Complying with Aircraft Painting Air Emission Regulations

The Dilemma Caused by Halogenated Solvents

By Jerry Bauer, PE, and Steve Anzelc, PE

Modern aircraft are typically spray-coated with an epoxy-based undercoating, or primer, followed by a polyurethane-based top layer, or topcoat. In order for these coatings to be sprayed and have acceptable performance and appearance, the coating mixtures must have the appropriate viscosity (which allows the coating to be spray-applied) and curing time. Both of these properties are dictated by the solvents, or thinners, in the coating. Historically, a wide variety of solvents have been used, such as methyl ethyl ketone (MEK), toluene, xylene, and methyl iso butyl ketone (MIBK).

Regulatory Concerns

Air emission regulations affecting the solvents used and emitted in aircraft painting were enacted in California and other urban areas in the 1980s and in the entire U.S. by the mid-1990s. Organic solvents that readily evaporate and react to form ground-level ozone are classified as volatile organic compounds (VOCs). Ground-level ozone is a harmful chemical, the primary constituent of smog formed through the reaction of VOCs, nitrous oxide (NO.) and sunlight. The Environmental Protection Agency (EPA) has evaluated which organic chemicals do or do not react to form ozone and has classified them as VOCs or non-VOCs.

There are two categories of air emission regulations affecting aircraft painting and VOCs. Aircraft manufacturers must meet both sets of limits.

- Coating limits: Typically 2.9 pounds per gallon VOC for a primer and 3.5 pounds per gallon VOC for a topcoat.

- Annual VOC emission limits: Typically associated with air permitting requirements ranging from 25-250 tons per year for new painting operations.

Aircraft manufacturers are generally allowed to meet the coating limits either by using low-VOC content coatings or by controlling VOC emissions with an air-pollution control system that destroys the VOCs. Meeting the coating limits by using low-VOC content coatings is more common and the most cost-effective compliance option.

However, in some regions with particularly stringent air quality regulations, aircraft manufacturers are forced to install emission control systems on new paint booth installations even if low-VOC coatings are used.

Solvent Substitutions

Paint suppliers have tried to reduce VOC content in coatings to allow customers to meet regulatory requirements. Two of the more common chemicals/chemical categories that can be used as paint solvents that are not VOCs are acetone and halogenated compounds (organic solvents that contain chlorine or fluorine), such as parachlorotrifluorobenzene (PCTFB), which is branded as Oxsol 100.

Acetone has a higher vapor pressure/lower flash point than most conventional solvents and can create quality as well as safety issues associated with its rapid evaporation rate. There are typically no added environmental concerns.

However, the halogenated solvent (which was introduced to reduce VOC emissions) does create significant unintended environmental issues in applications where an emissions control system is required to meet annual VOC emission limits. The elemental fluorine and chlorine in Oxsol 100 combine with the elemental hydrogen at elevated temperature to form hydrofluoric acid (HF) and hydrochloric acid (HCl) vapor that can combine with water vapor and condense to form a corrosive, dangerous mixture. Additionally, HF and HCl are both hazardous air pollutants that themselves
pose both health and corrosion issues. HF exposure to skin can cause significant health issues or, in extreme cases, death.

Thus, while halogenated solvents are intended to reduce VOC emissions and allow an aircraft company to meet VOC emission limits without installing VOC control systems, the halogenated compounds create undesirable issues for a facility that is required to use a VOC control system. In these cases, the benefit of reducing the VOC coating content (by replacing VOCs with halogenated solvents) is far outweighed by the negative collateral effects of generating HCl and HF air emissions.

In other words, while the paint supplier is trying to help aircraft manufacturers by using halogenated compounds that reduce the VOC content in order to meet the VOC limit per coating, he is adversely affecting an aircraft manufacturer already committed to using an emissions-control system to meet annual VOC limits.

**VOC Air-Emission Control Systems**

An emissions control system that treats VOC emissions from a typical, medium-sized aircraft paint booth will cost on the order of $1 million and require hundreds of thousands of dollars in annual operating costs (see Figure 1). If chlorinated and fluorinated compounds are present in the paint (as in the Oxsol 100 solvent) both the capital and operating costs can nearly double due to the following:

- The air emissions from the thermal oxidizer must be treated in a packed-bed wet scrubber in order to treat the acids created in the oxidizer from the halogenated compounds. The scrubber will require caustic storage and conveyance to neutralize the HF and HCl. Another consideration is the health and safety of workers involved in delivery, storage and conveyance of the caustic to the scrubber.

- Higher-cost, corrosion-resistant super alloys will be required for the oxidizer, ductwork and insulation because of the inclusion of corrosive HF and HCl. This can account for approximately half of the capital cost increase.

- An increase in VOC equipment sizing due to the requirement to supply fresh air in

![Figure 1: Typical regenerative thermal oxidizer used to oxidize VOCs.](Photo courtesy Munters Corp.)
lieu of recirculated air to the concentrator desorption systems (this prevents the creation of additional acid gas).

- Reduced life expectancy of equipment due to corrosion.

In the example above, if the paint supplier could replace halogenated solvents with non-halogenated VOC solvents (such as toluene or MEK) or non-halogenated, non-VOC solvents (such as acetone) in the aircraft coatings (primer and topcoat) used, the aircraft manufacturer could realize a capital savings of $1 million. That savings is achieved by eliminating the need for the packed-bed wet scrubber and using less costly construction materials for the oxidizer.

**Achieving Cost Savings**

In order for an aircraft manufacturing company to cost-effectively paint aircraft while meeting both quality standards and air-emission regulations, a design approach that involves the coating supplier, process engineer, facilities engineer and engineer-architect is needed. It is essential that these stakeholders communicate in an iterative fashion throughout the process rather than completing individual design components and “passing the ball.” Again, while using the halogenated paint solvent can be desirable (as it allows the facility to meet the VOC limits for a particular coating), the halogenated solvent causes undesirable collateral effects if the facility owner will be committed to installing the VOC control system in order to meet annual VOC emission limits or other regulatory requirements.

**Designing a New Paint Process**

A flow chart describing the traditional linear design and decision-making process for a new aircraft paint booth is shown in Figure 2. There is little communication between the project team members and little iteration in the process. The coating supplier does not know that the facility will be using a VOC control system and is trying to develop acceptable coatings with the lowest VOC content (regardless of whether halogenated chemicals are the substitute).

**Figure 2:** Traditional linear design and decision-making process limits opportunities for cost reduction.
Figure 3: A collaborative design process allows reconsideration of coating formulas to help avoid additional equipment and associated costs.

Steve Anzelc, PE, is a project manager in the Burns & McDonnell Aviation & Facilities Group. He manages aerospace manufacturing and assembly facility designs.

Jerry Bauer, PE, is a project manager in the Burns & McDonnell Environmental Group. He specializes in air pollution control and regulatory issues.

For more information, please e-mail jbauer@burnsmcd.com or sanzelc@burnsmcd.com.
Each step in the process can be lengthy: getting an air permit can require a year or longer. Developing, testing and approving a particular coating can take even longer. Using this linear approach precludes any potential for an alternative design because of the time requirement for each step.

A more progressive approach to the design and decision-making process associated with a new paint booth is shown in Figure 3 on page 7. Team members must communicate regularly with each other, and a number of iterations in the decision-making process are made. The coating supplier is contacted early on and the determination as to whether a VOC control system will be used is a factor in optimizing the coating formulation.

Conclusion
When designing an aircraft paint booth to cost-effectively meet air emissions regulations, communication and iteration between stakeholders, particularly the coating manufacturer, is the key to a successful project. The paint supplier may be thinking he is doing the aircraft manufacturer a favor by replacing a VOC with a halogenated solvent in a particular paint formulation when in fact he is causing undesirable downstream impacts on the VOC control system. A progressive approach that involves upfront involvement and communication between the paint supplier, process engineer, facilities engineer, and architect-engineer should be utilized to minimize schedule impacts and reduce costs.