

Petrobras P-36 Accident Rio de Janeiro, Brazil

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ABSTRACT

Petrobras P-36 was a floating offshore production unit operating in the Roncador Field, off the coast of Brazil, commencing operations May 2000. This structure was originally designed as a floating drilling unit and was modified from 1997 to 1999, into a floating production unit. These modifications included major equipment additions as well as structural upgrades.

On March 20, 2001 Petrobras P-36 capsized and sank after a series of explosions. The initial explosion has been attributed to the poor alignment of the emergency drain tank (EDT) to the production heater, the proximity of these structures allowed for the accumulation of hydrocarbons, eventually resulting in an explosion. After the initial explosion, volatile gas was provided with an escape route, this resulted in a second explosion, which caused major structural damage and the eventual sinking of the Petrobras P-36.

The accident was accredited to three major factors they include: mechanical component design flaws, human errors and economical factors. Investigations into the accident identify three mechanical design flaws these include: poor design placement of key safety-critical paths, component failure without sufficient backup and poor control of the emergency notification system layout.

As a result of the accident three major changes/consequences occurred: firstly they include the economical impact and financial losses that were experienced by Petrobras, though the increased cost of operations as well as the loss of assets. Secondly, there was development and modification of rules and standards for oil exploration for offshore Brazil, hopefully this will prevent a similar accident from reoccurring. The last consequence associated with the event was the environmental impact from oil loss.

Lessons learned as a result of the Petrobras P-36 accident amplified the importance of conducting safe operations and ensuring procedures are in place to help mitigate accidents; it is of uttermost importance to ensure redundancy in high-risk areas are adequate. The accident also illustrated the importance of training crew and personnel adequately, ensuring they understand equipment requirements and protocol associated with equipment. The last lesson learned for the incident is that operators must be responsible for establishing a mythology to prioritize efforts in emergency situations.

1 INTRODUCTION

Petrobras, founded in 1953 is a Brazilian multinational energy corporation headquartered in Rio de Janeiro, Brazil. Petrobras is one of the largest companies in Latin America, with the Brazilian

government owning 54% of the common shares of Petrobras. While the company has ceased to be Brazil's legal monopolist it remains a significant oil producer, with output of more than 2 million barrels (320,000 m³) of oil equivalent per day. In addition to being an oil producer, Petrobras owns oil refineries and oil tankers and is considered a world leader in development of advanced technology for oil production. In recent years Petrobras has been criticized heavily for its poor environmental and safety records.

The Petrobras P-36 platform was originally designed as a floating drilling unit, and later re-designed as a floating production unit, prior to being renamed the Petrobras P-36 platform this structure was known as the “Spirit of Columbus”. Constructed between 1984 and 1994 in Italy, it was designed as a modification of the Friede & Goldman L-1020 Trendsetter-Type, a semi-submersible design. From 1997 to 1999 the “Spirit of Columbus” was re-designed for Petrobras and re-named the Petrobras P-36.

The structure originally designed as a drilling and production unit contained twelve legs for a max water depth of 500m. An upgrade of the mooring system included the addition of four new legs, for a total of sixteen legs and an increased water depth ability of 1360m. Accompanying these changes was the installation of a new process facility, gas processing plant, new water injection system, and new facilities for riser’s supports. These modifications required the structure to be upgraded to support new equipment and to ensure compliance with stability and buoyancy requirements.

With modification complete the Petrobras P-36 structure was considered the world’s largest semisubmersible costing an estimate of \$350 million. It was designed with 2 pontoons and 4 legs, which were not modified during construction. The structure had the following particulars and had production capacity of 180,000 barrels of oil a day (b/d), a gas compression capacity of 4.8 million m³/day and a water injection capacity of 24,000 m³/day.

Table 1 Dimensions of Petrobras P-36

| Propriety | Dimension | Unit |
|------------------|------------------|-------------|
| Length | 112.8 | m |
| Width | 77 | m |
| Height | 119.1 | m |
| Weight | 34,600 | tons |

The Petrobras P-36 started operations in the Roncador, Field May 2000. The Roncador field is located in the Campos Basin, 130 km of the North- East Coast of Rio de Janerio in Brazil, first discovered in 1996. It contains an estimate of 2 billion barrels of crude and accounts for almost sixty percent of the Brazilian crude oil production.

The platform is connected to a total of twenty-six wells, twenty-one production wells and five-injection sites. A one hundred and seventy-six meter long pipeline, twenty inches in diameter, exports gas obtained from these wells, while crude was transferred via a VLCC (Very Large Crude Carrier).



Figure 1: Roncador Oil Field, Coast of Brazil

2 SUMMARY OF EVENTS

On March 14th, 2001 the Petrobras P-36 experienced two explosions, which eventually caused the death of 11 people and injured 137 more. The explosions were the results of several events, some of which could have been prevented or limited if the proper protocols had been exercised.

On March 14, 2001, drainage operations begin on the portside emergency drain tank (EDT) used for storage of oil and water during maintenance or emergency situations. Poor alignment of the port EDT to the production heater inside the production caisson permitted the entry of hydrocarbons into starboard EDT; this is considered to be the main factor leading to the explosions and the eventual sinking.



Figure 2: Petrobras P-36 at 16deg Tilt

The flow of oil, gas and water through the entry valve starboard of EDT caused the overall pressure in the tank to rise, eventually leading to overpressuring of the tank. The excess pressure in the EDT tanks caused the tanks to crack causing the first explosion and allowing the release of oil, water and gas, initiating the flooding of the starboard column. At the same time gas migrated to the upper level of the starboard column through open doors and ventilation hatches, where an unknown

ignition source caused the gas cloud which had developed to explode, this led to major structural damage.

Upon detection of the explosion two fire-fighting pumps were activated leading to further flooding, due to the rupture of the sea water pipe. Failure of airtight dampers, allowed for water to invade the aft starboard pontoon rooms, including the pump room, water injection room and the access tunnel. With the inflow of water causing the failure of seawater pumps the hole that was created in the explosion was allowed to remain open. As a result this allowed the platform's list to continuously grow eventually reaching an incline of sixteen degrees.



Figure 3: Petrobras P-36, March 20, 2001 (Capsized)

The submersion of the chain locker pipe at the main deck level led to down flooding in the platform. Continued slow flooding of the starboard aft pontoon continued till the deck box compartments and central caisson was completely flooded causing the platform to capsize and sink.

In an attempt to prevent loss of the platform 4,100 tons of nitrogen was pumped into the flooded compartments in an attempt to discharge an approximately 15% of the estimated 7 million litres of flooded seawater. The structure eventually capsized on March 20th, 2001.

3 MAIN CONTRIBUTING FACTORS

The sinking of the Petrobras P-36 has been attributed to several major factors. The most important factor leading to the sinking of the structure is the un-alignment of the EDT to the production header instead of to the production caisson, permitting the initial entry of hydrocarbons into the starboard EDT.

The second major factor leading to the sinking is considered to be the delay in the activation of the port EDT drainage pump, allowing the reverse flow of hydrocarbons. Failure of the ventilation dampers to close allowed for water to enter and further flood the starboard column and pontoon compartments.

Preventative measures should have been in place, these would include a contingency plan in the event of an emergency when two seawater pumps were under repair and a contingency plan and training for responding to emergency ballast and stability control situations. If contingency plans were in place, the sinking of the Petrobras could possibly have been prevented.

After the catastrophe of the Petrobras P-36 several agencies conducted investigations regarding the incident. These investigations identified the following areas of concern: mechanical component design flaws, human errors, economical factors.

Three mechanical components design flaws were identified as major contributing factors in the lost of the platform. The first is the poor design placement of key safety-critical paths; in particular this pertains to the proximity of the EDT to the seawater service pipe inside a main support column. This created a common node of failure. After the incident a record of the hazard analysis report for this design could not be found or could not be confirmed that it was ever completed, there is much speculation as to if it was actually completed. The ruptured seawater service pipe was no longer able to adequately provide for fire fighting, this combined with there being no alarm to notify operators that seawater was flooding the column and pontoon was a contributing factor in the design.

The second design flaw that was identified is component failure without sufficient backups. The valve closing off the isolated EDT had no redundancy in case of leakage, the seawater pump short circuited from the flooding, the valves to the ocean were fail-set and thereby locked in the open position allowing uncontrollable flooding of the column and pontoon.

The third and last design flaw identified was the alarm system and notification system design and layout. A combined total of 1,723 alarms were triggered in a total of seventeen minutes with no method of prioritization.

Human error is considered a major factor that lead to the loss of the structure, a lack of training and communication between crew help to create mass confusion with lack of purpose. With a total of 1,723 alarms triggered and no method of prioritization the proper and most efficient steps that could have aided in salvaging the platform were not taken.

In addition some basic steps should have been taken or enforced on a daily basis; these basic steps had the potential to minimize the flooding and explosions. All water sealed doors to key ballast compartments should have been kept closed as a daily occurrence or at least all compartments should have been shut once the initial explosion occurred, this step was not taken. This was blamed on poor and insufficient training.

Neglecting maintenance issues is considered another form of human error that lead to the sinking of the structure, problems and a concern regarding pressurizing issues in the pipes days before the initial explosion were neglected. Management of the rig had reported these concerns, even suggesting temporarily shutting down operations.

With a focus on cost cutting, in an effort to make the daily operations as profitable as possible, Petrobras publically extolled its shedding of prescriptive engineering, inspections and quality requirements. With no regulations in place in offshore Brazil, the Petrobras chose to operate in the most economical way possible, neglecting regular safety checks. This is combined with the fact that over the last decade the workforce had been downsized to half the original size, while production and operations had actually increased over the same period, this has created concerns regarding the work environment and safety issues and precautions being enforced.

4 RESULTS OF THE INCCIDENT

After the accident of the Petrobras P-36 several repercussions were experienced they include; economical impact, modification/development of rules and standards, and environmental impacts.

With the time production cost of the Petrobras P-36 estimated at \$350 million and insured for an estimated \$500 million, the end result was that the cost of the structure was split between the insurance agency and Petrobras, due to Petrobras being found negligent in operational activities that lead to the event. This combined with an insurance premiums increase of over 400%, a jump from 7.5 million to 48.8 million per year. It is estimated that losses incurred as a result of the accident at up to 1 billion a year, including a \$50 million a month in lost revenues, and \$35 million a month in operations. The credit rating of involved parties has not been affected, but the positive fiscal standing of the company is

tempered by its poor safety and environmental record, as Petrobras has been fined 4 times for oil spills, and accredited with the deaths of more than 90 oil workers to date.

The environmental impact associated with accident was initially thought to be minimal, this is due to the successful capping of the drilling and injection wells. The main source of environmental impact was due to sinking of the structure. With an estimated total of 1.2 million litres of diesel fuel and 300,000 litters of crude oil on board and in risers it is believed that this has leaked to the environment due to the breaking of the tanks when exposed to extreme pressure at deep-water depths.

To help aid in limiting the impact of this leaked oil twenty-six ships were stationed at the accident site with dispersants, skimmers, and 32,000m of booms. As well two sets of ocean barriers were placed around the platform as a precaution, supported by 2 barges equipped for oil retrieval and storage.

Before the Petrobras P-36 accident there was no formal procedure for risk assessments or inspections. This is partly due to their being no real risk assessment being in place or enforced in Brazil's offshore. Risk assessment and evaluation has since been incorporated into every aspect of the design spiral for structures constructed for offshore Brazil.

Following the sinking Brazil's National Petroleum Agency (ANP) issued new regulation "Technical Regulations of Operational Safety Management System for Marine Drilling Installations and Oil and Natural Gas Production." This requires a full safety management system - moving overall safety to the main driving factor in design.

The new regulations established seventeen management practices, divided into three groups related to leadership, personnel and management.

In general the goals of the new procedure were to: establish an objective approach to safety that required operators to document safety, health environmental procedures. They required operators to document their analysis of the main risks using qualitative methods such as hazard identification, at a minimum helping to create more regulation, provide better human training and prevent accidents of a similar nature from reoccurring.

5 CONCLUSION

As a result of the Petrobras P-36 accident changes have been made in the offshore industry in Brazil and several lessons learned should be noted for future operations. The major lessons learned are; efficiency and performance should not supersede safety, in industry there is the need for the continuous pursuit of safe operations. This includes the addition of redundancy where appropriate, and a system-engineering outlook to identify and prevent simultaneous or cascading failures created by the proximity of critical parts and subsystems.

The Petrobras P-36 accident also illustrated that modifications must be carefully analyzed for failure modes, even if modifications have become common practice or industry standards. As well, personnel must be trained and understand the components and equipment, especially fail-set components that can affect operations in an emergency.

Finally operators must be responsible for establishing a mythology to prioritize and focus response in emergency situations. This includes incidents when multiple alarms could be potentially sounding simultaneously or in a condensed period

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