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**COST-EFFECTIVE VENTILATION
OF A LARGE-AIRCRAFT PAINTING
FACILITY AT ROBINS AFB, GEORGIA**

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14. ABSTRACT Spray painting of large aircraft requires moving enormous quantities of air in an ordered manner to 1) clear overspray particles from the coated surface; 2) dilute the paint solvent vapors below their Lower Explosive Limit (LEL); and 3) keep concentrations of air toxic vapors and particles in the vicinity of the painting crew below the Occupational Exposure Limit (OEL). Standards promulgated in 29 CFR 1910.94 and 1910.107 prohibiting the use of partial exhaust recirculation were based on consensus standards that have since been revised to accommodate technology advances. Whereas the language of 29 CFR has not been revised, a body of interpretations has accumulated that provides a clear picture that a facility using technology that provides "equal or better protection" to its personnel enjoys immunity from citation under these standards. This paper describes the steps followed by a team of Robins AFB personnel to establish that an 80% recirculating design moving air at 60 ft/min will comply with 29 CFR 1910.1000 and National Fire Protection Association document 33, and to develop a set of design specifications for the construction of a climate-controlled hangar to paint C-5 aircraft ata cost saving of ~\$1M per plane compared to a conventionally designed (fresh air, 120 ft/min airflow) hangar.					
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Cost-Effective Ventilation of a Large-Aircraft Painting Facility at Robins AFB, Georgia

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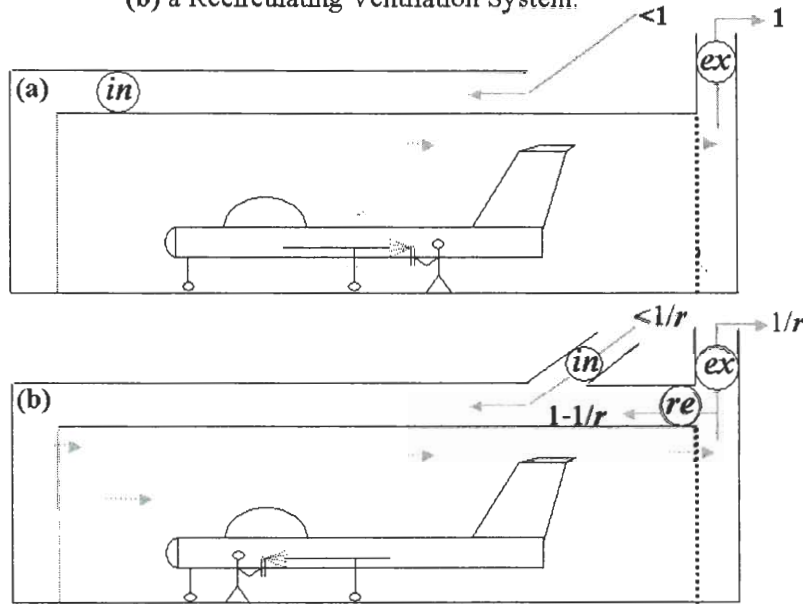
ABSTRACT

The text of 29 CFR 1910.107(d)(9), which was imported from the 1969 revision of a fire safety standard, prohibits recirculating ventilation in spray painting facilities. Devices to measure vapor concentrations obsoleted this standard almost immediately, but efforts to amend this statement have been frustrated. To accommodate advances in technology, OSHA invoked the designation "*de minimis* violation" to enable the use of recirculation and other technologies that *comply with the most current consensus standards applicable to their operations . . . when the employer's action provides equal or greater employee protection*. Whereas industry has adapted to this expedient, Department of Defense agencies have consistently interpreted that if 107(d)(9) is still in print and the alternative is called a *violation*, however qualified, military installations will not be given permission to employ exhaust recirculation (ER). Individual bases working in isolation have built a few examples of painting hangars using ER, but each of these facilities suffered from one or more serious design faults. Robins Air Force Base (RAFB), near Macon, Georgia, is acquiring a painting hangar to accommodate painting of C-5 aircraft in an ER ventilation system. Because the economics of exhausting 2.5 million cfm of temperature-controlled air is untenable, critical justification for using ER is provided by RAFB's environmental conditions, which require cooling and dehumidifying air used in the ventilation process during four to five months each year. This report identifies documentary precedents for competent designs of future paint facilities and describes the preparation and issuance of a design-and-build contract for construction of this new facility at RAFB.

INTRODUCTION

Exhaust recirculation (ER) is an engineering device employed in a spectrum of applications to modify the process that generates the exhaust. When ER is applied during spray painting of aircraft (Figure 1), air movement in the workspace is unchanged, but the volume of air ingested and exhausted is decreased and the concentration of solvent vapor

Figure 1. Air Movement Within (a) a Conventional Facility and (b) a Recirculating Ventilation System.



is increased, both in proportion to the fraction^{1,2} of the exhaust that is recirculated. In an ER system [Figure 1 (b)] of recirculation ratio r , only $1/r$ of the effluent from the painting area is exhausted, so the exhaust (*ex*) and intake (*in*) blowers are smaller than in a conventional ventilation system [Figure 1 (a)]. A third fan (*re*) returns the recirculated air [$1-1/r$ of the effluent stream] to the front of the painting area. The intake is slightly starved in both configurations to maintain negative pressure inside the ventilated volume, and air movement is identical inside the two painting areas. Solids are removed by the exhaust filters and concentrate only slightly.

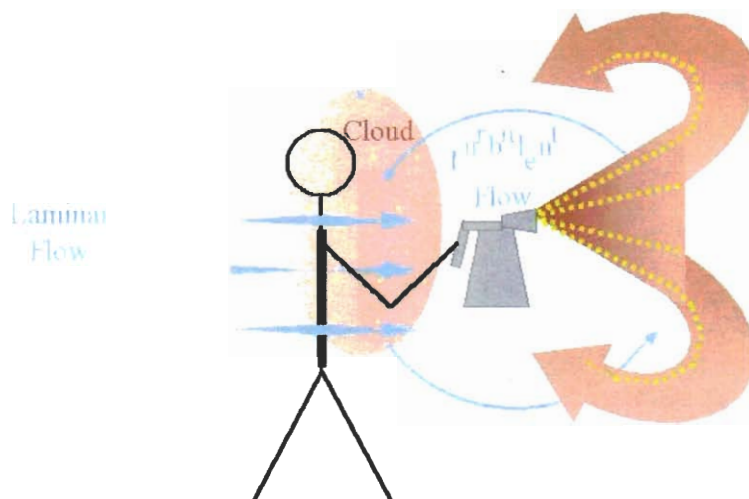
Until sensors became available to measure the concentration of vapor in the ventilation air stream, the risk of developing vapor concentrations in excess of the lower explosive limit (LEL) was uncontrolled, and prudence dictated³ that ER was an unacceptable technology. Infelicitously, the Occupational Safety and Health Administration (OSHA) codified their regulation⁴ governing aircraft spray painting by incorporating passages from reference 3—after devices to measure vapor concentrations entered the market but before the National Fire Protection Association (NFPA) issued the 1972 revision⁵, which specifies conditions under which ER is allowed.

ER offers several engineering benefits to the painting facility and its operation:

- If emission control is to be applied, the control system is both smaller and more efficient in the smaller, more-concentrated stream, and energy consumption by the control system is lower.
- If temperature and/or humidity of the painting environment require modification, the cost is proportional to the net volume of air treated (*i.e.*, the volume exhausted).
- Repeated filtration of airborne overspray particles decreases the fraction of the air toxic particulate matter (PM) that is emitted to the environment.

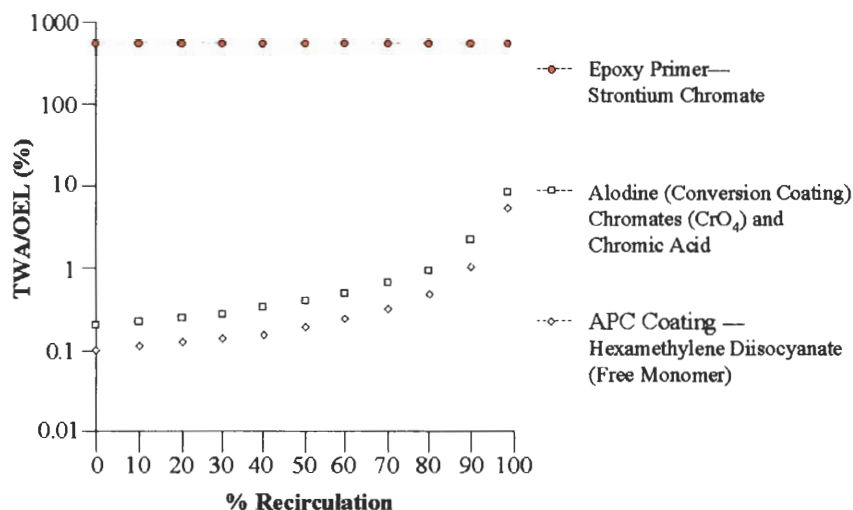
Although the average concentration of vapors in the exhaust increases with the fraction of exhaust recirculated, both modeling⁶⁻⁸ and measurements^{9,10} show that the increase in concentration is small enough to be neglected in a typical engineering calculation. Figure 2 broadly illustrates the turbulence created in a nominally laminar air pattern as it passes an obstacle (the painter), entrapment and return toward the painter of vapor and particles from the spray, and a stylized cloud of overspray contaminants at the painter's breathing zone. As the average increase in concentration at $1/r \geq 0.1$ (90% ER) is several orders of magnitude smaller than the concentrations consistently measured in the cloud, the increment to risk is less than the uncertainty of exposure measurements. Thus the increase of exposure risk to a painter in a well designed and properly maintained large facility is smaller than current sampling measurements can discriminate.

Figure 2. Cartoon Illustrating Turbulence and Resulting Concentration of Overspray Particles (•••) and Vapor (—) in a Cloud Downwind of a Painter.



The increase in concentration as exhaust flow rate decreases is described as a simple dilution process. For a recirculation rate of 50%, $1/r = (1 - 1/r) = 0.5$, $r = 2$, and the conventional and recirculated system's concentrations, C_o and C_r , respectively, are related^{1,2} as $(1) * C_o = (1/r) * C_r$, so $C_r = r * C_o$, *i.e.*, the exhaust concentration increases r -fold, and $C_r = 2C_o$ in this example. At 80% ER, $C_r = 5C_o$. Proper design implies a risk-benefit tradeoff, in which a limit is imposed by the increment of risk that is acceptable. The local cloud of overspray surrounding the painter dominates exposure in conventionally ventilated systems. The justifiable limit of the increment should be less than measurement methods can detect (a few percent of measured concentrations), and may in no event escalate the amount of personal protection needed to comply with exposure standards. Figure 3 displays modeled results for the dependence of concentration of the most-toxic component of each of three processes on recirculation rate. The lower plots illustrate that slight increases in recirculation above 90% ($1/r < 0.1$, $C_r > 10C_o$) cause exposure risk to escalate⁶ drastically.

Figure 3. Typical Plot of Concentration in Multiples of the Occupational Exposure Limit (OEL) at Different Recirculation Rates



Note, however, that the model⁶ employs very conservative assumptions. Thus the shape of the plot for hexamethylene diisocyanate (HDI) is representative, but the values are much exaggerated because the model ignores that HDI reacts almost completely. The slope for strontium chromate appears flat because it is a solid particle that is effectively removed by the exhaust filters and thus accumulates very slowly. The importance of installing efficient filters correctly and maintaining them properly in a facility using ER may be demonstrated with the model, by substituting a lower value for efficiency of particle removal, which will cause the chromate concentration to increase rapidly.

However, the idea of *any* increase is disturbing to conservative members of the industrial hygiene (IH) community, even though the facility using ER is compliant with exposure standards specified¹¹ by OSHA. Thus, the interpretation of 29 CFR 1910.107 (d)(9) has been a matter of contention and official clarification for three decades. The invocation¹² of a *de minimis* violation to condone advances in technology: “An employer who complies with a consensus standard rather than as OSHA standard in effect at the time of inspection and clearly provides equal or greater employee protection will not¹³ be cited” is an elegant legal remedy. The concept of *de minimis* violations has been consistently upheld in both area-specific¹⁴ and related¹⁵ standard opinions posted to the OSHA website. However, inclusion of *violation* in the name of the remedy creates a problem of perception by the military mind, which is conditioned to avoid violations of any sort. The same problem of perception also attaches to the standard opinion¹⁶ stating that standards for ventilation rates prescribed in 29 CFR 1910.94 (d)(c)(i) for spray painting operations are not enforceable, even though large-aircraft painting facilities in the Air Force have quietly operated in accordance with this principle.

Consistent with the interpretations^{12,14,16} above, OSHA inspectors did not cite L3 or Air Force facilities using ER ventilation to paint aircraft at Seymour Johnson Air Force Base (SJAFB), N.C., and at Mountain Home AFB (MHAFB), Idaho. SJAFB’s facility design

placed a vapor control system inside the ER loop, lowering¹⁷ both total emissions and the increase in exposure within the workplace. The concept earned a 1994 award by EPA for environmental excellence and has profound implications¹⁷ for source reduction strategies.

THE LARGE AIRCRAFT PAINTING HANGAR

Planning

Robins AFB (RAFB), located in central Georgia, is one of three primary maintenance depots for Air Force (AF) aircraft, and is the primary depot for the C-5. In a typical year, 20 C-5s are painted. Each C-5 has 30,000 sq ft of painted surface, and over 250 gallons of paint is consumed per coat. For typically four to five months each year the outside temperature and humidity exceed the upper limits specified by coating manufacturers for application and curing of their products and by AF Occupational Safety and Health (AFOSH) standards for the workplace. In January 2000 the civil engineering (CE) and environmental management (EM) groups at RAFB began a process of developing a requirements document (RD) for a new hangar to house the application of corrosion control coatings to C-5 aircraft, the largest airframes in the AF inventory. After analyzing the design and operation of existing large-aircraft painting hangars at other AF maintenance centers, CE submitted its initial draft RD in March 2001 to EM for comment. To attain full use of the facility, the draft RD included process cooling and dehumidification (PCD) in the conceptual design. During their review process EM staff initiated contact with the Air Force Research Laboratory (MLQ), which encouraged the use of ER. In December 2001 the chief of EM requested that ER be considered as an element in the design before he would give final signature approval.

Although earlier proposals by RAFB teams in 1988 and in 1995 to incorporate ER into painting hangars had been summarily disapproved by the IH office (bioenvironmental engineering; SGPB), CE and EM notified SGPB informally in January and formally in February 2002 that they were presenting a strong economic justification to use ER in the new hangar. SGPB staff responded initially that federal health standards appeared to prohibit ER in such facilities, but began investigating sources of information about ER facilities located at MHAFB⁹ and (as a temporary experiment) at Hill AFB¹⁰ (HAFB). Direct contact by SGPB with the former chief of the corresponding office at MHAFB elicited a referral to MLQ, which engaged at once in the ongoing process of education.

After digesting the body of information about ER in painting operations, SGPB concluded that ER could be risk appropriate and safe in the new hangar. The regional OSHA office in Atlanta, which is familiar with ER and the controversies still surrounding it, responded to SGPB's telephone inquiry that ER done properly in accordance with current-day industry standards would be allowed as a *de minimis* violation. To complete their determination that the prohibition of ER in 29 CFR⁴ is no longer binding, SGPB submitted a detailed inquiry—including modeled⁶ estimates of conditions in a conventional and an ER facility—to their command office (HQ AFMC/SGPB) about the permissibility of ER in the proposed hangar. In June 2002 HQ AFMC/SGPB responded that using ER is compliant with applicable regulations, and that RAFB may pursue the use of ER with appropriate fail-safe controls. This decision cited OSHA's 1987 letter¹² of

interpretation in which their policy¹³ is upheld that use of consensus standards is allowed providing technology used gives equal or greater health and safety protection for workers (*i.e.*, that compliance with applicable consensus standards^{11,18,19} is achieved with the same or a lower level of personal protective equipment compared to that required by the same process performed without ER).

The C-5's wingspan is 225 ft, its overall length is 250 ft and the height at the tail is 65 ft. A hangar that can accommodate a C-5 (Figure 4) and allow clearances for ingress, egress, and painting can have a ventilation cross section as small as 20,000 sq ft if the plane enters nose first and a raised center channel is used to accommodate the empennage. To provide 120 ft/min of air movement, as typically used by AF painting operations to ensure that the linear flow rate will not drop below 100 ft/min as filters occlude, the ventilation system must move almost 2.5 million cfm. PCD was necessary to justify building the new hangar, but the cost to apply PCD to 2.5 Mcfm of air would be stupendous, both during construction and in operation. A combination of ER and a lower ventilation rate [condoned in an OSHA standard interpretation¹⁶ that 29 CFR 1910.94 (6)(c)(ii), and not the preceding paragraph, is the enforceable standard for ventilation rates in spray painting enclosures] can realistically decrease the intake and exhaust rates (and the energy consumption by PCD) by ~80%. Calculations by the LaPuma ER model⁶ indicate⁷ that higher recirculation rates could be allowed, but practical considerations—delivering enough cooling into the make-up (fresh) air stream to offset the heat loads in and into the hangar, satisfying the requirement for air exchanges—cause rapid diminution of return at ER rates of 90% and higher. Nonetheless, ER at 80% in a 60 ft/min stream was estimated to decrease the cost for power during the painting of a C-5 by \$750K–1M compared to conventional AF ventilation techniques. ER will also decrease construction and maintenance costs by decreasing the requirement for chiller capacity.

Figure 4. C-5 Loadstar, reproduced from http://www.af.mil/photos/images/011205_12.jpg



Design and Procurement

The prospect of a well designed, active template for cost-efficient painting hangar design drew the Air Force Civil Engineer Support Agency (HQ AFCESA/CESM) in to support the design and construction efforts. Following some preparatory exchanges by e-mail and telephone, RAFB convened the first meeting of a project team—comprising representatives from CE, SGPB, EM, safety, fire, maintenance, the Army Corps of Engineers (CoE), the command construction office (HQ AFMC/CECC), MLQ and CESM, plus base architects and aircraft painters—in late August 2002. RAFB repeated their commitment to full compliance of the new facility with fire, safety, health and environmental standards as the top priority and, predictably, a number of points to be negotiated surfaced.

Architectural & Engineering (A&E) Firm to Prepare the Request for Proposals (RFP)

CoE proposed to add the task of preparing the RFP to their existing contract with an A&E firm that had limited experience with aircraft painting facilities. A similar arrangement was allowed during acquisition of the maintenance facility for B-1 aircraft at MHAFB, and that A&E's lack of relevant experience contributed to serious deficiencies⁹ in the air movement patterns inside the finished structure. RAFB agreed to review the credentials of the proposed A&E. A strategic innovation in the specifications for the painting hangar was inclusion of the user equipment to accomplish the preparation and painting activities, which carried a requirement that the processes be demonstrated prior to final acceptance. After reviewers of the qualification package submitted by CoE's contractor concluded (October 2002) that the firm did not possess adequate experience with requirements for spray painting operations, an open selection process was held to select an A-E firm to write the RFP. The A&E firm selected were appraised at the start of December 2002 of RAFB's intention that the facility design include ER.

Educating RAFB Personnel about Exhaust Recirculation

Whereas the RD required only EM's concurrence, local fire and safety offices also must approve plans before construction. Also, the best fix possible is of no practical value until its users accept it, and unfamiliarity with ER led to anxiety among the maintainers and painters present for the project team meeting. CE and MLQ's discussions with the latter group were only marginally productive until observing an aircraft painting operation in an ER facility was proposed. At MLQ's instigation, L3 Communications Integrated Systems (L3) graciously agreed to host a tour of their large-aircraft painting facility in Greenville, Texas, which had been recommended a decade earlier by Environmental Protection Agency (EPA) personnel as a model painting hangar using ER. In early January 2003, L3 personnel generously tailored a presentation of the plant's facilities and capabilities to a team of six RAFB painters and maintainers. L3's respective function managers also lead tours of the various functional areas, and permitted the team members access to the design and acquisition documents that had been developed in the course of designing and constructing their hangar. The hands-on experience convinced the team members of the practicability and safety of ER and provided invaluable practical insights into features and equipment to be installed in the new hangar.

Discussions with RAFB fire and safety offices started before the team meeting. The design of L-3's hangar includes a nominal dead air space above the painting area (seen in Figure 5, reproduced from <http://www.l-3com.com/is/aisfacilities/gfac-01.htm> with permission), and the ceiling was accepted by their team of regulators as being outside the painting area. Fire engineers at HQ AFCESA/CEF concurred that the applicable NFPA¹⁸ and ANSI¹⁹ standards allow ER but took a conservative position about the rating of equipment on the ceiling and in other areas. Item-by-item evaluations continued with HQ AFCESA/CEF throughout 2003.

Figure 5. Hangar at L3 Communications Integrated Systems. Reproduced From <http://www.l-3com.com/is/aisfacilities/efac-01.htm>.



Educating A&E Personnel about Exhaust Recirculation

Although some quantitative differences were unresolved within the project team at the time of the design charrette (*e.g.*, CE advocated more-aggressive application of ER and less net ventilation than did the shop personnel), the project team agreed to present a unified front during the meeting, which was held at RAFB in mid January 2003. This meeting brought together the project team, CoE staff, and the A&E contractor to draft a conceptual design and set requirements for the facility. To best use CESM and MLQ consultants, ER was discussed the first day. The A&E expressed reservations about incorporating the technique but listened to RAFB's arguments. The following week the A&E submitted to RAFB modeling calculations based on invalid assumptions about volatility and reactivity of hexamethylene diisocyanate (HDI) and the physical state of strontium chromate (SrCrO_4), which indicated that ER would create concentrations far exceeding personal exposure¹¹ standards. After exchanges with RAFB personnel corrected the assumptions, the A&E's engineer repeated the modeling and concurred that at least 75% ER could be applied at a linear flow rate of 60 ft/min.

However, at the start of March 2003 the A&E issued a calculatedly subversive letter centered around legal speculation that ER will inevitably invite litigation. Their response to initial comments was a second message insisting that RAFB exempt the firm from liability in any litigation involving the hangar. Within days an HQ AFMC/CECC employee raised the issue of the prohibition in 29 CFR⁴ to the command environmental office (HQ AFMC/CEVQ), who relayed the comment to MLQ and to LtC LaPuma of the Uniform Services University of the Health Sciences. Both a position paper from the AF Institute for Environmental Risk Analysis (AFIERA/RSHI) and LtC LaPuma responded to and resolved the internal query. RAFB's response to the A&E's letter was an objective analysis of the relevant OSHA and NFPA regulations that was submitted for comment by the project team, revised several times, and sent to the base legal office (WRALC/JA) for evaluation. After several exchanges with CE (representing the project team), JA concurred with the principles stated and suggested several clarifying revisions that were implemented before RAFB delivered the final position paper to HQ AFMC/CECC in June to transmit to CoE and thence to the A&E.

The procurement process resumed, with a demand from the A&E that high-efficiency particle air (HEPA) filters and chemical scrubbers be introduced into the recirculating loop of the ventilation system to remove traces of SrCrO₄ and HDI. The justification offered was an interpretation that "the engineering design must reduce the concentrations to as low a level as possible before the use of PPE." These new requirements exceed measures used in compliant ER facilities at L3, MHAFFB and SJAFB, and are in conflict with acquisition reform guidance²⁰ to make intelligent management decisions balancing risk and economic benefit. They directly impose a significant cost burden for increased fan power, for HEPA filters, for the hardware, and for installation, removal and disposal to provide protection in excess of what the standard¹¹ requires. The chemical scrubbers have been eliminated from the RFP, but a final decision about the HEPA filters is pending at the time of writing this report.

In August and September 2003, a team consisting of members from Robins AFB, AFMC, Corps of Engineers and the RFP A&E firm reviewed technical proposals from three design-build firms invited to propose on this contract. The RFP A&E contributed constructively in their review of the exhaust recirculation designs proposed by each of the three firms, and the entire team stands committed to a well engineered facility and successful demonstration of exhaust recirculation in Air Force paint hangars. In September 2003, the design-build contract was awarded to The Austin Company. At this time, design of the facility is in the initial stages. A subsequent report will describe the details of procurement, construction and performance qualification of the facility.

CONCLUSIONS

Air Force personnel have systematically secured a full set of approvals as required to satisfy all applicable requirements and to comply with all applicable regulations and standards during the development of a design and a procurement package for a large-aircraft painting hangar employing ER and ventilating along the flight axis of the plane. To ensure safety, design elements will be included to limit all categories of risk. As an example of exposure risk control, fail-safe interlocks to the paint guns will interrupt

delivery if detected vapor concentrations exceed preset limits or if the ventilation rate decreases significantly. To protect process capability, fan capacity will be so distributed that failure of a single unit will not decrease airflow below the minimum operating rate.

When the new hangar comes on line it will

- Provide optimum conditions for application and curing of spray coatings
- Reduce heat stress to workers during Georgia summers
- Create no detectable increase in exposure risk to workers
- Consume 80% less power during hot and cold weather than a conventional facility
- Comply with environmental and safety regulations

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18. *Standard for Spray Application Using Combustible or Flammable Materials*, NFPA 33, National Fire Protection Association, Quincy, Mass., 2000.
19. *Standard for the Recirculation of Air from Industrial Process Systems*, ANSI Z9.7-1998, American Industrial Hygiene Association, Fairfax, Virginia.
20. *The Defense Acquisition System*, DoDD 5000.1; *Defense Acquisition Policies and Procedures*, DoDI 5000.2, Service Correspondence and Directives Directorate, Washington, D.C., 2003.

KEYWORDS

Acquisition, Aircraft painting, CAIV, Chromate, C-5, *De Minimis* Violation, Exhaust Recirculation, Industrial Hygiene, Isocyanate, NFPA 33, Robins AFB, 29 CFR 1910.107(d)(9), 29 CFR 1910.1000.

APPENDIX A

OSHA Standard Interpretations:

*09/17/2001—Full compliance with NFPA 33-2000 may be considered
a de minimis violation*

06/24/2002—Hierarchy of controls for exposure to air contaminants



Standard Interpretations

09/17/2001 - Full compliance with NFPA 33-2000 may be considered a de minimis violation.

Standard Interpretations - Table of Contents

• **Standard Number:** 1910.107(d)(9)

September 17, 2001

Robert Trinkl, Corporate Safety Manager
Harley-Davidson Motor Company
3700 West Juneau Avenue
P.O. Box 653
Milwaukee, WI 53201

Dear Mr. Trinkl:

Thank you for your July 11 letter to Ann Williams, the Occupational Safety and Health Administration's (OSHA's) Assistant Regional Administrator for Region V. Your letter has been referred to the [Directorate of Enforcement Programs] for a response. This letter constitutes OSHA's interpretation only of the requirements discussed and may not be applicable to any situation not delineated within your original correspondence. You had a question about whether you could comply with National Fire Protection Association (NFPA) 33-1995 instead of 29 CFR 1910.107(d)(9). Our response to your paraphrased scenario and question is provided below.

Scenario: We are considering installing recirculated air systems in spray booths in a new plant. The systems would be designed to comply with NFPA 33-1995 requirements and would use approximately 80% recirculated air and 20% fresh air. Employees would wear appropriate protective clothing including positive-pressure, air-supplied hoods.

We have found four letters of interpretation on OSHA's web site which seem to pertain to this type of situation (October 16, 1987, Branstutter; November 3, 1989, Slavin; August 27, 1991, Ellis; and July 28, 1997, Karandikar). All four of these letters either allow the use of recirculated air (under specific conditions) or say that its use, in compliance with NFPA 33, would be considered a *de minimis* violation and would not be cited.

Question: Would the use of recirculated air as described above be considered a "*de minimis*" violation of 29 CFR 1910.107(d)(9)

Response: As you may know, NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, was updated in 2000. According to subsection 5.5.1 of NFPA 33-2000, "*air exhausted from spray areas shall not be recirculated.*" However, the standard does provide an exception if the recirculated air is, "*make-up air for an unmanned spray operation or cascaded to subsequent unmanned spray operations, provided all of the following conditions have been met:*

- a. Solid particulates have been removed from the recirculated air.

- b. The concentration of vapors in the exhaust airstream does not exceed 25 percent of the lower flammable limit.
- c. Listed equipment is used to monitor the concentration of vapors in all exhaust airstreams.
- d. An alarm will sound and the spray operation will automatically shut down if the concentration of any vapor in the exhaust airstream exceeds 25 percent of the lower flammable limit.
- e. Equipment installed to process and remove contaminants from the air exhausted from spray operations is approved by the authority having jurisdiction."

Also, subsection 5.5.2 allows, **"recirculated air to occupied spaces,"** including spray areas, spray booths, spray rooms, and other process areas, but states that, **"other requirements addressing the toxicity and the permissible exposure limits,"** such as ANSI Z9.7, **Recirculation of Air from Industrial Process Exhaust Systems**, will also apply. According to ANSI Z9.7, **"the potential for return of toxic contaminants to the facility through recirculation of industrial process air requires that this process be thoroughly analyzed and well-designed."** This ANSI standard also lists several other standards and information which you may wish to review.

De minimis violations are violations of existing OSHA standards which have no direct or immediate relationship to safety or health and result in no citation or penalty; they do not have to be abated. Under the current OSHA policy on **de minimis** violations, employers are allowed to comply with the most current consensus standards applicable to their operations, rather than with the OSHA standard in effect at the time of inspection, **when the employer's action provides equal or greater employee protection.** Therefore, pursuant to the policy for **de minimis** violations, employers that **fully** comply with NFPA 33-2000, Section 5.5, Recirculation of Exhaust, (including subsections 5.5.1 through 5.5.2), would not be cited under 1910.107(d)(9). Also, please note that the referenced letters of interpretation will be reviewed and updated or removed to reflect the current information.

Thank you for your interest in occupational safety and health. We hope you find this information helpful. OSHA requirements are set by statute, standards and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep appraised of such developments, you can consult OSHA's website at <http://www.osha.gov>. If you have any further questions, please feel free to contact the Office of General Industry Compliance Assistance at (202) 693-1850.

Sincerely,

Richard E. Fairfax, Director
[Directorate of Enforcement Programs]

cc: Regional Administrator, Region V

[Corrected 3/9/2004]



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Standard Interpretations

06/24/2002 - Hierarchy of controls for exposure to air contaminants.

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• **Standard Number:** 1910.1000; 1910.107(d)(9)

June 24, 2002

Robert Trinkl, Corporate Safety Manager
Harley-Davidson Motor Company
3700 West Juneau Avenue
P.O. Box 653
Milwaukee, WI 53201

Dear Mr. Trinkl:

Thank you for your October 4 letter to Richard Fairfax, Director of the Occupational Safety and Health Administration's (OSHA's) Directorate of Compliance Programs (DCP). This letter constitutes OSHA's interpretation only of the requirements discussed and may not be applicable to any question not delineated within your original correspondence. Your question is restated below, followed by our response.

Question: Can we use personal protective equipment (air-supplied hoods) to protect our employees from exposures in excess of OSHA PELs and/or toxic contaminants while working in recirculated air paint spray booths that meet the requirements stated in NFPA 33-2000?

Reply: Employers must use engineering or administrative controls to bring employee exposure to airborne contaminants within the levels permitted under 29 CFR 1910.1000. You may use personal protective equipment (PPE) to supplement engineering and administrative controls only when these controls cannot be feasibly implemented to reduce employee exposure to permissible levels. Thus, when it is not feasible to achieve compliance through administrative or engineering controls, you must also use PPE or other protective measures to prevent employee exposure to air contaminants from exceeding the prescribed limits.

Any personal protective equipment must be approved for the particular use by a qualified person. Also, whenever respirators are used, employers must comply with the provisions of 29 CFR 1910.134.

In your letter, you referenced the provisions of NFPA 33-2000, subsection 5.5, and implied that, by complying with these provisions, an employer can protect employees from exposure to unhealthy concentrations of air contaminants. In our first letter to you, (September 17, 2001) we addressed your question regarding compliance with NFPA 33-2000 instead of the spray finishing ventilation requirements of 29 CFR 1910.107(d)(9).

As we explained, both 1910.107(d)(9) and NFPA 33-2000, subsection 5.5 are designed to prevent fire and explosion hazards during spray finishing operations, not to protect employees from air contaminant exposures. As you may know, the Occupational Safety

and Health (OSH) Act requires that employers limit employee exposure to air contaminants in accordance with the provisions of 29 CFR 1910.1000.

Your July 11, 2001 letter to Ann Williams, the Occupational Safety and Health Administration's (OSHA's) Assistant Regional Administrator for Region V, also proposes the use of recirculated air (80% recirculated air and 20% fresh air) to protect employees in a spray booth from air contaminants. While it is questionable whether this method can reliably maintain employee air contaminant exposures at or below acceptable levels, 29 CFR 1910.1000 is a performance-based standard; it does not specify the engineering or administrative controls that an employer must implement to prevent exposures to unhealthy concentrations of air contaminants. For further assistance in this area, you may want to contact the nearest OSHA Area Office.

George Yoksas, Area Director
U.S. Department of Labor - OSHA
Henry S. Reuss Building
310 W. Wisconsin Ave, Suite 1180
Milwaukee, WI 53202
Phone: (414) 297-3315

Thank you for your interest in occupational safety and health. We hope you find this information helpful. OSHA requirements are set by statute, standards and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at <http://www.osha.gov>. If you have any further questions, please feel free to contact the [Office of General Industry Enforcement] at (202) 693-1850.

Sincerely,

Richard E. Fairfax, Director
Directorate of Compliance Programs

cc: Regional Administrator, Region 5

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Occupational Safety & Health Administration
200 Constitution Avenue, NW
Washington, DC 20210

APPENDIX B

11 March 2004 HQ AFCESA/CES interpretation that NFPA 33 does not require use of HEPA filters to recirculate exhaust air in ventilating systems that are not direct fired

From: Walker Fred NMI Jr Civ HQ AFCESA/CES
Sent: Thursday, March 11, 2004 5:08 PM
To: Thovson Jerry K Civ 778 CES/CECM; Walker Fred NMI Jr Civ HQ AFCESA/CES; Wander Joe D Civ AFRL/MLQL
Cc: Deaver William H III Civ 778 CES/CECM
Subject: RE: HEPA Filters Issue (Paint/Depaint Hangars, UHHZ 003011/003014)

NESHAP compliant 3-stage filters are considered adequate to meet NFPA requirements for recirculation of air through in-direct fired heating units.

Fred Walker

USAF Chief Fire Engineer
HQ AFCESA/CESM
139 Barnes Drive - Suite 1, Tyndall AFB, FL 32403-5319
PH (850) 283-6315 DSN 523-6315
FAX (850) 283-6219 DSN 523-6219
Internet: fred.walker@tyndall.af.mil

Download the new Criteria Guidance UFC 3-600-01 (MilHDBK 10081D) at:
http://www.lantdiv.navy.mil/pls/lantdiv/docs/folder/EICO/UFC_CMS/3_600_01.pdf
Visit the Air Force Civil Engineer Support Agency Home Page at:
<http://www.afcesa.af.mil>.
Visit the public Air Force Fire Protection Engineering Web site at:
<http://www.afcesa.af.mil/Directorate/CES/Mechanical/FireEngr/default.htm>

-----Original Message-----

From: Thovson Jerry K Civ 778 CES/CECM [mailto:Jerry.Thovson@robins.af.mil]
Sent: Thursday, March 11, 2004 12:47 PM
To: Walker Fred Civ HQ AFCESA/CES; Wander Joe D Civ AFRL/MLQL
Cc: Deaver William H III Civ 778 CES/CECM
Subject: HEPA Filters Issue (Paint/Depaint Hangars, UHHZ 003011/003014)

Fred/Joe,

I need an answer by Friday, 19 March, on this issue. We have done our best in our earlier e-mails to explain how the additional data from the paint spray tests has reduced the amount of fine particles that could only be captured by the HEPA filters. Our conclusion is that we can reduce the particulates to a safe level from a fire safety standpoint with the NESHAP-compliant 3-stage filters and would like your concurrence on deleting the HEPA filter requirement. You are the only one who has not concurred with this recommendation and we need to know what to tell the contractor by the 23rd of March.

Please call if you need to discuss this further with me.

Thanks,

Jerry Thovson
778CES/CECM
478-926-8840

APPENDIX C

Design Guidance Document from Warner Robins Air Logistics Center

7 May 2003

Air Recirculation in Paint Hangars:

*UHHZ 003011, Construct Large Aircraft Aircraft Corrosion Control Paint Hangar,
Building 59, Warner Robins Air Logistics Center (WR-ALC), Robins AFB GA*

7 May 2003

AIR RECIRCULATION IN PAINT HANGARS

UHHZ 003011, CONSTRUCT LARGE AIRCRAFT CORROSION CONTROL PAINT
HANGAR, BUILDING 59, WARNER ROBINS AIR LOGISTICS CENTER (WR-ALC),
ROBINS AFB GA

1. PLAN FOR COMPLIANCE

- a. Based on the discussion and analysis below, the RFP shall require: "Provide air recirculation and environmental monitoring in compliance with 29 CFR 1910.107(d)(9) and OSHA Formal Interpretation Letter, dated 6/24/2002, entitled "Hierarchy of controls for exposure to air contaminants;" and with engineering controls to comply with 29 CFR 1910.1000. Engineering controls include all areas such as the filter wall, uniform airflow, air monitoring (for organic and aerosol particles in addition to Lower Explosive Limit (LEL) monitoring required by 29 CFR 1910.107(d)(9)), and access to aircraft surfaces. Provide cooling for at least 30% outside air (initial operation will be 20% outside air with backup for the single largest unit). Air handlers shall ensure outside air remains evenly mixed with recirculated air. For example, if air handlers are placed on both sides of the dock, then each side must have a backup for the single largest section. Worker and workplace exposure levels shall be checked during acceptance testing at 80% recirculation, and adjustments to heating, ventilation and process cooling (HVPC) control sequences shall be made based on those results. Acceptance criteria for chemicals of concern as measured at the painters' breathing zones during routine painting of an aircraft are: equal or less than current concentrations of 600x the occupational exposure level (OEL) for strontium chromate, and less than the OEL for isocyanates and any volatile organic chemicals (VOCs). This would be regardless of use of PPE."
- b. Continued compliance shall be accomplished by continuous air monitoring of the recirculated air and annual worker exposure tests.

2. SUMMARY OF ISSUES

- a. Worker exposure is covered under 29 CFR 1910.1000 on "Air Contaminants". WR-ALC is providing engineering and administrative controls first, and using PPE as necessary to comply with 29 CFR 1910.1000(a) – (d). PPE is required to comply with standards based on exposure monitoring in the current non-recirculating air hangar (building 54). The new system does not introduce any new PPE requirement.
- b. Rules regarding air recirculation are covered under 29 CFR 1910.107(d)(9) on "Spray finishing using flammable and combustible materials." Per OSHA Formal Interpretation Letter, dated 6/24/2002, entitled "Hierarchy of controls for exposure to air contaminants", this requirement is designed to prevent explosion/fire hazards, not personnel hazards.

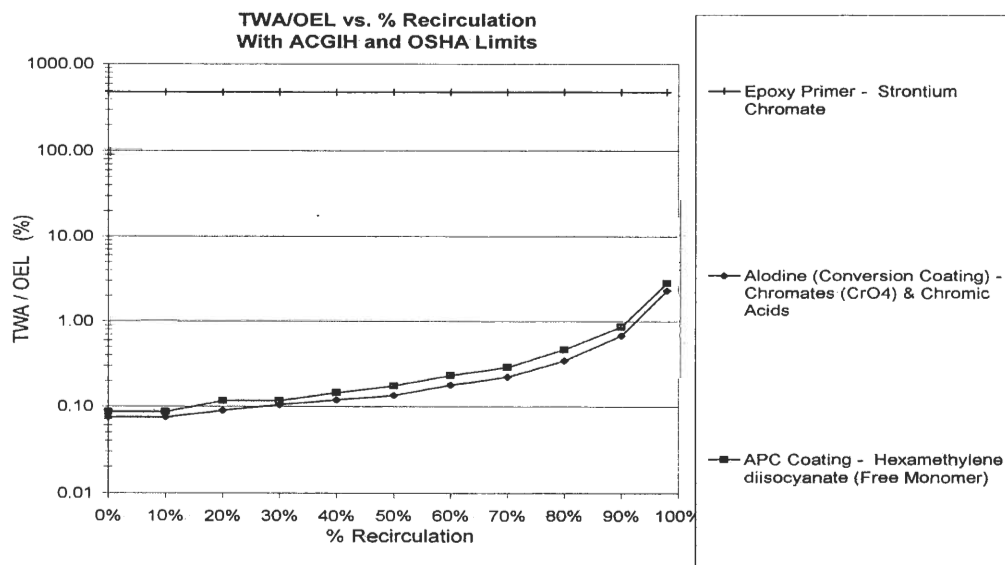
- c. Other issues include environmental protection, energy conservation and heat stress. WR-ALC believes that we are in compliance with applicable regulations and executive orders for these issues with air recirculation, while meeting exposure and safety standards, as discussed below.
- d. The Base Bioenvironmental Engineering Office (78MDG/SGPB) has been, and will continue to be, directly involved in the planning, design, construction and operation of the paint hangar. As discussed below, the information in this document indicates that the Base is in compliance with respect to standards for worker exposure.

3. 29 CFR 1910.1000: AIR CONTAMINANTS

- a. 29 CFR 1910.1000(e) states, "To achieve compliance with paragraphs (a) through (d) of this section, administrative or engineering controls must first be determined and implemented whenever feasible. When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposure of employees to air contaminants within the limits prescribed in this section." WR-ALC believes that we are in compliance with paragraphs (a) – (d) by ensuring that workers are not exposed above the ceiling values, 8-hour time-weighted-average values or acceptable ceiling concentrations (as applicable under Tables Z-1, Z-2 or Z-3), including the computation formula for workers exposed to more than one substance. WR-ALC is providing engineering and administrative controls first, and then using personal protective equipment where such controls are not feasible to achieve full compliance.
- b. The two chemicals that have been identified to be of concern are strontium chromate and isocyanates. Present engineering and administrative controls in building 54 (with 100% outside air) reduce the measured 8-hour time-weighted-average exposure for strontium chromate to between 500 and 600x the OEL of 0.0005mg/m³ (ACGIH Threshold Limit Value, which is more stringent than OSHA, but is an Air Force requirement per AFOSH Std 48-8, Controlling Exposures to Hazardous Materials). Per 29 CFR 1910.1000(e), personal protective equipment is then used to reduce the exposure to less than the OEL. Present engineering and administrative controls in building 54 (with 100% outside air) reduce the measured 8-hour time-weighted-average exposure for isocyanates to less than 0.25x the OEL of 0.034mg/m³. The use of PPE provides increased worker protection from potential isocyanate exposure.
- c. These readings have held consistent for the 5 years that C-5 aircraft have been painted in building 54 (FY1998 – FY2002 inclusive). There is no pay differential for hazardous duty for the workers in building 54 since worker exposure is being controlled through a combination of engineering controls and PPE. Annual occupational exams are provided for workers to assess their exposures to isocyanate and chromate. Also, there have been no medical symptoms reported associated with either chromate or isocyanate exposure.
- d. One tool for evaluating the impact of air recirculation on these readings is to use software modeling. This provides data to make an informed decision on air recirculation. An exposure modeling program, developed by Lt Col Peter LaPuma, USAF, BSC, PhD, PE, conservatively predicts what concentration levels might be expected for a variety of chemicals (solids, liquids and gases) under differing levels of air recirculation.
- e. The predictions of the LaPuma model provide conservative estimates of concentration levels within an enclosure. Care must be taken, however, because the model is susceptible to error

when assumptions that contain inaccuracies are input for calculating its estimates. For example, the initial assumptions used by the RFP consultant and Robins AFB for the existing operation in building 54 resulted in estimated exposure concentration levels 2000x the OEL for strontium chromate – an estimate that was clearly contrary to the actual measured exposure concentrations in building 54, as set forth in subparagraph 3b, above. Accordingly, the Base reviewed the inputs into the model and determined that the amount of strontium chromate in the overspray should be reduced because the overspray (which has a particle size of 0.5 – 1.5 microns) contained less strontium chromate (which has a particle size of 1 – 8 microns) than was in the bulk of the paint spray that was impacting the planes; and the amount of HDI monomer that did not react with the polyurethane was less than 1% of the unmixed component amount. After adjusting the input to the model to reflect these actual circumstances, the model demonstrated that it could provide an estimate that agrees with the actual measured exposure concentration levels in building 54.

- f. The RFP consultant then reported to the government that their calculations for the new hangar indicated a concentration of over 1000x the OEL for strontium chromate even with 100% outside air, which is worse than building 54. Based on similarities with building 54 (same aircraft, same application rate of primer, same work practices), we determined that similar refinements to the model assumptions were sufficiently supported. WR-ALC anticipates no significant change to worker exposures with a recirculating air hangar design: 500x the OEL for strontium chromate and 0.46x the OEL for isocyanates at 80% recirculation.



- g. Accurate modeling of airborne solids, with or without air recirculation, requires precise information on paint application efficiency, overall particle sizes, strontium chromate particle sizes, and (for air recirculation) filter efficiencies within those particle sizes. AFIERA is presently testing the particular primer/application equipment being used on the C-5 to determine the particle size distribution, which will help refine the model. Large particle sizes (2 microns

and larger) are more likely to adhere to the aircraft and are more efficiently removed by the filters. The standard for high-efficiency filters is 99.97% of 0.3-micron particles.

- h. 29 CFR 1910.1000, per Formal Interpretation Letter, dated 6/24/2002, entitled "Hierarchy of controls for exposure to air contaminants", states "29 CFR 1910.1000 is a performance-based standard; it does not specify the engineering or administrative controls that an employer must implement to prevent exposures to unhealthy concentrations of air contaminants." Also, OSHA Field Operation Manual, OSHA Instruction CPL 2.45B CH-4, dated December 13, 1993, states in paragraph 6(a)(2) that a de minimis violation occurs when, "An employer complies with a proposed standard or amendment or a consensus standard rather than with the standard in effect at the time of the inspection and the employer's action clearly provides equal or greater employee protection or the employer complies with a written interpretation issued by the OSHA Regional or National Office."
- i. The new hangar will have the following engineering controls:
 - i. Electrostatic paint guns, which are better than 70% efficient, meaning there is less than 30% overspray.
 - ii. A larger volume and more uniform airflow compared to building 54, which will improve the dilution ratio, which reduces contaminant concentration.
 - iii. Backup air handlers to ensure rated air flow (60 fpm average, 50 fpm minimum) even with one air handler out of service. All other critical systems will have similar redundancy.
 - iv. Emergency generator to power telescoping manlifts to ensure safe egress on loss of power.
 - v. A separate large-item paint booth to eliminate painting two objects in the hangar at the same time.
 - vi. More efficient access to the aircraft, minimizing exposure times.
 - vii. Automatic shutdown of the paint spray guns in the event of any of the following: loss of power, loss of breathing air, insufficient airflow, or high pressure drop through filters. Any of these, apart from loss of power, will also result in shutting off the recirculation fans and using only the outside and exhaust air fans.
 - viii. Recirculated air shall be continually monitored and the monitoring system shall shut off paint operations should an unacceptable level of air contaminants be detected. Recirculated air will be shut off, and the outside/exhaust will continue operating to reduce the level of contaminants until the source of the alarm is determined and corrected. This includes volatile organic compounds or solvents also found in the paints, such as xylene and butyl acetate, not just strontium chromate and isocyanates. The Base Bioenvironmental Engineer will establish the alarm and shutdown levels.

- j. The new paint hangar will have the following administrative controls:
 - i. Workers have been and will continue to simultaneously paint and move in the direction of the exhaust filter wall. This serves to eliminate or reduce overspray exposures from other workers.
 - ii. Loss of breathing air incorporates automatic shut down of paint gun apparatus and activation of the evacuation alarm. Remaining air in the compressed air system is bled out and supplied to the workers until they reach the furthest extent of the airline and then disconnect the airline. At that point, workers will use Organic Vapor (OV)/P100 emergency egress filter cartridges, which calculations indicate will protect the workers the 10 minutes necessary to completely exit the hangar. Workers presently, and in the new hangar, will egress upwind out of the heaviest contaminated air.
 - iii. Annual personnel tests will continue to be made to ensure proper PPE.
- 4. 29 CFR 1910.107(d)(9): “Both 1910.107(d)(9) and NFPA 33-2000, subsection 5.5 are designed to prevent fire and explosion hazards during spray finishing operations, not to protect employees from air contaminant exposures.”
 - a. OSHA 1910.107(d)(9) states, “Air exhausted from spray operations shall not be recirculated.” However, OSHA Formal Interpretation Letter, dated 6/24/2002, entitled “Hierarchy of controls for exposure to air contaminants”, states “both 1910.107(d)(9) and NFPA 33-2000, subsection 5.5 are designed to prevent fire and explosion hazards during spray finishing operations, not to protect employees from air contaminant exposures.” OSHA Formal Interpretation Letter, dated 9/17/2001, entitled “Full compliance with NFPA 33-2000 may be considered a de minimis violation”, states, “Under the current OSHA policy on de minimis violations, employers are allowed to comply with the most current consensus standards applicable to their operations, rather than with the OSHA standard in effect at the time of inspection, when the employer’s action provides equal or greater employee protection. Therefore, pursuant to the policy for de minimis violations, employers that fully comply with NFPA 33-2000, Section 5.5, Recirculation of Exhaust (including subsections 5.5.1 through 5.5.2), would not be cited under 1910.107(d)(9).” WR-ALC is putting good faith reliance upon the foregoing interpretations to the extent that they deal with whether a recirculating system may be used, and the standards for employee protection.
 - b. NFPA 33-2000, paragraph 5.5.2 states, “The provisions of 5.5.1 shall not disallow the use of recirculated air to occupied spaces.” Paragraph 5.5.1 allows air recirculation as an exception: “Exception: Air exhausted from a spray operation shall be permitted to be recirculated provided all of the following conditions have been met:
 - i. Solid particles have been removed from the recirculated air.
 - ii. The concentrations of vapors in the exhaust airstream do not exceed 25% of the lower flammable limit.
 - iii. Listed equipment is used to monitor the concentration of vapors in all exhaust air streams.

- iv. An alarm will sound and the spray operation will automatically shut down if the concentration of any vapor in the exhaust stream exceeds 25% of the lower flammable limit.
 - v. Equipment installed to process and remove contaminants from the air exhausted for spray operations is approved by the authority having jurisdiction.”
- c. The new paint hangar will meet all the conditions of NFPA 33-2000, paragraph 5.5.1 (Exception) by:
 - i. Removal of 99.97% of solid particles 0.3 µm in size (larger particles are removed at a higher efficiency). AFIERA is doing tests now to determine particle size distributions so the project can provide proper filtration.
 - ii. The concentrations of vapors are not calculated to exceed 2% of the lower flammable limit (VOCs) based on the LaPuma program.
 - iii. A recognized testing laboratory, such as Underwriters Laboratories, will list the monitoring system.
 - iv. The monitoring system will include a trigger point to shut down spray operations if the concentration exceeds a safe level as determined by the base fire department, which will be less than 25% of the lower flammable limit. (Additional setpoints will trigger this shutdown at lower concentrations to meet ANSI Z9.7 and OSHA 1910.1000.)
 - v. The authority having jurisdiction (Base Fire Marshall or his deputy) will approve particulate filters for fire safety under this NFPA standard. No other equipment is anticipated.
- d. OSHA Formal Interpretation Letter, dated 9/17/2001, also states, “subsection 5.5.2 allows ‘recirculated air to occupied spaces,’ including spray areas, spray booths, spray rooms, and other process areas.” This letter also quotes ANSI Z9.7, “the potential for return of toxic contaminants to the facility through recirculation of industrial process air requires that this process be thoroughly analyzed and well-designed.” The process has been thoroughly analyzed, and WR-ALC will ensure that the design and construction meet our analysis.
- e. OSHA Formal Interpretation Letters, including the two cited above, state: “This letter constitutes OSHA's interpretation only of the requirements discussed and may not be applicable to any question not delineated within [the] original correspondence.” WR-ALC has considered the applicability of both the question and the response of these Formal Interpretation Letters. We believe that the proposed project falls clearly within the situations delineated in the Formal Interpretation Letters, because the letters indicate that recirculation systems may be used and under what conditions. We have analyzed our situation and are confident that the proposed project can comply with these requirements.

5. OTHER CONSIDERATIONS

- a. While compliance with the two standards above is necessary, there are other considerations to be made regarding air recirculation.
- b. OSHA does not specifically address heat stress issues as a substance-specific standard. However, OSHA's Technical Manual, Section III, Chapter 4, paragraph I(b)(1) notes, "The American Conference of Governmental Industrial Hygienists (1992) states that workers should not be permitted to work when their deep body temperature exceeds 38°C (100.4°F)." Paragraph 5(c) gives several engineering controls, including air conditioning, but it notes "Air conditioning is a method of air cooling, but it is expensive to install and operate." Providing cooling allows enhanced work/rest cycles.
- c. Executive Order 13123 requires "Section 203. Industrial and Laboratory Facilities. Through life-cycle cost-effective measures, each agency shall reduce energy consumption per square foot, per unit of production, or per other unit as applicable by 20 percent by 2005 and 25 percent by 2010 relative to 1990. No facilities will be exempt from these goals unless they meet new criteria for exemptions, as issued by DOE." Air recirculation will reduce total facility energy consumption by approximately 30%, save natural resources and reduce the emission of greenhouse gases.
- d. The project VOC limits under the Clean Air Act is presently 40 tons per year. The projected production level is 22.5 tons per year. If these limits change in the future, or if production levels change, the WR-ALC will need to review how to resolve these issues. Air recirculation allows more flexibility in designing to resolve these issues.
- e. After ensuring personnel exposure and fire safety, and in addition to the above benefits, air recirculation at the anticipated 80% level has lower first costs; lower operating costs, and less maintenance than a 100% outside air system.
 - i. First costs estimated at \$2,500,000 are about 1/3 of the cost of a 100% outside air system estimated at \$7,000,000. This includes an estimated \$50,000 for the air monitoring system for the recirculated air system.
 - ii. Operating costs estimated at \$200,000/year are about 1/5 of the cost of a 100% outside air system, estimated at \$1,000,000/year.
 - iii. Maintenance costs estimated at \$350,000/year are about 25% less than the cost for a 100% outside air system estimated at \$500,000/year. This is due to 50% less total mechanical equipment (chillers, air handlers, fans, cooling towers, and controls). This includes an additional \$5,000/year to maintain the air monitoring system for recirculated air. This building and its systems will receive full preventive/predictive maintenance.
 - iv. An additional benefit is that the paint system will be more effectively applied, reducing the amount of rework. This will indirectly reduce worker exposures, because less paint will need to be applied to the aircraft.

- End of Document -

APPENDIX D

Air Quality Specialists Report to The Austin Company

19 April 2005:

*Recirculation Ventilation Assessment for the Robins Air Force Base
Aircraft Paint Hangar and Paint Booth*

FINAL REPORT

RECIRCULATION VENTILATION ASSESSMENT FOR THE ROBINS AIR FORCE BASE AIRCRAFT PAINT HANGAR AND PAINT BOOTH

Submitted by:

**Air Quality Specialists
4533 MacArthur Blvd., #564
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Submitted to:

**The Austin Company
55 Waugh Drive
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Prepared by:

**Jacqueline Ayer
Director, Engineering Operations**

April 19, 2005

Robins Air Force Base intends to construct a new aircraft paint hangar and a smaller paint spray booth, and has contracted with The Austin Company (Austin) to complete the installation. Robins AFB has requested that a recirculation ventilation system be installed in both the hangar and the spray booth in an effort to reduce utility costs associated with their operation. Air Quality Specialists (AQS) was retained by Austin to conduct a recirculation assessment in order to ensure that a safe and efficient recirculation system is developed. The results of this assessment are summarized herein, along with the various assumptions upon which assessment was based. AQS has prepared this recirculation ventilation assessment in accordance with the information provided by Austin and Air Force staff members.

RECIRCULATION SYSTEM ENGINEERING PARAMETERS

Austin provided AQS with the basic engineering parameters for the hangar and the booth (summarized in Table 1), and requested that AQS evaluate the applicability of an 80% recirculation rate.

Table 1. Robins Hangar and Booth Engineering Design Parameters

Parameter	Hangar	Spray Booth
Total Flow rate	1,080,000 cfm	103,500 cfm
Coating application system	Electrostatic	Electrostatic
Maximum primer usage	120 gal per 3 hr paint cycle	8 gal per 1 hr paint cycle
Maximum topcoat usage	135 gal per 4 hr paint cycle	12 gal per 2 hr paint cycle
Maximum APC usage	225 gal per 7 hr paint cycle;	12 gal per 2 hr paint cycle

AQS developed a mathematical model to project constituent concentrations in the hangar and the spray booth based on the engineering parameters provided. The model considers only worst-case (highest concentration) scenarios by assuming steady-state conditions in which the maximum coating usage rate is applied. In addition, recent material safety data sheet information (MSDS) was obtained from coating manufacturers to ensure that all compounds are appropriately identified; the component mix ratios recommended by the manufacturer were also employed.

RECIRCULATION MODEL DESCRIPTION

The recirculation model developed for this project employs coating usage rates, material safety data sheet (MSDS) information, coating mix ratio data, and booth airflow parameters to calculate concentrations of solid-phase and vapor-phase constituents that are released via electrostatic spray application in the enclosure. Various recirculation rates are then imposed on this baseline constituent data to predict the concentrations introduced into the intake stream after the recirculated air is mixed with fresh make-up air. The model considers solid-phase constituent concentration reductions that occur due to electrostatic spray gun transfer, overspray drop-out, and filtration. The predicted concentrations are then reconciled with their respective threshold limit values (TLVs) or permissible exposure levels (PELs) and summed to project the intake air quality. The summed value, referred to herein as the OSHA Factor, is not related to worker exposure, and it does not in any way predict worker exposure. Rather, it is a parametric tool for ascertaining the quality of the intake air provided to the paint enclosure. Indeed, numerous studies have conclusively demonstrated that worker exposure levels are a function of the spray coating operation itself, and are significantly impacted by air flow direction, target configuration, spray pattern and worker expertise. Previous recirculation ventilation

assessments using this modeling approach have demonstrated that there is no correlation between constituent concentrations measured in recirculation system intake air and worker exposure. These studies have considered both urethane topcoat and chromate primer applications with the same result.

MODELING ASSUMPTIONS

The recirculation modeling results were developed based on the following assumptions:

1. The electrostatic spray system transfer efficiency is 75%, and the overspray dropout efficiency is 22%. (This value is typically used by regulatory agency staff in estimating emissions from large aircraft paint operations).
2. The recirculated air is relatively well mixed with the fresh make-up air.
3. Complete evaporation of all the volatile constituents occurs instantaneously; no reaction or deposition occurs to remove the volatiles from the process air. This assumption overestimates vapor-phase concentrations (particularly semi-volatile constituents), and therefore ensures conservative results.
4. A filtration efficiency of 99.94% is applied to all solid phase constituents in the primer, APC, and topcoat materials, including polymeric isocyanate, dibutyltin dilaurate, and strontium chromate. This filtration efficiency was derived based on electrostatic spray gun particulate size distribution data reconciled with ATI filter system operating data obtained from EPA Method 319 test results. For further information on how this filtration efficiency was derived, please see Appendix A.
5. Hexamethylenediisocyanate is present in both the urethane topcoat and the APC coat employed at Robins AFB. Aerospace topcoat manufacturers typically employ pre-polymerized isocyanates in urethane formulations because their use slows the polymerization process sufficiently to achieve a high quality finish. In the polymer form, isocyanates are considered non-volatile, and are filtered out (removed) from the exhaust stream prior to recirculation. However, residual quantities of isocyanate monomer do occur in aerospace urethanes. Isocyanate monomer is considered highly toxic, and because it is in the vapor phase, it cannot be removed via filtration. Therefore, the recirculation system designed for Robins' topcoat operations must anticipate and adequately address the presence of monomeric isocyanate in the recirculated stream. There is ongoing and extensive debate regarding the quantity of monomer that is actually present in a typical aerospace topcoat process. At the heart of the debate is the fact that monomeric isocyanate is highly reactive, and the concentration will vary simply by exposure to ambient moisture. This, coupled with uncertainties in the quantity of monomer initially present in the catalyst component, and the quantity remaining after mixing with the base component, places a clear and definitive answer to the monomer question beyond the scope of this project. Instead, the recirculation model developed for this project relies on breathing zone isocyanate monomer concentration data collected by Robins Bio-Environmental Engineering staff as follows:

- A) According to data provided by Robins staff, current administrative and engineering controls (i.e. no recirculation) reduce breathing zone isocyanate monomer concentrations below 25% of the AFOSH TLV of 0.035 mg/m^3 (or 0.00875 mg/m^3).

- B) The model assumes that this measured value represents the monomer concentration throughout the entire cone-shaped spray volume which envelops the painter.
 - C) By reconciling the maximum projected diameter of the cone-shaped space with the measured concentration, the number of painters, and the cross-sectional area of the spray enclosure, the model yields a conservative estimate of the average monomeric concentration in the exhaust stream under no recirculation conditions.
 - D) The model then imposes a 0% recirculation condition on each topcoat application scenario, and uses the concentration value developed in step C to derive an adjustment factor which uniquely defines the coating monomer content for each scenario (e.g. APC coating in the spray booth; urethane topcoat application in the hangar, etc.).
 - E) The model then applies the unique adjustment factors developed in step D to project the monomer concentration in the ventilation air that is introduced into the enclosure under various percent recirculation profiles. Recirculation results are considered acceptable only if the recirculation profile yields a monomer concentration that is well below the 0.00875 mg/m^3 value reported in Step A.
6. It is understood that the recirculation system designed for Robins' painting operations must pose no additional exposure risk to facility operators beyond the inherent exposure generated by the coating operation itself. Present engineering and administrative controls in Robins primer operations (with no recirculation) reduce the hexavalent chrome (Cr^{+6}) concentration in the painter breathing zone to 600 times the AFOSH TLV of 0.0005 mg/m^3 (or 0.3 mg/m^3). Thus, it must be demonstrated that recirculation ventilation will maintain intake air Cr^{+6} concentrations significantly below these measured levels. The model is configured to specifically address this Cr^{+6} issue; it reconciles primer chrome content data with air flow characteristics and the transfer, dropout, and filtration efficiencies described above to predict the resulting Cr^{+6} concentration in the recirculated stream. The Cr^{+6} result is then directly compared to the measured results to demonstrate adequate operation. In addition, the model addresses other primer constituents, and predicts their concentrations in the recirculated stream to adequately assess the intake air quality.
7. There were some poorly identified compounds in the MSDS data (such as anti-mar and float agents). In some cases, CAS numbers or exposure limits are identified, in other cases they are not. Per instructions from Robins staff, the constituents for which no limits or CAS numbers are specified are presumed to be non-hazardous, and are not included in the OSHA Factor results.

Detailed spreadsheet results for the APC coat, urethane topcoat, and primer recirculation assessments are provided in Appendix B, and summarized in Tables 2 and 3. The spreadsheets provide OSHA Factor results for various operating conditions, and are discussed in more detail below.

Table 2. Recirculation Assessment Results for Hangar and Paint Booth

Coating Operation	Parameter	Hangar 80% Recirculation	Booth 80% Recirculation
APC Coating	OSHA Factor results throughout paint cycle	0.66	1.32
Urethane Topcoat	OSHA Factor results throughout paint cycle	0.692	1.41
Primer	Non-Chrome OSHA Factor	0.397	0.829
	Measured breathing zone Cr ⁺⁶ concentration with existing (non-recirculating) engineering and administrative controls and	0.300 mg/m ³	0.300 mg/m ³
	Recirculation air Cr+6 concentration	0.00225 mg/m ³	0.00469 mg/m ³
	Reduction factor	133	64

Table 3. Cumulative OSHA Factor Results (averaged over entire shift)

Coating Operation	Hangar with 80% Recirculation	Booth with 80% Recirculation
APC Coating	0.577	0.330
Urethane Topcoat	0.346	0.353
Primer (non-chrome)	0.149	0.104

DISCUSSION OF RESULTS

The assessment was performed for 80% recirculation in the hangar and the spray booth. The spreadsheet results also report constituent concentrations in the exhaust air upstream of the exhaust filters. Table 2 summarizes the OSHA Factor results obtained for just the duration of the paint cycle; if an entire 8 hour work cycle is assumed, then the OSHA Factor results are reduced to the values indicated in Table 3. Because they consider an entire 8 hour work cycle, the Table 3 results are more applicable in determining ambient conditions presented by intake air constituent concentrations. In accordance with standard health and safety assessment procedures, an OSHA Factor that is well below 1.0 is indicative of an acceptable ambient work environment. For the APC coat and the urethane topcoat operations, the model projects ambient operating conditions that are well below threshold health and safety levels, as indicated in Table 3. The same is true for the primer application when non-chrome compounds are considered.

Using existing administrative and engineering controls (and without recirculation), the breathing zone Cr^{+6} concentrations cannot be brought below the applicable AFOSH standard, and in fact exceed the standard by a factor of 600. Given this circumstance, it follows that the recirculation system design must ensure that breathing zone Cr^{+6} levels are not increased. The model was configured to project ambient Cr^{+6} concentrations; hangar and paint booth results indicate that ambient Cr^{+6} levels are 135 and 85 times lower than the measured values. In other words, these results indicate that the proposed recirculation rates will not have a discernible impact on measured breathing zone concentrations.

The OSHA Factor and ambient Cr^{+6} concentration results conclusively demonstrate that the proposed recirculation rates will not increase worker exposure beyond that presented by existing engineering and administrative controls in which recirculation is not considered.

APPENDIX A

FILTRATION EFFICIENCY DERIVATION FOR USE IN ROBINS AFB RECIRCULATION ASSESSMENT

APPENDIX A

FILTRATION EFFICIENCY DERIVATION FOR USE IN ROBINS AFB PAINT BOOTH AND HANGAR RECIRCULATION ASSESSMENT

To ensure the proper design of a recirculating ventilation system, it is of primary importance to accurately establish the particulate removal efficiency of the filtration system that will be installed. The paint hangar and paint booth planned for installation at Robins AFB will apply coatings using an electrostatic spray system. As indicated in the body of the report, the presence of hexavalent chromium in the primer and isocyanate polymers in the topcoats could impose significant constraints on the recirculation system design if they are not adequately removed via filtration. The recirculation design described herein relies on a three-stage filter system manufactured by Air Technology, Inc. (ATI) to achieve an adequate level of filtration. However, an overall filtration efficiency must be derived for the ATI system as it applies to reducing electrostatic system overspray particulate. The overall filtration efficiency that is derived can then be applied to the recirculation model discussed in the report. The following procedure was employed to derive the particulate removal efficiency for the ATI three-stage system:

1. Using the Proposed EPA Method 319 test results obtained from the filter manufacturer, ascertain the removal efficiency achieved for each particulate size range established by the test method.
2. Identify the appropriate particle size distribution data set for the specific coating material and spray application system that is used. The data should be arranged such that, for each size range, the cumulative mass fraction percentage in that size range is reported.
3. Multiply the cumulative mass percent within each size range (from step 2) by the filtration efficiency achieved within each size range by the filter system (from step 1).
4. Add together each of the multiplied results from step 3 to determine the overall filtration efficiency¹

This analysis was performed using a rather limited size distribution data set obtained for electrostatic spray coating operations provided by Dr. Joe Wander. These data were reconciled with Method 319 test results provided by ATI for their Aerospace 3000 3-stage filter product line to derive an overall filtration efficiency for the electrostatic spray operation. The results of this analysis are presented in Table A-1. It is understood that more detailed size distribution data may exist, however access to this information is rather limited. Other size distribution data could be employed in future analyses when such information is made available.

¹ By using the cumulative mass fraction data rather than the number density data, a representative mass-based filtration efficiency value is obtained. This is important, because the OSHA PEL values that are employed are based on mass of compound per unit volume

TABLE A-1. DETERMINATION OF APPROPRIATE FILTRATION EFFICIENCY FOR RECIRCULATION ASSESSMENT

SEM Electrostatic Spray Operation Particle Size Distribution Data (Data provided by Dr. Joe Wander, Tyndall AFB)

Data set	Particulate Diameter Size Ranges (microns)															
	1	2	3	4	6	8	10	12	16	20	25	30	35	40	50	70
	Cumulative Mass Fraction Within Each Size Range															
Topcoat 1	0.14	1.12	2.82	6.01	8.87	14.53	21	29.38	43.73	58.46	77.65	86.98	95.2	100	100	100
Topcoat 2	0	0.67	1.62	3.27	7.9	14.02	20.8	28.3	48.27	52.32	59.61	70.63	82.3	92.26	100	100
Topcoat 3	0	0.27	0.84	1.86	4.31	9.66	15.02	29.64	50.76	61.74	76.03	82.98	89.11	96.43	100	100
Topcoat 4	0.01	0.33	1.3	1.81	4.98	8.97	12	21.15	45.54	70.23	77.21	80.03	85.78	90.55	92.41	100

ATI Aerospace 3000 Method 319 Filtration Efficiency Test Results

Solid phase	90%	96%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Liquid phase	79%	96%	99.5%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Using the solid phase results will yield the most conservative numbers

DETERMINE OVERALL EFFICIENCY FOR TOPCOAT OPERATIONS

Using Solid Phase test Results

Combining filtration efficiency with topcoat size distribution data and using the averaged size distribution data reconciled with the solid phase Method 315 results to yield the most conservative overall efficiency

0.14% of mass has	89.6% efficiency
0.5% of mass has	96.0% efficiency
1.05% of mass has	98.5% efficiency
1.59% of mass has	99.0% efficiency
96.76% of mass has	100.0% efficiency

Overall efficiency based on ATI solid phase results: 99.94%

Using Liquid Phase test Results

Combining filtration efficiency with topcoat size distribution data and using the averaged size distribution data reconciled with the liquid phase Method 315 results to yield the most conservative overall efficiency

0.14% of mass has	79.2% efficiency
0.5% of mass has	96.0% efficiency
1.0% of mass has	99.5% efficiency
98.4% of mass has	100.0% efficiency

Overall efficiency based on ATI liquid phase results: 99.95%

NO SEM DATA ARE AVAILABLE FOR PRIMER OPERATIONS, THUS NO ANALYSIS WAS DONE

APPENDIX B

PAINT HANGAR AND SPRAY BOOTH SPREADSHEET RESULTS OF RECIRCULATION ASSESSMENT

PAINT HANGAR RESULTS

Filename: Primer recirculation for Hangar
October 25, 2004 8:11 PM

MSDS Information from DEFT; usage/duty cycle data from Austin data package

Painter operates: 3 hours/shift 1080000 cfm
Shift interval: 8 hours 64800000 cfm
Coating usage rate: 120 gal/cycle 1835136 m3/hr
40.00 gal/hr
460.80 lb/hr

Component 02Y040A Catalyst 1
Mix ratio (volume basis) 3 1
Density (lb/gallon) 12.68 8.04
11.52 as applied

NON-CHROME COMPONENTS

Components	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	PEL/TWA ppm	80% recirculation mg/m3	OSHA Factor
Methyl n-amyl ketone	0.4755	19.02	4.711	50	237	18.84
4-Chlorobenzotrifluoride	0.4755	19.02	4.711	NI	NI	18.84
2-Chlorobenzotrifluoride	0.0095	0.38	0.094	NI	NI	0.38
n-Butyl acetate	0.4755	19.02	4.711	150	723	18.84
Methyl n-propyl ketone	1.4265	57.060	14.133	200	715	56.53
Methyl isobutyl ketone	0.0951	3.804	0.942	50	208	3.77
Aromatic hydrocarbons	0.1100	4.40	1.090	100	441	4.36
n-Butyl alcohol	0.2010	8.040	1.991	20	62	7.97
1,2,4-Trimethylbenzene	0.1005	4.02	0.996	25	125	3.98
1,3,5-Trimethylbenzene	0.1005	4.020	0.996	25	125	3.98
Amino silane ester	0.1005	4.02	0.996	200	1846	3.7467

OSHA Factor (non-chrome compounds): 0.397
Cumulative OSHA Factor averaged over entire shift: 0.149

CHROME COMPONENT	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	Concentration at 80% recirc	Measured breathing zone Cr+6 concentration with existing administrative & engineering controls:
02Y040A	0.4848	19.39	0.93667	0.00225 mg/m3	0.300 mg/m3
Cr+6 in SrCrO4	0.00%				

Cr+6 concentrations in the recirculated stream are lower than measured breathing zone concentrations by a factor of 133

- For solid-phase SrCrO4, the following efficiencies are assumed: Transfer = 75.00% Dropout = 22.00% Filtration = 99.94%
- Items shown in bold employ OSHA PELs, ACGIH TWAs, or manufacturer recommended values obtained from either the MSDS or the specification package
- The % by weight of hexavalent chrome in SrCrO4 is: 25.49%

Filename: APC coating recirculation for Hangar
 October 25, 2004 8:08 PM
 MSDS Information from DEFT; usage/duty cycle data from Austin data package

Transfer efficiency:	75.00%	Flow rate:	1080000 cfm	Hangar cross sectional area:	61,000 ft2	Topcoat Operation
Dropout efficiency:	22.00%		64800000 cfm	Paint cone cross sectional diameter:	6 ft	
Filtration efficiency:	99.94%		1835136 m3/hr	Paint cone cross sectional area:	28.26 ft2	
				Number of painters:	8 painters	
Painter operates:	7 hours/shift			Total paint cross sectional area:	226.08 ft2	
Shift interval:	8 hours			ratio of paint cone/hangar cross section:	0.0037 :1	
Coating usage rate:	225 gal/cycle			Measured concentration in breathing zone:	0.00875 mg HDI monomer/m3 (25% of PEL)	
	32.14 gal/hr			Concentration averaged across exhaust face:	0.000032 mg HDI monomer/m3	
	295.07 lb/hr			Adjustment to 0% recirculation value to reconcile with measured values: 382797		

Component	DEFTHANE	Catalyst
Mix ratio (volume basis)	3	1
Density (lb/gallon)	9.27	8.91

9.18 as applied

Components	DEFTHANE	Catalyst	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	PEL/TWA ppm	80% recirculation		0% recirculation	
							mg/m3	OSHA Factor	mg/m3	OSHA Factor
Methyl n-amyl ketone	25.00%	5.00%	1.8495	59.45	27,021,916	50	237	0.24852	14.72	0.06213
Propylene glycol monomethyl ether acetate	1.00%	0.00%	0.0695	2.23	1,015,787	100	548	0.00404	0.55	0.00101
Dipropylene glycol monomethyl ether	1.00%	0.00%	0.0695	2.23	1,015,787	100	615	0.00360	0.55	0.00090
Xylene	5.00%	0.00%	0.3476	11.17	5,078,937	100	441	0.02510	2.77	0.00628
Ethylbenzene	5.00%	0.00%	0.3476	11.17	5,078,937	100	441	0.02510	2.77	0.00628
Diisobutyl ketone	0.10%	0.00%	0.0070	0.223	101,579	25	148	0.00150	0.06	0.00037
Aromatic hydrocarbons	0.10%	0.00%	0.0070	0.223	101,579	100	441	0.00050	0.06	0.00013
Ethyl 3-ethoxy-propionate	5.00%	5.00%	0.4590	14.75	6,706,169	50	303	0.04824	3.65	0.01206
Anti-Mar agent	0.20%	0.00%	0.0139	0.447	203,157	NI	NI	NI	0.11	NI
2,4-Pentanedione	5.00%	0.00%	0.3476	11.17	5,078,937	20	83	0.13338	2.77	0.03334
Dibutyltin dilaurate	0.10%	0.00%	0.0070	0.223	101,579	N/A	0.1	0.00003	0.01079	0.10794
Polymeric HDI	0.00%	70.00%	1.5593	50.12	22,781,250	0.005	0.035	0.00581	0.16599	2.42072
Monomeric HDI	0.00%	70.00%	1.5593	50.119	22,781,250	0.005	0.035	0.0001297	0.00371	0.000032
Branched acetate ester alcohol	0.00%	20.00%	0.4455	14.32	6,508,929	NI	NI	14.19	3.55	NI
							Cumulative OSHA Factor		69.395	
							Factor averaged over entire shift		0.577	
							Exhaust volume flow rate (cfm)		216000	
							Recirculation volume flow rate (cfm)		864000	
									1080000	
									0	

- Items shown in bold employ OSHA PELs, ACGIH TWAs, or manufacturers recommended values obtained from either the MSDS or Appendix A of the specification package
- Items shown in italics are assumed to be in the solid phase due to vapor pressure or other characteristics
- Two anti-mar agents are combined in this spreadsheet

Filename: Urethane recirculation for Hangar

October 25, 2004 8:05 PM

MSDS Information from DEFT; usage/duty cycle data from Austin data package

Transfer efficiency: 75.00% Flow rate: 1080000 cfm
Dropout efficiency: 22.00% 64800000 cfm
Filtration efficiency: 99.94% 1835136 m3/hr

Painter operates: 4 hours/shift

Shift interval: 8 hours

Coating usage rate: 135 gal/cycle

33.75 gal/hr

334.97 lb/hr

Topcoat Operation

61,000 ft2

6 ft

28.26 ft2

8 painters

226.08 ft2

0.0037 :1

ratio of paint cone/hangar cross section: 0.00875 mg HDI monomer/m3 (25% of PEL)

Measured concentration in breathing zone: 0.000032 mg HDI monomer/m3

Concentration averaged across exhaust face: 0.000032 mg HDI monomer/m3

Adjustment to 0% recirculation value to reconcile with measured values: 435480.3

Component	Mix ratio (volume basis)	Density (lb/gallon)	Catalyst	Mixed	Release Rate	unfiltered concentration	PEL/TWA	80% recirculation		0% recirculation	
								mg/m3	OSHA Factor	mg/m3	OSHA Factor
Components	03GY321	3	1	10.23	9.9250 as applied	0.4963	150	16.748	0.0230	4.148	0.0057
								28.152	0.0921	6.973	0.0230
								2.589	0.0058	0.641	0.0015
Ethyl 3-ethoxypropionate	5.00%	20.00%	0.00%	0.0767	1,177,031	0.1250703	N/A	10	0.0003	0.00030	0.0125
Ethylbenzene	1.00%	0.00%	0.00%	0.0153	235,406	0.12828	NI	NI	NI	NI	NI
Anti-Float agent (CaCO3)	1.00%	0.00%	0.00%	0.0767	1,177,031	0.1250703	NI	NI	NI	NI	NI
Flow agent	0.20%	0.00%	0.00%	0.0767	1,177,031	0.1250703	NI	NI	NI	NI	NI
Dibutyltin dilaurate	0.10%	0.00%	0.00%	0.0767	1,177,031	0.1250703	NI	NI	NI	NI	NI
2,4-Pentanedione	5.00%	0.00%	0.00%	0.3836	12,947	5,885,156	20	83	0.155	3.207	0.0386
Methyl n-amyl ketone	20.00%	0.00%	0.00%	1.5345	51,789	12,827,73	50	237	0.217	12.828	0.0541
Butyl carbitol acetate	5.00%	0.00%	0.00%	0.3836	12,947	5,885,156	NI	NI	NI	NI	NI
Polymeric HDI	0.00%	75.00%	0.00%	1.6894	57,016	25,916,548	0.005	0.035	0.0066	2.753871	78.6820
Monomeric HDI	0.00%	75.00%	0.00%	1.6894	57,016	25,916,548	0.005	0.035	0.0001297	0.004	0.00093
Aromatic hydrocarbons	0.00%	1.00%	0.00%	0.0225	0.760	345,554	100	441	0.00171	0.188	0.0004
1,3,5-Trimethylbenzene	0.00%	1.00%	0.00%	0.0225	0.760	345,554	25	125	0.00603	0.188	0.0015
Cumulative OSHA Factor averaged over entire shift								0.692		78.945	
Exhaust volume flow rate (cfm)								0.346		39.473	
Recirculation volume flow rate (cfm)								216000		1080000	
								864000		0	

- Items shown in bold employ OSHA PELs, ACGIH TWAs or manufacturer recommended values obtained from either the MSDS or Appendix A of the specification package
- Items shown in italics are assumed to be in the solid phase due to vapor pressure or other characteristics
- Two anti-mar agents are combined in this spreadsheet

SPRAY BOOTH RESULTS

Filename: Primer recirculation for Spray Booth
 October 25, 2004 8:02 PM
 MSDS Information from DEFT; usage/duty cycle data from Austin data package

Painter operates: 1 hours/shift
 Shift interval: 8 hours
 Coating usage rate: 8 gal/cycle
 8.00 gal/hr
 92.16 lb/hr

Flow rate: 103500 cfm
 6210000 cfh
 175867.2 m3/hr

Component 02Y040A Catalyst 1
 Mix ratio (volume basis) 3 1
 Density (lb/gallon) 12.68 8.04
 11.52 as applied

NON-CHROME COMPONENTS									
	02Y040A	Catalyst	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	PEL/TWA mg/m3	80% recirculation mg/m3	OSHA Factor	
Methyl n-amyl ketone	5.00%	0.00%	0.4755	3.80	1,729,091	9.832	50	237	0.16594
4-Chlorobenzotrifluoride	5.00%	0.00%	0.4755	3.80	1,729,091	9.832	NI	NI	NI
2-Chlorobenzotrifluoride	0.10%	0.00%	0.0095	0.08	34,582	0.197	NI	NI	NI
n-Butyl acetate	5.00%	0.00%	0.4755	3.80	1,729,091	9.832	150	723	0.05439
Methyl n-propyl ketone	15.00%	0.00%	1.4265	11.412	5,187,273	29,495	200	715	0.16501
Methyl isobutyl ketone	1.00%	0.00%	0.0951	0.761	345,818	1.966	50	208	0.01784
Aromatic hydrocarbons	0.10%	5.00%	0.1100	0.88	400,036	2.275	100	441	0.02063
n-Butyl alcohol	0.00%	10.00%	0.2010	1.608	730,909	4.156	20	62	0.26813
1,2,4-Trimethylbenzene	0.00%	5.00%	0.1005	0.80	365,455	2.078	25	125	0.06650
1,3,5-Trimethylbenzene	0.00%	5.00%	0.1005	0.804	365,455	2.078	25	125	0.06650
Amino silane ester	0.00%	5.00%	0.1005	0.80	365,455	2.078	200	1846	0.0042357
Cumulative OSHA Factor (non-chrome compounds):							0.829		
OSHA Factor averaged over entire shift:							0.104		

CHROME COMPONENT	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	Concentration at 80% recirc mg/m3	Measured breathing zone Cr+6 concentration with existing administrative & engineering controls: 0.300 mg/m3
Cr+6 in SrCrO4	0.4848	3.88	1,762,995	0.00469	

Cr+6 concentrations in the recirculated stream are lower than measured breathing zone concentrations by a factor of 64

- For solid-phase SrCrO4, the following efficiencies are assumed: Transfer 75.00% Dropout = 22.00% Filtration = 99.94%
- Items shown in bold employ OSHA PELs, ACGIH TWAs, or manufacturer recommended values obtained from either the MSDS or the specification package
- The % by weight of hexavalent chromium in SrCrO4 is: 25.49%

Filename: APC coating recirculation for Spray Booth
 October 25, 2004 7:51 PM
 MSDS Information from DEFT; usage/duty cycle data from Austin data package

Transfer efficiency:	75.00%	Flow rate	103500 cfm	Booth cross sectional area:	1,380 ft2	Topcoat Operation
Dropout efficiency:	22.00%		6210000 cfm	Paint cone cross sectional diameter:	6 ft	
Filtration efficiency:	99.94%		175867.2 m3/hr	Paint cone cross sectional area:	28.26 ft2	
Painter operates:	2 hours/shift			Number of painters:	2 painters	
Shift interval:	8 hours			Total paint cross sectional area:	56.52 ft2	
Coating usage rate:	12 gal/cycle			ratio of paint cone/hangar cross section:	0.0410 :1	
	6.00 gal/hr			Measured concentration in breathing zone:	0.00875 mg HDI monomer/m3	
	55.08 lb/hr			Concentration averaged across exhaust face:	0.0003584 mg HDI monomer/m3	

Adjustment to 0% recirculation value to reconcile with measured value: 67473

Component	DEFTHANE	Catalyst
Mix ratio (volume basis)	3	1
Density (lb/gallon)	9.27	8.91

9.18 as applied

	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	PEL/TWA ppm	80% recirculation		0% recirculation	
					mg/m3	OSHA Factor	mg/m3	OSHA Factor
Components DEFTHANE								
Methyl n-amyl ketone	1.8495	11.10	5,044,091	50	237	0.48407	28.68	0.12102
Propylene glycol monomethyl ether acetate	0.0695	0.42	189,614	100	548	0.00787	1.08	0.00197
Dipropylene glycol monomethyl ether	0.0695	0.42	189,614	100	615	0.00701	1.08	0.00175
Xylene	0.3476	2.09	948,068	100	441	0.04890	5.39	0.01222
Ethylbenzene	0.3476	2.09	948,068	100	441	0.04890	5.39	0.01222
Diisobutyl ketone	0.0070	0.042	18,961	25	148	0.00291	0.11	0.00073
Aromatic hydrocarbons	0.0070	0.042	18,961	100	441	0.00098	0.11	0.00024
Ethyl 3-ethoxypropionate	0.4590	2.75	1,251,818	50	303	0.09397	7.12	0.02349
Anti-Mar agent	0.0139	0.083	37,923	NI	NI	NI	0.22	NI
2,4-Pentanedione	0.3476	2.09	948,068	20	83	0.25980	5.39	0.06495
Dibutyltin dilaurate	0.0070	0.042	18,961	N/A	0.1	0.000050	0.02	0.21024
Polymeric HDI	1.5593	9.36	4,252,500	0.005	0.035	0.0113	4.72	134,71813
Monomeric HDI	1.5593	9.35550	4,252,500	0.005	0.035	0.0014	0.0003584	0.01024
Branched acetate ester alcohol	0.4455	2.67	1,215,000	NI	NI	0.04096	6.91	NI
				Cumulative OSHA Factor averaged over entire shift		1.32	135.2	
				Exhaust volume flow rate (cfm)		0.330	33.794	
				Recirculation volume flow rate (cfm)		20700	103500	
						82800	0	

- Items shown in bold employ OSHA PELs, ACGIH TWAs, or manufacturers recommended values obtained from either the MSDS or Appendix A of the specification package
 - Items shown in *italics* are assumed to be in the solid phase due to vapor pressure or other characteristics
 - Two anti-mar agents are combined in this spreadsheet

Filename: Urethane recirculation for Spray Booth
 October 25, 2004 7:55 PM
 MSDS Information from DEFT; usage/duty cycle data from Austin data package

Transfer efficiency:	75.00%	Flow rate	103500 cfm	Topcoat Operation	1,380 ft2
Dropout efficiency:	22.00%		6210000 cfm	Booth cross sectional area:	6 ft
Filtration efficiency:	99.94%		175867.2 m3/hr	Paint cone cross sectional diameter:	28.269 ft2
Painter operates:	2 hours/shift			Paint cone cross sectional area:	2 painters
Shift interval:	8 hours			Number of painters:	56.538 ft2
Coating usage rate:	12 gal/cycle			Total paint cross sectional area:	ratio of paint cone/hangar cross section: 0.04096957 :1
	6 gal/hr				Measured concentration in breathing zone: 0.00875 mg HDI monomer/m3
	59.55 lb/hr				Concentration averaged across exhaust face: 0.0003585 mg HDI monomer/m3

Adjustment to 0% recirculation value to reconcile with measured value: 73080

Component 03GY321		Catalyst	Adjustment to 0% recirculation value to reconcile with measured value: 73080										
Mix ratio (volume basis)	Density (lb/gallon)	3	1	9.9250 as applied									
		10.23	9.01	Mixed (lb/gal)	Release Rate (lb/hr	unfiltered concentration (mg/m3)	PEL/TWA (mg/m3	80% recirculation mg/m3	0% recirculation at exhaust face (no filter) mg/m3	OSHA Factor	OSHA Factor	OSHA Factor	
Components	03GY321	5.00%	Catalyst	0.4963	2.978	7.69563	150	30.78	0.0426	7.696	0.0106	0.0106	
n-Butyl acetate	5.00%	20.00%	5.00%	0.8341	5.005	12.93525	50	51.74	0.1708	12.935	0.0427	0.0427	
Ethyl 3-ethoxypropionate	1.00%	0.00%	0.00%	0.0767	0.460	1.18982	100	4.76	0.0108	1.190	0.0027	0.0027	
Ethylbenzene	1.00%	0.00%	0.00%	0.0767	0.460	0.2320146	N/A	0.93	0.0928	0.232	0.0232	0.0232	
Anti-Float agent (CaCO3)	0.20%	0.00%	0.00%	0.0153	0.092	0.23796	NI	0.95	NI	0.238	NI	NI	
Anti-Mar agent	1.00%	0.00%	0.00%	0.0767	0.460	1.18982	NI	4.76	NI	1.190	NI	NI	
Flow agent	0.10%	0.00%	0.00%	0.0077	0.046	0.0232015	N/A	0.1	0.00056	0.023201	0.2320	0.2320	
Dibutyltin dilaurate	5.00%	0.00%	0.00%	0.3836	2.302	5.94909	20	23.80	0.287	5.949	0.0717	0.0717	
2,4-Pentanedione	20.00%	0.00%	0.00%	1.5345	9.207	23.79636	50	95.19	0.402	23.796	0.1004	0.1004	
Methyl n-amyl ketone	5.00%	0.00%	0.00%	0.3836	2.302	5.94909	NI	23.80	NI	5.949	NI	NI	
Butyl carbitol acetate	0.00%	75.00%	75.00%	1.6894	10.136	5.1086294	0.005	0.0123	0.350	5.1086294	145.9608	145.9608	
Polymeric HDI	0.00%	75.00%	75.00%	1.6894	10.136	26.19810	0.005	0.0014	0.041	0.0003585	0.01024	0.01024	
Monomeric HDI	0.00%	1.00%	1.00%	0.0225	0.135	0.34931	100	1.40	0.00317	0.349	0.0008	0.0008	
Aromatic hydrocarbons	0.00%	1.00%	1.00%	0.0225	0.135	0.34931	25	1.40	0.01118	0.349	0.0028	0.0028	
1,3,5-trimethylbenzene													

Filename: Urethane recirculation for Spray Booth: 70% recirculation

April 20, 2005 1:52 PM

MSDS Information from DEFT; usage/duty cycle data from Austin data package

Transfer efficiency: 75.00% Flow rate 103500 cfm
Dropout efficiency: 22.00% 6210000 cfh
Filtration efficiency: 99.94% 175867.2 m3/hr

Painter operates: 2 hours/shift

Shift interval: 8 hours

Coating usage rate: 12 gal/cycle

6 gal/hr

59.55 lb/hr

Topcoat Operation

1,380 ft2

6 ft

Paint cone cross sectional area:

28.269 ft2

Number of painters:

2 painters

Total paint cross sectional area:

56.538 ft2

ratio of paint cone/hangar cross section:

0.04096957 :1

Measured concentration in breathing zone:

0.00875 mg HDI monomer/m3

Concentration averaged across exhaust face:

0.0003585 mg HDI monomer/m3

Adjustment to 0% recirculation value to reconcile with measured value: 73080

Component 03GY321 Catalyst

Mix ratio (volume basis) 3 1

Density (lb/gallon) 10.23 9.01

9.9250 as applied

Components	Mixed (lb/gal)	Release Rate lb/hr	unfiltered concentration (mg/m3)	PEL/TWA ppm	mg/m3	70% recirculation		0% recirculation	
						mg/m3	OSHA Factor	mg/m3	OSHA Factor
n-Butyl acetate	0.4963	2.978	7.69563	150	723	17.96	0.0248	7.696	0.0106
Ethyl 3-ethoxypropionate	0.8341	5.005	12.93525	50	303	30.18	0.0996	12.935	0.0427
Ethylbenzene	0.0767	0.460	1.18982	100	441	2.78	0.0063	1.190	0.0027
Anti-Float agent (CaCO3)	0.0767	0.460	0.2320146	N/A	10	0.54	0.0541	0.232	0.0232
Anti-Mar agent	0.0153	0.092	0.23796	NI	NI	0.56	NI	0.238	NI
Flow agent	0.0767	0.460	1.18982	NI	NI	2.78	NI	1.190	NI
Dibutyltin dilaurate	0.0077	0.046	0.0232015	N/A	0.1	0.000032	0.00032	0.023201	0.2320
2,4-Pentanedione	0.3836	2.302	5.94909	20	83	13.88	0.167	5.949	0.0717
Methyl n-amyl ketone	1.5345	9.207	23.79636	50	237	55.52	0.234	23.796	0.1004
Butyl carbitol acetate	0.3836	2.302	5.94909	NI	NI	13.88	NI	5.949	NI
Polymeric HDI	1.6894	10.136	5.1086294	0.005	0.035	0.0072	0.204	5.1086294	145.9608
Monomeric HDI	1.6894	10.136	26.19810	0.005	0.035	0.0008	0.024	0.0003585	0.01024
Aromatic hydrocarbons	0.0225	0.135	0.34931	100	441	0.82	0.00185	0.349	0.0008
1,3,5-trimethylbenzene	0.0225	0.135	0.34931	25	125	0.82	0.00652	0.349	0.0028
Cumulative OSHA Factor averaged over entire shift									146.458
Exhaust volume flow rate (cfm)									36.614
Recirculation volume flow rate (cfm)									103500
									0

- Items shown in bold employ OSHA PELs, ACGIH TWAs or manufacturer recommended values obtained from either the MSDS or Appendix A of the specification package

- Items shown in italics are assumed to be in the solid phase due to vapor pressure or other characteristics

- Two anti-mar agents are combined in this spreadsheet

MSDS Information from DEFT; usage/duty cycle data from Austin data package

Painter operates:	1 hours/shift	Flow rate:	103500 cfm
Shift interval:	8 hours		6210000 cfh
Coating usage rate:	8 gal/cycle		175867.2 m3/hr
	8.00 gal/hr		
	92.16 lb/hr		

Component	Mix ratio (volume basis)	Density (lb/gallon)	Catalyst	11.52 as applied	unfiltered	70% recirculation
	02Y040A	3	1			
		12.68	8.04			
NON-CHROME COMPONENTS						
Methyl n-amyl ketone	5.00%	02Y040A	Catalyst	Mixed (lb/gal)	Release Rate (lb/hr)	concentration (mg/m3)
4-Chlorobenzotrifluoride	5.00%		0.00%	0.4755	3.80	1,729,091
2-Chlorobenzotrifluoride	0.10%		0.00%	0.4755	3.80	1,729,091
n-Butyl acetate	5.00%		0.00%	0.0095	0.08	34,582
Methyl n-propyl ketone	15.00%		0.00%	0.4755	3.80	1,729,091
Methyl isobutyl ketone	1.00%		0.00%	1.4265	11.412	5,187,273
Aromatic hydrocarbons	0.10%		5.00%	0.0951	0.761	345,818
n-Butyl alcohol	0.00%		10.00%	0.1100	0.88	400,036
1,2,4-Trimethylbenzene	0.00%		5.00%	0.2010	1.608	730,909
1,3,5-Trimethylbenzene	0.00%		5.00%	0.1005	0.80	365,455
Amino silane ester	0.00%		5.00%	0.1005	0.804	365,455
				0.1005	0.80	365,455
					OSHA Factor (non-chrome compounds):	
					Cumulative OSHA Factor averaged over entire shift:	
					0.484	
					0.060	

CHROME COMPONENT	02Y040A 5.10%	Catalyst 0.00%	Mixed (lb/gal) 0.4848	Release Rate lb/hr 3.88	mg/hr 1,762,995	unfiltered concentration (mg/m3) 1.95479	Concentration at 70% recirc 0.00274 mg/m3	Measured breathing zone Cr+6 concentration with existing administrative & engineering controls: 0.300 mg/m3
Cr+6 in SrCrO4								

Cr+6 concentrations in the recirculated stream are lower than measured breathing zone concentrations by a factor of 110

Item	Transfer	Dropout	Filtration
- For solid-phase SrCrO ₄ , the following efficiencies are assumed:	75.00%	22.00%	99.94%
- Items shown in bold employ OSHA PELs, ACGIH TWAs, or manufacturer recommended values obtained from either the MSDS or the specification package			
The % by weight of hexavalent chromium in SrCrO ₄ is:	25.49%		

Filename: APC coating recirculation for Spray Booth: 70% Recirculation
 April 20, 2005 1:56 PM

MSDS Information from DEFT; usage/duty cycle data from Austin data package

Transfer efficiency:	75.00%	Flow rate	103500 cfm	Topcoat Operation	
Dropout efficiency:	22.00%		6210000 cfm	Booth cross sectional area:	1,380 ft ²
Filtration efficiency:	99.94%		175867.2 m ³ /hr	Paint cone cross sectional diameter:	6 ft
Painter operates:	2 hours/shift			Paint cone cross sectional area:	28.26 ft ²
Shift interval:	8 hours			Number of painters:	2 painters
Coating usage rate:	12 gal/cycle			Total paint cross sectional area:	56.52 ft ²
	6.00 gal/hr			ratio of paint cone/hangar cross section:	0.0410 :1
	55.08 lb/hr			Measured concentration in breathing zone:	0.00875 mg HDI monomer/m ³
				Concentration averaged across exhaust face:	0.0003584 mg HDI monomer/m ³

Adjustment to 0% recirculation value to reconcile with measured value: 67473

Component		DEFTHANE	Catalyst	9.18 as applied				unfiltered		70% recirculation		0% recirculation	
Mix ratio (volume basis)	Density (lb/gallon)		1	Mixed (lb/gal)	Release Rate lb/hr	mg/hr	concentration (mg/m3)	ppm	mg/m3	OSHA Factor	mg/m3	OSHA Factor	at exhaust face (no filter)
		3	8.91										
		9.27											
Components													
	DEFTHANE	25.00%	Catalyst										
		5.00%	5.00%	1.8495	11.10	5,044,091	28.681	50	237	66.92	28.68	0.12102	
	Methyl n-amyl ketone	1.00%	0.00%	0.0695	0.42	189,614	1.078	100	548	2.52	0.00459	1.08	0.00197
	Propylene glycol monomethyl ether acetate	1.00%	0.00%	0.0695	0.42	189,614	1.078	100	615	2.52	0.00409	1.08	0.00175
	Dipropylene glycol monomethyl ether	5.00%	0.00%	0.3476	2.09	948,068	5.391	100	441	12.58	0.02852	5.39	0.01222
	Xylene	5.00%	0.00%	0.3476	2.09	948,068	5.391	100	441	12.58	0.02852	5.39	0.01222
	Ethylbenzene	0.10%	0.00%	0.0070	0.042	18,961	0.108	25	148	0.25	0.00170	0.11	0.00073
	Diisobutyl ketone	0.10%	0.00%	0.0070	0.042	18,961	0.108	100	441	0.25	0.00057	0.11	0.00024
	Aromatic hydrocarbons	5.00%	5.00%	0.4590	2.75	1,251,818	7.118	50	303	16.61	0.05481	7.12	0.02349
	Ethyl 3-ethoxypropionate	0.20%	0.00%	0.0139	0.083	37,923	0.216	NI	NI	0.50	NI	0.22	NI
	Anti-Mar agent	5.00%	0.00%	0.3476	2.09	948,068	5.391	20	83	12.58	0.15155	5.39	0.06495
	2,4-Pentanedione	0.10%	0.00%	0.0070	0.042	18,961	0.0210242	N/A	0.1	0.000029	0.00029	0.02	0.21024
	Dibutyltin dilaurate	0.00%	70.00%	1.5593	9.36	4,252,500	4.71513	0.005	0.035	0.0066	0.18861	4.72	134.71813
	Polymeric HDI	0.00%	70.00%	1.5593	9.35550	4,252,500	24.18018	0.005	0.035	0.0008	0.02389	0.0003584	0.01024
	Monomeric HDI	0.00%	20.00%	0.4455	2.67	1,215,000	6.909	NI	NI	16.12	6.91	NI	NI
	Branched acetate ester alcohol												
				Cumulative OSHA Factor averaged over entire shift				Cumulative OSHA Factor				135.2	
				Exhaust volume flow rate (cfm)				0.192				33.794	
				Recirculation volume flow rate (cfm)				31050				103500	
								72450				0	

- Items shown in bold employ OSHA PELs, ACGIH TWAs, or manufacturers recommended values obtained from either the MSDS or Appendix A of the specification package
- Items shown in italics are assumed to be in the solid phase due to vapor pressure or other characteristics
- Two anti-mar agents are combined in this spreadsheet