AIR POLLUTION CONTROL SOLUTIONS

Environmental Protection with Enhanced Emissions Control Technologies

CLYDE BERGEMANN

Proven Technologies in Global Markets

Widespread awareness of environmental protection, as well as health concerns, has and will continue to be a key consideration of countries around the world. With more stringent legislation taking effect in many countries worldwide, industries are putting a strong focus on investment in pollution controls to ensure their standards comply with local and international targets.

With over 60 years experience of air pollution control technologies, Clyde Bergemann is key to supporting the progress of companies in meeting these targets. Our proven technologies include modern electrostatic precipitators and fabric filter systems for particulate control, circulating dry scrubbers, spray dryer absorbers and dry sorbent injection for acid gas removal, and activated carbon injection for mercury and trace metal removal.

Our experienced team of engineers ensure the highest quality of service is provided to our global customer base on a turnkey basis, from initial enquiry through to the commissioning of the equipment and after sales support. Our expertise supports new and rebuild projects and continues a strong focus on retrofit and maintenance on existing plants.

Key Technologies

Clyde Bergemann offers demonstrated solutions for air pollution control with our technology portfolio servicing many industries including power generation, coal or biomass fired boilers, waste-to-energy plants, iron and steel, cement, pulp and paper, and other industrial applications.

Our portfolio includes the following technologies:

Particulate Control

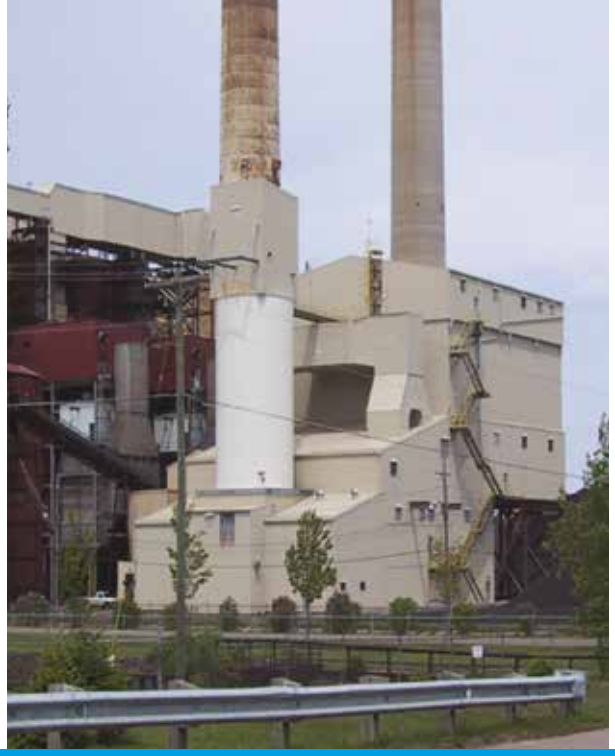
- Electrostatic precipitators
- Fabric filters

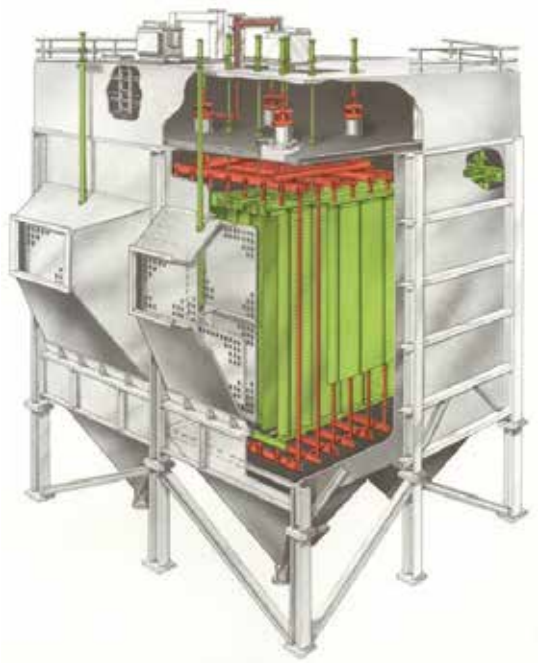
Acid Gas Removal (SO_2, HCl, HF, SO_3)

- Circulating dry scrubbers (hydrated lime based)
- Spray dryer absorbers (lime based)
- Dry sorbent injection (Trona, sodium bicarbonate and hydrated lime)

Mercury and Trace Metal Removal

- Powdered activated carbon injection





Globally Certified for a Range of Applications

Custom Designed to Suit Applications

Clyde Bergemann's strategy is to provide customer focused solutions and reliable aftermarket replacement components and service to users of air pollution control systems.

Our technologies and services can be applied to a number of industries from power generation plants including those burning coal, oil, biomass and waste, to industrial manufacturing plants such as iron and steel, cement and pulp and paper.

Our comprehensive process engineering capabilities include determination of the size, geometry and the mechanical, electrical and structural characteristics of the system to meet customer specifications.

A Range of Products and Services Meeting Customer Specifications

Our complete services for the air pollution control market include:

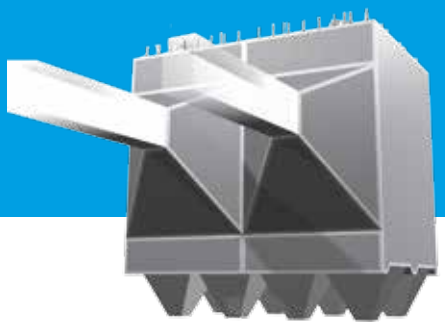
Engineering Systems

- New equipment
- Major rebuilds
- Balance of plant design
- ESP, fabric filters, $DeSO_x$, mercury control
- Auxiliary equipment

Services

- Parts and service
- Performance assessment
- Compliance and optimisation
- Project management
- Application, design, process and project engineering
- Field services

Electrostatic Precipitators



Electrostatic Precipitators (ESP) for Efficient Particulate Control

Clyde Bergemann offers proven wet and dry ESP technology which has been successfully installed in applications across the globe in industries such as major coal and oil-fired power generation plants, power generation from biomass, waste-to-energy, iron and steel, cement and pulp & paper.

With over 1,500 installations worldwide, our experience and knowledge of the industries allows us to design accurate and highly efficient configurations to ensure targeted emission levels are achieved.

Your Advantages:

- Typical collection efficiencies exceed 99.9%
- Can reduce emissions to less than 10 mg/Nm^3
- Low cost of ownership (low capital costs, almost no maintenance, minimal wear parts, low pressure drop)
- Reliable design with high durability to ensure long lifespan of technology

Special Design Features of our ESP Technology

- No moving parts inside casing and gas flow
- Virtually maintenance free design - entire rapping system is located outside the gas stream
- All electric single impulse (ESI) rapping devices are located on casing roof and maintenance can be carried out during operation
- Frequency and intensity of rapping devices can be infinitely adjusted to process needs
- Rigid electrode design - RIGITRODE® is state-of the-art, unbreakable and customised for application specific characteristics
- The MODULOK™ Collecting Electrode is specifically designed to achieve exact plate alignment and structural integrity
- State-of-the-art microprocessor based ESP controls including:
  - DOCIV automatic voltage power controller
  - OPTI-RAP™ rapping system controller

ESP Technology & Solutions to Achieve Emissions less than 10 mg/Nm³

Key Design Elements for Enhanced Performance

RIGITRODE® - discharge electrodes

- fabricated from tubing with strategically spaced corona studs welded along the length of the electrode
- assembled into the ESP as a rigid structural matrix
- structural stiffness resists displacement due to electrical forces and lateral forces resulting from over-full hoppers.

MODULOK™ - collecting plates

- exact plate alignment and structural integrity
- excellent rapping response for dislodging the collected particulate
- no field assembly required
- eliminates deformation and oil-canning which can occur when individual panels are welded together along their vertical height

We also offer a variety of rapping system options where the entire rapping system is located outside the gas stream and can achieve plate accelerations in excess of 100g.

How it Works

The electrostatic precipitator (ESP) is a high efficiency particulate removal device that collects particulate matter from high temperature combustion or process gas streams.

The system works by negatively charging the particulate matter entrained in the gas stream with high voltage discharge electrodes which electrostatically influence those particles to be attracted to positively grounded collecting plates within the ESP.

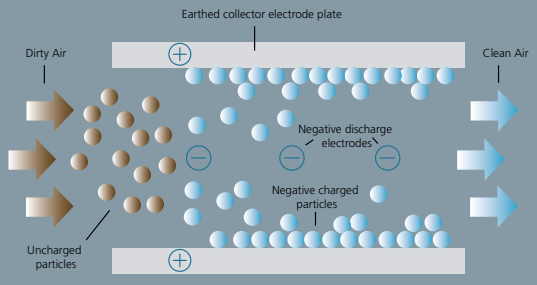


Image: the ESP Process

Cleaning of the plates occurs when a rapping device is activated and dislodges the dust causing it to fall into hoppers below the ESP. The cleaned gases pass out of the ESP and through a stack into the atmosphere.

Fabric Filters

Pulse Jet and Reverse Air Fabric Filters for Low Emission Levels

Clyde Bergemann offers a wide range of fabric filter systems for a variety of process applications providing effective technical and commercial solutions where high collection efficiency and low emission levels are required.

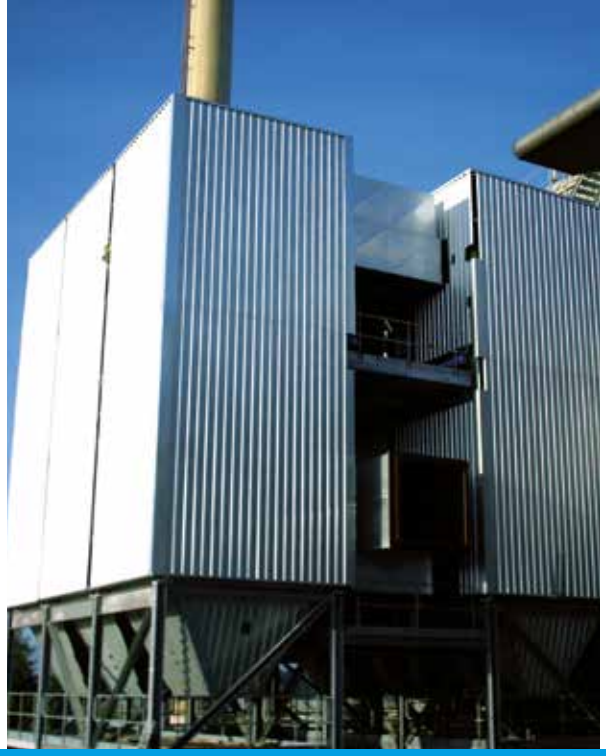
Our fabric filters are installed on a range of applications including coal and oil-fired power generation plants, power generation from biomass, waste-to-energy, iron and steel, cement and pulp & paper.

Your Advantages:

- Can reduce emissions to less than 5 mg/Nm^3
- Prolonged bag life increases plant availability and reduced operational costs

Special Design Features of Our Fabric Filter Technology

- Patented stepped inlet manifold for uniform gas distribution to all filter modules, helping
  - reduce pressure drop
  - minimise particulate fallout in inlet manifold
  - significant improvement in flow distribution compared to conventional tapered designs
- Patented inlet vane system - uniformly turns and distributes the gas flow reducing bag wear, reducing pressure drop and extending bag life
- Lower pressure drop - reduces I.D. fan power consumption which lowers operational costs, and extends cleaning cycle which prolongs bag life
- Smaller filters are designed in modular form for faster site assembly minimising site costs and programme lead times
- Improved gas flow distribution is achieved without relying on increased fabric pressure loss to balance the individual module gas flow
- Each turn within the manifold is individually vaned to prevent flow separation and minimise fall out



Top Door and Walk-In Plenum Pulse Jet Designs

Clyde Bergemann offers both Top Door and Walk-in Plenum type Pulse-Jet Fabric Filter Systems. With Pulse-Jet Filters, gas flows from the outside to the inside of the bags.

The design of the manifold and gas distribution package used in our Fabric Filters is based on 40 years of field and flow model experience and has been designed to achieve the following essential objectives:

- Minimal system mechanical pressure drop
- Balance gas flow and dust distribution among modules
- Minimise dust fall out in the inlet manifold

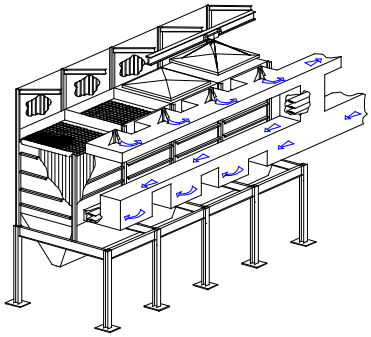


Image: Patented stepped inlet manifold

How it Works

Fabric filters are high efficiency collection devices capable of collecting fine particulate from the gas stream.

In a pulse jet fabric filter, particulates in the flue gas stream are deposited on the outside surface of the filter bag which then build up to form a dust cake. When the dust cake reaches a level where flow is restricted, cleaning is initiated. The dust is removed by injecting a pulse of clean compressed air down the inside of the bag.

The collected dustcake is dislodged and falls down into the hopper.

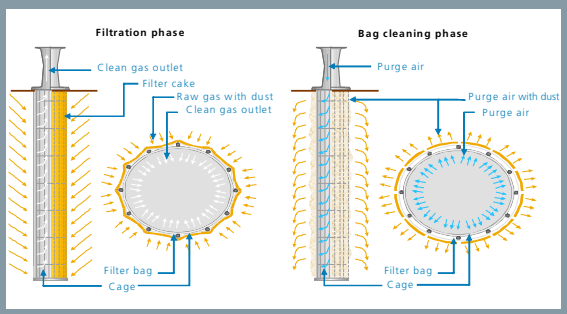


Image: fabric filter cleaning

Solutions for Acid Gas and Mercury Removal

Dry Scrubbing Systems for Removal of Acid Gases (such as SOx, HCl, HF) and Mercury

A dry scrubbing system is used to remove pollutants from an exhaust stream by injection of a reagent into the stream to neutralise or remove acid gases / metals. Unlike wet scrubbing systems, the dry approach produces a dry residue and has no requirement for waste water handling.

Clyde Bergemann offers three types of dry scrubbing systems: circulating dry scrubbers, spray dryer absorbers and dry sorbent injection. Our technologies remove gaseous pollutants and heavy metals from exhaust gas streams through the introduction of calcium, sodium and carbon based reagents to transform or capture gaseous and toxic pollutants into particulate matter which can be collected downstream in a particulate collection device (electrostatic precipitator or fabric filter). Our technology is capable of removing more than 97% of acid gases (including SO_2) from the flue gas and has demonstrated greater than 97% removal efficiency of mercury.

Our dry scrubbing technology has been successfully installed on applications such as coal-fired generation, waste-to-energy plants and biomass facilities.

Circulating Dry Scrubber (CDS) - Highest efficiency of removal for SO_2/SO_3/HCl/HF among dry or semi-dry technology

Clyde Bergemann's CDS technology removes acid gas pollutants and heavy metals from utility and industrial flue gas streams through use of calcium based reagent by capture onto particulate matter and further collection downstream in a particulate collection device.

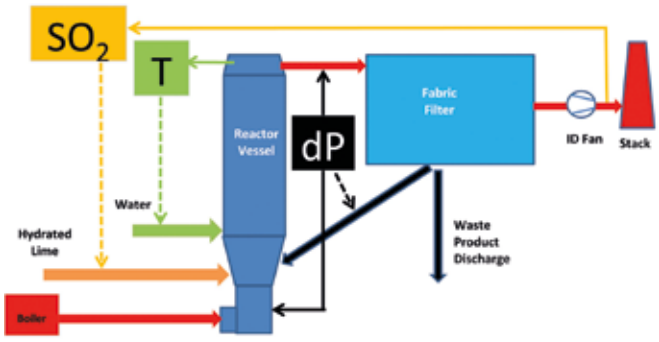
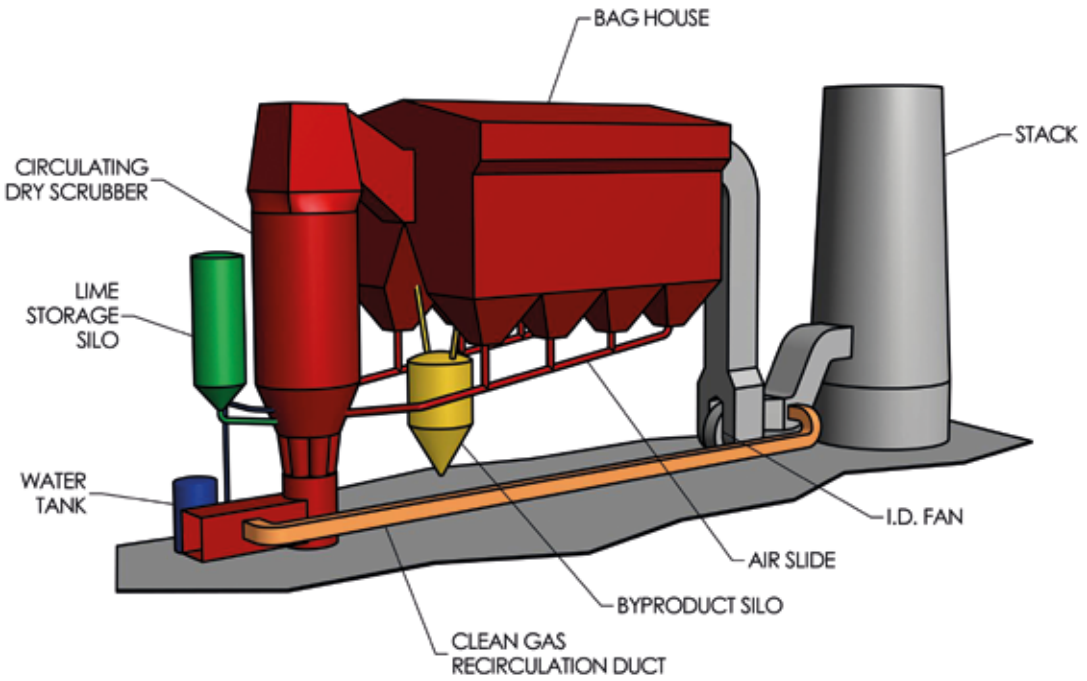


Image: Flow diagram



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CDS is controlled primarily by three separate feedback control loops: temperature, sulphur dioxide emission and pressure drop. Flue gas enters the CDS vessel and is cooled to enhance the mitigation reaction mechanism. Dry sorbent, hydrated lime, is conveyed into the vessel, which acts as a reactor, for scrubbing of the flue gas in the fluidised bed of ash and lime. The ash/lime mixture leaving the vessel is collected in the fabric filter (or electrostatic precipitator) and then recycled back to the CDS vessel to optimize the use of lime reagent. Scrubbed flue gas exits the fabric filter and out through the stack.

Your Advantages:

- Highest efficiency for acid gas scrubbing & capture of pollutants like SO_2/SO_3/HCI/Hg/metals, among dry or semi-dry technology
- Capable of 50% turndown without clean gas recirculation
- Fewer moving parts translates to high reliability & lower annual maintenance costs
- More efficient and rapid humidification of gas
- Zero liquid effluent discharge

Spray Dryer Absorber - precision and reliabilty for pollution control

Clyde Bergemann´s Spray Dryer Absorber (SDA) incorporates a state-of-the-art SDA vessel with direct drive-variable speed rotary atomisers, pulse jet fabric filter design and reagent storage and preparation systems built to our specifications.
Flue gas enters the SDA system through an inlet gas disperser located at the top of the vessel. Swirl vanes in the disperser turn the gas counter-current to the rotating atomiser disk and directs it into the chamber where it comes into contact with the atomised reagent slurry. Acid gas absorption, droplet evaporation and gas cooling occur as the flue gas mixes with the slurry. Scrubbled flue gas and entrained particulates exit through the outlet duct and are collected in the downstream particulate collector.

Your Advantages:

- Over 97% removal of acid gases, including SO_2
- Precise control of droplet size
- Efficient mixing of gas and atomised slurry
- Rapid response to variations of gas conditions
- Consistent emissions control performance
- Continuous operation during system maintenance when equipped with multiple atomisers

Proven to Remove over 97% of Acid Gases and Mercury

Dry Sorbent Injection - Proven Technology for Reduced Emissions

Clyde Bergemann offers dry sorbent injection (DSI) technology for introducing sorbents into the gas stream to reduce pollutants such as acid gases, mercury and other heavy metals. This reliability comes from applying proven material storage and conveying technologies to the various sorbents that can be used for mitigating emissions.

Our injection systems are designed to accommodate readily available sorbents. For SOx, and other acid gas emissions, Trona, sodium bicarbonate or hydrated lime is typically used. For mercury control, the choice would be powdered activated carbon (PAC), or brominated powdered activated carbon (BPAC) for low chloride fuels.

Mercury Reduction

The current preferred technology for mercury control is by the injection of activated carbon. The concept is that the mercury adsorbs onto the surface of the activated carbon. Depending upon the characteristics of the fuel, either a standard powdered activated carbon (PAC) or a brominated activated carbon (BPAC) can be injected into the flue gas stream to achieve a given reduction in mercury.

Injection is typically after the air heater where gas temperatures are below 177^{O} C/350^{O} F.

Removal efficiencies and reagent consumption will vary according to the type of APC equipment downstream. A fabric filter system can achieve mercury removal efficiencies greater than 90% whereas plants that utilise an electrostatic precipitator typically experience lower removal efficiencies and/or higher reagent consumption rates.

Your Advantages:

- Low capital investment costs
- Continuous operation during maintenance
- Optimised dispersion of dry sorbent
- Accurate control of sorbent injection rate
- Compatible with fabric filter and electrostatic precipitator technology
- System pre-assembly and testing to reduce installation cost and schedule

Rebuild, Replacement and After Sales Capabilities

Clyde Bergemann's experienced engineers evaluate the most cost effective approach to performance enhancement, refurbishment or replacement of air pollution control technology. Design, supply, service, installation and guaranteed performance provide a complete package to our customers.

Mechanical Systems

- correction of existing collector problems
- designs provided to minimise wear and tear
- improved performance
- increased capacity
- increase service life of aged equipment

Electrical Systems

- improved reliability of air pollution control technology
- state-of-the art microprocessor based controls

Rapping Systems

- increased availability leading to better performance
- controlled rapping for precise operation
- maintenance free
- designed for maximum service life and easy operator interface

Our experienced teams of trained personnel make thorough field inspections to determine the most economical and efficient approach to system performance improvement and to identify maintenance requirements. Additionally, experienced construction and service engineers assist in the erection, start-up and commissioning of all of our technologies.

Our extensive inventory of critical spare parts for our equipment supports long term system optimisation programs or immediate parts requirements in a prompt and accurate fashion. We can also provide spare parts for our competitors' technologies.

Technologies Proven to Ensure Target Emission Reduction Levels are Reached

Case 1
New Air Pollution Control technologies to the existing Petrobrazi oil refinery in Romania with OMV Petrom S.A.Fabric

In 2014 Clyde Bergemann completed a turnkey project for the retrofit plant in Romania. As part of the modernisation upgrade and expansion program Clyde Bergemann supplied and installed a new Electrostatic Precipitator (ESP) and a Dust Removal System (DRS) including stack to meet the emissions regulations in Romania. The ESP, DRS and stack are located on a Fluid Catalytic Cracking (FCC) process on the outlet of the existing Waste Heat Recovery Boiler.

To collect particulate matter the filter is equipped with factory built MODULOK™ modular collector plates.

Your Advantages:

- The overall program contributed to a cleaner environment with emission reductions well within the target limits
- Fully integrated solution covering all equipment and facilities
- Complete turn-key responsibility covering all civil, mechanical, electrical & automation designs and supply as well as the installation works, in the Clyde Bergemann scope

Case 2
Fabric Filter Equipment for Russia´s largest coal-fired power plant - Reftinskaya GRES

In 2013 Clyde Bergemann received a large scale contract with Enel OGK5, the Russian subsidiary of the major European Power utility Enel Spa., Italy. The project scope included design, manufacture, delivery and commissioning of a fabric filter for the 500 MW capacity Unit 7 at Reftinskaya GRES, one of the largest coal fired generating stations in the region. Clyde Bergemann was responsible for designing in compliance with Russian design standards and obtaining all necessary Russian legal permits for the delivery to the site in the Urals.

The Clyde Bergemann up flow technology and patented stepped inlet manifold design provided superior gas distribution in the filter.

Your Advantages:

- New Fabric Filter designed to suit existing plant space constraints, replacing the old ESP
- Complete engineering solution including modification and upgrade of the existing structures
- State of the art instrumentation and control system

Turnkey upgrade of electrostatic precipitators

Case 3
Fabric Filters, Mercury and Acid Gas Control on a 1,000 MW USA Coal-Fired Power Generation Facility

In May 2010, Clyde Bergemann completed a three year environmental retrofit project on two major power generation stations in northeast USA. The turnkey project involved retrofitting six boilers in total at two plants and included demolishing existing equipment, hot-to-cold air heater ductwork conversions and erecting new air pollution control systems and balance of plant equipment, associated piping, electrical power and control work and thermal insulation.

The primary air pollution control technologies included ten pulse jet fabric filters for particulate control, six trona storage and injection systems for SO_2 reduction and six powder activated carbon injection systems for mercury reduction.

Your Advantages:

- SO_2 emissions reduced by > 82%
- Mercury levels reduced by > 97%
- Particulate emissions reduced to < 0.001 lb/MMBtu
- Sorbent injection rates were below guaranteed levels
- Significant operating cost savings over the lifetime of the systems produced by lower system pressure losses combined with reduced sorbent and power consumption rates

Case 4
Electrostatic Precipitators
E.On - Puertollano Power Plant, Spain

In 2009 Clyde Bergemann provided a full turnkey solution for an upgrade of the Puertollano power plant's ESP systems. The upgrade included demolition of redundant ESP's, installation of components for the final field of the two existing ESP's, ducting from the air preheater outlet and the addition of a new parallel ESP.

Additionally, new transformer rectifiers and controls, inlet and outlet ducting, ash handling system, access walkways and insulation and sheeting were all included.

Your Advantages:

- Shutdown of only 50 days compared to competitors 100 days therefore increased plant availability
- Preliminary testing showed reduced emission levels from 200 mg/Nm^3 to < 50mg/Nm^3
- Lower cost solution in comparison to competitor solutions offered

Clyde Bergemann is represented in over 40 countries worldwide.

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