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UPGRADE OF A FLARE NETWORK FOR A NEW REFINERY UNIT

Abstract

The purpose of this study was to prepare material for technical specification of study to answer the following questions: Will the existing flare network be able to cope with the additional load from new unit? If modification is required, where and what to do?

Review of existing data was done, in view of calculation per relevant API standards. Data showed great dispersion of values and justify the need to get a complete reevaluation of pressure safety valve loads based on existing effective situation in the refinery. The highest possible load estimate from all existing and future units shows the big flare is able to cope with added new expected flare load in case of electrical failure. The piping network study should be done to evaluate possible modification of intermediate collectors to keep pressure safety valve backpressure and gas velocity in collectors in usual ranges. Static and, if needed, dynamic simulations must be used to assess the flare network. Based on available data, the technical specification material was prepared. Further work requires simulation and adequate software, which is not available in the refinery and must be outsourced.

Keywords: flare, revamp, refinery, safety, emergency

Introduction

The purpose of a flare system is to collect the flammable material from unit due to above normal pressure in equipment and to direct them to safe location for burning. The flare system is an essential part of the relief and depressurizing mechanism associated with safe plant operations. Flare system is collecting gases and liquids from various units in case of fire, or other failures such as electricity, cooling water, blocked outlet, instrument air, utility (i.e. steam in case of turbine operated pump or compressor). It is vital that when called upon to operate, it functions as designed and does not introduce new hazards into the site at a time of emergency.

Historically, flare systems tended to be designed and installed when the site was constructed with particular project hazard assumptions, flaring scenarios and process conditions in mind. During the intervening years, many modifications will have been made to the refinery connected to the flare system. A flare system by its nature is complex in detail and usually requires specialist analysis.

It is therefore essential that the flare system is reviewed upon installation of a new unit or revamp of existing unit.

Flare system principle

A gas flare, alternatively known as a flare stack, is a gas combustion device used in industrial plants such as petroleum refineries, chemical plants, natural gas processing plants as well as at oil or gas production sites having oil wells, gas wells, offshore oil and gas rigs and landfills.

Figure 1: Flare stack at refinery

In industrial plants, flare stacks are primarily used for burning off flammable gas released by pressure relief valves during unplanned over-pressuring of plant equipment. During plant or partial plant startups and shutdowns, flare stacks are also often used for the planned combustion of gases over relatively short periods. A great deal of gas flaring at many oil and gas production sites has nothing to do with protection against the dangers of over-pressuring industrial plant equipment.

When petroleum crude oil is extracted and produced from onshore or offshore oil wells, raw natural gas associated with the oil is produced to the surface as well. Especially in areas of the world lacking pipelines and other gas transportation infrastructure, vast amounts of such associated gas are commonly flared as waste or unusable gas. The flaring of associated gas may occur at the top of a vertical flare stack (as in the adjacent photo) or it may occur in a ground-level flare in an earthen pit.

Overall flare system in industrial plants

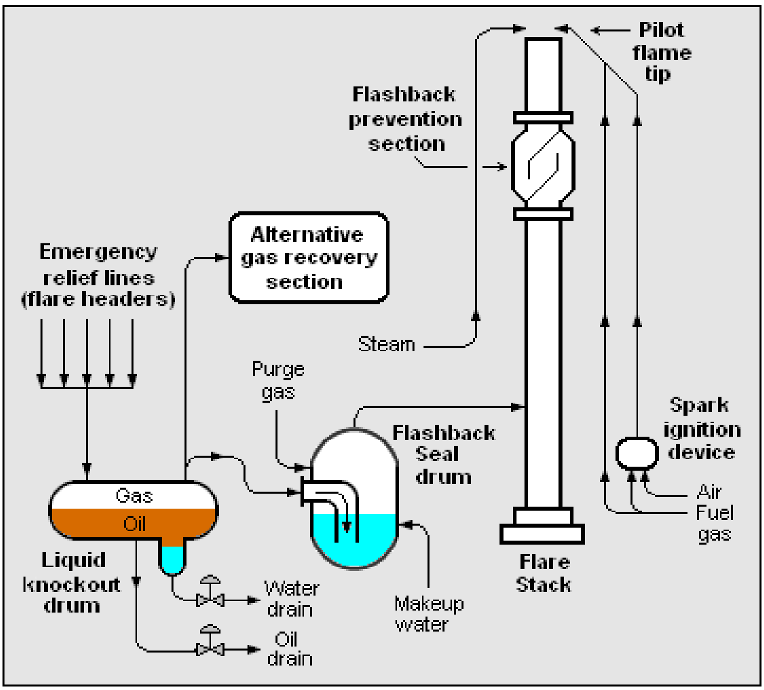

Figure 2: Schematic flow diagram of an overall vertical, elevated flare stack system in an industrial plant

Whenever industrial plant equipment items are over-pressured, the pressure relief valves provided as essential safety devices on the equipment automatically release gases and sometimes liquids as well. Those pressure relief valves are required by industrial design codes and standards as well as by law. The released gases and liquids are routed through large piping systems called flare headers to a vertical elevated flare. The released gases are burned as they exit the flare stacks. The size and brightness of the resulting flame depends upon the flammable material's flow rate in terms of joules per hour (or btu per hour).

Most industrial plant flares have a vapor-liquid separator (also known as a knockout drum) upstream of the flare to remove any large amounts of liquid that may accompany the relieved gases.

Steam is very often injected into the flame to reduce the formation of black smoke. When too much steam is added to the flame, a condition known as "over steaming" can occur resulting in reduced combustion efficiency and higher emissions. In order to keep the flare system functional, a small amount of gas is continuously burned, like a pilot light, so that the system is always ready for its primary purpose as an over-pressure safety system.

The above flow diagram (Figure 2) depicts the typical components of an overall industrial flare stack system:

- Knockouts drum to remove any oil and/or water from the relieved gases.
- Water seal drum to prevent any flashback of the flame from the top of the flare stack.
- Alternative gas recovery system for use during partial plant startups and/or shutdowns as well as other times when required. The recovered gas is routed into the fuel gas system of the overall industrial plant.
- Steam injection system to provide an external momentum force used for efficient mixing of air with the relieved gas, which promotes smokeless burning.
- Pilot flame (with its ignition system) that burns all the time so that it is available to ignite relieved gases whenever needed.
- Flare stack/tip, including a flashback prevention section at the upper part of the flare stack.

Further, we will review more in details the pressure safety valve type and its significance for flare network design. In case of conventional type pressure safety valve, built-up backpressure in flare network should not exceed 10 % of the set pressure at 10 % allowable overpressure. In case of balanced type pressure safety valve, built-up backpressure should not exceed 50 % of the set pressure at 10 % allowable overpressure. In case of use pilot type pressure safety valve, built-up backpressure should not exceed 100 % of the set pressure at 10 % allowable overpressure.

Methodology for flare system capacity evaluation

The objective of the study is to check flare network so that backpressure of pressure safety valves falls within limits.

The classical methodology for flare network assessment is as followed:

During the first phase, the engineering will identify worst-case multiple relief valve flare system loading scenarios throughout the refinery to be used, based on existing unit data, new unit data and recalculation if data is missing. This case can be divided in two in case new unit data is still not available:

1. Calculation and programing of existing flare release from pressure safety valve, blowdown emergency valves with geometry of the piping network based on isometrics. This is usual the most time demanding part.
2. Integration of new unit release loads when data are available.

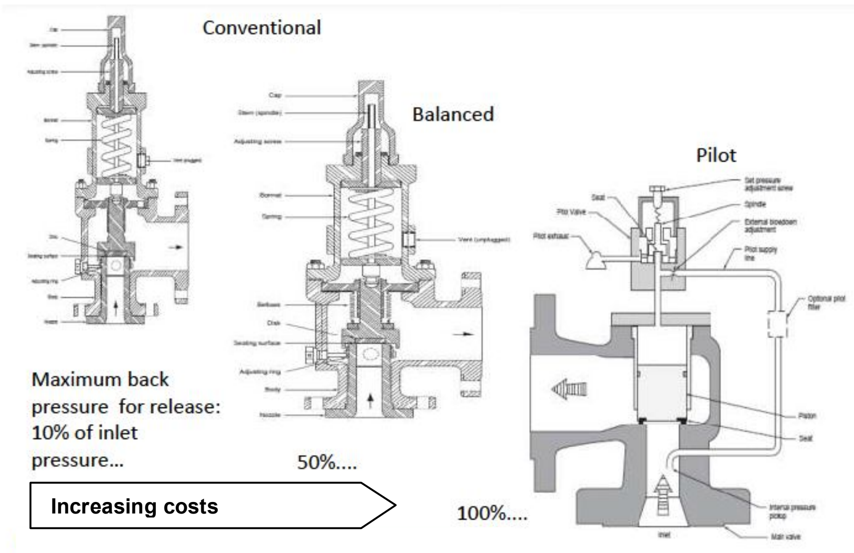

Figure 3: Different types of pressure safety valves (source API 520)

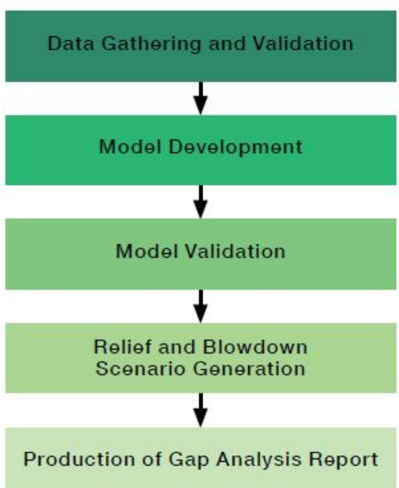

Figure 4: Flare network simulation methodology

First steady state and then, if needed, dynamic simulation can be used. Steady state is considering maximum load from pressure safety valve with mitigation of time factorwhile dynamic simulation can lead to reduced investment by taking into account time factor and accumulation of gases in the flare network.

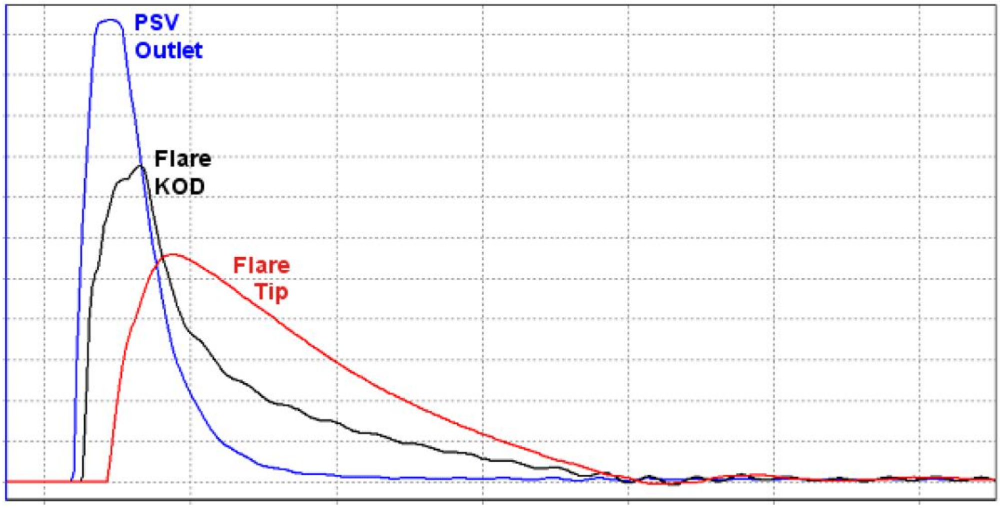

Figure 5: Interest of dynamic simulation versus steady state (flow versus time)

Ahigh integrity pressure protection system (HIPPS) is a type of safety instrumented system (SIS) designed to prevent over-pressurization of a plant which can be implemented as well to limit load to flare stack in case of emergency [13].

During the second phase of the study is determined the adequacy of the refinery flare system:

1. Flare system scenario identification.
2. Flare system modeling.
3. Flare system process design and modification.
4. Flare stack and tip rating.
5. Radiation, dispersions, emissions and noise evaluation.
6. Mechanical integrity reviews.
7. Sweeping gas minimum flow estimate.

For safety purpose, a continuous purge with non-condensable, oxygen free gas is required through the flare system. The continuous purge ensures that atmospheric air does not enter the stack via the flare tip during low flow condition; purge gas also limits the risk of burn back which causes deterioration of the flare tip quickly.

The number of scenarios is identified for different scenario classes:

- Fire scenario,
- Loss of instrument air scenario,
- Loss of electrical power scenario.

The second phase comprised of following major tasks:

- Conduct a comprehensive evaluation of the refinery's relief (flare) system (including relief valve discharge piping, sub-headers, headers, and flare) for the purpose of determining relief system capacity.
- In addition to the relief header hydraulic analysis, perform an evaluation of the flare thermal radiation, flare tip velocity, and flare knockout drum.

At the initiation of this project, the project team from site gathered the requisite process and engineering information. Using the process information as well as engineering information relative to the existing relief valves, contractor utilizes licensed commercial computer process simulation software to evaluate any missing or outdated pressure safety valve capacity information. Contractor uses the programs to evaluate the vapor and liquid relief capacities of each valve as well as relief requirements for all identified credible relief scenarios. For the relief system evaluation task, the contractor constructs detailed computer process simulations of the refinery relief system using the simulation software's fluid flow (hydraulics) package. The identified relief scenarios are then modeled for the purpose of determining the presence of excessive back-pressures (i.e., inadequate capacities). For sections of the relief system identified as bottlenecks, the contractor modeled modifications that would increase the system capacity. The following constrains have to be considered:

Headers:

- Velocity < 0,35 Mach
- $\rho\ V^2 < 50000$ kg/(m s^2)
- Noise < 100 db one meter from source

Tailpipes:

- Velocity < 0,7 Mach
- $\rho\ V^2 < 100000$ kg/(m s^2)
- Noise < 100 db one meter from source

Where applicable, the contractor will develop additional debottlenecking recomm-endations, including pressure vessel pressure re-rating, process or operational changes to reduce the required relief loadings, and potential modifications to exist-ing relief valves (e.g., decreasing set pressures, increasing orifice sizes, or replacing conventional with balanced-bellows relief valves). The final report provided to the client contains detailed calculations, a tabulated summary of each over-pressure scenario, a tabulated summary of the flare thermal radiation and tip velocity for three worst-case over-pressure scenarios, check of the flare knockout drum capacity, a working copy of the simulations, and proposed modifications if needed, including corrosion prevention measures such as heat tracing and insulation.

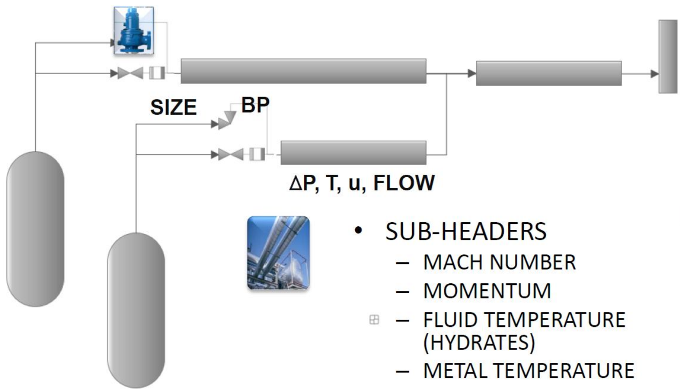

Figure 6: A simulation representation of flare network (source Inprocess)

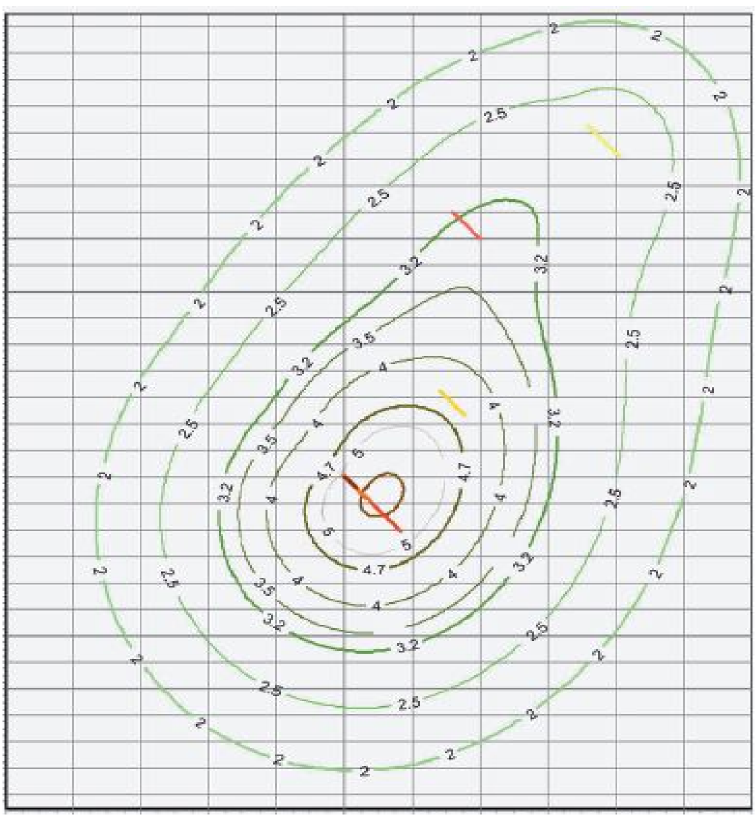

Figure 7: Mapping of radiation from flare network [15]

Project

Investigation was limited to evaluate potential additional capacity of old flare of which stack is designed for a maximum load of about 700 t/h.

Preliminary calculations

About 230 pressure safety valve exhausts are collected in main flare system. The normal practice is to have calculation of flow, temperature, pressure and molecular weight for each possible case of release to flare for each valve, excluding spare valves and thermal expansion valves:

1. blocked outlet, inadvertent valve opening, check-valve malfunctioning,
2. electrical failure,
3. exchanger tube rupture,
4. cooling water failure,
5. instrument air failure,
6. steam failure,
7. fuel oil/gas failure,
8. nitrogen failure,
9. fire.

These calculations must be done on basis of API (American Petroleum Institute) recommended practice 520 [1-2].

From pressure safety valve to flare stack: collector network

Based on the individual data of each pressure safety valve in electrical case, the relief pressure of each valve and geometry of flare system (piping diameter, length, angle), the total pressure drop from each pressure safety valve to flare tip can be calculated, taking into account ALL the discharge flows in the flare network at same time. The flare stack of was checked for the existing operating units based on maximum range of installed flowmeters most recent data.

Based on available data, an additional 500 t/h load is available for the new complex (including all side units).

Data validation

A detailed flare study with clear calculations of each 230 pressure safety valve of flow, MW, release pressure and temperature for each emergency case is needed, especially since several units were revamped or/and modified since flare design.

Load from new unit

As an indication, licensors were required to provide in the technical proposal an estimated flare load of new unit only in case of electrical failure.

The licensors estimated maximum flare load from new complex for electrical failure case is 170 t/h, which is in most cases the highest load on refineries flare tip.

Maximum flare load

The maximum additional flare load is estimated to be 170 t/h which is a reasonable estimate based on assumptions of licensors. This value is below calculated maximum flare load available; therefore, flare stack will not have to be replaced based on maximum load. Still, detailed checking by experienced engineering and/or flare stack supplier is required to confirm that other characteristics of flared gases such as temperature, molecular weight, H_2S or water content will be compatible with existing flare.

Network of piping toward flare

Expected additional flare load has to be checked integrating the new load of gases and liquids from new unit. If a collector has insufficient section, the upstream pressure in the flare gas collector which is the backpressure of safety valves located on units will be increased due to this bottleneck. A conventional pressure relief valve (pressure safety valve) cannot be designed to have more than 10 % of upstream pressure as a backpressure (API std 520 - Part 1, "5.3.3.1.3 In a conventional pressure safety valve application, built-up backpressure should not exceed 10 % of the set pressure at 10 % allowable overpressure"). In low pressure units (typical set pressure of pressure safety valve = 3,5 barg), the maximum backpressure in the header behind each pressure safety valve in case of general electrical failure should not exceed 0.35 barg. Further calculations require specialized software, relief load for each pressure safety valve connected to the system in every cases and geometry of the flare system. A qualified engineering must perform this checking of full flare network to make sure that: (1) No overpressure exist behind any pressure safety valve for all cases of flare releases, (2) The speed in flare network does not locally exceed sound speed. The traditional and cheapest method in case of above trouble is to increase locally flare collector diameter. Another option could be to install more costly below type pressure safety valve or even more expensive pilot pressure safety valve instead of conventional type pressure safety valve.

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NADOGRADNJA SIGURNOSNE MREŽE BAKLJE ZBOG NOVE PROCESNE JEDINICE

Sažetak

Svrha studije o nadogradnji sustava baklje je traženje odgovora na sljedeća pitanja: Hoće li postojeća mreža biti u mogućnosti nositi se s dodatnim opterećenjem novih jedinica?; Ako je potrebna izmjena, gdje i što treba učiniti kako bi se smanjili troškovi?

Analiza postojećih podataka procesnih jedinica, s obzirom na izračun po relevantnim standardima API 520/521 na temelju postojećeg stanja u rafineriji. Procjena najviše mogućeg opterećenja iz svih postojećih i budućih jedinica (obično slučaj električnog kvara) da bi provjerili veličinu baklje može preuzeti dodano očekivano opterećenje. Studija mreže cjevovoda treba biti učinjena kako bi se procijenila moguća promjena internih kolektora radi zadržavanja povratnog tlaka PSV i brzine plina u kolektorima u sigurnom rasponu. Za provjeru mreže baklje mora se koristiti statička i, ako je potrebno, dinamička simulacija, pa čak i rafiniranija metoda procjene.

Predložene su izmjene cjevovoda mreže baklje.

Ključne riječi: baklja, nadogradnja, rafinerija nafte, sigurnost

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