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Proper design essential for storage, flow and metering of powdered activated carbon

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Powdered activated carbon (PAC) used as a sorbent for control of mercury emissions from coal fired power plants exhibits properties which can present challenging problems for storage, flow and metering. Over time, PAC material can densify and get packed in storage silos and possibly cutting off flow entirely. Controlled flow and accurate metering are critical to effectively using PAC and to achieving targeted mercury emission reductions. Inadequate equipment and system design can result in excessive PAC consumption resulting in high operating costs or insufficient PAC injection resulting in mercury removal rates that are out-of-regulatory compliance.

A typical PAC storage and metering system consists of a carbon steel storage silo, silo vent filter, pneumatic fill line, discharge assisting equipment such as fluidizing bin bottoms or bin activators, intermediate storage hoppers/bins, and gravimetric or volumetric screw feeders or rotary airlocks for discharging of PAC into a pneumatic conveying system. Suppliers also include all necessary valves, instrumentation and controls, and interconnecting piping. A dedicated truck unloading control panel should be provided and include the necessary lights, switches, relays and alarms to ensure safe filling, storing and conveying of the material. All components up to the pneumatic conveying system are located out of sight inside the silo skirt area or may be mounted on the silo exterior walls or top deck. A typical three feed train system layout is shown in Figure 1.

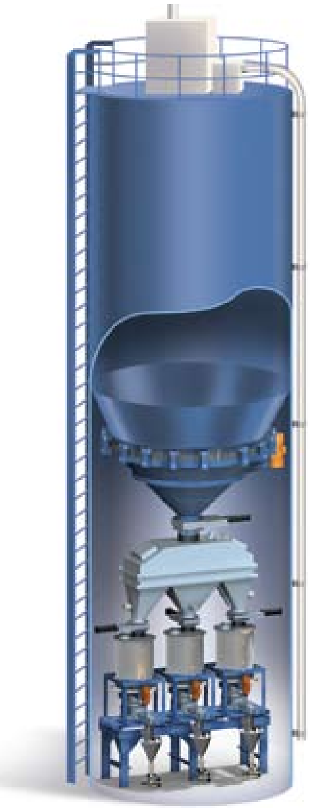

Figure 1: *PAC Storage & Metering System showing bin activator, distribution hopper, intermediate storage bin, feeders, eductor inlet cones, and eductors (all located within the silo under-skirt area)*

With the exception of the silo ladder, pneumatic fill line, silo vent filter, and truck unloading control panel, all system components shown in Figure 1 are shipped pre-assembled. After rigging at the jobsite, only process and utility connections at the system battery limits are required to complete installation.

PAC storage silos are engineered to meet PAC flow demand. A typical PAC silo for a 2 or 3 feed system is 14 feet in diameter X 80 feet tall. The physical properties of PAC (bulk density, particle size distribution, moisture content and compressibility) can cause significant compaction within the tall silo. Discharge of PAC, already compacted in the silo, to the downstream feeders can be complicated by material rat holing or arching.

Bin activators (see Figure 2) overcome potential flow problems and reduce PAC bulk density variation. Bin activators influence the entire mass of PAC

Figure 2: *Bin activator*

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in the silo whereas aeration devices such as air pads, air slides, buttons or cones provide only localized influence. Compaction issues and resultant variations in PAC bulk density associated with aeration/fluidization devices lead to inaccurate feeder performance. Properly designed bin activators consist of a 45 degree sloped section, primary and secondary baffles, and a vibrator/motor assembly. Conical sections with slopes that are too shallow can impede flow causing build-up of material thus requiring high energy input for material mobilization.

Steep cone sections can lead to compaction requiring large outlet sizes or cycling of the vibrator unit. In these instances, the forces required to activate the material in the bin exceed the forces required to discharge material from the activator outlet. This can cause material to compact and jam and stop flow altogether. An optimal conical shape promotes material flow with minimal force requirements, high efficiency and low energy consumption. A cone shaped primary baffle provides maximum vibratory force into the material thus facilitating even drawdown of material in the silo on a first-in, first-out basis. An adjustable secondary baffle located beneath the primary baffle moves at an amplitude different than that of the activator body. This creates motion in the material at the activator outlet assuring continuous free flow. The bin activator should run continuously when discharging material, and not cycle because cycling can cause first-in, last- out product flow. Bin activators should be designed with a mounting ring for welding or bolting to the silo.

Using a bin activator also reduces utility costs because no additional compressed air beyond instrument air (for pneumatic gates) is required. Furthermore, maintenance costs associated with an air fluidization system are eliminated and the chance of generating fugitive dust is dramatically reduced.

Once the PAC material is effectively discharged from the silo through the bin activator, a distribution hopper feeding two or more intermediate storage bins separates and directs the PAC inventory for on-demand metering using gravimetric or volumetric screw feeders. Uniform flow distribution of PAC from the bin activator is achieved using the distribution hopper. Each hopper outlet is isolated using automated slide gate valves. Also, each outlet leg is equipped with a vibrator to further ensure reliable material discharge upon demand.

From the distribution hopper, material flows to two or more intermediate storage bins which also become the feed hoppers for the downstream feeders. Each intermediate storage bin should be equipped with a dedicated bin activator to provide positive, problem-free discharge of material. This bin (See Figure 3) coupled with a screw feeder is an integral part of the scale system.

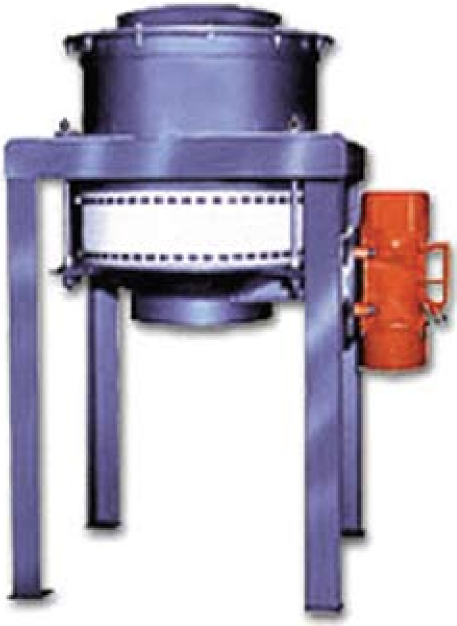

Figure 3: *Figure 3:Intermediate storage tank / feeder hopper*

PAC material is then discharged directly to volumetric or gravimetric feeders metering material into a pneumatic conveying system for injection into the flue gas duct. Volumetric feeders usually represent the simplest and lowest capital cost alternative. Here a fixed volume of material is discharged into the process on a unit time basis. If volumetric feeding with rotary valves in lieu of volumetric screw feeders is used, typical accuracies of about 5 percent to 10 percent on a minute-to-minute basis are achieved. As such, rotary valves are not recommended for this type of application due to PAC bulk density variation and the relative high cost of material.

Volumetric screw feeders are considerably more accurate than rotary valves, but are also subject to inaccuracies if the bulk density of the material varies as the feeder cannot recognize density changes. Thus volumetric feeders are best applied when the material bulk density is consistent and long term feed accuracy is not critical. Volumetric screw feeders require calibration on a regular basis to ensure that the mass feed rate at the maximum rpm is keyed into to the system controls. Calibration requires that an operator collect a material sample over a specified time period and at a known feeder rpm. The sample weight is measured and the true mass flow rate is calculated.

Some volumetric feeder designs incorporate an agitator/conditioner as part of a metering screw to condition and meter the material. This feature can increase the accuracy of the volumetric screw feeder to ±1-1½ percent. Currently available volumetric feeders feature only two moving parts (drive and screw) in a compact design providing low maintenance. (see Figure 4)

Figure 4: *Volumetric screw feeder with metering screw*

Gravimetric screw feeders are ideally suited for metering of powders, flakes, or pellets where it is necessary to precisely control feed rates on a loss-of-weight basis and in cases where the material bulk density can vary. As control of material flow is governed by weight, a weighing system to include platform scales, weigh hoppers or load cells is required adding cost as compared to volumetric feeders. Using the weighing system, dramatically higher feed accuracies are realized and performance can be documented. Loss-in-weight screw feeding is particularly useful in processes requiring multiple feeders to simultaneously dispense material.

For critical feed rate requirements typified by the metering of expensive reagents such as PAC, gravimetric feeding provides accuracies of ± ½ percent. Like commercially available volumetric screw feeders, gravimetric feeders can be provided with only two moving parts for reduced downtime and maintenance.

With PAC manufactures changing technology to provide much higher bulk density PAC material, it is extremely important to choose a screw feeder carefully. A gravimetric screw feeder which has the flexibility to change out the screw and tube should be chosen. This will address significant future PAC bulk density changes as well as future capacity increases and eliminate costly retrofits in the future. A typical gravimetric feeder, with controls, is shown in Figure 5.

Figure 5: *Gravimetric screw feeder controls*

While gravimetric screw feeders are slightly more expensive than volumetric feeders, in PAC applications for mercury abatement the payback of the incremental cost can occur within weeks. A typical system may have two feed trains, each delivering 300 pounds of PAC an hour. A gravimetric screw feeder, because of its inherent accuracy, effectively prevents losses of excess PAC with an associated savings in operating cost.

The feeder control system represents another critical component for any PAC metering system. Any PLC-based control system should incorporate a user-friendly HMI with automated feed rate optimization, batch history, discharge data, and security controls with associated alarms. Batch histories (rate logging) should archive the previous 200 records. For remote PLC or DCS control, analog input should be available for remote entry of feed rates.

Bulk density, particle size distribution, moisture content, and compressibility must be understood when designing PAC storage and handling equipment and systems as have been described here. In critical cases, pilot tests should be conducted to better understand the handling and flow properties of several different types of PAC and how best to control the storage, flow and metering of material prior to injection into mercury laden flue gases.

Physical properties measured for PAC materials to be evaluated should include slide angle, angle of repose, loose bulk density, packed bulk density, compressibility, mean particle diameter, particle size distribution, and moisture content. All of these properties can affect operating conditions for a material handling system, and each must be considered in setting up the size and type of equipment best suited for delivering a consistent flow and bulk density for accurately metering the PAC. Pilot testing can validate the optimum equipment selection, controls, and operating conditions for sizing of an integrated PAC storage and metering system.

Applying pilot test data and sound equipment and system design practices will result in accurate PAC delivery, flow rate flexibility, reduced operating costs, and long term reliability.

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All illustrations courtesy of ***Metalfab, Inc.***

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