Case Study 3 – Explosion Incident

Background

The *Ciudade de São Matheus* (CDSM) is a floating production, storage and offloading (FPSO) facility.

Prosafe was an engineering company engaged by Petróleo Brasileiro S.A (Petrobras) in 2007 to design, construct, commission and operate the FPSO on behalf of Petrobras. Prosafe was later acquired by a company called BW Offshore (BW) in 2010.

The specification required the FPSO to have a gas processing system and an oil processing system. The systems were designed to receive oil and gas from wells that would be directed to each plant as required. The oil processing system was designed to separate oil, gas and water which would be stored in cargo tanks, to be transferred to a tanker during offloading.

The gas processing system was designed to separate the lighter portion of the gas from its heaviest part (a by-product known as **condensate**). The condensate was required to be processed in two ways:

1) If there was no oil production, the gas would be processed onboard the FPSO before it would be recombined with the condensate and transferred through a pipeline to a Gas Treatment Unit (GTU) located onshore.
2) If there was oil production, the condensate would be sent to the oil processing system to be mixed with the oil (to stabilize the condensate) and stored in the cargo tanks.

In April 2007, Prosafe issued an initial Safety Case for the FPSO design based on this usage to demonstrate that hazards associated with the FPSO had been identified, risks had been assessed and control measures were implemented to reduce the level of risk to be as low as reasonably practicable (ALARP).

In October 2007, during design, Petrobras requested Prosafe to assess the possibility of storing pure condensate in the cargo tanks.

Prosafe determined that pure condensate could be stored in the cargo tanks for short periods.

At the end of design, Prosafe issued the final Safety Case for the FPSO. **It contained no indication that the storage of pure condensate in the cargo tanks had been considered in the design.**

Production began in June 2009, with only wells from a gas reservoir (no oil production). As initially specified, condensate was being exported to the onshore GTU via the gas pipeline. From September 2009, the export of condensate through the pipeline was stopped and condensate was primarily stored in the cargo tanks, which was supposed to be a **temporary state**. **However, the practice of storing pure condensate in the cargo tanks continued until February 2015.**

During 2010, Prosafe was acquired by BW. The existing Prosafe Management System was to be migrated, meaning that all the documentation would have to be reviewed/modified prior to being handed over to Operations. During this process many, important documents were destroyed or deleted.

The Incident

On February 11th 2015, the FPSO was storing approximately 70,000 cubic meters of pure condensate in the cargo tanks. While attempting to drain the condensate from the cargo tanks, a leak occurred inside the pump room which was detected by the gas detectors. The ventilation system was automatically stopped, and personnel began to move to the muster points. The production plant was not automatically stopped.

A team was sent to the pump room to investigate the alarm. They identified that a flange in the piping was leaking, reported a pool of condensate (approximately $2m^2$) and confirmed the presence of an explosive atmosphere. Another team was sent to assess the required repairs.

A third team were sent to repair the leak and clean up the leaked condensate. After attempting to use absorbent blankets to clean the spill, it was decided to use a fire hose to perform a "water sweep". After the water sweep commenced, there was a request to increase water pressure at which point a powerful explosion occurred.

The incident report suggested:

- That the leak was caused by a failed spade (blank) fitted to one of the pipe-flange connections.
- That the likely source of ignition was static electricity from the water jet.

The explosion **killed 9** and **injured 26** people.

The explosion ruptured the bulkhead between the pump room and the engine room, causing substantial damage to the pump room, engine room, the area near the entrance to the pump room access shaft and accommodation cabins. The cost of repairs was approximately USD 250 million.

Figure 1 Photos from footage of the explosion

Incident Review

The explosion was the result of a series of events which occurred over a period of eight years. The application of appropriate processes and activities within an engineering management system, at **any point** up to the explosion, **may have prevented it**.

The table below lists and discusses the key events and process/es which could have prevented this incident from occurring.

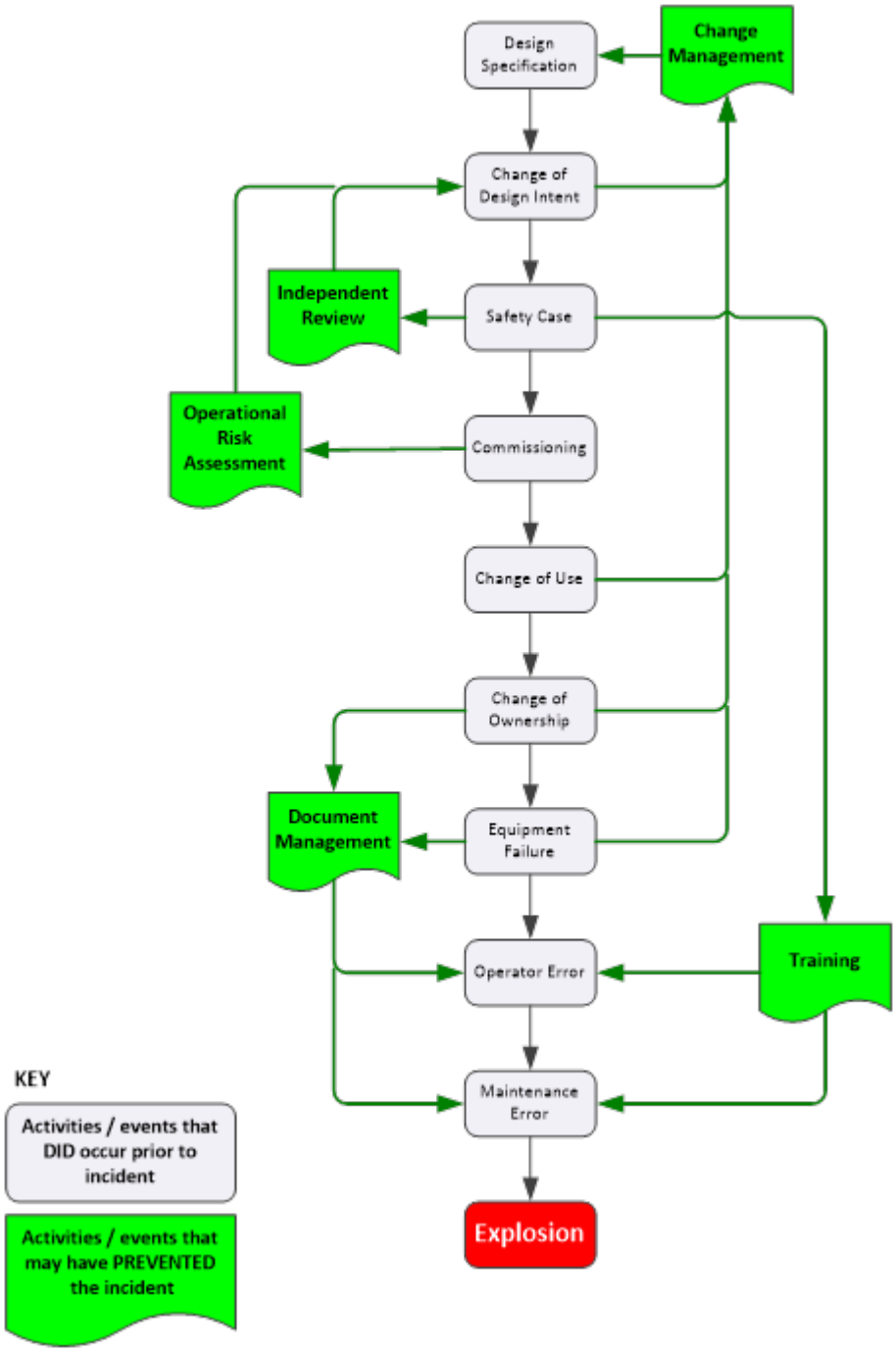
The accompanying flowchart summarises the engineering management system failures that contributed to the causation of the explosion.

Table 1 Activities (process/es) within an engineering management system, in relation to incident causation

Event	Applicable Engineering Process(es)	Discussion
Design Specification	Requirements Definition Concept of Operations Concept of Maintenance	Initial specification should have identified the context for the design and **how it would be used**. This enables the designer to make appropriate design decisions. The design was **never specified** to store pure condensate.
Change of Design Intent	Change Management (Change of Use)	Identification of the **change of use** of the FPSO would have identified the requirement for the **design to be changed** to be suitable for handling pure condensate.
Safety Case	Independent Review (Due Diligence)	Independent review of the Safety Case may have identified the **absence of consideration** for the storage of pure condensate.
Commissioning	Operational Risk Assessment	An operational risk assessment should have identified that the FPSO had not been designed to be operated in the intended manner.
Change of Use	Change Management (Change of Use)	Use of the FPSO was **changed** without reviewing the **impact of the change** with the designer. This may have prevented the FPSO being operated in a manner which it was **not designed for**.
Change of Ownership	Document Management (Operating Procedures)	Many documents were changed/disposed of without **understanding their relevance** and the potential **impact of the changes** to procedures.

Event	Applicable Engineering Process(es)	Discussion
Equipment Failure	Change Management (Design Change) Document Management (Operating Procedures)	Equipment failure occurred due to the unmanaged previous **change of use** which did not identify material incompatibility between the pure condensate and valve seals. To address the failure, maintenance personnel modified **pipework** to bypass the failed valves and pipework, which constitutes a **design change**. This **unauthorised design change** resulted in a system with: • Components which were **not fit-for-purpose** (inadequate strength). • **Increased loads** on the system (pump static discharge into closed pipes). Necessary changes to **operating procedures** to reflect the **design change** were **not documented**.
Operational Error	Document Management (Operating Procedures) Operator Training (Competency)	The pump was **operated incorrectly**, which overloaded the modified pipework and caused it to leak. This provided the **fuel source** for the explosion.
Maintenance Error	Document Management (Maintenance Procedures) Operator Training (Competency)	The maintenance personnel were operating equipment within an **explosive atmosphere**. Inadequate training, complacency or ignorance of the potential hazards resulted in the **unsafe practices**. This provided the **source of ignition** for the explosion.

Figure 2 What engineering management activities may have prevented this incident?



Additional Resources

Investigation report of the explosion incident occurred on 11/02/2015 in the FPSO Cidade de sao mateus. (2015). Retrieved from Brazilian National Agency of Petroleum, Natural Gas and Biofuels: https://www.norskoljeoggass.no/globalassets/dokumenter/drift/fpso-cidade-de-sao-mateus/anp_final_report_fpso_cdsm_accident_.pdf