EMGT 835 Field Project:

Cost Analysis Procedures for Use in Promoting Fine Filtration Media

By

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Master Of Science

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An EMGT Field Project report submitted to the Engineering Management Program and the Faculty of the Graduate School of The University of Kansas in partial fulfillment of the requirements for the degree of Master of Science.

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- James Plummer (co-worker) was very helpful in providing technical review of the training manual for clarity and ease of use for people without engineering degrees or similar technical backgrounds.
- I appreciate the efforts of Marc Moreano (employee's manager) to ensure the procedures manual was optimally practical for use by {company name}'s product managers.
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- Finally, I would like to thank my parents, my fiancée, and my friends for encouraging me to complete the project and the program.

EXECUTIVE SUMMARY

The field project is a cost analysis procedures manual to be used within {company name} to quantify the cost of operations and materials for current and recommended dust collection practices. The estimated benefits from changing filtration medias can be used to determine a recovery period for the additional funds (cost differential) required for the upgrade in technology. In addition, the procedures manual provides direction for comparing alternative media options based on a life cycle analysis (net present value and equivalent uniform monthly cost).

Cost estimation sheets have been included for quick reference when the production managers are providing general information to the customer. A sample cost analysis has been included as well.

The procedures manual has been prepared with suitable technical information to allow product managers to provide accurate information to customers. However, as very few product managers have suitable technical background or experience, the use of theory has been kept to a minimum or has been presented in an appropriate manner.

Selections from the New York Blower Company's Engineering Letters and a technical paper by the author have been included for addition reading at the product manager's discretion.

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INTRODUCTION / PROJECT BACKGROUND

The purpose of this project is to develop a cost analysis tool and the procedures for calculating and presenting the economic and operational benefits of fine filtration media to {company name}'s customers. The tool will eventually be implemented at all of the offices that are involved with the sale of filtration media for industrial applications. Initially, however, the cost analysis activities will be coordinated out of the Kansas City office.

{Company name} provides filtration media for industrial dust collection applications. The company has developed several filtration medias that provide significant benefits, both economically and operational-wise, to the end user. Understandably, the purchase of these medias requires an increase in material cost above traditional medias. However, the benefits can be quantified and used to offset the additional funds required for the upgrade.

Currently one or two people (including the author) are involved with the cost analysis procedure. Not only does this procedure take up a portion of their time from other duties, it also inherently involves a time delay with the offices outside of the United States. Furthermore, there are currently only a few individuals in the applicable product management roles who technically understand the basis of the calculations and can adequately convey such information to the customer.

Therefore, this project has several important objectives. First, it will develop the required calculation sheets and procedures to calculate the costs associated with various types of dust collection systems. Excel worksheets will be initially developed in imperial units, but worksheets with metric units will be required for international quotes and for activities coordinated by the international offices.

Second, it will present the basics of economic analysis used by customers to make purchasing decisions. Topics will include payback schedule, equivalent uniform monthly cost, and net present value.

Finally, the procedures book will include appropriate technical background to promote accurate evaluations of customers' systems and limit the use of "rules of thumb" that are really only applicable to specific situations or operating conditions.

It is important to provide background for both subjects in a manner than can be understood by non-technical staff members and customers. This is imperative for correctly calculating costs and benefits and for providing correct information to the customer.

The result of this project will be a cost analysis procedure book complete with background information, methodology, example calculation sheets (Excel), and guidelines for presentation. It will also include warnings and guidelines for situations that may significantly increase the risk level related to the sale.

LITERATURE REVIEW

All of the information used in preparing the procedures manual is available in many mechanical engineering textbooks, engineering reference books (including PE review books), textbooks on economic analysis and vendor information. The information used in preparing the procedures manual includes:

a) NYB Engineering Letters (published by New York Blower Fan Company):
   i) System Calculation (Letter #1)
   ii) Fan Laws and System Curves (Letter #2)
   iii) Understanding Fan Performance Curves (Letter #3)
   iv) Temperature And Altitude Affect Fan Selection (Letter #4)
   v) Field Testing of Fan Systems (Letter #7)
   vi) Selection Criteria for Fan Dampers (Letter #11)

b) Mechanical Engineering Reference Manual for the PE Exam

c) Capital Investment Analysis For Engineering And Management (EMGT Finance Course book)

d) Industrial Ventilation Manual

SUMMARY AND CONCLUSIONS

It is challenging to provide technical guidance to non-technical people, especially when the technical aptitudes in the group range from individuals with a weak understanding of the subject to individuals who are fairly mechanically adept. At best, such undertakings should aim for the middle of the range.

Furthermore, it is very easy to assign generalities to various applications or industries, either in an attempt to streamline the process, or out of lack of experience. Therefore, it is very important to emphasize that every application is unique and deserves sufficient review.

There is also an inherent temptation to "make it work" in order to provide the customer compelling evidence to convince him to purchase the advanced media. The two parameters that are most likely to be aggressively estimated are the reduction in static pressure and the reduction in cleaning energy. Hopefully, the procedure guidelines, the experience of the product manager, and the approval process will promote using accurate estimates in cost analysis activities.

It is also important to recognize that cost justification is not feasible in some applications, and such conclusions should be presented to the customer. This is important for two reasons. First, customers generally respect vendors who provide accurate information, especially when it may not be beneficial to the sale of goods or services. Second, it protects the company from implied or actual warranties related to expectations that cannot be met in the application.

In reality, the customer must be able to control the system to the anticipated operating conditions. With cleaning functions, this is typically an easy change requiring quick modification of settings on a controller or within a control system's architecture. At a minimum, the customer may need to update the control board to a more modern unit.

Ensuring the customer can control the system airflow to the anticipated operating point may be more problematic. First, the customer must have some form of fan control installed on the system, whether it is a variable frequency drive, an inlet damper, or an outlet damper.

If the customer has an inlet damper or a variable frequency drive (VFD), the fan output can be readily changed. In the case of an inlet damper, a significant reduction in static pressure may also require a change in fan speed (sheave change or VFD) to ensure the fan is operating on an acceptable part of the fan curve. For a VFD, either type of damper may be used for the same concerns.

If the customer has an outlet damper (but no VFD), then the customer must change the sheaves on the fan to achieve the reduction in fan energy.

Of course, the setting of any type of control device must be modified in order to control the airflow to the design operating point when the resistance across the media changes.

SUGGESTIONS FOR ADDITIONAL WORK

Rarely is a procedures manual complete upon first distribution. Therefore, it is expected that this effort will continue and adapt based on acquired information, case histories, and available tools. Several additions are currently being considered or are under development:

a) A metric version of the procedures manual will be required for the international offices, as well as for the domestic office for applicable situations.

b) The manual and calculation sheets should be updated to include interest factors.

c) Additional financial analysis tools should be considered including the internal rate of return (IRR).

d) A paper-based approval form should be generated and executed to ensure correct information is provided to the customer and such information does not put the company at risk.

e) It would be helpful to have a program that links with the business programs used across the company. It is very important, however, that these interface programs include functions that require appropriate review and approval activities before information can be sent to the customer.

BIBLIOGRAPHY / REFERENCES

{Refer to the appropriate section in the procedures manual}

Cost Analysis Procedures for Use in Promoting Fine Filtration Media

Prepared By: David A. Renfert, PE
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Revision No: X

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INTRODUCTION

Most companies do not release funding for projects or capital expenditures of financial significance without first performing a cost analysis on the proposed actions. The review methods range from quick analyses to detailed programs involving many functions in the plant.

{Company name} has been evaluating the financial impact of improvement strategies for baghouse applications, including upgrading the baghouse media to fine filtration products (ePTFE membrane bags or pleated filter elements). This procedures manual has been compiled to provide a standard methodology of evaluating a customer's operations and presenting accurate information to be used in financial decisions.

This manual also includes technical information on system resistance and fan operation to ensure accurate evaluation of the customers' applications. This level of review is required for several reasons:

- Typically used "rules of thumb" generally only apply to specific situations or operating conditions and should be used with caution.
- Appropriate technical review is required to estimate both the current fan performance and the expected changes in performance based on a change in the system configuration or the fan operation. This is especially important to minimize any warranty risk (actual or implied) to {company name}.
- Providing qualified and accurate information to the customer maintains {company name}'s reputation as technical experts in the baghouse industry.

The appendix includes cost estimation charts, example cost analyses, and several reference documents for use by appropriate individuals in evaluating customers' systems and performing cost analyses.

SYSTEM STATIC PRESSURE

Static Pressure Basics

The static pressure of a system represents the energy required to overcome the resistance to the airflow moving through the system components. The units of static pressure are inches water column (w.c.); one (1) inch w.c. corresponds to the pressure that will raise a column of water one (1) vertical inch. Inches water gage (w.g.) are also used for units of static pressure.

Types of System Losses

The components of a system's static pressure fall into one of four categories, as described below:

- *Duct or equipment losses* include hoods, ductwork, cyclones, and physical equipment that do not change configuration (baghouse without media included). These losses are often called "dynamic losses" as they are directly proportional to the square of the flow. They are also dependent on the density of the gas stream.
- The *fabric media loss* is dependent on several factors including grain loading, material characteristics, air-to-cloth ratio, and cleaning frequency. Since several of these variables will change when the airflow changes, there is not a general performance curve for media loss. However, the relationship between airflow and media loss is typically considered a linear function.
- An *artificial loss* is applied to a system by the manipulation of device or assembly, such as a blast gate (slide gate) on a segment or an outlet damper on

a fan. The loss across a blast gate is dependent on the open area in the throat of the device and is also dynamic in nature.

An outlet damper changes the resistance in the system based on the position of the damper. Specific information on fan dampers is covered in the Fan Basics section and in the appendix.

- *Special losses* are attributed to specific devices or equipment, such as heat transfer coils, fan silencers, and burners. The manufacturer of these devices should be consulted for appropriate information on expected losses.

System Static Pressure

The total system loss at a given airflow is the summation of all the loss components for the volumetric rate of gas (air) moved through the system:

SP (inches w.c.) = dynamic losses + media loss + artificial loss + special losses

For a duct network with several branches, the system static pressure is the sum of the branch losses from the start of the governing segment (worst case) to the end of the system, plus other applicable losses. The other segments in the duct network must be balanced with the governing branch to make sure the appropriate air volumes are handled in each segment.

For a basic duct system with a baghouse (and media), there is a general equation that correlates the static pressure, SP (inches w.c.) with the flowrate, Q (acfm) through the system:

$$SP = (C_1 \times Q^2) + (C_2 \times Q)$$

The first term (C_1 x Q^2) on the right side of the equation represents the dynamic losses in the system, while the second term represents the media loss (assuming a linear relationship with airflow). The coefficients C_1 and C_2 are specific to the system and the application.

Since the dynamic losses vary by the square of the airflow, they are typically the controlling factors in the air volumetric rate moved by a fan.

System Curves

A plot of the system static pressure versus airflow results in a quadratic curve (Figure 1). Changing a component of the system static pressure will change the system curve.

A common change in a dust collection system is the condition of the media. This can be problematic if the flow in the system is not controlled to the design operating point.

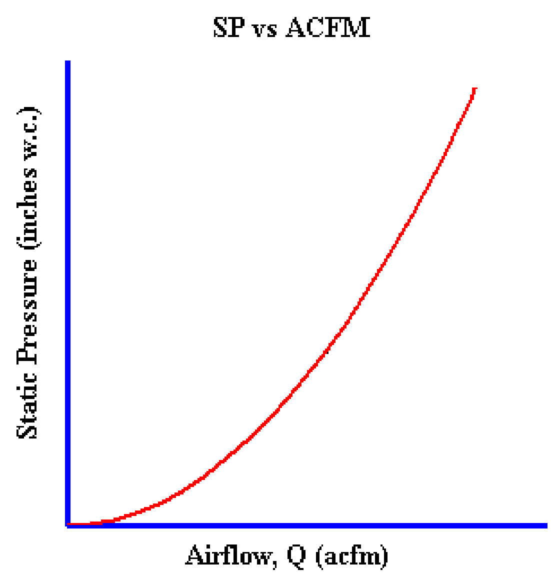

Figure 1: General System Curve

System Operating Point

A fan system does not have unlimited airflow capacity; the system airflow is determined by the point (volumetric rate) at which the loss through the system matches the static output of the fan. This point is called the operating point.

As discussed in the Fan Basics section, the operating point of a system will change whenever either the fan static output is modified or when the system resistance changes.

FAN BASICS

Basic Fan Operation

A fan is basically a "rotating shovel" that moves a given volumetric rate (acfm) of gas (air) based on the speed of the fan (revolutions per minute or rpm) and the resistance (static pressure or SP, inches w.c.) of the system or application in which it operates. The performance of fan is often described differently, based on the situation:

- A fan provides a specific volumetric rate against a specific system resistance.
- A fan develops a specific static pressure for a specific volumetric rate.

A particular point of operation (acfm @ "X" inches w.c. SP) results in a level of energy (brakehorsepower or BHP) required by the device turning the fan (typically a motor, but steam-driven fans exist as well). The energy required by the fan is dependent on several factors including gas stream conditions and system efficiencies.

Although centrifugal fans are commonly used in dust collection systems, there are many types of fans that can be used based on the requirements of the application.

Fan Charts

Fans are rated for standard conditions per specific testing guidelines. Fan manufacturers document performance and energy requirements in chart form for their general catalogs. An example fan chart is included in the appendix.

When selecting or evaluating a fan using a fan chart, the engineer or designer uses a specific methodology to correlate the actual fan performance to that at standard conditions so appropriate information can be obtained.

Details on fan selection can be found in the Industrial Ventilation Manual.

Fan Curves

A plot of the fan static pressure versus air volume for specific operating conditions (rpm, gas density) results in a fan curve. Accordingly, fan manufacturers provide specific fan curves after the operating conditions are established. Figure 2 shows the performance curve for a centrifugal fan providing 10,000 acfm against a system resistance of 14 inches w.g., when the gas stream temperature is 70 degree Fahrenheit.

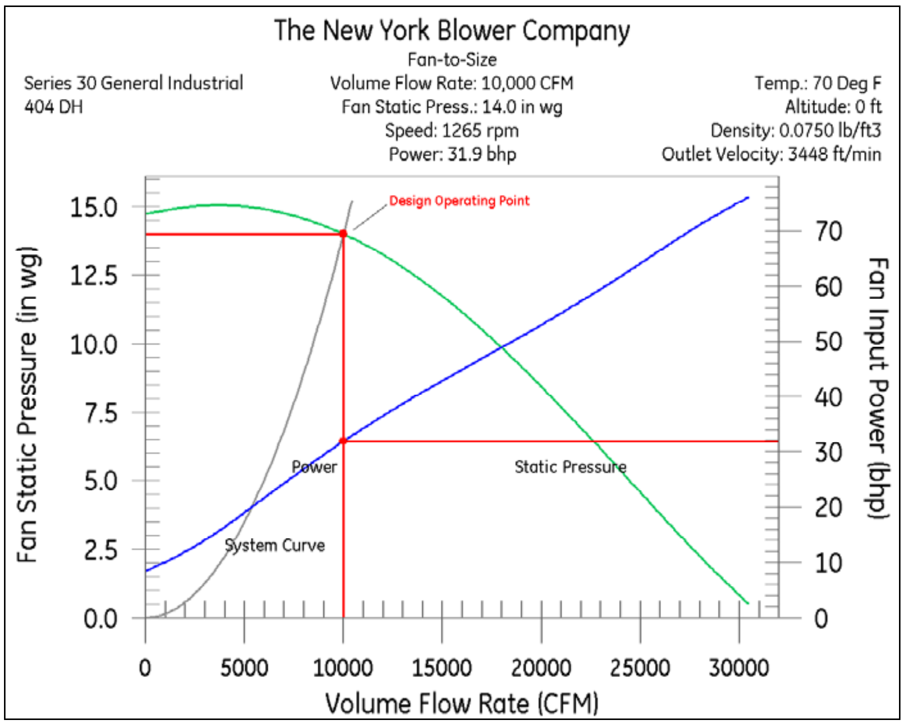

Figure 2: General Fan Performance Curve

For this air volumetric rate, the fan requires an input power of 31.9 BHP. The input power for a fan depends on several variables including the fan static efficiency and the efficiencies of the drive components (motor and sheave assemblies, as applicable).

The BHP required for a specific operating point can be determined from the following equation:

$$\textbf{BHP} = \frac{\text{ACFM x SP (in. w.g.)}}{6356 \text{ x } \eta_{drive} \text{ x } \eta_{motor} \text{ x } \eta_{fan}}$$

where: 6356 = coefficient

η_ = efficiency

The operating point of a fan system is the point where the system resistance curve intersects the fan static pressure curve. When either the fan's static pressure output or the system's resistance changes, the flow in the system changes. For a fixed fan (constant speed), the operating point will move to the left or right of the design operating point based on the changes to the system resistance.

The fan curve shown in Figure 2 is typical for a specific type of centrifugal fan. It is important to note that there are many types of centrifugal fans (air foil, backward-inclined, etc.), and each type has a unique curve.

Fan Performance for Different Gas Stream Conditions

The volumetric rate of air (acfm) moved by a fan does not change for different gas densities if the system and fan are subject to the same conditions. This is because the reduction in fan static pressure is matched by the decrease in system resistance, as both of these values are dependent on the gas stream conditions.

However, the mass flow rate does change based on gas stream conditions, as does the energy draw for the fan. In fact, correct motor selection requires the engineer or designer to evaluate the energy required for the application across the range of gas stream conditions.

Additional information on fan performance for varying gas stream conditions and system configurations can be found in NYB Engineering Letter #4 (included in the appendix).

Fan Control

Controlling the airflow in a dust collection system is very important to both the performance of the system and the performance of the media. Excessive airflow can lead to excess system losses, excessive material entrainment, abrasion damage and aggressive operating conditions in the baghouse including high air-to-cloth ratios and high can velocities.

Preferably, every fan system will have some means of controlling the airflow to the design operating point. This is especially important when the media is new, as the decreased resistance will allow more airflow through the system. The potential air volumetric rate could be significantly higher than the design level.

The performance of a fan can be controlled by changing the rotational speed with a variable frequency drive (VFD) or by using dampers. Figure 3 shows a fan system controlled by changing the fan speed.

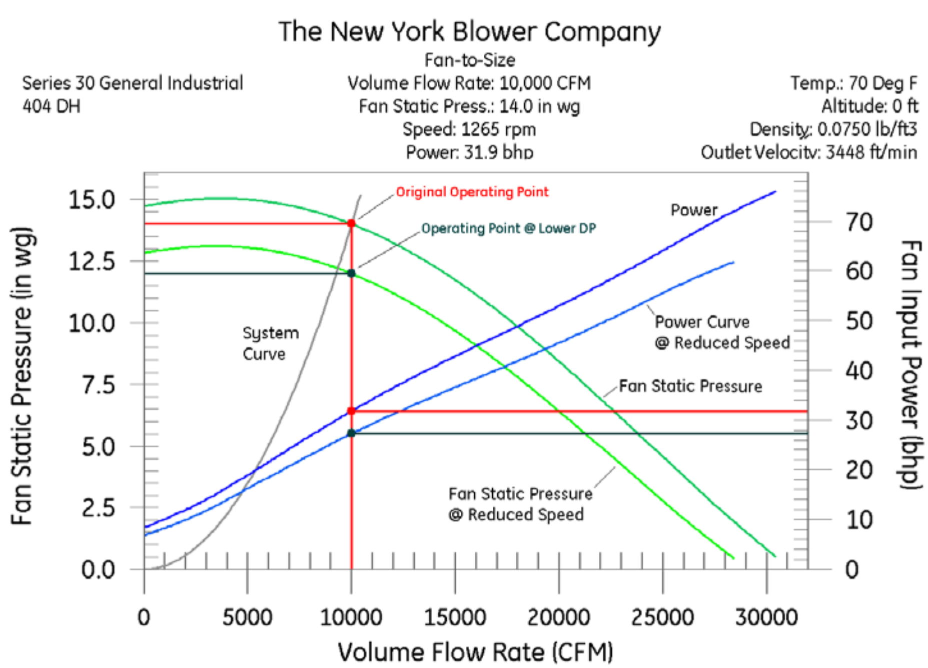

Figure 3: Fan Control by Changing Fan Speed

Changing the fan speed results in fan static pressure curves and BHP curves that are offset from the design curve in accordance with the fan laws. The system curve is not affected by a change in fan speed.

A reduction in fan rotation rate lowers the BHP draw for a given airflow, thereby reducing the energy required for the application.

VFD-controlled fans are often used in applications where the flow rate changes based on the needs of the process, or when it is desirable to run at reduced flow levels while a system comes up to temperature (kiln systems). However, fan suppliers may not recommend variable frequency drives below a certain motor HP rating due to the upfront cost of the control equipment.

Inlet and outlet dampers are also used to control the performance of a fan, but each device affects the fan system differently:

- An inlet damper changes the static pressure output and energy draw of the fan.
- An outlet damper changes the resistance of the system.

Since an inlet damper changes the fan performance, its use in controlling air flow will also lower the energy draw for a reduction in static pressure. However, although an inlet damper does change a fan's output, its use does not provide the same performance response as variable speed control.

Rather, an inlet damper "bends" the performance curves; the degree of change is based on the position of the damper (percent open). Figure 4 shows a fan system that is controlled using an inlet damper.

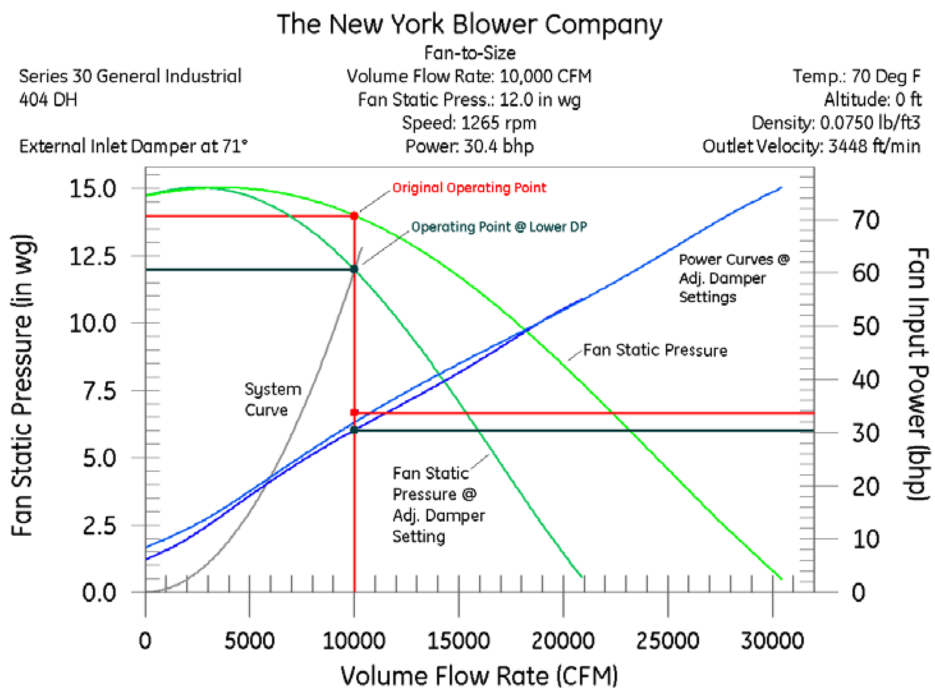

Figure 4: Fan Control by Changing Inlet Damper Position

It is important to note that the reduction in fan energy when using an inlet damper is not the same as that when the speed is changed. This difference in BHP draw between the two options has been documented in Figures 3 and 4.

An outlet damper will not provide fan energy savings when the media loss is reduced because the decrease in system resistance due to the differential pressure across the media is replaced by the resistance created by the damper. However, for systems that run with high differential pressure across the media, a significant decrease in system static pressure (including an upgrade in media) may allow for a reduction in fan speed, thereby providing a decrease in energy costs. In this case, the fan should be re-sheaved.

It is very important to note that for either an inlet or an outlet damper, the position of the damper (percent open) and the change in the fan system is not a linear function.

Many fan systems have more than one type of fan control. For example, a kiln system fan may have a VFD to limit the flow while the system comes on line and an inlet damper to position the operating point to a preferred location on the fan curve.

Specific information on dampers is included in the appendix (NYB Engineering Letters #11).

Estimating Fan Performance

Although there are many "guidelines" for estimating the flow in a fan system, the use of the appropriate fan curve at the operating conditions in conjunction with field measurements and system information provides the most accurate results. Appropriate measurements and information include:

- Gas stream temperature (preferably near the fan)
- Amperage draw on the fan motor (can be related to the BHP)
- Rotational speed of the fan (rpm)
- Type of damper(s) and position (percent of open)
- Differential pressure across the media (flange-to-flange for multiple compartment units)
- System configuration (segment length, diameter, etc.)
- Pressure readings at various points in the system

It should be noted that there are specific methods for correctly determining the airflow in a system. Chapters 6 and 9 of the Industrial Ventilation Manual and NYB Engineering Letter #7 (included in the appendix) have specific information.

Reviewing Changes to Fan Systems

When reviewing changes to a fan system (gas stream conditions, fan configuration, system configuration, etc.), it is important to understand the response of the system and the fan to those various changes. The following documents have been included in the appendix for reference:

- NYB Engineering Letter #1: System Calculation
- NYB Engineering Letter #2: Fan Laws and System Curves
- NYB Engineering Letter #3: Understanding Fan Performance Curves
- NYB Engineering Letter #4: Temperature And Altitude Affect Fan Selection

The Industrial Ventilation Manual (Chapter 6) also has appropriate information.

A common error occurs when evaluating the increase in airflow when the differential pressure is reduced in a dust collection system. A reduction in system static pressure will bring about an increase in airflow; the new volumetric rate is determined by the point where the new static pressure curve intersects the fan static pressure curve. However, the increase in airflow is limited by two parameters:

- The static pressure related to the dynamic components of the system varies by the square of the flow. For example, a 10% increase in air volume increases the static pressure requirement 21%.
- The fan static pressure decreases with increasing air volume (if the fan has been selected and configured correctly)

Figure 5 shows the change in air volume based on a reduction in static pressure at the design air volume (14" to 10" w.g.). At the reduced system resistance, the operating point moves out on the curve until the new static pressure curve intersects the fan curve.

At this point, the fan provides 11,600 acfm against a system resistance of 13.4 inches w.c.

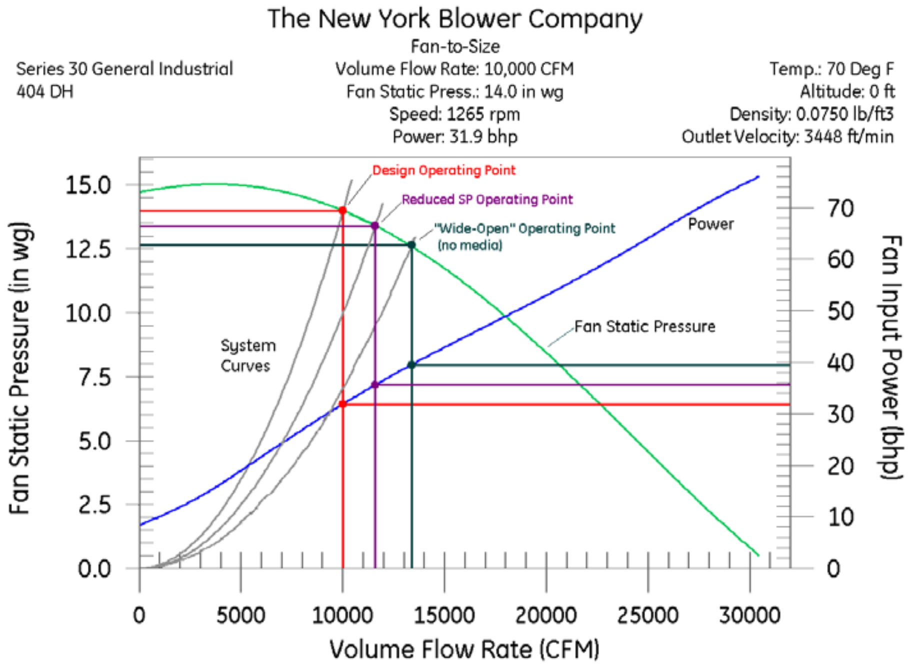

Figure 5: Changes in System Static Pressure

As shown in Figure 5, there is a maximum air volumetric rate that a fan will move in a fixed system. This condition is known as "wide-open" and reflects the situation where no artificial or media losses are applied to the system. The amperage draw associated with this operating point is often referred to as wide-open amps.

The only way to achieve higher airflow in the system is to modify the system (hoods, ductwork, etc.), increase the speed of the fan, or replace the fan with a higher-capacity model.

When considering increasing the speed of a fan, it is very important to note that there is a maximum safe speed for a fan based on the materials of construction, equipment fabrication, and the temperature of the application.

The performance of a fan is also limited by the capacity of the fan motor. If the motor does not have the required BHP capacity for the wide-open condition or the coldest operating condition, the motor starter will disengage, thereby cutting power to the fan.

POTENTIAL PAYBACK ITEMS

This section contains potential payback items that can be realized when upgrading the customer's baghouse to fine filtration media or other improvement strategies. It should be noted that several of these benefits are intrinsic and may be better documented in correspondence form only, especially if the situation may create an implied warranty.

For example, a customer may "internally" acknowledge an increase in filtration efficiency, but may not report the improvement to the regulatory agencies in order to avoid being locked into a tight operating permit.

Energy Saving Items

1) General comments on energy savings:
   a) The expected energy savings will be calculated with theoretical formulas unless specific information is known for the system. To that end, the formulas use assumed values for fan static efficiencies, mechanical efficiencies, motor efficiencies, power factors, etc.
   b) The reduction in energy associated with using an inlet damper is not the same as that obtained when the speed of the fan is reduced. Therefore, unless specific information is known about the fan and related components, the best course of action is to provide a theoretical analysis.
2) Reduction in static pressure:
   a) Reducing the system resistance (differential pressure) will reduce the fan energy required for the application. However, two conditions must be met in order to achieve the energy savings:

i) The flow must be controlled to the same air volumetric rate as the previous operating condition.

ii) The performance of the fan must be changed by either reducing the fan speed (variable frequency drive or changing the sheaves), or by using an <u>inlet</u> damper.

b) An <u>outlet</u> damper changes the resistance of a system, but does not affect the performance of a fan (fan static pressure) or the energy draw. Therefore, if an outlet damper is used to control the flow in a fan system, the energy draw is not reduced unless the speed of the fan is changed as well.

3) Reduction in air volume (and static pressure):

a) In some situations, infiltration air is used to limit the temperature in the baghouse to protect the media. By installing higher temperature-rated media, the customer may be able to reduce the amount of infiltration air to lower the overall air volume of the system. In addition, higher air temperatures (lower densities) in the system will further reduce the energy draw on the fan.

b) The installation of fine filtration media in the baghouse and the reduced air volume in the system will lower the static pressure loss in the system.

c) Refer to the AIST 2004 Technical Paper (in appendix).

4) Increased airflow with same or lower energy draw:

a) For some situations, the differential pressure may be high enough that the customer can increase the air volumetric rate while operating at the same or less energy draw. However, these situations require review by qualified technical resources.

5) Running with higher temperature:

   a) Installing higher temperature-rated media will allow the customer to increase the temperature of the system, thereby lowering the density of the gas stream to reduce the energy draw by the fan. Running with a higher temperature may also allow the customer to improve the production output of the system (kilns, dryers, calciners).

   b) Refer to the AIST 2004 Technical Paper (in appendix).

6) Reduction in cleaning frequency:

   a) Compressed air usage (pressure and frequency):

      i) Since a compressed air system is typically the most expensive utility in a plant, any reduction in usage is beneficial:

         (1) A significant reduction in compressed air usage may allow a plant to run a compressor in standby mode (unloaded) or in reserve.

         (2) Many plants are limited in compressed air capacity and any reduction in compressed air demand will have benefits around the plant.

      ii) Controlling the cleaning cycle based on the differential pressure across the media will generally lower the overall cleaning frequency (and compressed air usage) unless the baghouse is operating under excessive conditions (i.e. high DP, high A/C ratio, grain loading, etc.). The cost for the controller must be included in the payback analysis.

      iii) Installing fine filtration media generally reduces both the pressure and frequency of the cleaning function.

b) Reverse air energy (pressure and frequency):

i) A reduction in cleaning pressure and frequency will reduce the operating costs associated with the cleaning function. In some cases, the reverse-air fan may run in standby-mode (recirculating) more often. In other cases it maybe turned off when cleaning is not required.

ii) Utilizing an acoustic horn to supplement or replace the reverse-air cleaning energy often provides a return-on-investment for the customer.

c) Mechanical cleaning (shaker baghouses):

i) The energy draw for mechanically cleaning the bags may decrease with a reduced dust coating, but the more quantifiable savings are associated with the frequency of cleaning. The most effective payback occurs when acoustic cleaning technology is used in conjunction with ePTFE membrane bags, which can possibly eliminate the need for shaking.

d) Acoustic horn technology:

i) For reverse-air baghouses and shaker baghouses, acoustic horns are often used to supplement or replace the traditional cleaning methods. The operating cost is based on the compressed air used to operate the driver on the horns.

ii) The costs of the acoustic horns must be included in the cost analysis.

Operational Cost Benefits

1) Decreased labor and material costs associated with downtime activities:

a) Problematic baghouses often require significant labor and material costs to remedy the situation (temporarily in some cases). In many cases, the labor resources must be pulled from other activities, thereby creating more disruptions in the plant. A customer may be able to provide appropriate costs that can be used in a payback analysis.

2) Increased media life:
   a) Decreasing the cleaning function (pressure and frequency) when upgrading to fine filtration media will provide longer bag life, especially if the condition of the bag is improved (blinding, etc.). This provides several economic benefits:
      i) Longer bag life may provide media cost savings over an extended purchase schedule. The potential savings are dependent on both the cost differential and the expected increase in service life.
      ii) The labor costs over an extended schedule will decrease when the bag life is increased.
      iii) Reduced downtime for bag change-outs (or spot changing) may allow for an increase in production.

Reduced Labor for Installing Pleated Filter Elements

The installation time and mobilization costs are reduced when bags and cages are replaced with pleated elements. It is important to note that the associated costs differ based on the situation. The following items should be considered:

1) The first installation involves removing existing bags and cages and installing pleated elements and associated components (snapbands). This cost is still less than a bag change-out as the mobilization and material movement costs are reduced (especially for bottom load collectors).

2) The second installation of pleated elements will require less time.
3) Appropriate labor costs are available from the services product management team.

Equipment Maintenance

Shaker cleaning mechanisms often require significant downtime and repair costs. The customer may have specific information that can be incorporated into the payback analysis.

Material Costs

1) The cost differential for upgrading to pleated elements is reduced if the customer needs to by new cages.
2) In many cases, the installation of membrane bags will require the customer to purchase appropriate cages. In several of those cases, it may be more cost effective for the customer to upgrade to pleated elements.

Improvement in Media Configuration

Several bag/cage configurations are particularly problematic and require substantial labor efforts to install. These designs include flange-top bags, two-piece cages, and the "twistlock" design (or similar). There is an inherent benefit to the customer to upgrade to pleated elements. Discuss with appropriate product management.

Production/Environmental Benefits

1) Improved production runs/rates:
   a) A customer may realize an increase in the overall production rate for a process if the amount of downtime due to the baghouse is decreased. The customer

may be able to provide a profit value per unit processed ($ per pound, etc.) that can be incorporated into a payback analysis.

2) Reduced emissions/reduced fees:
   a) Some customers may pay an annual fee based on quantified emission levels. Upgrading to higher efficiency media will reduce the level of emissions and the required fee. However, appropriate documentation will most likely be requested, as well as applicable performance guarantees.
3) Retained product:
   a) Upgrading to fine filtration will increase the amount of material retained in the baghouse. For those applications where the collected dust is an intermediate or final product of value, an increase in retained product improves the production rate and revenue for the facility. Examples include finish mills (cement), dryers (various industries), and ventilation systems for material handling applications.
4) Increased airflow:
   a) Increasing the airflow in a system may provide improvements in production rates and product quality (dryer systems). In addition, some process rates may improve if the flow in an ancillary dust collection system increases.
   b) For some processes, an increase in airflow may allow for better utilization of fuel (combustion).

5) Dry-scrubbing improvements:

   a) Fine filtration allows for less cleaning frequency which promotes better utilization of the adsorptive materials (lime, etc.).

6) Sale of Surplus Power:

   a) Electric utilities that reduce internal electricity demands can sell the unused demand to the grid. The internal cost for electricity is less than the price provided to a customer, so there is a potential increase in revenue.

FORMULAS USED IN COST ANALYSIS CALCULATIONS

A. Fan Operating Cost Associated with Media Loss (System Fans)

Fan Energy (BHP)[1,2] = ACFM x DP (in. w.c.) ÷ [6356 x (η_{drive} x η_{motor} x η_{fan})]

Yearly Operating Cost = BHP x 0.746 (kw per hp) x [$ per kw-hr] x 24 hrs per day x [days per year]

B. Cleaning Time Per Period (Cycles)

Pulsejet Cleaning:

Cycles Per Minute (pulsejet) = no. of valves firing at once x [60 seconds per minute ÷ pulse frequency (seconds)]

Reverse Air/Shaker Cleaning:

Cycles Per Day = no. of compartments cleaning at once x [60 minutes per hour ÷ cleaning frequency (minutes)] x 24 hrs per day

Cleaning Hours Per Day = # of cycles per day x [cleaning time (minutes)] ÷ 60 minutes per hour

Recirculating Hours Per Day (hrs) = 24 (hrs per day) – cleaning hours per day

C. Cost to Clean Bags with Reverse-Air Fans

Fan Energy (BHP)[1,2,3] = ACFM x DP (in. w.c.) ÷ [6356 x (η_{drive} x η_{motor} x η_{fan})]

If cycle times are known (cycle times determined from formulas under item B):

Yearly Operating Cost (Cleaning) = BHP_{clean} x 0.746 (kw per hp) x [$ per kw-hr] x [cleaning hrs per day] x [days per year]

Yearly Operating Cost (Recirculating) = $BHP_{recirc.}$ x 0.746 (kw per hp) x [$ per kw-hr] x [recirculating hrs per day] x [days per year]

If cycle times are not known:

Yearly Operating Cost (Cleaning) = BHP_{clean} x 0.746 (kwh per hp) x [$ per kwh] x 24 hours per day x [days per year] x [% time cleaning]

Yearly Operating Cost (Recirculating) = BHP_{recirc} x 0.746 (kw per hp) x [$ per kw-hr] x 24 hrs per day x [days per year] x [1- % time cleaning]

FORMULAS USED IN COST ANALYSIS CALCULATIONS (cont.)

D. Operating Cost to Compress Air

Cubic feet of air per pulse[4] = act. cubic ft. per 0.1-second pulse (@100 psig) x [on-time (seconds) ÷ 0.1] x [cleaning pressure (psig) ÷ 100]

Compressed-air usage (CFM) = Cu. feet per pulse x cycles per minute {from item B}

Energy to Compress Air (BHP)[5] = CFM x 0.25 (bhp per cfm) ÷ η_{motor}

Annual Operating Cost = BHP x 0.746 (kwh per hp) x [$ per kwh] x [hours per day] x [days per year]

E. Cost to Mechanically Clean Bags (Shaker)

<u>If cycle times are known (cycle times determined from formulas under item B):</u>

Annual Operating Cost[6] = BHP x 0.746 (kwh per hp) x [$ per kwh] x [cleaning hours per day] x [days per year]

<u>If cycle times are not known:</u>

Annual Operating Cost[6] = BHP x 0.746 (kwh per hp) x [$ per kwh] x 24 hours per day x [days per year] x [% time cleaning]

F. Cost for Acoustic Horn Use (Shaker and Reverse Air)

Compressed Air Usage Per Day Per Horn (SCF per Day) = [SCF per horn cycle] x [cycles per hour] x 24 hrs per day

Annual Operating Cost = SCF Per Day x [# of horns operating] x [days per year]

G. Retained Product

$ Profit per hour = tons per hour x 2000 lbs per ton x [improved filtration efficiency[7] - standard filtration efficiency[7]] x [$ profit per pound]

NOTES FOR FORMULAS USED IN COST ANALYSIS CALCULATIONS

1. For calculation purposes, the payback model deals with the energy associated with the media loss. Therefore, the differential pressure (DP) can be used in place of the fan static pressure (FSP) in the calculation of brakehorsepower.
2. Assume fan efficiency (η_{fan}) = 0.75, motor efficiency (η_{motor}) = 0.9, and drive efficiency (η_{drive}) = 0.99. Note: for direct-drive fans, the drive efficiency is 100%.
3. Use the required acfm and SP (DP) for the appropriate reverse-air fan operating mode (cleaning versus recirculating):
   - Typically, a reverse-air fan is sized to provide an air volume (acfm) of 1.5 times the cloth area in a compartment at a static pressure of 2" above the peak static pressure of main fan. However, the payback model deals with the cost associated with the loss across the media. Therefore, the static pressure for cleaning can be assumed to be 2" above the average compartment differential pressure.
   - For the recirculating function, assume the fan backs up on the curve to a low-flow, high static pressure condition. The maximum air volume in this condition can be estimated at 1/3 to 1/2 times the air volume when cleaning. The static pressure can be estimated at 1.33 times the static pressure applied to the system when cleaning.
4. Assumes a linear relationship between the cleaning pressure and the flow through the valve.
5. It is difficult to estimate the percentage of time a compressor runs unloaded, so the calculation determines the theoretical costs to produce the volume of compressed air used for cleaning media. Motor efficiency (η_{motor}) = 0.9.

6. An actual amperage draw on the shaker motor must be obtained to calculate actual operating costs. As this information may not be readily available, the motor rating can be used to calculate operating costs.
7. Ideally, the results of a stack test would be used to determine filtration efficiency (as long as inlet loading to the baghouse is known). However, this information may not be readily available, or the customer may not wish to divulge such information. In such cases, internal VESA test results may be used as long as appropriate disclaimers are used, especially those associated with implied warranties.

COST ANALYSIS BACKGROUND

Cost analysis methodology involves documenting the costs and benefits of various options and reviewing the data through several evaluation methods. The choice of evaluation methods depends on the situation and a company's accounting practices.

Costs and Benefits Associated with Filtration Media

For {company name}'s fabric filter business, the following definitions are appropriate for cost analysis activities:

- *Component costs* are the expenses associated with using a particular filtration media. In addition to the cost of the media (bags or pleats), the cost analysis must also include any components required in conjunction with the media. These items may include, but are not limited to, cages (upgrade from current), tensioning (upgrade from current), acoustic horns, and labor activities.
- *Operating costs* are the expenses associated with using the media in the application. These costs include the fan energy cost related to the media (or the system) and the cost to clean the media (compressed air systems, reverse-air fans, shaker assemblies, or acoustic technologies).
- *Benefits* are the expected improvements in the performance of the system upon upgrading the baghouse media to fine filtration products. For a payback period analysis (see below), the benefits that are used correspond to the improvements to the original operating or performance parameters.

The appendix contains estimation charts for fan operating cost and the theoretical costs associated with compressed air usage.

Cost Analysis Methods

Cost analysis or economic justification activities involve evaluating purchase options (or investments) against a set of decision criteria and making a decision on the appropriate course of action.

There are many cost analysis methods to choose from. For {company name}'s activities in promoting fine filtration media, the following cost analysis methods have been identified as most applicable and are described in subsequent sections:

- Payback Period (Cost Recovery Schedule)
- Comparative Analysis (Net Present Value, Equivalent Uniform Monthly Cost)

The section Potential Payback Items provides a list of the possible items to consider as part of a cost analysis.

Payback Period

The payback period refers to the point in time when the expected benefits of upgrading the filter media recover (or offset) the additional costs for the upgrade (including any required components). This analysis method assumes equivalent life of each option. The general formula for the payback period is:

$$\text{Payback Period (months)} = \frac{\text{Additional Costs for Media Upgrade}}{\text{Expected Monthly Benefits Achieved with Upgrade}}$$

If the payback period is less than or equal to the current media life, then the upgrade is typically a desirable investment.

The benefits that should be considered for a payback period calculation include (but are not limited to) reduced operating costs, production improvements, and the increase in retained product when the collected material is of value.

It should be noted that, although an option may not have a favorable payback period, it is still a desirable undertaking if the net costs are more favorable than those for the current media when reviewed over an extended period of time, as discussed in the next section.

Comparative Analysis Methods

Oftentimes, it is useful to compare the net costs associated with two or more options over an extended period of time. Comparative analysis methods are useful when payback period analyses do not show optimum results, there are significant differences in the cost of the options and the expected benefits, or the options have unequal life cycles.

Net Present Value (NPV) analysis evaluates the net costs of an option throughout its life cycle as an initial investment required to fund the option. The net costs are the totaled costs minus any revenue components. When comparing two or more options, the option with the least negative (or most positive) net present value is the desired option.

Sometimes it is desirable to compare several options based on an average cost over a given period (month, year, etc.). The Equivalent Uniform Monthly Cost (EUMC) method converts the costs and benefits over a life cycle into average monthly values. The option with the lowest average monthly cost (net) is the desired option. When interest factors are not considered, the average monthly cost (net) is equivalent to the net present value divided by the analysis period (in months).

For either comparative method, the costs that should be considered include the media costs, operating energy costs, and the labor costs for installing the media. The revenues for either option include (but are not limited to) the amount of retained product and increased production or output levels.

For comparative analysis, it is desirable (but not essential) to use a review period that is a common multiple of the life cycle of each option. For example, if a media with a 12-month life cycle is compared to a media with an 18-month life cycle, then the analysis period should be 36 months. A financial analysis book (see bibliography) should be consulted for appropriate background in this area.

Interest Considerations (Time Value of Money)

At this time, the effects of interest are not included in the calculations. However, it is important to note that the effects of interest will change the results and may alter the purchase decision.

The reader is advised to consult a financial analysis book (see bibliography) for appropriate background in this area.

GUIDELINES FOR COST ANALYSIS ACTIVITIES

When performing a cost analysis of a customer's system, it is very important to make accurate, achievable estimates of the improvements in the customer's operations. This is important for several reasons, but two of the most important reasons follow:

- It limits the risk to the company for implied (or direct) warranties for system performance.
- It maintains the reputation of both the company and the performance of its products. An unsatisfied customer is unlikely to make a repeat purchase, and is likely to try a competitor's products.

General Guidelines

The following guidelines should be reviewed when estimating the expecting performance of {company name}'s fine filtration products in a customer's application:

- At no time should the expected performance be over-estimated for the sake of selling the product. "Tweaking the numbers" to "make it work" most likely will create a significant level of risk to the company.
- A "rule of thumb" analysis should be avoided unless the background of the rule is understood and is of technical merit. Sections on system pressure, fan operation, as well as numerous technical documents developed by the New York Blower Company (see appendix) have been included in the procedures manual for the product manager's reference when reviewing a customer's application.
- Every application should be reviewed in detail to reduce the potential for performance issues and media life issues. For example, short media life due

to abrasion should be discussed in detail with the customer before the sale of the products.

- The cleaning function should be evaluated for capacity and performance. This includes compressed air capacity, cleaning valve size (pulse-jet and plenum pulse units), reverse air fan output (air volume and static pressure), and reverse-air and shaker baghouse operation (isolation dampers, etc.).
- As a general rule, {company name} will not provide guarantee statements as to a system's air volumetric rate. The product manager can provide statements regarding the reduction in static pressure, but it is generally up to the customer to determine the affect this reduction will have on the system unless detailed information has been provided to {company name} (see next bullet item).
- In special cases, qualified individuals may review detailed information and provide estimates on improved performance. However any such statements require review of appropriate individuals.
- At no time should a customer be provided with an estimate (or guarantee) related to the production output of a system. This applies to systems producing a product, such a spray dryer, or systems producing energy output, such as a boiler train or a power plant system. Specific case histories may be provided to the customer for their reference.

Guidelines for Estimating Reduction in Static Pressure and Cleaning Functions

There are several parameters to review when estimating the reduction in static pressure and cleaning function that a customer will achieve by upgrading to fine filtration media. These parameters include material properties, gas stream chemistry, equipment configuration, and the baghouse operating parameters (air-to-cloth ratio, can velocity, grain loading).

Specific guidelines for these topics are under development, and will be provided as a separate sheet and in subsequent revisions of this manual.

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APPENDIX

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Costing Chart for Fan Operation

Directions for use:

A. Find cost factor in chart based on customers cost (internal source or external source) for electricity and the estimated system static pressure.
B. Multiply the factor by ACFM for the system, divide by 10000, and multiply by number of operating days.

Cost ($) per day per 10000 ACFM

Cost ($) per kwh	Static Pressure (inches w.c.)														
	1.00	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**	**8.00**	**9.00**	**10.00**	**11.00**	**12.00**	**13.00**	**14.00**	**15.00**
$0.005	$0.23	$0.45	$0.68	$0.90	$1.13	$1.35	$1.58	$1.81	$2.03	$2.26	$2.48	$2.71	$2.94	$3.16	$3.39
$0.010	$0.45	$0.90	$1.35	$1.81	$2.26	$2.71	$3.16	$3.61	$4.06	$4.52	$4.97	$5.42	$5.87	$6.32	$6.77
$0.015	$0.68	$1.35	$2.03	$2.71	$3.39	$4.06	$4.74	$5.42	$6.10	$6.775	$7.45	$8.13	$8.81	$9.48	$10.16
$0.020	$0.90	$1.81	$2.71	$3.61	$4.52	$5.42	$6.32	$7.23	$8.13	$9.03	$9.94	$10.84	$11.74	$12.65	$13.55
$0.03	$1.13	$2.26	$3.39	$4.52	$5.65	$6.77	$7.90	$9.03	$10.16	$11.29	$12.42	$13.55	$14.68	$15.81	$16.94
$0.030	$1.35	$2.71	$4.06	$5.42	$6.77	$8.13	$9.48	$10.84	$12.19	$13.55	$14.90	$16.26	$17.61	$18.97	$20.32
$0.035	$1.58	$3.16	$4.74	$6.32	$7.90	$9.48	$11.07	$12.65	$14.23	$15.81	$17.39	$18.97	$20.55	$22.13	$23.71
$0.040	$1.81	$3.61	$5.42	$7.23	$9.03	$10.84	$12.65	$14.45	$16.26	$18.07	$19.87	$21.68	$23.49	$25.29	$27.10
$0.045	$2.03	$4.06	$6.10	$8.13	$10.16	$12.19	$14.23	$16.26	$18.29	$20.32	$22.36	$24.39	$26.42	$28.45	$30.49
$0.050	$2.26	$4.52	$6.77	$9.03	$11.29	$13.55	$15.81	$18.07	$20.32	$22.58	$24.84	$27.10	$29.36	$31.61	$33.87
$0.055	$2.48	$4.97	$7.45	$9.94	$12.42	$14.90	$17.39	$19.87	$22.36	$24.84	$27.32	$29.81	$32.29	$34.78	$37.26
$0.060	$2.71	$5.42	$8.13	$10.84	$13.55	$16.26	$18.97	$21.68	$24.39	$27.10	$29.81	$32.52	$35.23	$37.94	$40.65
$0.065	$2.94	$5.87	$8.81	$11.74	$14.68	$17.61	$20.55	$23.49	$26.42	$29.36	$32.29	$35.23	$38.16	$41.10	$44.03
$0.070	$3.16	$6.32	$9.48	$12.65	$15.81	$18.97	$22.13	$25.29	$28.45	$31.61	$34.78	$37.94	$41.10	$44.26	$47.42
$0.075	$3.39	$6.77	$10.16	$13.55	$16.94	$20.32	$23.71	$27.10	$30.49	$33.87	$37.26	$40.65	$44.03	$47.42	$50.81
$0.080	$3.61	$7.23	$10.84	$14.45	$18.07	$21.68	$25.29	$28.90	$32.52	$36.13	$39.74	$43.36	$46.97	$50.58	$54.20
$0.085	$3.84	$7.68	$11.52	$15.36	$19.19	$23.03	$26.87	$30.71	$34.55	$38.39	$42.23	$46.07	$49.91	$53.74	$57.58
$0.090	$4.06	$8.13	$12.19	$16.26	$20.32	$24.39	$28.45	$32.52	$36.58	$40.65	$44.71	$48.78	$52.84	$56.91	$60.97
$0.095	$4.29	$8.58	$12.87	$17.16	$21.45	$25.74	$30.03	$34.32	$38.62	$42.91	$47.20	$51.49	$55.78	$60.07	$64.36
$0.100	$4.52	$9.03	$13.55	$18.07	$22.58	$27.10	$31.61	$36.13	$40.65	$45.16	$49.68	$54.20	$58.71	$63.23	$67.75
$0.105	$4.74	$9.48	$14.23	$18.97	$23.71	$28.45	$33.20	$37.94	$42.68	$47.42	$52.16	$56.91	$61.65	$66.39	$71.13
$0.110	$4.97	$9.94	$14.90	$19.87	$24.84	$29.81	$34.78	$39.74	$44.71	$49.68	$54.65	$59.62	$64.58	$69.55	$74.52
$0.115	$5.19	$10.39	$15.58	$20.78	$25.97	$31.16	$36.36	$41.55	$46.74	$51.94	$57.13	$62.33	$67.52	$72.71	$77.91
$0.120	$5.42	$10.84	$16.26	$21.68	$27.10	$32.52	$37.94	$43.36	$48.78	$54.20	$59.62	$65.04	$70.46	$75.88	$81.29
$0.125	$5.65	$11.29	$16.94	$22.58	$28.23	$33.87	$39.52	$45.16	$50.81	$56.455	$62.10	$67.75	$73.39	$79.04	$84.68
$0.130	$5.87	$11.74	$17.61	$23.49	$29.36	$35.23	$41.10	$46.97	$52.84	$58.71	$64.58	$70.46	$76.33	$82.20	$88.07
$0.14	$6.10	$12.19	$18.29	$24.39	$30.49	$36.58	$42.68	$48.78	$54.87	$60.97	$67.07	$73.17	$79.26	$85.36	$91.46
$0.140	$6.32	$12.65	$18.97	$25.29	$31.61	$37.94	$44.26	$50.58	$56.91	$63.23	$69.55	$75.88	$82.20	$88.52	$94.84
$0.145	$6.55	$13.10	$19.65	$26.20	$32.74	$39.29	$45.84	$52.39	$58.94	$65.49	$72.04	$78.59	$85.13	$91.68	$98.23
$0.150	$6.77	$13.55	$20.32	$27.10	$33.87	$40.65	$47.42	$54.20	$60.97	$67.75	$74.52	$81.29	$88.07	$94.84	$101.62

Notes:

1. General Equation:

$$\frac{\text{ACFM} \times \text{SP (in. w.c.)} \times 0.746 \text{ (kw per hp)} \times \text{Unit Cost of Electric Energy (dollars per kw-hr)} \times \text{(hours per day)}}{6356 \times \text{Fan Efficiency} \times \text{Motor Efficiency} \times \text{Drive Efficiency}}$$

2. System SP reductions are process dependent and should be applied under advisement.
3. Assume 24 hours per day operation

Costing Chart for Compressed Air Usage

Directions for use:

A. Find cost factor in chart based on valve size, cleaning pressure, and cleaning frequency.
B. Multiple cost factor by ratio = actual cost/$0.06. {tables based on $0.06 per Kwh}
C. Multiply the factor by the number of valves firing at once.
D. Multiple the result by the number of operating days.

Notes:

1. See formula sheet for equations.
2. Assume 24 hours per day operation
3. Tablulated costs are based on the theoretical cost to produce compressed-air.
4. Compressed air usage based on 100 ms on-time and 100 psig cleaning pressure.

Compressed Air Usage per Valve per Pulse	
3/4" single	1.0
1" single	1.7
1.5" DD	4.5
2.0" DD	5.5
2.5" DD	8.9
3.0" DD	12.0

Valve Size = 3/4" Single

Pulse Frequency	**Daily Compressed Air Usage Cost Per Valve (@psig)**							
(time between pulses)	65	70	75	80	85	90	95	100
1	$11.64	$12.53	$13.43	$14.32	$15.22	$16.11	$17.01	$17.90
2	$5.82	$6.27	$6.71	$7.16	$7.61	$8.06	$8.50	$8.95
3	$3.88	$4.18	$4.48	$4.77	$5.07	$5.37	$5.67	$5.97
4	$2.91	$3.13	$3.36	$3.58	$3.80	$4.03	$4.25	$4.48
5	$2.33	$2.51	$2.69	$2.86	$3.04	$3.22	$3.40	$3.58
6	$1.94	$2.09	$2.24	$2.39	$2.54	$2.69	$2.83	$2.98
7	$1.66	$1.79	$1.92	$2.05	$2.17	$2.30	$2.43	$2.56
8	$1.45	$1.57	$1.68	$1.79	$1.90	$2.01	$2.13	$2.24
9	$1.29	$1.39	$1.49	$1.59	$1.69	$1.79	$1.89	$1.99
10	$1.16	$1.25	$1.34	$1.43	$1.52	$1.61	$1.70	$1.79
12	$0.97	$1.04	$1.12	$1.19	$1.27	$1.34	$1.42	$1.49
14	$0.83	$0.90	$0.96	$1.02	$1.09	$1.15	$1.21	$1.28
15	$0.78	$0.84	$0.90	$0.95	$1.01	$1.07	$1.13	$1.19
16	$0.73	$0.78	$0.84	$0.90	$0.95	$1.01	$1.06	$1.12
18	$0.65	$0.70	$0.75	$0.80	$0.85	$0.90	$0.94	$0.99
20	$0.58	$0.63	$0.67	$0.72	$0.76	$0.81	$0.85	$0.90
25	$0.47	$0.50	$0.54	$0.57	$0.61	$0.64	$0.68	$0.72
30	$0.39	$0.42	$0.45	$0.48	$0.51	$0.54	$0.57	$0.60

Valve Size = 1" Single

Pulse Frequency	**Daily Compressed Air Usage Cost Per Valve (@psig)**							
(time between pulses)	65	70	75	80	85	90	95	100
1	$19.78	$21.31	$22.83	$24.35	$25.87	$27.39	$28.91	$30.44
2	$9.89	$10.65	$11.41	$12.17	$12.94	$13.70	$14.46	$15.22
3	$6.59	$7.10	$7.61	$8.12	$8.62	$9.13	$9.64	$10.15
4	$4.95	$5.33	$5.71	$6.09	$6.47	$6.85	$7.23	$7.61
5	$3.96	$4.26	$4.57	$4.87	$5.17	$5.48	$5.78	$6.09
6	$3.30	$3.55	$3.80	$4.06	$4.31	$4.57	$4.82	$5.07
7	$2.83	$3.04	$3.26	$3.48	$3.70	$3.91	$4.13	$4.35
8	$2.47	$2.66	$2.85	$3.04	$3.23	$3.42	$3.61	$3.80
9	$2.20	$2.37	$2.54	$2.71	$2.87	$3.04	$3.21	$3.38
10	$1.98	$2.13	$2.28	$2.43	$2.59	$2.74	$2.89	$3.04
12	$1.65	$1.78	$1.90	$2.03	$2.16	$2.28	$2.41	$2.54
14	$1.41	$1.52	$1.63	$1.74	$1.85	$1.96	$2.07	$2.17
15	$1.32	$1.42	$1.52	$1.62	$1.72	$1.83	$1.93	$2.03
16	$1.24	$1.33	$1.43	$1.52	$1.62	$1.71	$1.81	$1.90
18	$1.10	$1.18	$1.27	$1.35	$1.44	$1.52	$1.61	$1.69
20	$0.99	$1.07	$1.14	$1.22	$1.29	$1.37	$1.45	$1.52
25	$0.79	$0.85	$0.91	$0.97	$1.03	$1.10	$1.16	$1.22
30	$0.66	$0.71	$0.76	$0.81	$0.86	$0.91	$0.96	$1.01

Valve Size = 1-1/2" Double Diaphragm

Pulse Frequency	**Daily Compressed Air Usage Cost Per Valve (@psig)**							
(time between pulses)	65	70	75	80	85	90	95	100
1	$52.37	$56.40	$60.43	$64.45	$68.48	$72.51	$76.54	$80.57
2	$26.18	$28.20	$30.21	$32.23	$34.24	$36.26	$38.27	$40.28
3	$17.46	$18.80	$20.14	$21.48	$22.83	$24.17	$25.51	$26.86
4	$13.09	$14.10	$15.11	$16.11	$17.12	$18.13	$19.13	$20.14
5	$10.47	$11.28	$12.09	$12.89	$13.70	$14.50	$15.31	$16.11
6	$8.73	$9.40	$10.07	$10.74	$11.41	$12.09	$12.76	$13.43
7	$7.48	$8.06	$8.63	$9.21	$9.78	$10.36	$10.93	$11.51
8	$6.55	$7.05	$7.55	$8.06	$8.56	$9.06	$9.57	$10.07
9	$5.82	$6.27	$6.71	$7.16	$7.61	$8.06	$8.50	$8.95
10	$5.24	$5.64	$6.04	$6.45	$6.85	$7.25	$7.65	$8.06
12	$4.36	$4.70	$5.04	$5.37	$5.71	$6.04	$6.38	$6.71
14	$3.74	$4.03	$4.32	$4.60	$4.89	$5.18	$5.47	$5.75
15	$3.49	$3.76	$4.03	$4.30	$4.57	$4.83	$5.10	$5.37
16	$3.27	$3.52	$3.78	$4.03	$4.28	$4.53	$4.78	$5.04
18	$2.91	$3.13	$3.36	$3.58	$3.80	$4.03	$4.25	$4.48
20	$2.62	$2.82	$3.02	$3.22	$3.42	$3.63	$3.83	$4.03
25	$2.09	$2.26	$2.42	$2.58	$2.74	$2.90	$3.06	$3.22
30	$1.75	$1.88	$2.01	$2.15	$2.28	$2.42	$2.55	$2.69

Valve Size = 2" Double Diaphragm

Pulse Frequency	**Daily Compressed Air Usage Cost Per Valve (@psig)**							
(time between pulses)	65	70	75	80	85	90	95	100
1	$64.01	$68.93	$73.85	$78.78	$83.70	$88.62	$93.55	$98.47
2	$32.00	$34.47	$36.93	$39.39	$41.85	$44.31	$46.77	$49.24
3	$21.34	$22.98	$24.62	$26.26	$27.90	$29.54	$31.18	$32.82
4	$16.00	$17.23	$18.46	$19.69	$20.93	$22.16	$23.39	$24.62
5	$12.80	$13.79	$14.77	$15.76	$16.74	$17.72	$18.71	$19.69
6	$10.67	$11.49	$12.31	$13.13	$13.95	$14.77	$15.59	$16.41
7	$9.14	$9.85	$10.55	$11.25	$11.96	$12.66	$13.36	$14.07
8	$8.00	$8.62	$9.23	$9.85	$10.46	$11.08	$11.69	$12.31
9	$7.11	$7.66	$8.21	$8.75	$9.30	$9.85	$10.39	$10.94
10	$6.40	$6.89	$7.39	$7.88	$8.37	$8.86	$9.35	$9.85
12	$5.33	$5.74	$6.15	$6.56	$6.98	$7.39	$7.80	$8.21
14	$4.57	$4.92	$5.28	$5.63	$5.98	$6.33	$6.68	$7.03
15	$4.27	$4.60	$4.92	$5.25	$5.58	$5.91	$6.24	$6.56
16	$4.00	$4.31	$4.62	$4.92	$5.23	$5.54	$5.85	$6.15
18	$3.56	$3.83	$4.10	$4.38	$4.65	$4.92	$5.20	$5.47
20	$3.20	$3.45	$3.69	$3.94	$4.19	$4.43	$4.68	$4.92
25	$2.56	$2.76	$2.95	$3.15	$3.35	$3.54	$3.74	$3.94
30	$2.13	$2.30	$2.46	$2.63	$2.79	$2.95	$3.12	$3.28

Customer Name	**Sample Application**
Location	**Anywhere USA**
Baghouse Reference	

Operation Information

Operating Hours/day	24
Operating Days per year	360
Cost per kwH	0.06
Current Bag Life (months)	30
System Throughput (tons/hr)	12
System Throughput (lb/hr)	24000
$ Profit/pound	$0.10

System Information

System Flow (ACFM)	207,110
DP (inches wc):	9.00
Improved DP (inches wc):	6.00
Current Pulse Frequency (seconds)	15.00
New Pulse Frequency (seconds)	30.00
New Pulse Duration (seconds)	0.10
Current Pulse Duration (seconds)	0.10
Current Compressed Air Pressure (PSIG)	90.00
New Compressed Air Pressure (PSIG)	75.00

Operating Costs	**Current Material**		**Upgrade**
Fan Energy	$15,153.28	*per month*	$10,102.18
Compressed air	$773.45	*per month*	$322.27

Material Costs	**Current Material**	**Upgrade**
No. of Filter Elements (actual)	5,200	5,200
Material Price (per bag)	$37.50	$66.10
Cages (if req'd)	$0.00	$0.00
total	$195,000.00	$343,720.00

Payback Schedule

Determines the months required to recover the cost of the investment, assuming equal life cycles of two alternatives. A recover period less than estimated life of current media is desirable.

Cost differential (materials)	$148,720.00	**Payback Schedule (mos)**
Energy Savings (per month)	$5,502.27	**25.80**
Recovered Product Funds (per month)	$262.80	

Life Cycle Cost Analysis

Net Present Value: **Evaluates costs throughout life cycle as an initial investment required to fund option.**

Equivalent Uniform Monthly Cost: **Determines an average cost per month for the option.**

	Current Material		**Upgrade**
Labor Cost per Installation	$20,000		$20,000
Media Life (months)	30		36
Analysis Period (Months)	72		72
# of installations	3		2
Total Cost for Operations	$1,146,724		$750,561
Total Media Expense (material + labor)	$645,000		$727,440
Net Present Value	**$1,791,724**	***versus***	**$1,478,001**
Equivalent Uniform Monthly Cost	**$24,885**	***versus***	**$20,528**
Total Product Profit per Month	**$258,924**	***versus***	**$259,187**

NOTES:
- Statements regarding media life and operational performances are for illustrative purposes only and do not reflect a performance guarantee in any form.
- Performance estimates based on typical installations.

Customer Name	**Sample Application**
Location	**Anywhere USA**
Baghouse Reference	

Compressed-Air Calculator

Before		After	
3.00	size of valve	3.00	size of valve
12.0	rated cf per pulse (100 ms @ 100 psi)	12.0	rated cf per pulse (100 ms @ 100 psi)
90	psi	75	psi
0.10	Pulse duration	0.10	Pulse duration
10.80	actual cf per pulse	9.00	actual cf per pulse
2	number of valves firing at 1 time	2	number of valves firing at 1 time
15.00	pulse frequency (seconds)	30.00	pulse frequency (seconds)
0.25	hp per cfm of compressed air	0.25	hp per cfm of compressed air
0.746	kw per hp	0.746	kw per hp
0.9	motor efficiency	0.9	motor efficiency
$ 0.060	cost per kwh	$ 0.060	cost per kwh
24	hours per day	24	hours per day
360	days per yr	360	days per yr
$ 9,281	per year	$ 3,867	per year

Compressed Air Usage per Valve per Pulse

(based on 100 ms on-time & 100 psi)

3/4" valve	0.75	1.0
1" valve	1.00	1.7
1.5" DD valve	1.50	4.5
2.0" DD valve	2.00	5.5
2.5" DD valve	2.50	8.9
3.0" DD valve	3.00	12.0