Carbon Conversion Efficiency and Emissions Indices (Soot, THC, and NO_x) from a Lab-Scale Generic Air and Steam Assisted Flares

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Abstract

The upstream and downstream energy sectors dispose of waste hydrocarbon gases through a practice known as flaring. The goal of semi-continuous flaring, which is a consequence of a standard process operation, is to reduce the net environmental and health impacts of releasing materials into the atmosphere by first combusting them. When this process flaring occurs at facilities that have access to steam or compressed air these fluids are often co-injected to enhance the combustion and are known as assisted flares. These assisting fluids have been observed to have the benefit of reducing soot emissions, as well as reducing the luminosity and thermal radiation, but over-assisting can trigger an increase in other emissions (*i.e.*, unburned hydrocarbons). Petrochemical companies have been found to be in violation of flare performance standards by not effectively managing this potential trade-off. From an economic perspective, it is important to optimise the amount of assisted fluids for a given flare gas composition and flow rate as these fluids represent an operating cost to the facility.

To study this trade-off a lab-scale test facility was established capable of handling fuel flow rates equivalent to ~50 kW, and provide compressed air and steam. Through the measurement of CH_4, C_2H_6, C_3H_8, C_4H_{10}, CO, CO_2, NO_x and soot 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 was estimated.

A series of tests using either methane or propane were conducted on a generic assisted flare consisting of two concentric stainless-steel tubes, with the exit planes of the tubes being coincident. The fuel flowed through the annular space between the outer tube (25.4 mm o.d. and 22.9 mm i.d.) and different inner tubes with outer diameters of either 6.35 mm or 12.7 mm, which carried the assisting fluid. Starting from the case of no assisted flow and having a fixed fuel flow rate, the flow rate of the assisting fluid was incrementally increased until the flare was extinguished.

The pattern observed was that at no or low assisted flow the combustion efficiency was high (>99%), while the soot and NO_x emissions were also highest. As the flow rate of assisting fluid was increased the combustion efficiency remained the same, but the soot and NO_x emissions could drop two orders of magnitude. Further increasing in the flow of assisting fluid provoked a sudden and catastrophic drop in efficiency and emitting mostly unburned hydrocarbons. The separation between getting the benefits of reduced soot and NO_x emissions and the drop in efficiency was greater for air assist.