Technologies for H_2S Control

Reviewing Different Methods and Benefits of H_2S Removal from Process Gas

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Hydrogen sulfide (H_2S) is a hazardous gas found naturally and in industrial processes. With an odour threshold of 0.01-0.15 ppm, its removal is mandated in regulated areas due to health and environment concerns. H_2S is commonly produced during anaerobic digestion where organic matter and sulfates are present, necessitating its removal from gas streams to meet quality standards and prevent equipment corrosion. Furthermore, gases used for power generation in turbines or engines cannot exceed H_2S concentrations outlined in the manufacturer's specifications to prevent corrosion.

H_2S can be treated through various technologies such as liquid redox, chemical oxidation scrubbers, biological processes, scavengers, and fixed-bed activated carbon. The selection of these technologies is dependent on the application, process conditions, and removal requirements.

Liquid Redox

Liquid redox is a technology that incorporates chelated iron to convert H_2S into solid sulfur. The chemical reactions are the following:

$H_2S + 2Fe^{3+} \rightarrow S + 2Fe^{2+} + 2H+$
(Reduction of iron)

$2Fe^{2+} + \frac{1}{2}O_2 + H_2O \rightarrow 2Fe^{3+} + 2OH-$
(Oxidation of iron)

$H_2S + O_2 \rightarrow S + H_2O$
(Overall reaction)

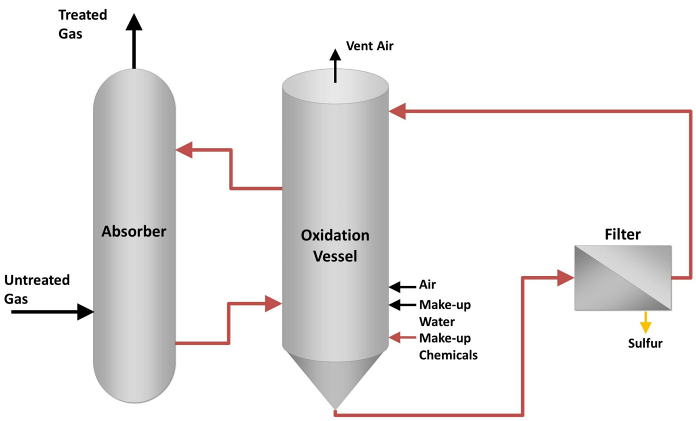

FIGURE 1. In a typical liquid redox system, a catalyst (typically chelated iron) converts H_2S gas into sulfur in an aqueous system

Oxygen is consumed in the reaction, whereas the chelating reagent is continually regenerated through forced oxidation using air. Filtration can be used to extract the produced solid sulfur and recycle the spent reagent back into the process. The produced solid sulfur can be sold as another product.

The major components of equipment used for this process include an absorber and an oxidation vessel (Figure 1). The absorber allows the H_2S to be absorbed into liquid and converted into solid sulfur. The reagent is sent to the oxidation vessel where through forced oxidation it is regenerated into its active form. The regenerated solution is sent back to the absorber for another cycle of operation.

The suitable material of construction for the process equipment is 316L stainless steel.

The benefits of these systems is minimal water consumption, minimal chemical addition, minimal waste production, low operating costs, and high removal efficiencies greater than 99.9%. Some of the drawbacks include higher capital costs due to increased control sophistication and some of the chelating agents are potentially hazardous.

Chemical Oxidation Scrubber

Chemical oxidation scrubbers utilize sodium hydroxide (NaOH) to neutralize H_2S after it is absorbed in the scrubbing liquid. It is then oxidized by the chemical agent, hydrogen peroxide or sodium hypochlorite to form soluble sodium sulfate which is removed from the system using a blowdown stream. This stream is either treated or sent to disposal.

The most typically used equipment is packed-bed scrubbers, preferably vertical countercurrent packed-bed scrubbers (Figure 2). These scrubbers have high efficiency, additional mass transfer, smaller equipment size, and pumping costs. The design of the process is a countercurrent operation where gas flows upward and the liquid flows downward through spray nozzles or a liquid distributor. Fiber-reinforced plastic (FRP) is used as the material of choice, especially if sodium hypochlorite is an oxidizing agent.

Some of the drawbacks include the caustic nit being selective to H_2S in the presence of other contaminants like carbon dioxide, hence interference must be minimized, and the management of the blowdown stream increases the operating costs. However, the benefits include its compact size, low cost, capability of handling large fluctuations in inlet composition and removal efficiencies greater than 99.9%.

Biological Processes

Biological processes like biotrickling filters use microbes to consume H_2S and convert it into sulfuric acid. This system consists of a vessel with a packed or porous media section (Figure 3). In terms of the process equipment, concrete structures are used for large gas-flows and FRP is used for smaller units.

The drawbacks include sensitivity to humidity, temperature and fluctuating H_2S inlet loading, long residence times, and requirement of large vessels. In addition, the media cannot dry, or the microbes will become inactive. However, the benefits include little operation or maintenance, and only daily checks of pH and media pressure drops are required.

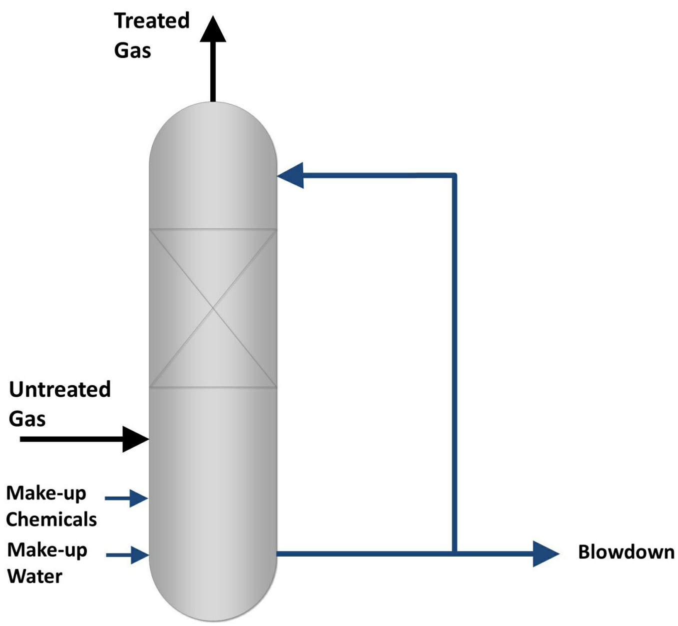

FIGURE 2. A chemical oxidation system neutralizes H_2S gas using a base, typically sodium hydroxide

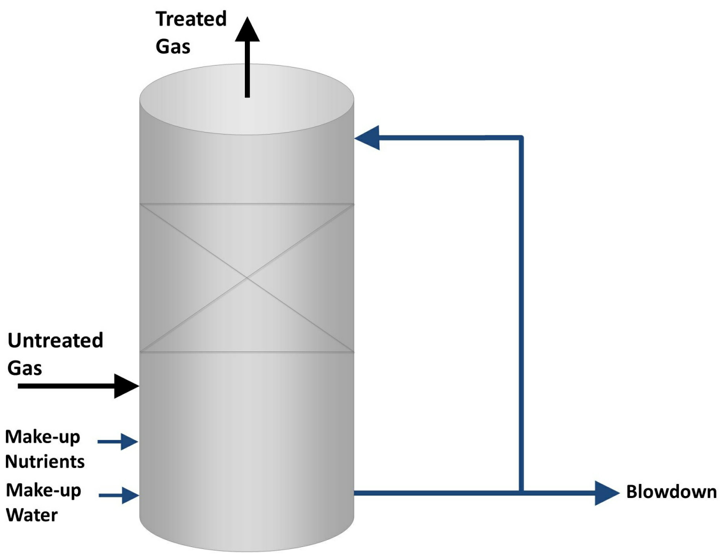

FIGURE 3. Biotrickling processes use autotrophic microbes to consume and transform H_2S

Scavengers

Scavengers are chemicals in liquid or solid phase that react with H_2S. These reactions are irreversible, necessitating periodic replacement and disposal of reaction byproducts. Depending on the type of scavenger used, byproducts can be hazardous, making disposal costly. Unlike other technologies, this process does not eliminate H_2S. Instead, a waste gas with a high H_2S concentration is produced during the scavenger regeneration process, which can either be treated or sent for disposal.

The equipment for this process consists of vertical towers, where the gas flows up through the liquid or media (Figure 4). Carbon steel is often used as the material of construction for processing equipment. For liquid systems, gas is usually bubbled through a liquid-filled absorber vessel. For solid systems, the gas flows up or down through a fixed bed. The scavenger is consumed in this process; hence, two vessels are installed in parallel such that one vessel can be taken offline to replace the scavenger.

The advantages of scavengers is their selectivity of H_2S over CO_2 compared to other discussed technologies and relatively low capital cost. The disadvantages include higher operating costs, high chemical consumption and treatment of waste streams, and sensitivity to high temperature and required gas with high humidity.

Fixed Bed Activated Carbon

Fixed bed activated carbon physically absorbs H_2S onto its surface, offering high efficiency with simple operation (Figure 5). Carbon beds are particularly suitable when very low outlet concentrations are required. Materials for equipment include coated carbon steel, FRP, and plastics.

Despite sensitivity to humidity and temperature, operating under positive pressure enhances adsorption, with materials including coated carbon steel, FRP, and plastics.

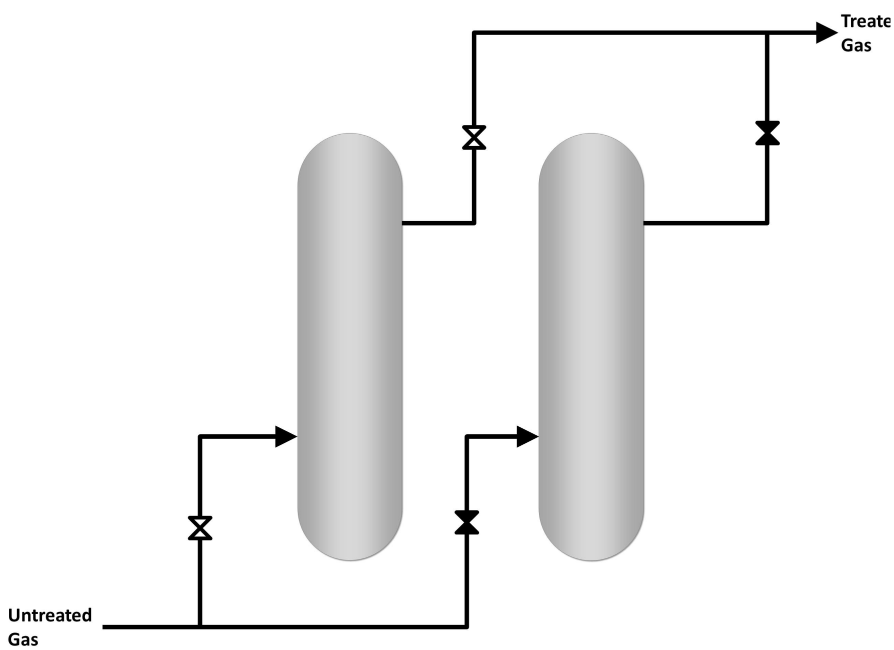

FIGURE 4. A scavenger system involves the injection of a liquid or solid chemical to irreversibly react with H_2S

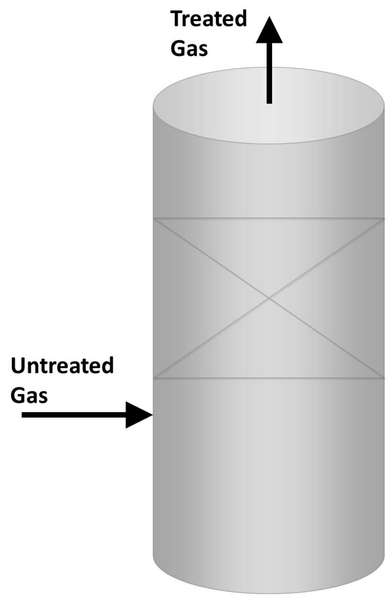

FIGURE 5. Adsorption of H_2S using a fixed-bed activated-carbon process is appropriate when a very low outlet concentration of H_2S is required

Technology Selection

Selection of H_2S removal technology primarily considers cost and technical suitability. Regenerative or biological methods are often more cost-effective for high H_2S loadings due to lower chemical and media consumption. Non-regenerative options are simpler and offer lower upfront cost but may incur high operating costs for high-load applications. Biotrickling filters excel in stable H_2S conditions, but not in industries where conditions vary.

The choice between non-regenerative technologies often depends on plant preference and waste management capabilities. Liquid redox systems historically suited high H_2S loadings but were costly for lower loads. Advancements have made them more viable for smaller applications, while chemical oxidation and scavenger systems remain popular despite higher operating costs.

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