Emergency flare tip repair

Conditions in this case study pre-empted a relaxed remedy that called for no time constraints. The work had to be done and done now. Here are the measures we took to complete the job quickly

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Two propane storage tank flares (24-in. and 14-in. diameters) near the Arabian Gulf were discovered to have been damaged and in need of immediate repair. These flares served a large LPG storage facility. However, before the flare tip repairs could be undertaken, the flare gases would have to be diverted to an emergency, temporary flare. The propane storage tanks could not be emptied nor could the vapor flow be shut down because no excess onshore storage capacity existed. Also, LPG ships equipped with vapor recovery capability could not be located to receive and hold the LPG product. The company management felt that the flare situation had to be rectified on an emergency basis.

From 'scratch.' The temporary flares had to be constructed from scratch and located a safe distance away. A minimum safe distance had to be calculated because of safety, the expense of construction, and the urgency of the situation. If repairs were not completed prior to total failure of the main propane flare, then large quantities of propane vapors would be released to the atmosphere. These vapors could subsequently be ignited with catastrophic results. The simplified plot plan in Fig. 1 illustrates the over-all layout and spatial relationships between tanks and piping.

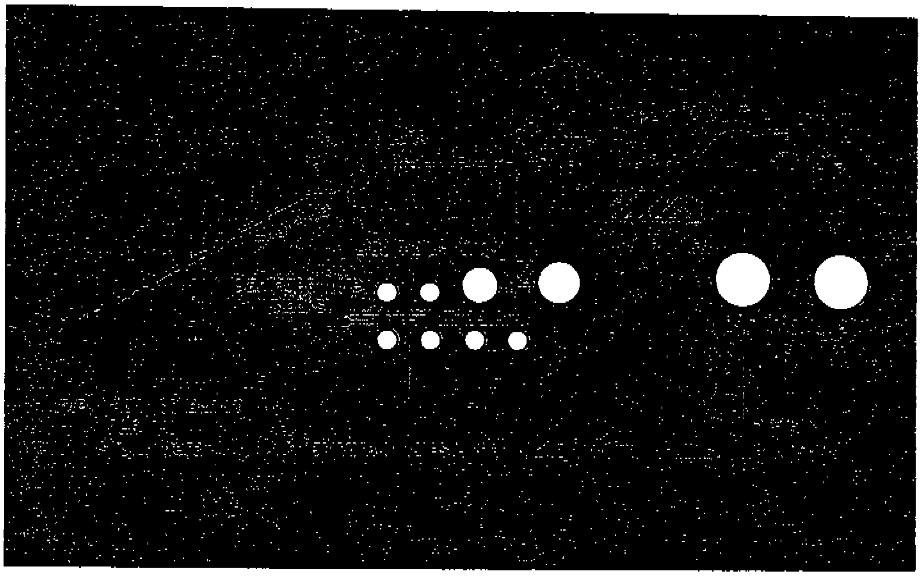

Fig. 1—Over-all layout and spatial relationships between tanks and piping.

TABLE 1 — General information relevant to selecting an acceptable radiant heat load factor

BTU/hr./sq.ft	Effects
2000	Burns in 10–20 seconds
1500	Up to several minutes exposure allowable
1000	Less than 20 minutes exposure to persons doing emergency work
500	No restrictions
300	Intensity of sun on a hot day

TABLE 2 — Flare line flow characteristics

24" Flare Line	14" Flare Line
$\dot{m}$ = 62,000 lbs/hr	$\dot{m}$ = 50,000 lbs/hr
H = 20,000 Btu/lb	H = 20,000 Btu/lb
Q = $\dot{m}$ H = 1.24 x 10^9 Btu/hr	Q = $\dot{m}$H = 10^9 Btu/hr

F = 0.3 (Flame emissivity factor for butane and propane)

One of the first steps involved selecting an acceptable radiant heat load factor that could be tolerated onshore (See Table 1). Because workers would be required to be in the general area, a value of 500 Btu/hr/sq ft was chosen as the limiting value for the radiant heat load. Spacing calculations were made for each temporary flare line size. The calculations proceeded as follows. First, the flare line flow characteristics were obtained from the plant foreman (Table 2). Secondly, the general equation for predicting radiant heat flux from a point source was used. The equation is of the form:

$$K = \frac{FQ}{4\pi D^2}$$

However, this can be reduced to consider atmospheric absorption.

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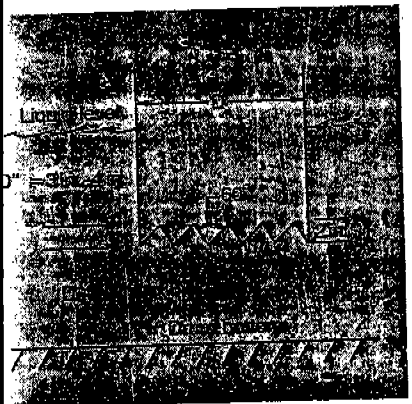

2—Flare-gas inlet dipleg should be ar-
ged this way to avoid pulsation of the flare
ne-front and/or unnecessary noise.

This factor can be estimated by using:

$$\tau = 0.79 \left(\frac{100}{r}\right)^{1/16} \left(\frac{100}{D}\right)^{1/16}$$

Where r is relative humidity (%), D is the distance (ft) from the flame center to the illuminated area, and τ is the fraction of K transmitted through the atmosphere. Using a relative humidity of 50 percent, we find that:

$$\tau = \frac{0.85}{D^{0.0625}}$$

Taking the 24-in. flare line size for illustrative purposes, we calculate:

$$K = \frac{\tau F Q}{4\pi D^2} = \frac{(0.85)(0.3)(1.24)(10^9)}{D^{2.0625}(12.48)}$$

$$= (2.54 \times 10^7)(D^{-2.0625})$$

The next step is to add in the K value that was selected as being allowable, viz., 500 ft.

TABLE 3 — Summary of calculations

Flare Diameter / K	500 btu/hr/sq ft	1,000 Btu/hr/sq ft
14 in.	D = 165 ft	D = 116 ft
24 in.	D = 182 ft	D = 146 ft

Table 3 summarizes the calculations. A value of 1,000 Btu/hr/sq ft is also included for comparison purposes.

As expected, the 24-in. flare is the limiting case, with a 182-ft spacing required for an assumed radiation value of 500 Btu/hr/sq ft.

Shell Oil equation. These distances calculated are to be measured from the flame center, which depends, in part, on wind and flame shape. The Shell Oil Co. flame shape/length equation $L = 6.785V^{0.61}$ was used (where V is the exit velocity in feet per second) to calculate the flame length. In this case, the 14-in. flare is the worst case with an exit velocity (derived from $Q = VA$) of 112 fps. The flame length is about 91 ft. The flame width is not a significant parameter for this situation. Therefore, using the 182-ft value and one-half of 91 ft, the temporary flame tip should be located about 225 ft from the point where 500 Btu/hr/sq ft could be tolerated. In actuality, a final spacing factor of 200 ft was used to avoid an extra set of pilings and to speed up construction of the temporary flare lines.

Safety factors. Besides calculating the safe spacing distance, certain other engineering factors affecting plant safety had to be addressed. The important ones are:

1. All work and construction materials required must be planned out in detail with all pre-fabrication accomplished ahead of time. The objective here is to minimize usage time of the temporary flare and to restore normal flaring as soon as possible.

2. To avoid flame liftoff, the maximum exit velocity of the temporary flare tip (assuming a straight, open-end pipe) should not exceed 160 fps and should be, preferably, closer to 100 fps.

3. Ideally, the elevation for the temporary flare tip should be at least 50 ft for smoke dispersal and pollution control purposes. However, since this is a temporary flare, then something less than 50 ft will probably be acceptable because of structural support considerations.

4. A flare seal drum is required. The following details are pertinent for design:

- The flare gas inlet dipleg should be as shown as in Fig. 2 to avoid pulsation of the flare flame front and/or unnecessary noise.
- Distance "D" (liquid seal level) should be 3 to 4 in.
- The distance between the end of the dipleg and the bottom of the liquid seal pot should be at least D/4.
- The flare gas inlet line should slope toward the K.O. drum.
- The dipleg should be 10 ft in length (minimum).
- The seal drum should be constructed to withstand a design pressure of 150 psig. Experience has shown that a vessel of this type can withstand an internal explosion and hence prevent flashback.

5. If a liquid seal drum is not used, then a hydrocarbon gas purge may be an alternative method to prevent internal burning or flashback. The source of purge gas must be reliable and assured during *any single contingency* such as a power or air failure. The purge rate must be calculated and reviewed by either safety or fire prevention for adequacy.

Ignition. One other item of interest concerns how the temporary flare should have been ignited, because there was insufficient time to construct proper flare ignitors. Also, no volunteers appeared with matches. The method selected simply involved strapping two 20-minute road flares to each flare line. As a back-up precaution, 24-hour watch was established that had access to a speed boat, flare gun, and flares.

The flare tip repair operation was a success. Flares were put back into service within five days. Telephone poles near the shoreline and exposed to the temporary flares were smoking by the third day. An occasional shoreward breeze also made onshore conditions uncomfortable because of heat and pollution for certain periods. But the spacing of 200 ft was, in the final analysis, satisfactory.

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