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Technical Requirements for Using Recirculation Paint Spray Booths

A Review of Applicable Codes and Standards

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Abstract

The use of spray painting has been an important part of manufacturing since the late 1800s. Over time the technologies associated with this process have evolved and become increasingly complex in response to environmental, worker health, safety and other requirements. One way in which environmental concerns for air quality can be more easily addressed is to recirculate air flows within paint spray booths, thereby allowing a reduction in the exhaust rate from the booths. This technique, applied in both manned and unmanned operations, has been utilized since the late 1970s and codes and standards have evolved to address the practice. This paper reviews the history of paint booth recirculation and summarizes the pertinent parts of the codes and standards that govern the practice. Understanding the codes and standards should allow the reader, with appropriate technical assistance, to apply the technique in a safe and code compliant manner.

Historical Context

Man's use of paint to beautify and protect objects is as old as history itself. For much of man's history however, little was known of the importance of using paints in a manner that protected the painter's health and limited the painting operation's environmental impact. As a result, in the past, painting operations were sometimes the source of significant negative impact on the environment and worker health. Additionally, many paints are flammable as applied or have combustible residues which have been involved with starting and fueling damaging fires. As man has progressed into manufacturing products in a modern context, multiple objectives have emerged that must be integrated in a responsible manner. These objectives include protecting worker health, protecting the environment, producing quality products that compete globally, reducing energy use and minimizing fire risk to operations.

One of the first ways manufacturers integrated quality paint finishing with safety was to apply paint with spray guns in spray booths. This process developed in the late 1800s and allowed fast application of paint in an aesthetically pleasing manner with collection of waste paint in a controlled way. Over the years many improvements occurred in the basic arrangement of paint spraying and paint spray booths. Many of these developments evolved in the automotive industry because the high volume of manufacturing and high quality demands magnified the impact of

technology changes. The high volumes of paint used in the automotive industry also drove the need for environmental regulation in the form of limits on air pollution.

Limiting air pollution from painting operations has often involved changes in coating chemistry. These changes include reducing volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) in the paints. Demands for higher performance coatings have also required paint chemistry changes. Paint chemistry changes and performance demands have often made control of the paint spraying environment more important, sometimes necessitating close control of the temperature and relativity humidity in the spray booth. This control can be quite costly in both initial capital cost and energy consumption costs when the large air volumes associated with paint spray booths are considered. Control of temperature and relativity humidity typically requires cooling capacity to dehumidify and cool outside air in the summer and heating and humidification capacity in the winter. Each of these services often must be sized for near-worst case climatic conditions as production cannot stop or quality be sacrificed in bad weather.

Paralleling changes in paint chemistry were changes in paint application technologies designed to improve quality and reduce negative impacts such as air pollution. These improvements included electrostatic paint application, high volume low pressure (HVLP) spray guns and other spray technologies. Each of these technologies improves transfer efficiency and thereby reduces the amount of paint overspray and overall amount of paint required. In some cases, robotic paint application has been used to improve uniformity of process and remove human operators from a process with potential negative health impacts.

For some applications, experience has shown that compliance with air pollution limits while maintaining product quality cannot be achieved by coating and application equipment selection alone. That is, the required performance characteristics of the paint cannot be achieved without the use of elevated levels of VOCs or HAPs. Additionally, certain manufacturing facilities use a lot of paint and / or are in areas with existing higher levels of air pollutants. For these applications, some sort of air pollution control, or abatement, is necessary.

Most methods of VOC and HAP abatement used in paint spray operations involve capture and thermal destruction of the compounds in oxidizers at 1400°F or higher temperatures. These undesirable compounds are typically lightly concentrated in the large volumes of air passed through most spray booths. Thermal destruction in an oxidizer necessitates heating the entire booth exhaust airstream and can require very large quantities of energy, mostly used to heat benign air rather than destroying undesirable compounds. One strategy used to limit this problem is to use oxidizer designs that incorporate highly efficient heat recovery, for example a Regenerative Thermal Oxidizer (RTO). Another approach has been to concentrate the booth exhaust by using zeolite or carbon based absorption techniques where solvents are essentially stripped from the booth exhaust and transferred into a smaller airstream for incineration. For each of these techniques, the initial volume of air requiring treatment can be substantially reduced by recirculation of the spray booth air and elevation of the solvent concentration prior to exhaust discharge to the oxidizer or concentrator.

Paint Booth Recirculation

Starting in the late 1970s initial efforts were made to recirculate paint spray booths[1]. In 1981, John Deere received a patent for a recirculated paint spray booth that included manned operation using pressure fed breathing air supply.[2] At the time, codes and standards prohibited the recirculation of spray booths; however, the technique was of such benefit that codes and standards began to accept the technique in a controlled manner. The use of recirculated spray booths was first allowed in the 1985 edition of NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*.[3] Reportedly, in 1989, OSHA first issued a policy directive allowing use of manned recirculated paint spray booths operated under the Permissible Exposure Limits (PEL).[4]

To understand recirculation of paint booths, first consider non-recirculated paint spray booths. Conventional spray booths have an exhaust fan that draws air through the work chamber, across the part being painted, through an air cleaning apparatus (water scrubber or dry filter) and discharges the air outside the building. In better quality systems an air supply unit is used to supply make up air to the booth. The volume of air is often based on maintaining a 100 feet per minute air velocity in the booth. Experience has shown that this velocity usually does an effective job of capturing and transporting the paint overspray to the booth filters or scrubber, although lower and higher velocities are sometimes used. Note that in conventional booths air makes only one pass through the system and no air is recirculated.

In recirculated paint booths the volume of air being moved through the spray area of the paint booth is often the same as with a conventional booth. However, instead of all air being exhausted, a portion is returned back to the booth air supply forming a recirculation loop. A side stream of the recirculation loop is drawn off and exhausted. Fresh air is supplied to the recirculation loop at the booth supply plenum to offset the amount of air being exhausted. Reference can be made to figures one and two which shown both conventional and recirculated paint booths air flows.

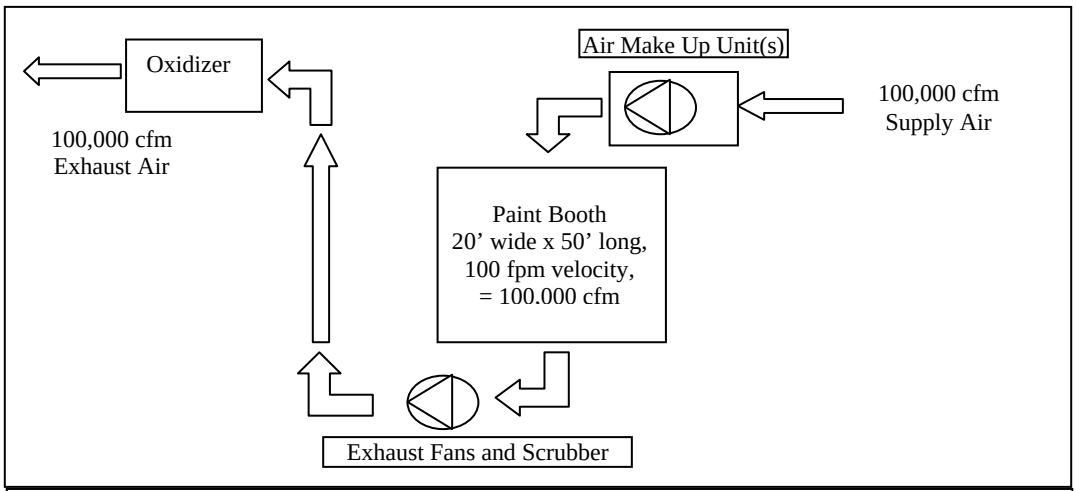

Figure 1: Non-recirculated paint booth airflow in a 20 foot wide by 50 foot long paint booth with VOC abatement.

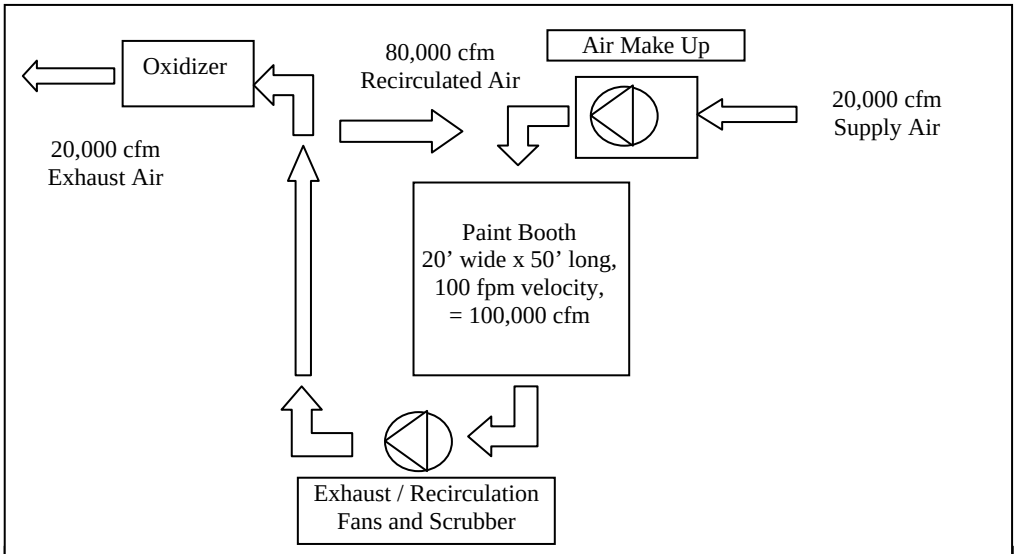

Figure 2: Recirculated paint booth airflow in a 20 foot wide by 50 foot long paint booth with VOC abatement. In this example, a ratio of 80% recirculated air to 20% fresh air is used.

Consideration of the differences in airflows between the recirculated and non-recirculated paint booths yields several important observations. These observations include the following:

The velocity in the paint booth is the same in each example, therefore it is expected that the capture of overspray will be the same in each case.

The volume of makeup air that must be supplied and conditioned for the process is 80% less in the recirculated system. This should decrease the initial capital expenditure and ongoing energy costs for the recirculated system.

The volume of exhaust air that must be abated for the process is 80% less in the recirculated system. This should decrease the initial capital expenditure and ongoing energy costs for the recirculated system.

Given that the volume of paint sprayed is the same in each case, the average solvent concentration in the recirculated case should be 5 times the level of the non-recirculated design. Higher solvent concentrations have fire safety and worker health implications that must be considered in the design.

Codes and Standards

From the above analysis, it is apparent that paint booth recirculation can have economic benefit in reducing the amount of makeup air that must be conditioned and exhaust air that must be abated. It is also apparent that solvent concentrations will be elevated in the recirculated booth and that fire safety and health concerns must be addressed. To ensure these concerns are addressed, some safe criteria must be established for comparison to the proposed design. One set of criteria that can be used are existing codes and standards.

Typically, architects, engineers and health and safety professionals use codes and standards to help ensure that systems are designed to some commonly agreed upon safe condition. Some codes and standards are actually adopted into law and therefore must legally be complied with in a design. Other codes and standards are voluntary. Paint spraying operations have a long history in industry and have been addressed in a number of codes and standards. A list of codes and standards that directly address paint spraying operations in industry follows. Note that the year included in the code or standard name references the most current version of the document as of the date of this analysis. Users should check for more current versions when using this report. Additionally, in many cases local adoption of a code or standard update many not occur until several years after its release, therefore, local authorities may enforce earlier versions of the code or standard.

International Code Council (ICC) Codes: These include the International Building Code (IBC-2009), the International Fire Code (IFC-2009) and the International Mechanical Code (IMC-2009). Each of these codes has been adopted into law in most areas of the United States. According to the ICC, the IBC has been adopted at the state or local level in all 50 states, the IFC in 42 states and the IMC in 47 states.[5] The ICC codes specifically address paint spraying operations in the following manner:

International Building Code (IBC-2009): Section 416 *Application of Flammable Finishes* is a relatively short section that requires the use of the International Fire Code for spray booth design, construction and maintenance requirements.

International Fire Code (IFC-2009): Chapter 15, *Flammable Finishes* is a fairly involved chapter that addresses application of flammable finishes including spray applications. The chapter lists a number of requirements for spray booth construction including adopting by reference NFPA 33 *Standard for Spray Application Using Flammable or Combustible Materials* (see below). The chapter includes requirements of ventilation of spray booths, including recirculated booths, and also references the International Mechanical Code for ventilation requirements.

International Mechanical Code (IMC-2009): Section 502.7 *Application of Flammable Finishes* discusses exhaust systems associated with flammable finishing operations including paint spray booths. The chapter includes requirements of ventilation of spray booths, including recirculated booths.

NFPA 33-2011, *Standard for Spray Application Using Flammable or Combustible Materials*. This standard is published by the National Fire Protection Association. NFPA 33 is the most in-depth and widely used standard regarding spray painting. This standard is incorporated by reference with regard to spray booth construction by the International Fire Code. Note that the NFPA 33 has specific requirements related to recirculated spray booths.

ANSI/AIHA Z9.3-2007 *American National Standard for Spray Finishing Operations: Safety Code for Design, Construction, and Ventilation*. This ANSI approved standard is published by the American Industrial Hygiene Association. This safety code refers to and specifically adopts the NFPA 33 standard in several areas including ventilation requirements. However, the ANSI Z9.3 standard includes a number of additional requirements related to control of worker exposures to toxics. The Z9.3 code does specifically mention paint booth recirculation.

Code of Federal Regulations, Title 29, Part 1910, Section 107, *"Spray Finishing Using Flammable and Combustible Materials."* This section of the Occupational Safety and Health Standards addresses paint spray applications and includes requirements for booth ventilation. Paint booth recirculation is also addressed. Note that OSHA has issued several interpretations that clarify policy with respect to this section of the Federal Code. Additionally, OSHA has stated that NFPA 33-1969 is the source for this section of the OSHA code.

Code of Federal Regulations, Title 29, Part 1910, Section 94c, *"Ventilation, Spray Finishing Operations."* This section of the Occupational Safety and Health Standards addresses paint spray applications and includes requirements for booth ventilation. Paint booth recirculation is not specifically addressed; however, booth make up air is addressed. Note that OSHA has issued several interpretations that clarify policy with respect to this section of the Federal Code. Additionally, OSHA has stated that ANSI Z9.3-1964 is the source for this section of the OSHA code.

There are other codes and standards that address non-ventilation related aspects of paint spray booth design. NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials, C*hapter 2 lists 28 referenced codes, standards and publications that have been mentioned in the NFPA 33 standard. Prominent among these are NFPA 13 *Standard for the Installation of Sprinkler Systems*, which gives sprinkler system requirements for paint booths. Also prominent is NFPA 70 *National Electrical Code* which gives requirements for electrical wiring requirements in and around spray booths.

There are a number of other codes and standards that bear on spray painting operations. Many of these standards relate to ventilation and worker health issues, fire safety issues or air pollution control. Some of these codes and standards are referenced in the primary spray finishing standards previously mentioned.

ANSI/AIHA Z9.7-*2007 American National Standard for the Recirculation of Air from Industrial Process Exhaust Systems.* This ANSI approved standard is published by the American Industrial Hygiene Association. This safety standard does not specifically mention paint booth recirculation; rather, it addresses general safety aspects of recirculation of air from process exhaust systems. The Z9.7 standard is specifically mentioned in the NFPA 33 standard as a source to consult when addressing the toxicity and permissible exposure limits requirements of recirculated spray booths.

Industrial Ventilation: A Manual of Recommended Practice. Published by the American Conference of Governmental Industrial Hygienists. Although a manual rather than a code or standard, this reference offers practical advice on matters of industrial ventilation including recirculation of process exhausts. The manual does not specifically address recirculation of paint spray booths.

NFPA 91-2010*, Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*. This standard is published by the National Fire Protection Association. According to its scope, NFPA 91 addresses ***"minimum requirements for the design, construction, installation, operation, testing, and maintenance of exhaust systems for air conveying of vapors, gases, mists, and noncombustible particulate solids"***. This standard is incorporated by

reference in the ventilation chapter of NFPA 33 and in the OSHA Code of Federal Regulations, 29 CFR 1910.107. Note that the NFPA 91 does not specifically mention recirculated spray booths.

Code of Federal Regulations, Title 29, Part 1910, Subpart Z, *"Toxic and Hazardous Substances."* This section of the Occupational Safety and Health Standards addresses chemicals present in the workplace which are capable of causing harm. Sections of Subpart Z address limits on average and peak exposure to chemicals. It also includes rules to calculate the effect of varying concentrations and exposures to mixtures of chemicals. Hazard Communication requirements are also addressed in this subpart. While the recirculation of paint spray booths clearly may impact worker exposure to toxic and hazardous substances, a complete examination of the requirements in this area is considered beyond the scope of this analysis.

Clean Air Act, Title 42, U.S.C. §7401 et seq. (1970) plus subsequent amendments.
The Clean Air Act (CAA), administered by the Environmental Protection Agency, is the federal law that regulates air emissions. Paint spraying operations often generate air pollutants and therefore are impacted by air quality control requirements. Typically, paint spraying systems will require air quality permitting and compliance with air pollution control laws. Achieving compliance with these laws may affect the design of the paint spray booth and so must be considered in designing the paint spray system, however, a complete examination of the requirements in this area is considered beyond the scope of this analysis.

Engineering Analysis of Codes and Standards

A review of the above referenced codes and standards clearly indicates that recirculation of paint spray booths is a technique that has been deemed acceptable under certain circumstances. Several ICC codes and NFPA standards make reference to paint booth recirculation and both OSHA and EPA have reviewed and commented on recirculated paint spray booths. To ensure that the technique is applied correctly and in a code compliant and safe manner, a detailed review of the requirements listed in the codes and standards is required.

ICC Codes

With respect to state and local building and fire / life safety authorities having jurisdiction (AHJ), the ICC codes would typically be the documents used to judge compliance. This would include other requirements adopted by reference in the ICC codes. It is important to note that not all areas of the country have adopted the ICC codes and even those that have adopted the codes frequently adopt local changes. The actual requirements are normally outlined by law in the states and local areas. When considering installation of paint finishing operations in a specific area, local authorities should be consulted to ensure knowledge of the governing law.

Review of the ICC codes indicates that spray finishing operations are principally addressed in the International Fire Code. Note that both construction and operational permits for spray painting with flammable finishes may be required by local authorities. Operational permits are authorized by IFC section 105.6.42 *Spraying or dipping*, which states: ***"An operational permit is required to conduct a spraying or dipping operation utilizing flammable or combustible liquids or the***

application of combustible powders regulated by Chapter 15." Additionally, section 105.7.10, *Spraying or dipping,* authorizes construction permits stating: ***"A construction permit is required to install or modify a spray room, dip tank or booth."***

With respect to paint spray booth ventilation including recirculation, the IFC has the following requirements:

Compliance with section 502.7 of the International Mechanical Code.

Continued operation of the ventilation system during and immediately after spraying operations. An interlock between the spray equipment and ventilation system is required.

Average air velocity over the open face or cross section of the booth not less than 100 feet per minute.

Articles being sprayed cannot obstruct collection of overspray.

Nominally, the IFC indicates in section 1504.7.2 that ***"Air exhausted from spraying operations shall not be recirculated."*** However, the code allows several exceptions to this prohibition as indicated:

"Exceptions:

1. ***Air exhausted from spraying operations is allowed to be recirculated as makeup air for unmanned spray operations provided that:***

1.1. The solid particulate has been removed.

1.2. The vapor concentration is less than 25 percent of the LFL.

1.3. Approved equipment is used to monitor the vapor concentration.

1.4. When the vapor concentration exceeds 25 percent of the LFL, the following shall occur:

   a. ***An alarm shall sound; and***

   b. ***Spray operations shall automatically shut down.***

1.5. In the event of shutdown of the vapor concentration monitor, 100 percent of the air volume specified in Section 510 of the International Mechanical Code is automatically exhausted.

2. ***Air exhausted from spraying operations is allowed to be recirculated as makeup air to manned spraying operations where all of the conditions provided in Exception 1 are included in the installation and documents have been prepared to show that the installation does not pose a life safety hazard to personnel inside the spray booth, spray space or spray room."***

The IFC requirement to interlock the paint spray equipment to the ventilation system is easily addressed by installing a solenoid valve in the spray painting compressed air supply that is powered by a motor starter auxiliary contact and pressure switch associated with exhaust fan airflow. Airless spray systems can be handled by interlocking the paint pump in the same manner.

The IFC requirement to maintain 100 fpm velocity through the paint booth is easily complied with on many systems and the 100 fpm design velocity has been used by designers for many years. However, in practice several questions arise that can be subject to misunderstanding. For example, is the 100 fpm velocity meant to exist in an empty booth or with product present? For some products of small cross sectional area perpendicular to air flow there is little difference. However, for a large product that occupies a substantial percentage of the booth cross section the difference can be considerable. In addition, the IFC's 100 fpm requirement does not differentiate as to the type of application equipment. Experience has shown that electrostatic or HVLP application equipment can often be successfully applied at lower booth air velocities. In recognition of these facts, NFPA 33 has abandoned stipulation of specific booth velocities and instead specifies that the design must effectively capture overspray and limit flammable vapor concentrations to less than 25% of the lower flammability limit (LFL). Additionally, OSHA 29 CFR 1910.94(c)(6)(i) specifies 100-150 fpm velocities in certain booth arrangements, however, this OSHA requirement is not applicable to enclosed booths with adequate air replacement systems. OHSA has issued standard interpretations that indicate no OSHA requirements for minimum velocities in a fully enclosed booth exist, rather, flammable vapor concentrations must be maintained below 25% of the lower flammability limit.[6]

Section 1504.7.2 of the IFC allows recirculation of paint spray booths in both manned and unmanned applications under certain circumstances. These include filtration of solid particulate matter and maintenance of a concentration of flammable vapor less than 25% of the LFL. The vapor concentration must be monitored by an approved (listed) device that will alarm when the 25% LFL limit is exceeded and stop the spraying operation. Additionally, if the monitoring device shuts down, 100% of the air specified in IMC section 510 must be exhausted. Section 510 of the International Mechanical Code addresses Hazardous Exhaust Systems. Note that the requirement is only that the volume of air exhausted must meet the requirements of IMC section 510. The code does not require compliance with all sections of IMC section 510, most of which do not deal with air volume quantities. IMC Section 510.3 *Design and operation* indicates:

"***The design and operation of the exhaust system shall be such that flammable contaminants are diluted in noncontaminated air to maintain concentrations in the exhaust flow below 25 percent of the contaminant's lower flammability limit."***

The requirement reduces to: if the recirculated booth's solvent monitor shuts down, the booth recirculation air must not exceed 25% of the LFL. This is accomplished by interlocking the paint supply system to the solvent monitor such that no solvent can be sprayed unless the monitor is actually on (not shutdown) and not in an alarm condition.

NFPA Codes and Standards

As noted in the Codes and Standards section of this report, there are several NFPA codes and standards that address aspects of paint spraying operations. NFPA 70 and NFPA 13 deal with electrical issues and sprinkler systems and are outside the scope of this document. NFPA 91-2010, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids* is referenced in OSHA spray painting codes and NFPA 33, however, this standard mostly deals with the mechanics of duct construction, clearances to combustibles, maintenance

and similar issues. The NFPA 91 standard does have some information on allowable concentrations of contaminates, the essential requirement being maintenance of flammable concentrations below 25% of the LFL.

With respect to spray booth design requirements, NFPA 33 *Standard for Spray Application Using Flammable or Combustible Materials* is the essential standard. The standard addresses almost all fire safety aspects of spray paint system design, including ventilation. The NFPA 33 standard in section 1.1.9 specifically states it is not intended to address ***"… the hazards of toxicity or to industrial health and hygiene."*** Clearly the intent of NFPA 33 is principally to address fire safety. Chapter 7 of the standard, entitled *Ventilation*, addresses safety ventilation of paint spray systems. This chapter specifies performance requirements such as collecting overspray and keeping solvent vapor concentrations below 25% of the LFL. Construction, support, routing and manifolding of ducts are also addressed. Section 7.3, *Make-Up Air*, requires an adequate supply of clean make-up air and specifies that the make-up air intake not be located such that exhaust air discharge can recirculate back into the fresh air intake. This section might be taken to prohibit recirculation of paint booths; however, that is clearly not the intent as section 7.5 of the standard, *Recirculation of Exhaust*, gives a number of requirements for paint booth recirculation as follows:

"7.5.1* Air exhausted from spray areas shall not be recirculated unless all of the following requirements have been met:

(1) Recirculation shall be allowed only for unmanned spray operation and for cascaded to subsequent unmanned spray operations,

(2) Solid particulates shall be removed from the recirculated air.

(3) The concentration of vapors in the exhaust airstream shall not exceed 25 percent of the lower flammable limit.

(4) Listed equipment shall be used to monitor the concentration of vapors in all exhaust airstreams.

(5) The equipment specified in 7.5.1(4) shall sound an alarm and shall automatically shut down the spray operation if the concentration of any vapor in the exhaust airstream exceeds 25 percent of the lower flammable limit.

(6) All equipment installed to process and remove contaminates from the air exhausted from spray operations shall be approved.

7.5.2* The provisions of 7.5.1 shall not disallow the use of recirculated air to occupied spaces. However, other requirements addressing the toxicity and the permissible exposure limits shall also apply. (See ANSI/AIHA Z9.7, American National Standard for the Recirculation of Air from Industrial Process Exhaust Systems.)"

Comparing the NFPA 33 booth recirculation requirements with those of the IFC indicates that the requirements are very similar. Items 7.5.1 of the NFPA requirements match item 1 through 1.4 of the IFC section 1504.7.2 requirements previously discussed. There are a few differences, however. NFPA 33 does not have a specific corollary to item 1.5, but the general NFPA 33 requirement to remain

below 25% of the LFL fulfills the same purpose. NFPA 33 adds the requirement that equipment used in the recirculation process be "approved", which under the NFPA's official definitions means acceptable to the authority having jurisdiction (AHJ). However, review of the system by the local AHJ would be a normal requirement of the International Fire Code also.

Paragraph 7.5.2 of NFPA 33 allows recirculation of paint booth air to occupied spaces, but indicates that air toxicity and exposure limits must be addressed. The standard directs the user to ANSI/AIHA Z9.7-*2007 American National Standard for the Recirculation of Air from Industrial Process Exhaust Systems* for guidance on this topic. ANSI/AIHA standards are next examined.

ANSI/AIHA Standards

As indicated in the codes and standards section of this report, there are several standards that are published by the American Industrial Hygiene Association that relate to paint spray booths and booth recirculation. Foremost is ANSI/AIHA Z9.3-2007 *American National Standard for Spray Finishing Operations: Safety Code for Design, Construction, and Ventilation* which is totally dedicated to spray finishing applications. This standard adopts many of the NFPA 33 requirements but adds requirements related to toxicity exposures of workers, indicating in section 4.3, ***"The toxicity as well as the fire and explosion potential of the materials being used, including their vapors and residues, shall be considered in determining adequate ventilation parameters."*** However, with respect to ventilation requirements, ANSI Z9.3 adopts the NFPA 33 requirements indicating in section 6.0 *General Provisions,* ***"Ventilation shall be provided in accordance with the provisions of Chapter 7 of ANSI/NFPA 33–2003."*** Further, ANSI Z9.3 completely adopts the NFPA 33 requirements with respect to paint booth recirculation in section 8.7, *Re-circulation:* ***"Air exhausted from spray operations shall not be re-circulated, except under conditions set forth in Section 5-5 of ANSI/NFPA 33-2003 and ANSI/AIHA Z9.7.*** Clearly there is no conflict between the ANSI/AIHA Z9.3 requirements and NFPA 33 requirements with respect to paint booth recirculation.

Both the NFPA 33 and ANSI/AIHA Z9.3 standards reference ANSI/AIHA Z9.7-*2007 American National Standard for the Recirculation of Air from Industrial Process Exhaust Systems.* According to this standard:

4.1 Specific design parameters shall be evaluated when air is recirculated within a building. These include the process itself and the toxicity of the materials in use…"

4.2 …To ensure proper air quality, effective occupant protection and satisfactory system performance, a pre-design "Hazard Evaluation" as defined in Appendix B of the OSHA Hazard Communication Standard shall be performed, documented, and incorporated into the design process….

4.2.1 Material Requiring Special Precautions

Exhaust air streams containing carcinogens, or highly toxic substances or materials with acute toxicity (such as sensitizers and asphyxiates) require special precautions. Those agents that do not have a suitable, effective air cleaning method capable of removing sufficient contaminant to achieve airborne concentration as low as 10% of the acceptable level shall not be recirculated.

Exhaust air streams containing highly toxic substances as defined in the OSHA Hazard Communication Standard, for which suitable, effective cleaning devices exist, shall not be recirculated unless the following provisions are met:

- ***There is a functioning CMD*** {Continuous Monitoring Device} ***in the exhaust air stream capable of detecting at least as low as 10% the acceptable level in the discharge ductwork.***
- ***The CMD shall be calibrated and maintained in accordance with the manufacturer's specifications.***
- ***There is a capability to direct the exhaust outlet to the outside or to a back-up air cleaning device in the event the air cleaner fails. Alternatively, the process could be shut down until repairs are made.***
- ***Air cleaning device failure will not result in an employee exposure above the acceptable level.***

The above ANSI/AIHA Z9.7 requirements indicate that a Hazard Evaluation as defined in Appendix of the OSHA Hazard Communication Standard (29 CFR 1910.1200 App B) must be conducted. This appendix to the OSHA standard outlines a performance based hazard evaluation but does not specify the exact methods that must be used in the evaluation.

The ANSI/AIHA Z9.7 standard also indicates that exhaust streams containing carcinogens or highly or acutely toxic materials must be capable of being cleaned to 10% of their "acceptable level". Acceptable level is defined by the standard as, ***"A concentration of contaminant in air in the workplace less than the levels allowed by the official agency having jurisdiction."*** Assuming that the OSHA Permissible Exposure Limit (PEL) would be an "acceptable level", this section would require filtration or cleaning to reduce return concentrations to 10% of the PEL. It is unstated, but presumed, that dilution by partial recirculation / partial fresh air supply (for example an 80/20 mix) would be considered an acceptable "***effective air cleaning method***". Potentially, other methods such as carbon or zeolite filtration could also be used to clean the recirculation airstream. If reduction to this level cannot be achieved, then recirculation cannot be used. If reduction to 10% of the PEL can be achieved, then a Continuous Monitoring Device (CDM) must be used to alarm and stop the process in the event of elevations in the concentrations above the 10% level.

The CMD requirement mirrors the monitoring requirements of the IFC and NFPA 33. Recalling from the review of the IFC and NFPA 33 standards that the solvent monitoring device was stipulated to limit the flammable vapor concentration to 25% of the LFL, this can be compared the CMD requirement in ANSI/AIHA Z9.7. Solvent levels required to reach 25% of the LFL are substantially greater than the PEL or TLV levels. For example, the OSHA PEL for toluene is 200 ppm TWA while the lower flammability limit in air is about 1.27% or 12,700 ppm. From this one can conclude that the ANSI/AIHA Z9.7 requirement to limit concentrations to 10% of the "acceptable level" is more stringent than the 25% of the LFL requirement. As such, the ANSI/AIHA Z9.7 requirements will typically be the limiting factor on the ventilation design of the manned recirculated spray booths.

OSHA Code

As indicated in the codes and standards section of this report, OSHA principally addresses paint spraying operations in two sections of the code, 29 CFR 1910.107, *"Spray Finishing Using Flammable and Combustible Materials.",* and 29 CFR 1910.94c, *"Ventilation, Spray Finishing Operations."* These requirements were derived from the NFPA 33 and ANSI Z9.3 standards from the 1960s and as such do not incorporate standards changes that have occurred over the years. OSHA typically recognizes standards changes via interpretations and policy directives issued in response to specific questions from the field.

Review of the above OSHA code sections would seem to preclude paint spray booth recirculation. For example, in 29 CFR 1910.107(d)(9) the code states, ***"Air exhausted from spray operations shall not be recirculated."*** However, OSHA has issued a number of interpretations over the years that indicate the practice is acceptable under certain circumstances. These interpretations center on OSHA's allowed use of updated consensus standards when the level of employee protection is maintained or enhanced. These variances from the strict wording of the code may technically violate the letter of the OSHA code, but have no negative effect and are considered "De minimis" violations. For example, specific to paint booth recirculation, OSHA issued a standard interpretation letter[7] in 2002 that indicated:

"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)."

In addition to the above, the same OSHA interpretation letter references use of ANSI/AIHA Z9.7 for the evaluation of the "toxicity and permissible exposure limits" as required by the NFPA 33 standard. Therefore, in terms of current policy, OSHA would appear to allow manned occupation of recirculated spray booths when the NFPA 33-2000 and ANSI/AIHA Z9.7 (or its equal) standards are followed. This will limit return recirculation air to toxic concentrations of 10% or less of the "acceptable level", presumed to be the PEL. Recirculation of unmanned booths would only have to maintain 25% or less of the LFL as indicated in recent editions of the NFPA 33 standard.

Typically, paint spray workers wear personal protective equipment to limit their exposure to paint overspray or other chemicals such as cleaning solvents. In some cases this equipment may include positive pressure ventilation where workers in the booth wear a respirator or hood supplied with clean pressurized breathing air from outside the booth. Using this equipment, workers could possibly work in the recirculated spray booth environment with toxic concentrations above the normal permissible exposure limits. The permissibility of this practice has been addressed by OSHA in a standard interpretation letter in June of 2002[8] which stated:

"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"…..

"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."

The June 2002 standard interpretation letter makes it clear that employee exposure must be limited per 29 CFR 1910.1000 *Air Contaminants*. To the extent "feasible", employers must use engineering and administrative controls to comply with the limits. Only when engineering and administrative controls are not feasible can personal protective equipment be used to supplement the control methods. The term "feasible" in not defined in the interpretation letter. Feasibility may apply to both economic and technical feasibility and, with respect to OSHA policy, has been the subject of legal action in the past. What seems clear is that employee exposure should be maintained within the limits of 29 CFR 1910.1000 *Air Contaminates* without reliance upon personal protective equipment unless clearly not feasible. Prudence would advise having a proposed design reviewed by local OSHA officials prior to execution if engineering and administrative controls are believed technically or economically infeasible. In any case, appropriate personal protective equipment should be used during all paint spraying activities.

Summary

Recirculation of paint spray booths is an effective method to minimize energy consumption, reduce capital expenditures and ease compliance with air pollution standards. The method is recognized by code making and enforcement authorities which have, for the most part adopted equal requirements based on the NFPA 33 and ANSI/AIHA Z9.7 standards. Manufacturers who consider adoption of paint booth recirculation must integrate these requirements along with other air quality and worker safety requirements. Local code authorities having jurisdiction, air quality authorities and workplace safety officials must be consulted during the design process to ensure a compliant and safe design.

Endnotes:

[1] Darvin Charles,; Paint Spray Booth Design Using Recirculation/Partitioning Ventilation, Volatile Organic Compounds (VOC) Recovery Seminar, September 16-I 7, 1998, Sustainable Technology Division, Technology Transfer and Support Division, Air Pollution Prevention and Control Division, National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency Cincinnati, OH 45268

[2] Deere & Company, "Paint Spraying Assembly", U.S. Patent No. 4266504, (May 12, 1981)

[3] Darvin, Charles; Proffitt, David; Ayer, Jackie. "Paint Spray Booth Design Using Recirculation / Partitioning Ventilation", Environmental Progress (Vol. 17, No.3) Fall 1998

[4] Ibid

[5] International Code Council website, "International Code Adoptions", September 26, 2010, http://www.iccsafe.org/GR/Pages/adoptions.aspx

[6] Occupational Health and Safety Administration website, Standard Interpretations, 10/22/2001 - Clarification of minimum face velocity requirements for spray booths. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=21875

[7] Occupational Health and Safety Administration website, Standard Interpretations, 9/17/2001 - Full compliance with NFPA 33-2000 may be considered a de minimus violation. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24016

[8] Occupational Health and Safety Administration website, Standard Interpretations, 6/24/2002 - Hierarchy of controls for exposure to air contaminants http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24185