



Establishing a Test Facility for Measuring the Carbon Conversion Efficiency and Emissions Indices for Lab-Scale Air and Steam Assisted Flares

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Abstract

Open-atmosphere jet diffusion flames are commonly used in both the upstream and downstream energy sectors to dispose of waste hydrocarbon gases in a practice known as flaring. Process flares at industrial facilities that have access to steam or compressed air often co-inject those fluids at, or near, the exit of the stack are known as assisted flares. The purpose of using these assisting fluids in the flaring process is to reduce the soot emissions and luminosity of the flame. An operational challenge for these flares is to benefit from reducing one set of emissions without incurring the cost of increasing another (*i.e.*, reducing soot at the expense of generating unburned hydrocarbons). A number of petrochemical companies have been found to be in violation of flare performance standards by not effectively managing this potential trade-off.

To better understand the effects of air- and steam-assist on flaring operations in terms of carbon conversion efficiency and selected pollutant emissions, a lab-scale test facility has been established. The facility was designed to handle fuel flow rates equivalent to ~50 kW and include supplying mixtures of C1 to C3 bottled fuels, and providing compressed air to 1000 SLPM and steam to 408 g/min at 207 kPa produced by an electric boiler. The products of combustion are captured by a hood and extracted through an exhaust duct where the gases, vapors, and particulates are fully mixed for sampling. Screens with 1.59 mm openings and 50% blockage extend from the hood to the floor to allow combustion and dilution air in to support the flaring process, while preventing room air currents from affecting the flame.

The principal variables that can be manipulated in this facility include the physical geometry and the arrangement of the fuel and assist-flows of the flare system, as well as the flow rate of fuel and flow rate of either air or steam.

Sampling of the fully mixed products from the exhaust duct is done through a 6.35 mm o.d. L-shaped stainless-steel probe and transferred to photoacoustic extinctions and low source NO_x analyzer to measure the soot and NO_x concentrations. Sample can also be transferred into a 10 L Tedlar bag and introduced into a gas chromatograph to measure the concentrations of CH₄, C₂H₆, C₃H₈, C₄H₁₀, CO, and CO₂. This information can be used to estimate the carbon conversion efficiency (*i.e.*, the carbon in hydrocarbon fuel to carbon dioxide) and the emission indices (*i.e.*, the mass of a particular species per kilogram of fuel flared) for soot, unburnt hydrocarbons, and NO_x.