Using pressure monitoring to maintain dust collection system performance

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Running your dust collection system with no ongoing maintenance or performance monitoring plan can lead to costly cleanup efforts and dangerous plant conditions. This article describes how to use static pressure measurements to monitor your dust collection system’s performance and find small deviations before they become big problems.

As soon as your dust collection system is commissioned, it begins to degrade. Leaving that degradation unchecked until there’s dusting at the hoods or some other external problem sign reduces your system’s performance and can result in fugitive dust accumulation in the workspace and dust buildup, blockage, and premature erosion in your system. This can be costly and time-consuming to clean up or repair and can create a potential dust explosion hazard.

NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids requires that a dust collection system be inspected and maintained to sustain ongoing performance. Pressure monitoring is a proven and relatively low-effort way to meet that requirement. Pressure monitoring is a predictive maintenance approach that involves taking static pressure measurements at various dust collection system locations to identify and fix small system problems such as plugged or leaking ducts, plugged (or blinded) filter media, poor fan performance, or altered blast gate positions. Problems like these affect the system’s airflow and velocity and, if not identified early, can become major problems that shut down your system. Before learning how pressure monitoring works, however, it’s important to understand some dust collection system basics and how static pressure and airflow interact in your dust collection system.

Dust collection system basics

A typical dust collection system, as shown in Figure 1, consists of one or more dust hoods or enclosures located at dust sources and connected by ductwork to a dust collector and fan. The fan creates a vacuum inside the system, which draws airborne dust from the workspace into the hoods or enclosures, through the ductwork, and into the dust collector. Bag or cartridge filters in the dust collector separate the dust from the airstream. A pulse-jet filter...
cleaning system uses compressed air to periodically clean accumulated dust from the filters' surfaces. The collected dust settles into a hopper and is discharged through an airlock either into a bin for disposal or to be recycled back into the process. The clean air is either vented outside the building or recirculated back into the workspace.

During dust collection system design, the airflow and static pressure at various duct locations are calculated to determine the fan size needed to achieve the required conveying velocity (typically 3,500 to 4,500 fpm, depending on the dust’s characteristics). Static pressure is the air pressure inside the duct, relative to atmospheric pressure, expressed in inches of water column. On the vacuum side of the system’s fan, duct air pressure is less than atmospheric pressure, so the static pressure will be a negative number.

A dust collector’s differential pressure (the difference between the static pressure on the filters’ clean and dirty sides) should typically vary just ½ - to 1-inch water column during normal operation and pulse-jet cleaning. A wider differential pressure range can cause airflow variability at the hoods, which can lead to dust not being effectively exhausted from the workspace.

A dust collection system’s performance can also be diminished by:

- Room air drafts
- Interfering operator technique at the hoods
- Changes to hood or enclosure shapes or locations
- Blast gate position changes
- Dust buildup, air leakage, or moisture infiltration in the ductwork
- Filter blinding (dust lodged within the filter media that can’t be removed by pulse-jet cleaning)
- Dust bridging between filters
- Inadequate filter cleaning
- A poorly sized or operated airlock device causing dust to back up in the dust collector’s hopper up to the filters
- Air leakage or ambient moisture infiltration at the airlock device
- Fan speed or damper position changes
- Fan or fan housing wear or dust buildup

How static pressure and airflow interact in your dust collection system

The graph in Figure 2 shows how static pressure and airflow interact in a dust collection system. The blue line represents the system’s fan performance, which is a function of the static pressure at the fan inlet and the total airflow. The red line represents the system resistance, which is the sum of the airflow resistance of all the dust collection system’s components. The point at which the two curves meet (Q 0, SP 0) is the system’s operating point.

As the graph shows, an increase in system resistance reduces airflow (Q 1) and increases the static pressure (SP 1), while a decrease in system resistance increases airflow (Q 2) and reduces the static pressure (SP 2). This generally explains a problem that impacts the entire dust collection system, such as a high dust collector differential pressure or a fan running too slowly.

A problem that’s located in a branch of the system, however, before all the branch airflows are combined into the main duct, can be more complicated. Whether the airflow has changed in all or just part of the system, and how, depends on the nature and location of the change’s cause. For example, you may see a decreased static pressure reading in a branch duct, indicating higher-than-design airflow in the affected branch but, at the same time, see an increased static pressure reading at the fan inlet, indicating a lower-than-design total system airflow.

The four possible problem conditions for a single test point are: high static pressure, high airflow; high static pressure, low airflow; low static pressure, high airflow; and low static pressure, low airflow.\(^2\)

**High static pressure, high airflow.** High branch airflow may be due to a restriction in an adjacent duct branch caused by:

- A plugged duct
- An undersized orifice
- A blast gate that’s closed too far
- A blocked air bleed

High total system airflow may be caused by:

- The fan inlet slide gate being opened too far
- The fan operating at an excessive speed because the belt pulley was incorrectly sized or the fan motor speed is too high
- Low differential pressure because of a defective pressure indicator or too-frequent bag cleaning

**High static pressure, low airflow.** Low branch airflow may be due to a restriction between the duct branch air inlet and the test point caused by:

- A plugged duct
- A poorly cut flange gasket partially blocking the duct
- An undersized orifice
- A blast gate that’s closed too far
- A blocked air bleed
**Establishing a pressure monitoring regime**

NFPA 91 requires testing for new or modified dust collection systems. During commissioning, actual airflow and static pressure measurements are taken at various system locations to demonstrate that the system can perform as designed. This establishes baseline airflow and static pressure values you can reference when pressure monitoring your system’s performance. A complete system baseline includes a schematic drawing with the test points labeled and data tables that include the measurements in Table I. Airflow values in the table are calculated by multiplying the velocity measurement by the duct’s cross-sectional area (in square feet) at that location.

As previously stated, pressure monitoring involves looking for small performance changes in your dust collection system that indicate minor problems. With a timely response, these minor problems are often easy and inexpensive to fix, without requiring much downtime. A reasonable change threshold (or limit) for a dust collection system is ±10 percent of the design airflow (which equates to ±10 percent of the design velocity). A drop of greater than 10 percent can start to cause dust to drop out of the duct airstream, while an increase of greater than 10 percent can cause erosion to the ductwork. Since the Fan Laws (fundamental rules governing fan performance) tell us that a 10 percent change in airflow equates to approximately a 20 percent change in static pressure, static pressure can be reliably used as a surrogate for airflow.

The static pressure information collected during commissioning provides a baseline static pressure profile of the dust collection system, as shown in Figure 3. The figure shows the baseline static pressure at each lettered test point. Installing manhelic pressure gauges at selected system test points in occupied areas and marking the gauges at ±20 percent of the baseline values allows you to easily see when a static pressure change exceeds the limit, indicating that the airflow has changed at least ±10 percent from design. Since the test points may not always be conveniently located, you may want to run a tube with the end installed flush with the inside of a vertical duct or the side or top wall of a horizontal duct to a convenient location for gathering data.

While it’s possible to install automatic devices that signal an alarm when the static pressure exceeds the ±20 percent limit, an operator will still need to interpret the cause of the static pressure change and take corrective action.

Pressure monitoring falls into two categories: **alert** (or short-term) monitoring and **degradation** (or longer-term) monitoring. Degradation monitoring provides reference information for troubleshooting your dust collection system; alert monitoring provides the information you need for daily system management.
Alert monitoring. Alert monitoring warns of sudden, noticeable changes that hurt dust collection system performance, such as a slipping fan belt, water in compressed air that’s causing filter blinding, or trash sucked into the system and restricting airflow in one or more branches. Conduct alert monitoring daily and record the values weekly. Where troubleshooting reveals additional problem areas, add those areas to your alert monitoring. Note that monitoring a system location where all the branch airflows have been combined will tell you if the total system airflow is within the limits, but it’s also very important to monitor branch airflow. By the time the total static pressure change reaches ±20 percent at a given location, the airflow in one or more branch ducts may be much more than 10 percent from baseline, and the system may require significant cleanout effort.

Recommended locations to monitor total system airflow include:
Fan inlet static pressure. Take corrective action if the static pressure at the fan inlet exceeds ±20 percent of baseline.

Fan motor amps. The fan motor amps are directly proportional to system airflow. Take corrective action if the motor amps exceed ±10 percent of baseline, which is equivalent to ±10 percent system airflow.

Dust collector differential pressure. As previously stated, differential pressure should remain within ½ - to 1-inch water column of baseline during normal operation and pulse-jet cleaning. Note the differential pressure value daily and track trends.

Recommended locations to monitor branch airflow include:
Selected hood static pressures. Routinely monitor occupied workstations on heavier dust load branches.
Selected duct branch static pressures. Routinely monitor branches that are more likely to plug from heavy dust loads or other reasons.

Degradation monitoring. Alert monitoring well-chosen test points will warn you of sudden dust collection system problems. However, some changes, such as aging filters, fan-belt wear and slippage, slow dust buildup in the ducts, and erosion holes from abrasion, take time to develop. Degradation monitoring generates a data history that shows which problem branches you should add to alert monitoring and which corrective actions you should use to bring the dust collection system back within baseline limits.

Monitor all test points on a newly commissioned dust collection system weekly for two to three months to build a data history and learn where the system begins to fail first. Take corrective action and add any problem areas to your alert monitoring points. Then reduce the degradation monitoring frequency to semi-annually for the first year and annually after that.

Using your dust collection system’s static pressure profile to diagnose airflow problems
Once you’ve established a pressure-monitoring regime, you still need to know how to interpret your monitoring results. When analyzing your system’s static pressure profile, look for areas where the static pressure reverses from low to high or from high to low. The problem should be nearby, either upstream toward the air inlets or downstream toward the fan.

Measure the static pressure (SP) at each test point and

<table>
<thead>
<tr>
<th>System component</th>
<th>Capture velocity (ft/min)</th>
<th>Face velocity (ft/min)</th>
<th>Duct velocity (ft/min)</th>
<th>Static pressure (inches of water column)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoods</td>
<td>At each open hood</td>
<td>At each enclosure</td>
<td>Airflow at each hood</td>
<td>At each hood</td>
<td>Smoke test</td>
</tr>
<tr>
<td>Ducts</td>
<td></td>
<td></td>
<td>Airflow in each branch</td>
<td>In each branch</td>
<td>All blast gates secured at baseline positions</td>
</tr>
<tr>
<td>Fan</td>
<td></td>
<td></td>
<td>Total airflow</td>
<td>At the fan inlet</td>
<td>Fan rpm, fan motor amps</td>
</tr>
<tr>
<td>Dust collector</td>
<td></td>
<td></td>
<td>Total airflow</td>
<td>Differential pressure</td>
<td>Condition of new filters, compressed air pressure, rotary airlock</td>
</tr>
</tbody>
</table>
Figure 3

Baseline static pressure profile
test points designated by letters

-2.26
-4.54
-4.87
-5.64
-5.35
-5.77
-7.35
-7.81
-7.00
-11.83

Problem area where arrows change direction

Figure 4

Static pressure changes indicating blockage in a branch duct

Table II

Example static pressure profile data showing blockage in a duct branch

<table>
<thead>
<tr>
<th>Test point</th>
<th>Measured SP</th>
<th>Baseline SP</th>
<th>Percent change</th>
<th>HI (&gt; +20 percent)</th>
<th>LO (&lt; -20 percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-1.58</td>
<td>-2.26</td>
<td>-30.1</td>
<td>LO</td>
<td>LO</td>
</tr>
<tr>
<td>B</td>
<td>-3.27</td>
<td>-4.54</td>
<td>-28.0</td>
<td>LO</td>
<td>LO</td>
</tr>
<tr>
<td>C</td>
<td>-3.41</td>
<td>-4.87</td>
<td>-30.0</td>
<td>LO</td>
<td>LO</td>
</tr>
<tr>
<td>D</td>
<td>-7.22</td>
<td>-5.64</td>
<td>+28.0</td>
<td>HI</td>
<td>LO</td>
</tr>
<tr>
<td>E</td>
<td>-3.69</td>
<td>-5.35</td>
<td>-31.0</td>
<td>LO</td>
<td>LO</td>
</tr>
<tr>
<td>F</td>
<td>-7.21</td>
<td>-5.77</td>
<td>+25.0</td>
<td>HI</td>
<td>HI</td>
</tr>
<tr>
<td>G</td>
<td>-9.26</td>
<td>-7.35</td>
<td>+26.0</td>
<td>HI</td>
<td>HI</td>
</tr>
<tr>
<td>H</td>
<td>-9.76</td>
<td>-7.81</td>
<td>+25.0</td>
<td>HI</td>
<td>HI</td>
</tr>
<tr>
<td>I</td>
<td>-8.75</td>
<td>-7.00</td>
<td>+25.0</td>
<td>HI</td>
<td>HI</td>
</tr>
<tr>
<td>J</td>
<td>-14.32</td>
<td>-11.83</td>
<td>+21.0</td>
<td>HI</td>
<td>HI</td>
</tr>
</tbody>
</table>
calculate the percentage change from baseline (being careful to include the plus or minus sign) using the following equation:

\[
\frac{(\text{Test SP} - \text{Baseline SP})}{\text{Baseline SP}} \times 100 = \text{Percent change}
\]

Let’s look at a couple of examples.

Table II shows example static pressure profile data for the dust collection system from Figure 3.

If a test point’s static pressure has decreased more than 20 percent from baseline, that test point is marked “LO” in the table; if the static pressure has increased more than 20 percent from baseline, that test point is marked “HI.”

We can relate this test data to the physical dust collection system by placing “up” arrows next to test points with HI static pressure changes and “down” arrows next to test points with LO static pressure changes, as shown in Figure 4. In the figure, the arrows change directions between test points C and E, which are LO, and test point F, which is HI. This indicates that something has happened inside the duct between these points to restrict airflow at test point F. In this case, some trash that had been sucked into the system became stuck in a duct junction, blocking airflow.

Table III shows another example data set for the same dust collection system.

In this example, each test point has a LO static pressure, as shown in Figure 5, indicating a system-wide problem, either in the main duct, the dust collector, or the fan. We can use Table III to determine the most likely cause.

Blockage in the main duct would show HI static pressure values in the duct upstream from the blockage, as in the previous example. Since there are no HI static pressure test points, this is unlikely to be the cause.

Blockage in the dust collector (or high differential pressure) is also unlikely to be the cause because the

### Table III

<table>
<thead>
<tr>
<th>Test point</th>
<th>Measured SP</th>
<th>Baseline SP</th>
<th>Percent change</th>
<th>HI (&gt; +20 percent)</th>
<th>LO (&lt; -20 percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-1.36</td>
<td>-2.26</td>
<td>-39.8</td>
<td>LO</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>-2.59</td>
<td>-4.54</td>
<td>-43.0</td>
<td>LO</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>-3.16</td>
<td>-4.87</td>
<td>-35.1</td>
<td>LO</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>-3.44</td>
<td>-5.64</td>
<td>-39.0</td>
<td>LO</td>
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<tr>
<td>E</td>
<td>-3.53</td>
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<td>-34.0</td>
<td>LO</td>
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<td>G</td>
<td>-4.85</td>
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<td>-34.0</td>
<td>LO</td>
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<tr>
<td>H</td>
<td>-5.31</td>
<td>-7.81</td>
<td>-32.0</td>
<td>LO</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>-4.55</td>
<td>-7.00</td>
<td>-35.0</td>
<td>LO</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>-7.81</td>
<td>-11.83</td>
<td>-34.0</td>
<td>LO</td>
<td></td>
</tr>
</tbody>
</table>
differential pressure (the difference between the static pressure at test points H and J) is just 2.5 inches water column, much less than the baseline differential pressure of 4.02 inches water column. Also, if there was blockage in the dust collector, the static pressure at test point J, which is the only test point downstream from the dust collector, would have been HI.

In this example, the problem is in the fan, but there is no blockage. The fan is actually operating in reverse because the wires were switched during motor replacement. A fan will deliver roughly 50 to 60 percent of design airflow when operating in reverse.

References
1. NFPA 91 is available at www.nfpa.org.

For further reading
Find more information on dust collection systems in articles listed under “Dust collection and dust control” in Powder and Bulk Engineering’s article index in the December 2014 issue or the Article Archive on PBE’s website, www.powderbulk.com. (All articles listed in the archive are available for free download to registered users.)

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