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HYDROGEN SULFIDE REMOVAL FROM BIOGAS
Part 3B: Iron Sponge Design Considerations: Vessel Sizing

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When designing an iron sponge system, the primary concerns are to ensure that: 1) there is adequate contact time for the H_2S to react with the ferric oxide, 2) channeling or short circuiting does not occur, 3) spent media can easily be removed, and 4) the system is large enough to not require overly frequent media changes.

For an explanation of the mechanism of the iron sponge H_2S removal system, please refer to the fact sheet: **Hydrogen Sulfide Removal from Biogas Part 3A: Iron Sponge Basics**.

It should be noted that as with many types of designs, it is important to identify the limiting factor and that it may be different for differing systems/conditions.

DETERMINING THE VESSELS MINIMUM DIAMETER

The minimum diameter should be calculated two ways to determine whether the velocity of the gas, or H_2S deposition rate, limits the size of the reactor (Arnold and Stewart, 2008).

Limiting the velocity of the gas to 10 ft/min ensures that there is proper contact with the bed.

$$d_{min} = \sqrt{360 \frac{Q_g\, T\, Z}{P}}$$

Where:

d_{min}: minimum inside diameter, inches
Q_g: gas flow, million cubic feet per day
T: operating temperature, ^oR
Z: compressibility factor, ± 1
P: operating pressure, psia

To convert operating temperature from ^oF to ^oR,

$$^oR = {}^oF + 459.67$$

The compressibility factor will typically have a value of 1 for the pressures most biogas iron sponge systems will operate at (< 15 psi).

The operating pressure, psia, (per square inch absolute) can be determined by adding atmospheric pressure (14.69 psi at sea level) to the pressure of the biogas which will typically be between 4 to 16" of water column or 0.14 to 0.58 psi.

It is also important to make sure that the rate at which H_2S is deposited, doesn't exceed 15 grains of H_2S per minute per ft^2 of bed cross sectional area perpendicular to biogas flow.

$$d_{min} = \sqrt{5.34x10^6\, Q_g\, MF}$$

Where:

MF: the mole fraction of H_2S in biogas

The mole fraction can be calculated from the concentration of H_2S in biogas in ppm.

$$MF = \frac{concentration\ H_2S\ in\ ppm}{1{,}000{,}000}$$

After calculating the two minimum diameters, the larger of the two values is the recommended minimum size diameter.

Maximum diameter

If the velocity of gas through the bed is too low, channeling (bypassing) of the biogas through the bed can occur. The following equation can be used to determine the maximum recommended diameter.

$$d_{max} = \sqrt{1{,}800 \frac{Q_g\, T\, Z}{P}}$$

Any diameter between the minimum and maximum diameter can then be selected, and is best determined by selecting a tank based on availability (capital cost).

Reactor Height

A gas contact time of a minimum of 60 seconds is recommended. The recommended minimum height can be determined from:

$$H \geq 3{,}600 \frac{Q_g\, T\, Z}{P\, d^2}$$

Where:

H: depth of the reactor bed, ft

d: reactor vessel inside diameter, in

It is recommended that the minimum height should be at least 5 ft or as calculated; whichever is greater.

Sizing for time between iron sponge media changeouts

Increasing the size of the reactor beyond the calculated height/diameter will increase the time between changing out the reactor media.

To determine how long the reactor can go between media changeouts the following equation can be used.

$$t_c = 3.14\ x\ 10^{-8} \frac{Fe\, d^2\, H\, e}{Q_g\, MF}$$

Where:

t_c: Change out time, days

Fe: Iron sponge content lbs Fe_2O_3 per bushel of media

e: reaction efficiency, 0.6 to 0.8

Typically iron sponge contains 15 lbs Fe_2O_3 per bushel. Higher Fe_2O_3 content per bushel translates into more Fe_2O_3 to react, and a longer time between replacement and/or regeneration.

To determine how many bushels are required to fill a reactor:

$$Bushels = 4.4\ x\ 10^{-3}\ d^2\ H$$

Recommendations

Because it is necessary to take a reactor offline when changing spent iron sponge, it is usual practice to operate two or more reactors such that biogas flow can be routed through one reactor, while the other is being regenerated or the media replaced.

The above equations should be used to determine the volume of iron sponge that a system may require for operation. Beyond that, additional design considerations are necessary to ensure adequate moisture, temperature and pH levels are maintained in the reactor, and that the media is adequately supported such that gas can evenly flow through the reactor bed.

Consideration should also be taken to ensure that the reactor is designed such that replacement of the iron sponge is made as easy as possible through providing adequate access to the reactor.

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REFERENCE

Arnold, K., & Stewart, M. 2008. *Surface production operations, Design of Gas-Handling Systems and Facilities, Volume 2, Second Edition.*