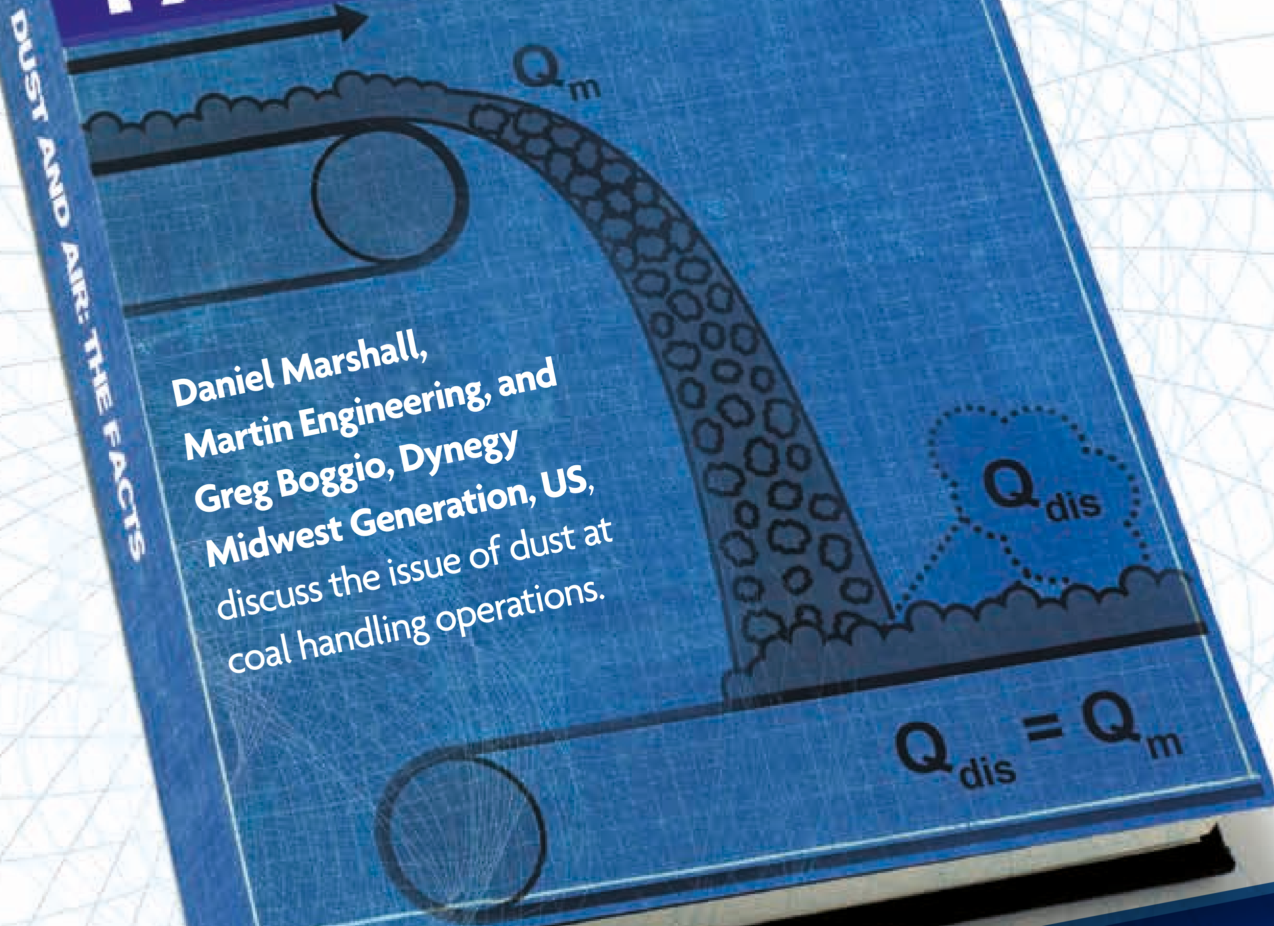
DUST AND AIR: THE FACTS

Daniel Marshall, Martin Engineering, and Greg Boggio, Dynegy Midwest Generation, US, discuss the issue of dust at coal handling operations.



Dust has been an issue of concern and research ever since bulk solids were first transported by conveyor belt. Airborne dust travels in the air currents created by the handling of bulk solids. Extensive research has been conducted to determine the quantity of air created at a transfer point, resulting in three different methodologies to predict the amount of air generated (see below). While close, each of these approaches vary slightly from the reality of an actual coal application.

The use of actual measured airflows is the most accurate way to size a dust control system. These airflows can be minimised by mechanically altering the construction of the transfer point. A full understanding of the airflows involved allows a user to specify a dust collection system large enough to be effective, but not so large as to waste capacity and capital.

Background

A great deal of research has been conducted on the effects of dust. This research has concentrated on a number of issues, such as combustion, health impacts, environmental impacts, safety impacts and maintenance aspects. All research has illustrated how dust is undesirable and often dangerous.

Although much research has been conducted on the effects of dust, the elusive and difficult-to-manage behaviour of dust has prevented as much research into the origins of dust in a transfer point setting. A

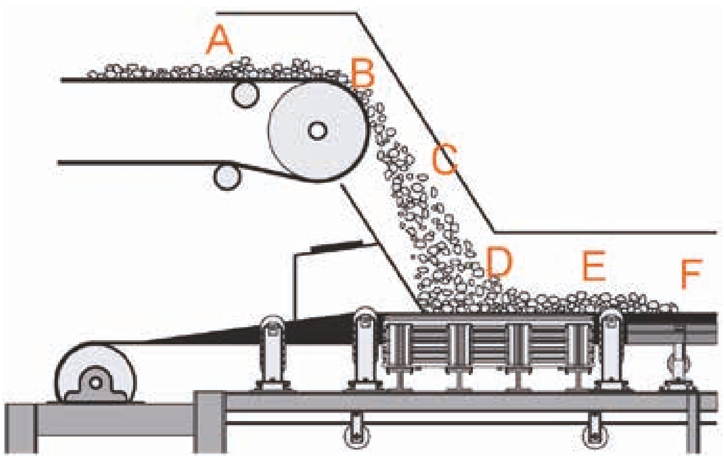


Figure 1. Basic regions of a conveyor transfer.

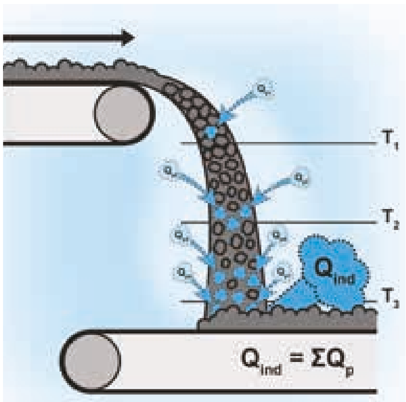


Figure 2. Illustration of induced air.

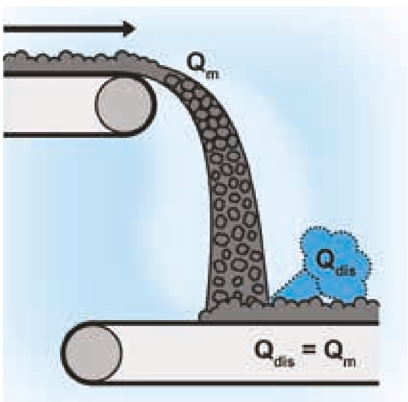


Figure 3. Illustration of displaced air.

transfer point is defined as the point where one belt conveyor dumps material onto another.

Any time material is moved, it may be fractured mechanically. This fracturing creates pieces of the material that are much smaller than the original pieces. Once these small particles become airborne, they become airborne dust. Experience has shown that, generally, if this dust had a diameter greater than 500 μm, the particle falls fairly quickly and re-enter the material stream. If the particle is smaller than 500 μm, it will remain airborne.

Once this particle remains airborne, the question of where it travels becomes critical. Logic would dictate that the particle will be influenced by and follow the currents of moving air in the environment. The greater the airflow, the farther the dust particles will be dispersed.

Given this knowledge, it becomes vitally important to understand the nature of the airflows and velocities within a transfer point to predict the behaviour of the dust created.

Several methods are used to calculate airflows in a transfer point. These methods include the method described in *Industrial Ventilation*, the technique described in the *Dust Control Handbook* and the approach described in *Foundations*.[1,2,3]

This article will attempt to find a correlation between these theoretical methods and the reality of an application.

Theory

All calculation methods use similar inputs to determine the air generated in a transfer point (Figure 1). A basic transfer point is broken into several geometric sections:

- A: Entry area.
- B: Head pulley drop-off.
- C: Free-fall region.
- D: Impact region.
- E: Settling zone.
- F: Exit area.

Generally, the air enters at A and exits at F. Air will move through the transfer point, while the direction and speed will change. The movement of the conveyed material from A to F influences this general trend. The material itself pulls the air through the transfer point due to the no-slip condition between the air and the material. This condition means that, where the air is touching the material, air velocity will be identical to the velocity of the material. The viscosity of the air will also force the rest of the air body to move in that direction.

The mechanical event of impact between material and belt occurs at the impact region (D), which produces a localised airflow generation. This air will travel through the transfer point enclosure toward the exit (F). Since dust travels with air, it becomes vitally important to quantify this airflow.

Method 1

Industrial Ventilation states that air is created at a rate proportional to the belt width of the conveyor belt. There is an additional airflow added if the drop height is greater than 3 ft. This additional air also depends on belt width. The equations for this methodology are shown below:

- $Q_{Ex} = 350 \cdot BW + Q_D$

Q_{Ex} = Exhaust air (ft^3/min).
BW = Belt width (ft).
Q_D = Additional air generated from drop.

If the material drop is less than 3 ft, $Q_D = 0$. If the material drop is more than 3 ft and BW is < 3, then $Q_D = 700$. If the material drop is more than 3 ft and BW is > 3, then $Q_D = 1000$.

Method 2

The *Dust Control Handbook* states that air is created at a rate equal to the amount of air induced. Induced air is the quantification of all the air that the material stream pulls into itself as it travels through the transfer point. As the material travels on the loading belt, it remains in the same shape. As it passes over the head pulley drop off (Region B in Figure 1), it begins to separate. As the material falls in the free-fall region (Region C), it continues to spread and creates small pockets of vacuum between the material particles. Nature abhors a vacuum, so the stream fills these small voids with any air it can (Figure 2).

Figure 2 shows that for every second the material is in freefall, it pulls more and more air into itself. This pulled air (Q_p) is drawn from the easiest place that it can come from, usually the entry area (Region A in Figure 1). When the stream contacts the receiving belt at the impact zone (Region D), all the air that the material stream has accumulated is instantly expelled. The equation used to quantify the induced air is shown below:

$$Q_{ind} = k \cdot A_U \cdot \sqrt[3]{\frac{R \cdot S^2}{D}}$$

Q_{ind} = Induced air (ft^3/min).
A_U = Open area that air can enter system (ft^3).
R = Material load (tph).
S = Height of material free-fall (ft).
D = Average material diameter (ft).
k = Conversion factor (10).

Method 3

Foundations employs a method that begins with the induced air to the *Dust Control Handbook* methodology and adds additional factors for displaced air and generated air.

The displaced air (Q_{dis}) is the volume of the material stream over time. This value is calculated in ft^3/min, as that is the industry standard. Displaced air is shown in Figure 3. The equation for displaced air is as follows.

$$Q_{dis} = \frac{k \cdot L}{\rho}$$

Q_{dis} = Displaced air (ft^3/min).
L = Material load (tph).
ρ = Material bulk density (lbs/ft^3).
k = Conversion factor (33.3).

There may be another device that generates air. This is usually in the form of a crusher, a foam dust suppression system or some type of mill. The actual airflows for these items can typically be supplied by the manufacturer, measured or calculated. A dust collection system can also impact the amount of air in a transfer point, but it will subtract from the flow, as it is pulling air. These external airflows are designated as Q_{gen}, or the air generated by other means.

The airflow that is created or introduced by a transfer point is called the total air (Q_{Tot}). It is the sum of the displaced air, the induced air and the generated air. This is the driving factor in the speed of the air through the settling zone (Region E in Figure 1), and this is the air that exits the transfer point at the exit zone (Region F). This air carries dust, so must be minimised with engineering controls. The equation for total air is shown as follows:

$$Q_{Tot} = Q_{ind} + Q_{dis} + Q_{gen}$$

Q_{Tot} = Total air (ft^3/min).
Q_{ind} = Induced air (ft^3/min).
Q_{dis} = Displaced air (ft^3/min).
Q_{gen} = Generated air (ft^3/min).

Correlating data

Each methodology had to be compared using the same application. This was

Table 1. Airflows calculated from *Industrial Ventilation Manual* methodology

Conveyor	Belt width (ft)	Freefall height (ft)	Material air (ft^3/min)	Drop air(ft^3/min)	Q_{Tot} (ft^3/min)
F	36	35	1050	700	1750
D	36	3	1050	0	1050
A – B	36	9	1050	700	1750

Table 2 Airflows calculated from *Dust Control Handbook* methodology

Conveyor	Load (tph)	A_U (ft^2)	Freefall height (ft)	Material dia. (ft)	k_{ind}	Q_{ind} (ft^3/min)	Q_{Tot} (ft^3/min)
F	440	1.16	35	0.17	10	1715	1715
D	440	2.25	3	0.17	10	647	647
A – B	440	0.8	9	0.33	10	380	380

Table 3. Airflows calculated from *Foundations* methodology

Conveyor	Load (tph)	Density (lb/ft^3)	k dis	A_U (ft^2)	Freefall height (ft)	Material dia. (ft)	k_{ind}	Q_{dis} (ft^3/min)	Q_{ind} (ft^3/min)	Q_{Tot} (ft^3/min)
F	440	40	33.3	1.16	35	0.17	10	366.3	1715	2082
D	440	40	33.3	2.25	3	0.17	10	366.3	647	1013
A – B	440	40	33.3	0.8	9	0.33	10	366.3	380	746

Table 4. Collected velocity data and calculated airflows

Conveyor	Measured air velocity (ft/min)	Exit length (ft)	Exit height (ft)	Exit area (ft^2)	Measured flow (ft^3/min)
F	550	2	0.833	2	1100
D	588	3	0.75	2.25	1323
A – B	550	3	0.416	1.25	687.5

Table 5. Difference (%) between calculated and measured airflows for all methodologies

Conveyor	*Industrial Ventilation Manual*	*Dust Control Handbook*	*Foundations*
F	59.1	55.9	89.2
D	-20.6	-51.1	-23.4
A – B	154.5	-44.8	8.5
Average	64.3	-13.3	24.8

Table 6. Comparisons of airflows using *Dust Control Handbook* methodology, mathematically neglecting all drops but the first.

Conveyor	Measured airflow (ft^3/min)	Modified calculated airflow (ft^3/min)	Modfied difference (%)
F	1100	641	-41.7
D	1323	647	-51.1
A – B	688	380	-44.8
		Average	-45.9

Table 7. Comparisons of airflows using *Foundations* methodology, mathematically neglecting all drops but the first.

Conveyor	Calculated airflow (ft^3/min)	Measured airflow (ft^3/min)	Difference (%)
F	1008	1100	-8.4
D	1013	1323	-23.4
A – B	746	688	8.5
		Average	-7.8

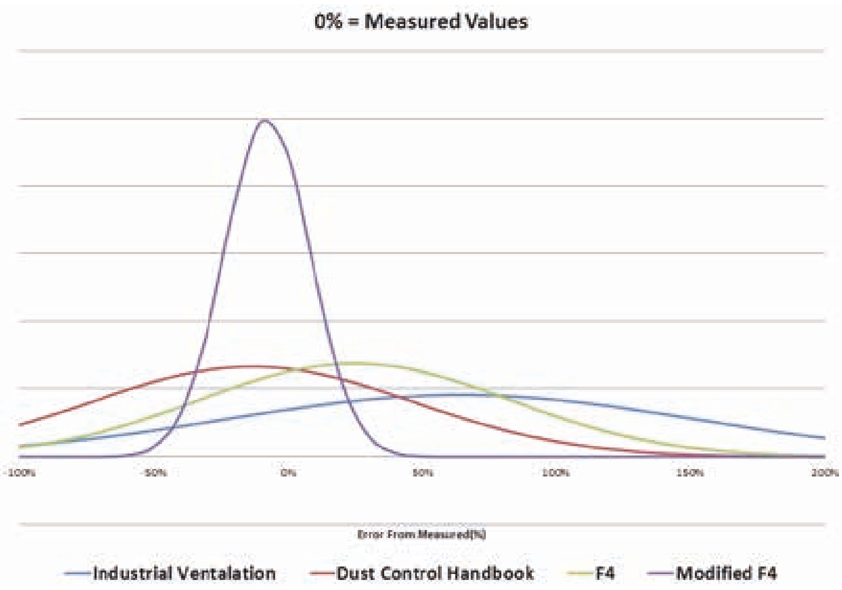


Figure 4. Standard distribution of error for each calculation method.

accomplished on three conveyors belts (A-B, D and F) at the Hennepin coal-fired power plant in Hennepin, Illinois. The information needed to calculate the airflows using each methodology was collected from each conveyor. The airflows were then calculated using the methodologies. These airflows can be seen in Tables 1 – 3.

The actual air velocity was measured at every transfer point using a pitot tube manometer. The pitot tube was placed into the exit area of the chute and the velocity was measured. This velocity was multiplied by the cross-sectional area of the chute to find the total airflow. This data is shown in Table 4.

Discussion

The total quantity of airflow produced in a transfer point was calculated for every one of the methodologyies These varied from actual airflow measured by a certain percentage (Table 5).

Each method used to predict the airflow produced average values that deviated >10% from the actual airflow. A method had to be determined to better represent the airflow generated by a transfer point.

Conveyor F included a drop height of 35 ft. This was not a continuous drop, but rather a series of smaller drops. It is reasonable to assume that the induced air from the first drop would be drawn from the entry area. When the material stream came in contact with the first impact, all of this air would be expelled. Rather than travelling through the transfer point, this air would be drawn and induced by the next fall. The first fall would limit the amount of air in the material stream. The method described in the *Dust Control Handbook* was altered to reflect this. The first drop height was used in the calculation and subsequent drops were ignored.

Table 6 shows that the assumption about drops does bring all of the induced air computations together, but that they are lower than actual measured airflow by a factor of 45%. The *Dust Control Handbook* did not take into account the displaced air. When this displaced air factor was included – per the *Foundations* methodology – the differences clustered around 0%, as shown in Table 7.

The methodologies produce a mean and a standard deviation of the airflows, relative to the measured flow. These deviations were used to generate and compare standard distribution curves for the respective methodologies (Figure 4).

Each methodology can give a statistical representation of the airflow, but none are exactly accurate. The methodologies can provide much insight into methods for reducing airflows. Since dust travels in air, it makes sense that to minimise dust, airflow must also be minimised. Every part of the air generation equations should be analysed to determine the greatest impact on air produced.

Displaced air

The two factors that are drivers of the displaced air are bulk density and material flow, neither of which can be changed. The density is a property of the material and the flow is set by the design considerations of the bulk handling system. Because neither can be altered, the displaced air is considered the baseline.

Generated air

The generated air is caused by another piece of equipment that is necessary to the process and therefore cannot be removed.

Induced air

Like displaced air, there are factors of induced air that cannot be changed. These factors are the material load and the diameter of the material. All other factors, aside from the constant, can be changed through design. Of these factors, each has a unique impact on the air created. If the open area through which air can enter the system is increased or lowered, the airflow is increased or lowered in direct proportion. If the freefall distance is changed, the airflow is altered by a factor of the cube root of the change squared.

If the process of the material stream expanding happens regardless of the conditions, a vacuum will be created between the particles. This vacuum must be filled with air, and the source of this air is irrelevant. If the area through which air can enter the chute is so small that the vacuum cannot be fed entirely by this source, the vacuum will draw air from other sources. The vacuum can draw all the air from the induced air that has just been released. If the open area is reduced to zero, the entire induced air factor reduces to zero.

If the material free-fall is lowered, the material stream cannot draw as much air, as the stream does not have a chance to spread and create voids that result in vacuums. This factor can also be reduced by not allowing the material to spread and create vacuums in the first place. Reducing the free-fall distance to zero will also reduce the induced air to zero.

While the open area and the drop height can both impact the air induced, the cost and difficulty of altering the drop height makes changing the open area a far more desirable proposition.

This is the reason that much research has been done in the area of sealing the transfer point. Technologies exist to seal the transfer chute, ranging from flat supports (Figure 5) under the belt to rubber seals between the chute wall and the belt (Figure 6) and rubber curtains on

Figure 5. Belt support.

Figure 6. Rubber chute wall seal.

Figure 7. Entry and exit curtains.

the exits and entrance (Figure 7). The supports, combined with the sealing technology, create a very tight seal against the belt. The rubber curtains can be used to create a seal around the entry and exit that can conform to the material stream. Openings in the chute can be closed with cut steel or rubber. Rubber is a desirable solution, as it is flexible and easier to work with than steel, but it is non-porous and can be used to restrict air. It can also be cut to fit around odd moving geometries.

Conclusion

When considering the types of coal the industry is handling today, dust will always be present. This dust will be contained in the transfer chutes or escape at the exit areas. There are many methods to predict and improve the size and effectiveness of a dust control system. A best practice has been developed for predicting and minimising airflow.

This practice begins by reviewing all the different methods for computing the airflows within a transfer point. Operators should then calculate potential airflow using each industry-accepted method and compare those numbers to the actual airflow at the exit area. The methodologies outlined in the *Dust Control Handbook*, *Industrial Ventilation* and *Foundations* all give statistical representations of the airflow, but a measured airflow is always accurate.

The configuration of the problem area should be observed and the location where the dust is being generated should be identified. Operators should address the obvious problems, starting at the entry area working to the exit, sealing up the entire transfer area. When addressing each area, it is important to remember one simple phrase: tight is right. Sealing the transfer point will help reduce the airflow, contain the dust and be the most economical solution. After everything is sealed, it is vital to again check the exit area airflow to compare the results.

Finally, if the problem area still does not meet expectations, then operators must investigate suppression and collection. When specifying a system for suppressing or collecting the dust, workers must remember to size the system to meet the measured airflows, rather than the calculated airflows. This will generate a solution that is sized to the reality of the application.

Quantifying and reducing the airflow will allow a user to specify a dust collection system large enough to be effective, but not so large as to waste capacity. WC

References

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