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MODELING AND VALIDATION OF DIRECT INJECTION OF AN ALKALINE SOLUTION INTO GAS STREAM PIPELINE IN CO-CURRENT CONFIGURATION FOR SWEETENING OF SOUR GASES



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BACKGROUND

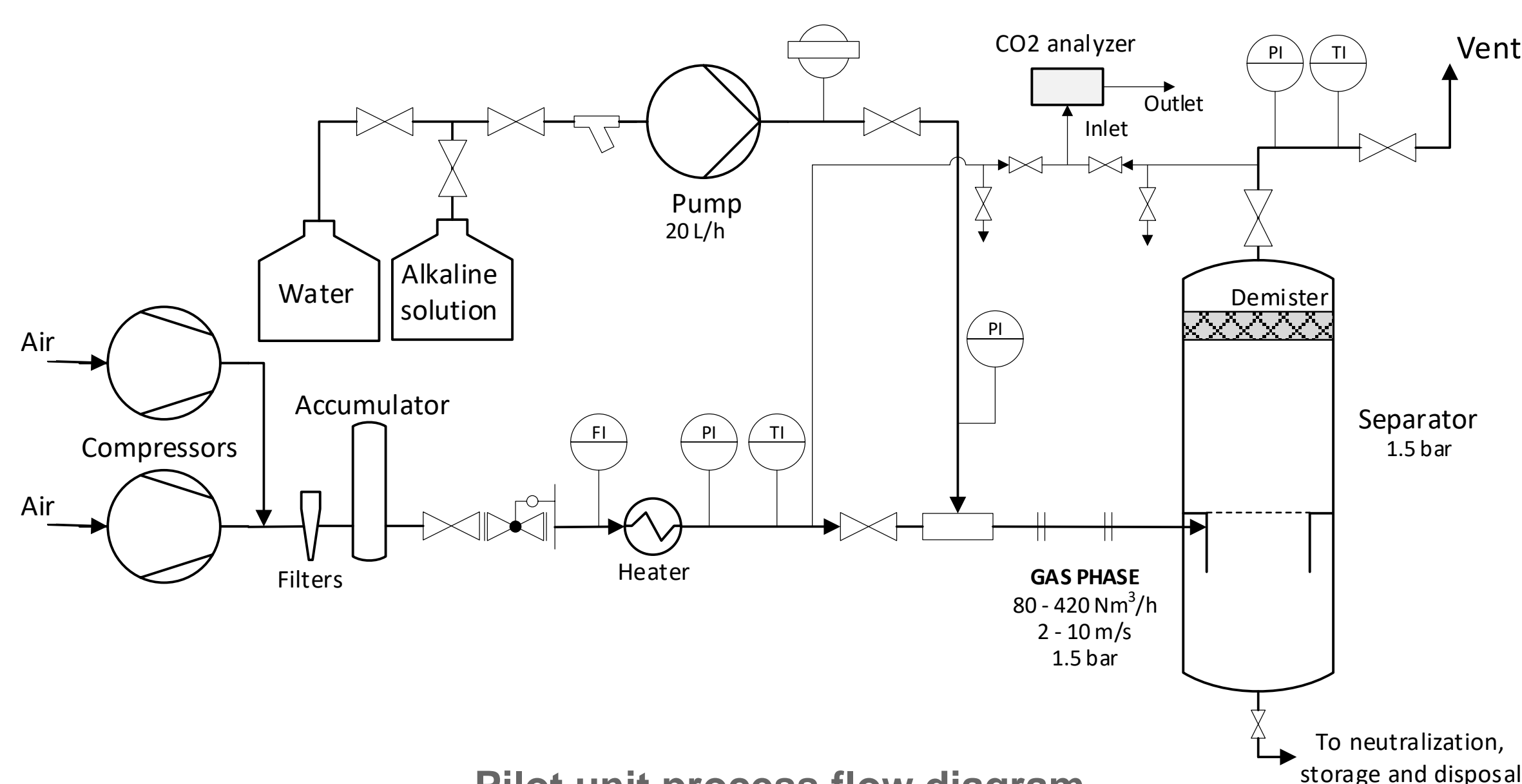
Oil and gas produced offshore frequently present high amount of acid gases, which must be removed to avoid operating and safety issues. Low space availability in offshore installations requires simple and non-space demanding acid gas removal systems, as direct injection of liquid chemicals (scavengers) in gas streams using simple quills. The removal of the acid gas species occurs via absorption of the species into the liquid phase, where the reaction with the scavenger takes place. Despite being frequently applied in offshore installations, the study of such systems is poorly developed, and their design is basically empirical, causing the use of excessive chemicals that ultimately may end up in the water discharge into the sea containing relatively large amounts of unspent scavengers which is detrimental to the environment [1].

OBJECTIVE

Investigate the removal of a sour species (CO₂) from a gas stream (air) by direct injection of NaOH aqueous solution in co-current configuration by comparing three injectors and estimating the mass transfer coefficients and the whole performance of the apparatus.

PILOT UNIT

A pilot-scale continuous-flow unit was specifically designed, developed, and assembled for this work. The unit was operated for absorbing atmospheric CO₂ from air by injecting and dispersing a basic aqueous solution of NaOH under conditions of ultra-fast chemical reaction.



EXPERIMENTAL CAMPAIGN

A total of 24 experiments were carried out using three types of injectors according to the table presented below. An operating pressure of 1.5 bar and a NaOH solution (0.25 M) were used in the experiments performed at average temperatures in the range 11.5 to 27.4 °C.



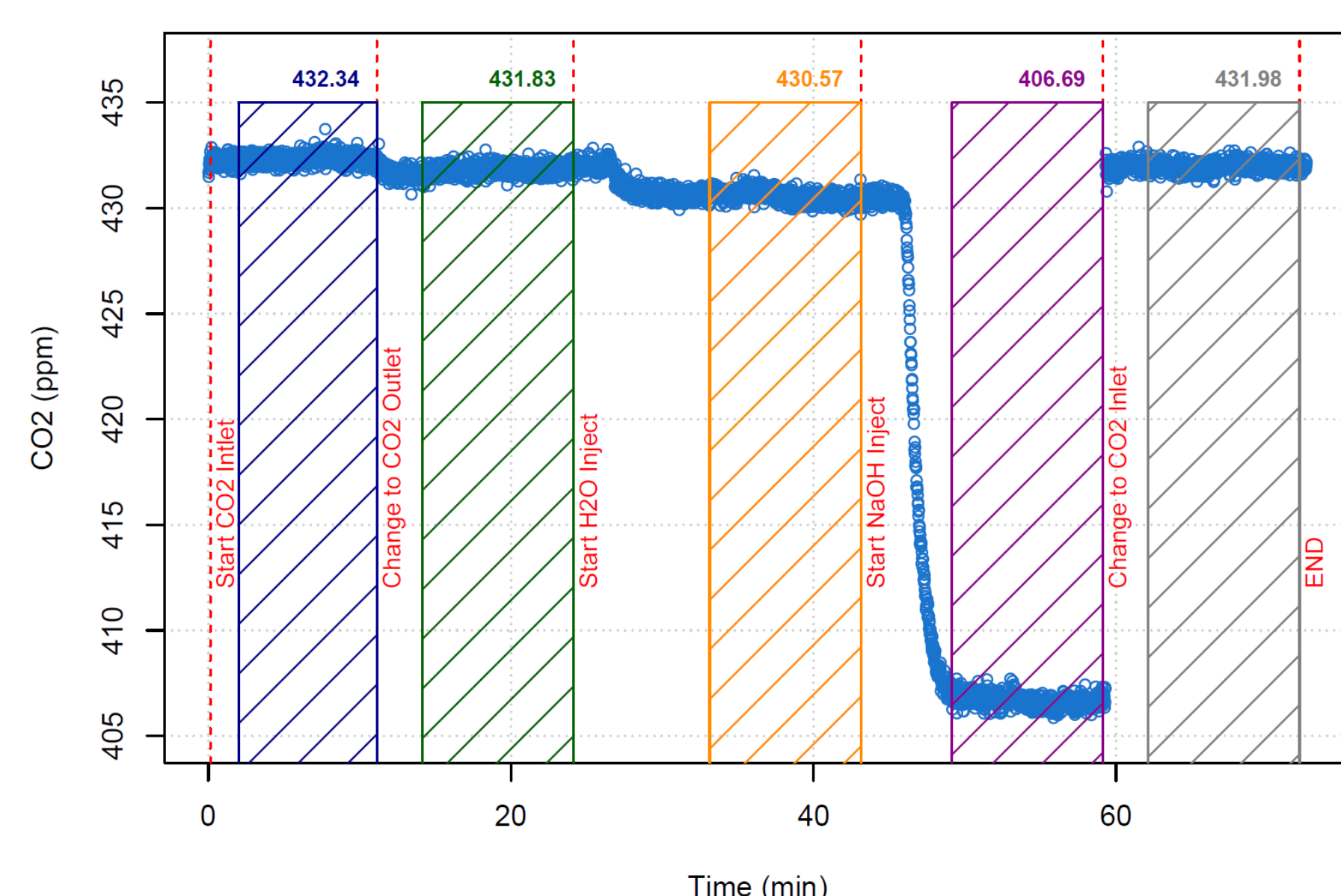
Injection devices	XAPR150	PJ15	Quill
Liquid flow rate injected, L/h	16.1	16.6	20
Gas flow rate*, Nm ³ /h	84	168	251
Pipeline length, m	11	23	

* The presented gas flow rate values correspond to gas velocities of 2, 4, 6 and 10 m/s, which are comparable to real gas velocities used in oil and gas operations.

A typical experimental output is shown in the following figure, where five main experimental steps are identified.

Experimental Steps

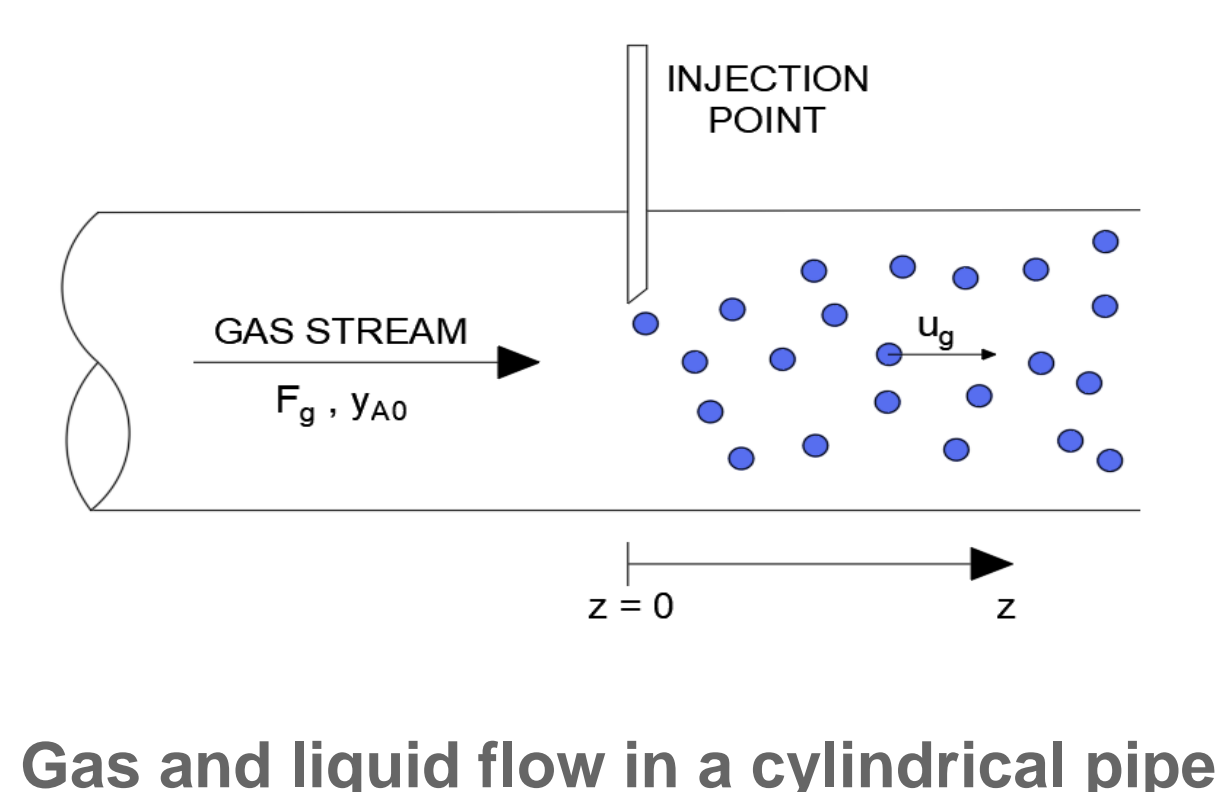
- CO₂ inlet
- CO₂ outlet
- H₂O injection
- NaOH injection
- CO₂ inlet - again



MODEL DEVELOPMENT

Model hypotheses:

- One-dimensional steady state two-phase flow
- Spherical and constant-size liquid droplets dispersed in the gas phase
- Only CO₂ transfers from the gas phase to the liquid droplets
- Co-current "plug flow" is assumed for both gas and liquid phases (no relative motion)
- Isobaric and isothermal process



At the operating conditions of the experiments (low CO₂ (A) partial pressure and high concentration of NaOH (B) in the aqueous phase), the reaction (CO₂ + 2OH⁻ → CO₃²⁻ + H₂O) is infinitely fast and occurring at the gas-liquid droplet interface, as verified using the criteria below [2]:

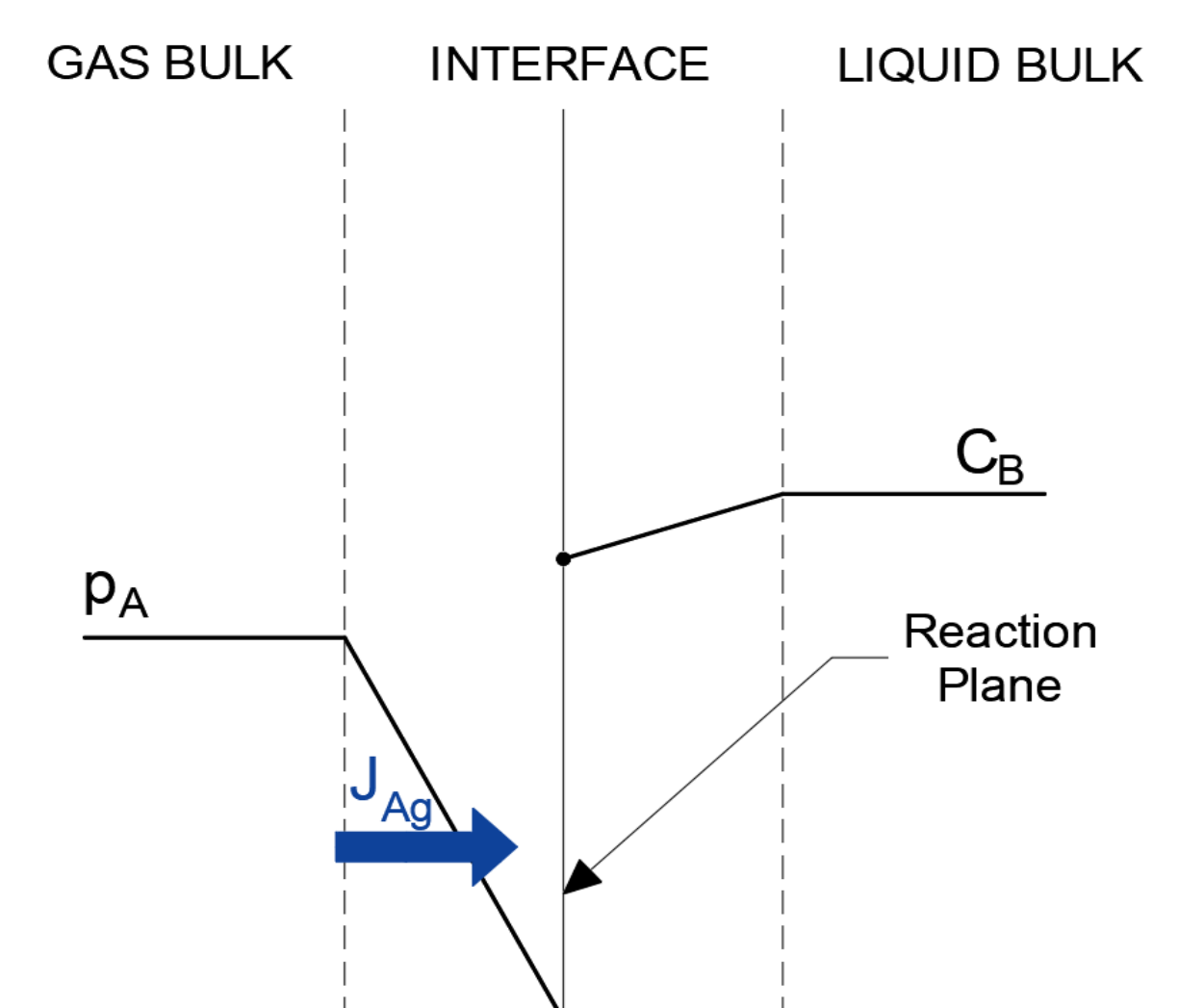
$$E_{A\infty} < M_H/5; \quad M_H = \frac{\sqrt{D_{Al} \cdot k \cdot C_B}}{k_{Al}}$$

$E_{A\infty}$ Enhancement factor for an infinitely fast reaction
 M_H Hatta number

$$\frac{D_{Ag}}{D_{Bl}} \leq \frac{C_B}{\frac{p_A}{R \cdot T} \cdot 2}$$

The volumetric mass transfer coefficient is obtained by integrating the differential molar balance of CO₂ in the gas phase along the reaction zone:

$$a \cdot k_g = \frac{G}{P \cdot L} \cdot \ln \left(\frac{y_{CO_2 0}}{y_{CO_2}} \right)$$



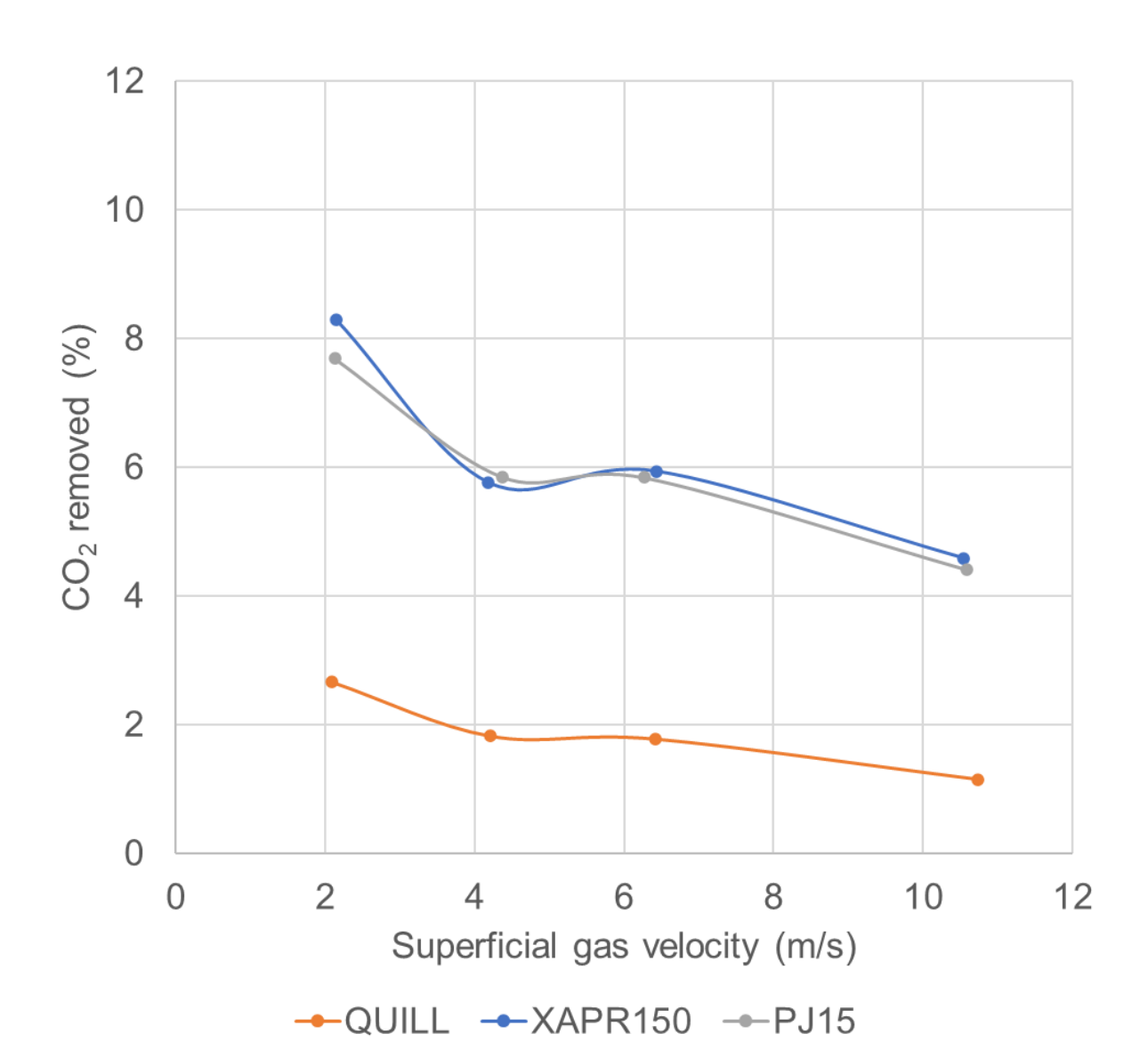
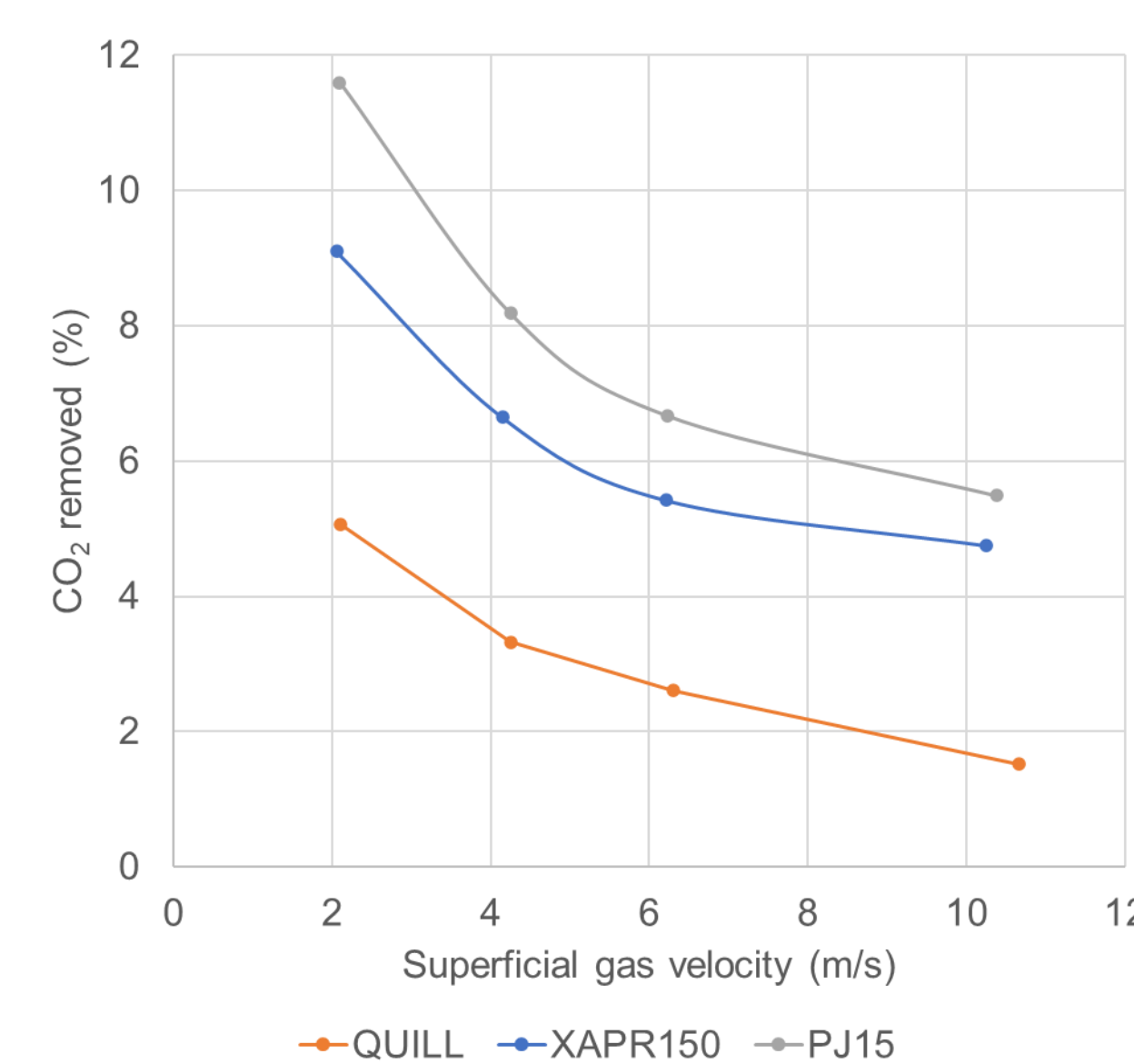
RESULTS

Carbon dioxide removed

According to the following expression, the percentage of CO₂ removed is estimated.

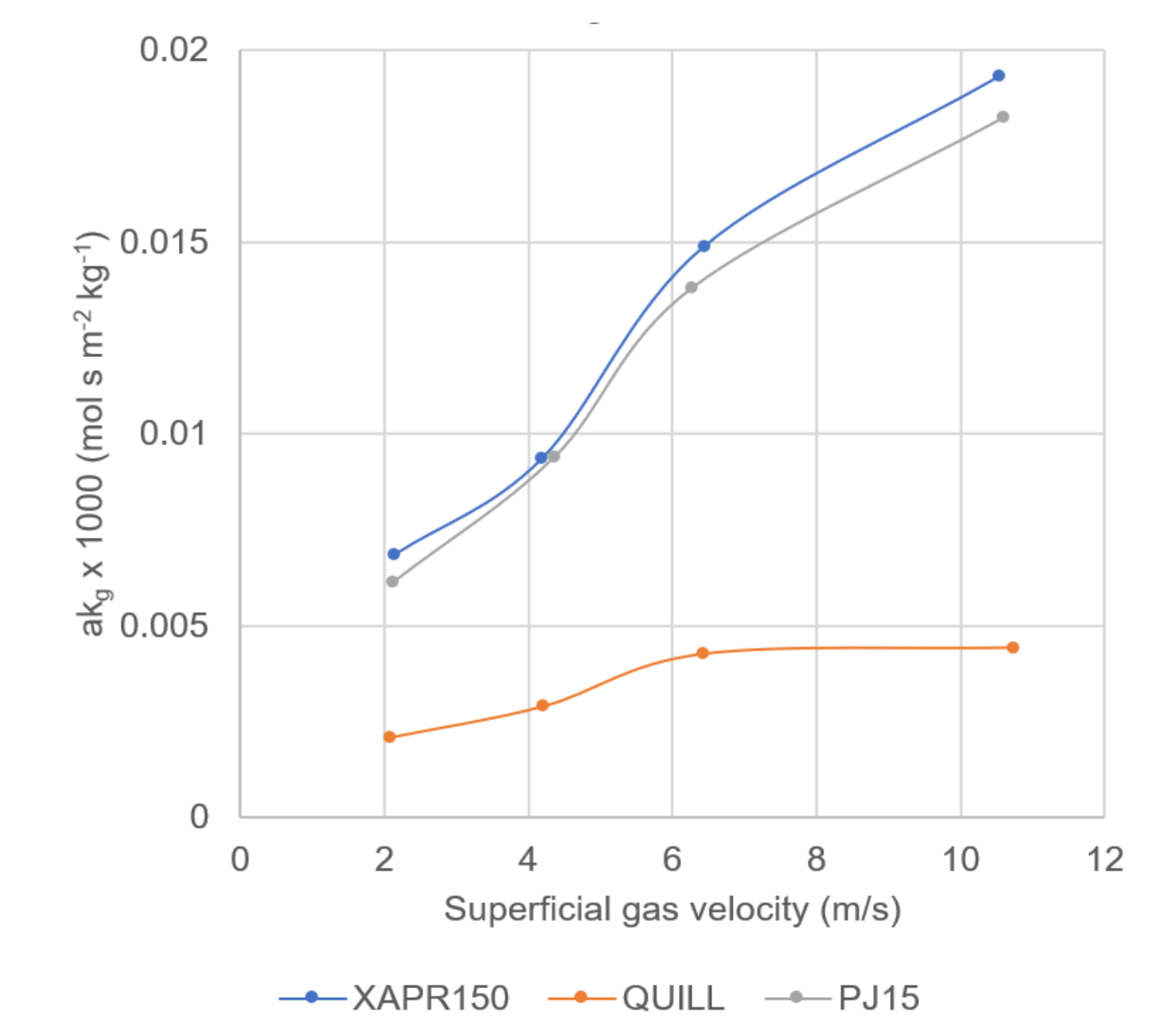
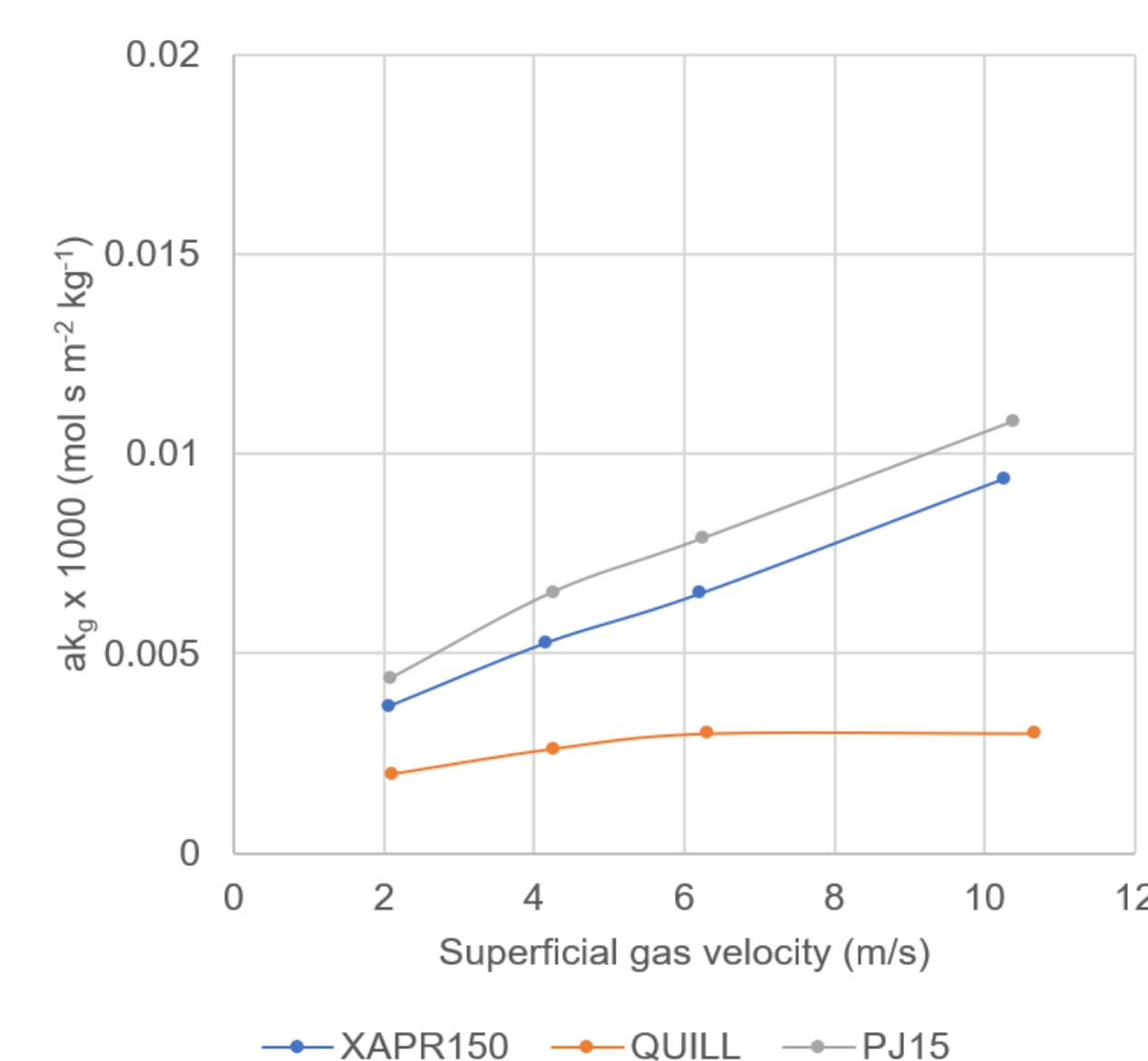
$$CO_{2\text{removed}} (\%) = \frac{CO_{20} - CO_2}{CO_{20}} \times 100$$

For the case XAPR150 – 4 m/s – 11 m, the average of removed CO₂ is 6.39 ± 0.55 (SD)



Mass transfer coefficient and specific surface area

Applying the model developed for this work, the following results are obtained.



- The use of spray atomizers leads to increased mass transfer coefficients, and it is therefore something to be considered instead of using simple quills.

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