Wet Electrostatic Precipitators: A proven technology for sulfuric acid gas and mist cleaning

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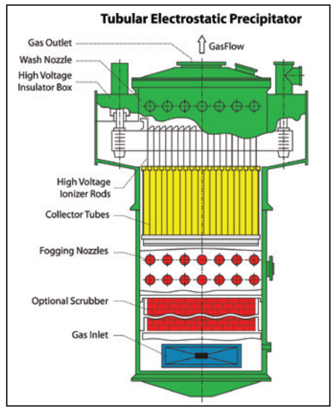
The extremely high collection efficiency of sub-micron particulate and sulfuric acid mist makes the wet electrostatic precipitator an ideal choice for gas cleaning of processes with a very high concentration of emissions, like metallurgical and spent acid regeneration plants and sulfur recovery units (SRU). These plants typically produce fine particulate and sulfuric acid mist in the sub-micron range. This particulate and mist, if allowed to pass into the contact section of the acid plant, will result in fouling of the catalyst bed, excessive corrosion, and potentially the production of "black" or low quality acid.

Due to the high dust and acid removal requirements that are necessary, the wet electrostatic precipitators operate at collection efficiencies of 99.5 to 99.9 percent in various metallurgical process facilities, such as a sulfuric acid regeneration plants, zinc roasting plants, nickel flash smelters, copper smelters, and sulfur recovery units (SRU).

Acid mist precipitators or wet electrostatic precipitators (WESPs) are used in metallurgical acid plants to protect the catalyst beds. These plants are usually non-ferrous smelters, processing copper, zinc, lead, nickel, molybdenum, zirconium, and gold ores. WESPs are also used in spent acid recovery sulfuric acid plants where reprocessed or "spent" acid is converted into SO_2 feedstock for the formation of new sulfuric acid. Another application for WESPs is protecting the sulfuric acid plants used to reduce SO_2 and SO_3 emissions from heavy oil- and coal-fired boilers where the fuel has high concentrations of sulfur.

WESPs efficiently collect sub-micron dusts and acid mists. These fine particulates usually contain heavy metals, such as arsenic, lead, zinc, cadmium and, other metals depending upon the content of the ores. The emission from these metallurgical processes can contain flotation oils used to separate the various constitutes in the ore, such as sulfides. These oils evaporate in the high temperature of the metallurgical process and condense into mists, in the quenching section of the gas cleaning plant, and are then collected by the WESP. WESPs are also used for tail gas cleaning where it is necessary to remove particulate, mists, and aerosols, as well as reduce visible emissions.



Tubular electrostatic precipitator

Advantages of wet electrostatic precipitators

WESPs have several advantages over other types of gas cleaning equipment, including high efficiency collection of submicron particulate, mist, and

Beltran WESPs at copper smelting plant.

aerosols; and low pressure loss since the internal structure is open tubes, which do not easily plug or restrict gas flow. Another advantage of WESPs is that they can remove dusts that are conductive or have high resistivity, which are problematic for dry ESPs. Since a lot of metallurgical dusts have high resistivity, the wet environment of the WESP coats the particulate with moisture, which makes the dust conductive and enables collection with high efficiency.

WESPs operate by charging and collecting the particulate, mists, and aerosols with a corona formed by the collector surfaces and the sharp pointed discharge electrodes. High voltage power supplies charge the WESPs at high voltage, usually between 30 and 75 kilovolts, depending upon the WESP design and the process gas conditions. The WESP is usually formed with a collector of tubes or plates, with discharge electrodes held in the center of the collector structure by a high voltage frame supported by non-conducting insulators. Since the process gases are saturated and contain electrically conductive mists and aerosols, the insulators have to be operated dry, purged by dry, clean, and heated purge gases (usually ambient air). The WESP can be operated by the collection of liquid acid droplets, mists, and aerosols, flushing the collector plates, or with the operation of continuous fogging sprays into the collector section. WESPs usually have deluge or wash nozzles mounted to periodically wash the WESP of solids and collected particulate, which may not be removed by the draining acid/water collected by the WESP.

Beltran WESP design

The collection efficiency of the WESP is expressed in the DA equation and is an exponential function of the three parameters: 1) collector surface area (A); 2) gas flow rate (F); and 3) drift velocity (W). These are really two parameters, A/F, which are related to the size of the WESP box, and W, which is proportional to the electrical power applied to the process gases. Since the efficiency is proportional to the product of these two parameters, it is possible to design a WESP either with a large box and low power, or a smaller box and higher power, for the same efficiency. The consumption of electrical power for WESPs is usually low compared to other gas cleaning equipment such as venturi scrubbers, bag filters, or other types of high pressure devices. WESPs are constructed of expensive, corrosion-resistant materials, making it better to maximize W and minimize A/F, the size of the WESP. The exponent in the DA equation can be substituted with the parameters voltage, tube or plate length, inter-electrode spacing, and gas velocity through the collector. The efficiency increases with greater field strength (operating voltage divided by inter-electrode spacing), collector length, and reduced process gas velocity.

Beltran WESPs at zinc roasting operation.

The collection efficiency of the WESP varies with the size of the particulate, mist, or aerosol. Since gas phase reaction and evaporation/condensation form particles around 0.1 to 1.0 microns, considerable acid mist and particles form in this size range. As particles increase in size from the submicron range they are more easily collected since field charging increases. Also, as particles decrease in size from the submicron range they are more easily collected, since diffusion charging increases. Therefore the collection efficiency curve versus particle size forms a U-shaped curve with its minimum in the submicron range. The collection efficiency is also related to corona power of the WESP, with the minimum efficiency increasing with greater corona power. To minimize the size of the WESP and maximize the operating efficiency, the WESP should be designed to maximize W, the drift velocity, or the rate at which particulate, mists and aerosols move to the collector plates.

Although the basic principle and design of the electrostatic precipitator have been around since the early 1900s, recent innovations have produced dramatic advances in efficiency, cost effectiveness, ease of maintenance, and wider applicability.

Beltran Wet Electrostatic Precipitators in particular have demonstrated a level of performance that environmental and plant engineers appreciate. However, it is important for engineers to recognize that there are key differences in features and benefits offered by the various precipitator systems. Although they may share the similar operating principles and basic structures, WESPs can vary greatly in design, materials, gas flow rate, durability—as well as collection efficiency.

A basic WESP is comprised of an array of ionizing electrodes such that negatively charged discharge rods generate a strong electric field and corona. These are surrounded by or interfaced with positively charged or grounded collection surfaces, which attract and hold the charged particles. In operation, the source gas is passed through the electrode array, which induces a negative charge in even the most minute, submicron-size particles, propelling them toward the grounded collection surfaces, where they adhere as the cleaned gas is passed through. The captured particles are cleansed from the plates by recirculating water sprays; residues, including aqueous sulfuric acid, are extracted for further use or disposal. The cleaned gas is ducted to downstream equipment or to the stack, depending on the application.

The round tube design has the disadvantage of wasting space in the vessel due to the nesting of the round tubes, so round tube WESPs require larger size vessels. If the size of the vessel is not increased, the gas will flow through at a greater velocity and require longer tubes for comparable collection efficiencies. This then requires the WESP to be considerably taller and the tubes longer for the same efficiency. This has a further disadvantage in that the high voltage discharge electrodes are longer and the electrodes have a greater likelihood of swinging or vibrating during operation. This causes sparking and the WESP to operate at lower field strengths and voltages, lowering operating power and efficiency. In addition, longer tubes are more difficult to clean, since the wash sprays have more difficulty penetrating into the high L/D tubes. This causes dust build-up in the tube, which increases sparking and reduces operating voltage, operating power, and collection efficiency.

There is a major economic disadvantage to designing WESPs with round tubes, in that the surface area on the outside of the round tube is wasted. Only the surface area of the inside of the tube is utilized for collection; therefore, the round design has to use twice the collector material to obtain the same collector surface as the flat plate, hexagonal, or square tube design.

Beltran WESPs are designed with the use of advanced materials of construction, and utilize the advantages of other shape collector tubes, such as the hexagonal and square tubes. Flat plate electrostatic precipitators have operated efficiently since the early part of the last century. This design does not have uniform field strength, since the field is greatest opposite the discharge electrode wire or spike and weakest at the area between the discharge electrodes. This difference is overcome by making the plate length slightly longer to compensate for the field asymmetry. Flat plate ESPs have operated at high efficiency for over 100 years.

Beltran WESPs are available with two designs: the hexagonal tube design and the square design. The hexagonal design has the advantage that its shape is almost the same as a round tube (field strength symmetry) but it takes advantage of the fact that both sides of the hexagonal wall material are utilized for the collection surface. However, when hexagonal tubes are nested into a round, square, or rectangular housing vessel, because of the nesting shape of the hexagonal tubes, about 15 percent of the cross-sectional area is wasted. This then requires an increase in tube length to compensate for the increased velocity for the same collection efficiency.

The most efficient design when considering collection efficiency, compactness, and economic design is the square tube collector configuration. The square tube collector completely utilizes the cross-section of a square or rectangular vessel and can be effectively utilized in a round vessel, as well as the hexagonal. Due to the square tube's high utilization of the vessel cross-section it can be operated at a lower velocity, so that the required tube length is lower, making it more efficient and easier to wash since the wash sprays penetrate the collector. The high voltage frame is more rigid, does not swing, and stays more accurately aligned, resulting in more efficient and reliable performance. Because of the shorter tube length, lower stabilizing insulators are not required, and the insulators can be mounted on the clean gas side of the WESP, reducing the requirement for heated purge air and resulting in more reliable WESP operation.

The Beltran WESP collection efficiency is increased with increasing corona power. Multi-pointed star discharge electrodes are utilized to maximize corona power and WESP operating efficiency. Multi-pointed star discharge electrodes overcome the problems of current suppression of the space charge effect, whereby the corona power is significantly reduced by the high concentration of submicron particles, mists, and aerosol present in the process gases. This reduces the corona power of the WESP operation and can lower the collection efficiency. Multi-pointed star discharge electrodes overcome this issue by enabling the multi-pointed stars to charge and repel some of the submicron particles, then enabling the next star to increase its corona power, and further repeating this phenomenon almost 100 times as the gases flow up the tube. This type of electrode can produce considerable efficiency in single or multiple pass WESPs, usually utilized in acid plants.

WESPs can be utilized in various configurations, such as: single WESPs, two WESPs in series, two WESPs in parallel, or multiple WESPs in parallel or in series. Smaller gas flows are usually treated with one WESP. This also depends on the efficiency requirements; however one WESP unit can produce reliable service at 99.5 percent efficiency, for smaller flows. Typical plants have two WESPs in series so that one WESP can be washed while one operates. Sometimes two WESPs are designed to be utilized in parallel, for similar purpose. Two in series has the advantage of the first WESP overcoming the current suppression condition while the second WESP operates at full power. This will depend on the gas flow rate, inlet and outlet process conditions, amount of particulate, mist and aerosol at inlet and outlet, etc. Larger plants will require more WESPs in parallel and usually two WESPs in series; so one WESP can be taken offline for washing or maintenance, or washed online.

Materials of WESP construction

Beltran WESPs are built of metal alloys, thermoplastic materials, thermosetting materials, and conductive graphite composite materials. Metal alloys are expensive and have extended delivery time, but their biggest disadvantage is the unreliable performance with regard to corrosion. The sulfuric acid WESP operates in highly corrosive environments, including sulfuric, hydrochloric, and hydrofluoric acid and other impurities, as well as increased temperature. Because of the high cost of more robust chrome-nickel-molybdenum alloys, like C-276, C-22 and C-2000, designers are attempting to utilize less of these materials.

- Conductive graphite composite materials have these advantages:
- Highly corrosion resistant
- Good mechanical properties
- Electrically conductive
- Homogenous
- Do not require water/acid film to ground WESP
- Fire retardant and thermally robust
- Cost effective

Beltran WESP systems are designed with advanced electronic controls, which can optimize operating parameters such as gas flow, saturation temperature, corona intensity, etc., to achieve maximum efficiency.

Since the WESP operates at cooler temperatures—usually at the process gas saturation temperature between 100-170° F— the WESP is uniquely adept at capturing condensable organic materials and acid mists, making this technology an invaluable component for sulfuric acid production plants, petrochemical refineries, and spent acid recovery plants.

Beltran Technologies has more than 1,000 installations worldwide and over 100 WESPs operating at sulfuric acid plants.

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