

Paste Plant Self-Cleaning Tar Fumes Ventilation Ducts, Design and Operation

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Abstract

Anodes and cathodes manufacturing generates carcinogenic tar fumes. Capture of tar fumes by ventilation ducts deteriorates when ducts become obstructed by tar and dust accumulation. Modifications to a coke fine tar fumes scrubber were performed to make ducts self-cleaning. Coke fines injection point was added to each tar fume collection point. With clean ducts the capture capacity of the system remains unchanged. History of this development is reported. Working principles are described. Points to check when designing, starting and operating this system are also described, this avoid repetition of mistakes made in the past, when putting into service first versions of this type of scrubber. This description is done from a long-term user of this type of installation.

Keywords: PAH scrubber; self-cleaning ventilation ducts; workplace environment.

1. Introduction

Carbon anode manufacturing processes are based on using coal tar pitch (CTP) binder. During the production of hot green paste and green anodes containing this binder, Volatile Organic Matter (VOM) compounds in the form of fumes are generated. This VOM usually contains carcinogenic, polycyclic aromatic hydrocarbons (PAH's) that workers should be protected from.

To achieve this, green paste plants usually have ventilation systems to convey the gas containing VOM to a scrubber for treatment. These ventilation ducts suffer internal buildup over time by accumulation of condensed VOM, mixed with solid particles which forms a crust that reduces the internal diameter of the ventilation ducts. This causes a reduction of capture capacity of the ventilation system and workers may become exposed to carcinogenic material.

Cleaning of these ventilation ducts is a very unpleasant and hazardous job. Cleaning of ducts is often done manually using metal scrapers or steam lances. Recuperated material is sticky, dirty and highly carcinogenic. Workers doing this job need to be very well protected to avoid any contact with material they remove.

An accidental observation made while reviewing the scrubbing process led to the development of a coke fines injection process for keeping ventilation ducts clean. This in turn, has allowed the capture capacity of VOM to be maintained and eliminated most of the ventilation ducts cleaning.

2. Coke fines scrubber description

The cleaning process that will be described below requires as a prerequisite a coke fines tar scrubber (CFTS).

A CFTS consists of a dust collector, ducting to capture contaminants at their sources and a fine coke supply system.

A CFTS is a variation of an alumina fluoride scrubber. The principle is identical and only the scrubbing medium is different. In both cases, the dust collector is preceded by a vertical duct, often a venturi, where the scrubbing medium is injected. This forms a “cake” on the surface of the dust collector filter. In the case of an alumina fluoride scrubber, hydrofluoric acid is adsorbed on the metallurgical alumina surface and recycled in the electrolysis pot to produce aluminium.

A CFTS uses petroleum coke fines, usually produced by a ball mill, or coming from a dust collector for coke dust. Unlike an alumina scrubber, capture of tar fumes is not done by adsorption on the surface of coke fines, because tar fumes pass through scrubbers without being captured. The mechanism of removal is capture of condensed tar onto coke fines. For this reason, gas containing tar fumes should be at a temperature of 40C or lower so VOM is condensed when it contacts coke fines. Capture is then done by wetting fine coke with condensed tar. Fine coke loaded with tar is then recycled in anode manufacturing.

3. History

A CFTS was installed at the plant A in 1985. It replaced a water-based lamellar separator scrubber which was not very efficient. The wet scrubber generated contaminated water and tarry mud which were both difficult to get rid of.



Figure 1. Fresh and loaded coke injection points at venturi throat before dust collector

In 1991, while inspecting the venturi throat where coke was injected (Figure 1), an interesting observation was made. The duct before coke fines injection point was very dirty, whilst the duct downstream coke fines injection point was clean. About half the coke fines injected in venturi throat was delivered to a VOM capture duct connected to a forced-air green paste cooler, which generated a large quantity of tar fumes. This duct stayed clean afterward.

The scrubber manufacturer, Procédair Industries (now Five Solios), started including coke fines local injection points in its scrubber system design [1]. When Eirich mixer coolers were installed at plant A, in 1999 and 2000, local coke fines injection points were added to all VOM capture points of the paste plant. It took time and experimentation to make the local coke fines injection system fully functional.

4. Coke fine scrubber

4.1. Traditional coke fine scrubber

In a traditional CFTS system, the only fine coke injection point is located at the middle of the venturi throat before the dust collector filters the tar loaded coke fines (Figure 2 a). There may be two CFTS configurations, with and without tar loaded coke fines recirculation. Only one configuration is shown here, the configuration without tar loaded coke fines recirculation, to keep description simple.

The scrubber is also supplied, when there is a water injection system to cool down green paste, with an air intake heater, to raise the gas temperature arriving at the dust collector above the dew point. This avoids water vapour condensation to liquid form, which would plug the dust collector.

4.2. Scrubber With Coke Fines Local Injection Points

To make ventilation ducts self-cleaning, local coke fines injection points are added to each VOM capture points. A dosing and pneumatic transport system is added to supply each injection point with fine coke (Figure 2b).

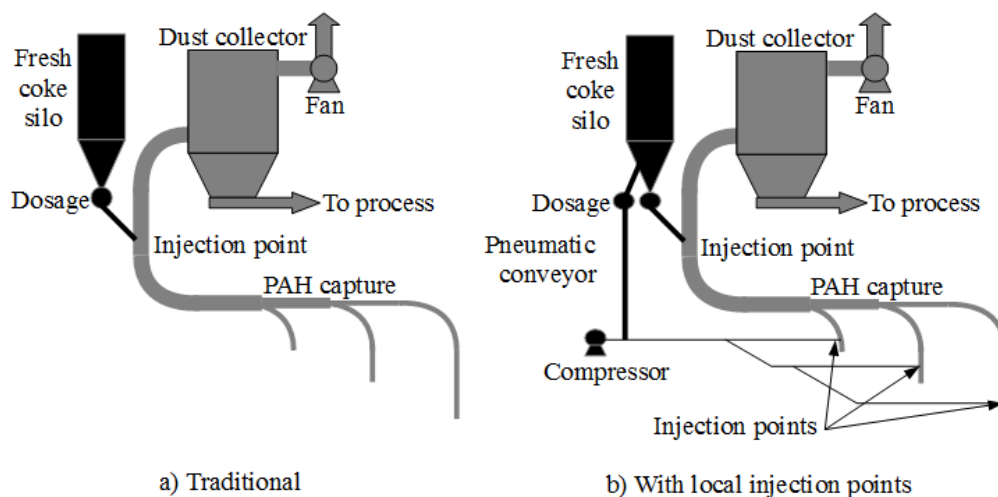


Figure 2. Fine coke tar scrubber schematic

The coke fines dosing system is made of one or many rotary valves fed by a fine coke silo(s). Fine coke is then fed to one or many pneumatic transport system and each pneumatic branch may be subdivided into many branches, using Y connectors.

Only part of the total coke fines supply is sent to local injection points. The other part is still injected into venturi throat before the dust collector.

5. Points to consider in design

5.1. Air temperature at dust collector

As mentioned earlier, the temperature of air arriving at the CFTS should be lower than the condensation temperature of VOM to be removed. The rule of thumb is that the temperature of air arriving at the dust collector should be at or lower than 40C. Air cooling is done by diluting VOM with cooler air. Dilution is controlled by airflow in each branch of the ventilation duct network. This means that warmer dilution air will require a bigger total airflow. Weather at the location where the scrubber is installed may have a significant impact on the scrubber design.

Air arriving at the dust collector should also be warm enough to avoid condensation of water vapour contained in the air. An intake air heater is then installed to keep the air temperature arriving at dust collector higher than the dew point in air arriving at the dust collector. Here again, the local weather will dictate if an intake air heater is required or not.

5.2. Transport of Coke Fines in Ducts

Unlike a traditional coke fines scrubber, a CFTS with local injection points has to transport coke fines. This implies that the airspeed in ducts should be greater than the airspeed where coke fines would settle out. An air speed between 15 and 20 m/s [2] should be maintained to avoid fine coke settling. The airspeed in ducts depends on two parameters, the airflow and duct diameter. When airflow is determined, the diameter of the duct should be calculated to obtain the air speed required to transport coke fines.

Air distribution across the ventilation system is critical to get good VOM capture, so careful attention needs to be paid to airflow and airspeed.

When designing the ventilation system, special attention has to be given to junctions between ducts. If the angle between two ducts is too large, this may cause the formation of a vortex in the main duct. This vortex leads to a local drop of air velocity in the main duct, which may be lower than speed required for fine coke transportation, causing fine coke settling. A coke fines accumulation then forms and, over a long period of time, ends up obstructing the main duct.

The best method to measure air speed is a simple Pitot tube. As a precaution, when taking the airspeed measurement, it is best to stop fine coke feeding in the duct, to avoid plugging Pitot tube.

5.3. Coke Fines Flow at Injection Points

Coke fines flow at each injection point should be sufficient to absorb all VOM captured at this point. So the coke fines flow should be adjusted according to the VOM quantity to absorb. No measurement method is available to make this adjustment but too much fine coke is not really a problem. Not enough coke fines will cause a fouling of the duct over a long period of time.

A lack of coke fines should not confuse with coke fines that are not distributed correctly. The coke fines injection point has to be designed to distribute coke as uniformly as possible in the duct. Even with a lot of effort to distribute coke fines uniformly, coke fines have to travel a certain distance before being uniformly distributed across ducts. In this non-uniform distribution distance, VOM WILL form a sticky mix with coke fines and will adhere to the ventilation duct (Figure 3). If this deposit of VOM and coke fines is not removed, it will grow and partially obstruct ducts, reducing air flow and VOM capture efficiency. This point will be covered later.



Figure 3. Duct with injection point, showing accumulation

If ventilation ducts show buildup in locations away from the injection point, coke fines flow should be increased. If the VOM-coke fines mix is not sticky, the problem may be with airspeed at the position where settling occurs.

The speed of each rotary valve will allow adjustment of coke fines flow at the injection points it feeds. If coke fines flow is later divided between two or more transport pipes, it is possible that coke split between each branch will not be done correctly, because of wear at the injection or split points, or unbalancing caused by differences in pneumatic transport pipes length or size. This problem of unequal split should be corrected to keep ventilation ducts clean.

Wear or jamming of a rotary valve may lead to an imbalance of coke distribution between ventilation branches, leading to a lack or overfeeding of fine coke supply in one or more branches.

The total coke fines flow should be sufficient to keep the tar loaded coke fines dry. Capture of VOM at the dust collector depends on the total coke fines flow used in scrubbing. This includes fine coke at the venturi throat just before dust collector. When the tar level in loaded coke fines raises to around 3% (as measured by quinoline insoluble extraction test used for pitch), tar loaded coke fines become sticky and can form deposits in the dust collector hopper. This requires a manual intervention in the dust collector to remove buildup which is undesirable.

Lack of coke fines may also cause plugging of dust collector bags or cartridges, because of wetting of bags or cartridges by liquid tar. When this occurs, bags and cartridges become impermeable to air and have to be replaced. Plugging problems may affect part of the dust collector only, depending on the air and/or fine coke distribution across bags or cartridges in the dust collector.

6. Operation of local injection points in fine coke scrubber

6.1. Start-up

Like all new installations, start-up of a new CFTS must be done carefully. The first step is to balance the ventilation system to get an air speed in ducts high enough to transport coke fines up to the dust collector.

The second step is to start up the coke fines pneumatic transport system leading to the local injection points and to make sure that fine coke distribution between injection points is reasonably uniform. To do that, it is a good idea to plan an inspection door at each coke fines injection point. These inspection doors have two purposes 1) check fine coke flow at each injection point and 2)

make removal of sticky deposits in the ventilation duct side possible. Inspection doors should be easily and safely accessible to make inspection and cleaning by operators easy.

The third step is first operation with VOM. Regular inspections of injection points and of the dust collector allows detection of insufficient fine coke flow. This can be detected by deposits in ducts, and adjusted by the coke fines flow and split between injection points, up to dust collector itself.

6.2. Regular operation

Once steady state is achieved, an inspection and cleaning schedule should be implemented.

A regular inspection routine, once/shift, once/day or once/ week (depending on the deposition rate) keeps the coke fines injection points clean. Cleaning is done by using steel scrapers with the handle length adapted to suit the duct diameter to be cleaned. Deposits to be cleaned are usually quite dry and friable. Deposits may fall in ventilated equipment or be sucked by airflow, into the dust collector. It is imperative not to let deposits accumulate inside the ducts.

Inspections can be made while in operation or when stopped, often depending on inspection doors size. A small inspection door may be opened in operation without disturbing the ventilation balance too much. A large inspection door can significantly disrupt ventilation balance. In this case, an inspection should be made when process is stopped. An alternative may be inspection when ventilation is operating, but outside the green paste production time. Not having VOM to capture, disturbances to ventilation balance do not have any effect on VOM capture, so it will not expose workers to VOM.

A good understanding of the working principles of fine coke scrubbing and of duct cleaning using coke fines is essential to maintain the operations of both systems. This paper seeks to explain the sort of information that an operator of these systems should know. (See Table 1 for a detailed checklist).

As an example of the above, Figures 4 and 5 show the change in a duct before and after the fine local coke injection point implementation at plant B.



Figure 4. Ventilation duct before fine coke injection point implementation



Figure 5. Ventilation duct after fine coke injection point implementation

Table 1–Diagnostic checklist for fine coke tar scrubber

Variable to be controlled	Reason	Measurements	Control	Method
Air temperature	Avoid water condensation on dust collector bags or cartridges.	→ Air temperature → Air dew point	Keeps air temperature at the dust collector inlet above the dew point.	Heat intake air when required
Air temperature	Condense PAH (PAH not condensed not captured).	Air temperature	Keeps air temperature below 40C (to condense fluorene and other light PAHs).	Dilution by air at capture points
Airspeed	Ensure fine coke transport in ducts (or coke fines settling in ducts).	Measure airspeed with a Pitot tube or anemometer	Keep airspeed above air speed required to convey fine coke.	Adjust shutters used to balance the ventilation system.
Airflow distribution between ventilation system branches	Ensure coke fines transport in ducts (or else settling in ducts if airspeed is insufficient).	Airspeed measurement using Pitot tube or anemometer	Keep airspeed above air speed required to convey fine coke.	Adjust shutters used to balance the ventilation system.
Fine coke flow	→ Ensure condensed PAH capture → Clean ducts from condensed PAH	→ Visual inspection of local injection points for deposits → Inspection of scrubber dust collector	Rotary valves feeding speed	Adjustment in PLC
Fine coke flow split between ventilation system branches.	-> Clean each branch from condensed PAH	Visual inspection of local injection points for deposits	Modify split between fine coke transport pipes.	→ Lengthen / shorten transport pipes to balance → Install larger or smaller diameter transport pipes to balance → Modify transition between pipes

7. Effect on Ducts Cleaning Cost

Implementation of a self-cleaning ventilation duct system reduces manual cleaning costs. Unfortunately, it was not possible to quantify cleaning costs before and after the implementation for direct comparison in this study. It is widely recognized at both Plant A and Plant B that the effort required to clean ducts has been reduced substantially as a result of a successful implementation of the CFTS systems.

8. Conclusion

Self-cleaning ventilation ducts from a CFTS requires implementation of a number of necessary systems.

The VOM capture ventilation ducts need to have local coke fines injection points installed, with fine coke flow sufficient to capture condensed VOM and convey it to the scrubber dust collector. Tar loaded coke fines requires an air speed sufficient to keep it in suspension up to the dust collector.

Implementation of this type of self-cleaning ventilation ducts improves the paste plant working environment and reduces carcinogenic tar fumes when present and the need for manual and messy removal of coke fines/tar buildup.

9. References

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