Facts Concerning Dust and Air

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1. Introduction

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 that are created by the handling of bulk solids. Extensive research has been conducted to determine the quantity of air created at a transfer point. The *Industrial Ventilation Guide*, the *Dust Control Handbook* and *Foundations* all have slightly different methodologies developed to predict the amount of air generated. While close, each of these approaches has certain variations 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 minimized by mechanically altering the construction of the transfer point. A full understanding of the airflows involved will allow a user to specify a dust collection system large enough to be effective, but not so large as to waste capacity and capital.

2. Background

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

Though much research has been conducted on the effects of dust, the elusive and difficult behavior of dust has prevented as much research into the origin of said dust in a transfer point setting. A 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 microns, the particle will fall fairly quickly and reenter the material stream. If the particle is smaller in diameter than 500 microns, that particle 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 behavior of the dust created.

Several methods are used in industry to compute airflows in a transfer point. These methods include the method described in the *Industrial Ventilation Manual*, the technique described in the *Dust Control Handbook*, and the approach described in the Martin Engineering *Foundations* book.

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

3. Theory

There are several methods used in industry to calculate airflows. All calculation methods use similar inputs to determine the air generated in a transfer point.

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

These zones are shown below in Figure 1.

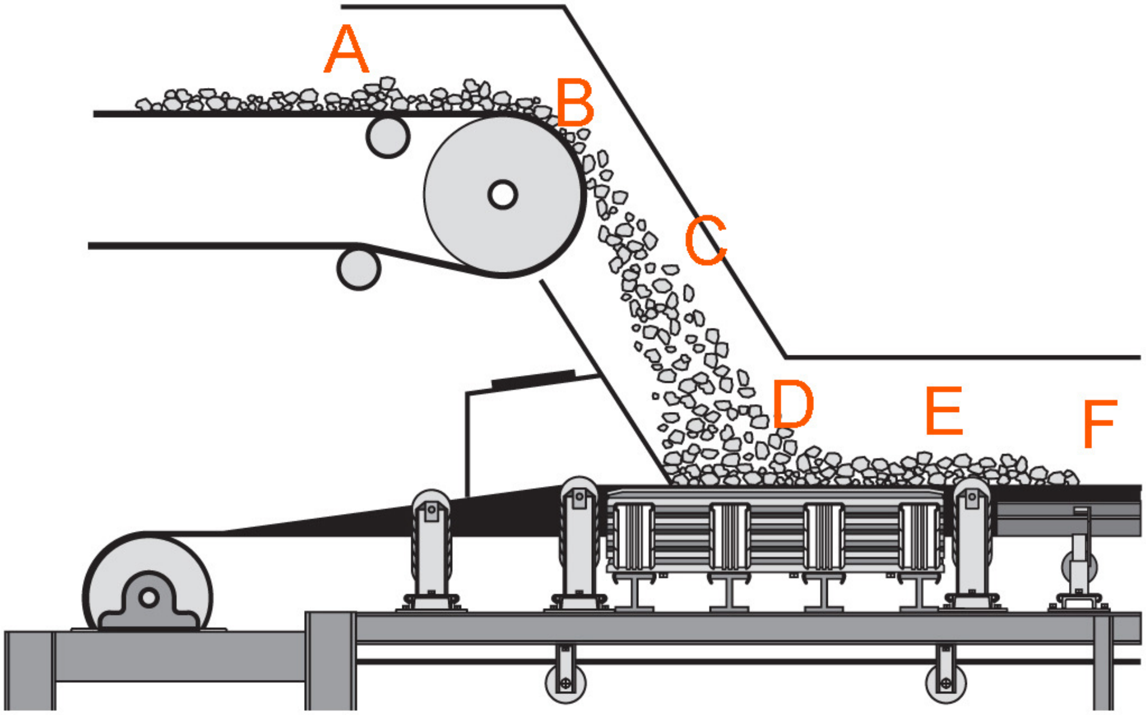

Figure 1 -- Basic Regions of a Conveyor Transfer

Generally, the air enters at the entry area (A) and exits at the exit area (F). Air will move through the transfer point, while the direction and speed will change. This basic trend is greatly influenced by the fact that the material conveyed also moves from A to F. The material itself will pull 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, the air velocity will be identical to the velocity of the material. The viscosity of the air will force the rest of the air body to move in that direction, as well.

The mechanical event of impact between material and belt occurs at the Impact Region (D), which produces a localized 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.

Industrial Ventilation Manual Methodology

The *Industrial Ventilation Manual* 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'. This additional air is also dependent on the belt width. The equations for this methodology are shown below.

Exhaust Air (cubic feet per minute CFM)

$$Q_{Ex} = 350 \cdot BW + Q_D \qquad \text{Exhaust Air} \qquad (1)$$

Inputs
Belt Width (ft.) = BW
Additional Air Generated from Drop = Q_D
    If material drop is less than 3', $Q_D = 0$
    If material drop is more than 3' and BW is < 3, $Q_D = 700$
    If material drop is more than 3' and BW is > 3, $Q_D = 1000$

Dust Control Handbook Methodology

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 is traveling 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 in Figure 1), it continues to spread and creates small pockets of vacuum between the material particles. Nature abhors a vacuum, so the stream will fill these small voids with any air it can. This phenomenon is illustrated below in figure 2.

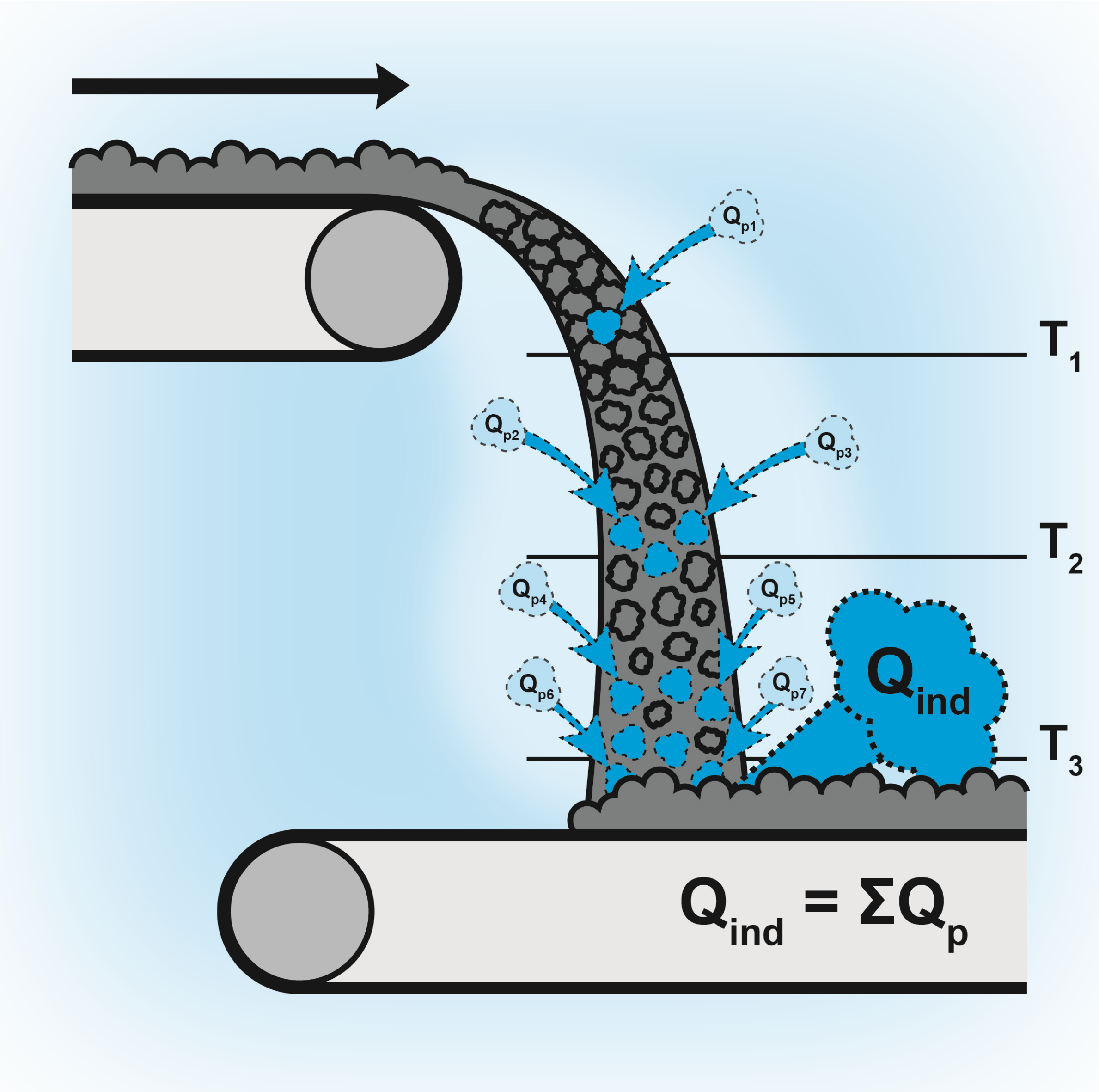

Figure 2 Illustration of Induced Air

This figure shows that for every second the material is in free-fall, it is pulling 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 in Figure 1), all the air that the material stream has accumulated is instantly expelled.

The equation used to quantify the induced air is shown below.

Induced Air (cubic feet per minute CFM)

$$Q_{ind} = k \cdot A_U \cdot \sqrt[3]{\frac{R \cdot S^2}{D}} \qquad \text{Induced air} \qquad (2)$$

Inputs
Open area that air can enter system (cubic feet) = A_u
Material Load (tons per hour TPH) = R
Height of material free-fall (feet) = S
Average material diameter (ft) = D
Conversion Factor (10) = k

Foundations Methodology

The *Foundations* book employs a method that begins with the induced air from 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 cubic feet per minute, as that is the industry standard. Displaced air is shown below in figure 3.

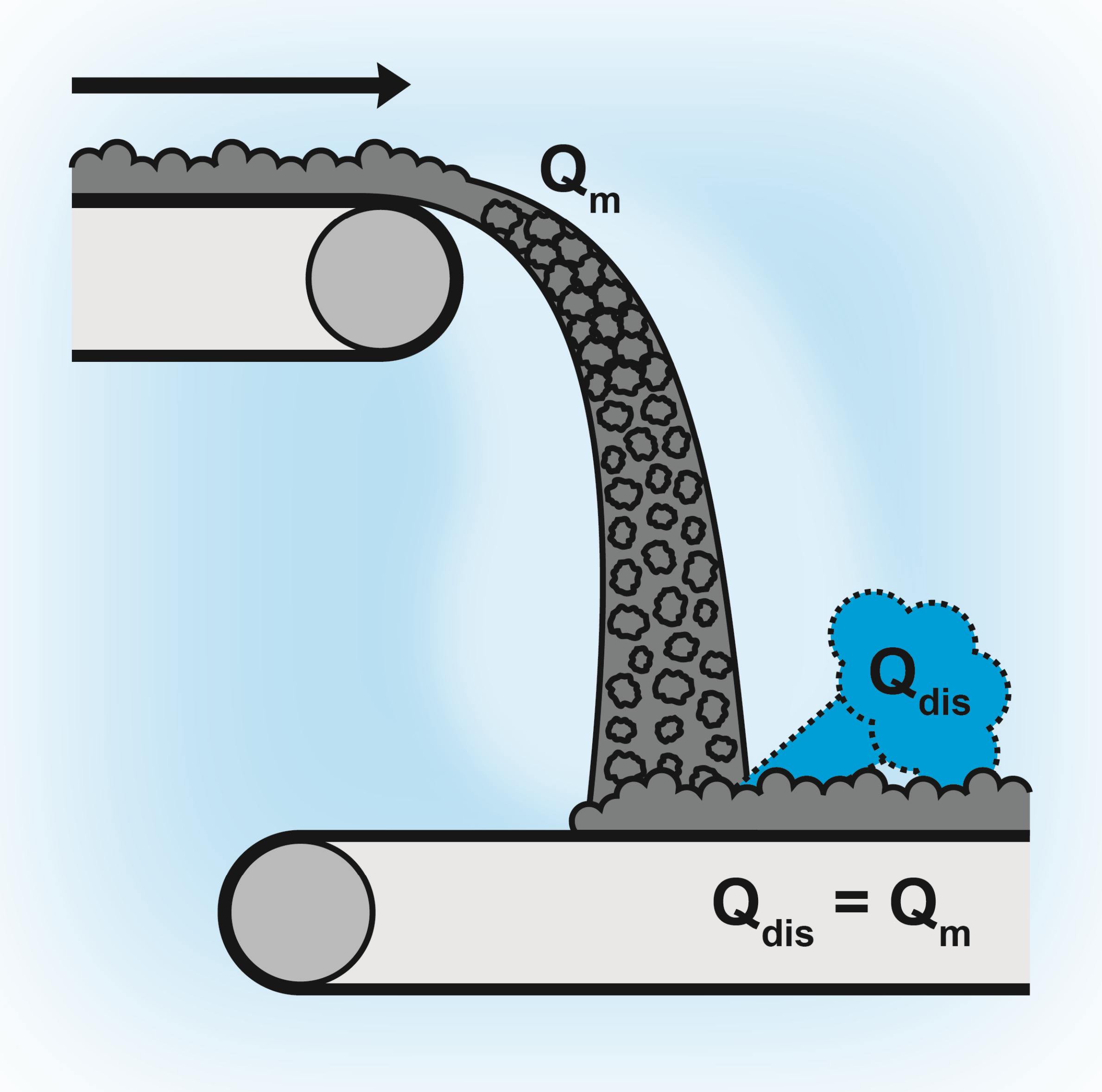

Figure 3 Illustration of Displaced Air

The equation for displaced air is as follows.

Displaced Air (cubic feet per minute CFM)

$$Q_{dis} = \frac{k \cdot L}{\rho}$$ Displaced air (3)

Inputs
Material Load (tons per hour TPH) = L
Material Bulk Density (pounds per cubic feet) = ρ
Conversion Factor (33.3) = k

There may be another device that is generating 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 air flow 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 will be 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 in Figure 1). This is the air that carries dust, so this is the air that must be minimized with engineering controls.

The equation for total air is shown as follows.

Total Air (cubic feet per minute CFM)

$$Q_{Tot} = Q_{ind} + Q_{dis} + Q_{gen}$$ Total air (4)

Inputs
Induced Air (CFM) = Q_{ind}
Displaced Air (CFM) = Q_{dis}
Generated Air (CFM) = Q_{gen}

4. Correlating Data

The information needed to calculate the airflows using each methodology was collected from each conveyor, and the airflows were then calculated using each methodology. The following tables tabulate these airflows.

Conveyor	Belt Width (in)	Belt Width (ft)	Freefall height (ft)	Material Air (CFM)	Drop air (CFM)	Q tot (CFM)
Conveyor "F"	36	3	35	1050	700	1750
Conveyor "D"	36	3	3	1050	0	1050
Conveyor "A-B"	36	3	9	1050	700	1750

Table 1 Airflows Calculated from Industrial Ventilation Guidebook methodology.

Conveyor	Load (TPH)	Au (ft2)	Freefall height (ft)	Material Diameter (ft)	k ind	Q ind (CFM)	Q tot (CFM)
Conveyor "F"	440	1.16	35	0.17	10	1715	1715
Conveyor "D"	440	2.25	3	0.17	10	647	647
Conveyor "A-B"	440	0.8	9	0.33	10	380	380

Table 2 Airflows Calculated from Dust Control Handbook methodology.

Conveyor	Load (TPH)	Density (lb/ft3)	k dis	Au (ft2)	Freefall height (ft)	Material Diameter (ft)	k ind	Qdis (CFM)	Q ind (CFM)	Q tot (CFM)
Conveyor "F"	440	40	33.3	1.16	35	0.17	10	366.3	1715	2082
Conveyor "D"	440	40	33.3	2.25	3	0.17	10	366.3	647	1013
Conveyor "A-B"	440	40	33.3	0.8	9	0.33	10	366.3	380	746

Table 3 Airflows Calculated from Foundations methodology.

Each methodology had to be compared using the same application. This was accomplished at Hennepin Power Station in Hennepin, IL.

The actual air velocity was measured at each transfer point using a pitot tube manometer. The pitot tube was placed into the exit area of the chute (Region F in Figure 1), and the velocity was measured. This velocity was multiplied by the cross sectional area of the chute to find the total air flow. This data is tabulated below.

Conveyor	Measured Air Velocity (FPM)	Exit length (in)	Exit height (in)	Exit length (ft)	Exit height (ft)	Exit Area (ft2)	Measured Flow (CFM)
Conveyor "F"	550	24	10	2	0.833	2	1100
Conveyor "D"	588	36	9	3	0.75	2.25	1323
Conveyor "A-B"	550	36	5	3	0.416	1.25	687.5

Table 4.1 Collected Velocity Data and Calculated Air Flows

5. Discussion

The total quantity of air flow produced in a transfer point has been calculated in Section 3 and correlated in Section 4 for each methodology. These varied from reality by a certain percentage, as shown below.

Conveyor	Industrial Ventilation Percent Difference (%)	Dust Control Handbook Percent Difference (%)	Foundations Percent Difference (%)
Conveyor "F"	59.1%	55.9%	89.2%
Conveyor "D"	-20.6%	-51.1%	-23.4%
Conveyor "A-B"	154.5%	-44.8%	8.5%
Average	64.3%	-13.3%	24.8%

Table 5.1 Comparison of Calculated and Measured Air Flows for all Methodologies

It is of note that each method used to predict the airflow produced average values that deviated greater than 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'. 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 (Region A in Figure 1). When the material stream came in contact with the first impact, all of this air would be expelled. Rather than traveling 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.

Conveyor	Measured Air Flow (CFM)	Modified Dust Control Handbook Calculated Air flow (CFM)	Modified Dust Control Handbook Percent Difference (%)
Conveyor "F"	1100	641	-41.7%
Conveyor "D"	1323	647	-51.1%
Conveyor "A-B"	688	380	-44.8%
		Average	-45.9%

Table 5.2 Comparisons of Airflows Using *Dust Control Handbook* Methodology, Mathematically Neglecting All Drops but the First

Table 5.2 shows that the assumption about drops does bring all of the induced air computations together, but they are lower than actual 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 5.3.

Conveyor	Calculated Air Flow (CFM)	Measured Air Flow (CFM)	Percent Difference (%)
Conveyor "F"	1008	1100	-8.4%
Conveyor "D"	1013	1323	-23.4%
Conveyor "A-B"	746	688	8.5%
		Average	-7.8%

Table 5.3 Comparisons of Airflows Using Foundations Methodology, Neglecting All Drops but the First

Each methodology produces 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 each methodology, shown below in Figure 5.1.

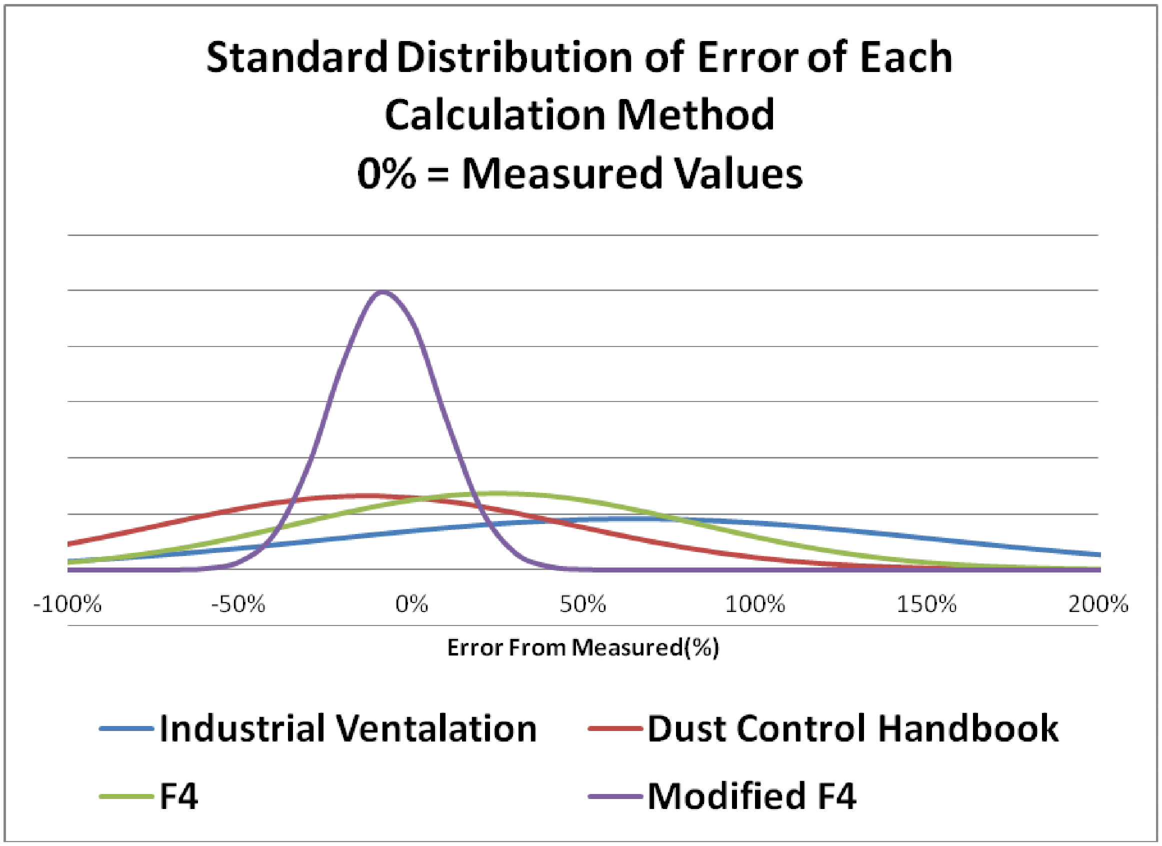

Figure 5.1 Statistical Breakdowns of Airflow Calculation Methodologies

This breakdown shows that each methodology can give a statistical representation of the airflow, but none are exactly accurate.

The various methodologies can provide much insight into methods for reducing airflows. Since dust travels in air, it makes sense that to minimize dust, airflow must be minimized. Each part of the air generation equations should be analyzed 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 system (A_u) = is increased or lowered, the air flow is increased or lowered in direct proportion. If the free-fall distance (S) 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 very 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 under the belt, to rubber seals between the chute wall and the belt, to rubber curtains on the exits and entrance. 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 very flexible and much easier to work with than steel, but it is nonporous and can be used to restrict air. It can also be cut to fit around odd moving geometries.

These technologies are shown below.

Figure 5.2 Belt Support

Figure 5.3 Rubber Chute-wall Seal

Figure 5.4 Entry and Exit Curtains

6. 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” was developed for predicting and minimizing airflow.

Begin by reviewing all the different methods for computing the air flows within a transfer point. Calculate potential air flow using each industry-accepted method accepted and compare those numbers to the actual air flow at the exit area. The methodologies outlined in the *Dust Control Handbook*, the *Industrial Ventilation Guidebook* and *Foundations* all give statistical representations of the airflow, but a measured airflow is always accurate.

Then observe the configuration of the problem area and identify where the dust is being generated. Address the obvious problems, starting at the entry area working to the exit, sealing up the entire transfer area. When addressing each area, 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, again check the exit area airflow to compare the results of your efforts.

Finally, if the problem area still does not meet expectations, then investigate suppression and collection. When specifying a system for suppressing or collecting the dust, 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.

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A self-described “numbers guy,” Daniel Marshall holds a B.S. in Mechanical Engineering from Northern Arizona University. He joined Martin Engineering in 2000 as a Research and Development Engineer, and has moved to Product Development and Application Engineering. Marshall is instrumental in the design and application of dust suppression systems and other components to improve the conveying of bulk materials.

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Greg began his career in 1979, when a strong back was the only qualification for a coal handling position. Physically digging his way through the fuel department, he earned a degree in hard labor. Over the years, he has developed and supported multiple system design changes that have resulted in a clean, efficient and safe fuel handling system.