TO AUTOMATE WHERE NO PLANT HAS AUTOMATED BEFORE: ACID WASHING OF PACKED-TOWER CHEMICAL SCRUBBERS

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ABSTRACT

The Orange County Sanitation District (Sanitation District), under a capital improvement project, developed an automated procedure to perform acid washing on packed tower chemical scrubbers. Packed-tower chemical scrubbers operate with an alkaline solution, composed of sodium hydroxide, an oxidant, and make-up water. The make-up water may be chlorinated secondary treated wastewater or city water, which are both hard water sources and contribute to scale build up on the random pack media in the chemical scrubbers. In addition, the use of sodium hydroxide contributes to scaling on the packed media. Acid washing is necessary to maintain optimum performance within the chemical scrubber.

KEYWORDS

Acid washing, scrubber, automation, media fouling, scale removal

INTRODUCTION

The Orange County Sanitation District (Sanitation District) operates two wastewater treatment plants with a total flow of approximately 250 million gallons per day (MGD). Between both plants, there are currently a total of 29 operating scrubbers capable of treating over 850,000 cubic feet per minute (cfm) of foul air from plant treatment processes and the sewer trunk lines. Packed-tower chemical scrubbers operate with an alkaline solution, composed of sodium hydroxide, an oxidant, and make-up water. The make-up water may be chlorinated secondary treated wastewater or city water, which are both hard water sources and contribute to scale build up on the random pack media in the chemical scrubbers.

Due to aging systems and the need to capture and treat more foul air, the Sanitation District initiated several capital improvement projects to demolish existing scrubbers and construct new odor treatment facilities. For new facilities, it is the Sanitation District’s goal to incorporate automation when possible.
During the design of the new chemical scrubber systems, the Sanitation District decided to automate scrubber acid washing into future projects. This was in line with the agency’s long-term vision, and would make it easier for Operators to perform cleaning. The automated acid washing strategy has been designed into capital projects, which are currently in the design and construction phases. Future capital improvement projects for chemical scrubbers will also use this automated procedure.

Regular acid washing of chemical scrubbers is necessary to maintain clean media in the chemical scrubbers. The media is generally composed of small pieces of plastic that allows airflow through it and has a large surface area to maximize the liquid-air interface where the chemical reaction takes place. The reaction may produce precipitated solids. After operating at elevated pH levels, solids in the liquid will deposit on the plastic media. Over time this causes higher pressure drops, reduced airflow, and poor process control due to an additional source of reactants. Acid washing is necessary to remove the build-up on the media. Excessive build-up that can occur on scrubber media is shown in Figure 1. Excessive media scaling has occurred in the chemical scrubbers at the Sanitation District and more frequent acid washing likely would have prevented this.

**Figure 1 – Scale Build Up on Scrubber Media**

If the solids become excessive and acid washing is no longer effective, then the media may need to be replaced to return the scrubber to normal operating conditions. Figure 2 shows media replacement at a Sanitation District packed-tower chemical scrubber where the media had become solidified due to scaling. Replacing the media requires taking the scrubber out of service.
and a confined-space entry. Excessive scaling on the media may necessitate power tools to separate pieces of the media and remove it from the tower. A media change out can be time consuming and expensive, so it is preferable to avoid this through more frequent acid cleanings.

Figure 2 – Removal of Media within Chemical Scrubber

In ideal situations, acid washing is performed regularly to dissolve and remove the build up. There are several factors that contribute to infrequent acid washing:

- No back-up system to capture and treat foul air
- Insufficient staff time to perform acid washing; and,
- Other physical constraints that make it inconvenient to perform acid washing

METHODOLOGY

Several capital projects were initiated to re-build the odor control systems. The designs included packed tower chemical scrubbers. Since it is the Sanitation District’s goal to incorporate automation when possible, the designs included automation of the acid wash sequence. Automation of this process will serve as a tool for plant Operator to reduce the amount of time needed to attend to the scrubber during the acid washing process. If programmable logic could be implemented based upon the general acid washing procedure, then less time would needed by an Operator to complete the process.
Originally, the entire process was to be automated, but as details were discussed, it became apparent that certain segments would be automated with the Operator initiating each step of the procedure.

The capital improvement projects will incorporate features, such as standby scrubbers and hard-piped acid from bulk tanks to make acid washing convenient.

**Comparison of Manual and Automated Acid Wash Procedures**

During the design process, it was anticipated that the process would be fairly straightforward and it would include 1) rinse the scrubber tower until the pH was nearly neutral, 2) wash with acid with a pH setpoint, and 3) post rinse until the pH was nearly neutral. The team began by looking at what was currently being done manually at the Sanitation District and planned to review how other treatment plants automated their acid washing process. During the search process, no other treatment plants were identified that had automated the acid cleaning of chemical scrubbers.

The Sanitation District has Operations Manuals for the scrubbers that were developed with the original design and construction over 15 years ago. The manuals include procedures for acid washing. Although there are written procedures, Operators have discretion at every stage of the process. There may have also been minor modifications to the scrubber systems or nuances particular to individual scrubbers that require variations from the acid washing procedures presented in the manual.

In order to understand the current practice, an Operator at each plant was interviewed. The written procedure and Operator methods were used as the starting point for developing the process control strategy for the automation. The existing manual acid washing procedure is presented in Figure 3. Where the steps differed between the Operators, two parallel processes are shown.
Operator shuts off fan and pumps; locks and tags

Open valve so water fills sump then turn on pumps to rinse

Drain sump and refill with water

Add acid based on pump time then begin recirculation and continue acid addition in increments or Begin recirculation then add acid based on visual rise in sump level

Check pH frequently If pH rises quickly, add more acid

Recirculate for 4 hours with pH less than 4 or If pH remained less than 1 for an hour, let recirculate 4-24 hours

If scrubber has demister, open valve to feed acid and recirculate

Drain sump Fill with water

Recirculate Repeat as needed until pH is neutral

Acid wash complete and Operator returns scrubber to service

Figure 3 – Manual Acid Wash Procedure
The procedure involves the Operator initiating every step and he/she needs to check the pH throughout the process. The Operator uses this information to make decisions. In the washing process, the pH may rise quickly if the rinse was not effective or there is considerable carbonate build-up on the media, so the Operator remains nearby to increase the make-up rinse water during the rinse cycle or acid during the wash cycle.

The major elements of the proposed automated acid washing process for the new capital improvement projects are shown in Figure 4.

Figure 4 – Automated Acid Wash Procedure

The main difference between the old and new methods is that the automated approach will maintain a maximum pH for a specified period of time by adding more acid without the Operator manually initiating the feed. In addition, the rinse cycles will continue for the number of cycles specified by the Operator without attending to the process.

RESULTS

This section presents the details of the process control strategy and steps for each element, the rationale of the approach, and safety factors taken into consideration in developing this automation.
Control Strategy for Automation

Before initiating the acid wash procedure, the Operator will turn off the fans, recirculation pumps, and chemical pumps, and then manually isolate the sodium hydroxide and sodium hypochlorite feed lines, the fan, and the hydrogen sulfide and chlorine residual analyzers that monitor the inlet and outlet conditions of the foul air. The inlet damper will be placed in an “Out of Service” mode through a computer interface to prevent movement of the damper during the acid wash. The Operator will enter setpoints for each of the adjustable setpoints. The Operator adjustable setpoints are listed in Table 1 with a description of each.

<table>
<thead>
<tr>
<th>Operator Setpoint</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Drain time period</td>
<td>Amount of time allowed for draining the sump after a low level in the sump is achieved.</td>
</tr>
<tr>
<td>Flush time period</td>
<td>Time for rinsing the sump while empty and the drain valve is open. This allows for sediment to be flushed.</td>
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<tr>
<td>Rinse level</td>
<td>The target water level to be maintained in the sump during the rinse cycle.</td>
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<tr>
<td>Rinse recirculation time period</td>
<td>Amount of time that the rinse continues to recirculate through the scrubber.</td>
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<tr>
<td>Overflow time delay</td>
<td>A wait period following the shutdown of the recirculation pump to allow foam and floating solids to drain through the overflow pipe.</td>
</tr>
<tr>
<td>Number of rinse cycles</td>
<td>The number of times that the sump will refill with rinse water. Each cycle will recirculate for the amount of time specified.</td>
</tr>
<tr>
<td>Acid wash level</td>
<td>The target water level in the sump for the acid wash cycle.</td>
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<tr>
<td>Acid pump time</td>
<td>Amount of time that the acid pump runs during the wash cycle.</td>
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<tr>
<td>Acid wash pH</td>
<td>The target pH for the duration of acid washing. If pH rises above this level, additional acid is added to the sump.</td>
</tr>
<tr>
<td>pH below time duration</td>
<td>The amount of time that pH needs to remain below the acid wash pH level.</td>
</tr>
<tr>
<td>Demister recirculation time period</td>
<td>Time that the acid wash is pumped through the demister and scrubber bed.</td>
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The acid washing process was divided into three main components: the pre-rinse, the acid wash and the post-rinse. After the scrubber is taken out of service and the chemicals drained, the pre-rinse is performed to neutralize the pH. Following this, the main step of the process is washing
the tower with an acid-water mixture. This will be performed for both the main bed of the scrubber then the demister section and the main bed together. The final step is to perform a post rinse to neutralize the pH prior to returning the scrubber to normal operation.

**Pre-Rinse Cycle**

When the Operator initiates the automated rinse cycle, the drain valve on the sump will open and once the level indicator shows that it is below the low level setpoint, the valve will remain open for the additional drain time period. The drain valve will close and the water will fill to reach the rinse level in the sump. The valve to the demister section of the scrubber will open and the recirculation pump starts. The water level will drop in the sump while it is being pumped to the top of the tower and sprayed over the media.

Next the make-up water valve will open until the rinse level in the sump is raised to the setpoint. Recirculation will continue for the rinse recirculation time period entered by the Operator. After the recirculation pump stops, there will be a wait period for the overflow time delay period. The drain valve will then open for the time specified after the sump level reaches the low setpoint. Following this, water will be added to the sump for the flush time period with the drain open. The rinse cycle will repeat for the number of rinse cycles input by the Operator.

Depending on the composition of the solution used for the normal operation of the scrubber, more or less pre-rinse cycles may be needed. For a scrubber that uses solely sodium hydroxide as opposed to sodium hydroxide and sodium hypochlorite, the normal operating pH will be higher; therefore, it may take more rinse cycles to reduce the pH to neutral during the pre-rinse process. In addition, the scrubber operating pH may vary due to the nature of the contaminant loading. Since the operating pH may vary, Operators will be able to enter the number of pre-rinse cycles to be performed as an input setpoint.

**Acid Wash Cycle**

The Operator will initiate the acid wash sequence, which will close the sump drain and open the water supply valve until the liquid level reaches the acid wash level setpoint. The water supply valve and the demister valves will close; the demister valve will still be opened from the rinse cycle. This will route the recirculated solution only into the scrubber bed below the demister. The recirculation pump will be started and then the acid valves will be manually opened for the acid pump time period. The pH of the solution will be checked every ten minutes and compared with the acid wash pH setpoint. If the pH is below the setpoint then the acid wash will continue uninterrupted for the specified time period. If the pH rises above the setpoint, then acid will be added for the acid pump time period.

If the addition of acid during the wash cycle causes the sump to overflow, then the acid pump will be shut down and the valve on the acid line closed. The recirculation pump will also shut off and the sump drain opened until the acid wash level is achieved in the sump. The recirculation pump will be restarted, pH is monitored, and acid is added, if necessary.
After the pH has remained below the setpoint for the specified time, the recirculation pump will be shut off. The next action will not occur until the overflow time delay has expired. The wait period was added to allow any floating solids or foam to float out the overflow drain.

In order to reduce mist and droplets from escaping at the stack of the scrubber during normal operation, an additional section, the demister, is located above the spray distribution system. Since the purpose is to capture moisture, it also receives alkaline solution and scaling likely to be present, although not as prevalent as the lower section of the tower. Many of the Sanitation District’s existing scrubbers do not have acid routed to the demister section, so washing of this section will be a new feature in some cases. Scale that can occur on the underside of a demister is shown in Figure 5, and the new procedure will minimize this situation.

**Figure 5 – Scale on Underside of Demister Support**

To remove build-up on the demister, the acid solution will be sprayed on the demister for a period of time following the acid washing of just the main media bed. After the main bed of the scrubber has been washed, the demister valve will be opened and the valve to the top of the scrubber packing is closed, which will allow the acid solution to be routed to the demister media for cleaning. Following these steps, the recirculation pump will be started, and the wash continues for the demister recirculation time period. This will allow the scale to be removed from the demister section of the scrubber.

The recirculation will continue for the specified demister recirculation time period. The pH will be checked in the same manner during the initial acid wash cycle. The pH of the solution will be checked every ten minutes and compared with the acid wash pH setpoint. If the pH is below the setpoint then the acid wash will continue uninterrupted for the specified time period. If the pH
rises above the setpoint, then acid will be added for the acid pump time period. After the pH conditions have been satisfied, the recirculation pump will be shut off. When the overflow time delay has expired, the acid wash will be complete and indicated on the display screen.

Once the automated acid wash cycle is completed, then the Operator can decide if the acid wash cycle should be repeated. Typically, the Operator will manually verify the pH with an independent probe or pH paper. If the manual pH measurement is high, then the acid wash cycle would be repeated.

**Post–Rinse Cycle**

Following the completion of the acid wash, the Operator will initiate the automated post-rinse cycle. The drain valve on the sump will open and after the level indicator shows that the level in the sump is below the low level setpoint, the valve will remain open for the additional drain time period. The drain valve will close and the water will fill to reach the rinse level in the sump. The valve to the demister section of the scrubber will open and the recirculation pump starts. The water level will drop in the sump while it is being pumped to the top of the tower and sprayed over the media. The rinse water valve will open until the rinse level in the sump is back to the setpoint. Recirculation will continue for the rinse recirculation time period as entered by the Operator. After the recirculation pump stops, there will be a wait period for the overflow time delay period. The drain valve will then open for the time specified after the sump level reaches the low setpoint. Following this, water will be added to the sump for the flush time period with the drain open. The rinse cycle will repeat for the number of rinse cycles input by the Operator.

After the rinse, the Operator will need to prepare the scrubber to return to service. This will include manually closing the acid valve, opening the valves for sodium hydroxide and sodium hypochlorite, and opening the isolation valves for the hydrogen sulfide and chlorine residual analyzers. On the control screen, the Operator will indicate that the acid wash is complete.

**Safety Features**

Several safety features were incorporated into the automated acid wash cycle to give Operators control over the automated cycle. These features include: incorporation of several Operator-adjustable setpoint to give the Operator more control, leaving some elements as manual adjustments, placement of scrubber in an “Out of Service” mode to prevent other actions, automatic shutoff of pumps under certain conditions, and an emergency abort button.

The setpoints were designed to allow the Operator to control the process and do so in a safe manner. If a pH probe was out of calibration and reading too high, the acid pump could operate indefinitely in trying to achieve the setpoint. By limiting the amount of time that the acid pumps, this will prevent a potentially dangerous situation. When the scrubber is placed “Out of Service,” the damper will not be permitted to move. This will prevent the acid and fumes from migrating to through the ducts. In addition to push buttons for initiating each of the cycles, there will be a button to abort the process. In the case of an emergency, such as a leak in the acid pump piping or a failed probe, the entire process may be ceased.
The chemical valves are manually operated and have position indication in the control system. Manual operation of the chemical valves will be incorporated to provide the added safety measure that an Operator has to choose which valves are open and closed to prevent the feed of incompatible chemicals into the scrubber. Position indication on the chemical valves will be added to allow a hardwired interlock between the chemical valves and the chemical pumps. If the acid valve is open and either or both of the sodium hydroxide and sodium hypochlorite valves are open, then it would not be possible to start the acid pumps.

Indicators will be on the control panel to indicate if one of three cycles is in progress or complete. The three cycles are pre-rinse, acid wash, and post-rinse. This will allow an Operator, who may not be the same one who initiated the wash, to know what stage of the cycle the acid washing is occurring.

To assist the Operator in troubleshooting problems, there will be either lights or indicators on control screen at a nearby workstation for the following: inlet fan, inlet damper, chemical valves, recirculation pumps, acid pumps, pH sensor, drain valve, and makeup water valve. The pH sensor gives a continuous readout.

CONCLUSIONS

Due to various factors, the automation became more complex than originally planned. Factors that contributed to the complexity included previous practice, safety in working with chemicals, and the number of instruments required for successful automation. The process control strategy will successfully meet the objectives of the Sanitation District to incorporate automation where possible and reduce the current need for Operators to frequently attend to the acid washing. The next step is to complete construction and implement the automation in the new capital improvement projects.

REFERENCES


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