coustics'08 Paris
June 29-July 4, 2008
www.acoustics08-paris.org

Prediction of noise emissions from industrial flares

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In many industries where combustible waste gases are obtained, flares are used to burn these gases in a controlled manner. Among other environmental aspects, the noise emissions associated with flaring are becoming increasingly important in many countries as population density goes up and residential and industrial areas move closer together. Installing noise control equipment on flares is almost impossible while they are in service, since flares are typically a safety related plant component that can only be turned off after the connected plant has been shut down. Accordingly, in order to plan appropriate noise control measures in time and to avoid unnecessary costs, predicting the noise emissions of flares as early in the design process as possible is crucial. This requires knowledge of the relevant individual noise sources associated to the flare system and the ability to calculate their respective contribution - in the operating condition in question - to the overall noise emission, based on the data available in the planning stage. The present paper summarizes these sources and outlines some of the individual effects and parameters having an influence on the acoustical characteristics of flares.

1 Introduction

The safe operation of hydrocarbon and petrochemical industry plants sometimes requires the venting of combustible gases. While the amounts of waste gas to be disposed are usually small during normal operation, large or even very large flow rates may occur during start-up or shut-down of individual process units or, in particular, during an emergency shut-down of the plant. In most cases, environmental concerns forbid the venting of unburned gases directly to the atmosphere since they may contain toxic or hazardous components and could ignite in an uncontrolled way at some point, causing explosions or fires. Instead, it is common practice to dispose of the gases by burning them in a flare.

Basically, a flare is a device by which combustible gases are reliably ignited and burnt in a controlled manner at a defined location. This needs to be accomplished in a safe way for all possible operating conditions and flow rates, protecting persons and environment from thermal radiation, hot gases, pollutant emissions and unnecessary annoyance.

2 Flare types

Depending on the respective application, modern industrial flares can be divided into the following three categories [1]:

- Elevated flares – characterized by a vertical, high stack (“flare stack”, up to > 200 m). At the open top end of the stack, the waste gases are burnt in the form of a single flame.
- Ground flares – typically with a number of burners firing into the base of a stack which is open at the top (diameter up to > 15 m). Here, combustion takes place inside the stack and the flames are not visible from the outside.
- “Multi-point” ground flares – where the waste gases are distributed to a large number of individual burners (several hundreds), which are usually arranged in rows on a surface (1,000 m² up to > 10,000 m²) and which are surrounded by screens (up to 20 m) to keep out wind and for protection from thermal radiation and noise.

3 Flare noise and noise control

Plant owners operating flares not only have to comply with environmental regulations concerning noise, but may also need to take into account the public perception of flaring and the associated influence on the relationship between the facility and its neighbors.

For an acoustic optimization of flares, different primary noise control measures (e.g. low-noise burner design) and secondary noise control measures (e.g. silencers and screens) - depending on the type of the flare in question - can be applied.

However, a decisive characteristic of most flare systems is that they can, under no circumstances, be shut down without creating an intolerable safety hazard while the connected plant is still operational. As a consequence, if a flare emits too much noise after being placed into operation, there will usually be no economically acceptable possibility, for several years (until the next shut-down of the plant), to modify its noise control concept.

Instead, the optimum noise control concept must be worked out at the design stage of the flare. For this purpose, it is essential to be able to predict the level and characteristics of the flare’s expected noise emissions with sufficient accuracy.

4 Simple prediction models

Simple relations to predict the sound emission of flares can, for example, be taken from the VDI guideline VDI 3732 [2]. In this guideline, it is distinguished between elevated flares and ground flares, and the following equations are given to calculate the A-weighted sound power level of the noise emitted by these flares:

Ground flares: $$L_{WA} = 100 + 15 \cdot \lg\left(\frac{Q}{Q_0}\right) \qquad (1)$$

Elevated flares: $$L_{WA} = 112 + 17 \cdot \lg\left(\frac{Q}{Q_0}\right) \qquad (2)$$

Here, L_{WA} is the A-weighted sound power level in dB (re $1 \cdot 10^{-12}$ W) of the total noise emitted by the flare, Q is the gas mass flow rate burnt in the flare in t/h and Q_0 is the reference mass flow rate of 1 t/h. A decisive advantage of these equations is that the respective operating condition can be taken into account by means of a single input quantity Q, so that the expected noise emissions can quickly be estimated.

However, as the relations in equations (1) and (2) are obtained from a regression of measurement data obtained for a relatively small number of similar flares, the range of flare types and operating conditions for which the given approximations lead to useful results, is rather limited. Thus, ideally and in order to avoid significant inaccuracies, equations (1) and (2) should only be applied for flare systems with the following features:

- Flare type: Standard design with steam injection for smoke suppression
- Operating condition: Design gas and steam flow rate for smokeless combustion
- Gas properties: ≈ ethylene; low pressure at flare burner

5 Requirements for universal noise prediction models

Modern flare systems are highly optimized, special solutions, tailor-made for a specific application. Typically, one flare differs quite distinctly from another, and there is no such thing as a “standard design”. Furthermore, industrial flares often need to be operated in very different scenarios and it is not only the design operating condition that is relevant in terms of noise. Therefore, planning of efficient noise control for flares requires a reliable prediction of the noise emissions to be expected for a wide range of configurations and operating conditions.

How much noise is generated by the individual sound sources of a flare and how much of this noise is actually received at a specific location in the neighborhood, depends on a variety of parameters, e.g. [3]:

- Flare type and geometry: Elevated flare, ground flare, multi-point flare; number, design and arrangement of burner(s); stack height and diameter
- Smoke suppression equipment: Steam/air injection, number, arrangement, design etc. of injectors; combustion air blowers, air blower characteristics
- Flare load: Partial load, full load, design case; excess of / lack of steam or air
- Properties of flare gas and of supporting steam and air: Flow rate, composition, temperature, pressure, exit velocity
- Flame volume and length
- (Control) valve parameters: Type, pressure drop, staging, connected pipes
- Spectrum, directivity, tonality and impulsiveness of the emitted noise
- Noise control features: Mufflers, absorptive linings, noise screens, insulation
- Conditions of sound propagation

A universally applicable flare noise prediction model, which is intended to serve as a basis for noise control planning, must be able to take into account the effects and parameters described above in order to guarantee sufficient planning safety.

6 Comparison of models

To illustrate the increased prediction accuracy of models taking the described input parameters into account, results of the simple model from VDI 3732 [2] and from a more sophisticated model (MÜLLER-BBM) are compared with measured data in the following. The 4.5 MW ground flare burner modeled is equipped with steam injectors for smoke suppression. Fig. 1 shows the A-weighted sound power level L_{WA} of the burner in octave bands, calculated from the two models and as obtained from measurements.

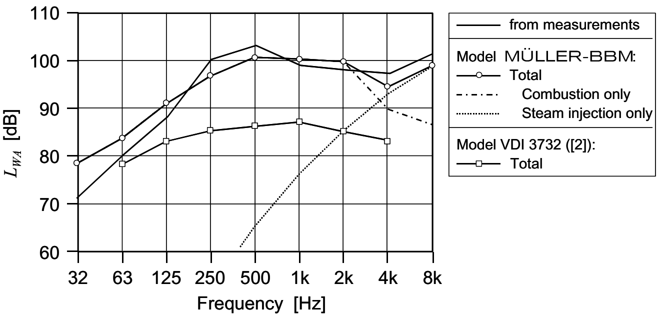

Fig. 1 A-weighted sound power level L_{WA} of a 4.5 MW flare burner with steam injection for smoke suppression: values from different prediction models ([2] and MÜLLER-BBM) compared with measured values. The total sound power levels are 108 dB (measurement), 106 dB (model MÜLLER-BBM) and 93 dB (model [2]).

It can be seen from Fig. 1 that the measured data (solid line, no symbols) is much better reproduced by the MÜLLER-BBM model (solid line, circles) than by model [2] (solid line, squares).

Apart from a better quantitative prediction, the correct identification of the individual partial sound sources - in the present case the combustion itself (dash-dotted line) and the jet noise from the steam injection (dotted line) - is an important advantage of sophisticated models. Based on this information, the influence of these sources on the total sound emission can be considered separately and an acoustically optimized design of the flare and the required noise control measures can be worked out that exactly fits the requirements in the respective operating condition of the flare.

References

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