METAL FINISHING VENTILATION DESIGN

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Introduction

Concepts of ventilation design, as they relate to the metal finishing industry, rest in a number of responsible areas. First and foremost is employee safety. Tank emissions must be controlled to prevent hazardous concentrations of gases, vapors, mists and dusts from building up in the workroom air.

The latest flurry of regulatory activity from Washington addresses air emissions. Now that same good exhaust air which protects workers must be scrubbed, filtered or otherwise treated before being released to the outside ambient air. In between these two ends of the ventilation path we have had other topics, such as energy conservation and resource recovery, to consider in deriving a final design concept.

Now we have a business era when all of these regulatory and operational pressures are coming to bear on the metal finishing industry at the same time. In today’s treacherous business climate any relief that a company can get from a pressing regulatory requirement might just be enough to help it hold on. By being able to downsize a chromium exhaust system from 30,000 to 20,000 cfm, a plater might be able to save $50,000 in capital and installation costs, possibly enough to help squeeze through a difficult financing situation. In a similar thought, excess heating requirements for large quantities of make-up air might cause someone to get completely out of one line of business or otherwise pass up what could have been a good business opportunity.

In this paper we hope to reveal some of those forces which make ventilation design a critical component in the survivability of the modern metal finisher. By understanding these various influences, the owner/operator will be in a better position to make sound technical and executive decisions regarding facility operation and design. The facility manager can no longer afford to use the old standards and old rules of thumb to dictate design. Whatever advantage that can be gained through improved capture concepts or more clever integration of resource recycling may very well be the edge that will enable one metal finisher to stand out over others.

Let us now look at the different elements which should make up the full design effort. Due to the range of considerations, we will not go into any deep detail. It is more important to be certain that the complete picture has been addressed.
OSHA Guidelines

The guidance for ventilation design starts with 29 CFR 1910.94 on Ventilation and subparagraph 1910.94 (d) on Open Surface Tanks. The concept of open surface tanks can cover anything from leather tanning to dip coating of rubber gloves, but for this presentation the discussion is limited to the surface finishing industry.

Note that in the initial statement I referred to the OSHA standard as a guidance document. It is most important that you clearly understand what we mean. When the rules and regulations of the Occupational Safety and Health Act were first promulgated around 1970, a good number of safe practices and guidelines were incorporated. What was once a guideline, now became law.

This was true of paragraph 1910.94 of the rules and regulations. If someone had a grinding operation, spray booth or open surface tank that did not meet the stipulated ventilation requirements, it was cause for citation under OSHA enforcement.

Later, after the concept of employee exposure became the realistic governing force, the ventilation section reverted back to its original position of a guideline. Around 1980 OSHA issued a field directive which stated that as long as no employee was exposed above the PEL, no employer should be cited under 1910.94 in the situation where the ventilation system otherwise fell short of the 1910.94 ventilation rules.

If employees were exposed to airborne concentrations above the PEL, and the 1910.94 ventilation criteria were not met, the employer would be cited and fined under both sections. The emphasis, however, had shifted back toward control of worker exposure and away from the concept of required design criteria.

Here is how the process works. The first element is recognizing the hazard posed by the toxicity of the contained chemical mixture. By referring to section 1910.1000 of the OSHA rules, one will find the Permissible Exposure Levels (PEL's) of the different chemicals making up the tank solution. These values are compared with the numbers shown in Table G-12 of 1910.94 (d) to determine the Hazard Potential of the solution. Operating conditions of the tank (i.e. temperature, electrolytic action, agitation, etc.) are then compared with the listings of Table G-13 to estimate the Rate of Evolution of the hazardous constituents from the tank. Those two criteria are then combined and matched against basic hood designs and relative dimensions in Table G-14 and Table G-15 to determine the relative exhaust rate.
This process is repeated for each tank in the line until a system has been defined. Unfortunately this analysis contains a flaw that is just as important as recognizing that paragraph 1910.94 is only a guide. There is no allowance for concentration. Using this procedure a very dilute solution of a hazardous ingredient would be controlled to the same degree as a highly concentrated solution.

In fact we have seen proposals by equipment suppliers recommending that a hot dichromate seal tank containing 500 parts per million of sodium dichromate be vented in the same manner as a hard chromium plating tank. This is totally absurd! The potentials for worker exposure at these two operations are worlds apart. Certainly a chromium plating tank, containing 32 ounces of chromium trioxide per gallon and presenting a high amount of misting due to electrolytic action, needs a high amount of exhaust ventilation control. Placing a piece of anodized aluminum in a hot chromate seal solution offers no measurable exposure to the worker.

This is where the metal finisher must begin to search. Fairly reasonable reductions in ventilation design capacity can be achieved without jeopardizing the safety of the worker. When we start to factor in concepts of production rate and specialized hood design, the savings can be multiplied.

**Emission Controls**

To this point in the history of the Clean Air Act, metal finishers have been relatively free of regulatory impositions. The exception has been those states which proceeded on their own to develop standards for controlling what has become known as the "air toxics". These are for the most part the four hundred or so toxic chemicals listed in various registries, such as the OSHA Z-tables. California, New Jersey and Connecticut are examples of states presently enforcing requirements for controlling emissions of toxic air pollutants.

The brunt of this emission control effort has been felt by the chromium platers. The level of control imposed by the respective agencies has required the installation of particulate removing devices. Wet scrubbers have been available for some time to remove chromic acid mist as well as other offensive emissions from exhaust air streams, but state agencies requiring the application of best available control technology, commonly referred to as BACT level control, have in effect forced the application of multi-stage fabric mist eliminators.
These are typically 3-6 inch thick battings of polyolefin polymer fibers. The density of the packing is sufficient to remove micron-sized mist particles. A single stage mist eliminator of 6-inch batting is capable of removing 95% of chromic acid mist from an air stream.

One difficulty in selecting control equipment arises in attempting to understand what the regulatory agencies are looking for in terms of the level of control. In the Clean Air Act revisions of 1990 the federal government has defined BACT as 95% removal efficiency under a proposed early compliance plan covering chromium platers. California, which typically leads everyone else in calling for the most severe control technology, has applied a production-based standard that has in essence pushed BACT above the 99% removal efficiency level.

The cost of such control equipment has grown dramatically with increased control efficiency. A simple wet fan separator or single pass mesh pad could provide 95% removal efficiency at a cost ranging around $1-$2 per cfm. Now high efficiency mesh pads with automatic or manual spray down systems and high pressure blowers will provide +99% removal efficiency, but only in the range of $4-$5 per cfm. The larger horsepower blower motors and more extensive routine service requirements add new operating expenses to the higher initial capital investment.

The application of emissions control equipment needs careful consideration. The facility director must determine exactly which air streams must be controlled and to what degree. All too often equipment suppliers appear ready to install an acid scrubbing system, an alkaline scrubbing system and a heavy metal system when in fact only one tenth of what is proposed may actually be required. Extraordinary capital outlays for oversized or unnecessary control equipment and increased operating expenses to support that equipment are the business impediments which must be overcome.

Design Considerations

When I was in industry, the aerospace corporation for which I worked agreed to take a close look at its plating operations to see whether or not significant savings could be realized from the controlled application of exhaust ventilation. This was the time of the Arab oil embargo, when energy conservation was a national priority. All business entities, both labor and management, were working together for the common good.
The basic speculation was that existing ventilation design guides were built for worst case conditions. If a company were plating hundreds of car bumpers per hour at high current densities, and the exhaust ventilation system were designed to the listed guidelines, the workers involved with that operation would be adequately protected.

Given that basic premise, we further speculated that if a company were doing specialty plating, such as small areas of complex aerospace components, using low current densities, the amount of exhaust ventilation needed to control process emissions should be much less. In other words the standard ventilation guidelines would provide a high degree of overkill relative to the true needs for emission control.

There was a distinct possibility, therefore, that the amount of ventilation could be reduced without jeopardizing the safety of the worker. The resultant savings in heated make-up air and electrical power for the blowers would be significant and everlasting.

We then embarked on a program of testing and evaluation to see what could be accomplished. The air flow at each tank was measured and compared with the design criteria previously described. At the same time air monitoring was performed on the platers and at the tanks to characterize typical airborne concentrations of hazardous ingredients.

For the most part personal monitoring of the workers was a waste of time. They actually spend such little time at any tank that rarely, if ever, was a measurable reading obtained. Area monitoring right at the tank proved more useful. In general we found that the amount of airflow sweeping across any one tank could be reduced below the recommended limits with no observable increase in airborne contaminants.

Now if we add considerations for the concentration of the hazardous agent in the solution and factors effecting the misting rate, we can see that the old bibles of ventilation design are not necessarily your best friend. Eighty percent of the electrical power of chromium plating is lost in the formation of gas bubbles which rise to the surface of the solution developing into a mist that must be controlled. Chromic acid anodizing, conducted at one-tenth the current density of plating, generates far less mist.

Certain basic design features of the tank improve the situation. By using a long narrow tank and exhausting across the short side, a lower slot velocity can achieve a higher capture effect at the front of the tank. A higher freeboard between the liquid level and
top edge of the tank gives the emanating mist more chance to slow down. This means that a lower capture velocity can be used to control that mist.

Air agitation offers design considerations for evaluation in this same setting. One of our more significant headaches came out of a best intention. At one site, where we were involved with the design of a new plating department, a fine aeration tube was installed at the bottom of the new anodize tank. Instead of getting the typical rolling boil observed in typical air agitation systems, we would get a fine diffuse gassing which should provide more uniform mixing.

Unfortunately it also formed a mist which was extremely difficult to control. The older air wand formed large particles which might occasionally splash out of the tank, but for the most part fell back into the solution. The very fine mist formed during plating behaved like a gas, making it controllable with the capturing air flow. The mist generated by the new dispersion tube turned out to have a perfect particle size to give it enough kinetic energy to pass through the capture flow of the ventilation system but insufficient mass to fall back into the tank.

Often a significant potential for exposure arises during the period of solution make up, when various dry powders or concentrates are added to the water in the tank. Once the solution is mixed, and the tank is in operation, the exposure potential may be low. The exposure comes in weighing out the raw chemicals and then pouring them into the tank.

It might be better to rely on personal protective equipment, or a designated mixing tank, to provide the higher degree of protection needed for this specific operation. A specifically controlled mixing station appears even more appealing in the light of the new OSHA cadmium standard. Under the stringent controls of that regulation, it becomes extremely burdensome for an employer to allow a potential exposure above the Permissible Exposure Level (PEL) of 5 micrograms per cubic meter of air.

Instead of increasing the ventilation rates at the cadmium plating tanks to the highest rating to match the new hazard potential, it would probably be more cost effective to set up an isolated weighing/mixing station. That location could have a separate ventilation system to keep dust levels below the PEL (or even the Action Level). As a separate system the ventilation could be shut down when the mixing station is not in use. Then it would merely be a matter of transferring the pre-mixed make up to the appropriate run tank using a pump or container arrangement.
All of our examples so far describe conditions where reductions in exhaust ventilation can be made in order to realize capital and operating expense savings. In general we have challenged the old design concept of bigger exhaust is better. To be fair, however, we must caution that there are circumstances where reductions may not be feasible. In fact for one operation, aluminum bright dipping, old handbooks are inadequate.

In aluminum bright dipping a hot solution (+200 F) of a strong phosphoric acid mix containing 2-5% nitric acid is used to rapidly etch aluminum. The resulting chemical reaction is quite exothermic, and molar quantities of gases are formed as reaction products.

A tremendous amount of outgassing takes place within seconds. It is barely possible to get one rotation of a barrel completed, before the extreme frothing action pushes the barrel up out of the tank. Even with the highest rated standard exhaust design, the escaping gases are projected far beyond the range of influence of the ventilation flow. Special hood configurations and design concepts are generally needed to control these emissions totally.

The point of this review has been to alert metal finishers to the basic fact that good exhaust ventilation design may be a major factor effecting their survivability. They can no longer afford to relinquish the responsibility for system design to the sheet metal vendors who fabricate and install ducting and hoods.

By using the water from the first rinse tank to spray down the batting of the dry mist eliminators previously described, the chromium plater can conserve water and recycle the captured chromium as make up. A concept such as this must be achieved through total system integration, not sheet metal design.

The modern metal finisher must be prepared to challenge the old rules regarding ventilation design in order to get peak efficiency out of his or her operation. Understanding these design concepts and applying them judiciously to the various processes has become as important as buying the proper rectifiers or obtaining the best financing.