Calculating Flare Carbon-Conversion Efficiency and Species Emission Rates in a Closed-Loop Wind Tunnel

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Abstract

Satellite data suggest worldwide flared volumes exceed 140 billion m^3 annually, where much of it is associated with development of unconventional oil and gas resources. Flaring in Canada has risen sharply in recent years, directly related to a rapid expansion in hydrofractured tight oil and tight gas developments. Data and models to accurately predict flare emissions are critically lacking such that current emission factors relied upon to calculate pollutant inventories and guide regulation are questionably relevant. Despite strong evidence that flares subjected to crosswinds can undergo fuel stripping mechanisms that degrade efficiency and lead to emissions of unburned fuel, the majority of published flare experiments have not considered the impact of a crosswind and there are essentially experimental data available on the effects of turbulent crosswinds on flare performance.

Accurate flare experiments over a wide range of possible scenarios may only be achieved in an environment where the wind conditions can be systematically controlled and manipulated. This work presents a methodology to determine the carbon conversion efficiency and species emission rates of a flare burning in a closed-loop wind tunnel. The developed methodology is based on solving the unsteady mass balance problem to relate accumulation rates of measured species in the wind tunnel to emission rates, while considering complicating factors such as infiltration and exfiltration of gases from the wind tunnel, potential for reburning of products within the wind tunnel, and presence of inert species in the fuel stream. The methodology is assessed by simulating a wide range of scenarios that are likely to be encountered, while calculating the achievable uncertainty in the determined carbon conversion efficiency.