



Organic Finishing

Energy Reduction in Paint Booths

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Design Approaches to Help Reduce Energy Costs Without Affecting Performance

If you own a paint booth, you know where most of the energy in your plant is going. The paint booth will require more energy to operate than most of the rest of your processes combined. What are the options for reducing energy usage in paint booths? Is it necessary to reduce performance in order to save on energy consumption? This article will examine common ways to reduce energy bills. Some methods are just common sense, while others involve getting the best design for your engineering dollars.

There are several sources of energy that must be addressed. The first, and most obvious, is the air moving machinery. Exhaust fans and air replacement units require huge amounts of energy to maintain airflow in the paint booth. The second energy source is the energy that is required for heating and cooling the air used in the booth.

Lighting is the third area of possible energy savings. The use of modern T8 or T5-HO fixtures allows us to use current technology to reduce energy as low as possible without reducing performance.

Conformal Shape Design

The airflow used in a booth is directly related to the cross-sectional area of the booth. For most vehicles, we recommend 4–5 ft of clearance all the way around the product. But there are objects for which this is not the best design. Take, for example, a fixed-wing aircraft. This product is tall in the center to accommodate the tail assembly and low on the wing tips. Thus, it makes sense to lower the roof over the wingtips to reduce the cross sectional area. This will result in a savings of 15%–30% of the energy required for a non-conformal shaped booth. For large aircraft, like transports, the savings may exceed 40%.

Consideration must be given to accessibility of painter, helper, and equipment to determine the nearest approach of the walls and ceiling to the aircraft. Generally, about 6–7 ft above the fuselage and wings is sufficient to allow a man to stand on those surfaces and paint, whereas 4–5 ft above the tail is usually sufficient. Consideration should be given to fall protection if the worker walks on the higher parts of the product.

A typical business jet would require a 75-ft square floor plan and maybe 30-ft in height. In a crossdraft paint booth, the airflow required conventionally is



Figure 1: Conformally shaped aircraft booth

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75 × 30 × 100 fpm or 225,000 cfm of air. With a conformal design, the wing area would be at 16 ft above the floor (see Figure 1) and the tail would be at 30 ft. If we use a tail “slot” of 30 ft wide, that reduces the airflow to 162,000 cfm. This is a reduction of 28%, and its most notable presence is on the balance sheet under “energy.”

This principle should be used wherever possible to reduce energy usage. This simple approach will reduce energy without affecting paint booth performance. This same principle can be used to drastically reduce the amount of air used in downdraft paint booths for aircraft and other products.

Air Moving Machinery

The use of variable frequency drives (VFDs) for motors assures that the booth will operate at top efficiency and at the lowest energy usage. It is known that as the fan speed is changed, the motor horsepower consumption is related by the third power as follows:

$$HP1/HP2 = (RPM1/RPM2)^3$$

When filters are initially installed, they are clean and fan resistance is low. Typically, when a spray booth designer configures the booth for 100 fpm, they will figure the airflow will decrease to 50–70 fpm when the filters are dirty. In this fashion, the fan is operated at constant speed regardless of filter loading and paint booth performance—and energy usage suffers. If there was a way to start the fan at a low speed and adjust the speed upward as the filters become soiled, the energy consumption would be greatly reduced. The fan curve shown in Figure 2 illustrates this quantitatively.

Suppose we had a large aircraft hanger, (unrelated to the one in the previous section) that required an airflow of 35,000 cfm to achieve 100 fpm of air velocity. At the initial point of operation the resistance is low, 1" water column (WC) static pressure (SP), and at the design point the resistance has increased to 3" WC. (This is somewhat below the filter

maximum resistance point of 4.0" WC.) At the initial point, the fan speed is 975 rpm and the horsepower is a low 20 HP.

Since we want to preserve an airflow of 35,000 cfm (or 100 fpm) even as the filters become more clogged with overspray, the purpose of the VFD automatically accomplishes this. By moving along the vertical line in the fan curve at 35,000 cfm, we see that when the pressure differential reaches the design point of 3" WC, the speed has increased to 1,143 rpm and the horsepower is at 28 HP. There are control systems available to do this work automatically.

In the absence of a VFD the fan operates at the same rpm regardless of the pressure differential. Note that the red line in Figure 2 shows a constant speed system starting at 100 fpm and 35,000 cfm (at the initial point) in the booth, and at the design point of 3" the airflow has fallen off to 22,750 cfm (at full loading) in the booth. The new air velocity can be calculated as: 22,750 cfm × 100 fpm/35,000 cfm = 65 fpm. The horsepower in this case is 18–20 HP all the way. Note that even though the air volume has dropped off by 35%, there is no energy savings.

Use of a VFD will optimize energy usage at all speeds and maintain paint booth performance levels at the best point of performance. With the VFD, it is even possible to redefine the optimum point of performance to 90 fpm or 75 fpm if required. Much will depend on the paint and the painting process.

Motors come in a variety of styles. It is possible to purchase a premium efficiency motor that will save 3% of the energy. They use copper die-cast rotors in lieu of aluminum, which leads to better efficiency. This advantage also extends to a flatter efficiency curve over a variable loaded motor. The increased cost of these motors is very low.

Multi-Mode Operation

Most paint booths are used in several modes of operation. Common practice is to do all or some of the paint booth functions listed in Table 1.

It is apparent that most energy is being used during painting and curing. But during the other functions, much less energy is used and the control system should have a way to reduce the airflow

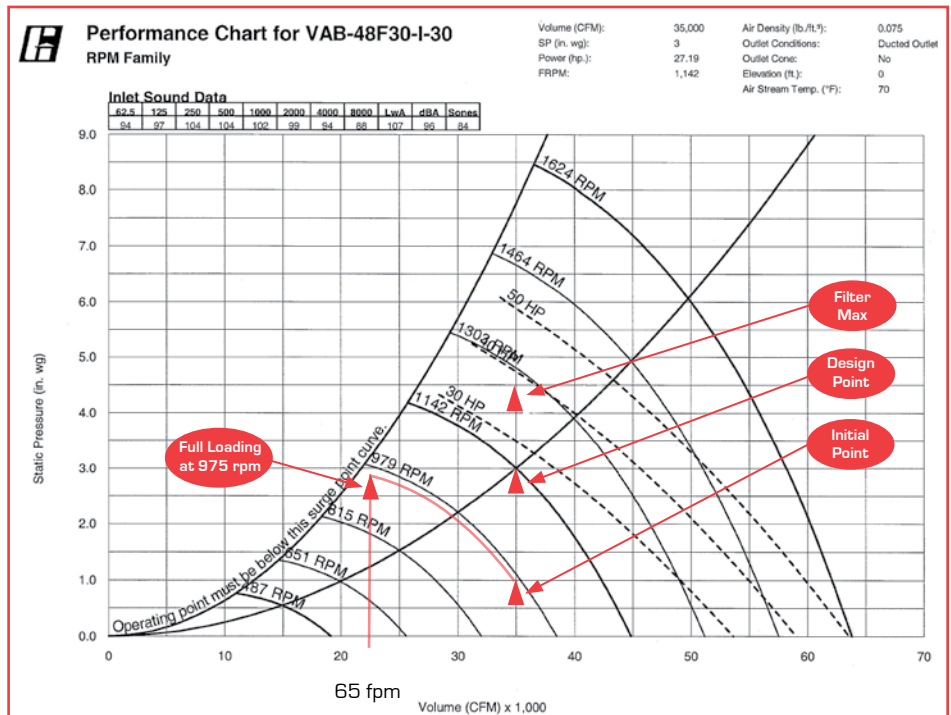


Figure 2

Mode of Operation	Function	Airflow Rate	Temperature
Painting	Painting	75-100 fpm	Comfort
Preparation	Masking, Touch-up	35-50 fpm	Comfort
Wash/Solvent Wipe	Cleaning	50 fpm	Comfort
Sanding/Body Work	Sanding	75 fpm	Comfort
Curing/Drying	Drying Paint to Touch	100 fpm	120-140° F
Standby	Idle	10-15 fpm	50-60° F

Table 1

and temperature requirements as required.

Notice that the airflow in the booth changes depending on the mode. This means that the exhaust fans and the supply system must be equipped with VFDs to control their speed. Actual settings in all modes of operation are determined empirically at the time of commissioning.

Using Energy Recovery Devices

In a paint booth, air is introduced into the booth at the conditions required of the paint booth. The air is then removed from the booth by the exhaust fans and dumped into the atmosphere. The cost of energy for the replacement air system is a substantial fraction of the booth energy cost. All of the common energy recovery devices require good filtration to protect the heat exchange surfaces from fouling with overspray.

If the energy present in the exhaust air could be swapped with the energy being used in the air replacement system, substantial savings could be realized. One way to do this is to install a coil system using a heat transfer fluid to pick up heat in the 75F exhaust air and then pump the fluid to another coil that adds that energy to the incoming air stream. This is called a "runaround" loop and is about 55% effective. It works well when the intake source and the exhaust location are far apart. (It does require energy to perform.) The coils represent static pressure resistance and the fluid must be pumped, all of which require additional energy usage.

Another way to share energy is to use a plate-style heat exchanger and allow the exhaust air to be on one side of the plates and the supply air to be on the

other. These systems are about 60% effective. The supply system and the exhaust system must be adjacent to avoid installing a lot of ductwork. This method is inherently more effective, but it is important to remember that it also requires expenditure of energy to overcome static pressure resistance.

There are also heat recovery wheel devices that will work well in climates where the aforementioned units will not work. They are bulky and do require significant sacrifices in floor space to be included in the design. This design requires a small motor to turn the wheel, as well as static pressure resistance that must be overcome.

All of the previously noted systems use energy to save energy. A prudent spray booth engineer will spend some time to determine if the balance is a good balance and not just wasted in overcoming static resistance or in pumping fluid or turning the wheel.

Cooling a Spray Booth

It is becoming more popular to cool the spray booth environment to comfort conditions, especially in places where temperatures are at extremes. Let us look at the example we already started for a business jet. Using conformal design, we were able to reduce airflow to a mere 162,000 cfm. Without energy recovery of any kind, the cooling load in the southwest portion of the country could be 800 tons of refrigeration (TR). This is a significant consumption of energy, and a prudent spray booth designer would immediately look for ways to reduce that requirement.

If the designer uses an energy recovery device as previously mentioned, the energy required is reduced to about 450

TR. This is a large number, but it is just the tip of the cost iceberg. In addition to the air handler, consideration must be given to a water chiller (with pumping system) or a direct expansion condensing unit.

In the Southwest United States, a climate exists that is very hot, but also very dry. In such a climate, it is possible to use evaporative cooling to get most of the cooling that is needed. Evaporative cooling is also known domestically as a "swamp cooler," and people from that area use this technology to air condition their homes. This is a very economical cooling method and can also be used to further reduce the cooling load.

If you get 55% savings from the energy recovery cell and then get 300 TR equivalent from the evaporative media, it only leaves 100 TR or so of refrigeration. This is a more manageable project and is very energy friendly for the benefit it provides.

In booths that use polyurethane finishes, the higher humidity provided by the evaporative media is also a benefit to the painting process.

Recirculation

Recirculation of exhaust gases is another way to significantly reduce the energy costs of a paint booth. In this scenario, 80% of the exhaust is recirculated back to the front of the booth to be re-used to remove overspray from the painted object. The fresh air is thus reduced to 20% of the amount required with a "once through" system.

In the aforementioned example, the fresh air is reduced to 32,400 cfm. If cooling is required, the demand is reduced to just 162 TR. If energy recovery is used, the cooling load goes to 90 TR. This is a manageable project and much easier to rationalize and to obtain funding.

Recirculation offers another benefit not immediately visible to paint booth engineers. Without recirculation, the air conditioning load would require a good bit of reheat to get the air to the room conditions. Dehumidification requires that the air be sub-cooled past the set point of the room to get the moisture

out. In order to get the air to room temperature, heat must be added.

In a recirculation system, the heat of compression of the recirculation fans adds most of the reheat required to maintain control of the temperature in the booth.

Consideration must be given to fire safety and controls (such as monitors and alarms) that must be added to reduce these risks. In addition, personnel health is a major concern. Therefore, controls (such as high-efficiency particle filtration and carbon adsorption, and monitors) must be added to reduce these risks.

It is highly unlikely that operators would paint in these booths without personnel protective equipment with breathable air and hood. (GFS has done recirculation systems at several installations.) Recirculation rates are typically 80% recirculated and 20% fresh air, but recirculation rates up to 60/40, and as low as 90/10, have been done. Climate conditions have a lot to do with the recirculation rate, as does personnel safety.

Lighting

One of the benefits of our current technology is improved lighting at reduced power. We currently use T8 fluorescent fixtures in most designs. Some high-bay facilities use HID lighting. Fluorescent fixtures are low-energy consumers.

Recently, the emergence of T5 fixtures and tubes has increased interest. T5-HO tubes will give off much more light than a plain T5 light. In fact, T5 lights have no real advantage in 2008 over T8 lights. T5-HO lights will use more power per fixture, but it is possible to reduce fixtures because they create more light. They may not be suitable for small booths where they would reduce the number of fixtures from 16 to 5, but in large rooms they provide good coverage with no shadows and good color correction.

Their intensity also makes them good in high-bay facilities up to about 35 ft. Above that point, the use of HID lights is required.

Energy Guidelines

Many building designers have used guidelines as a reference to achieve a minimum standard of energy efficiency (i.e., ASHRAE 90.1 and LEED for New Construction and Major Renovation). Unfortunately, industrial processes, such as paint booths, are exempt from these standards, thus leaving the design of such large energy consumers to the supplier of the industrial systems.

To the end-user, this means that the capital and operating expense costs for the system are the result of the available resources and knowledge of the designer. It is this supplier's performance that mandates how effective and energy-efficient your system operates.

This is why it is very important to make an informative selection on the supplier of your paint finishing system. Investigate past projects that the suppliers have completed and look to see if energy-saving techniques were utilized. Ask for contacts from these companies and ask for a site visit or tour. Also make sure you investigate your company's energy costs, production hours, and that you have an understanding of what type of energy your proposed system will utilize.

Find out if your utility providers have incentive programs that will assist in paying for energy saving technology. Let your system designer know that you want a system that is designed as efficiently as possible. A resourceful and quality supplier will have the knowledge to describe and design different energy saving measures. They will be able to determine the feasibility of different solutions and provide a recommendation that will meet your needs.

For the sake of our planet we should always strive to get the best value in energy-saving equipment.

Summary

Even though a paint booth will consume large quantities of your energy budget, there are design approaches that will reduce your energy usage without reducing performance of the booth in any way. The main performance factors of a paint booth are fire safety, personnel safety, and painting performance.

The big energy hogs are air tempering and air moving, so be careful when you address the design of those items and you will get a reduced energy design that still meets your needs.

