EPA-452/F-03-019

Air Pollution Control Technology Fact Sheet

Name of Technology: Flare

This includes elevated flares, steam-assisted flares, air-assisted flares, non-assisted flares, pressure-assisted flares, and enclosed ground flares.

Type of Technology: Destruction by thermal oxidation.

Applicable Pollutants: Volatile organic compounds (VOC), with the exception of halogenated compounds (EPA, 1995).

Achievable Emission Limits/Reductions:

VOC destruction efficiency depends upon an adequate flame temperature, sufficient residence time in the combustion zone, and turbulent mixing (EPA, 1992). A properly operated flare can achieve a destruction efficiency of 98 percent or greater when controlling emission streams with heat contents greater than 11 megajoules per standard cubic meter (MJ/sm^3) (300 British thermal units per standard cubic foot (Btu/scf)) (EPA, 1995; AWMA, 1992; EPA, 1992; EPA, 1991).

Applicable Source Type: Point

Typical Industrial Applications:

Flares can be used to control almost any VOC stream, and can typically handle large fluctuations in VOC concentration, flow rate, heating value, and inert species content. Flaring is appropriate for continuous, batch, and variable flow vent stream applications, but the primary use is that of a safety device used to control a large volume of pollutant resulting from upset conditions. Flares find their primary application in the petroleum and petrochemical industries. The majority of chemical plants and refineries have existing flare systems designed to relieve emergency process upsets that require release of large volumes of gas. These large diameter flares are designed to handle emergency releases, but can also be used to control vent streams from various process operations. Gases flared from refineries, petroleum production, and the chemical industry are composed largely of low molecular weight VOC and have high heating values. Flares used to control waste gases from blast furnaces consist of inert species and carbon monoxide with a low heating value. Gases flared from coke ovens are intermediate in composition to the other two groups and have a moderate heating value (EPA, 1995; EPA, 1992).

Emission Stream Characteristics:

a. **Air Flow:** The flow rate through the flare is dependent upon the properties of the waste gas stream and the configuration of the flare. Steam-, air-, and pressure-assisted flares add flow to the waste stream in order to improve flame stability. In cases where the heating value of the waste gas is too low or too high, auxiliary fuel or additional air must be added to the flow, respectively. The maximum flow through commercially available flares is about 500 standard cubic meters per second (sm^3/sec) (1,060,000 standard cubic feet per minute (scfm)), and the minimum can approach zero flow (EPA, 1995).

b. **Temperature:** The discharge temperature is typically in the range of 500 to 1100°C (1000 to 2000°F), depending upon the composition of the waste gas flow (AWMA, 1992).

c. **Pollutant Loading:** Depending upon the type of flare configuration (e.g., elevated or ground flares) and the source of the waste stream, the capacity of flares to treat waste gases can vary up to about 50,000 kilograms per hour (kg/hr) (100,000 pounds per hour (lb/hr)) of hydrocarbon gases for ground flares and about 1 million kg/hr (2 million lb/hr) or more for elevated flares (EPA, 1991). Flares are not subject to the safety concern of incinerators regarding having a high concentration of organics in the waste gas. This is because flaring is an open combustion process and does not have an enclosed combustion chamber that can create an explosive environment. Incinerators, however, have an enclosed combustion chamber, which requires that the concentration of the waste gas be substantially below the lower flammable level (lower explosive limit, or LEL) of the specific compound being controlled to avoid the potential for explosion (as a rule, a safety factor of four (i.e., 25% of the LEL) is used).

d. **Other Considerations:** The waste gas stream must have a heating value of greater than 11 MJ/scm (300 Btu/scf). If this minimum is not met by the waste gas, auxiliary fuel must be introduced in sufficient quantity to make up the difference (EPA, 1995).

Emission Stream Pretreatment Requirements:

Liquids that may be in the vent stream gas or that may condense out in the collection header and transfer lines are removed by a knock-out drum. The knock-out or disentrainment drum is typically either a horizontal or vertical vessel located at or close to the base of the flare, or a vertical vessel located inside the base of the flare stack. Liquid in the vent stream can extinguish the flame or cause irregular combustion and smoking. In addition, flaring liquids can generate a spray of burning chemicals that could reach ground level and create a safety hazard (EPA, 1995).

Cost Information:

Typical elevated flares are primarily safety devices which prevent the emissions of large quantities of raw unburned hydrocarbons during plant upset conditions. The capital costs of elevated flare systems can range from $10,000 to $3,000,000, depending upon the application (Gonzalez, 1999). The controlling factors in the cost of the flare are the basic support structure of the flare, the size and height, and the auxiliary equipment. Other factors influencing the cost are the degree of sophistication desired (i.e., manual vs. automatic control) and the number of appurtenances selected, such as knock-out drums, seals, controls, ladders, and platforms. The minimum flare diameter is 2.5 centimeters (cm) (1 inch); the maximum flare diameter currently commercially available is 2.3 meters (90 inches). (EPA, 1996)

Operating costs for an elevated flare depend largely upon the design of the flare (e.g., a steam-assisted flare will require steam), the flow rate (this will determine the diameter of the flare tip), and the heating value of the gas to be controlled (this will be a factor in determining the height of the flare and the amount of auxiliary natural gas required to achieve the desired destruction temperature) (EPA, 1996).

The following are cost ranges (expressed in 2002 dollars) for elevated steam-assisted flares of conventional design under typical operating conditions, developed using EPA cost-estimating spreadsheets (EPA, 1996) and referenced to the volumetric flow rate of the waste stream treated. Costs were calculated for flares with tips between 2.5 cm (2 in) and 2.3 m (90 in) in diameter, burning 100 percent combustible waste gas (no air) with a heat content of approximately 4000 kcal/m^3 (450 Btu/scf), and operated between 1 and 100 hours per year. Flares in the lower end of the capital, operating &

maintenance, and annualized cost ranges have higher flow capacity (approximately 90 m^3/s or 190,000 scfm), with a flare tip diameter of up to 2.3 m (90 in), and operate 100 hours per year or more. The higher end of the cost ranges have lower flow capacity (approximately 0.01 m^3/s, or 24 scfm), flare tip diameters as small as 2.5 cm (1 inch), and operate fewer than ten hours per year.

Because flares are primarily safety devices which deal with flows of short duration (generally an upset condition or an accidental release from a process) rather than a control device which treats a continuous waste stream, it is not entirely appropriate to compare the cost effectiveness of flares to other control devices. Cost per ton of pollutant controlled largely depends upon the annual hours of operation. Infrequent use of the flare (approximately ten hours per year) will result in greater cost per ton of pollutant controlled., while more frequent use (approximately 100 hours per year) is represented by the lower costs per ton of pollutant controlled in the ranges presented below.

- **a.** **Capital Cost:** \$27,000 to \$4,000,000 per sm^3/sec (\$13 to \$21,000 per scfm)
- **b.** **O & M Cost:** \$2,000 to \$20,000 per sm^3/sec (\$1 to \$10 per scfm), annually
- **c.** **Annualized Cost:** \$6,000 to \$650,000 per sm^3/sec (\$3 to \$300 per scfm), annually
- **d.** **Cost Effectiveness:** \$17 to \$6,500 per metric ton (\$15 to \$5,800 per short ton), annualized cost per ton per year of pollutant controlled

Theory of Operation:

Flaring is a VOC combustion control process in which the VOC are piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete (> 98%) VOC destruction. Completeness of combustion in a flare is governed by flame temperature, residence time in the combustion zone, turbulent mixing of the gas stream components to complete the oxidation reaction, and available oxygen for free radical formation. Combustion is complete if all VOC are converted to carbon dioxide and water. Incomplete combustion results in some of the VOC being unaltered or converted to other organic compounds such as aldehydes or acids.

Flares are generally categorized in two ways: (1) by the height of the flare tip (i.e., ground or elevated), and (2) by the method of enhancing mixing at the flare tip (i.e., steam-assisted, air-assisted, pressure-assisted, or non-assisted). Elevating the flare can prevent potentially dangerous conditions at ground level where the open flame (i.e., an ignition source) is located near a process unit. Elevating the flare also allows the products of combustion to be dispersed above working areas to reduce the effects of noise, heat, smoke, and objectionable odors.

In most flares, combustion occurs by means of a diffusion flame. A diffusion flame is one in which air diffuses across the boundary of the fuel/combustion product stream toward the center of the fuel flow, forming the envelope of a combustible gas mixture around a core of fuel gas. This mixture, on ignition, establishes a stable flame zone around the gas core above the burner tip. This inner gas core is heated by diffusion of hot combustion products from the flame zone.

Cracking can occur with the formation of small hot particles of carbon that give the flame its characteristic luminosity. If there is an oxygen deficiency and if the carbon particles are cooled to below their ignition temperature, smoking occurs. In large diffusion flames, combustion product vortices can form around burning portions of the gas and shut off the supply of oxygen. This localized instability causes flame flickering, which can be accompanied by soot formation. As in all combustion processes, an adequate air supply and good mixing are required to complete combustion and minimize smoke. The various flare designs differ primarily in their accomplishment of mixing.

Steam-assisted flares are single burner tips, elevated above ground level for safety reasons, that burn the vented gas in a diffusion flame. They reportedly account for the majority of the flares installed and are the predominant flare type found in refineries and chemical plants. To ensure an adequate air supply and good mixing, this type of flare system injects steam into the combustion zone to promote turbulence for mixing and to induce air into the flame.

Some flares use forced air to provide the combustion air and the mixing required for smokeless operation. These flares are built with a spider-shaped burner (with many small gas orifices) located inside but near the top of a steel cylinder 0.6 meters (24 inches) or more in diameter. Combustion air is provided by a fan in the bottom of the cylinder. The amount of combustion air can be varied by varying the fan speed. The principal advantage of air-assisted flares is that they can be used where steam is not available. Although air assistance is not usually used on large flares (because it is generally not economical when the gas volume is large) the number of large air-assisted flares being built is increasing.

The non-assisted flare consists of a flare tip without any auxiliary provision for enhancing the mixing of air into its flame. Its use is limited to gas streams that have a low heat content and a low carbon/hydrogen ratio that burn readily without producing smoke. These streams require less air for complete combustion, have lower combustion temperatures that minimize cracking reactions, and are more resistant to cracking.

Pressure-assisted flares use the vent stream pressure to promote mixing at the burner tip. Several vendors now market proprietary, high pressure drop burner tip designs. If sufficient vent stream pressure is available, these flares can be applied to streams previously requiring steam or air assist for smokeless operation. Pressure-assisted flares generally (but not necessarily) have the burner arrangement at ground level, and consequently, must be located in a remote area of the plant where there is plenty of space available. They have multiple burner heads that are staged to operate based on the quantity of gas being released. The size, design, number, and group arrangement of the burner heads depend on the vent gas characteristics.

An enclosed flare's burner heads are inside a shell that is internally insulated. The shell reduces noise, luminosity, and heat radiation and provides wind protection. Enclosed, or ground-based flares are generally used instead of elevated flares for aesthetic or safety reasons. A high nozzle pressure drop is usually adequate to provide the mixing necessary for smokeless operation and air or steam assistance is not required. In this context, enclosed flares can be considered a special class of pressure-assisted or non-assisted flares. The height must be adequate for creating enough draft to supply sufficient air for smokeless combustion and for dispersion of the thermal plume. These flares are always at ground level.

Enclosed flares generally have less capacity than open flares and are used to combust continuous, constant flow vent streams, although reliable and efficient operation can be attained over a wide range of design capacity. Stable combustion can be obtained with lower heat content vent gases than is possible with open flare designs (1.9 to 2.2 MJ/sm^3 (50 to 60 Btu/scf)), probably due to their isolation from wind effects. Enclosed flares are typically used at landfills to destroy landfill gas. (EPA, 1995)

Advantages:

Advantages of flares over other types of VOC oxidizers include (EPA, 1992; EPA, 1991):

1. Can be an economical way to dispose of sudden releases of large amounts of gas;
2. In many cases do not require auxiliary fuel to support combustion; and
3. Can be used to control intermittent or fluctuating waste streams.

12. Disadvantages:

Disadvantages of flares include (EPA, 1995):

d. Can produce undesirable noise, smoke, heat radiation, and light;
e. Can be a source of SO_x, NO_x, and CO;
f. Cannot be used to treat waste streams with halogenated compounds; and
g. Released heat from combustion is lost.

Other Considerations:

Flaring is considered as a control option when the heating value of the emission stream cannot be recovered because of uncertain of intermittent flow as in process upsets of emergencies. If the waste gas has a heating value high enough to sustain combustion (i.e. greater than 11 MJ/sm^3 or 300 Btu/scf), the stream may serve as a fuel gas for an incinerator if one is employed at the site (EPA, 1991).

References:

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