macrotek

Advanced Clean Air Solutions

SULFCAT®

Regenerative H_2S Gas Scrubbing System

SULFCAT® H_2S Removal

Hydrogen sulfide (H_2S) is a toxic and corrosive gas that occurs naturally but can also be produced through many industrial processes. In addition, H_2S has an odor threshold of 0.01-0.15 ppm (OSHA). Due to the very low odour threshold, in countries where nuisance odor is regulated H_2S removal from process gas or off-gas is required. Since H_2S is produced through anaerobic digestion, it is prevalent where organic matter and sulfates are present. As a result, pipeline gas specifications exist to ensure natural gas quality. Furthermore, when natural gas, syngas or biogas is used in turbines or engines for power generation, H_2S concentrations cannot exceed the engine manufacturer's specifications due to corrosion concerns. Further, during combustion H_2S is oxidized to sulfur dioxide, a highly regulated air pollutant which necessitates its removal before combustion. It is clear that H_2S removal is important for the environment, industrial equipment integrity, and human health.

H_2S can be removed from process gas through various technologies depending on the application, process conditions and removal requirements. Some applications where H_2S treatment is of particular concern are listed below:

- Landfill gas recovery
- Natural gas production
- Waste-to-energy systems,
- Biogas production, and
- Wastewater treatment plants

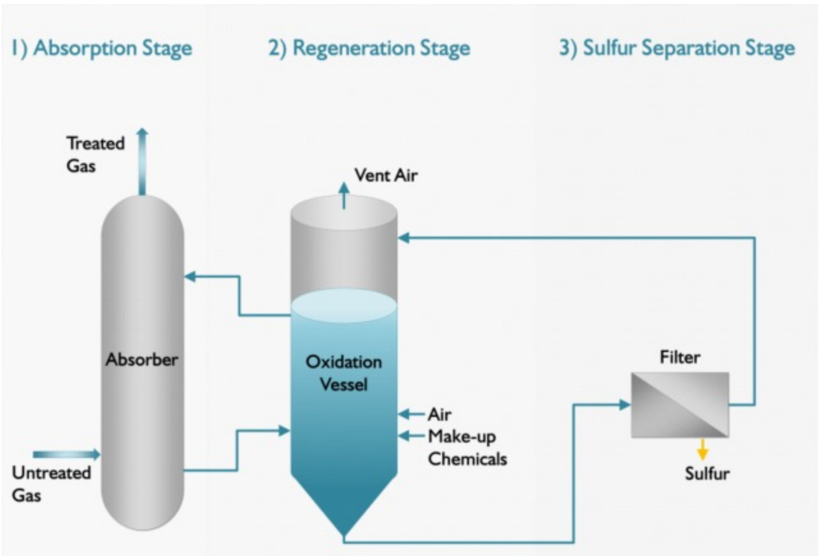
In all these instances, H_2S levels can range from low to high depending on the specific process conditions. For example, the recovered gas from a landfill can contain H_2S levels anywhere from a few ppm to 5% vol. This vast range is a result of the waste characteristics, more specifically, the sulfate content of the waste stream that can undergo anaerobic conversion to H_2S via sulfate-reducing bacteria. As sulfate is prevalent in drywall and other construction materials, the construction and demolition (C&D) waste streams entering the landfill directly affect the levels of H_2S that will eventually be present in the landfill gas.

As mentioned, various technologies are available for H_2S removal, however this article will discuss the features, benefits, and application range of Macrotek's regenerative SULFCAT® technology.

How it Works

The SULFCAT process is a liquid redox system that works by first absorbing H_2S from the gas with a specially designed absorber tower. The H_2S then undergoes a series of reactions that convert the absorbed H_2S gas to elemental sulfur and water. The reactions are promoted by the FeRedox™ reagent that contains a suspension of stabilized, sub-micron-sized iron-based particles. The solid sulfur is filtered out of the solution and the filtrate is recycled back to the process to capture more H_2S. A number of reaction pathways occur in the process, however, all reactions can be summarized by the following overall reaction:

$$H_2S_{(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow S_{2(s)} + H_2O_{(l)}$$



The process contains three stages. The first is the absorption stage, where the H_2S-laden gas contacts the liquid phase, and the H_2S in the gas is selectively absorbed into the liquid. The treated gas then exits the top of the column. The H_2S removal efficiency is a function of the operating conditions and absorber design. Increasing the contact zone height and residence time increases H_2S removal efficiency. Typical efficiencies are 99.9%, but can be optimized per the process requirements.

Once the H_2S absorbs into the liquid phase, it dissociates and reacts with iron in the re-circulating liquid to form elemental sulfur and water. This reaction reduces the iron from its active oxidation state to an inactive state. The spent iron and sulfur mixture is sent to the second stage of the process, the regeneration stage. External blowers supply air to a liquid filled contactor to oxidize the iron back to its active form. The air is then vented to the atmosphere. The regenerated solution is sent back to the absorber to complete another cycle.

Finally, in the third stage, a slipstream of the liquid solution is sent to a filtration system to separate the solid sulfur from the solution. The filtrate is recycled back to the process while the low moisture content sulfur filter cake is discharged from the system.

The defining feature of the SULFCAT process is that the chemistry is regenerative, meaning the iron that is used to convert the H_2S to sulfur is continually regenerated directly within the process rather than being consumed. This results in substantially reduced chemical make-up and waste generations rates compared to non regenerative technologies.

Previously, liquid redox systems were best suited for applications with high H_2S loadings including natural gas, syngas and landfill gas applications. However, through the development of the SULFCAT process, the application range has been widened and the technology is now suitable for lower H_2S levels.

Alternative H_2S Removal Technologies

H_2S can be removed from process gas through various technologies depending on the application, process conditions and removal requirements. Most H_2S removal technologies fall under the non-regenerative classification. Examples of these technologies are chemical oxidation scrubbers, liquid or solid scavengers, and activated carbon beds. A brief description of each technology is provided below.

Chemical Oxidation

In a chemical oxidation scrubber, sodium hydroxide (NaOH) is used to neutralize H_2S after absorption into the scrubbing liquid. The absorbed H_2S is then oxidized using a chemical oxidizing agent, typically hydrogen peroxide (H_2O_2) or sodium hypochlorite (NaOCl), to form soluble sodium sulfate (Na_2SO_4). Chemical oxidation scrubbers are compact and low in capital cost, however, the rate of chemical consumption and wastewater generation can be high relative to the amount of H_2S that is treated.

Scavengers

Scavengers can either be liquid or solid phase media that react with H_2S. Typically these reactions are irreversible (non-regenerative) resulting in the need to periodically replace and dispose the scavenger. The most common liquid scavenger are triazines which react with H_2S to form water soluble sulfur compounds. Common solid scavengers include metal oxides, particularly iron, which react with H_2S to form sulfides. Similar to chemical oxidation scrubbers, scavenger systems are relatively low in capital cost but high in operating cost due to the single-use scavenger media.

Activated Carbon Bed

Adsorption of H_2S is a physical process where H_2S is captured onto the surface of activated carbon. The media has a large specific surface area due to its inner pore structure that provides a large adsorptive capacity. Like scavenger systems, activated carbon is a single-use chemistry and the carbon must be manually replaced after it is fully spent.

Process Features	SULFCAT®	Chemical Oxidation	Scavengers	Activated Carbon
Minimal Waste Generation	√			
Regenerative Reagent	√			
Low Reagent Consumption	√			
Usable By-Product Generation	√			
Low Fresh Water Requirement	√		√	√
Low Operating Costs	√			
Low Capital Costs		√	√	√

Comparing SULFCAT to Competing Technologies

The primary differentiator between SULFCAT and the alternative technologies discussed above is that the chemistry is regenerative. This results in substantially reduced operating costs due to the lower chemical make-up rates and waste generation rates. The difference in rates can be illustrated by the following example.

Process conditions:

- Gas Type: Landfill gas
- Gas Flow: 5000 scfm
- H_2S Concentration: 2500 ppm
- Required H_2S Outlet 25 ppm

In this example, a landfill is recovering and treating their gas to be sent to a gas-to-energy plant. The H_2S levels in the gas must be reduced to 25ppm to meet the engine's required inlet specifications. The landfill is considering two technologies for the treatment of H_2S: a chemical scrubber and the SULFCAT process. The following table compares the primary process inputs and outputs for each option.

	SULFCAT®	Chemical Oxidation Scrubber
Chemical Usage	11 kg/hr [1]	190 kg/hr [2]
Water Usage	80 kg/hr	200 kg/hr
Water Generation	60 kg/hr	600 kg/hr
Power	55 HP	10 HP

[1] FeRedox and 50% NaOH

[2] 50% NaOH and 50% H_2O_2

While the power consumption is slightly higher, the chemical make-up rates and the waste generation rates for the SULFCAT option are a small fraction of those of a chemical oxidation scrubber. The operating cost is also a small fraction, representing a 90% reduction compared to a chemical oxidation scrubber.

The SULFCAT Advantage

The SULFCAT system is of rugged construction to meet the needs of any industrial environment. The equipment is also modularized and pre-packaged to allow the shortest lead time, installation time, and lowest installation cost possible.

For applications where H_2S loading is variable and future process conditions are difficult to predict, a SULFCAT system can easily be optimized after original installation to increase the design capacity without overhauling the original equipment.

Recent advancements in instrumentation and control systems have reduced operator interaction and improved system reliability. The automated control system handles much of the day to day process variability, allowing operators to focus on other areas of the plant. Remote access to the control system also enhances an operator's ability to monitor and even make control adjustments to the system remotely.

The SULFCAT process uses non-toxic chemistry for the conversion of H_2S to solid sulfur. The near-ambient temperature and pressure also make the system inherently safe to operate.

In some cases, the sulfur that is produced in the system can be sold to sulfur producers or the agriculture industry. This potentially converts an expense to a revenue generating stream.

The SULFCAT process can be used in most applications where the H_2S loading in the gas between 0.05 to 15 tonnes per day. Since the FeRedox reagent is selective to H_2S, the CO_2 or other non-condensable content in the gas has minimal effect on the system, therefore a wide variety of gases can be processed from combustible gases to simply H_2S-laden air streams.

Conclusion

The regenerative, modularized and automated nature of the SULFCAT® system results in an attractive and feasible solution for H_2S removal. Compared to non-regenerative technologies, the lower operating costs result in short payback periods and substantial long term savings.

In the past, liquid redox systems were best suited for applications with very high H_2S loadings. The high capital cost of a liquid redox system resulted in a technology which was not economically feasible for lower H_2S loadings. The SULFCAT process represents an advance in the technology which now expands the application range to moderate and even low levels of H_2S, making the SULFCAT system one of the most cost-effective methods of treating H_2S available on the market today.

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