**EXHIBIT 5.3: Sample Calculation for Acid Gas Removal (AGR) Vent Emissions, continued**

CALCULATION METHODOLOGY:
The AGR unit-based $CH_4$ emission factor from Table 5-4 is multiplied by the number of AGR units and converted from a daily basis to an annual basis.

$$CH_4: \quad (1\,\text{AGR}) \times \frac{0.1167\ \text{tonne}\ CH_4}{\text{day - AGR}} \times \frac{365\ \text{day}}{\text{yr}} = \underline{42.60\ \text{tonnes}\ CH_4/\text{yr}}$$

Note that the treated gas throughput-based $CH_4$ emission factor could have been used instead of the unit-based factor if the AGR throughput data had been available.

### 5.1.4 $CO_2$ Venting from Sour Gas Processing

Sour gas processing can directly vent the $CO_2$ removed from the sour gas stream to the atmosphere or capture the $CO_2$ for other uses, such as enhanced oil recovery. For systems that vent the waste $CO_2$, emissions can be estimated by material balance using the known throughput and $CO_2$ concentrations of the inlet and outlet gas streams (CAPP, 2003). Methane emissions from sour gas processing are assumed to be insignificant, but can also be estimated by material balance.

The material balance equation for estimating the $CO_2$ emissions is:

$$E_{CO_2} = \left[ \left( \frac{\text{Volume}}{\text{time}} \times CO_2\ \text{mole\%} \right)_{\text{sour}} - \left( \frac{\text{Volume}}{\text{time}} \times CO_2\ \text{mole\%} \right)_{\text{sweet}} \right] \times \frac{44}{\text{molar volume conversion}}$$

(Equation 5-1)

where:

| | | |
|---|---|---|
| $E_{CO2}$ | = | mass emissions of $CO_2$ per year (in pounds or kg) |
| Volume | = | volume of the sour and sweet gas (in scf or $m^3$ at STP conditions) |
| Molar volume conversion | = | conversion from molar volume to mass (379.3 scf/lbmole or 23.685 $m^3$/kgmole) |


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This approach is demonstrated in following exhibit.

**EXHIBIT 5.4a: Sample Calculation for $CO_2$ Venting Emissions from Sour Gas Processing**

INPUT DATA:
A sour gas processing facility has the following operating parameters:

Unit inlet stream: 150,000 $\times 10^6$ scf/yr sour gas processed with 3.0 mole % $CO_2$
Unit outlet stream: 148,500 $\times 10^6$ scf/yr sweet gas produced with 2.0 mole % $CO_2$

CALCULATION METHODOLOGY:
The $CO_2$ vented emissions are estimated using the material balance from Equation 5-1. Methane emissions are assumed to be insignificant.

$$E_{CO_2} = \left[ \left( \frac{\text{Volume}}{\text{time}} \times CO_2 \text{ mole\%} \right)_{\text{sour}} - \left( \frac{\text{Volume}}{\text{time}} \times CO_2 \text{ mole\%} \right)_{\text{sweet}} \right] \times \frac{44}{\text{molar volume conversion}}$$

$$CO_2 = \left( \frac{150{,}000 \times 10^6 \text{ scf gas}}{\text{yr}} \times \frac{0.030 \text{ scf } CO_2}{\text{scf gas}} \right) - \left( \frac{148{,}500 \times 10^6 \text{ scf gas}}{\text{yr}} \times \frac{0.020 \text{ scf } CO_2}{\text{scf gas}} \right)$$

$$\times \frac{\text{lbmole } CO_2}{379.3 \text{ scf } CO_2} \times \frac{44 \text{ lb } CO_2}{\text{lbmole } CO_2} \times \frac{\text{tonnes}}{2204.62 \text{ lb}} = \underline{80{,}506 \text{ tonnes/yr } CO_2}$$

Alternatively, the acid gas may be sent to an incinerator. In this case, the $CO_2$ emissions vented from the incinerator can be calculated based on the volume of acid gas to the incinerator and the mole fraction of $CO_2$ in the acid gas. The material balance equation for this approach is:

$$CO_2 \text{ emitted} = \left( \frac{\text{Volume}}{\text{time}} \times CO_2 \text{ mole\%} \right)_{\text{Acid gas}} \times \frac{44}{\text{molar volume conversion}} \qquad \text{(Equation 5-2)}$$

where:

| | | |
|---|---|---|
| $E_{CO2}$ | = | mass emissions of $CO_2$ per year (in pounds or kg) |
| Volume | = | volume of the acid gas (in scf or $m^3$ at STP conditions) |
| Molar volume conversion | = | conversion from molar volume to mass (379.3 scf/lbmole or 23.685 $m^3$/kgmole) |


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**EXHIBIT 5.4b: Sample Calculation for $CO_2$ Venting Emissions from Sour Gas Processing**

INPUT DATA:
$76{,}500 \times 10^6$ scf/yr of an acid gas stream with 2 mole% $CO_2$

CALCULATION METHODOLOGY:
The $CO_2$ vented emissions are estimated using the material balance from Equation 5-2.

$$CO_2 \text{ emitted} = \left( \frac{\text{Volume}}{\text{time}} \times CO_2 \text{ mole\%} \right)_{\text{Acid gas}} \times \frac{44}{\text{molar volume conversion}}$$

$$CO_2 = \left( \frac{76{,}500 \times 10^6 \text{ scf gas}}{\text{yr}} \times \frac{0.02 \text{ scf } CO_2}{\text{scf gas}} \right) \times \frac{\text{lbmole } CO_2}{379.3 \text{ scf } CO_2} \times \frac{44 \text{ lb } CO_2}{\text{lbmole } CO_2} \times \frac{\text{tonnes}}{2204.62 \text{ lb}}$$

$$= \underline{80{,}506 \text{ tonnes/yr } CO_2}$$

## 5.2 Refinery Processes

There are a number of specialized process vents in refineries. Many of these are associated with catalyst regeneration, such as the catalytic cracking regeneration, catalytic reformer regeneration, etc. Others are used to vent a waste material, such as the hydrogen plant. This section will address each vent by process.

### *5.2.1 Catalytic Cracking Regenerator*

The catalytic cracking process deposits coke on the catalyst as a byproduct of the reaction. That coke must be burned off to restore the activity of the catalyst. The coke is continuously burned off in the regenerator. This process vent will be a significant source of $CO_2$ emissions, but $CH_4$ emissions are likely to be negligible.

Catalytic crackers (FCCUs) are operated in two basic modes:

1. Full, or complete, CO burn mode, where essentially all CO is combusted to $CO_2$ within the regenerator. The exhaust gas typically contains approximately 2% $O_2$ and less than 1%


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