Flare Application and Environmental Factors

By: Mr. Christopher Lum and Ir. Mohd. Fadzil bin Mohd. Tap

Flares, as highly visible and sometimes noisy attractors of attention, become focal points for public and environmental authority's attention. Resulting regulatory and public relations pressures demand careful attention to flare design. Problems include smoke control, avoidance of excessive noise, emission avoidance and others. For these solutions, there is no substitute for experience through proven operation.

Historically, flare system designers' major concern has been the safety of the relief system. Increased emphasis on environmental factors has complicated the design of flare systems. More stringent environmental requirements have been anticipated and met through the use of entirely new design approaches.

The field of flare system design originally developed from the desire to burn vented combustible gases. Early designs were aimed at obtaining positive ignition, with little or no regard to the results of the ensuing combustion. Attempts to improve upon the designs were totally ineffectual until a successful smokeless design was developed in the 1950's. Since that time, there has been a tremendous evolution in flare system design. Today's flare systems designer must be concerned not only with smokeless requirements but must also investigate on the total environmental impact, including thermal radiation, noise production, ground level concentration of combustion products, visible light and in some instance, aesthetics of the design. Meeting increasingly stringent environmental requirements has necessitated large research and development expenditures, in which only a handful of flare manufacturers owns.

SMOKE SUPPRESSION

The flare system's most dramatic impact on the environment is its potential for the production of very large flames and enormous clouds of smoke. Such emission can be seen from many miles and quickly attracts the attention of neighbours, public authorities and environmentalists. Current environmental requirements force the plant designer to route more of the vented gases into the flare system, resulting in larger flare sizes even though the capacity of the attached plant may be the same as previous designs. In addition, the use of larger components in plant design has increased the amount of gas that the flare must handle smokelessly.

Normally, the flare designer's first environmental consideration is whether the waste gas will produce smoke. Research indicates that the weight ratio of hydrogen-to-carbon of the waste gas is one of the key factors. However, it has been found that identical H/C ratios will in one case produce smoke, and in another, burn without smoke production. Careful investigation of the data shows that instantaneous H/C ratios in the combustion zone may greatly exceed the average, due to the lack of mixing of waste gases. This observation is supported by flow studies which show that turbulent flow, with Reynolds numbers as high as 50,000, failed to promote mixing of the gasses.

Presence of the liquid phase of hydrocarbons in the relief vapor can also render H/C ratio predictions invalid. Liquid droplets as small as 15 microns can negate smokeless equipment operation, with larger particles producing even greater consequences in the form of fallouot of burning liquid particles as well as unwarranted smoke production. Careful consideration must be given to knock out drum design and location.

The traditional approach to smoke suppression is the injection of steam into the combustion zone; however, there is no total agreement as to the chemistry of physical phenomenon associated with this injection. Since black smoke is clearly an indication of unburned carbon escaping from the combustion zone, the carbon must be completely burned or chemically combined to prevent its escape. Steam injection leads to two endothermic reactions which effect the desired end : the waste/gas shift [($C + H_2O = CO + H_2$)], and steam reforming chemistry ($C_x H_y + H_2O = XCO + ZH_2$). Regardless of which reaction dominates, the end result is smoke elimination.

Other factors which lead to the success of steam injection allow the use of smoke suppressants other than steam. These factors include the eduction of air into the combustion zone and turbulent mixing which increases reaction rates and elevates reaction temperatures. These two factors make the use of high pressure gas, air or other smoke suppressants possible but with overall lower efficiencies in terms of pounds of suppressants to pounds of hydrocarbons as a result of the loss of the aforementioned chemical reactions.

Another apparent factor is the total kinetic energy in the combustion zone, exclusive of chemical energy release from the combustion process. Such energy levels can be created from high velocity discharge and/or from adding additional energy from a secondary source. The total energy required is a function of gas composition, burner design, quantity of gas being burned and other factors. Extensive experience is required with gasses of similar composition to accurately predict the required energy level.

While most smokeless designs use some suppressant to obtain smokeless burning, it is possible to achieve smokeless burning without a suppressant as long as a satisfactory energy level can be produced. Pioneer work in John Zink test facilities has produced a proprietary method for maintaining energy levels under virtually infinite turndown ratios. Designs obtaining smokeless burning without suppressants are operationally successful in capacities up to several million pounds per hour (Figure 1a & 1b).

Figure 1a

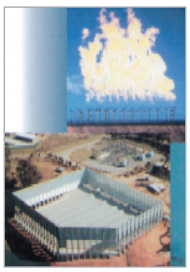
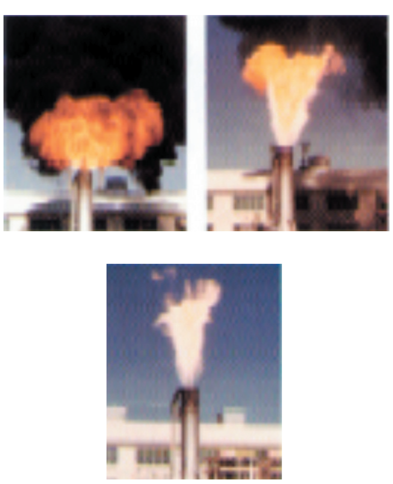


Figure 1b

Where a secondary energy source is required, the most common choice is low pressure air. When properly utilised, the low pressure air can boost kinetic energy to the smokeless burning level as well as provide primary air to the combustion process (Figures 2a, 2b and 2c). An additional advantage of low pressure air-suppressed smokeless flares is their lower overall installation cost and lower yearly operational cost.



Figures 2a, 2b and 2c

THERMAL RADIATION

Accurate prediction of thermal radiation is becoming increasingly important with larger plants and correspondingly larger flare relief loads. Ever-increasing "emergency" vent rates and economically unfeasible flare heights have made it more important that cooperative studies between the user and manufacturer be employed to determine flare height.

Several methods have been proposed for calculating flare heights. The overriding consensus of the authors of these methods is that flares, as any combustion process, cannot simply be scaled up from correspondingly small test. Numerous large scale tests have been used to develop a proprietary computer program for radiation prediction. Among the factors considered are quantity of gas to be burned, composition, smoke suppression method, flare burner design and ambient conditions.

The question of what constitute an acceptable radiation level is equally important in determining flare heights. The John Zink research facilities have been used to determine the physiological limits of a person wearing normal plant clothing, i.e hard hat, long sleeved shirt and gloves.

This "human testing" has disclosed that radiant impact levels of 15000 BTU/hr/ft^2 can be tolerated for an indefinite period of time by an active worker. An impact level of 1650 BTU/hr/ft^2 requires limiting exposure time to five minutes or less or the use of additional clothing. Impact levels as high as 3000 BTU/hr/ft^2 were tested. Limited over-exposure resulted in a skin reaction similar to a mild sunburn.

NOISE

Many neighbour complaints are prompted by flaring noise. Noise control is a social as well as a legal responsibility. Flaring noise can be attributed mainly to two sources: smoke suppressant injection and combustion. Careful orifice design can greatly reduce the suppressant injection noise on steam flares. However, in practice, the minimum size of suppressant orifices is limited due to plugging by line scale, etc. Additional gains in suppressant noise reduction have been made by improving the efficiency of suppressant usage and through the use of the highly responsive optical smoke suppressant control previously discussed.

Combustion noise is related to energy release. Smokeless burning results in and obvious increase in the energy released and the potential for greater combustion noise generation. Therefore, it is inevitable that open smokeless flaring will result in some combustion noise.

EMISSION

In chemical plant applications where gases other than hydrocarbons are being flared, careful considerations must be given to design. In these cases, there is no substitute for experience with a similar application. Open burning is dependent on the combustion process being sufficiently exothermic to maintain ignition. Flares burning in the open air transfer a tremendous amount of heat away from the flame, and as the temperature levels decrease, the combustion process can cease.

The amount of energy (Low Heating Value, LHV) necessary to maintain ignition varies. There is no fixed value for the minimum level required; however, experience allows prediction of the minimum LHV. In cases where the waste gas does not contain sufficient energy to support combustion, it is necessary to make use of special endothermic flare designs.

Flaring of gases such as chlorinated hydrocarbons, phosgene and sulfur compounds require additional consi-deration. Burning of chlorine containing compounds will result in production of HCl. Sulfur compounds produce SO_2 and SO_3, all of which have legal threshold concentration limits. Flares, unlike oxidisers and furnaces, do not adapt themselves to post-combustion removal of these contaminates; therefore, the approach has been to design stack heights sufficient to provide an allowable ground level concentration.

The prediction of ground level concentration of combustion products is a developing area with several approaches available. Dispersion model such as the Pasquill-Gifford method and plume rise model such as Briggs method seem to lend themselves to flare applications, providing one recognises the exothermic characteristics of the flare.

However, the Briggs method is based on measurement from stacks not flares. A modified approach has been by Peters. If Peters method is used, one must remember to reduce the heat release by an appropriate level due to radiation transfer from the flame, and if appropriate, due to smoke.

SOCIAL IMPACT

Visible light and noise from an elevated flare can be an extremely sensitive problem with the neighbours of a process plant. Although elimination of light is not a legal responsibility in Malaysia, it is in several countries. The light of an elevated flare focuses attention on the process plant, leading to many complaints which might otherwise go unregistered.

Plants have the responsibility of limiting flaring activity by tightening operational procedures and practice. However, this cannot completely eliminate some day to day flaring. The alternative to visible flaring is a low-level enclosed burning system (Figure 3). In addition to providing a hidden flame, the equally important benefit of noise reduction is realised. Full load noise levels of less than 70 dBA adjacent to the flare have been achieved.

Figure 3

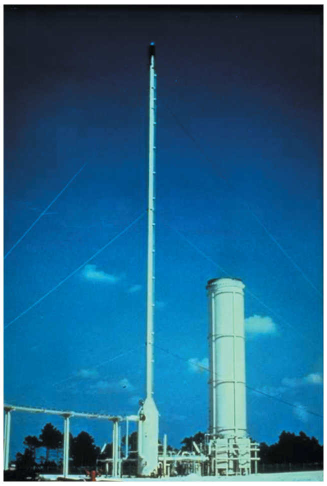


Figure 4

For most plants, it is desirable to use a flare system which combines a low-level flare with an elevated flare (Figure 4). Day to day and startup flaring loads are burned in the low-level flare and infrequent high volume emergency loads are handled by both low-level and elevated flares. When properly designed, such combined systems can prevent visible flaring for virtually all of the plant's operating time. Elimination of light and noise as a focal point is a proven public relations asset to the plant operator.

SUMMARY

Today's designer of flaring systems is faced with increased public awareness of the flares impact on the environment. Equipment selection and system design require careful consideration of safety and environmental aspects. Improved communication and early cooperation between flare manufacturer and plant designer is essential to successful, environmentally-responsible flare system design. ■