Amine Cold Box Scrubber Installation Reference Guide

Dakota International Incorporated is a manufacture of packed bed gas scrubbers for cold box core machines. Dakota Scrubbers™ are designed specifically for the foundry environment with simplicity, reliability and safety as primary goals. Scrubbers are required during core making to comply with environmental regulations and provide core machine operators with a safe odor free working environment.

Theory of Scrubber Operation

Dakota Scrubbers™ are packed bed countercurrent gas absorption systems designed to absorb amine from core machine purge gas. Scrubbers work by absorbing amine, which is in the gas phase, from the core machine exhaust gas into a recirculating sulfuric acid solution. The amine is then neutralized through chemical reaction where two moles of amine react with one mole of acid to form a neutral amine sulfate salt.

Amine is a catalyst in the core making process, which means it is not consumed except for minor adsorption on the sand and resin. As the amine is purged from the core box the contaminated gas stream is pulled up through a bed of wetted media (packed bed) using an exhaust fan. A sulfuric acid scrubbing solution is continuously pumped from the scrubber's liquid reservoir and distributed over the top of the packed bed through a spray nozzle. The scrubbing solution cascades down through the packed bed countercurrent to the gas flow back to the liquid reservoir. The packed bed provides a large surface area for absorption of amine into the scrubbing solution for reaction with sulfuric acid.

The gas stream then passes through a mist eliminator assembly to remove entrained water droplets from the gas steam prior to discharge from the scrubber and exhaust fan.

After the sulfuric acid in solution is consumed the scrubbing solution is considered "spent" and is drained from the scrubber and replaced with a fresh batch of sulfuric acid solution. The pH of the scrubbing solution is continuously monitored for automatic indication that the scrubber solutions is "spent" and needs replacement. Water lost due to evaporation is also monitored and automatically replaced.

The "spent" scrubbing solution is typically sent off site for recycling where the amine is recovered for reuse.

Amine Scrubber Chemistry

The chemistry for all amine catalysts is very similar with two moles of amine reacting with one mole of sulfuric acid to form one mole of amine sulfate. The chemical equation is:

$$\text{pH } 4.5 \qquad 2[R_3N] + [H_2SO_4] \Rightarrow [R_3NH]_2[SO_4]$$

The scrubber is initially charged with a 22-25 percent by weight sulfuric acid solution. This sulfuric acid solution starts at less than 1.0 pH and rises as amine is absorbed in the scrubber system. As the scrubber solution rises to pH 4.5 the scrubber efficiency begins to decrease. The decrease in scrubber efficiency is a result of the exponential increase of free amine in the acid-base equilibrium. As the free amine in solution increases the partial vapor pressure of amine above the solution also rises exponentially. Ultimately the scrubber outlet amine concentration is limited to the partial vapor pressure of amine of the recirculating amine sulfate salt solution.

Capture Efficiency

Capture efficiency is defined as the efficiency at which emissions are captured at the emission source, in our case the core machines.

A scrubber that provides a 99.9 % scrubbing efficiency is of little use if the odors are not captured correctly at the source. Capture efficiency is of equal importance to scrubbing efficiency when looking at the overall effectiveness of a scrubber installation’s ability to provide core room workers with a clean working environment.

<u>Enclosed Core Machines</u>

Good design practice requires that each core machine enclosure be provided with enough exhaust capacity to maintain a 100-200 feet per min face velocity at all enclosure openings.

For example if a core machine enclosure has a single door opening which measures 4 feet by 5 feet, the minimum exhaust capacity provided can be calculated as follows:
(4 feet) x (5 feet) x (100 feet/minute) = 2,000 cubic feet per minute

It is important to remember that amine gas is heavier than air and will settle to the floor. For this reason it is best to locate exhaust plenums near the floor, however special care should be taken to prevent sand or other debris from being sucked into the exhaust plenums.

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Core Machines Without Enclosures

If a core machine is not enclosed, the core machine exhaust manifold should be vented directly to the scrubber and in addition a side draft should be provided to capture fugitive amine fumes released from the core box parting line and fresh cores. Dampers should be provided to balance the system.

As a general rule the pressure in the core machine exhaust manifold should be maintained between +/- 1 psig. To prevent a high negative pressure it is best to run the hose from the core machine exhaust manifold into a duct with a diameter larger than the hose to provide an annular region where excess air is provided as required to maintain constant velocities in the exhaust ductwork. As an alternative, a gravity or actuating damper may be used on the core box manifold exhaust duct to maintain the +/- 1 psig recommended pressure.

Scrubbing Efficiency

Scrubbing efficiency is determined by the packing height in the scrubber and the corresponding number of transfer units (NTU). The height per transfer unit (HTU) can be calculated theoretically or determined by experimentation.

HTU = height per transfer unit

$$NTU = \frac{\text{packing height}}{HTU}$$

NTU = natural log of C_{in}/C_{out} where C_{in} is the amine inlet concentration and C_{out} is the amine outlet concentration

For example if we determine experimentally that the height per transfer unit for a particular type of packing is 12 inches and we have a packing height of 96 inches in our scrubber and an inlet concentration of 200 parts per million (ppm) amine then:

$$NTU = \frac{96 \text{ inches}}{12 \text{ inches}} = 8$$

8 = natural log of C_{in}/C_{out}

$e^8 = 200\text{ppm}/ C_{out}$

$C_{out} = 0.07$ ppm

$$\frac{200 \text{ ppm} - 0.07 \text{ ppm}}{200 \text{ ppm}} = 99.9\% \text{ scrubbing efficiency}$$

TRI-PACKS® Packing

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Particulate Control

Preventing particulate from entering the scrubber will save time and money in the long run. Sand entering the scrubber system will require periodic removal and may be classified as hazardous waste. Sand will also shorten the life span of pumps, pH sensors, flow meters and spray nozzles. Fine particulate such as that from shake out lines can lead to fouling of the scrubbers packed bed and mist eliminator components.

The following particulate controls have proven to be effective and should all be considered along with available space and budget.

Sand Drop Out Box

A sand drop out box provides a large section of duct where the gas velocity is reduced and allows particulate to drop out of the gas stream. Most designs incorporate an impingement plate or baffle to help reduce the particulates velocity and direct the particulate to the bottom of the sand drop out box where it can be removed via a hopper with a slide or spring gate. The disadvantages are space requirements and removal efficiency especially for fine particulate. The advantages are lower cost and minimal pressure drop.

Cyclones and Inertial Separators

The cyclone uses the principle of inertial separation by forcing the gas to change direction and as the gas changes direction the inertia of the particulates causes them to continue in their original direction and become separated from the gas stream. The advantage is higher removal efficiency of fine particulate than a sand drop out box. The disadvantages are space requirements, cost and increased pressure drop.

Fabric Filter

Our experience shows that fabric filters are an excellent choice for eliminating particulate from entering the scrubber system. A simple arrangement that uses a standard furnace filter at the ductwork plenums provides very high removal efficiencies at low pressure drops. It is however critical that the filters be replaced on a regular if not daily basis. The pressure drop across a new filter can be monitored for a short period of time to establish proper replacement intervals. The advantage is superior removal efficiencies. The disadvantage is the maintenance required to replace filters.

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Frequently Asked Questions (FAQ)

What are the disadvantages of indoors vs. outdoors scrubber installations?

Outdoor scrubber installations require the following provisions

- Scrubber vessel must be fabricated from thermoplastic UV light inhibitor.
- A sump heater is required for outdoor installations to prevent freeze up in cold weather climates.
- Insulation for all liquid piping must be provided to prevent freeze up.

Indoor scrubber installations

- When the gas stream passes through the wetted packed bed it essentially becomes saturated and the humid gas stream may condense out in the ductwork downstream of the scrubber, if the gas stream is discharged indoors provisions need to be made for condensation.
- The gas discharged from the scrubber will be very humid and if discharged indoors will increase the humidity of the environment.

How much water is lost due to evaporation?

- Evaporation losses depend on the humidity of the ambient air. The less humid the air the greater the evaporation losses in the scrubber.
- The scrubber is designed to maintain a liquid level within a one-inch range and typical water makeup cycles occur every few hours.

What is the batch life of a fresh acid solution?

- Batch life varies with the amount of amine that is captured and removed in the scrubber.
- Acid replacement may be required every few weeks or once a year depending amine consumption and volume of the scrubber liquid reservoir

How do I dispose of the "spent acid" waste solution from an amine scrubber?

- Most suppliers of amine catalyst offer recycling programs for their customers spent acid solution.
- Ashland Specialty Chemical offers their Isocycle^{SM} program. See Ashland Chemical's Bulletin #2016-2 "Isocycle^{SM} Amine Catalyst Recycling Program".