

Sparger Design and its Effect on Gas Holdup in MEA Triazine Based H₂S Bubble Columns

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ABSTRACT

This paper focuses on the overall column design parameters for the removal of H₂S from natural gas with the emphasis on the effect of the sparger/distributor design on achieved Gas holdup and its potential effect on scavenging efficiency. Numerous oil and gas producers utilize triazine based liquid scavengers for H₂S removal for applications up to approximately 2 tons of H₂S removal per day (4409 lbs of H₂S per day). Column designs are generally simplistic and usually consist of a vertical column, a gas inlet, liquid scavenger inlet and gas/scavenger outlet. Various configurations exist for example; continuous co-current, continuous counter-current and dual systems. What they all have in common is a sparger or distributor through which the gas enters the column.

Numerous studies have been conducted on bubble characteristics through a bubble column, specifically gas holdup as it relates to superficial gas velocity. In most studies the liquid phase is water, the effect of liquid viscosity, liquid and gas density is well documented. Relatively few studies have been conducted on sparger design and its effect on Gas holdup in liquid triazine based applications.

Keywords: MEA Triazine, H₂S Removal, H₂S Scavenging, Bubble Reactors, H₂S Bubble Columns, Sparger design, Gas Holdup

INTRODUCTION

The introduction aims at providing a brief overview of the sulfur recovery systems currently being utilized in the oilfield (Western Canada). Attention will be drawn to bubble column applications and the design of the towers.

Sour gas makes up about one-third of all the gas produced in Alberta; the province also accounts for nearly 85 per cent of Canada's sour gas production. British Columbia's natural gas industry contributes most of the remainder of Canada's sour gas. There are over 6,000 sour gas wells and 18,000 kilometers of operating sour gas pipelines in Alberta. Sour gas is processed at approximately 250 plants in Alberta, including more than 50 larger facilities that produce elemental Sulphur.¹

The following sulfur recovery systems are currently being utilized in Western Canada:

- Claus Process – This process is used for large sulfur removal applications, >10 tons/day (22046 lbs/day). They are mainly used in the refinery and oilsands industry.
- Amine Plants – These are common in the conventional oil and gas industry. They are typically used for applications requiring 1 – 10 tons of sulfur removal per day.
- Absorber Towers (Scavenger Towers) – Various configurations are used; Co-Current and Counter-current configurations are common. These are typically used for sulfur removal of < 1 ton/day but bigger applications up to 5 tons per day can be found. These are non-regenerative sweetening systems, thus the absorbent is used and disposed.
- In-Line Injection of absorbent. Chemical is injected directly into the pipeline
- Downhole Injection – Absorbent is injected continuously down the producing well, most commonly the annular space. The absorbent mixes with the produced fluids and are sweetened.
- Adsorber Technology – these are usually mixed metal oxide beds. Usually placed in a tower configuration.

Monoethanolamine (MEA) triazine is one of the most widely used H_2S scavengers in the oil and gas industry. The product is well understood and has a history of usage spanning 20 + years. Due to its adoption as the “go to” H_2S scavenger, the product has moved into a commodity status (low cost) which only strengthens its use case. Other absorbent chemistries are sometimes added to triazine to create products that has a higher H_2S scavenger uptake and better kinetics. An example of this is the addition of formaldehyde to triazine products. In general, triazine based H_2S scavengers have a triazine activity up to 60%, with uptake values ranging between 4 and 13 liters per kg of H_2S removed (0.40 to 1.29 gallons per lb of H_2S removed). The theoretical uptake values depend purely on the product composition and its stoichiometric ratio to H_2S . Other factors like temperature, pressure, tower design. Superficial gas velocities etc. affects the overall gas holdup of the system and thus scavenging efficiencies.

Bubble Column Reactors (Continuous Flooded)

There are currently two main types of continuously flooded bubble column reactors (scavenger towers) utilized; co-current and counter current. In both systems H_2S scavenger (absorbent) is injected continuously into the columns. Both systems are flooded (loaded with scavenger) with the main difference between them that in the co-current system the liquid and gas flows upwards in the column, depending on the configuration, to a post scrubber separator where the spent scavenger is separated from the gas. In the counter-current system the scavenger level is controlled in the tower, thus the spend is removed from the bottom of the tower. In co-current systems the scavenger is injected (usually) at the gas inlet whereas in counter-current systems it is injected at the top of the tower. Both configurations can utilize tower packing.

On average, the majority of the well-designed Triazine continuous flooded bubble columns achieve efficiency values of 70-85%. Efficiency relates to the amount of Triazine used to remove a certain amount of H_2S per day compared to theoretical values (based on stoichiometric ratios). Tower sizes vary from 8 ft S/S (Seam to Seam) up to 30 ft S/S (9.14 meters S/S) with diameters in the range of 24” to 120” (60.96 to 304.80 cm).

One aspect that is common with both configurations (co-current and counter-current) is the sparger designs utilized. The main purpose of the sparger is to ensure proper distribution of gas through the liquid phase via bubble creation. Sparger designs are simplistic and no real rule of thumb exists for the design of them. They usually consist of perforated pipes with smaller pipes branching off. The number of holes and hole sizes vary greatly. In bubble column design, a commonly asked question is how the sparger design affects performance. Does the perforation (hole) size matter? how many holes? hole spacing?. This paper focuses on answering these questions, specifically for a triazine based application.

Numerous papers have been written investigating the effect of sparger design on column performance. None however has used Triazine as the liquid phase. Three main reference documents will be utilized throughout this paper, these publications were written within the last 15 years with the main goal of reviewing and summarizing past papers on various subjects related to bubble column reactors.^{2,3,4}

Gas Holdup

The main parameter evaluated in this study is gas hold-up (ϵ_g). Most studies investigate this parameter as it plays an important role in understanding and summarizing gas transport phenomena within bubble columns. The gas holdup profile within a bubble column summarizes the fluid dynamics and is thus critical for scaling up lab tests to industrial applications. It is defined as the volume fraction of gas that is occupying the absorbent (Equation 1).⁵

$$\epsilon_g = \frac{V_{\text{total}} - V_c}{V_{\text{total}}} \quad (1)$$

Where V_{total} = total fluid volume, V_c = volume of liquid absorbent above sparger

Gas holdup depends on the bubble size distribution and their rise velocity; thus, it provides a good indication of how effective a sparger is in generating a small bubble size distribution and a large interfacial contact area between the gas and liquid.

Variables

Numerous variables exist that have an influence on gas hold-up; pressure, temperature, bubble coalescence, bubble break-up, liquid properties (density, viscosity etc.), gas properties (gas density), mode of operation (co-current or counter current, batch), superficial gas velocity, superficial liquid velocity, column diameter (wall effects), column height (back mixing, coalescence), sparger design, and tower packing.^{2,3,4} This paper will focus on the variables related to sparger design; specifically hole size, open hole area %, hole spacing and number of holes and how these affect the gas holdup.

EXPERIMENTAL PROCEDURE

Equipment and Experimental Setup

Numerous tests were conducted to investigate the effect of sparger design on gas holdup. The equipment used included a 1-meter tall cast acrylic cylinder, aluminum base, rotameter and air supply. A summary of the equipment can be seen in Table 1. The equipment setup is visually displayed in Figure 1.

Air flow was regulated by a rotameter up to 400 SCFH (Standard Cubic Feet per Day) with 25 SCFH increments. The acrylic cylinder screws into the base with a fluoroelastomer (FKM) o-ring providing the seal between the parts. The column diameter of 0.189 m was selected based on numerous studies showing the wall effect to be negligible in columns with diameters bigger than 0.15 m.⁶

Table 1: Equipment

Equipment	Description
Cast Acrylic Column	Diameter (D_c): 0.189 m (0.62 ft), Height (H_c): 1 m (3.28 ft)
Aluminum Base	Acrylic Column screws into base. Air supply via base.
FKM o-ring	Perforated plate support and provide seal between base and column
Rotameter	0 - 400 SCFH scale with 25 SCFH intervals
Air Supply	2 X commercial air pumps
Miscellaneous Items	Hoses, clamps etc.

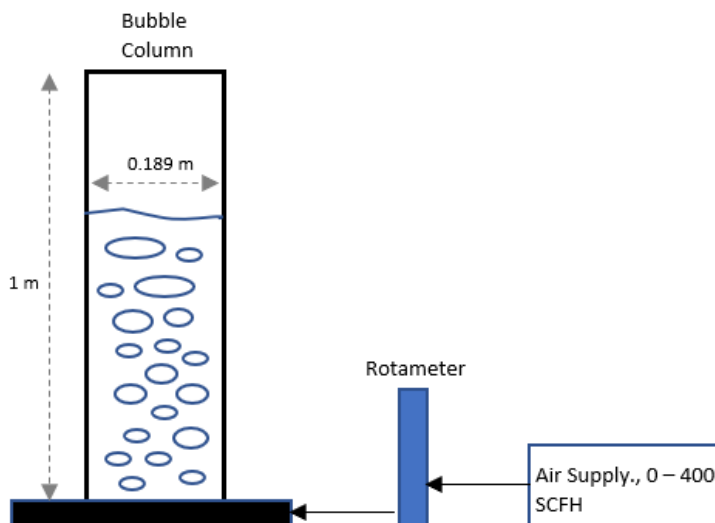
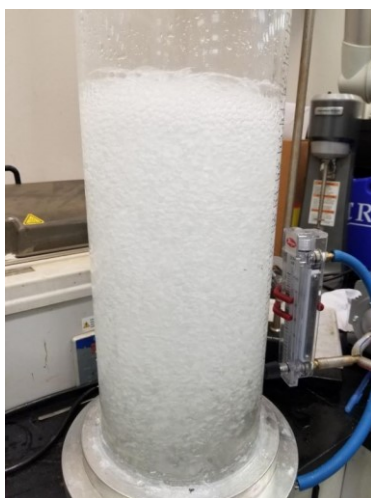


Figure 1: Experimental Setup

Spargers

The spargers used in this study consisted of aluminum circular perforated disks (plates) with a thickness of 1 mm. Holes were arranged in a square pattern with hole distances (spacing) at 10, 20 and 30 mm. In total 12 plates were used with the number of holes set at 9, 25, 49 and 169, corresponding to open hole area of 0.26% to 1.57% based on column cross sectional area. Hole diameters (d_o) varied between 1.17 and 7.9 mm. A summary of the sparger plates can be seen in Table 2 and Figure 2.

Table 2: Sparger Information

Sparger Type	Perforated Plate
Number of Spargers	12
Hole Arrangement	Square
Hole Spacing	10 - 30 mm
Hole Sizes (d_o)	1.17 - 7.9 mm
# of Holes (N_o)	9 - 169
Open hole Area (ϕ)	0.26 - 1.57%

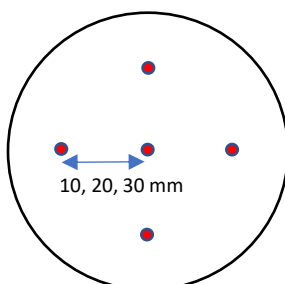


Figure 2: Plate hole arrangement

It should be mentioned that one perforated pipe sparger was also used to compare performance to perforated plates. The perforated pipe sparger consisted of 25 holes with diameters of 1.9 mm, spaced 20 mm apart.

System Conditions and Fluid Properties

The testing conditions and fluid properties can be seen in Table 3. The liquid used in this study is a mixture of MEA triazine (hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine), water and methanol. The blend consisted of ~ 40 - 42% active triazine, the rest being water and Methanol (41 - 43% water, 13 - 15% methanol). This Triazine activity was chosen as it is a good representation of what is currently being used in the oil and gas industry.

Table 3: System Conditions and Fluid Properties

Temperature	Ambient (21 °C)
Pressure	Atmospheric (0.1 MPa)
Superficial Gas Velocities (U_g) (m/s)	0.02 - 0.1
Gas	Air
Gas Density (kg/m ³)	1.225 at 21 °C (69.8 °F)
Liquid	Mixture of MEA Triazine, Water and Methanol
Liquid Density (kg/m ³)	1060 at 21 °C (69.8 °F)
Liquid Viscosity (Pa-s)	0.01138 at 21 °C (69.8 °F)
Liquid Surface Tension (N/m)	0.04
MEA Triazine Activity	40 - 42%
Mode of Operation	Semi-Batch
Aspect Ratio (H_c/D_c)	2
Packing	No

Procedure

Tests were conducted by placing a perforated plate in the column and securing it. The column was then filled with the triazine mixture up to a predetermined level. The air pumps were switched on and airflow is regulated by the rotameter. For this study the airflow was started at 75 SCFH and increased by increments of 25 SCFH (Standard Cubic Feet per Hour) up to 350 SCFH. That corresponded to superficial gas velocities of 0.021 m/s up to 0.1 m/s. The maximum superficial gas velocity (U_g) of 0.1 m/s was selected since at velocities above 0.1 m/s it becomes increasingly difficult to accurately determine the gas holdup with the volumetric fraction method (Equation 1) due to turbulence in the column. The superficial gas velocity range of 0.02 – 0.1 m/s was also investigated by most authors allowing for good comparative studies.^{2, 3, 4}

At each gas flowrate, the difference in volume is recorded and used to calculate the gas holdup (ϵ_g).

Protocols

The following studies were conducted.

1. Constant open hole area (ϕ) % and number of holes (N_o) - Three different open hole areas were investigated, 0.26%, 0.88% and 1.57%. For each open hole area, three perforated plates were used with different number of holes each; 9, 25 and 49 holes. The sizes of the holes were adjusted to still provide the corresponding open hole area. Spacing between the holes were kept constant at 20 mm. The data was then represented differently by keeping the number of holes constant (9, 25 and 49) and increasing hole size for each perforated plate (increasing % open hole area). The same test was done for water as a comparative study, 49 hole perforated plates only.