex due to design & subsystems
Noise Level	85 dBA	>95dBA

Gardner Denver Success in China

- There were 9 bidders for the Shandong Chiping Xinyuan Aluminum Co. Ltd's 6 * 660MW supercritical unit power station project. Gardner Denver, Nash China won the project with the highest price!

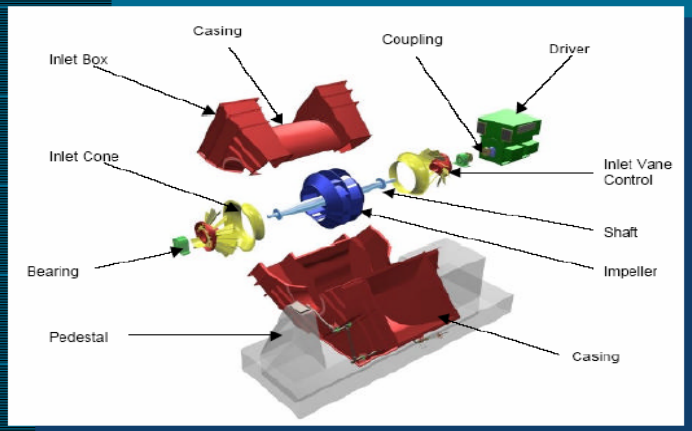
  The project includes 12 sets of CF2007 flue gas desulfurization (FGD) oxidation blowers, 18 sets of TC-11E condenser vacuum pumps and 6 sets of 2BE4 720 FGD vacuum pumps.
- Chiping Xinyuan Aluminum Co. Limited is a subsidiary of Shandong Xinfa Group which is one of China's largest private companies.
- This is the third success in a row, following the Pingwei and the Wanzhou power projects. These have all occurred since Nash China started the "TOTAL SOLUTION" strategy at the end of 2012.

  The original design called for roots blowers. Considerable effort was needed to persuade the Design Institute to change the specifications
-

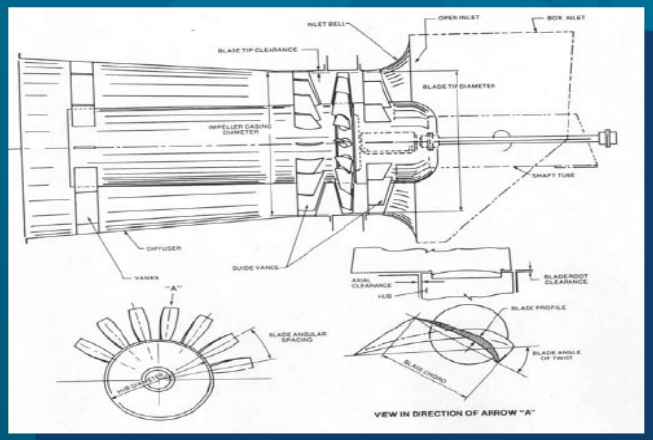
  The "TOTAL SOLUTION" strategy brought Nash orders for 20 sets of blowers, 30 sets of condenser vacuum pump packages and 10 sets of flue gas desulfurization vacuum pumps during 2013.

Fans, centrifugal or axial (courtesy of Marsulex

Fans



Typical Centrifugal Booster Fan
(courtesy Howden Power)

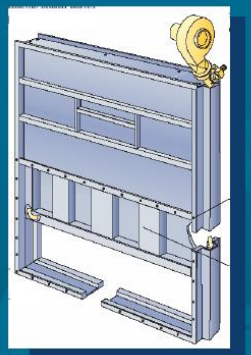


Typical Axial Booster Fan

Dampers *courtesy of Marsulex*

Dampers

Double Louver Damper
(Courtesy Braden-Europe)



Guillotine Damper
(Courtesy Braden-Europe)

- Used for flow control and / or isolation of equipment for maintenance