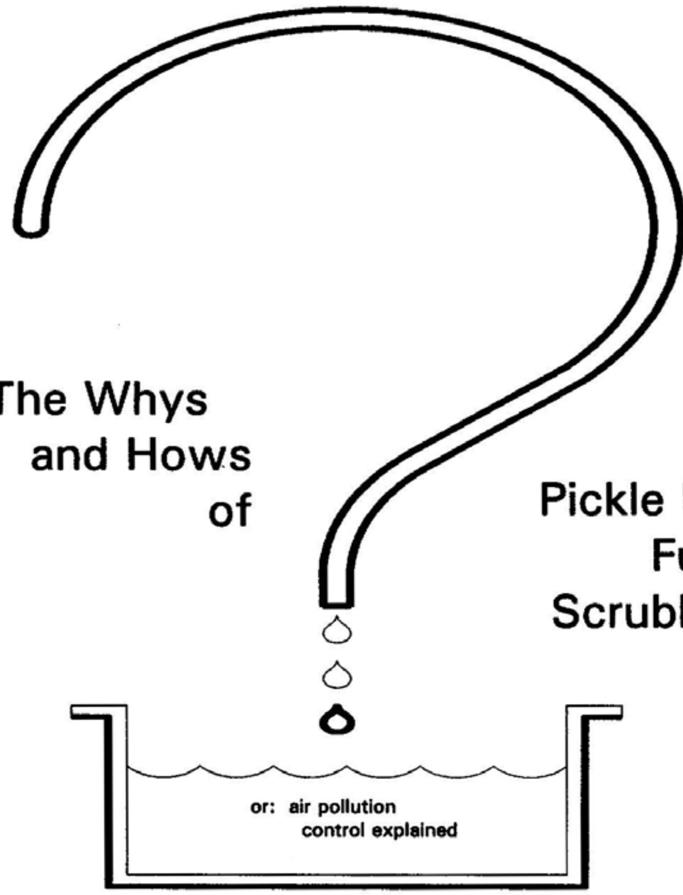
The Whys and Hows of Pickle Line Fume Scrubbers



or: air pollution control explained

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April 1998 Edition

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TABLE OF CONTENTS

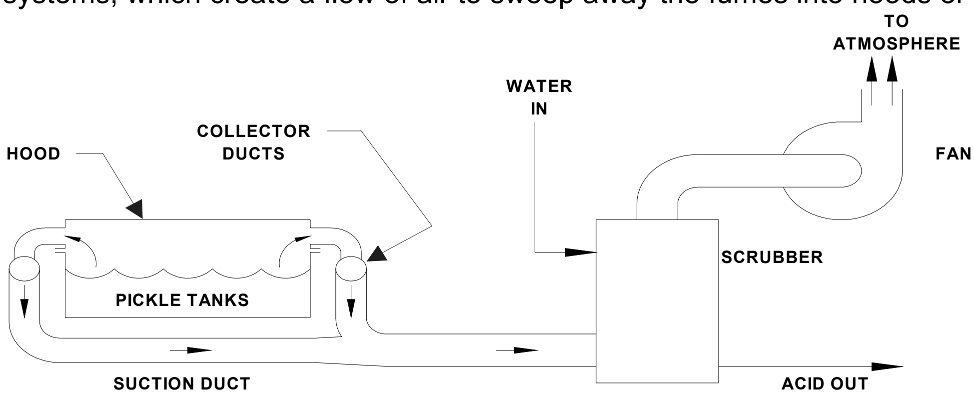
Introduction

This manual is a practical guide, in simple terms understandable by the pickle line operators and supervisors, to fume scrubbers - what they do, how they work, what attention they need, and how they fit into the overall pickling operation. It is not a technical paper on fume exhaust or scrubber system design - there are other Esco publications which give more technical detail for any interested readers.

Scrubbers - who needs them?

All pickle tanks emit acid fumes from the surface - these fumes are created by both the natural vapor pressure of the acid at the warm temperatures used to increase pickling speed, and minute droplets generated at the tank surface by the bursting of hydrogen bubbles, which are produced by the action of the acid on the metal.

If these fumes are allowed to escape into the building, they are a potential health hazard for operators, and can also cause serious corrosion damage to mill buildings and equipment - especially electrical equipment - and to finished product in storage. To prevent these problems, pickle lines are usually equipped with induced draft (suction) fume exhaust systems, which create a flow of air to sweep away the fumes into hoods or covers.



Typical fume exhaust system

The fume exhaust air is now contaminated with acid fumes, and must be cleaned, both to meet pollution control regulations, and also to avoid simply transferring the health and corrosion problems to the outside of the plant. Removal of the acid fumes from the air is the job of the fume scrubber - without a scrubber, the problem has merely been moved to another location; with it, the exhaust air is cleaned of acid to a safe level.

So who needs a scrubber? You do!

The scrubber story

There are as many types of scrubber as there are inventors. This review sticks to the mainstream, and describes the most common types and applications. But, for every rule there is an exception, and nothing is certain.

What do they do?

There are many other gas cleaning devices, besides fume scrubbers - baghouses, electrostatic precipitators and entrainment eliminators for example - so why are wet scrubbers always used in pickling applications? The answer lies in that little word *'wet'.*

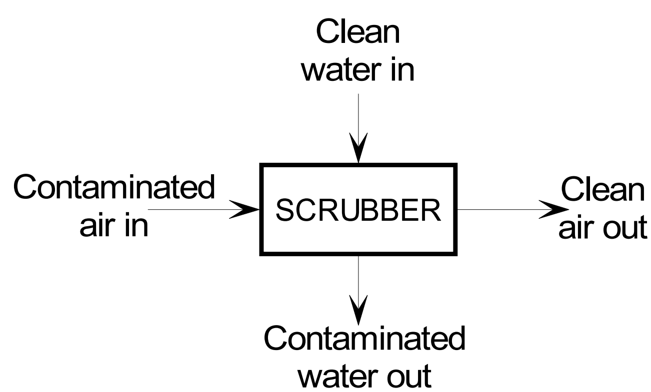
The air coming off the pickle tank exhaust system is always wet from the steam and droplets of acid coming off the tank surface. It is also extremely corrosive - even dilute solutions of pickling acids are corrosive to normal materials. Even if the air was dry, it would still be necessary to add water to absorb the acid gases. All of these factors favor the use of simple, corrosion-resistant wet scrubbers, over more complex mechanical devices.

Water is the universal scrubbing medium - it is plentiful, cheap, non-toxic, non-corrosive and widely available, and readily dissolves or mixes with all the common pickling acids.

In a scrubber, the corrosive acid fumes - gases or droplets - are transferred from the air stream to the scrubbing water. This transfer is the result of turbulent contact between the air and the water - different types of scrubber use different ways of bringing about this contact. Soluble gases, like hydrochloric or hydrofluoric, dissolve in the water; acid droplets, like sulfuric, impact on the water, and mix with it.

There must always be some acid fumes in the gas stream to make them dissolve, even in pure water. This means that **no scrubber can ever be 100% efficient** - we can come as close as we like, by using bigger scrubbers, but never attain 100%.

This is why the fume exhaust equipment, even after the scrubber, must always be acid-resistant, and also why it is not a good idea to try and return scrubbed air to the pickle house.



What a scrubber does

So what do fume scrubbers do? They take acid fumes out of air, and transfer them to water. They clean air, and contaminate water!

How do they do it?

The purpose of a fume scrubber is to contact a lot of air with a little water. For example, a 20,000 cfm air flow will only need 2-6 gpm of water to dissolve the acid fumes, so, because 20,000 cfm is equal to 150,000 gpm, what the scrubber has to do is mix 150,000 gal of air with 2-6 gal of water - a formidable task!

To do this, there are two basic methods:

- divide the water up into numerous small droplets which are dispersed in the air.
- create small bubbles of air passing through a pool of water.

The first of these is the way packed scrubbers work; the second is the way plate scrubbers work.

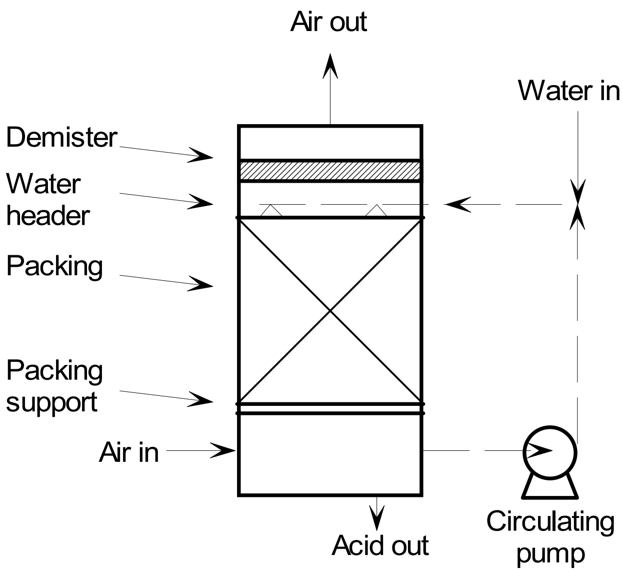
Using droplets - packed scrubbers

The obvious way to disperse the water into the air as droplets is to simply spray the water into an empty vessel through which the air is passing - what could be simpler or less trouble? The problem with this is that the spray pattern soon breaks up, the droplets agglomerate or hit the scrubber walls, and the contact between gas and liquid is inefficient. To avoid these problems, the liquid is dispersed by running it over *packing* - a bed of small, hollow, plastic or ceramic shapes, designed to keep renewing the splashing and breakup of the water, while at the same time making a longer and more tortuous path for the air to travel.

These shapes are referred to as *random packing.* There are other, more expensive types of packing, called *structured packing* which are more efficient, but also more difficult to install and maintain. Structured packing is not generally used in pickling scrubbers.

Figure 1 shows how this is done in practice in a typical packed scrubber. The water is delivered to the top of the packing bed, and runs down, by gravity, splashing over the packing, while the air enters the bottom of the scrubber, and is washed by the water as it passes upwards through the bed. This illustrates also the very important principle of *countercurrent flow*, whereby the most contaminated gas contacts the most contaminated water at the bottom of the scrubber, and the cleanest gas contacts the cleanest water at the top of the scrubber.

To get even flow and good contacting of air and water, the water has to be distributed evenly over the top of the packing bed - this is usually done by a distribution header, equipped with spray nozzles. Also, to ensure that the gas can flow through the whole bed, the packing is held up by a packing support. This packing support has to be open enough to allow the water and air to pass through without creating too much pressure drop, while still being strong enough to hold the packing up, even when it is dirty, and flooded with water.



Components of a packed scrubber
Figure 1

Figure 1 also shows a couple of disadvantages of packed scrubbers. The main one is that, in order to function properly, the packing needs quite a high water flow rate - about 200 gpm of water for 20,000 cfm of air. Providing this flow as fresh water would be very expensive, and would also produce 200 gpm of slightly contaminated effluent, which would have to be treated. So, instead of using fresh water, most packed scrubbers have recirculation pumps, which pump the water from the bottom of the scrubber to the top of the packing. A small, continuous, flow of water has to be added to the scrubber to purge the acid removed from the gas stream, through the overflow. The disadvantages of this are:

- the pump requires maintenance.
- the water at the top of the packing is now contaminated, so the advantages of countercurrent flow are no longer obtained.
- any dirt in the water is pumped back into the packing, where it may separate and block the distribution header or the packing.

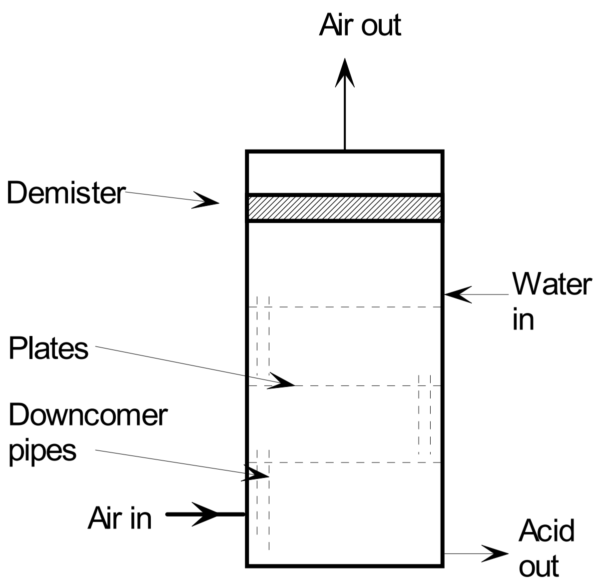
Higher scrubbing efficiency can be obtained in packed scrubbers by increasing the depth of the packing bed.

Using bubbles - plate scrubbers

The obvious way to bubble the air through the water is to inject the air into the bottom of a tank, through small holes. Like the spray tower idea for droplets, this is inefficient, because the pressure drop needed to force the air through the water is very high, and also the bubbles tend to agglomerate and grow.

Instead, the water is flooded in a shallow layer on a plate full of small holes, and the air passes upwards at high speed through the holes. The flow of the gas prevents the water from falling through the holes, and, at the same time, creates violent agitation of the water on the tray, so giving very good water/air contact.

Figure 2 shows how this is done in practice. A single plate is not usually enough to give a satisfactory efficiency, so several plates are installed in a tower. The water needed to purge out the dissolved fumes is delivered to the top plate and, because it is prevented from falling through the holes in the plate by the air flow, this water overflows the outlet weir, and runs through a downcomer pipe to the inlet side of the plate below. This process is repeated for each plate, until the contaminated water is discharged from the bottom plate.



Components of a plate scrubber
Figure 2

Because the water forms a pool on each plate, a high flow of water is not needed for efficient contacting - a small flow is needed to flush out dissolved fumes, and also to offset a little weeping that occurs through the holes, due to surface tension effects. In general, recirculation pumps are unnecessary on plate scrubbers, and these scrubbers operate in true countercurrent flow.

Plate scrubbers are simple and have no moving parts, but require careful installation, to ensure the plates are level, and a steady air flow.

Higher scrubbing efficiency can be obtained in plate scrubbers by increasing the number of plates.

Undoing the mixing

Scrubbers promote intimate mixing of air and water - but we want this mixing to be confined to the scrubber. It would be disastrous if the air and water stayed mixed, and discharged together from the stack - this would give a whole new meaning to the term ‘acid rain’. For this reason, a key element of a scrubber - shown in both Figures 1 and 2 - is the demister. This is a device that ensures that the air leaving the scrubber is as free as possible of water droplets.

Demisters all work on the principle that air can change direction much more easily than water drops. By guiding the air through a channel or maze with several changes of direction, the water droplets are made to impact on a solid surface, where they build into larger drops, which are too heavy to be carried by the air.

There are two main types of demister:

- knitted mesh
- chevron

The knitted mesh type is simple to handle and install, and separates the water by agglomerating it on fine plastic fibers. Its disadvantages are that it tends to remove dust, as well as water, and the fine plastic fibers deteriorate in time. Eventually (3-5 years), the accumulated dust and fiber debris plug up the demister, and it has to be replaced.

The chevron type of demister consists of a bank of parallel, S-shaped blades, through which the gas passes - the water is removed by impact on the blade surface. This type of demister is not susceptible to plugging, and has an almost unlimited life.

Both types of demister will remove over 99.99% of the droplets created in wet scrubbers.

Which model do you prefer?

No type of fume scrubber is inherently better than any other. Given a specified flow rate and efficiency, a scrubber of any type can be designed to meet the specs. Factors which may affect the final selection include:

- available space
- available pressure drop
- range of operating air flow
- maintainability
- location
- cost

Here, we summarize the pros and cons of different scrubber types, as applied to pickling.

Packed

The packed scrubber has, for many years, been the workhorse of fume scrubbers. Before the development of modern plastics, the only way to build an acid-resistant scrubber was to use ceramic packing in a rubber/brick lined shell. Nowadays, packed scrubbers are lighter, cheaper and more corrosion-resistant thanks to the development of FRP and thermoplastics materials.

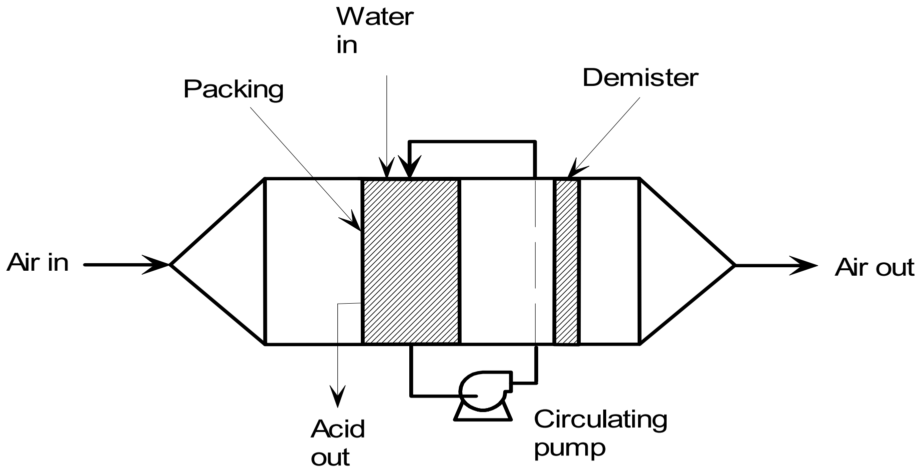
There are numerous scrubber vendors, with standard catalogue packed scrubbers, in a wide range of materials.

The packed scrubber's strengths are its simple construction, toleration of poor installation, and ability to operate over a wide range of gas flow rates.

However, to keep a packed scrubber running at design efficiency (as opposed to just 'running' i.e. having the air flow through it) requires a significant maintenance effort to keep the circulating pump going, ensuring that the water distribution on to the packing is even, and keeping the packing clean.

Cross-flow

The conventional packed scrubber is a vertical tower, with the air flowing up, and the water running down. A variation on this is the cross-flow scrubber, Figure 3. In the cross-flow scrubber, the air flows horizontally through the packing, while the liquid



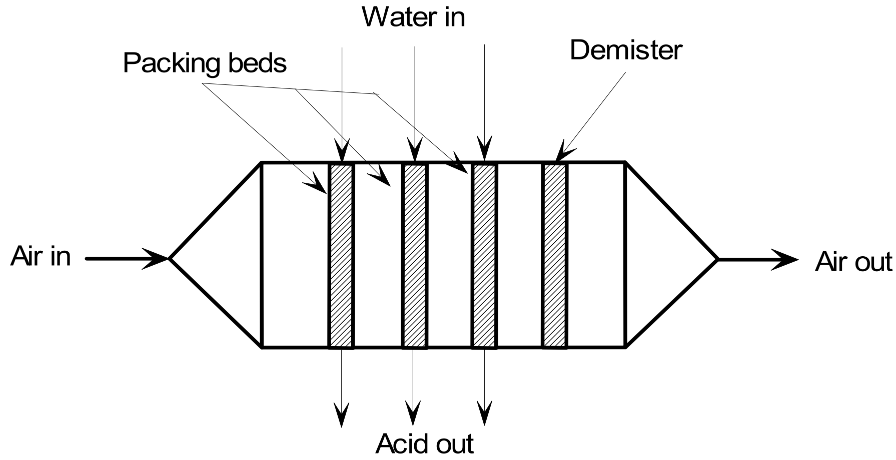
Components of a crossflow scrubber
Figure 3

still flows down, across the flow of the water. The basic set-up is the same as for conventional packed scrubbers, and a circulating pump is still needed to keep the packing wet.

The advantage of the cross-flow scrubber is that it needs less head room, and the ducting is usually simpler and less-expensive than for a vertical scrubber. However, cross-flow scrubbers are slightly less efficient than vertical counterflow when removing soluble gases.

An advanced type of cross-flow scrubber emulates the multi-stage scrubbing of a plate scrubber. In this version, Figure 4, there are several packed beds in series. Each bed has a separate water supply, or circulation system, and may use a structured packing, rather than a random one.

The advanced type of scrubber has quite a high pressure drop, and is not, presently, used in pickling applications. Random packed cross-flow units are widely used.



Components of a multi-stage crossflow scrubber
Figure 4

Plate

Plate scrubbers for corrosive duties were not really feasible until the development of modern plastics materials, and are therefore relatively new in pickling service (plate scrubbers have been used for non-corrosive services for over a century).

There are therefore relatively few vendors of this type of scrubber, and plate scrubbers are usually custom-designed for the application.

The plate scrubber's advantages are its low maintenance requirements, and once-through flow of water, which is useful in making high strength solutions for recycle. However, a plate scrubber needs careful installation (to level the plates), and has a limited range of air flow variation.

All that is needed to keep a plate scrubber operating at design efficiency is the proper flow rate of water to the top tray, and an air flow rate within the designed range.

Fighting corrosion

Acids used in pickling are, naturally, highly corrosive. This means that the whole fume exhaust system must be corrosion resistant against the pickling acid solutions. Some common misconceptions are:

> *"The acid is very dilute, so it won't be so corrosive" WRONG!* Dilute acids are frequently even more corrosive than concentrated acids.
>
> *"There is no acid after the scrubber" WRONG!* No scrubber is 100% efficient, so there is always acid right up to the tip of the stack, especially if the scrubber is not being operated correctly.
>
> *"Use a coated fan impeller, there's not much acid there"! WRONG!* This is the last place to be taking chances - one nick in the coating, and the impeller is history.

"We can always use stainless steel" WRONG! Of the common pickling acids, stainless will only stand up to sulfuric at low temperatures (100°F or below).

Fortunately, we have a large number of engineered plastics materials to choose from nowadays. Many of these have excellent acid resistance, good mechanical strength and can be easily fabricated. Plastics are ideal materials of construction for fume control systems and scrubbers, but some plastics are better than others.

PVC is widely used, and is quite cheap. It has a nominal temperature limit of 140°F, but will distort at temperatures below this if continuously stressed. Also, after a year or two in service, PVC tends to become brittle , and is liable to be easily damaged.

Polypropylene is, in many ways, the best material for scrubbers and fume control. It is relatively inexpensive, has good temperature resistance, long life, and is easy to fabricate. Material for use outdoors needs to be U-V stabilized. The downside to polypropylene is its flexibility - it needs to be quite thick to provide good strength.

Fiberglas reinforced plastic (FRP) using polyester or vinyl ester resins is strong and long-lasting, and has good temperature resistance. FRP is truly corrosion-resistant on the contact side - the other side has some corrosion resistance, and will not be damaged by atmospheric corrosion, but is not resistant to immersion or continuous contact. Like polypropylene, FRP needs a U-V stabilizer for outdoor service.

Other plastics materials and exotic alloys and metals are used in special applications, but most systems are made of the three basic plastics.

Finally, remember that **all** the system must be corrosion-resistant - don't be tempted to put a steel nipple in for sampling, just because it's only a small connection - it will corrode just as fast.

Pickling applications

What do we need?

The job to be done by a pickle line fume scrubber depends on the type of acid being used, the type of pickling system, and the quality and size of the fume exhaust system. Batch picklers usually have low acid concentrations in the fume collection system, because of the large exhaust volumes needed to control open tanks. Continuous strip picklers with closed covers use much lower exhaust volumes, and have medium acid concentrations, while tower picklers also have lower exhaust volumes with high acid concentrations because of the acid sprays.

HCl - the invisible scourge

Hydrochloric (muriatic) acid is widely used for pickling carbon steel strip, wire strand, for some rod coil and for some galvanizers. This acid is very corrosive to all metals, and requires very good fume control, if the pickling system and surrounding buildings and equipment are to be protected.

Hydrochloric acid is so aggressive because it is a gas - hydrogen chloride (HCl) - dissolved in water. When this gas escapes into the building, it spreads through the air until it reaches a puddle or droplet of water in which it can dissolve. This water may well be condensation behind the building insulation, or on an electrical box - as the HCl gas dissolves, it re-forms very corrosive hydrochloric acid, which damages the building or equipment.

To control this acid, we need to arrange for it to contact water inside a scrubber. Here, it is quickly dissolved and removed from the air before it can attack buildings and equipment. For HCl scrubbing, plate and packed scrubbers are both widely used and suitable devices, but plate scrubbers have the advantage that they produce a small volume of fairly strong acid, which can be returned to the pickle tank as recovered acid. This recovers the acid, which would otherwise be wasted, and so reduces the cost of waste treatment.

One problem that can sometimes arise in HCl pickling is the formation of aerosols - very fine droplets of liquid, that flow like a gas, but are already liquid. The particles will go right through a conventional scrubber completely untouched. The reasons for formation of these aerosols is not well understood, but they seem to appear if the exhaust gas from the pickle line is very warm, and is suddenly cooled, for example, by mixing with a colder stream of air. This will usually only happen in high temperature strip lines which have very tight fume covers, or in acid regeneration plants.

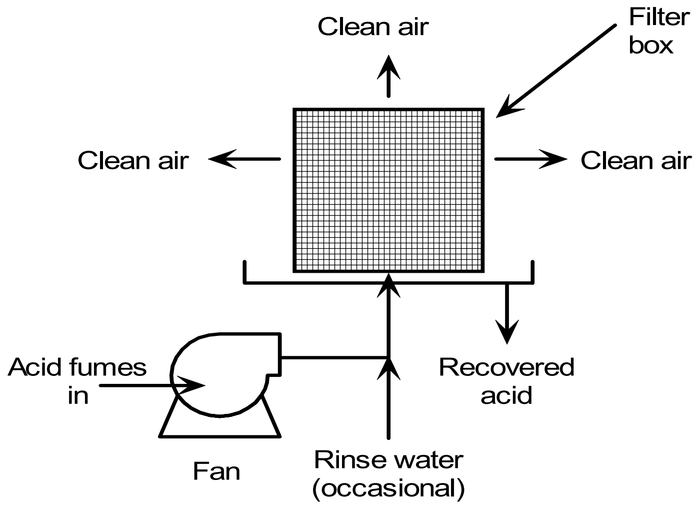
The best way to deal with HCl aerosol is to not make it - change process conditions to avoid forming an aerosol. If this is not possible, then a high energy scrubber (such as a venturi), a cooling scrubber or an agglomerating filter must be used.

Sulfuric - fine drops

Sulfuric acid tanks do not emit acid vapors, but they do generate very fine droplets - almost aerosol size. These droplets are produced by the bursting of very fine hydrogen bubbles, which are created in the pickling process by the action of the acid on the steel, at the surface of the tank. These droplets are the acrid fume which can be smelled near sulfuric pickling tanks.

The droplets are not fine enough to be true aerosols, but are too fine to be removed in a conventional entrainment eliminator. Removal of the droplets is a purely mechanical process - the acid droplets have to impact on a surface, and caused to agglomerate until they are large enough to separate from the air. Packed and plate scrubbers have been successfully used for this purpose, and, in this application, cross-flow scrubbers are just as efficient as vertical counterflow towers.

Another device which has been used successfully for sulfuric acid removal is the fume filter, Figure 5. In the fume filter, the air passes at low velocity through a compacted fibrous bed. As it flows through, the droplets impact on the fibers,



Sulfuric acid fume filter system
Figure 5

agglomerate, and eventually become large enough to drain away by gravity. Of course, such an efficient filter also removes dirt and dust from the air, so it requires washing at regular intervals to remove this dirt. However, while packed and plate scrubbers usually use several gpm of water on a continuous basis, the filter only uses 30-50 gal/day for rinsing, and this water can be returned to the pickle tank - truly a ‘no-effluent’ scrubber.

Nitric/HF - but not NO_x

Stainless steel and titanium pickling both use mixed nitric/hydrofluoric acids for pickling. Nitric acid is a low boiling liquid, and hydrofluoric acid (HF) is a gas, like HCl, so these tanks emit vapors. In addition, they discharge droplets, generated by the bursting of nitrogen oxide (NO_x) bubbles - however, these droplets are not so fine as the sulfuric droplets made in steel pickling, and are less of a problem.

The nitric and HF vapors and droplets are easily removed in a packed or plate scrubber, using a small throughput of water. The NO_x gases are not easily removed, however, because they are not very soluble in water - unfortunately, these gases are dark brown in color, and are highly visible.

One problem that can occur in HF scrubbers is scaling, caused by the deposit of insoluble calcium fluoride. This is produced by the reaction of hard (calcium-bearing) water with the hydrofluoric acid, and can plug up the packing, the outlet pipes, downcomers or re-circulation piping. The best way to avoid this problem is to install a water softener to remove the calcium from the supply to the scrubber.

The NO_x problem

Dark brown nitrogen dioxide (NO_2) is one of the main components of NO_x, and this creates a visible exhaust from the stack at very low concentrations - typically in the range 70-200 ppmv in industrial conditions. At this low concentration, the NO_2 is only slowly soluble in water, and requires a very large scrubber. Furthermore, the NO_2 reacts with the water to produce other oxides of nitrogen, which are then released back into the air.

In order to deal with these problems, NO_x absorption systems use large, multi-tower scrubbing systems, with special chemical solutions used for absorption. These are very expensive to install, and complex to operate, so there is a strong incentive to try and avoid generating NO_x and to minimize its visibility - most places in North America do not limit NO_x emissions, but do limit the stack color.

What to do depends on the application - some techniques that have been used include: reducing pickling temperatures; adding hydrogen peroxide or urea to the pickle tanks to suppress NO_x formation; and dispersing the NO_x in several small stacks to reduce visibility.

Specifying a scrubber

If you need to purchase a fume scrubber, it is important for you to specify what you need. You are responsible to the regulatory authorities for the permitting and operation of the scrubber. If you just say 'we want a scrubber for pickling ....', and provide no other data, then you have no come-back on the vendor if your scrubber is designed on the basis of conditions in some other pickle line.

In the following paragraphs we explain the information required for proper design and selection of a scrubber. If you do not have this information, then, before specifying a scrubber, contract with the vendor or an independent engineer to obtain it.

How much is going in?

The main factor in sizing a scrubber is the required air flow capacity. This will usually be the same as the design capacity of the exhaust fan. The next most important consideration is the concentration of the acid fume in the entering air. This must be measured or estimated (using our emissions spreadsheet - see 'Want to know more?' on page 29), so that the correct water flow and scrubber efficiency can be determined.

What efficiency?

Most often, the regulations require that emissions from the stack are less than a specified concentration or amount. In order to meet this requirement, the scrubber inlet concentration must be carefully specified, because, once designed, scrubbers are essentially constant-efficiency devices. If the inlet concentration is higher than expected, the outlet concentration will be proportionately higher, and may be out of compliance.

The new NESHAP rules for HCl scrubbing depart from this practice, in that they specify scrubbing efficiency. For such scrubbers, specifying the inlet concentration is less critical - however, a general idea of the inlet concentration is needed for determination of scrubbing water requirements.

Other information

Your vendor will be able to select the most economical scrubber for you if you provide more information about your system, like:

- your exhaust fan specifications, or, if you prefer, the allowable pressure drop through the scrubber - usually you should expect a 4" to 6" w.c. pressure drop.
- what you plan to do with the scrubber effluent - water economy is much more important if you plan to return it to the pickle line, than if you are neutralizing it.
- any space limitations.
- will the scrubber be indoors or outside.

Regulations!

You should state, quite specifically, what regulations are to be met, or what emissions limits are required. Using such general phrases as 'shall meet current Federal, State and local EPA regulations' is too general. Many of these regulations can only be interpreted in terms of the specific conditions in your plant. Ultimately, you are responsible for the performance, not the vendor, so you should know what the target is.

Testing

It is a good idea to make a compliance test after start-up, done in accordance with the EPA-specified methods, part of the scrubber deliverables. This is especially true for HCl scrubbers, where the new rules require a compliance test after start-up. But, be aware, these tests are expensive, so do not expect the vendor to throw them in free of charge.

The rest of the system

The scrubber is only one part of the fume control system - its function is to clean the air before it is discharged outside the plant. There are other important items that are needed for proper and environmentally sound fume control.

Controlling fumes

Before the scrubber can clean the fumes from the air, these fumes must be collected - this is the job of the fume control system. Fume control systems are often referred to as *fume exhaust or fume extraction* systems - however, what we really want to do is *control* the fumes to prevent them getting out into the plant, not *extract* them. Extracting fumes only causes more operating expense by removing steam and acid from the space above the pickle tanks - heat and purchased acid are then wasted as the pickle tank replaces the extracted fumes. Ideally, there would be **no** fume exhaust - the tank would be completely closed, to prevent escape of steam and acid. However, this is rarely a practical solution, so fume control systems are required.

The purpose of fume control is to *prevent the escape of fumes* into the plant. This is done by ensuring that air flows in through all openings, so that fumes cannot flow out. The best control is obtained when the extraction ducts are located close to the openings - this minimizes the amount of air being drawn over the surface of the tank, where it picks up steam and acid. A small flow of air drawn from the right places is a lot more economical and efficient than a large flow drawn from the most convenient place.

It is not uncommon for owners to look for problems with the fume scrubber if the plant atmosphere becomes contaminated. This is a mistake - the fume collection system has to collect the fumes before the scrubber can remove them.

Waste treatment

The scrubber does not get rid of the fumes in the air - it simply cleans the air by transferring the fumes from the air to a water stream; it turns air-pollution into water-pollution! When designing or specifying a scrubber, it is important to think about what will be done with the effluent water. Ideally, it can be returned to the process - especially if the quantity can be kept low. If not, the effluent may be of use for scrubbing some other air stream, it may be locally treated, or it may go to a central treatment unit. Usually, it is desirable to minimize the scrubber effluent volume, but, if it is to be sent to a much larger existing treatment plant, this may not be necessary.

Do not overlook the possibility of using effluent from some other process - like rinsing - as scrubber water, to reduce total process effluent.

Stack rain

A frequent and annoying problem that can occur is acidic stack rain discharging from the stack. This is caused by fine droplets of water being carried up the stack by the gas flow. Acidic rain can arise from two sources:

- inadequate separation of the water from the air at the scrubber outlet
- condensation in the stack

Inadequate separation in the scrubber is the most common cause, and may be due to:

- air flow higher than design

- demister damaged, clogged or dislodged

Obviously, the solution to this is to fix the demister or reduce the air flow.

Condensation in the stack is usually only a problem in stacks operating at higher temperatures (over 140°F). This can be prevented by installing an additional entrainment separator at or near the top of the stack.

Tips to help you

Proper design saves money

Owners frequently do not appreciate the contribution that the fume exhaust and scrubbing system makes to maintaining good working conditions in the plant, reducing building and equipment maintenance, and reducing rusting of pickled product. They see such systems as an unnecessary expense, which should be minimized. Yet proper design can reduce both the installation costs and operating costs, or even save the wasted expense which results from purchasing a hopelessly undersized system! Ways in which proper design can save money include:

- volume of exhaust needed (this should always be the first design step).
- selecting the minimum exhaust volume required for control of the fumes, taking into account:
  - equipment location
  - cross drafts
  - building air flow
  - equipment interferences
- choosing the correct scrubber for the application, based on operating conditions, efficiency required, and what will be done with the liquid effluent.
- designing the ducting for correct balance, to minimize use of dampers.

Even a small reduction in the size of the exhaust system will pay for the cost of proper engineering many times over.

Choosing a good scrubber/fume exhaust system

Here are some ways in which new fume exhaust systems can be designed for reliability and minimum maintenance - many of these can be retrofitted to existing systems, too:

1. Construct equipment and ducting in FRP or polypropylene, rather than PVC. In service, PVC becomes brittle, and is liable to crack, leading to leaks of fumes and acid.
2. Make all connections, access ports and observation ports flanged and gasketted - avoid the use of flush mounting pads that require studs embedded in the plastic.

3. Use only bolts for fasteners - not studs. Use 304 SS bolts to prevent rusting, minimum 1/2” (12mm) size to prevent shearing from overtorquing, and always use washers both ends on plastic equipment. (Although SS does not resist corrosion by HCl, it is more rust- and corrosion-resistant than carbon steel.)

4. Use chevron (blade) type demisters, rather than mesh pads. Pads of plastic mesh plug up with dirt, and also tend to deteriorate in service, so they need replacement at regular intervals. Also, they are hard to clean properly.

5. Install a standby circulating pump on packed scrubbers. Most packed scrubber problems are caused by insufficient or no water circulation. An installed spare provides an immediate cure for pump failure or inefficiency. It is good practice to switch pumps on a regular basis, and to keep track of running hours - if the spare is left unused until it is needed, it may be seized or plugged. Also, if one of the pumps breaks down it needs to be fixed <u>immediately</u>, as otherwise there is no backup, and a pump failure will put the system out of compliance.
   A flow meter in the circulating line for packed scrubbers is the only way to ensure sufficient water supply to the packing - a pressure gauge does not prove flow, nor does the fact that the pump is running.

6. Make sure the packing support is robust, and is designed to stand the weight of the packing when it is plugged with dirt and loaded with water. Plastic packing is very light when clean, but can get very heavy in dirty service.

7. Ensure that the spray header which feeds the water on to the packing is easily accessible or removable. Distribution of the water evenly over the packed bed is very important in maintaining scrubber performance, so spray nozzles need to be checked and serviced regularly. Design spray nozzles for low pressure, so that they are as big as possible - big nozzles are much less likely to plug. Circulating pumps should not develop high pressure - high pressure pumps waste power, and create fine spray in the scrubber, which may overload the demister.

8. Install a flow meter on the fresh water supply to the scrubber - monitoring this will help to ensure that the HCl removed from the air is continuously discharged from the system with the lowest possible water consumption.
9. Install washdown ports in the ducting to allow for easy cleaning.

10. Drain all low points in the ducting through seal loops or pots.

11. Provide a drain on the fan casing, with a seal loop.

12. Locate the fan <u>after</u> the scrubber, to keep the scrubber under negative pressure - any leaks will be in, not out.

13. Use flanged flexible connectors to connect the duct to the fan, rather than wrap-around flex joints.

14. Balance ducting flows by correct sizing, rather than by use of dampers. Dampers corrode in service, and also lead to build-up of crystals and dirt in the ducting.

15. Keep it simple! Minimize the number of controls and devices that have to be checked and maintained. Gravity is more reliable than any pump, and overflow more reliable than any level switch. As far as possible, use instruments to provide information, not to control the system.

Figure 6 shows the items requiring attention on a packed scrubber, in diagrammatic form. Figure 7 shows the corresponding items for a plate scrubber. The new NESHAP rules for HCl make plate scrubbers more attractive than packed scrubbers, because plate scrubbers need much less attention and maintenance, having no pumps to maintain, and no packing to plug up.

<u>Troubleshooting scrubbers</u>

Other than mechanical problems (leaks, drainage etc.), there is really only one basic problem that can occur in a scrubber - it does not remove the fumes from the air to the desired efficiency level.

Before trying to trouble-shoot a scrubber, it is important to establish what the scrubber is <u>designed</u> to do, otherwise you may be trying to make the scrubber do a job it was never intended for. Go back to the vendor literature and find out.

* Design air flow rate
Design water flow rates - fresh
- recirculation (if a packed scrubber)
* Design pressure drop
Design inlet concentration
Design outlet concentration
* Design efficiency
Design acid concentration in effluent

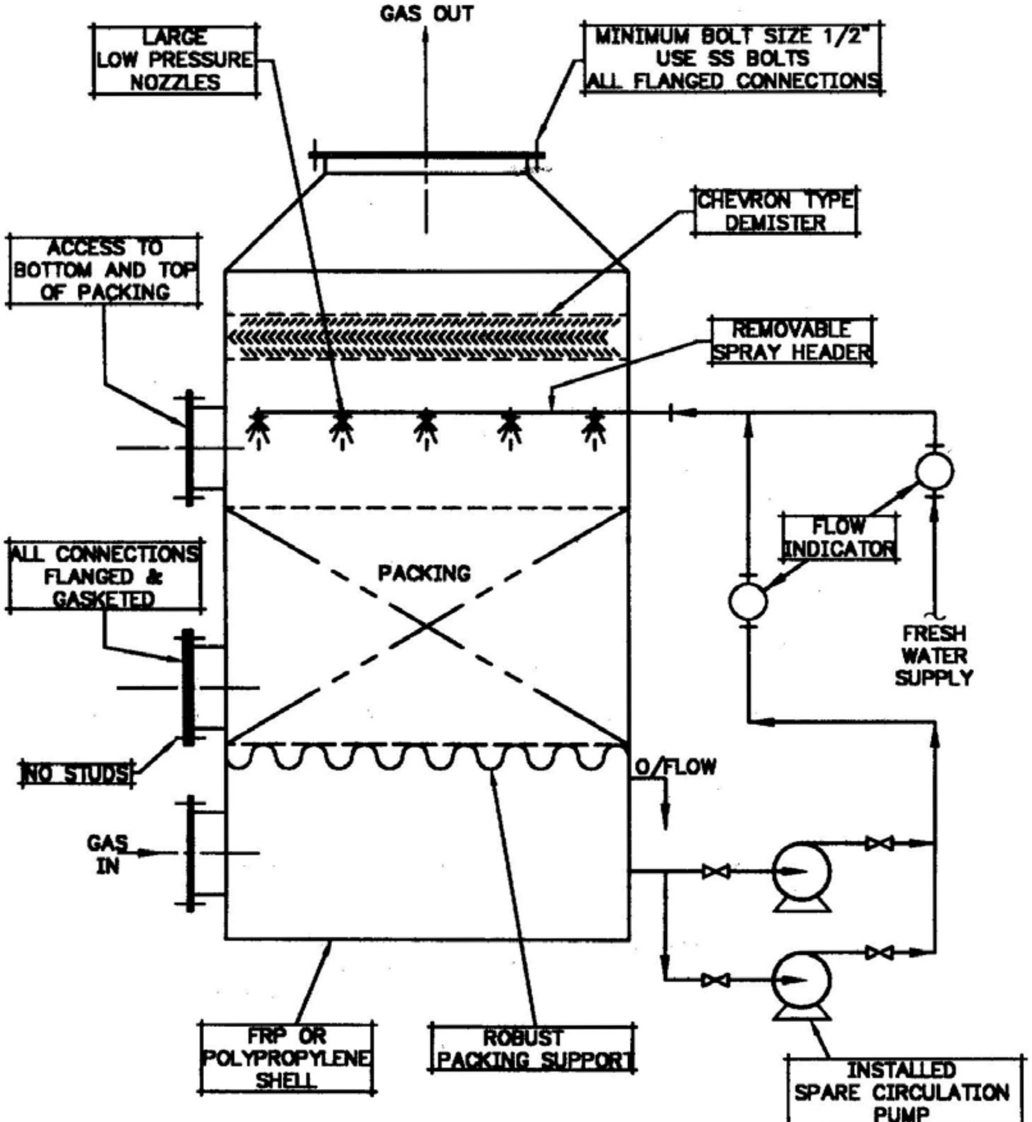


FIGURE 6
DESIGNING A PACKED SCRUBBER
FOR
RELIABILITY AND MINIMUM MAINTENANCE

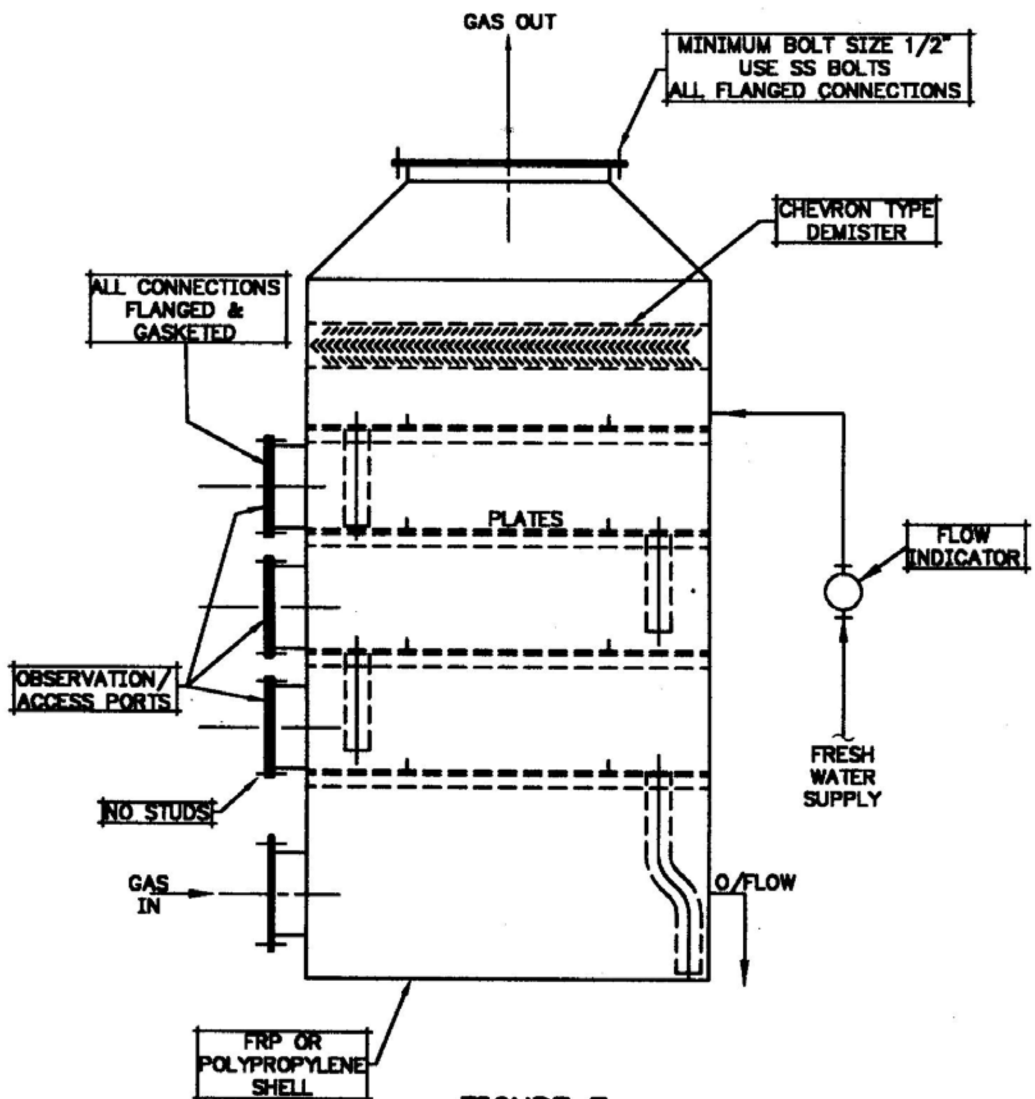


FIGURE 7
DESIGNING A PLATE SCRUBBER
FOR
RELIABILITY AND MINIMUM MAINTENANCE

Some of this information may not be available - but you certainly need the items marked with a *.

The following table summarizes possible reasons for low scrubber efficiency, and what could cause the problem.

Problem	Possible Reason	Indicator	Causes
Scrubber gas outlet fume concentration is too high.	Not enough fresh water.	High acid concentration in water.	Unreliable flow control. Blockage - lines or flow meter. Faulty flow meter.
	Air flow too low (plate scrubbers).	Plates run empty.	Ducting blocked. Loose fan belt. Fan running backwards (don't laugh, it has happened). Dampers closed. Fan deterioration.
	Air flow too high	High pressure drop across scrubber. Acid rain from stack.	Holes in ducting. Covers removed. No water flow (packed scrubbers).
	Water not overflowing from scrubber.	High acid concentration in water.	No make-up water. Overflow pipe blocked.
	Overflow too acidic.		Insufficient make-up water. Acid emissions from tanks too high.
	Liquid circulation flow rate too low (packed scrubbers).	Low pressure drop across scrubber.	Pump stopped. Pump worn out. Pump losing suction due to low liquid level. Leak in pump seal. Nozzles plugged or partly plugged.

Problem	Possible Reason	Indicator	Causes
			Valve closed. (Remember, for centrifugal pumps, pressure in the pipe does not prove there is flow!).
	Poor liquid distribution over packing.		Nozzles plugged or partly plugged.
	High pressure drop across scrubber.	Water blown off perforated trays.	Too much water flow. Water level in base too high (partly covering gas inlet). Packing plugged. Downcomers plugged. Demister plugged. Air flow too high.
	Low pressure drop across scrubber.	Water will not stay on perforated trays.	Insufficient water flow. Air flow too low. Packing support collapsed. Plate collapsed.
	High emission from the pickle tanks.	High acidity in scrubber water.	Acid temperature too high. Acid concentration too high. High liquid level in tank causing entrainment of acid. Broken steam sparger causing entrainment of acid.

Fume exhaust tips

The following series of mini-articles about fume control was published in the Esco News. They are reproduced here unedited - some of the points made in these articles duplicate material in other parts of this publication.

FUME EXHAUST TIPS #1

Keep the Flow Down

Fume exhaust is not a direct revenue-producing operation, although it does result in savings in maintenance costs (by reducing plant corrosion) and workers compensation costs (by protecting employee health and safety). However, in general, capital costs for fume exhaust must be minimized.

The most important factor in the cost of a fume exhaust system is the flow rate. A system should be designed for the minimum possible flow, and with the smallest acceptable safety factor. Excessive flows have the following disadvantages:

- higher cost of equipment
- higher water consumption in fume scrubber
- greater loss of process materials
- lower concentration of fumes make scrubbing more difficult
- increased cost for heating or air-conditioning of make up air

Ideally, the fume exhaust rate should be zero - as in special designs such as fumeless wire strand picklers. For many systems, this is not practical - for these, the flow should be minimized.

Flow reduction starts with hood and equipment design - these will be discussed in the next installment.

FUME EXHAUST TIPS #2

Hood and Equipment Design

Careful hood design helps minimize air flow rates - see tip #1 for reasons why this is a good thing. Wherever possible, hoods should be designed *as an integral part of the equipment,* and not as an add-on or afterthought - integrating hood and equipment design saves costs and improves air capture by allowing the hoods to be located at the best place, rather than wherever the process permits.

An important object in hood design is to try and *avoid extracting fumes* - the term fume extraction is misleading. What we are trying to get is a fume control system, i.e. something that will prevent fumes from escaping into the workplace. If we extract less fumes, less materials and heat are wasted, and the less fume scrubbing is needed. Here are some ways of achieving this:

- minimize the size of openings in hoods

- provide flaps or doors in hoods, to close off openings, but still allow access for operations
- locate exhaust air takeoffs near openings instead of at the center of the tank. In this way, a curtain of relatively clean air blocks escape of fumes, with minimum loss of process materials
- handle fume hoods, and maintain fume control equipment as carefully as process equipment; don't say "it's not important for production"!

FUME EXHAUST TIPS #3

Fans

The fan is the driving force for the fume exhaust system - it creates the air flow necessary for control of the fumes. Fans are sized on the basis of capacity (usually acfm) and head or pressure, (usually inches of water).

A fan does not have a fixed head and capacity - as the capacity increases, the discharge pressure generally decreases, and vice versa; in this way, the fan matches itself to the flow characteristics of the hood/duct system.

If your fume exhaust system is not controlling the fumes properly, this is usually a sign of reduced flow due to increased pressure drop somewhere in the system. A pressure survey can be carried out to establish where the high pressure drop is occurring.

Causes of pressure drop may be

- deposits of crystals in the duct
- liquid collecting in a low point
- collapsed duct
- corroded dampers
- garbage, such as plastic sheeting, in duct

In time, fan performance may deteriorate, due to worn or slipping drive belts or slight changes in impeller clearances, resulting from wear or maintenance. Fume exhaust fans should always be equipped with a casing drain to ensure removal of condensation and carryover, and this drain must be kept open.

Finally, if your system is not working well, especially after maintenance, make sure the fan is rotating in the right direction - we've seen more than one instance of fans going backwards!

FUME EXHAUST TIPS #4

Scrubbers - Part 1

A fume exhaust system is designed to control emissions of volatile hazardous materials into the workplace; it does this by carrying away these vapors in a stream of air. Before this air can be released to the atmosphere, it must be cleaned - *this is the job of the fume scrubber*.

Most of the scrubbers in fume control service fall into three categories:

- *entrainment eliminators*; these are for removing droplets of liquid (often very fine aerosol droplets that behave like gases). Typical applications are alkaline cleaners, chromic acid and sulfuric acid tanks.
- *packed scrubbers*; these are mainly for removing water-soluble gases, although they also serve as entrainment eliminators. Typical applications are pickle tank exhausts. A favorite configuration is the cross-flow type which needs less head room than the vertical counterflow tower, but is less water efficient. All packed scrubbers require large volumes of water, which is usually provided by recirculation pumps.
- *plate scrubbers*; these are for the same applications as packed scrubbers, but use much less water, and require no recirculation pumps. In many cases, a low volume of acid of high strength can be recovered from these scrubbers; this can be returned to the pickle tanks as make-up, thereby saving both the loss of acid and the use of caustic to neutralize it.

Any of these types of scrubber may be the 'best', depending on the application.

The scrubber can only remove fumes that are in the incoming air - if the fumes in the plant are bad, don't blame the scrubber; look for problems with the fan or the ducting. If the fumes in the stack are bad, then the scrubber may need attention.

Generally, scrubbers run with little attention, which is what they get.

FUME EXHAUST TIPS #5

Scrubbers - Part 2

Fume scrubbers, like most equipment, don't **always** work properly. This time we discuss scrubber problems, and what to do about them.

First of all, you have to know whether the scrubber is working as designed. This means looking up the specs to determine the *design flow, efficiency and pressure drop*, and then measuring their actual values.

If the flow is low, and the pressure drop high, or both, this indicates plugging - this may result from scaling (see 'Scaling Factors' in Esco News #7), plugging with solids from the air stream, collapsed or deteriorated packing, or a plugged demister. A physical inspection of the scrubber interior is the only way to tell.

Low efficiency can only be established by measuring **both** the inlet **and** the outlet concentrations of the contaminant - an outlet measurement alone is not enough. The scrubber may have high discharge concentrations, yet still working at design efficiency, if the process stream concentration is higher than anticipated!

Because a scrubber is essentially a device for contacting gas with liquid, most efficiency problems are the result of lack of contact, usually due to insufficient liquid flows (especially in packed scrubbers) or channelling of the liquid and gas. Typical causes of this are:

- Circulating pump not working (don't assume it's pumping just because it's running).
- Circulating lines plugged.
- Packing too small (small packing needs higher liquid flows).
- Plates not level (in plate scrubbers)
- Plugged or broken openings in the liquid feed headers, giving uneven liquid supply.

Other causes of low efficiency are:

- collapsed packing support - this reduces the amount of packing for contact between liquid and gas.
- broken or buckled plates.
- too high a concentration of contaminant in the scrubbing liquid. This is not a problem when fresh water is used for scrubbing, but may happen as a result of attempts to re-use or recycle water.

FUME EXHAUST TIPS #6

Don't blame the scrubber!

A fume control system consists of many parts - the hoods, duct, fan, scrubber and stack - yet, all too often, if the system doesn't work well, the first thought is 'the scrubber is not working properly'.

There are two main problems that arise in fume control - escape of fumes into the plant, and high pollutant levels in the stack. The second of these clearly points to scrubber problems, and causes and solutions were discussed in the last newsletter (TIPS #5).

Escape of fumes into the plant is unlikely to be due to the scrubber. The cause of this problem is insufficient air flow at the hood, which can result from:

- fan performance deterioration.
- closed or corroded dampers.
- holes in the ducting or hoods.
- blockage of the duct, by crystals or accumulated liquid.
- hoods not installed properly.
- excessive fume generation in the process.

A pressure survey will show the cause of the problem. Measure the pressure at various points in the system from the hood outlets to the fan discharge - key locations are: hood outlets; before and after dampers; before and after the scrubber; before and after the fan. Provided the fan is developing the correct pressure, the trouble spot is indicated by an abnormally large pressure drop.

FUME EXHAUST TIPS #7

Maintenance

Like other plant equipment, a fume exhaust system will not work well unless it is maintained. Generally, such systems don't need a lot of maintenance, as there are few moving parts - mostly, it is a matter of keeping the system clean. Remember, a fume exhaust system is designed to prevent noxious fumes and dust from escaping into the workspace, so it is inevitably going to get dirty if it does its job properly.

Here are some pointers for fume exhaust system maintenance:

- repair mechanical damage to hoods and ducts as soon as possible. Unrepaired FRP will deteriorate quickly, and unnecessary holes reduce useful draft by drawing air from areas that do not need to be controlled.
- repair leaks that drip acid immediately
- check fan belts weekly for tightness and wear.
- check weekly that the scrubber circulating pump is pumping - not just running, but actually pumping!
- check the scrubber make-up water supply flowmeter at least once a shift, and make sure the meter stays clean.
- install a differential pressure gauge across the scrubber, and monitor it daily. Increasing pressure drop could indicate plugging. A decrease could be due to reduced air flow or collapsed packing or plates.
- wash the hoods out weekly, and the ducting monthly.
- inspect the fan annually for mechanical damage, deterioration of the FRP, and leakage, especially at flanges, inspection ports and access openings.
- inspect the scrubber annually for deterioration of the shell, mechanical damage, plugging of packing, plugging of nozzles (test them, don't just look!) and plugging or deterioration of the demister.

FUME EXHAUST TIPS #8

What are the benefits?

Having implemented all the recommendations in tips 1 through 7, what can you expect to gain?

Firstly, better working conditions in the plant for operating and maintenance personnel.

Secondly, a cleaner and more reliable plant. Acid fumes from pickle lines work insidiously at corroding buildings, cranes, electrical pick-ups and controls in the pickle building, and, if allowed to spread through the rest of the plant, cause rusting and damage to machinery, equipment and pickled product.

Few companies break down maintenance costs in sufficient detail to separate the costs of corrosion, but those costs are real. Just note the cost next time the pickle house roof needs replacing, and consider whether that money could have been better spent in proper design and maintenance of the fume control system.

Thirdly, under the new NESHAP for HCl, you will save yourself a lot of record keeping, and monitoring costs. The new rules require proper operation, maintenance and inspection of HCl fume control systems, with records being kept and reporting of non-compliance. Consistent non-compliance can lead to more frequent reporting, and even require installation of expensive emission monitoring systems.

These are the benefits - the only question is: do you want them?

Want to know more?

The following publications by Esco give more detailed discussion of some aspects of fume scrubber and fume exhaust system design and operations. Copies are available from Esco by mail, or, in some cases, by fax or e-mail. Some of this material is also available from our Internet home page: www.mnsi.net/~pas/esco.htm.

'Design your pickle line for pollution control' - article by Neil Stone, published in the Wire Journal, 1980

'Economical fume control in pickle houses' - article by Neil Stone, published in the Wire Journal, 1981

'Pickle line fume control with plate scrubbers' - 1991 AISE Conference presentation (describes how plate scrubbers work, and what efficiencies can be expected)

'Fume control and scrubbing in hydrochloric acid pickle lines' - 1997 AISE Conference presentation (describes sizing of scrubbers, and the effect of the 1997 NESHAP rules on scrubber design)

Emissions spreadsheet - an Excel spreadsheet for estimating emission rates of acid fumes from pickling tanks. Includes HCl, nitric/HF and sulfuric acids.

Related publications that may be of interest:

'The Whys and Hows of Sulfuric Acid Pickling'

'The Whys and Hows of Hydrochloric Acid Pickling'

Need help?

If you have a specific scrubber problem, need a new or modified scrubber or fume exhaust system, or want more information, contact:

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