Risks Associated with Caissons on Ageing Offshore Facilities

D. Michael Johnson, DNV GL, Peter Joyce, BG Group, Sumeet Pabby, BG Group, Innes Lawtie, BG Group. Neil Arthur, BG Group, Paul Murray, DNV GL.

Managing ageing offshore oil and gas production facilities can present significant challenges to operating companies. One specific issue relates to caissons which are vertical tubulars suspended beneath the platform topsides, typically within the envelope of the jacket, used for sea-water intake, various discharge functions and as carriers for subsea infrastructure. A number of operators have experienced failure of caissons and as they fall to the sea bed, they have the potential to cause significant impact damage to subsea infrastructure, including pipelines, risers and the primary structure of the Asset itself. This paper examines the risks associated with caisson failure and how these can be evaluated. The measures that can be taken to reduce these risks are discussed along with the associated practical difficulties, particularly in terms of determining the condition of the caissons. The considerations are placed within the context of a specific example where temporary risk reduction measures were deployed while caisson removal was planned and initiated.

Keywords: Integrity, Ageing, Offshore, Risk, Caisson

Introduction

BG Group operates the Armada, Lomond, North Everest/CATS offshore facilities in the UK sector of the North Sea. All three assets are primarily gas production platforms, with associated condensate production. North Everest/CATS and Lomond have been in operation for over 20 years and Armada for 17 years.

The ageing of North Sea assets and the extension of operations beyond the original design life raises many integrity management issues and have been the focus for most operators in the sector. Evaluating the greatest threats from ageing related integrity issues is a particular challenge for an operator as there is a need to judge both the likelihood of failure and the potential consequences for what can be very case specific threats.

One threat addressed by BG Group related to caissons, which are essentially vertical steel pipes providing connection from the platform topside to the sea for various services such as fire water supply and water treatment. The integrity issues faced by caissons are significant and many damage mechanisms and failure modes have been identified in industry 1. BG Groups UKCS assets had experienced two historical caisson failures without further consequence.

One caisson of particular concern was an open drains caisson on the Lomond facility, which was located above the 20 inch gas export pipeline. Figure 1 shows the Lomond platform and a plan schematic of the jacket showing the path of the gas export pipeline and the caisson.

It was clear that the consequences of damage to the pipeline could be severe and work was required to:

- Understand the potential for damage to the pipeline.
- Assess the risks associated with the caisson given the age-related degradation of the caisson and the potential consequences should it suffer complete failure and become a dropped object hazard.
- Develop a plan of actions that would allow the risks to be reduced in the short, medium and long term.

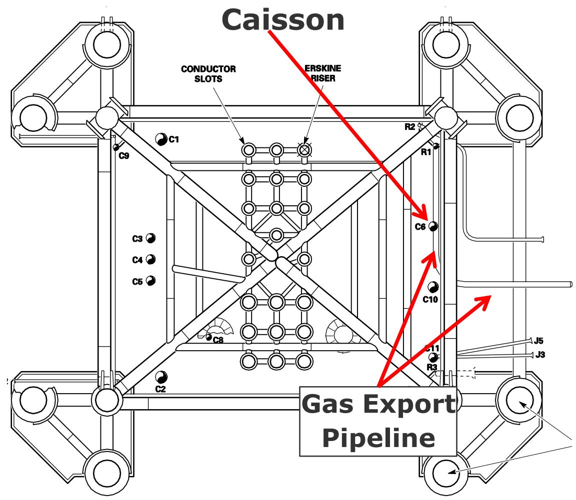


Figure 1: Lomond Platform and Location of Caisson and Pipeline

Background

There were a number of factors that provide context to the potential risks associated with the caisson, including:

- **Potential Failure Modes** – The failures of concern were those that would result in a substantial mass breaking off from the caisson and falling to the sea bed. This mass could be part of the caisson itself or loss of the equipment located within the caisson (the 'internals').
- **Caisson Integrity** – Inspection of the caisson was not easy and as a result, the information on the condition of the caisson and the internal equipment was very limited.
- **Sub Sea Isolation Valve (SSIV)** – The Lomond gas export pipeline is fitted with a subsea check valve some 100m outboard of the riser emergency shutdown valve (ESDV). The design intent of the check valve was that in the event of a rupture of the riser or inboard section of the pipeline, the 'flap' in the valve would be rapidly closed by the very high gas flows, providing isolation from the large inventory within the remaining 57.8km of the export pipeline. However, during a previous attempt to depressurise the riser through the Lomond flare system (admittedly at much lower flow rates than those following a pipe rupture), the SSIV did not provide isolation. There was therefore a lack of confidence in the SSIV ability to satisfy its design criteria with a concern that the SSIV was stuck in an open position. It was not practicable to proof test the valve.
- **Personnel on Board (POB)** – The normal operations POB for the Lomond facility was 76. However, a maintenance campaign was planned with a Flotel required alongside. In this case, the POB of the combined facility rose to 300. The plan was to have the platform in production for part of this period.

Risk criteria

A Quantified Risk Assessment (QRA) had been carried out for the facility based on generic accident frequencies with the most exposed personnel having an Individual Risk of fatality of 3.1×10^{-4} per year. Being generic, this did not include any consideration of the specific risks associated with caisson failure.

To meet regulatory requirements, BG Group needs to ensure that the calculated Individual Risk is less than 1.0×10^{-3} per year, including the risk from the open drains caisson. However, BG Group had also adopted a societal risk reporting criterion shown in the FN plot in Figure 2. Though not required for regulatory compliance, this criterion was used to identify where risks should be reported to senior management due to the potentially significant combination of safety, commercial and reputation risk. It should be noted that decisions made on the basis of meeting this criterion could easily lead to additional safeguards above those that would be required by a justification of risks being as low as reasonably practicable (ALARP).

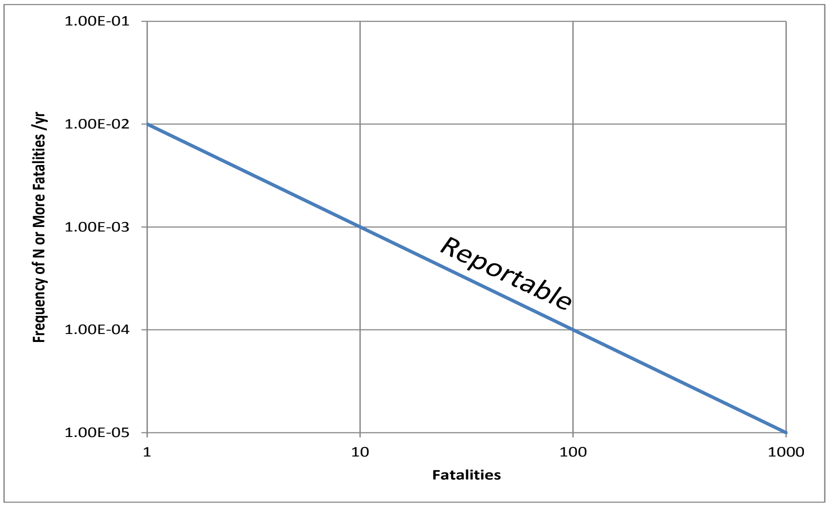


Figure 2: Societal Risk Reporting Criterion

Approach taken

The approach to addressing the issue had to take into account a range of factors that affected the likelihood of damage to the gas export pipeline and the potential consequences should this happen. It also had to provide sufficient information to allow the risks to be understood and an effective risk reduction programme developed and implemented. The steps taken were to:

- Conduct a preliminary risk assessment to determine the threat the caisson presented to the pipeline, based on the limited integrity information available, the likelihood of the caisson striking the pipeline if it failed and the expected outcome if that strike occurred.
- Assess the risks associated with the caisson in terms of both Individual and Societal Risk criteria.
- Determine immediate measures to be adopted for risk management.
- Define medium and long term risk reduction measures to be taken to ensure a longer term solution of the issue.

Risk assessment

Preliminary assessment

The integrity assessment had significant uncertainties and was unlikely to provide any reliable guide on the likelihood of failure.

A standard dropped object analysis indicated that if the caisson failed there was a 17% chance that it would strike the pipeline. However, the dropped object methodology is intended for items falling into the sea during a vessel transfer lifting operation and as a result the distance the object can move from the point at which it is dropped will be greater than for a vertical steel pipe that is already partially submerged and also vertically guided over its length. The estimated impact probability was therefore considered an underestimate.

The mass and impact energy were such that pipeline rupture was the expected outcome. Consequence assessment indicated that the mass release rate was such that the whole facility, including the flare, would be engulfed in a flammable cloud. If the SSIV functioned, this condition would be for a short time lasting for the order of a minute. If the SSIV did not function, this would extend to a period of over an hour.

Individual and societal risks

There were clearly uncertainties within the data that could be used to assess the risks associated with the caisson failure. It was therefore decided to estimate the range of possibilities using the upper and lower limits to the input information. These were then combined to give overall upper and lower limit to the risks. Given the unknown state of the SSIV, the risks were calculated for two separate cases:

- The SSIV is guaranteed to function as designed

- The SSIV was in a failed state and would not provide isolation.

This approach was preferred in comparison to calculating a single risk with some arbitrary reliability on the closure of the SSIV as it would allow the criticality of the SSIV to be understood.

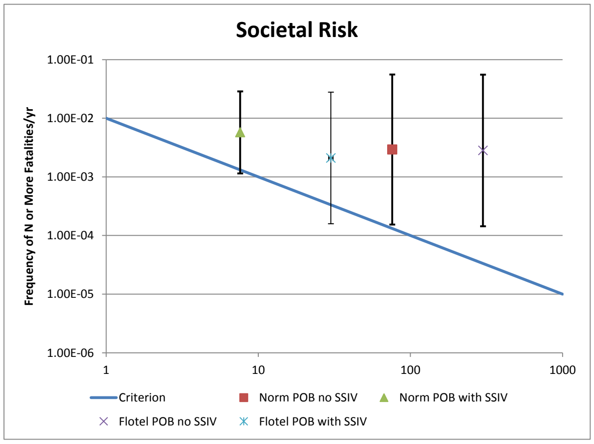
In the calculation of the individual and societal risks the analysis was kept relatively simple, ensuring that the relevance of the different assumptions was transparent. The parameters that needed to be considered in the calculations and the upper and lower estimates for the input data are given in Table 1.

Based on these calculations the upper and lower risk values were calculated. These are plotted in Figure 3, with the mean value being the geometric mean between the upper and lower limits. It should be noted that the societal risk plot provides points that the societal risk curves for the four separate cases being considered would pass through and includes the generic societal risk calculated for the facility QRA, they do not represent four points on a single curve formed by joining the points together.

It can be seen that there was every indication that the individual risks were intolerable and that the societal risks were significantly above the BG Group reporting line, almost regardless of the uncertainty. On this basis BG Group took the only short term risk reduction option available and the platform was immediately shut down and the gas export line was depressurised.

Table 1: Parameters used in calculating Individual and Societal Risks

Element	Range	Value	Justification
Caisson Failure Rate/yr	**Lower**	**8.3×10^{-3}**	**Based on 2 caisson failures from a population of 12 caissons over an operational period of 20 years and assuming a constant failure rate.**
	Upper	**5.6×10^{-2}**	**Assuming failure is due to ageing and has only been possible in the last 3 years rather than a constant failure rate over 20 years.**
Caisson Impact Probability	**Lower**	**0.17**	**The standard dropped object analysis uses a methodology that assumes an object dropped from above the water level and entering the water at any angle. The caisson was already in the water and aligned vertically, directed at the pipeline. The assessment was therefore considered optimistic and the upper limit takes the precautionary approach of assuming impact in all cases.**
	Upper	**1**	
Ignition Probability – SSIV functions	**Lower**	**0.1**	**OGP published data on ignition probability given platform engulfment. 1**
	Upper	**0.5**	**Presence of flare and likelihood of engulfment, but there is a possibility that the wind direction may prevent ignition.**
Ignition Probability – SSIV fails	**Lower**	**0.1**	**OGP published data on ignition probability given platform engulfment. [1]**
	Upper	**1**	**The long duration of the event and the presence of the flare makes ignition highly likely.**
Proportion of time outside for most exposed personnel	**All cases**	**0.25**	**Approximation for most exposed worker group, used for calculating their individual risk.**
Proportion of time offshore	**All cases**	**0.4**	**Based on normal rotation pattern, used for individual risk only**
Fatality Rate given Ignition and SSIV Functions	**All cases**	**0.1**	**Assumed all those outside are fatalities and that this approximates to 10% of personnel, used for societal risk**
Fatality Rate given Ignition and SSIV Fails	**All cases**	**1**	**The platform would be engulfed in a fire for over an hour, escape would be unlikely and collapse inevitable, used for societal risk**



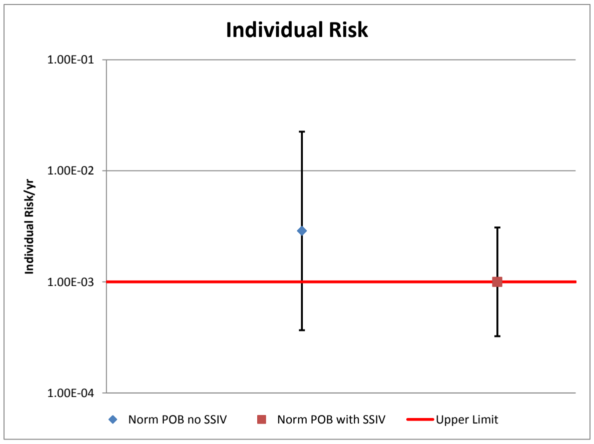


Figure 3: Calculated Risks for Different Cases

Medium and long term risk reduction

The next stage was to evaluate under what conditions production could be re-instated. The initial stages of this were carried out in a workshop to define possible risk reduction measures. Though there were many elements to the restoration of production, the primary ones were:

- Inspection of the caisson condition as far as would be practicable to re-assess the potential for failure; this would include the existing guides.
- Installation of a restraint designed to prevent the caisson and its internals from falling if it failed.
- Implementation of frequent visual inspections of the condition of the restraint and caisson.
- Investigation of the position of the flap within the SSIV, given that the pipeline was shut down and depressurised. Unless some confidence could be obtained that the flap was in the 'down' position, the precautionary assumption would be made that the SSIV was in a failed state.
- Recognising these as short to medium term solutions only, development of a plan for removal of the caisson and implementation of this as soon as practicable.

Given the potential impact energy of the caisson, protection of the pipeline was not practicable.

To assess the effect on risk, it was assumed that even given good inspection results and an engineered restraint, both the inspection and the restraint would have a 10% chance of failure. Being independent, they therefore provided two orders of magnitude reduction in risk, which effectively made the risks tolerable if ALARP for the individual risks and below the reporting line for the normal operations POB societal risk. However, the societal risks for the Flotel case with the SSIV in a failed state would still be above the reporting line. It was therefore important to gain some confidence in the condition of the SSIV to ensure that the Combined Operations could progress as planned.

The planned measures were implemented, with the restraint being fitted to the caisson and inspection carried out, prior to re-starting production. In addition, an acoustic 'ping' echo test was used to determine the position of the check valve flap while the pipeline was shutdown. This indicated that the flap was hanging down and this was considered sufficient to demonstrate that the valve would close in the event of an inboard rupture of the pipeline or riser.

Following completion of the medium term risk reduction measures and re-start of production, the condition of the restraint was regularly checked. During the following winter, the restraint suffered a partial failure and production was suspended again until measures could be taken to reduce the risks.

During the following year, the plan for the caisson removal was developed and executed. This involved a repeated sequence of lifting and cutting operations to remove the caisson in sections on the platform topside. Figure 4 shows views of the removal process, with the caisson partially removed retracted on the left and a section being removed on the topside on the right.

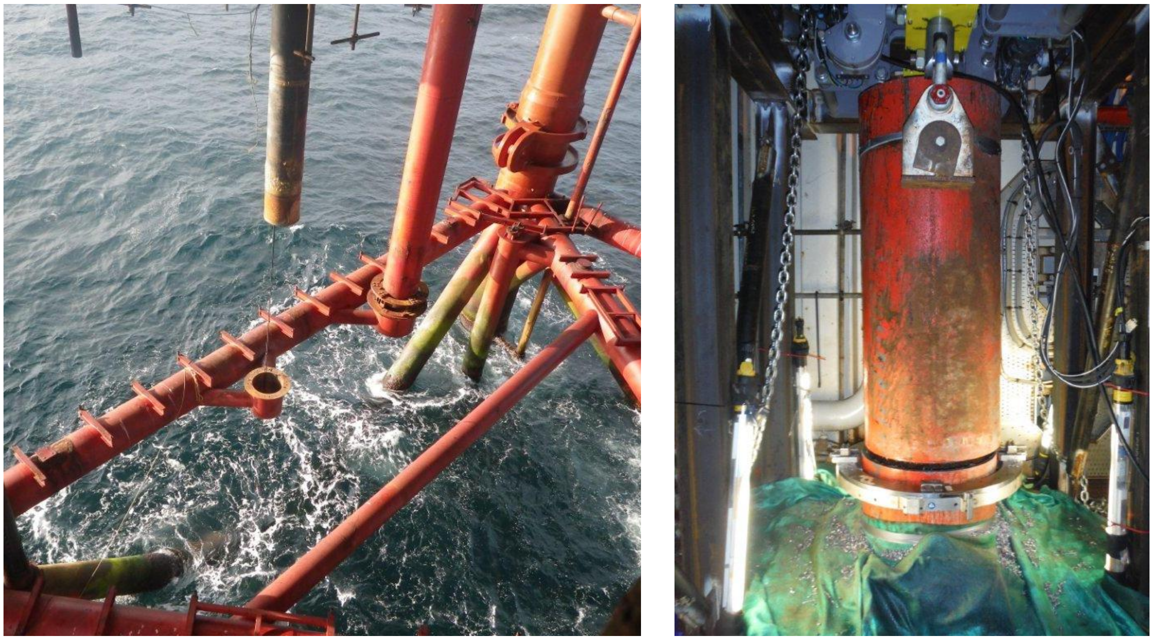


Figure 4: Removal of Caisson

The careful planning of this of the caisson removal allowed the work completed successfully. Examination of the sections removed showed that there were significant defects in some locations, as shown in Figure 5, vindicating the priority given to the removal rather than relying on the restraints for anything other than the minimum time required.

Figure 5: Illustration of Caisson Condition

Summary

Though some of the values used in this assessment could be disputed, their variation would be unlikely to have affected the decisions taken. Given the potential scale of the consequences, the operator took the precautionary approach in reducing the upper limits of the calculated risks to a level where they were not intolerable. This is consistent with the recently updated guidance from Oil and Gas UK Ltd on risk related decision making 3.

The risk assessment process had sufficient clarity to allow the basis of the decisions to be understood and the difficult decision to shut down justified. It also aided the definition of the conditions required for reinstatement of production.

At a more general level, the assessment demonstrated that caissons located above subsea pipelines can result in high risks as the asset ages. The case described in this paper shows that for existing assets the integrity of such caissons should be a focus in terms of risk management. In addition, this situation should be avoided in the design of future facilities.

References

1. R J Lee and S F Burch, HOIS Guidance on in-service inspection and integrity management of caisson, HOIS (13) R6 – Issue 2. July 2014.
2. Ignition Probabilities, Risk Assessment Data Directory, OGP, Report 434-6.1, March 2010.
3. Guidance on Risk Related Decision Making, Oil & Gas UK, July 2014.