WET ESP FOR THE COLLECTION OF SUBMICRON PARTICLES, MIST AND AIR TOXICS

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ABSTRACT

New regulations are restricting particulate, acid gas and organic emissions to extremely low levels. Wet tubular electrostatic precipitators, with their ability to generate strong electrical fields in a wet, cooled atmosphere have demonstrated particulate emissions less than 0.0003 gr/dscf, with toxic organic, heavy metals and acid mist collection exceeding 99%. Designing parameters, field test data and operating data from installations on these processes are discussed in the paper.

INTRODUCTION

New and proposed regulations are restricting particulate, acid gas and organic emissions to extremely low levels; with emphasis on heavy metal and toxic organic concentrations. Conventional scrubbing systems (wet or dry) are generally not effective in controlling submicron emissions, consisting primarily of acid gas mists, condensed heavy metals and condensed organics. Wet tubular electrostatic precipitators, because of their ability to generate strong electrical fields in a wet, cooled atmosphere, have been shown effective in "polishing" the flue gas. The net results are demonstrated particulate emissions as low as 0.0003 gr/dscf; overall heavy metals collection efficiencies exceeding 99% and toxic organic removal greater than 99.9999%.

These units have been used as the primary air pollution control systems, or as retrofits to up- grade existing Air Pollution Control (APC) systems.

DESIGN DESCRIPTION

Beltran Technologies has developed a unique wet tubular precipitator as a result of considerable research and development. The typical Beltran wet ESP is a vertical-flow, hexagonal or rectangular tube type precipitator. The schematic is shown in fig. 1. Typically the flue gases enter at the bottom and rise through the precipitator. There are generally two sets of spray headers. The first set continually cools and saturate the flue gases. The spray header set at the top and directly below the collector washes down the collector and electrodes. These are operated on a periodic as needed basis.

The tubular precipitator consists of an ionizing section and a collection section. The discharge electrode is in the form of a rod or tube with a number of sharp corona generating discharge points. Various collecting tube geometries have been utilized over the years, the most common being the round. The square configuration and/or the hexagonal shape is chosen because of ease in manufacturing and higher collection area per square foot of the cross-section. These geometries are much more space efficient than the round shape.

The precipitator uses solid ionizing rods instead of wires. The unique electrode design with ionizing stars is capable of attaining higher average electric field strengths than any other plate and wire or tube and wire designs. This higher field strength results in higher particle migration velocities that translate into a reduced collector area.

Entrained particulate matter and fog droplets that enter the electrostatic section are charged by the high voltage produced by the electrode and collected on the grounded plates. Most of the particulates are flushed into the bottom of the housing. The high voltage insulators are kept clean continuously using a purge-air system. These features result in very low maintenance. Optional internal scrubbers to remove acid gases, can be installed in the lower part of the housing.

WHY WET ESP?

The wet ESP is the most efficient sub-micron particulate collector. It's collection mechanism is electrical charging as opposed to inertia in cyclones and scrubbers.

Since fine particles do not have a significant mass, they generally go through cyclones and scrubbers with minimal collection. Also, high pressure drop is associated with cyclones, scrubbers and bag houses. The wet ESP has only a one-inch water column drop and is low in maintenance.

The unique electrode design allow for generation of a corona field 4 to 5 times more intense than standard wet or dry ESP's (Fig. 2). A major benefit of wet operation is that it eliminates particle re-entrainment.

There are other benefits to wet operation:

- Gas adsorption can take place
- Water provides a continuous cleaning action
- Lower gas stream temperatures are possible, allowing particulate to form by condensation or gas phase reaction
- Water is available as a quenching medium in case of duct fires
- Collection section acts as a demister
- Wet precipitators are easily integrated with scrubbers

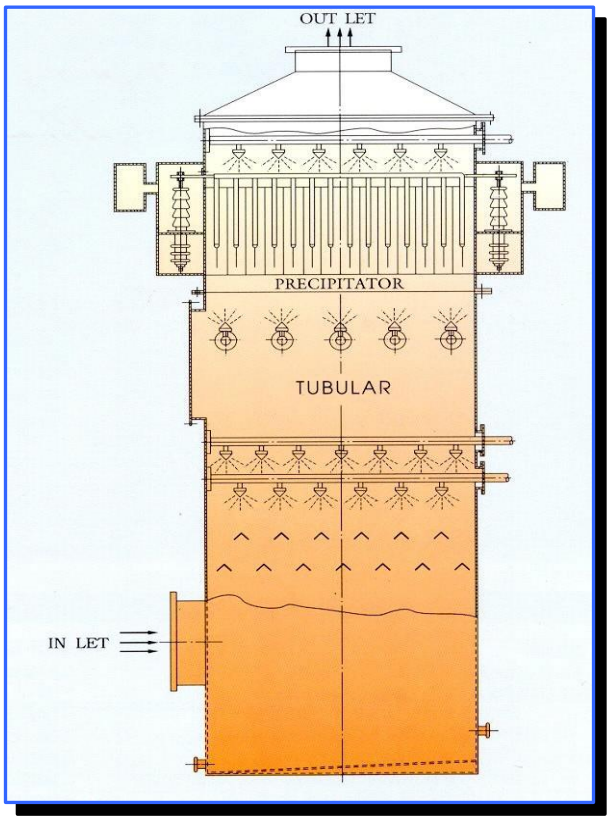

FIG 1

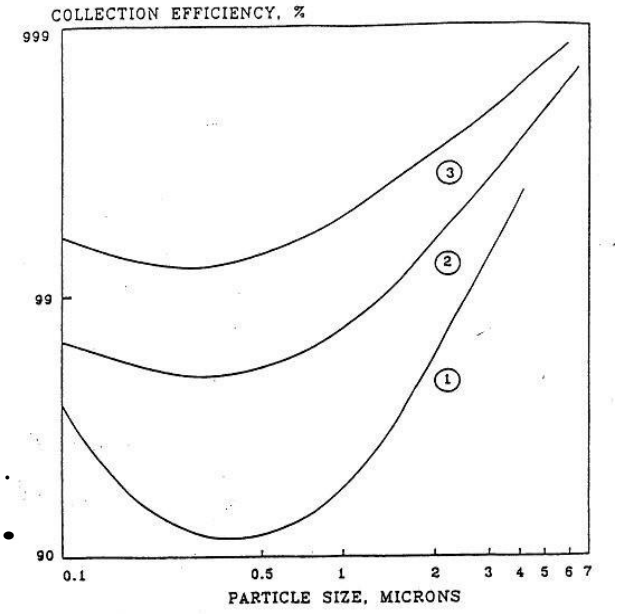

Fig. 2. Tubular electrostatic precipitator. Performance at Corona Power Levels of 1) 200, 2) 400, and 3) 1000 watts per 1000 CFM.

INDUSTRIAL APPLICATIONS

Beltran wet ESP have been installed on a variety of industrial emissions:

- Incineration
- Alternate Energy Sources

- SO_2 Scrubbing Processes
- Primary and Secondary Non-Ferrous Metals Industry
- Steel Industry
- Chemical Industry

All of these applications involve heavy concentrations of sub-micron particles.

Since the wet ESP is the most efficient sub-micron particulate collector; wet ESP is able to work in these applications very efficiently for capture of submicron particles.

1. INCINERATION EMISSION CONTROL

The incineration of waste materials, especially plastics, can generate hydrochloric acid, hydrofluoric acid and sulfur oxides. The corrosive nature of these flue gases demands that special attention be given to the materials of construction. A reasonable alternative to corrosion resistant metals is to use fiberglass reinforced polyester (FRP). The electrically conductive sections of the ESP can be made from special conductive FRP.

The wet ESP has been used with great success in many industrial applications where fine particulate emissions are the major concern. Overall collection efficiencies in excess of 99% have been demonstrated on a consistent and reliable basis.

2. ALTERNATE ENERGY SOURCES

Retort Oil Shale

Exhaust gases from oil shale retort contain a considerable amount of water (4 to 50 grain), and hydrocarbons (304 grain/SCF). Some dust as shale fines, and carbon is also present. The carrier gas is combustible and has high heating value. Very high tar mist removal efficiencies are required. Two Tubular precipitators in series have a 99% plus collection efficiency. Since the carrier gas is combustible, every flange connection is sealed tightly to prevent in-leakage of oxygen.

Coal/Wood Gasification

Coal gasification has received much attention in recent years. Similar processes have also been developed for wood gasification and municipal refuse gasification. Precipitators used in these processes are for gas clean up rather than for pollution control. Coal tar, fine unburned carbon, char ash, and volatilized heavy hydrocarbons are present in the gasifier exhaust. The gas cleaning train generally consists of a cyclone or some mechanical pre-filter after the gasifier, then a heat exchanger to recover heat, a medium or low energy scrubber to cool the gas and remove heavy tar particles, and a wet Tubular ESP to remove fine hydrocarbons. The particulate loading after the gasifier can be as high as 9-10 grains/CF of char (in case of wood gasification) and almost as much of hydrocarbons. Outlet loadings from the precipitator of 0.003 grain/CF or less are required.

3. SO_2 SCRUBBING PROCESSES

Many processes generate SO_2 in concentrations that are too low to be handled effectively in acid plants, but are high enough to violate air quality regulations. Scrubbing of SO2 gases is generally accomplished using one of the following processes:

1. Lime/Limestone Slurry Systems
2. Soda Ash/Caustic Scrubbing
3. Soluble Alkali Processes
4. Ammonia Scrubbing

Major industrial sources where these desulfurization techniques have been utilized are:

a) Utility plants
b) Recovery boiler off gases in pulp and paper industry
c) Cogeneration using petroleum coke
d) Tail gases from some metal smelting operations
e) Tail gases from single absorption type acid plants

Since FGD systems for utility plants are a topic for a separate paper by itself, the remaining four processes will be addressed in this paper.

Paper Industry

In ammonia based acid sulfite pulping processes, recovery boiler off gases are passed through an ammonia absorber. In the absorber, Ammonium sulfite and Ammonium bisulfite are produced. A very dense plume is observed at the absorber stack. The particle size is extremely fine, between 0.1 and 0.5 microns in diameter and the particles are not completely soluble in water.

Tubular precipitators used on these applications are constructed of fiberglass. A specially conductive fiberglass resin was developed for this application. The high voltage discharged electrode is made of graphite and high molybdenum stainless steelCarpenter-20 discharge discs have also been used. The particulate concentration is generally in 0.4 to 0.6 grain/CF range for properly operated units. Two pass Tubular precipitators have collection efficiencies in excess of 99% under the entire range of process conditions.

Cogeneration

Cogeneration using petroleum coke feedstock has been investigated. The exhaust from tangentially fired pulverized coke boiler is first cleaned by a Dry ESP. Ammonia scrubbing or Double alkali processes are used from SO_2 scrubbing. The presence of heavy metal impurities in the fuel act as a catalyst to promote further oxidation of SO_2 to SO_3. Tubular precipitators are used to collect fine acid mist and fine sulfite-bisulfite emissions.

Metal Smelting

Primary and second metal production usually involves smelting of the ore in a reduction furnace. Sulfur oxides generated during this operation are generally cleaned and taken to the acid plant if the concentration is above 5 percent. Tubular precipitators are used to control emissions. These precipitators are operated wet. Particulate loadings of about 0.3 to 0.4 grain/CF are common and heavy moisture load is usually present. Corrosive conditions dictate use of plastic or special alloy construction.

Acid Plants

In older acid plants in single absorption plants, 98% SO_2 conversation efficiency can be achieved. Tail gases from these plants require SO_2 scrubbing systems to comply with Federal regulations on allowable SO_2 emissions. Ammonia scrubbing is widely used. Tubular precipitators are used to control acid mist and sulfite-bisulfite emissions.

4. NON-FERROUS METALS INDUSTRY

Tubular Precipitators have been used in following the Non-Ferrous Metal operations.

1. Zirconium Calcining
2. Silver/Gold Refining
3. Molybdenum Roasting
4. Nickel Recovery using Electric Arc Furnace

Zirconium Calcining

Zirconium and hafnium are used in the nuclear industry for the fuel rod casings.

Zirconium and Hafnium are mined as Zircon sand. The ore is chlorinated, selectively precipitated, passed through a separation operation, chlorinated again, and then reduced. The exhaust from the calciner contains Zirconium oxide, Hafnium oxide, a trace amount of elemental sulfur, some chlorides and sulfuric acid mist and sulfur dioxide. The exhaust is first treated in a caustic packed bed scrubber. The two-pass Tubular precipitator made of FRP is used to remove fine particulates and acid mist. Collection efficiencies in 97-99 percent range are observed.

Silver/Gold Refining

In the bisulfate slime fusion process, filtered slime obtained from the tank house electrolytic refining operations is fused in two rotary batch kilns. The slime consists of appreciable quantities of Copper, Silver, and Selenium. Silica, Lead, Tellurium, Arsenic, gold and other organic materials are also present. The size of particles entering the precipitator is in the sub-micron range. Generally, the particulate loading is in 0.1 to 0.2 grain/CF, but at times can go as high as 0.4 to 0.5 grain/CF. Since the exhaust volumes are small from these processes, a low throughput velocity (high SCA) single pass unit is used for this application. Collection efficiencies of 98-99% are obtained on this application.

Molybdenum Roaster

Molybdenum disulfide is oxidized in the multilevel hearth furnace to Molybdenum trioxide and sulfur dioxide. The exhaust is first passed through a baghouse and then through a lead lined quench scrubber. The exhaust stream entering the precipitator contains organic compounds and sulfuric acid mist with some oxides of Molybdenum, Selenium, Rhenium, and Mercury. Chlorides and trace amounts of fluorides are also present in the air stream. Fiberglass reinforced plastic with synthetic veil on the inside surface is used as a material of construction. A high SCA, two pass Tubular precipitator system has collection efficiency in excess of 99%. The cleaned gases are then taken to an acid plant.

Nickel Recovery

Wastes from specialty steel making processes contain appreciable amounts of Nickel, and Chromium. The exhaust from electric arc furnace is taken to a high pressure drop (45" w.c.) venturi scrubber. The sub-micron particulate emission from Venturi was still very high (0.1 to 0.2 grain/CF). Apart from causing opacity problems, the particulate carryover was causing maintenance problems for the high pressure fan. Two pass Tubular precipitators installed on this process completely eliminated this problem and plume opacity is reduced to almost zero. The unit is operated continuously wet to prevent accumulation of lead and zinc on the collector plates.

5. STEEL INDUSTRY

Typical applications where Tubular precipitators are used in the steel industry are:

1. Scarfing
2. Sintering
3. Coke Oven Exhaust

Scarfing

Very fine Iron oxide particulates are created during scarfing operations. Particulate loadings of 1 grain/CF and greater are commonly encountered. The particle size is mainly in the sub-micron to 2 micron range. The exhaust stream coming from the scarfer is generally completely saturated. Wet Tubular precipitators are used in this application. Collection efficiency of 99 percent and higher are

required to meet the opacity regulations.

Sintering

Sintering is generally used to beneficiate ores by a high temperature agglomeration process. Sintering process transforms raw ore into a product which is uniform in size, has not many fines, is convenient to handle, and has better chemistry. Particulate loading from these processes range from 0.1 to 0.5 grain/CF. Very high amounts of condensable organic matter is also present (0.05 to 0.3 grain/CF). Tubular units using stainless steel construction have been used in this application.

Coke Oven Exhaust

Exhausts from coke oven batteries are cooled in a quencher and then cleaned in a Tar mist type Tubular precipitator. The exhaust contains tar, fine unburned carbon, ash, etc. The coke oven gas, after being cleaned, can be used as a fuel source. Part of the cleaned gas is further cleaned in a fuel gas precipitator to be used to fire coke oven batteries. Since the carrier gas is combustible, all the precautions required for oil shale precipitators are also applicable here. Insulator purging is done using cleaned gas from the fuel gas precipitator.

6. CHEMICAL INDUSTRY

The Tubular precipitators are used as acid mist precipitators in:

1. Sulfuric Acid Plants
2. Sulfonation Plants

Sulphuric Acid Plants

Tubular precipitators have been used in metallurgical type acid plants to clean up smelter gases before they can be taken to the acid plant. Tubular precipitators are also used in sulfuric acid plants using H_2S or spent sulfuric acid as a feed material. Lead and FRP construction have been used in this service. In some applications, Hastelloy has been used. Conductive FRP construction, square tube has also been used. Two stage, two pass Tubular precipitators used on Copper smelter off gases and on Gold and Arsenic roaster off gases have achieved 99.5% plus efficiency.

Sulfonation Plant

Surfactants are organic compounds that have both a water soluble (hydrophilic) and a water insoluble (hydrophobic) group. Very dense white plume is generated during transfer of oleum to the storage tank. The acid mist loadings are generally 0.25 to 0.3 grain/CF. Very fine size distribution (0.1 to 0.3 micron) is encountered. Low throughput velocities are required to achieve high collection efficiencies (99.5%) and are used to control opacity of the exhaust stream.

CONCLUSION

Wet Tubular electrostatic precipitators are ideally suited in applications involving high concentrations of fine particulates or for control of organic and acid mists. Further, they are suitable for difficult and highly corrosive applications in gas cleaning.