DEALING WITH THE COMPLEXITIES OF COINCIDENT FLARING HAZARDS IN EXPANDING OFFSHORE FACILITIES

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There are a growing number of facilities in the North Sea that have added processing capacity by using bridge-linked platforms to existing facilities. These may be for third-party tie-backs, or simply to provide additional drilling, separation, compression, water handling, gas sweetening, or other enhancement to the facilities.

When expanding a facility using a new bridge-linked platform, it is often assumed that as the facilities are segregated sufficiently to ensure no escalation of a major accident event, the demands on flare system from individual processing platforms are independent, and therefore all the capacity of a shared flare system can be taken by each facility in turn.

We have been involved in a number of such projects in the North Sea, and in each case the assumption that there were no coincident flaring scenarios involving different processing platforms was found to be incorrect. The paper will outline the basis for this and the methodology used to assess the risk and reduce this to ALARP. It will also present lessons learned from how this has been tackled in real projects, and how it can be addressed in different project phases.

INTRODUCTION

The UK oil and gas industry has been producing since the 1970s, and is, in many ways now, a mature province. While the early industry was dominated by major new investments in field developments such as Forties, Beryl and Brae with large jacket platforms, subsequent development has focused more on sub-sea developments and tieing back fields to existing infrastructure. There is an increasing trend to extend the facility life by retro-fitting new jacket structures adjacent to existing production facilities, to provide new drilling, processing, utilities or accommodation facilities. Recent projects of this type have included:

- Britannia Satellite Platform (Britannia Operator Limited)
  - Constructed adjacent to the existing Britannia Platform, this provided new reception and compression facilities for the Callanish and Brodgar fields.
- Buzzard Expansion Project (Nexen UK Ltd.)
  - This added an additional jacket platform to the existing Buzzard complex to allow gas sweetening facilities to be installed.
- Forties Alpha Satellite Project (Apache North Sea Ltd.)
  - As of Q2 2012, this is nearing the end of detail design, and will provide additional well-slots, production, compression and power generation facilities adjacent to the Forties Alpha platform.
- Montrose Bridge Linked Platform (Talisman Energy Ltd.)
  - This will provide updated production and compression facilities for the life extension of the Montrose area.
- Lomond (BG Ltd.)
  - This will provide additional separation facilities for the Lomond Platform to accept third party fluids.

In this paper, the word "platform" is intended to encompass all the facilities located on top of one jacket within the bridge-linked complex.

These are all complex developments, with strong interactions between the brownfield and greenfield sides of the development. The individual platforms are generally spaced to allow sufficient separation between the platforms in order to make it unlikely that an event could escalate from one platform to another in the linked facility.

In terms of the emergency flare system, there tends to be an assumption that the separation distance between platforms will ensure that the platforms can be considered separate in terms of flare system demand, and that it is practicable to use an existing flare system to manage two or more separate production platforms. As a result, it is commonly assumed that there is no need to update a flare system if the individual flaring demands from each individual platforms is within the nominal flare capacity.

At Atkins, we have been involved in a number of these facility developments, and it is our experience that this assumption is in many ways flawed, and that the handling of the flaring system design needs to be done with care.

BACKGROUND

Relief and blowdown systems are generally built in line with the API Standards 520 and 521: these have been incorporated into ISO Standards BS ISO 4126 (ref. 1) and BS EN ISO 23251:2007 (ref. 2) respectively. (For the purposes of this document, they will be referred to by the API number, but the documents are effectively identical.)

API 520 gives guidance about the sizing of pressure relieving equipment, such as relief valves, bursting disks, etc. API 521 is concerned with the design of the relief system overall.

Common practice in design of facilities in the UK is to design the overall system for the maximum relief rate, which, in general, is made up of:

- Depressurisation of the facility to a sufficiently low pressure within a target time, and,
- The single highest flowrate relief source.

Different company standards apply to how these flowrates are determined. From a design point of view, the most common approach is to determine the peak depressurisation rate from blowdown, assuming that the plant is at high pressure trip conditions, and add on the additional source as appropriate (e.g. a Pressure Safety Valve (PSV) will be either at lifting pressure or peak back-pressure, depending on the design). Some companies will calculate the depressurisation rate at the design pressure of the source vessels, as opposed to the high pressure trip settings, which will lead to a higher rate and a more conservative design.

Application of these standards to a brown-field development is not always straightforward: flare system demand does not necessarily drop with time, even though normal operating pressures may drop, as the relief rates are determined at the set-pressure of the relieving device.

Also, there remains an assumption in sections of the industry that so-called “double jeopardy” events, requiring two flaring events at the same time, can be dismissed as a matter of course. In a traditional single-jacket facility fed from many platform wells, it may well be correct to assume that it is not possible to initiate a full plant blowdown and remain with significant residual production to the facility from the wells. Extend a facility to an additional jacket, where the facility may well not depressurise at the same time as the other facilities, and include large-distance sub-sea pipelines fed from multiple wells, and the probability of maintaining a significant production to the facility (and hence trying to produce to a platform which is shut down) while depressuring another facility via the same flare system increases markedly.

To illustrate this, consider a facility where a Fire and Gas Detection on one platform initiates a production shutdown across the facility, and depressurises the facilities on the platform where the gas detection occurs (see Figure 1). Typically, the frequency of such a shutdown is up to 1 per year. If we then consider that the other production jacket is fed from a sub-sea gas well complex, and that the pipeline ESDV is not shut in on the production shutdown, it is possible that only a single isolation valve would be shut between the reception separator and the pipeline. For instance, for a failure rate for a typical valve of 2×10^{-6} per hour, and a yearly test interval, the probability of failure on demand is approximately 0.0087. The result of this event would be an incident, with a frequency of 1 in 115 years whereby one platform would depressurise and the other platform would continue to produce to the flare. Analogous to the 1 in 100 year storm which is used as a design concept for the structure, this would be a 1 in 100 year test of the flare system, and is therefore a credible design case.

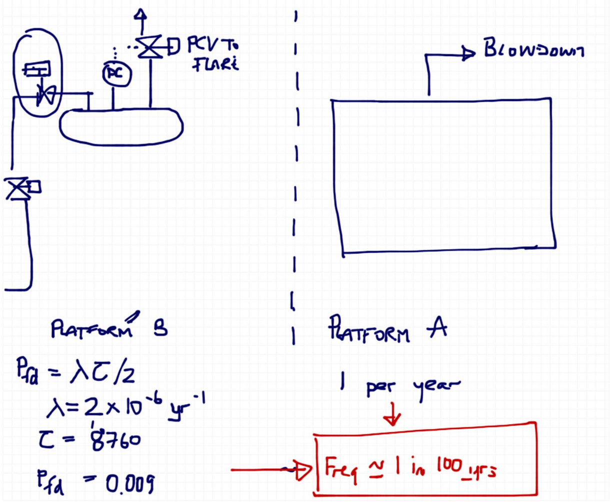

Figure 1. Blowdown of a Platform with Continued Production to a Bridge-Linked Platform

POTENTIAL CONSEQUENCES OF EXCESSIVE FLARING

The flare system is seldom tested to its ultimate limits, and it can be overlooked as a utility system rather than a key process system. There are three main consequences of excessive flaring as follows:

- Failure to reduce the pressure in a vessel sufficiently to prevent rupture during an incident
- High radiation from the flare leading to initially to burns, and potentially leading to fatality
- Loss of containment of the flare system, resulting from overpressure or flow induced turbulence fatigue, leading to release of hydrocarbon into process areas and subsequent risk of fire and explosion.

REVIEWING A FLARE SYSTEM DESIGN AT CONCEPT SELECTION PHASE

At the concept phase of a project, the new platform system design may not yet be complete, and it may be possible to incorporate a separate flaring system for the new facilities into the design with relatively little complexity. While the cost of a separate flare system, including flare tower and flare tip, is not insignificant, there are significant challenges to designing a flare system to cross over a bridge link. For example, it is complicated to ensure that there is a slope for pipework towards the flare system drum from all points in the new flare system, or even to predict in which direction pipework will slope across the bridge. Also, the flare system pipework crossing over a bridge would be relatively large.

It is recommended that the following flare cases are considered for each of the source platforms to a linked flare system. (Note that, for simplicity, the table below considers two production platforms: other permutations

Table 1. Flare Assessment Cases

Source 1	Source 2
Depressurisation of Facility 1 from maximum pressure	Depressurisation of Facility 2 from maximum pressure
Depressurisation of Facility 1 from maximum pressure	Maximum Relief Case on Facility 1
Depressurisation of Facility 1 from maximum pressure	Maximum Relief Case on Facility 2
Depressurisation of Facility 2 from maximum pressure	Maximum Relief Case on Facility 1
Depressurisation of Facility 2 from maximum pressure	Maximum Relief Case on Facility 2
Depressurisation of Facility 1 from maximum pressure	Continued Production on Facility 2 to Flare
Depressurisation of Facility 2 from maximum pressure	Continued Production on Facility 1 to Flare
Maximum Relief Case on Facility 1	Maximum Relief Case on Facility 2

and combinations would require to be considered if there are additional platforms in the complex). This list is not exhaustive, and all high flow cases to flare should be considered.

If it can be shown that the flare system is sufficiently large to manage all of these cases, then the provision of additional flare facilities for the new platform can be dismissed. However, if the capacity of the flare is less than the maximum of these cases, strong consideration should be given to providing dedicated blowdown facilities for the new platform individually. The "maximum pressure" number above would be based on individual company standards, as discussed before, and could either be depressurising from trip pressure or design pressure.

Clearly, at concept selection time there may not be sufficient detailed information to formally calculate the full blowdown rates: however, in general, there should be sufficient design information available to make reasonable assumptions about major inventory sizes, and to compile an estimate of the overall flare rates for the facility.

REVIEWING A FLARE SYSTEM DESIGN AT FEED/ DETAILED DESIGN PHASE

If due consideration has been given to the flare system during concept development, then it should be possible to either dismiss high rate flaring as a case, or provide an additional flare system for the new platform during the FEED/Detailed Design phase. However, if this has not been carried out, Atkins has developed a methodology for detailed consideration of the risks from coincident flaring, and this will be outlined below.

ATKINS' METHODOLOGY FOR DEALING WITH COINCIDENT FLARING

Two key aspects need to be considered in parallel in the assessment:

- What is the ultimate capacity of the flare system?
- What are the combinations of flare scenarios which need to be reviewed against that capacity?

Capacity of the Flare System

Determination of the ultimate capacity of the flare system is not necessarily straightforward in this situation. The design capacity of the system may be limited by:

- system back-pressure, either in the main flare headers or in individual sources,
- fatigue within the flare system due to vibration
- the flare tip design point
- radiation levels on the platform from high flaring
- gas concentrations on the platform from an unignited flare.

At some point above the design capacity of the system, the consequences of additional flaring will take a step-change upwards, e.g. from loss of containment from the flare. This is further complicated by the fact that flare tips are generally engineered to give low radiation at high flowrates, but the performance of the tip in terms of imposed back-pressure, and the resultant radiation, is not easily available above the flare tip design point.

For the purposes of the screening exercises carried out during the review, a starting point needs to be defined, and this can be progressively reviewed in parallel with the scenario definition stage.

Determination of Coincident Flaring Scenarios

The starting point for the scenario definition is the identification of the individual source flaring rates. These include:

- Peak blowdown rates from the highest pressure scenario (e.g. from trip settings, from design) for each platform
- Peak blowdown rates from the "normal operating pressure" of each platform
- Peak relief rates through PSVs
    - Depending on the design of the PSV, these may be at the lift pressure, or some pressure above that level.
- Maximum flowrates through pressure control valves to flare
    - These rates may be from normal operating pressure, or from the trip setpoint in the vessel.
- Maximum manual depressurisation rates for annulus depressurisation, routine pipeline operations, etc.
- Maximum production rates of gas to each platform.

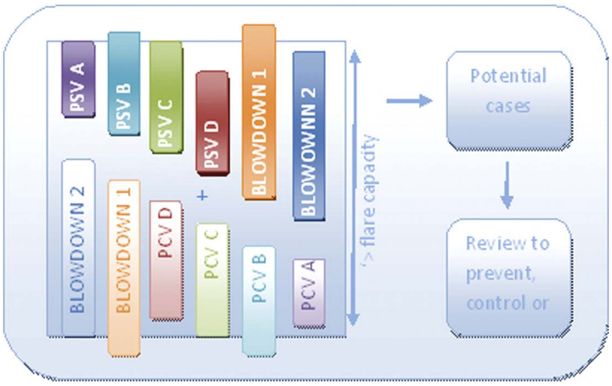

Figure 2. Generation of Candidate Coincident Flaring Scenarios

The process is illustrated in Figure 2.

The rates are organised in a matrix and combined as appropriate to the scenario: care must be taken at this stage to ensure that double-counting of flow is not carried out: for instance, if a blowdown valve and the pressure control valve are open on the same vessel, the flow out may not be as high as the two maximum rates added together. The combined flows are compared to the nominal capacity, and any combinations lower than the capacity can be discarded.

The list of combinations is examined to remove any that are not feasible: for instance, two PSVs on individual stages of a compressor are unlikely to be able to lift and maintain flow at the same time, as the flow through one would be likely to limit the flow to the other compressor. Similarly, it is unlikely that any flow through a separator PSV could occur at the same time as the PSV lifting on a downstream compressor. Additionally, blowdown will generally occur from normal operating conditions, unless there is a pre-existing condition which has a part of the plant at a higher pressure state. As a result:

- cases where a PSV lifts followed by a blowdown could be argued to result in a trip from blowdown conditions:
- a blowdown which then results in a PSV lifting due to failure to isolate the inlet flow would have blown down from normal operating conditions.

The typical variation in the blowdown rate for an individual vessel is shown below in Figure 3.

Once the individual scenarios are identified, then the principles of inherent safety are applied. If a modification can be made to ***prevent*** the high rate flaring without reducing the operability of the plant, then this should be considered. For example, the operating pressure of a vessel may be significantly removed from the trip setting, especially later in the production life where a field supply pressure may have dropped. In this case, it may be possible to reduce the trip pressure, and therefore reduce the flare rates.

If the flare rates cannot be reduced sufficiently to get below the flare limit, then the frequency of the events needs to be considered. In doing this, Atkins uses the Layer of Protection Analysis approach. All of the potential initiating events resulting in a combination of flowrates are identified, and these are then assessed in turn. The frequency of each initiating event is estimated, based either on operating experience, or industry failure rate data such as OREDA, the Offshore Reliability Database (reference 3). Each of the potential layers of protection is then assessed in turn to determine if they have any impact on the development of the event. Ultimately, the frequency of undesired incidents is estimated, and compared against a target frequency to determine if the incident occurs at a tolerably low frequency. Corporate targets are used for this, with lower frequency of events tolerated for high consequences, in line with the ALARP principle (reducing risks to As Low As Reasonably Practicable) and offshore risk profiles.

In carrying out the frequency assessment, care must be taken to account appropriately for release cases which are not independent, but are related to a common initiating event, or linked via a common cause failure. For example, the case illustrated in Figure 1 above is a case whereby a shutdown has failed to isolate production to a separator: the event whereby a shutdown happens, at the same time as a PCV has failed open due to equipment failure, and where the plant then depressurises, is not likely to have a common initiating event, and therefore happens at a significantly lower frequency. It is also very important to account for common mode failure in evaluating the probability of failure of individual layers of protection, and also to account for independence or inter-relationship of the layers where appropriate.

Ultimately, if an outcome occurs at a frequency greater than the tolerable frequency, consideration is required to identify whether there is a solution to further reduce the consequences or frequency of the event. This may entail installing additional instrumented protective systems, or widening the scope of the existing shutdowns to act on further end devices. In line with the ALARP principle, if the risk reduction from these modifications is not sufficient to justify the cost in terms of cash, trouble or technical difficulty, then the risk may be considered as low as reasonably practicable.

LEARNING FROM PREVIOUS SYSTEMS

The methodology as described has been applied to a number of bridge-linked platform developments in the UK Continental Shelf. In order to maintain client confidentiality, the learnings below are based on Atkins' understanding of the outcomes of the projects.

In all cases examined, to achieve an outcome considered ALARP required some modifications to the flare system. Not surprisingly, especially with high rate flare design facilities, the overall flare system does not have a significant amount of ullage to play around with, and when significant processing facilities are added on, the potential frequency of exceeding the flare capacity does increase significantly.

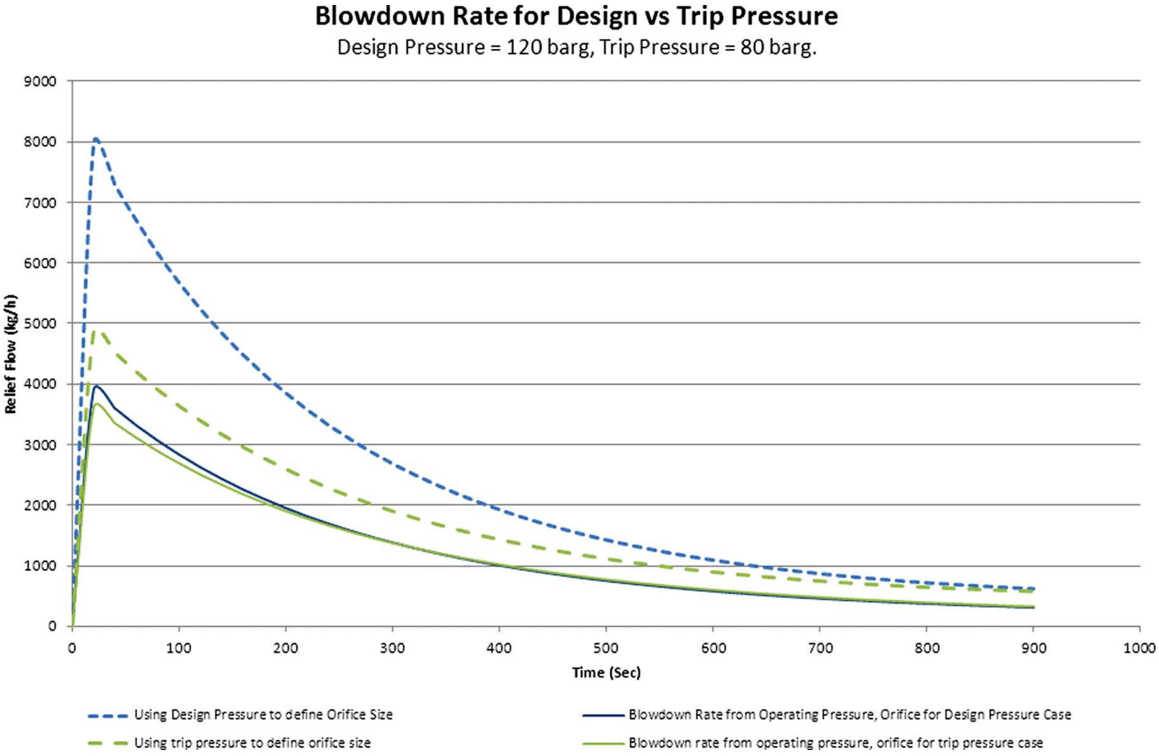

Figure 3. Blowdown Rates for a typical HP Separator from Design and Trip Pressure

The required changes made included:

- Installation of new flare tips
- Re-rating of the flare system by calculation of flare back-pressures and radiation using more sophisticated modelling,
    - This may require detailed radiation calculation and flare rate modelling, sometimes including plant dynamics.
- Segregation of blowdown inventories and modifications to blowdown systems to reduce the blowdown rates
- Actuation of additional valves on the flow from pipelines to separators to reduce the likelihood of flow into separation systems
- Addition of High Integrity Protection Systems to reduce the frequency of high PSV rates, e.g. from opening pipeline valves against full well closedin tubinghead pressure.

Arriving at the ALARP solution has been, in many cases, iterative, with progressive evaluation of the changes as the understanding of the frequency and consequences of events develops over the assessment. With the addition of the identified changes above, it has been possible to conclude that an ALARP design was achieved. It should be noted, however, that the evaluation and modelling associated with detailed assessment of the consequences and risk are not trivial, and that, if the issue could have been prevented at the concept evaluation stage, the capital cost of a flare modification could arguably have been the better technical and safety solution.

CONCLUSIONS

This paper has illustrated the issues of flaring from multiple sources to a common flare system for the case of a bridge-linked platform. Our analysis shows that it is not sufficient to dismiss coincident high rate flaring cases out of hand, but that careful consideration is required to determine if an additional flare system would be the best solution, preferably as early as possible in a project. If not, considerable modelling, redesign and evaluation effort may be required to achieve a design with an acceptably low risk.

REFERENCES

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2. BS EN ISO 23251:2007 + A1:2008 “Petroleum, petrochemical and natural gas industries. Pressure-relieving and depressuring systems”
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