Energy Aspects of Pollution Prevention

Energy Consumption of Painting and Coating Equipment

Project Report

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Iowa Waste Reduction Center

Contents

1. Abstract

The energy consumption of three common pieces of painting and coating equipment operating in a midwestern climate are examined. The impact of additional control devices regulating the airflow is investigated. The control devices are found to have a five to ten year financial payback period in a shop operating a single shift, with a small but definite improvement in the energy efficiency of the painting and coating equipment. Shops operating multiple shifts would have a payback period on the order of one year. Empirical measurements are found to agree with theoretical benefits within the limits of experimental error. The results, while not surprising, suggest opportunities for further improvements in efficiency, and therefore reduced environmental impact, through vigilant use of existing technology.

2. Executive Summary

Applying an AC motor speed control to the intake and exhaust vents in a liquid painting operation allows the operator to control the flow rate precisely. The cost of installing the equipment is outlined in Table 1 (Section 3: Results). After regulating the flow rate carefully, the reduction in the rate of energy consumption was used to predict the payback period. Calculations were made for shops operating during regular business hours and also for 24 hour operation. In the case of operating during business hours, the payback period for the paint booth is around seven years, and this is insufficient reason to justify installation as a cost-saving measure. However, additional benefits may be sufficient to motivate some shops to install this technology. See Section 5: Further Investigation for more discussion of other benefits that may impact this decision.

For a shop operating two or more shifts, the payback period is much shorter. This is due to both the greater number of hours of operation, and also the fact that heating requirements are greatest during second and third shift operation. With a payback period of 1 year, it would be easy to recommend this change to any shop that is operating multiple shifts.

The application on the 5-stage pretreatment system had a shorter payback period, due to the higher operating cost of the washer and the lower cost of equipment. Calculations for the 40-hour a week placed the payback period at 2 years, which is an excellent return on the relatively small investment. For full time operation, the payback period is even shorter, just slightly over six months.

The powder-coating booth did not see enough energy savings to justify the expense of outfitting it with the AC motor controllers for a shop operating 40 hours per week. The payback period under these conditions is over seven years. A seven-year payback period may be too long to convince a typical business to invest in this technology. During full-time operation, the payback period was found to be closer to two years. This payback period represents a substantial savings, as the equipment has an anticipated lifespan of more than ten years under these conditions. Again, there are other potential benefits that may provide additional motivation for some businesses.

Table 1:Costs Reduction for Three Types of Equipment

Equipment	Initial Cost Per Hour	Minimized Cost Per Hour	Relative Cost Reduction	AC Motor Controller Cost	Payback Period (at 40 hrs / week)
Paint Booth	$ 3.95	$ 3.03	23%	$ 5025	5400 hrs (7.5 years)
5 Stage Washer	$ 6.24	$ 5.77	7.5%	$ 1980	4200 hrs (2.1 years)
Powder Coating Booth	$0.18	$0.12	33%	$ 1175	19,600 hrs (9.4 Years)

Businesses may be interested in lowering energy use for any number of reasons. Based on these results, it is clear that applying AC motor speed controls to painting equipment is one means of achieving this goal. This is especially true for businesses that operate equipment in multiple shifts, pay higher than average energy prices, or can receive discounts or rebates from utilities for lowering energy use during peak hours. A more detailed discussion of the measurements and conclusions of this investigation are provided in the next section.

3. Results

Energy use of three common pieces of painting and coating equipment, specifically a 5-stage pretreatment system, a liquid paint spray booth, and a powder-coating booth, are examined. The equipment is operated in a climate that requires heating of make up air, both for the comfort of the workers and the performance of cleaning and coating chemistry used. Such an environment is common during the winter months in the Midwest, and heating costs to heat chemicals or replace exhausted air make up a substantial portion of the total operating costs for two of these three pieces of equipment. The efficiency of such equipment can be improved somewhat through the use of dampeners to limit the exhaust flow, but painting and coating equipment rarely comes equipped with such features. A more elegant solution, which also lends itself easily to feedback-loop control for consistent operation, is the use of AC motor speed controls to limit the airflow. This method allows more precise control of airflow, and has the added benefit of maintaining the inherent efficiency of the fan motors.

Liquid Paint Booth

Operating at the design specifications of the manufacturer, a cross draft paint booth consisting of a bank of filters 17 ft wide by 9 ft high, uses a 15 hp motor and a 5 hp motor for ventilation, and flows approximately 23,191 ft^3 of heated air. Adding motor speed controls and reducing the flow through the booth to the minimum-safe rate of 100 ft/min reduced the airflow by 5300 cfm, a reduction of 22.8% (actually 105 ft/min was taken as the minimum safe rate, to allow for variation caused by filter loading). There was a corresponding 23% reduction in the rate of gas use. In addition, the energy consumption of the electric motors decreased by around 16%. The result is a decrease of over 20% for all operating costs. The test was performed using paint filters that were near the end of their useful life, and larger savings would have resulted by testing with new filters.

Combining these measured reductions in energy consumption with the current cost of energy, the payback period of this equipment can be calculated. Using the USDOE average figures for commercial energy prices, the cost of installing the AC motor speed controls could be recouped in around seven years. In order to be certain that these savings are real, and not simply the product of conditions specific to this operation, the ‘worst case’ senario, which should provide the speed controls with the least opportunity for savings, was assumed. These assumptions included:

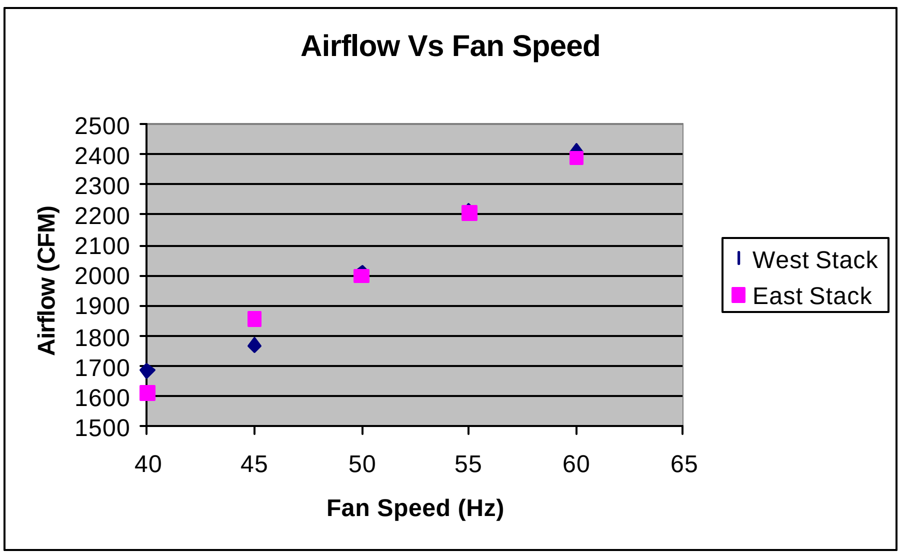
- Operation only during daylight hours, when heating costs are smallest.
- Operation only five days per week, reducing the total operating costs (and therefore the potential savings)
- Using filters that were near the end of their useful life, thus the filters acted like a dampener, reducing the effect of over-ventilation
- Neglecting air drawn into the booth from the shop.
- Operating at the lowest temperature recommended for the coating or chemical cleaners, rather than the warmer temperatures likely to be preferred by personnel.

All of these factors could contribute to the operating cost of the paint booth, with the factors involving temperature and hours of operation having the most impact on the results. For illustration, the cost savings for continuous operation is provided in the sub-section *Energy Use*: Table 2.

5-Stage Pretreatment System

Investigation into the 5-stage treatment system progressed in a similar manner. In the case of the treatment system, The most significant energy cost comes from maintaining the elevated temperature of the cleaning and phosphatising chemistry. The chemical tanks are held at 120-130 degrees F. The chemicals are cooled due to evaporation and contact with cooler air and parts during spraying. The steam and mist are exhausted through ducts to prevent buildup of humidity and phosphatising chemicals in the shop area. This investigation dealt primarily with adjusting the exaust flow to minimize over-ventilation. The effect of the speed controls on stack airflow over the range tested is indicated in Graph 1. The effect of cross-flow through the washer was also investigated, but observations indicated that cross flow did not have a significant role in the efficiency of the washer.

Graph 1: Airflow Reduction in 5 Stage Pretreatment System



In it's unmodified form, the washer exhausted around 2400 cfm of air per stack, and consumed 950 Cubic feet of natural gas per hour. After speed reduction with the AC motor controller, the rate of gas use was reduced to 880 ft^3/hr. The flow of air into the face of the washer was also reduced, but remained above 100 ft/min even at the lowest fan motor speed. This change represents a 7% reduction in operating costs. This is not as dramatic a reduction as the paint booth, but the washer's higher operating cost, and the fact that the speed controllers were less costly to install on the washer offsets the smaller reduction.

Powder Coating Booth

The powder coating booth has a lower operating cost, and was expected to benefit least from the variable speed drive. However, it also required the smallest drive, and therefore was the least expensive piece of equipment to modify. The cost of running the powder coating booth is based only on the electrical demand of the motors, as the booth does not require external ventilation. The variable speed drive was able to reduce the motor speed to 66% of its design speed, while still providing adequate ventilation.

The results indicate that even for a shop that operates its booth only 40 hours a week, sufficient energy is saved by fine-tuning the exhaust motors to allow the equipment to pay for itself. The payback period in this case comes close to ten years. It is not apparent that the energy savings in this case justify the cost of the equipment, and the decision to use control equipment would have to depend on other factors.

In the case of a shop operating it's booth continuously, however, the payback period is significantly shorter. The reduction in operating costs is large enough to pay back the cost of equipment in less than three years. This is a sufficiently rapid payback period to recommend this modification to a shop that is over-ventilating their powder booth by 30% or more.

Energy Use

The paint booth results are based on assuming the booth is operated 480 hrs per year while the temperature outside is less than 35 degrees (three months of winter), and 480 hrs per year when the temperature outside is less than 50 degrees (three months of cool spring/fall weather). The washer estimates are based on the washer being run in a facility that is maintained at 70 degrees F, 40 hrs a week for 50 weeks per year. The outdoor temperature is not taken into consideration for the washer because the chemical tanks are held at 130 degrees. At this temperature, heat losses from evaporation will be significant even during warm weather. The powder-coating booth is assumed to run 40 hrs per week for 50 weeks. The savings for the powder-coating booth are purely due to reducing the power of the motors; no heating is required for this booth.

Table 2: Operating Costs for Full Time Operation

Equipment	Initial Cost	Minimized Cost	Savings Per Year	AC Motor Controller Cost	Payback Period
Paint Booth	$3.16 Per Degree Day	$2.43 Per Degree Day	$ 4844	$ 5025	1.03 Years
5 Stage Washer	$149.76 Per Day	$138.48 Per Day	$ 3948	$ 1980	0.50 Years
Powder Coating Booth	$4.32 per Day	$2.88 Per Day	$ 525	$ 1175	2.24 Years

For facilities that operate three shifts, the operating costs for this equipment increases drastically. For the washer and powder coating booth, the operating cost increases approximately five times, due entirely to the additional hours of operation. For the paint booth, the situation is a little more complex. Simply multiplying the daytime cost by the additional hours of operation will not provide an accurate estimate because temperatures are generally lower at night. In order to calculate the total cost of running a paint booth year-round, it is necessary to calculate the operating cost on a degree-day basis. The number of degree-days in an area is equal to the sum of days requiring heating multiplied by the average difference between the reference temperature of 65 degrees and the outdoor temperature. For example, if the temperature outside for a day in February is 10 degrees, the heating demand for that day is 55 degree-days. If the temperature remains 10 degrees for a week, the heating demand for the week is 55*7=385 degree-days. The US DOE has recorded an average of 6635 degree-days per year for the Northern Midwest census division. The cost to operate a paint booth per degree-day is given in Table 2. The total cost for operating the paint booth continuously for one year in this region is also indicated in Table 2. Reducing the ventilation of the paint booth in this case would result in a savings of nearly $5000 per year. Clearly, there is a large potential savings for shops that operate paint booths and pretreatment systems over two or more shifts per day.

4. Conclusions

It is clear from this investigation that a shop utilizing a paint booth and a pretreatment system for two or more shifts per day has the potential to realize a significant reduction in operating costs by carefully controlling the operating parameters. The payback period is sufficiently short to justify the purchase and the additional work required to adjust the flow rate properly. For facilities that operate a paint booth for only one shift, the benefit is still present, but the payback period is longer and cost savings alone do not always justify the work. However, reducing the energy consumption of the operation still reduces the environmental impact, and in colder climates or in areas with higher-than-average energy prices, the benefit is even greater.

It is also clear that there is insufficient benefit from this technology to justify using it on small powder-coating operations. Powder coating booths are less costly to run, and air does not need to be exhausted into the atmosphere. However, large operations that run multiple shifts can realize cost savings. Related benefits, such as lower noise and higher coating efficiencies, might also be realized through further investigation.

The results of this investigation were not particularly surprising, as it was clear from the initial measurements that the ventilation fans were exhausting excess air. What is surprising is the ease with which we were able to improve the efficiency of these energy-hungry devices with the addition of common, inexpensive technology. This suggests that there may be a large population of industrial equipment that could be similarly improved. In years past homeowners have been bombarded with messages touting the importance of conserving resources, and as a result there is an abundance of energy-saving devices and products available for the homeowner. Programmable thermostats, low-flow showerheads, and high-efficiency stoves, refrigerators, and furnaces are constantly being improved. In contrast, the message to the industrial world has been more pollution-conscious, and need for energy efficient operation has been drown out by more pressing concerns. Even after the west coast suffered blackouts and energy shortages, few businesses seem concerned over the cost of energy. Many long term-predictions show that there is little reason for concern, as energy prices should be stable for years to come. But blackouts and shortages do demonstrate one thing, a shortage of supply for any reason, from natural disasters, political upheaval, or even new industry created from a healthy, robust economy, can drive prices up seemingly overnight. While average energy prices are stable, local energy prices can fluctuate rapidly. A season with exceptionally cold weather and high energy prices could be disastrous for a business of any size. Businesses that can get by on less will be less affected by changing prices, and more stable in the long run. Energy efficiency is a policy that makes good sense, no matter what the circumstance.

5. Method Details

A detailed description of the methods used for data collection in this investigation can be found in the Quality Assurance Project Plan (QAPP) for this project. This document is available upon request from the Iowa Waste Reduction Center, University of Northern Iowa, Cedar Falls, IA. Readers can contact the Iowa Waste Reduction Center at 1-800-422-3109.

6. Further Investigations

Several places in the text of this report allude to additional benefits provided by the ability to precisely control the intake and exhaust motor speed. This section will briefly discuss some of the observations and potential benefits. Some benefits are related to efficiency, while others are related to employee health and safety, or quality control.

One of the most notable and welcome benefits of adjusting the fan motor speed was the reduction of noise. While unmeasured, this noise reduction made it significantly easier to communicate in the paint booth, and also made spending time painting and taking measurements more pleasant. It should be noted that the most significant reduction in noise occurs very close to full speed operation. In the paint booth used for this investigation, it was possible to significantly reduce the noise without measurably reducing the airflow. This suggests that our exhaust fan and motor were operating above the speed at which they were most effective. The noise from the washer vents was also reduced, but noises from other sources (on the washer) drown out the majority of the benefit.

Adjusting the paint booth intake and exhaust separately allowed the flow through the open sides of the booth to be adjusted more precisely. It was possible to adjust the booth to have the slightly positive pressure that it was designed to operate with. The manufacturers method of adjusting the internal pressure was by changing the drive pulleys on the fan motors, a technique that proved to be inconvenient and ineffective.

Maintaining positive pressure in the booth improves finish quality, by preventing dust and debris from entering the booth during operation. It was also noted that carefully regulating airflow would allow the highest possible transfer efficiency, as the paint particles have slightly more time to come in contact with the finished surface before they are drawn into the filters. This effect may be more or less pronounced with electrostatic equipment.

Finally, the ease with which the fan rate can be changed provides a simple means to deal with filter loading. The rate of airflow through the booth is constantly changing as the filters become more loaded with paint, and are finally replaced. In most operations, the airflow through the booth simply changes over time. The motor speed controller provides the potential to standardize airflow. The flow can be adjusted manually, by having an employee measure the flow and set the fan speed on a periodic basis, or preferably, by automating the process using feedback controls. A simple electronic manometer and pitot tube could be adapted to provide a signal to the speed controller, and continuously regulate the flow for a very reasonable cost. This would also provide an alternative means of judging the condition of the paint filters, based on fan speed. This may prove to be a more accurate method of determining the useful life of filters, and for businesses that must manage filters as a hazardous waste, it has the potential to save thousands of dollars in disposal costs.