INVESTIGATION REPORT OF THE EXPLOSION INCIDENT OCCURRED ON 11/02/2015 IN THE FPSO CIDADE DE SÃO MATEUS

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Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

SUPERINTENDENCE OF OPERATIONAL SAFETY AND THE ENVIRONMENT (SSM)

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Summary

List of Abbreviations

ABS – American Bureau of Shipping.

ALARP – as low as reasonable practicable.

CCR – Central Control Room.

CCRM – Marine Control Room

CDSM – Cidade de São Mateus

CFD – Computer Fluid Dynamics

CFTV – Video Streaming Network

CIO – Offshore Incident Commander

CI – Incident Commander

COW – Crude Oil Washing

ECR – Engine Control Room

ERT – Emergency Response Team

ESSA – Emergency Systems Survivability Analysis

ETRERA – Escape Temporary Refuge, Evacuation and Rescue Analysis

FEA – Fire and Explosion Assessment

FPSO – Floating Production, Storage and Offloading

GCE – Manager Emergency Center

HAZID – Hazard Identification

HAZOP – Hazard Operability Studies

HEMP – Hazard & Effect Management Process

HSE – Health, Safety and Environment

HVAC – Heating, Ventilation and Air Conditioning

ICS – Incident Command System

IHM – Man-machine interface

LIE – Explosive Lower Limit

LTI – Long Time Isolation

MCE – Cause and Effect Matrix Ratio

MEDVAC – Aeromedical Rescue

MOC – Management of Change

NHHA – Non-Hydrocarbon Hazard Analysis

OIM – Offshore Installation Manager

OSC – On scene commander

PA – Public Address

P&ID – Piping and Instrumentation Diagram

PLEM - Pipe Line End Manifold

POB – People on board

PRE – Emergency Response Plan

PRS – Prosafe

PSV – Pressure safety valve

PT – Work Permit

QRA – Quantified Hazard Assessment

ROV – Remote operated vehicle

RVP – Reid Vapor Pressure

SCE – Safety critical element

SGSO – Operational Safety Management System

SISO - Integrated Operational Safety

TRE - Emergency Response Technician Team

UPS – Uninterruptible Power Supply

UTG – Gas treatment unit

UTGC – Cacimbas Gas treatment unit

UTI – Ullage-temperature-interface

Executive Summary

Approximately 11:30 as of the day 02.11.2015, while attempting to drain the liquid waste from the central cargo tank number 6 (6C) with the utilization of the alternative pump (stripping pump), there was leakage of the condensed material into the pumps room of the FPSO of the Cidade de São Mateus (FPSO CDSM), once operated by BW Offshore Brazil Ltda. (BW), in the field under concession of Petróleo Brasileiro S.A (Petrobras).

After alarm from the three fixed gas detectors installed at the bottom of the pumps room, three different teams have been sent to the location of the leakage in three different times, even with the confirmed presence of explosive environment by the fixed gas detectors.

The first team was sent to the pumps room to investigate the gas detection, despite the gas detection was confirmed by the fixed gas detectors installed in such environment. This team spotted the location of the leakage and its leader went to the control room to describe the response to the emergency command as per what he had seen on the site.

The second team, composed of the brigade leader who had previously incurred with the first team and two members of the FPSO CDSM maintenance team, it was intended to assess the services to be performed for the repair and to return to normal operation. During the mission of the second team, the portable detector of one of the members recorded 100% of the Explosive Lower Limit (LIE).

After the second team returned from the pumps room, the situation was considered controlled by the response team's command, although the brigade remained mobilized. The points of muster at the lunch room (temporary refuge), from the nursing ward and part of the muster point of the engine control room (ECR) have been demobilized. Personnel were exposed to take attitudes as typical of usual situations, how to use the elevator and prepare for lunch, addressing the cabins to change clothes.

Around 12:30, in the meantime the personnel were back and forth from the house ward, a third team entered into the pumps room. Such team was provided with absorbent blankets, fire hose, ladder and tools, with the purpose to clear the pool of liquids and tighten the connection screws which were indicating any leakage, even with the presence of explosive environment. This third team consisted of members of the ERT-1 brigade staff and other people of a response to the emergency technical team, informally gathered few days before the accident.

This team went to the site of the leakage, four decks below the main deck level. On the main deck, near the entrance to the pumps room, there were another brigade team (ERT-2), the technical team members of emergency response, the two squad leaders and the commander on the scene in order to support the third team.

After the unsuccessful attempt to render absorbent blankets during the repair of the connection and the local washing with the utilization of fire-fighting hose, around 12h38, a strong explosion occurred. At the bottom of the pumps room, a shock wave broke the bulkhead between the pumps room and the engine room, destroying such environment and causing the death of a utility operator of which appeared at their muster point, in the engine room control (ECR).

Also in the engine room, the pressure brought down the elevator door, projecting it to the last level of the house ward and making an impact on every floor within the accommodation. Certain personnel were injured, including two members of the ward rescue team who used the elevator and were trapped in the wreckage.

On the top of the pumps room, the overpressure caused the destruction of the roof of its single access, spreading in the destruction of the main deck and causing the immediate death of four people: two brigade leaders (who were also the safety technicians from the unit), the commander on the scene and the pumpman.

The lack of leadership from the brigade teams, the injury of members of the rescue team and the nursery ward unit explosion damage caused the failure in the attempt of care for towards the injured and missing rescue structures on board the unit.

Around 23:30, after the arrival of firefighters, one of the missing personnel were rescued, lifeless. The other missing personnel were found in the following days after the occurrence of the explosion, all of them lifelessly. The accident caused the death of nine people, twenty-six wounded out of seven in worst cases, and side damage to the facility.

During the investigation it was evidenced managerial decisions once taken by Petrobras, Prosafe and BW Offshore (the facility operator), throughout the life cycle of the FPSO Cidade de São Mateus, introduced risks in a not managed basis order upon the platform operation. The input risks created the necessary conditions for the occurrence of such major accident.

Underway of the project phase, the project criteria and the stand board for safety once adopted for the processing plant were not rendered in the existing cross docking load system prior to conversion of the unit.

The decision also during the conversion to store condensate material (hydrocarbons) in load tanks was taken in opposition to mandatory requirements of the project of the unit, which foresaw the condensate material to be stored along with crude oil.

In the phase of installation and commissioning, the cross docking load control system was not fully commissioned.

During the operational phase, the commissioning was not completed, the implementation of safeguards has not been concluded, recommendations arising from hazard prone analysis were not managed and there had been certain outdated and incomplete procedures. The Prosafe Company was acquired by BW Offshore (BW) in 2011 and, despite the ANP incurrence until the accident, resources had not been adequately furnished for the implementation of BW Safety Management System.

The presence of aromatic hydrocarbons in the condensed material stored triggered a chemical attack caused to the material from sealing to the load cross docking system shut-off valves, accelerating the widespread degradation of the cross docking load system. In an attempt to correct such problem, it was decided to maintain the operation of the FPSO CDSM and turn into significant modification into the systems, insulated tanks and lines, conduction of flows, utilization of alternative pipelines and the installation of spades .

While operational constraints resulting from the operation from the degraded system were included in the physical system, the marine team, responsible for the operation of storage systems, was subjected to overload staff and absence of key functions also being degraded over the course of time.

It was observed the stripping pump was operated with the offload closed during the days before the accident. The condensate material leakage was supposedly caused by such type of operation.

The leakage occurred through a flange which had an installed paddle and was located upstream of a directly linked to a slop tank valve. There is evidence that the installed spade did not meet the specification requirements and towards the pipe pressure class where it was installed.

The research showed that exposure of people during the response actions were from a response to the emergency procedure inappropriate without forecasting scenarios identified in risk assessments and their response resources.

It was not possible to determine the source of explosion of the ignition, however, the research team determined as a source more likely. Such ignition source was introduced into the site of the leakage by the response team action. The utilization of the fire hoses with non-conductive water jet within explosive atmosphere is remarkable fact of the lack of understanding of the risks involved and the possibility of electrostatic current generation, as it indicates rules and several good engineering practices.

On the day of the accident, there had been a delay on the helicopter rescue air medical service (MEDVAC), since the aircraft was based its operations and maintenance in Vitória, it has not been replaced by other equivalent arising from the same base. Thus, other aircraft were intended for care, including regular customized aircraft and MEDVAC dedicated to Macaé, which as per the time it was requested to attendance at Garoupa-1 platform (PGP-01).

The Emergency response procedures, in its different levels, were disjointed and did not guarantee the availability of resources in order to serve the accidental scenarios as described in the plans, for example, the care of multiple injuries.

The causes pointed out as well as the evidences as found by the NPA give evidence of lack of structuring of Petrobras and BW for managing the operational safety of the FPSO CDSM. The accident investigation process identified 28 (twenty eight) Root Causes, all correlated with the requirements established by ANP Resolution No. 43/2007 as of 06/12/2007 (SGSO). Additionally, 61 (sixty one) recommendations, setting additional requirements were addressed by ANP research team. Such recommendations were intended to prevent the recurrence of similar accidents and were directed to all active industry in the oil production segment and offshore natural gas and their implementations to be mandatory.

1. The procedural response and incident investigation performed by ANP

1.1. Monitoring the response upon the incident by ANP

On 11/02/2015 around 13:30, ANP has received from Petrobras, over the phone, the information of an explosion as of 12:30 had occurred in an area under its concession, the platform-ship FPSO Cidade de São Mateus, with deaths incurred. The statement had not contained details of the incident.

At approximately 15:00, there had been a new call from Petrobras furnishing more details, bringing information of the explosion occurred in the pumps room of the FPSO CDSM, causing three deaths and there were six people missing and six injured. It was also reported that there was smoke in the house ward and thirty-three people had disembarked over a whaling ship and were taken to the port of Vitória by the Astro Tupi vessel. They added the Incident Command was arranged at the headquarters of Petrobras Organizational Unit in Espírito Santo (UO-ES) and other Petrobras team was in Ventura building, in Rio de Janeiro, via video conference with the Incident Command.

As per such information the staff of the Superintendent of Operational Safety and Environment of ANP (SSM) gathered two teams in view of monitoring the incident, in order to: (i) approach ANP to the companies for the prompt service of any demand for event controlling, (ii) record the information for future investigation of the incident and (iii) evaluating the emergency response rendered by BW Offshore and Petrobras companies.

The two teams gathered were distributed as follows:

a) A team went to Vitória (Espírito Santo), in order to follow the Incident Command as observers, and came across to the Incident Command room late at night from the date of the accident.

b) Another team was in the late afternoon for Ventura Petrobras building in the center of the city of Rio de Janeiro, to monitor the events via video conference with the Incident Command, while the first team moved to the city of Vitória.

Other ANP servers were on standby to support the needs of the teams assigned for the response to the event.

ANP team remained in the incident command in Espírito Santo in the 11th, 12th and part of the day of 13.02.2015, and remained watching these activities on board the unit until the event was controlled, i.e. the unit to be under safe conditions. Valuable to note some of the information analyzed by the screen in accident investigation team is inured from the data collected since the ANP became aware of the occurrence of the event.

1.2. Incident Investigation Proceedings

In parallel to the response to the accident in place, ANP started an administrative proceeding on 12/02/2015 for the investigation of the event and determination of the causes. Due to the initial lack of access to the event site and search activities for missing the first on-site inspection activities took place on 03/05/2015. As below estated, it is briefly presented the activities performed by the research team.

1.2.1. Data accrual through enforcement actions

Beyond the initial response to the accident, ANP conducted the inspection activities presented in Table 1 below.

Tabela 1 – Enforcement actions conducted by the ANP in the investigation and response to the accident of FPSO CDSM

Date	Venue	Participants	Purposes
11/02/2015 to 13/02/2015	Vitória (ES) and Rio de Janeiro (RJ)	ANP	Monitoring of response actions and muster information.
25/02/2015 to 29/02/2015	Macaé-RJ	ANP, Brazilian Navy (MB), Federal Police (PF), Panamá Maritime Authority	Collection of the CFTV system data and supervisory
05/03/2015	FPSO CDSM	ANP and MB	Initial assessment of FPSO CDSM and the accident site
12/03/2015	Petrobras HQ (ES)	ANP, MB, PF and Civil Police / ES (PC-ES)	Collection Data of portable detectors

Date	Venue	Participants	Purposes
01/04/2015	Petrobras HD (ES)	ANP, MB, PF and PC-ES	Discussion of the facts disclosed by the investigation team of Petrobras / BW
13/07/2015 to 17/07/2015	BW HQ – ES and FPSO-CDSM	ANP	Audit SGSO scoped in the accident investigation

1.2.1.1. Data accrual from Video Streaming Network (CFTV) and the supervisory system data unit

The images of CFTV and data from supervisory system were extracted and collected by the ANP in the city of Macaé between the 25th and 29th of February 2015, activity in which were present the Brazilian Navy, the Federal Police and Maritime Authority of Panamá. After such extraction, the data were analyzed in ANP headquarter. The CFTV were observed as per the effects of the explosion, it is possible to identify the leaking fluid in bulk, on the ground floor of the local leakage, beyond the time when the siren had been activated.

From the information collected, it was sought to be identified the unit's supervisory system data information of the operations which were conducted by teams onboard when the accident occurred and what could have been caused inured from the event.

The impractical way of recording from supervisory data held it quite difficult to identify the equipment operation, which required a long teamwork from ANP. Besides the analysis of supervisory data, ANP conducted interviews and hearings with witnesses, as well as intense documentary analysis. A fact considered remarkable by the ANP's research team was the absence of registration in the supervisory system of the levels of load tanks data and some other equipment considered important.

The evaluation of the information in the CFTV and the supervisory system data enabled the fact-finding and points to be clarified with the personnel who were on board and together with the other unit involved in the management and response to the accident.

1.2.1.2. Data accrual from gas detectors

In view to understand the scenario created after the leakage and before the explosion, data were analyzed from portable gas detectors as found next to the casualties. Only one of these switches was found in functional conditions in order to export such data. The portable gas detector data used for monitoring the distance tube after the explosion were also analyzed.

The result of the analysis of data from portable gas detectors has shown the explosiveness level of the existing environment in the pumps room at the entrance of the brigade teams, maintenance and cleaning, and enables adjusting the schedule of events recorded between different devices and systems to the same standard.

1.2.2. Hearing of Witnesses

Many representatives of Petrobras and BW, both involved in the operation of FPSO CDSM, as in the management of the unit and in response to the accident were convened by the ANP to contribute to the clarification of the facts and practices on board of the FPSO before the accident. To this end, it was heard 23 (twenty three) witnesses at the central office of the ANP, between 04/05/2015 and 28/08/2015.

1.2.3. Analysis of data collected and investigation of causes of the accident

The methodology for the determination of causes was based on the practices indicated by the Guidelines for Investigating Chemical Process Incidents, AIChE, 2003, widely used around the world in the research process accidents.

The root causes were identified through the identification of the causal factors of the accident and the use of fault tree methodology in conjunction with the map of the root causes of Operational Safety Management System established by Resolution No. 43/2007 ANP, as indicated in Integrated Operational Safety (SISO). Extensive documentation was analyzed and discussed by the research team during months of work and the results are presented in this report.

2. Description of the explosion accident ocurred on 11/02/2015 in the FPSO Cidade de São Mateus

2.1. Loss of containment and response to the scenario with the presence of explosive prone environment

At 11:30 am the day 02/11/2015, during the emptying operation 6C cargo tank, there was condensate leak inside the FPSO CDSM pumps room. The leakage point was supposedly a flange upstream of the valve OP-068[1], which had an installed spade.

According to data from the supervisory system of the facility[2], the first gas sensor at high level[3] was around 11h31m42s. The same sensor detects the presence of gas at very high level[3] 14 seconds after the first detection. Subsequently, two different gas detectors indicate the presence of gas to 11h36m44s, featuring a confirmed detection of gas pumps room[4]. It was possible to view the condensate material leakage through the CFTV images analysis even before the gas alarm activation. Through the supervisory system data analysis we determined that closing the vapor supply valve stripping pump was commanded marine control room (CCRM) through the supervisory system of marine operator.

After gas detection, audible and visual alarms platform gas was activated and the teams began the displacement of their jobs to their respective muster points previously defined. At this time, the unity of the response structure was thrown functional and technical activities normally carried out by the teams were replaced by emergency response functions. Thus, safety technicians turned brigade leaders, production operators turned brigade members of teams, and similarly for other functions, a reply structure was formed.

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[1] Testimonies collected by ANP.

[2] Performed in independent technical analysis conducted by ANP.

[3] Gas detection in high level is defined as 10% concentration detection of the gas LIE, which as the Cause and Effect Matrix starts alarm actions. The gas detection at very high level is defined as 20% concentration detection LIE (Lower Limit Explosive) of gas, which as the Matrix Cause and Effect initiates actions to reduce the risk of fire or explosion, which include isolation and stoppage of process systems, starting the fire protection systems and closing of air ventilation and air conditioning system admissions.

[4] The confirmed gas detection is defined in the Response Plan for the installation of emergency as detection due to the activation of another gas detector in a given area.

The Figure 1 below, as taken from Emergency Response Plan unit [5], shows the response structure to the emergence of the FPSO Cidade de São Mateus, as well as muster points set for each of the people involved in emergency response. It is noteworthy that during the investigation it was shown that some people were assigned to different duties from those recommended in the Emergency Response Plan (PRE), i.e. individuals performed unforeseen functions in the proceedings. It was also observed that it was not designated any personnel to function Deputy Offshore Incident Commander, although provided in the emergency response structure as defined in PRE.

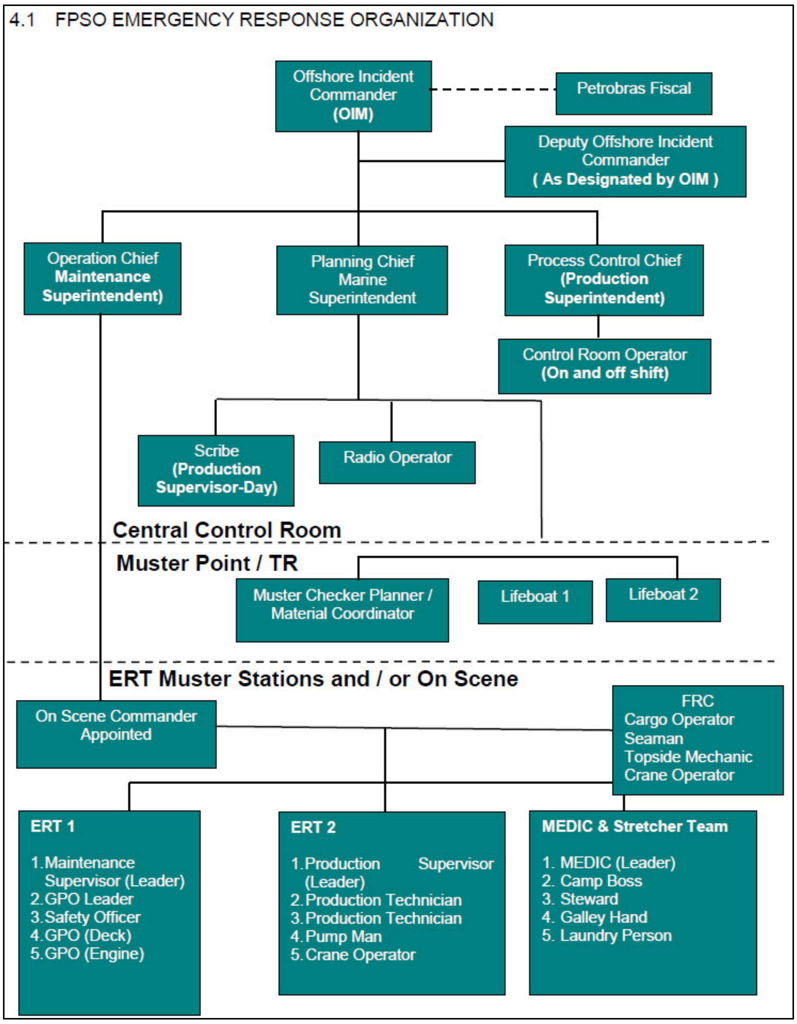

Figure 1 - Organization Chart and muster points of the emergency response team

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5 *Emergency Response and Contingency Plan* FPSO Cidade de São Mateus – Doc. n° MS-MP01279 Rev.1 – Issue date: 13/01/2015

At the time of the accident, the central control room (CCR) was the site designated as a muster of the following persons: (i) the installation manager (OIM), the offshore Incident Commander (CIO); (ii) Petrobras inspector; (iii) the marine superintendent, as the planning chief (CP); (iv) the superintendent of maintenance, as head of operations (CO); (v) the superintendent of production, as production control chief (CCP); (vi) the production supervisor (muster checker); (vii) radio backlash operator (scribe); (viii) the control room operators and (ix) the members of the Emergency Response Technical Team (TTRE).

The formation of TTRE was decided on 08.02.2015 and was characterized as one of the front changes to the response structure contained in the procedures of BW. This team had the main function to provide technical support to the team which had a muster with CCR.

There were other muster points for people who worked in the emergency response function, namely (i) fast rescue boat; (ii) ERT room room to the brigade team 1 (ERT1); (iii) near the chimney to the brigade team 2 (ERT2); and (iv) engine room control room (ECR). The other people on board that did not have emergency response function headed for temporary[6] refuge, in the case of FPSO CDSM was the cafeteria of the unit, near the CCR.

The OIM unit, which had embarked at 8h33 a.m. of that morning in the same aircraft it had its replacement as used to return to Vitória, it participated in a video conference between 9h30 and 10h40. When the gas alarm sounded, he was in his office reading the passage service and taking notice of the ongoing activities. By the time the alarm sounded, the OIM headed to their muster point in the CCR. In CCR, the OIM was informed of gas detection in the pumps room.

The CIO said in English via public announcement system (PA) unit which had a gas alarm in the pumps room under review, ordering everyone to be at their respective muster points. Then it was issued a similar announcement in Portuguese.

In view of addressing the supervisory system of marine team, the OIM has requested information from the ongoing operations in the pumps room next to the head of incident planning (attribution performed by the marine superintendent). After learning of the load between the thanks cross docking operation, ordered the arrest of the pump and the closure of

[6] Location (walls and roof) with fire protection (A-60) in order to protect people from possible fire events in the next process modules.

all system valves. Requested more details of the cross docking operation to the marine superintendent, who informed him about the problems of cross docking and header change operation that was underway when the time of the leak.

The CIO also called a muster situation (time out muster), with the participation of the people at CCR, without, however, having the presence of the brigade leaders, who at the time were the safety technicians and members of brigade teams (ERT1 and ERT2). The situation muster was intended the CCR team to update the CIO of all operations and ongoing conditions during the emergency, as well as the status of muster people on board.

The muster lasted about two minutes, having started at approximately 11:40 am[7]. At this time, the gas detection was at very high level in the pumps room by all three detectors located at the bottom of the pumps room. During the muster situation, CCR team knew not to specify the type of substance or the leaked amount therefore decided to send a team in order to investigate the problem which had originated the gas detection. Additionally, it was also decided to stop the pumps ballast and close all valves. The team assigned to this task should be equipped with brigade costume, self- contained breathing apparatus and portable gas detector, it had confirmation of the presence of gas in the pumps room. After the muster situation, all three gas detectors located on the bottom of the pumps room were inhibited. Inhibition of the detectors kept the visual alarm on the HMI screen, but preventing the execution of the actions foreseen in the Matrix Cause and the effect of even new further detection.

The CIO ordered the radio operator to call the base of BW operations and then passed the information about what was happening on board. Such communication occurred at about 11:45.

While production supervisor accounts for people in points against the No. 1 team squad reported to be ready for their muster point near the starboard lifeboat.

Around 11h49, the first team entry is sorted in the home pumps after the occurrence of gas alarm even with the detection confirmed that gas environment. This team consisted of two brigades of ERT1, one being their leader, and TTRE member (pump operator). At the same

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[7] Context in which the events were recorded during the emergency.

time, the staff count in the other muster places was completed. Detectors and audible alarms were inhibited not to interfere with communication between the team.

The pumps room of the FPSO CDSM home was an environment in which there was a common control procedure for the entry of people, it was endowed with fixed CO2 system whose drive demanded the absence of people in this environment. Everyone who entered the pumps room between the condensate leakage and the explosion had expressed the CIO authorized to do so.

During the descent of the first team to determine the source of the leak, the ported portable detectors for firefighters alarmed and indicated the presence of flammable gases. This detection was 30% LIE (Lower Explosive Limit) on the floor above the spill point and 100% LIE close to this point, thus indicating concentration within the explosive range. Still, they went and identified the leak point.

The leakage point was a flange located upstream of a valve (PB-068), connected directly to the tank bombordo slop (slop P), the fourth level below the main deck. At this time, the leak occurred as fillet in a pool of a dark-colored liquid of approximately 2 m on the ground. Figure 2 shows the position of the OP-068 valve and the location of the leak. Figure 3 shows the flange where the leak occurred in photograph taken before the crash.

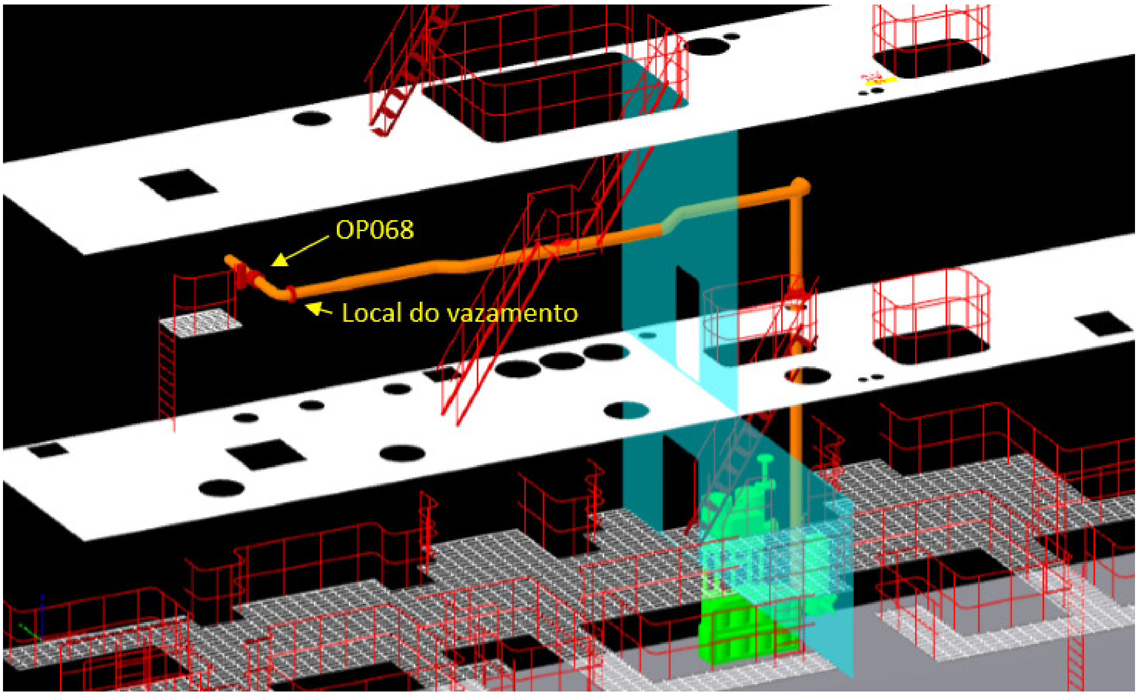

Figure 2 - Position of the OP-068 valve and location of the leak

Figure 3 - Photo taken before the crash highlighting the flange where the leak occurred

Inside the pumps room, the leader of ERT1 reported in Portuguese to the on scene commander (OSC), which was on the main deck near the entrance to the pumps room, which had a lot of gas in the atmosphere. By communication difficulties due to the use of self-contained breathing apparatus used by the brigade, the commander on the scene got the information that there was "zero gas" on site. This information was subsequently corrected by another person who went out of their muster, headed by the commander on the scene and personally conveyed the correct information.

After receiving the information from inside the pumps room in Portuguese, the commander on the scene, which was near the entrance to the pumps room, relayed in English to the Head of Operations in the CCR. The Head of Operations was responsible for updating the CIO on information coming from inside the pumps room and pass the orders of the CIO to the OSC.

At 11h54, after returning the first team to the main deck, the leader of ERT1 (who was also technical security) collected the detectors of other firefighters who came down to the pumps room and addressed the CCR. There CIO reported to the leakage characteristics and it was decided that the cleanliness would be made with absorbing blankets and evaluation by members of the maintenance team, to be planned the repair service.

From the information coming from the first team that went down to the pumps, the CIO and others in the CCR team tried to identify the leak point with the aid of process flow diagrams (P & IDs), but these flow charts did not show the flange where It happened the loss of containment. This fact caused doubt if the leak had occurred in its own OP-068 valve. It should be noted it was not possible to determine if the people who responded to the incident were aware that there was a spade which installed such flange.

At this time, there was a high pressure pump slop tank (slop P) and was ordered to the marine operator, Member of TTRE, relief this pressure on the main deck.

Simultaneously, it was undone an automatic action of the matrix of cause and effect (MCE) to allow the decrease of the temperature of electrical panels within the e-house e-house[8]. Such a situation occurred, because the detection of gas inside the pumps room carried the recirculation mode of ventilation air in such environment by closing the lids of the vents (dampers) of the e-house. Inside this environment there were the electrical panels of production systems and power generation. This led to forming the internal heating of these panels and the resulting shutdown of systems. To work around this problem and avoid stopping the production, it was ordered to return the unit's technical operation of air conditioning to the normal condition, on the contrary to the previously designed in logic systems shutdown in atypical situations[9].

With the information available, a second team was composed and ordered to get down on the site of the leak to evaluate the services to be performed to repair and return to normal operation. In parallel, it was ordered to the marine Superintendent to prepare a work permit (PT) for the repair to be executed later.

At 12:00:42, one of the three detectors of the pumps room was taken from inhibition, returning to indicate very high level of gas to 12:01:41, keeping the same statement by the time of the explosion.

The second team was gathered by the brigade leader who had previously descended with the first team and two members of TTRE[10], who were also members of the FPSO CDSM

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[8] Module containing medium and low voltage equipment, transformers, frequency inverters and equipment for power management.

[9] As per p. 52 ESD document, Fire & Gas System Cause and Effects Matrix - Doc No. 384-79-DOC-003 Rev. Z0 - Issue:. 10/14/2013

[10] Emergency Response Organizational Table

maintenance staff. The second team entered the pumps room to 12h07. During the descent of the second team, the portable detector of one of the members recorded 100% of the lower explosive limit (LIE).

Inside the pumps room, the second team requested, by radio, a ladder and tools and went out for some air. To exit the pumps room, around 12:15 pm, two of the three members of the second team were the CCR and reported to the CIO what was found inside the pumps room. The CIO has authorized the carrying out of the pool cleaning, ordered the verification of service needs and were available sealing stamps on stock unit that are compatible with the flange that had leak. Then the CIO ordered the marine operator to seek absorbing blankets for cleaning operation to be performed at the site of the leak.

A third team was then mobilized in order to drive the cleaning and accessing the flange which had leakage.

Around 12:20 pm, the CIO established telephone contact with the office operations manager in Vitória and informed about the problem and the cleanup plan.

Shortly before the third team entry in the pumps room, the CIO partially demobilized the muster stations[11]. This order was conveyed by notices in the public announcement (PA) system, as well as personal notices by phone.

After the demobilization of warnings, all the people at the muster point of the cafeteria, part of the ward support team and the team's engine room control room (ECR) were demobilized from their point of muster and released for lunch. Per unit rule, people could not consume meals with service overalls and therefore went to their cabins to change for lunch.

At 12h27 and after the demobilization of the muster points, the third team entered the pumps room, even with confirmed gas detection in this environment. For condensate cleaning were highlighted two members of ERT1 would use absorbing blankets. To access the flange were mobilized three members of TTRE belonging to the FPSO CDSM maintenance staff. Members of TTRE carried an aluminum ladder and two wrenches, with combined chrome and other common carbon steel. The fire hose, which was already assembled, was down already pressurized towards the pumps room. Every member of the third team were vested with the

[11] The CIO claims only the persons demobilized from the muster points.

brigade team clothing and portable detectors. One minute after going down, the portable detector member of the brigade already had 100% LIE.

Inside the pumps room, the third team has abandoned the plan to perform the cleaning with the absorbing webs and firefighters started cleaning with the use of the hose. It was then requested from the team who was out of the pumps room to attach a new stretch of fifteen meters to such activity. After mounting the passage and down the pumps room, it was asked the water pressure hoses to be increased. At this time, around 12h38m05s there had been the explosion which caused the damage to people and the equipment in various regions of the unit. Such damages are evidenced herein. In the attempt to assess the problem, repair the connection for which there was leakage and to perform the cleaning of the leaked material there were sent to the location of the leakage from different timeframes, three teams who entered the pumps room even with the gas confirmed detection on site and gas detection on their portable detectors.

2.2. Collateral damage to the explosion

Due to the blast, died immediately four people who were on the main deck, near the access to the pumps room, and the two of them leaders of ERT1 and ERT2 (safety technicians), the commander on the scene (electricity and instrumentation supervisor) and a member of TTRE (pump operator).

The pumps room and engine room were positioned below the houses. The location of the pumps room and engine room and the identification of the floors of the houses are shown in Figure 4.

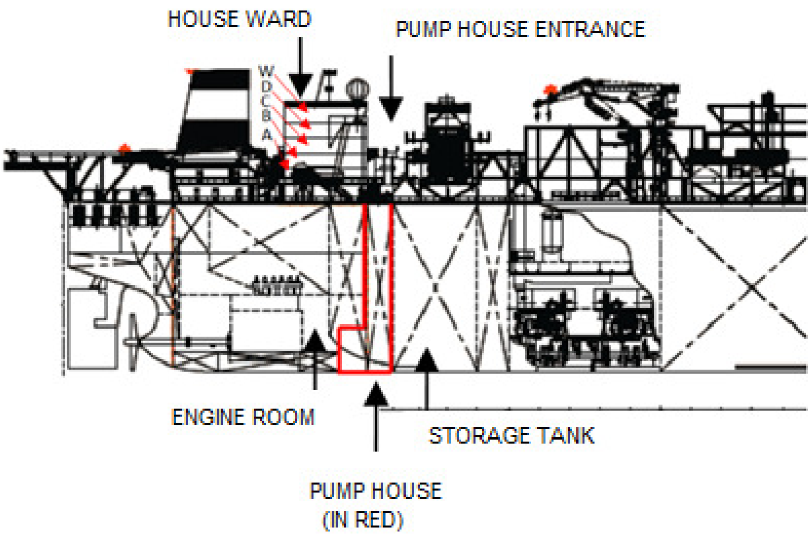

Figure 4 - Location of the pumps room and engine room

In the back of the pumps room, the pressure caused by the explosion broke the bulkhead between the pumps room and the engine room, causing destruction in this environment. The following figures show the damage caused to this area by the explosion.

Figure 5 - broken bulkhead between pumps room and engine room

Figure 6 - Access to the area where, due to the explosion, there was communication between the engine room and the pumps room

Figure 7 - Area where, due to the explosion, there was communication between the engine room and the pumps room

Figure 8 - bulkhead between the pumps room the folded engine room

Figure 9 - Destruction caused by explosion

The muster point of the engine room of the team was in the engine room control room (ECR) and this was necessary because these workers had roles in emergencies.

The pressure in the engine room caused the death of an operator of utilities which was located in the muster point in the engine control room (ECR). His body was only accessed and rescued around 0:00 on the day of 12.02.2015, shortly after the arrival of rescuers of the Body of Military FireFighters of Espírito Santo (CBMES). The following figures show the status of the engine room after the explosion.

Figure 10 - engine room control room (ECR) after explosion

Figure 11 - Port from the other control room entrance to the engine room which was located outside the room

Figure 12 - ECR Windows (broken glass and shrapnel inside the room)

After the explosion, the unit incurred in blackout, and both the main power generation system and the emergency generator were affected. This fact can be attributed to the lack of protection forecast for this area of the unit.

Figure 13 – Machine rooms after the explosion

Figure 13 – Machine rooms after the explosion

In the engine room it was found several damages, such as damaged engines, loose pieces of equipment, and also the bulkhead separating the pumps room and the engine room with an open tear dent due to the accident, large enough for people to cross. The control room of the the engine room impacted in curved walls, as well as the front door.

Figure 15 - Floor Part missing from in the outside of a room

Figure 16 - area of the door adjacent to the maintenance workshop thrown back the stair in distance

Figure 17 - vapored door maintenance workshop

Figure 18 - Other systems destroyed in the engine room

Figure 19 - hanging objects

Also in the engine room, the pressure wave hit the elevator landing which crossed towards the accommodation ward, being propagated into the house wards, reaching the environments, including the nursery ward. The elevator was thrown upwards and within its wreckage was later on found seriously two members injured from the rescue ward rescue team. These two people had been demobilized from their muster point in the nursery ward to have their lunch.

2.2.1 Damage to the house ward by the propagation boost from the elevator shaft

At the FPSO CDSM, the elevator linked decks between the engine room and the "D" level and it was thrown against the ceiling of the last ward on the top floor. It can be seen from Figure 20 that the square of the level of the elevator door machinery moved into the elevator shaft, unlike the other levels, in which the door moved out of the elevator.

Figure 20 - Elevator door in the engine room level (Left) and "D" level (right) after the explosion

This situation is considered critical, given that the houses should be the safest place the unit, providing for the gathering of people for normal operation and for emergency situations. The houses was where the greatest number of people would be during the emergency, as people focused points against the CCR, ward and temporary refuge (cafeteria). However, the houses proved to be vulnerable to the scene of the accident. Figure 21 shows the state of one of the corridors of the houses after the explosion.

Figure 21 – house ward corridor in level "A" of the unit after the explosion.

Figure 22 - Elevator door at the "D" deck after the explosion

The region near the elevators also suffered damages in the explosion. Figure 23 shows damage to a box in level "D" of the unit.

Figure 23 - Cabin in front of the elevator door after the explosion

2.2.2 Damage to the nursery ward

A serious consequence of the damage to the house ward was the spread of pressure to the nursery, located on the main deck starboard side, impairing proper care for the wounded. The ward was another place used as a muster point during the emergency.

According to testimonies, the explosion damage on the nursery ward had left this environment unable to provide any care to the injured ones. The first aid supplies were contaminated by residues of the explosion and the glass wool which came off of the lining of the accommodations partitions. The ward stretcher was designed to service in the deck of the explosion and it was found without the head protector. Figure 24 shows how the ward was found twenty and two days after the explosion.

Figure 24 – Nursery ward (22 days after the explosion)

2.2.3 Damages to the pumps room and the outskirts inlet

At the entrance of the house pumps, besides the deaths and injuries and damage to the structure also damage has occurred to the water and foam fire lines. The loss of containment of the fire-line pumps from home was one of the points of the flooding of pumps room.

The following figures show the damage to this region.

Figure 25 - Floor of the pumps room

Part of the main deck floor was broken and moved up, as can be seen in Figure 26.

Figure 26 – Pumps room entrance after the explosion.

Figure 27 shows the damage occurred in line pipes of fire after the crash. Damaged and blended lines with flexible lines as well as other equipment affected by the explosion can be observed.

Figure 27 - The status of fire line pipe from the input of the pumps room after the explosion

During the inspection activities conducted by the ANP, the floors of the pumps room had low lighting, missing or bulging steps and stairs destroyed replaced by provisional fitted with scaffold pipe. In the described conditions, where the sites were observed steel surface it was raised by the effect of explosion and several destroyed equipment.

Figure 28 - the pumps room entrance with raised roof and pipes

Figure 29 - damaged access and provisionally adapted for people crossing by

Figure 30 - ventilation system destroyed and hanging

Figure 31 - ventilation ducts hanging

Figure 32 - Low luminosity in the pumps room

Figure 33 - Ground damaged by explosion

2.3 Subsequent events after explosion occurence

After the explosion, people aboard the FPSO CDSM were disoriented and disorder settled on board. The production unit was paralyzed for automatic actuation of safety or CCR control systems, it is not possible to determine the cause. The unit's abandonment of alarm began to sound continuously.

The pressure caused by the explosion reached the houses and projected a cloud of glass wool particles in the air. People who were there left disoriented, trying to breathe better and get away from that thought were potentially attainable places for fear of subsequent explosions. There was also a lot of white smoke coming from the engine room and fireplace.

The death of the leaders of the brigade teams, the members of the rescue team injury and blast damage to ward unit caused the failure of the search for missing structures and care to the wounded on board the unit. There was also the fear that further explosions could occur and people sought to move away from the places affected by the explosion.

The coordinator of the abandonment of whaling point of Borest tried to take the order for organizing people, guiding them to make inquiries down the helipad, but the excitement kept counting and identification of individuals. The final number of missing only came later.

At 12h46, Petrobras' Fiscal aboard the FPSO CDSM informed the Emergency Center and the Sector Manager of Petrobras Production Operations worsening of the situation and asked for the aeromedical support. Later on, the OIM called the Operations Manager of BW and he asked for as much of aeromedical helicopter as needed. Only after the explosion, offices of the teams on the ground have begun the effective activation of the external structure response to the FPSO CDSM.

At one point, the smoke begins to also leave for an access below the helipad at that time, it was given the guidance to people they turn to the area of movement of cargo to the half deck of the ship. This displacement was carried out in groups, in which people were counted and gradually released for displacement.

When they arrived amidships, people of the first group viewed a person running towards the bow and followed him, disoriented, without knowing exactly why. It was production team member who was going toward the bow to manually stop the fire pumps. At that time the fire water flooded part of the main deck of the unit, some of the houses and the home of pumps because the explosion had caused disruption fire pipes near the entrance of the house pumps.

People gathered then in and around the temporary shelter where the wounded were also assisted by the nurse. Despite attempts to organize and command the crew to an abandonment by whaling starboard, some people refused to return to close to the houses and the house of pumps for fear of further explosions and planned to leave the unit by inflatable rafts in his own bow. This group was later persuaded to return to close to the houses, specifically the abandonment of whaling point on starboard.

Communications between the platform and Petrobras' offices were lost about twenty minutes after the explosion because of UPS load of completion (uninterrupted power supply unit) of unidade3. Other communications after this time were made through the emergency radio and mediated by the FPSO Cidade de Vitória (FPSO CVIT).

2.3.1 Unit abandonment using starboard whaling ship

The abandonment point it was found that the minimum crew for Navigation starboard lifeboat was incomplete because of the personal injury trained for its operation. The head of planning (marine superintendent) was then fired to man the lifeboat to possess knowledge to do so. There was uproar and some people with no surrender function organized themselves to try to seek missing persons and others who refused to land by lifeboats.

All the preparation for the injured landing was made towards using helicopters and the others would be landed through whaling, with subsequent transshipment to support vessels. However, many of those who were not wounded refusing to use the baleeiras3 and landed by helicopter.

With the explosion, the T[12] cards in dropout point of the starboard lifeboat were lost, making it impossible to control people. The count of people began to be made by hand, called at the entrance of whaling, since the list of persons on board (POB) previously released for abandoning point coordinator was outdated.

People then entered the whaling starboard and remained there until there was a recount using POB updated, made available after the entry of people in whaling, and waited for the order to lower the lifeboat.

The descent, which is usually controlled from inside the lifeboat, was taken by personnel in the platform about 14:00. When whaling was close to the sea, its release was made with difficulty by a person who had no such predefined assignment. The person who sailed to the whaling near the support boat also demonstrated not have a working knowledge of how to operate the boat.

2.3.2 Wounded care

People were injured inside the house wards. The explosion caused by airflow had thrown glass wool powder used for insulation and in the ceilings, causing skin and eye irritation of

[12] Individual identification card. This card is delivered to each person on board the unit at the time of shipment and is stored in its designated drop point. In an emergency, the card enables quick identification of missing persons in the dropout point.

many people. The pressure also caused the destruction of the nursery ward, located on the main deck starboard side, impairing care for the wounded.

On the main deck, other people were injured, mainly due to the pressure that threw people against structures, as well as shrapnel projection equipment damaged by the explosion. In the nine fatalities, a total of twenty-six injured, and seven had serious injury[13] and nineteen were hospitalized for less than 24 hours.

The amount and location of the people who were injured at the time of the explosion are listed in Table 2.

Table 2 - Number of injured at the time of the explosion environment

Location of the wounded	Number of wounded
Inside the pumps room*	1
Deck U - Nursery (house ward)	1
Deck U - locker room surroundings (ward)	2
Elevator (house ward)*	2
Entrance outskirst of pumps room *	4
Surroundings of the whaling starboard *	2
Cafeteria surroundings (house ward)	4
Central control room (CCR) (house ward)	1
Engine Control Room (ECR)	4
Other places on the (house ward) *	3
Location not confirmed	2

(*) Location of the occurrence of serious injury

The team formed to meet the scheduled injured in the emergency response plan consisted of a nurse and four helpers to care for the injured and for providing/search service materials. At the time of the accident, all four support staff nurses belonged to the hotel staff the FPSO CDSM.

Two of the four people responsible for hospitality compose the nursing professional staff were in the elevator at the time of the explosion and injured and arrested in what was left of

[13] As per Resolution ANP n° 44/2009.

the elevator, which was designed to the last houses of the floor. They were only rescued from inside the elevator after the departure of the first rescue helicopter.

The initial care from the first aid was made with the material which was found at hand, since the ward was hit by the impact of the explosion and there was a certain fear to another potential explosion to reach the house wards.

People were helping the wounded they found and adapted to the transport to where they could receive the first aids.

The care with serum and other resources in an attempt to stabilize the victims was done by nurse since none of the people on board had additional knowledge to basic first aid.

There was an office on the ground trying to contact via radio nurse on board to verify the need for support to perform care for victims, but the contact was not effective because of the great demand for service of the wounded. Thereafter no further consultation was made.

2.3.3 Aeromedical Rescue

The air medical rescue (MEDEVAC) contracted by Petrobras has a linked aircraft to Vitória operating base[14]. As per the charter contract of MEDEVAC aircraft[15] it is expected that the contractor shall maintain aircraft available every day of the month, 24 hours a day, and that in case of continuous availability of the aircraft, the contractor shall provide, as soon as possible, its return to operating condition or replacement.

With respect to that aircraft, on 02.05.2015 was informed to Petrobras representatives by the contractor, this would be transferred to the base in Macaé on 02/08/2015 for scheduled maintenance execution and correction follow-up items. The estimated forecast for the fulfillment of these services would be approximately five days, with the return scheduled for the day 02/13/2015 at Vitória base.

On 02.08.2015 the company that provides the service MEDVAC sent to Petrobras the availability plug[16] from such aircraft, containing maintenance activity data and the deadline

[14] Registration number PR-OMQ

[15] Email from the helicopters inspector to the Field Audit Committee of Petrobras, on 05/02/2015

[16] Informe de Resgate Aeromédico n° 00120/2015

for its completion (13.02.2015), and the caveat that MEDVAC aircraft base in Macaé[17] estaria cobrindo a base de Vitória durante a indisponibilidade da aeronave MEDVAC.

In this sense, we found that although the charter contract of MEDVAC aircraft had the aircraft replacement forecast by another of the same model or technically equal or higher, no aircraft of the same characteristic was maintained to replace MEDVAC in Vitória base.

Moreover, it was also found that, although in item 2.5.5 of passenger aircraft charter contract there was the prediction that Petrobras could require the passenger helicopter remained on guard full time to perform salvage missions aeromedical no passenger aircraft was maintained full-time in Vitória base in place of MEDVAC provided for that base.

Thus, since there is no substitute to that in aircraft maintenance, aircraft MEDVAC the base of Macaé would be the resource available to meet possible emergencies in the FPSO CDSM.

However, on 11/02/2015 at the time the MEDVAC aircraft Macaé was triggered as a result of the accident in the FPSO CDSM to 12h48, the aircraft was making a call to an instance in Grouper Platform (PGP-1), of According to the report rescue aeromédico18. The aircraft had been fired at 11h02, having landed in PGP-1 (rescue site) at 12h07 and taken off at 12.40. In this sense, the aircraft could only meet the emergency FPSO CDSM after the completion of service to the occurrence PGP-1. In this context, MEDVAC aircraft reached the FPSO CDSM to 15h25 arising from Macaé airport.

As an alternative to aeromedical aircraft, was provided to adapt a common aircraft passenger, who did not have all the materials and medical-surgical equipment of an ambulance aircraft. Is adapted aircraft landed on the FPSO to 14h53 coming from the Vitória airport.

Table 3 shows the information of all flights who attended emergency, aircraft types and the amount of people who have been rescued. In total, six helicopters were used for the landing of thirty people.

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[17] Matrícula PR-OMA

Table 3 - Flight aircraft for the FPSO CDSM after the accident

Acft. Prefix	**Acft. Type**	**Bound for**	**Landing time in FPSO**	**Number of People landed**
PR-LCE	Adapted passenger acft	Vitória	14:53	03
PR-OMA	MEDVAC	Macaé	15:25	04
PR-OMB	MEDVAC	Rio de Janeiro	15:44	03
PR-LCG	Adapted passenger acft	Vitória	16:18	05
PR-LDG	Passenger	Vitória	16:35	11
PR-LCK	Passenger	Vitória	16:50	04

Whereas, during the emergency, that: (i) the drive for the aircraft to stay on standby for air medical rescue was made to 12h48; (ii) the item 2.2.6.3 of the aero-medical aircraft charter agreement provides that the aircraft is ready to meet a medevac up to 25 (twenty-five) minutes of Petrobras notification; (iii) the 2.7 item of aeromedical team contract provides that the medical staff is available and ready to rescue running on the basis of up to twenty (20) minutes after the the drive time and (iv) the flight between Vitória airport and the FPSO CDSM is approximately 28 (twenty eight) minutes, it can be concluded that the MEDVAC aircraft could have reached the FPSO to 13h41 if the same was available in Victoria operation base at the time of the accident.

Thus, in Table 4 shows the delays in the landing of the first two aircraft addressed to the FPSO CDSM.

Table 4 - aircraft flights for the FPSO CDSM after the accident

Acft. prefix	**Type of acft.**	**Actual landing in FPSO (h)**	**Landing in FPSO as per the contract (h)**	**Delay on landing in FPSO**

				(h)
PR-LCE	Adapted passenger acft.	14:53	13:41	01:12
PR-OMA	MEDVAC	15:25		01:44

The delay of 1:44 a.m. registration of aircraft PR-SOMA base of Macaé can be attributed to air medical service that the aircraft performed in PGP-1 at the time of the accident and flight time between the airport Macaé and FPSO CDSM, greater than the flight time between the airport and Vitória FPSO CDSM. The delay of 1h12 of the aircraft under registration number PR-CSF can be attributed to the time required for adaptation of passenger aircraft.

It should be noted that both delays could have been avoided if the MEDVAC aircraft was ready and available on the Vitória base of operation or if a replacement aircraft had been provided while the main aeronova remained down for maintenance.

2.3.4 Searching mission on the day of the accident

After the explosion of the brigade teams lost their two leaders, who died, and no new command so that there was the search for the missing.

At this time, the disorientation escalated, it was not known what had happened exactly, or what systems were affected by the explosion, neither one knew the risk of further explosions and fire occurrence. People heard one of the missing who was in the engine room to call for help via radio and tried to arrange for an impromptu rescue, but this attempt was discouraged by other people on board because of the risk that the redemption offered to people due to the difficulty of secure access area to the site.

Around 14:00, after checking the updated list of persons on board[18] and landing of thirty-two people by whaling starboard, it determined the correct number of missing the FPSO CDSM. While this check was made, one of the brigade's third team managed to get out by their own means of pumps home alive, but badly injured.

[18] PB list from the day of the accident (SISO attachments)

At that moment, it was found the absence of the two people who were trapped inside the elevator. They were located through shouts from the rooftop of accommodation for people entering the houses to fetch their belongings. Despite the difficulty of access and openness of the lift debris, these people were rescued by the crew members and answered by the nurse, together with the other wounded to the realization of landing by helicopter.

The members of the third team that went down to the pumps and were near the spill site were considered missing. Around 15:00, the IOC was informed that external fire embark on FPSO CDSM.

From 16h50, after landing of people effected by the whaling starboard and six helicopters, remained three people on board. The search for the missing was only initiated after this time, since at night due to the delay in the arrival of foreign rescue team.

This decision was taken because the water from entering the unit was being monitored and would, if no action is taken, where possibly was in one of the missing would be flooded before long.

People then did the measurement of gases in the engine room with remote monitoring by the portable detector with running hose. As such detector did not indicate the presence of gas, two of the three people were in search of the missing person and identified their position, but failed to make access to its rescue. The external team of search and rescue, formed by firefighters from the state of Espirito Santo FPSO boarded the CDSM around 23:00 and was guided by staff on board how to get to the facilities operator. The site already had water close to the entrance and the team of firefighters was able to access the victim but found that this was already lifeless. His body was then taken to near the helipad location where the other bodies were also appointed.

During the external rescue team planning to enter the house of pumps and trace missing, there was the order of the crisis room installed in Petrobras building in Vitória, so that these people immediately abandon the platform because there was a risk of structural collapse. The total abandonment of the unit by the three remaining crew and fire occurred around 1:00 a.m. through whaling port side.

2.3.5 FPSO CDSM stability issue and total abandonment of the unit

To carry out the emptying of the tank 6C, the platform had been tilted so that the stern of the unit stay longer sunk in relation to its stem. This is due to the geometry of the unit's cargo tanks that had beams inside, typical for tanks simples3 tank units.

After the explosion it was found to partial flooding of the main deck, houses and part of the pumps house due to water ingress through the rupture of pipes of fire and, therefore, the fire fighting pumps were stopped. However, after some hours, it was found that the stern-prow gradient was increased and that water intake was probably compromised by systems which were connected with the sea compounders.

The crisis command set up by Petrobras triggered experts on the stability of vessels that simulated the effects on the ship's hull and, at one point indicated that there was structural risk for the unit. After hours with increasing level of water inside the house pumps and engine room, there was the achievement of a balance and the water level remained unchanged.

Response activities after the accident took place in action to close the doors of the sea compounders with the use of divers and such activity has been completed on 03.05.2015 and missing search activity was done in parallel to the emptying of the pumps and home machine Square.

The structural damage suffered perhaps the FPSO CDSM which caused the water intake still uncertain and the interlocutors BW indicate that such damages will only be identified when the unit is placed in the yard.

At the date of issuance of such report, the unit is still being degraded due to the accident and operations are underway for the unit is able to be placed in safe and can be transferred to a shipyard for repairs.

2.3.6 Searching mission after 11/02/2015

In the following days of the explosion, there was concern about the structural condition of the unit, because it was showing an inclination (trim) high. The source of water supply to the pumps house, engine room and number machinery space 6, was unknown and was made external inspection by ROV (underwater vehicle operated remotely), in which damages have not been verified on the outside of ship.

Potential water entry points considered during the emergency containment pipes were fire (that were broken), and communications of sea compounders[19].

On 13/02/2015, it was reported to the ANP that the analysis conducted by the personnel hired by Petrobras and BW showed that there was no structural risk of the unit, although there is flooding of about 15 meters of water pumps inside the house. This flooding made it impossible to rescue missing for an extended period after the accident, the last body only rescued on March 2, 2015[20].

[19] Daily report of 03.03.2015 sent by SISO

[20] Daily report of 02.03.2015 sent by SISO

3 Contextualization - The FPSO Cidade de São Mateus

3.2 Platform Project Features

The FPSO Cidade de São Mateus (FPSO CDSM) is a floating production, processing, storage and transfer of oil unit. On the date of the accident, its main production was natural gas not associated[21], with no oil wells connected to the platform. The processing of this gas in the platform, a liquid fraction was produced:-condensed natural gas liquid obtained in the process of the normal field separator, which is kept in a liquid state under pressure conditions and separation temperature[22]. The gas after processing was all cross docking for the pipeline, connected to the unit Cacimbas Gas Treatment (located on land). The condensate sometimes was exported by the gas by pipeline, but most of the time while in production, the condensate was stored in deck cargo tanks for further export by tanker.

The unit was operating at a water depth of 792 meters and was located in the Espírito Santo Basin, for production of Camarupim and Camarupim Norte fields, as illustrated in Figure 34 below.

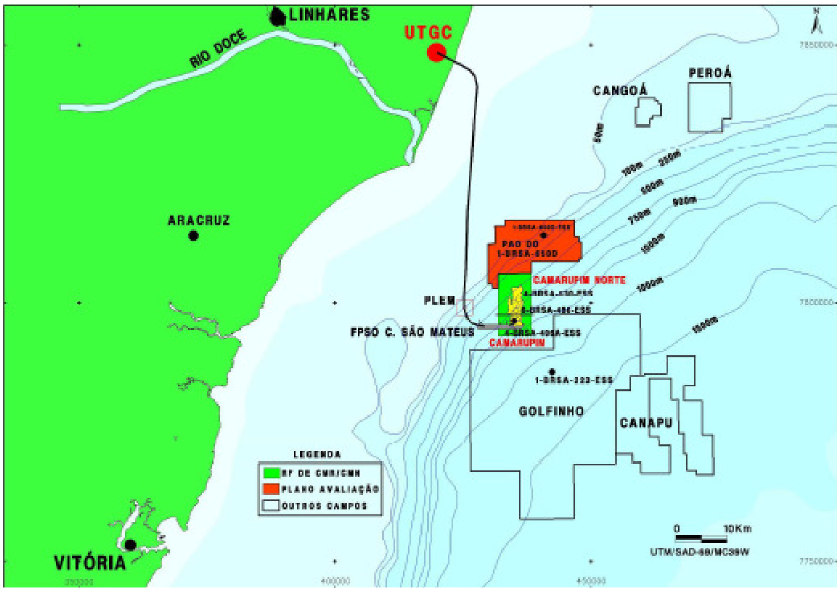

Figure 34 - Location of Camarupim and Camarupim Norte fields

[21] Gas not associated to oil

[22] As per definition upon ANP Ordinance nº 9, as of 21/01/2000

The declaration of commerciality of Camarupim and Camarupim Norte fields occurred respectively in December 2006 and July 2008[23], being the FPSO CDSM was hired in 2006 by the company Prosafe by Petrobras in a contract called "chartering and provision of services" (O&M) it would for ten years, renewable for the same period.

A technical description of the project "FPSO Gas" was provided by Petrobras still in the bidding process. This type of contract, the winner of the bidding company is also responsible for the basic design.

The fields in question have estimated total reserves of 4.4 billion cubic meters of gas, 0.7 million cubic meters of condensate, a proven reserve of 3.6 billion cubic meters of gas and 0.5 million meters cubic condensate. The volume of gas in place is around 14.3 billion cubic meters [24].

The unit was converted from oil tanker NAVARIN[24] on a FPSO at a shipyard in Singapore in the period between 2007 and 2008[25].

Table 5 below reports the main data of the installation, informed by the dealer[26].

Table 2 – Installation Data

Capacity of people (POR)	85
Oil production capacity	4.000 m³/d
Gas production capacity	10.000.000 m³/d
Oil production in 2014	0 m³/d
Condensate production (derived from the gas production in 2014)	373,2 m³/d
Gas production in 2014	2.242,07 M m³/d
Oil processing capacity	4.000m³/d

[23] Development plan - Camarupim fields / Camarupim Norte E & P / UO-ES, review September 2, 2013 (PAs No. 762 and 763/2009)

[24] It should be noted that there have been and there are other ships called Navarin. Still, that number IMO demonstrates that the vessel still had other names: 1989 - 1992 Nicoline MÆRSK; 1992 - 2001 MAERSK Navarin and 2001 - 2007 Navarin.

[25] *Survey Report* e-site of DNV_GL.

[26] Maritime Unit documentation submitted to the ANP in October 2014 (Case No. 48610.011977 / 2009).

Natural Gas Processing Capacity	10.000.000 Nm³/d
Gas processing capacity Fuel	10.000.000 Nm³/d
Oil storage capacity	160.396,20 m³/d

After his conversion and transfer to its final location, on 10/06/2009 [27]. It has made the production of 72 hours of continuous production and started paying by the unit's charter.

No oil well was connected to the unit from the beginning of its production, and the date of the incident entire production unit was coming from four wells of gas reservoirs. The natural gas produced by the FPSO CDSM was then drained by a duct 12 "in diameter and 6 km long that connects to a 24-duct" (PLEM) with 55 km long, which receives gas produced several other products and the aims for Cacimbas Gas Treatment Unit (UTGC).

3.2.1 FPSO CDSM Processing Plant Features

The FPSO CDSM processing plant has a gas processing system and an oil processing system.

The gas processing system receives the manifold gas collected from the non-associated gas wells (i.e., gas that is not associated with oil). The gas then passes through a series of separator vessels in order to separate the lighter portion of the gas from its heaviest part: the condensate. The gas flow then moves to a dehydration module for removing all the water and only then to follow a compression module that provides the necessary energy to that gas to be sent by pipeline to a processing unit on earth.

The condensed material, segregated after the lighter fraction of the gas oil would be sent to the processing system. If there was no production of oil, only after the gas compression module could be injected into the condensate to be exported from the gas in the pipeline.

The oil processing system of another manifold receive the collected oil from oil wells. This system was designed with separator vessels and heat exchangers enough to separate oil, gas and water. At the end of this system, oil - free gas and water - would be sent for storage on deck cargo tanks, where only go out when there was an offloading operation, ie when there

[27] Information collected together the representatives of BW and Petrobras for inspection activities conducted by ANP in the CDSM and FPSO BW's office in Vitória in the period between 13 and 17/7/2015

was a pumpeamento this content to a tanker by through a flexible hose existing on the platform. This oil processing system was designed to receive the condensate stream from the gas processing system and process it with the oil before sending to storage tanks. According to the specifications of the project, when there was no production of oil, this condensate would not be sent to this oil-processing system - and yes forwarded directly to the pipeline, to be exported by the gas.

3.2.2 Características do systema de armazenamento

The storage system of the FPSO CDSM has 33 (thirty-three) tanks, and seven (7) cargo tanks for storage of produced fluids. The main information about the tanks are listed in Table 6.

Table 3 – Cargo handling system tanks

Tank	Volume (m³)	Total Volume (m³)
2C	33273	160396,2
3C	23406	
4C	35127,6	
5C	23406	
6C	35020,8	
Slop dirty (P)	5081,4	
Slop clean (S)	5081,4	

From these seven tanks, five (2C to 6C) would be used primarily for the liquid product storage ready for sending to the tanker (export), and the slop tanks to be used to temporarily store and especially dirty water with oily waste, previously its treatment for disposal within the environmentally permissible limits. In turn, the technical specification made by Petrobras to hire the FPSO CDSM provided that the produced condensate could be designed in two ways in the unit[28]:

1) In case of oil production, the condensate is separated from the gas, and then sent to the inlet of the oil processing system;

[28] FPSO General Arrangement – Doc. n° 384-01-G-DWG-002_001 Rev. Z – Issue Date: 12/12/2008

2) If there is no production of oil, condensed material would be separated from the natural gas, and later, after dehydration, condensate would pumpeado within the pipeline export gas for subsequent separation of the UTG Cacimbas.

At the time it was the setting that the unit would be installed in Camarupim and Camarupim North gas field, Petrobras questioned the Prosafe in 2007 the oil processing system was able to stabilize the condensate in pure form for subsequent storage in cargo tanks, without the production of oil. This configuration was different from the two options specified for the drive, according to the questioning, to accomplish this it would be necessary to stabilize the thermodynamic parameter "Reid Vapor Pressure" (PVR) did not exceed 10 psia at 37.8 ° C.

The company Prosafe assessed the question of Petrobras, carries out computer simulations of the process with the data obtained with Petrobras and in August 2008 reported that the condensate would be stabilized in simulated conditions (PVR less than 10 psia) and can be stored in tanks for later unloading (offloading) for tankers. However, it said in the document that this assessment was for the initial periods[29] and it was recommended that the export of the condensate was performed by pipeline.

Whereas the unit operated for 1964 days since the beginning of activities in the field (already excluding the 24 days he spent in shutdown), the unit exported condensate through pumpeio in the pipeline (second choice of the technical description of the vessel) over only 187 days, with condensate stored in cargo tanks during the remaining days of operation.

The condensate flow produced by the plant was made by tankers using flexible hose (hoses) 20 "diameter and a length of 235 meters, and the use of their charge pumps (three), each capable of 5.000 m³/h[30]".

Since the start of production, offloading sixteen were made, the last of which was held in April 2014[31]. The seventeenth offloading was scheduled in October 2014 to take place

[29] It is understood that this study was conducted due to forecast delays in interconnection of the pipeline.

[30] Operational Safety Unit Documentation.

[31] Item b of the letter UO-ES 356/2015 of 04/16/2015.

between 15 and 19 December 2014[32], but due to a problem in a built-in flow meter calibration, this activity has been rescheduled for February 2015. At the time of the incident the unit stored about 70.000 cubic meters of condensate material[33].

3.2.3 Features of condensed material produced

After the accident, Petrobras collected and analyzed condensate samples from three storage tanks (tanks 2C, 3C and 5C) of the FPSO CDSM.

The results of distillation tests, density and vapor pressure, carried out by the laboratories of the Petrobras Research Center, were sent to ANP and evaluated by your server Center for Research and Analysis Technology (CPT). It was verified that the condensate in question consists of a mixture with a predominance of gasoline (naphtha) compounds and minor proportions of compatible Light Kerosene or diesel.

The gaseous fraction of the samples, in turn, is made up of LPG (liquefied petroleum gas), mainly, and to a lesser extent, natural gas (light naphtha) and natural gas (ethane). Furthermore, the vapor pressure (PVR) average of the sample collected in the tanks of the FPSO CDSM was 57.3 kPa (about 8.3 psia).

Gases that come off oils are unstable gases heavier than air and is therefore difficult to disperse. Consequently, the risk of explosion is greater. To prevent gas to be detached during transport and storage, the specification for vapor pressure is usually specified for PVR 10 to 12 psia.

To meet PVR specification, the gas dissolved in the crude oil must be removed, and such removal called stabilization. The crude oil can be stabilized by passing it separators in series, where the volatile components are vaporized. The stabilization of crude oil often requires the addition of heat in certain points of the processing train.

3.2.4 *Layout* of FPSO Cidade de São Mateus

[32] E-mail do dia 27/10/2014 entre o gerente setorial de operações Petrobras e o Gerente de Operações BW

[33] Reported data on the level of the tanks after the accident. Of these 70.000, there is an amount of water that the installation of the Operator fails to need.

The FPSO Cidade de São Mateus process plant consisted of modules whose layout is shown in top view in Figure 35, removal of the Safety Case of the unit. Accommodations (acommodation) and helideck remain in the unit's stern separation modules (M10 and M62), flare and alternative temporary refuge (FTR) are closer to the bow. It is observed that the house of pumps (pump room) was located next to the house ward.

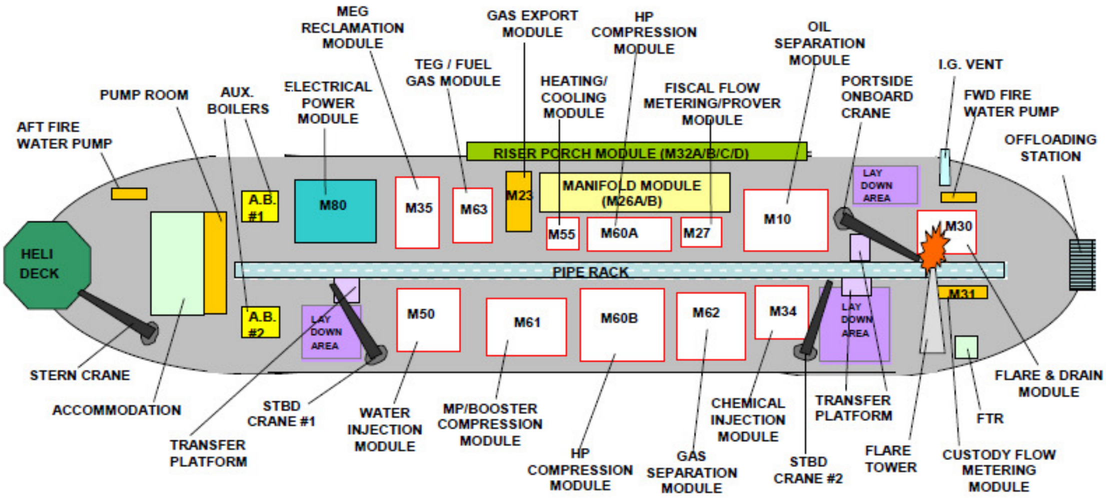

Figure 35 - Arrangement of modules and facilities of FPSO Cidade de São Mateus

Figure 36 below, withdrawal of the Safety Plan of the unit, shows the side view of the starboard side of the FPSO Cidade de São Mateus, highlighting areas of interest to this investigation. It is observed that the pumps house was adjacent to the engine room, to 6C tanks, slop starboard (S), slop of port (P). His entrance was made through its unique access, just ahead of the mega-structure of the houses.

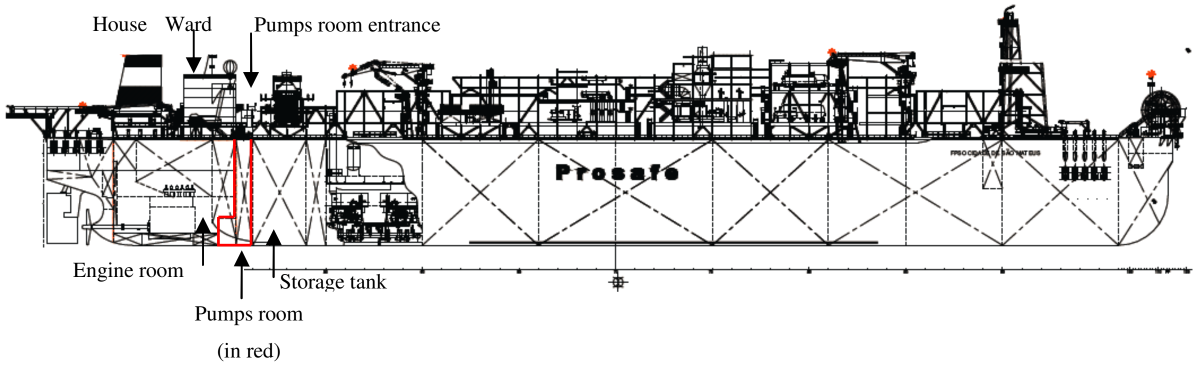

Figure 1 – Side view of FPSO Cidade de São Mateus

4. Operational safety management system rendered in the FPSO Cidade de São Mateus

4.1. Prosafe acquisition by BW Offshore and the following modification upon the operational safety management system

Prosafe, company initially contracted by Petrobras to convert and operate the FPSO was acquired on 25/11/2010 by BWGroup.

As of May 2011, changes were initiated in operational safety management system affect the FPSO CDSM, and the company BW Offshore (BW) began to introduce the practices of its management model. According to interlocutors of BW for action fiscalização, migration practices was made considering that corporate and operational procedures applicable to FPSO CDSM initially remain being those in force when the Prosafe was still the operator of the installation. Over time, each procedure gradually, it would be assessed by the BW team to a finding of its applicability and / or the review needs to be displayed, updated and compatible with BW management system.

Thus, according to the assessment of each procedure, they would be migrated to the document control system BW (Management System - MS) or excluded from the company's current documentation system.

The process of migration procedures described above was initiated in 2011 and was used initially a criterion that if a procedure had not been accessed in the last two years, this would be extinguished. Responsibility was given to the personnel on board the FPSO Cidade de São Mateus do the evaluation, having been shown that: (i) was not managed by a change management process; (ii) has not established a timetable for implementation of this migration; (iii) the operational management of the office staff of the FPSO CDSM did not participate actively in the process of reviewing the procedures, and that task was left to the edge of the FPSO CDSM personnel; and (iv) no prioritization was not established for the implementation of such migration, for example, priority complete unit of critical procedures.

Thus, it was observed that:

(i) The change management procedure in force on the day of the accident[34] did not include in its scope changes in procedures, only changes in the unit, in equipment, systems and people.

(ii) There was the definition of critical procedures for the FPSO Cidade de São Mateus, due to non-completion of the procedures migration process initiated in 2011.

It should be noted that in 2012, the internal audit BW had already flagged the need to update all operational procedures as described in the internal audit report in 2012[35]:

> *"Corroborating the risk study (Safety Case of the FPSO Cidade de São Mateus - Topsides[36]) addressed the issue in the" global issues "putting the need for a management system for documentation to avoid using outdated documents."*

Only in late 2014 was established as one of the performance targets for the year 2015 completion of the review and updating of procedures and their integration into the Management System (MS)[37].

Petrobras claimed throughout the research process that there was no change of the site operator, but only a change of ownership of the company Prosafe[38], maintaining the legal relationship established with Petrobras. As mentioned in the text, it was found several changes in procedures of the management system, which were readequados to BW management requirements, which interfere with the operational safety management FPSO CDSM, focus of the ANP Resolution No. 43/2007. These changes were found previously by the ANP and the change of the operator regarding the FPSO CDSM was made official at the agency on 06.10.2014 only after the notification to the ANP and Petrobras, therefore, more than three years after the start of changes .

[34] *Management of Change – Operations* – Doc. n° MS-PR00157 Rev.04 – Issue Date: 05/12/2014

[35] Audit Report FPSO Cidade de São Mateus – Issue Date: 31/08/2012

[36] Hazard and Operability Study (HAZOP) Report for FPSO Cidade de São Mateus – Topsides - Doc. n° ABSG-02-3358769-RL-SMS-004-2015 Rev. A – Issue Date: 09/01/2015

[37] KPI Operations Manager collected during audit

[38] Letter UO-ES 0528/2015, as of 03/06/2015

Throughout the text, the plant operator is referred to as BW Offshore (BW) as the Operational Safety Management Management System into force on FPSO CDSM on the date of the accident was this company.

4.2. BW Offshore and the hazard management structure of FPSO CDSM

According to the company's own website[39], BW Offshore (BW) is the second largest charter company with offices in major oil-producing areas around the world such as Europe, Asia, Africa and the Americas (USA and Brazil). It has a fleet of fourteen FPSOs and an FSO and operates two other FPSOs. Its holding company, BW Group, was established in Bermuda in 2003 after the restructuring of the company.

BW calls itself as the pioneer for being the first to operate an FPSO for GLP in Angola and have converted and installed the first FSO in the Arctic circle, and in 2007 have converted the largest FPSO in processing capacity, largest in-depth water already installed and the first unit of this type installed in the Gulf of Mexico, in the Cascade field, Petrobras[40].

In Brazil, BMW has an organizational structure focused on operating its five platforms. The Operational Security theme of platforms operated in Brazil was reporting directly to the vice president for health, safety, environment and quality (HSEQ VP) which is sold abroad in Singapore.

In its organizational structure in Brazil, BMW has an engineer to comply with legislation[41] which was directly subordinated to the general manager in Brazil, but reported to the vice president for health, safety, environment and quality. The law enforcement engineer had among its duties assist offshore units operating managers to ensure compliance with Brazilian regulatory requirements, including the requirements of the ANP, without any hierarchical level on the operation of the unit.

Inside the organizational structure, BW platforms operations managers in Brazil were subordinated directly to the General Manager. In his staff, the general manager still had a

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[39] Site of BW Offshore, access in 27/07/2015 - http://www.bwoffshore.com/company/history/

[40] Oil and Gas Journal, access in 03/02/2012 - http://www.ogj.com/articles/2012/03/first-gulf-of-mexico-fpso-receiving-cascade-oil.html

[41] Regulatory Compliance Engineer Brazil

supply manager, a senior systems administrator, a vice president of finance, a manager of human resources, a business manager, legal counsel and vice president of design modifications (Brazil).

The technical dependence of the local BW team in respect of the technical teams abroad to the operations of the platforms in Brazil was blatant. There was BW team's technical autonomy in Brazil in relation to various topics related to operational safety, such as change management, document control, issuing drawings updates, translations of documents and accident investigation.

It caught the attention of ANP research team the absence of engineering support structure and local security to support the operation in BW structure in Brazil. During inspection conducted by ANP in the BW office, was very common the need of the local staff use fonoconferências with the office of the BW in Singapore for clarification related to the design and operating parameters.

The operation of the FPSO CDSM was managed in an office BW in Vitória (ES). This office was crowded: a maintenance engineer, safety engineer, a medical officer, two buyers, one administrative assistant, one human resources assistant, an assistant personnel logistics and storekeeper. A safety technician was hired shortly before the accident and have the function to support the adequacy of the procedures to BW management practices.

4.2.1. Hazardous identification, safaty studies, analysis and hazard management of FPSO Cidade de São Mateus

The structuring of risk management as part of the implementation of an operational safety management system, involves the identification of hazards, analysis and installation risk management throughout its lifetime. Required by law in many countries, the Safety Case is a document produced by the installation operator to demonstrate that all hazards have been identified and assessed risks, demonstrate that the control measures were taken to reduce the level of risk to ALARP[42], level as well how to describe the company's safety management system to ensure that controls are effectively and consistently applied.

[42] As low as reasonably practicable, which means a risk value for which the cost involved in its reduction is disproportionate to the benefits generated.

In this sense, it was prepared by Prosafe the Safety Case of the FPSO Cidade de São Mateus[43], consists of seven sections, as shown in Figure 37, withdrawal of this document:

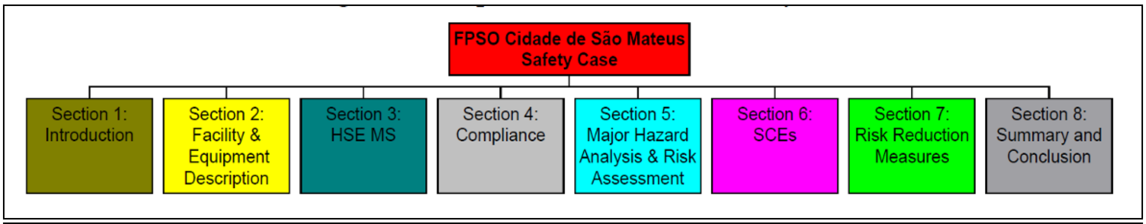

Figure 37 - Security Formal Analysis Studies

In section 5 (Major Hazard Analysis and Hazard Assessment) of the Safety Case have been described briefly the main results of all risk assessments prepared for the installation and which formed the basis for the preparation of the Safety Case, as listed in Table 7.

Table 4 – Prepared Safety Studies

Safety Study	**Last Version Date**
Layout Review Report[44]	16/04/2007
HAZID Study[45]	06/07/2007
Ship/Marine Systems HAZOP[46]	03/09/2007
Topside / Process HAZOP Study[47]	15/02/2008
Quantified Hazard Assessment (QRA) [48]	30/05/2008
Exhaust Dispersion Study[49]	14/04/2008
Non-Hydrocarbon Hazard Analysis (NHHA) [50]	14/04/2008
CFD Gas Dispersion Modeling for Gas Detector Location[51]	16/04/2008

[43] *Design and Operations Safety Case for* FPSO Cidade de São Mateus – Doc. n° 384-HS-0501-RPT-015 Rev. 0 – Issue Date: 12/12/2008

[44] Layout Review Report for Cidade de São Mateus FPSO – Doc. n° 384-HS-0501-RPT-001 Rev. 0 – Issue Date: 16/04/2007

[45] Hazard Identification (HAZID) Report – Doc. n° 384-HS-0501-RPT-003 Rev. 0 – Issue Date: 06/07/2007

[46] Hazard and Operability Study (HAZOP) Report for Ship Systems – Doc. n° 384-HS-RPT-004 Rev. 0 – Issue Date: 03/09/2007

[47] Topside Process HAZOP Study Report – Doc. n° 384-HS-RPT-001 Rev. 2 – Issue Date: 15/02/2008

[48] Quantified Hazard Assessment (QRA) – Doc. n° 384-HS-RPT-017 Rev. 0 – Issue Date: 30/05/2008

[49] Exhaust Dispersion Study - Doc n° 384-HS-0501-RPT-005 Rev.0 – Issue Date: 14/04/2008

[50] Non-Hydrocarbon Hazard Analysis Report – Doc. n° 384-HS-0501-RPT-007 Rev.0 – Issue Date: 14/04/2008

Safety Study	Last Version Date
Thermal Radiation and Gas Dispersion Study for Flare and Vent[52]	24/04/2008
Fire and Explosion Assessment (FEA)[53]	28/04/2008
Escape, Temporary Refuge, Evacuation and Rescue Analysis (ETRERA)[54]	22/05/2008
Fire Propagation and Structural Protection Analysis[55]	23/05/2008
Emergency Systems Survivability Analysis (ESSA)[56]	03/06/2008

The Safety Case[57]: Implementation Manual: (i) presents the requirements for its development, (ii) states that its scope is applicable for both new projects and conversions as for changes or improvements in the unit and existing vessels and (iii) sets the Safety Case is based on formal analysis studies of safety including: HAZOPs (Studies Hazard and Operability), HAZID (Hazard Identification), PHEM (Process Hazards and Effects Management), FEA (Fire Analysis and Explosions), ETRERA (temporary refuge analysis for escape, evacuation and rescue), THIS (Emergency Systems of Survival Analysis), QRA (Quantified Risk Assessment), among others.

The safety studies for the FPSO Cidade de São Mateus were developed in the unit's design phase and can be grouped as shown in Figure 38, into three categories: (i) the dangers and effects identification studies, (ii) Training risk assessment (quantitative) and (iii) risk assessment studies (qualitative).

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[51] CFD Gas Dispersion Modeling for Gas Detector Location – Doc. n° 384-HS-RPT-015 Rev.0 – Issue Date: 16/04/2008

[52] Thermal Radiation and Gas Dispersion Study for Flare and Vent – Doc. n° 384-HS-RPT-009 Rev.0 – Issue Date: 24/04/2008

[53] Fire and Explosion Assessment – Doc. n° 384-HS-RPT-010 Rev. 0 – Issue Date: 28/04/2008

[54] Escape, Temporary Refuge, Evacuation and Rescue Analysis – Doc. n° 384-HS-RPT-002 Rev. 1 – Issue Date: 22/05/2008

[55] Fire Propagation and Structural Protection Analysis – Doc. n° 384-HS-RPT-018 Rev. 0 – Issue Date: 23/05/2008

[56] Emergency Systems Survivability Analysis – Doc. n° 384-HS-0501- RPT-008 Rev. 0 – Issue Date: 03/06/2008 (enclosed to the SISO)

[57] Implementation Manual of Safety Case – Doc. n° 000-HS-DOC-002 Rev. 1 – Issue Date: 29/05/2009

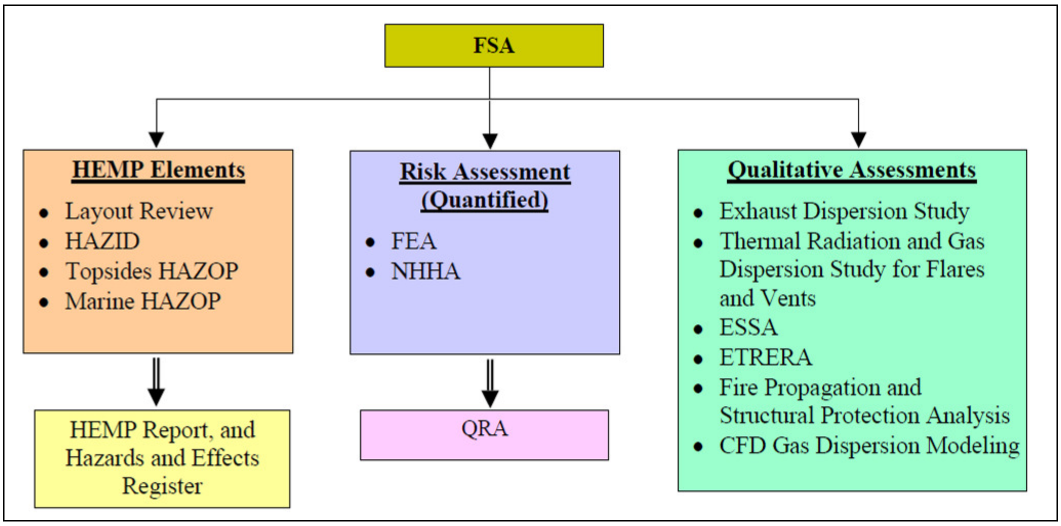


Figura 2 – Estudos de Análise Formal de Segurança (fonte: *Safety Case* da unidade)

During the research process, it was found that BW did not perform the monitoring of the implementation of the recommendations arising from the risk analyzes carried out before the unit's operation. It was justified by the representatives of BW of which all recommendations had already been identified yet completed the design phase and therefore, would not need to be managed.

Thus, in order to verify the degree of implementation of the recommendations, the ANP called for the close-out reports for each of the recommendations identified in risk analysis, to have been submitted, after the audit of the Agency, two kinds of forms, as shown in Figure 39 and Figure 40, taken from two close-out reports (the figures have been adapted to preserve signatures of officials).

Prosafe	HAZOP CLOSE-OUT SHEET		
ACTION NUMBER:	Status	Date Opened	Date Closed
ABB-2	Pending	07.06.07	03.09.07
RISK RANK = NA	Company:	Name:	Signature:
ACTIONEE:	ABB	[redacted]	
APPROVAL (Discipline)	PIPING ENGR		
APPROVAL (Project)	ENGR. MGR		

Figure 39 - Form with recommendation of the closing date

Prosafe Production	P384 PETROBRAS - CLOSE-OUT SHEET		
ACTION NUMBER:	Verification Type	Date Opened	Date Responded
ABB-12	Operations	07.06.07	10.12.08 ~~12.12.07~~
RISK RANK = M	Company:	Name:	Signature:
ACTIONEE:	PETROBRAS	[redacted]	
APPROVAL (Discipline)	PROSAFE		
APPROVAL (Project)	OIM		

Figure 40 - Form without recommendation of the closing date

From the analysis of the forms, it can be seen that:

(i) Some of the recommendations were classified as "pending" but it had closing date (date closed), demonstrating error in the form (Figure 39);

(ii) Not all the recommendations had closing date only response record date (date responded), which would suggest that were still open (Figure 40) and

(iii) Some recommendations were addressed to both the operator of the installation and as of Petrobras (Figure 39).

4.2.2. Events Identification for the pumps room

Considering the analysis of quantitative risks, it can be seen that we identified two greatest dangers (Major Hazards) relating to house pumps and engine room from the eleven listed in the study, namely: fire and explosion of the pumps house and fire and explosion in the engine room. For each of these scenarios, the risk related to exposure of people whose results were summarized in 5:10:15 section of the Safety Case of the unit was quantified.

With specific regard to the fire scenario and explosion in the pumps home quantitative studies risk assessment showed that: (i) there is a scaling potential for tanks that are adjacent to this environment, as for example, tanks load, slop tanks and fuel tanks, (ii) the likelihood of scaling would be greater for the burst scenario than to the fire scenario and (iii) in terms of the result, personnel who were present in the pumps house was fatally wounded and that there would be no immediate fatalities for the staff who were in temporary refuge (TR) or on the main deck.

The value obtained for annual average level of risk associated with fire and explosion in the scenario pumps house, whereas the normal exposure of persons to that scenery, was $6{,}71.10^{-6}$, which corresponds to a value below the ALARP region defined as being less than and greater than 1.10^{-5} 1.10^{-3}.

4.2.3. Managerial monitoring of the implementation of FPSO CDSM Operational Safety Management System

The managerial monitoring the safe operation of the FPSO CDSM was confused with the activities required for the operation. Among the routine activities of management of BW Team operations of Vitória office dealing with operational security issues in the operational management of the FPSO CDSM, the following are highlighted:

(i) Daily Meeting (morning call) between management operations and the personnel on board the FPSO CDSM, with the participation of OIM, superintendents, security technician and planner;

(ii) Monthly meeting in the Vitória office, with the participation of OIM and the staff of the FPSO CDSM operations management, video or fonoconferência;

(iii) Weekly meeting with Petrobras with the participation of the Operations Manager of BW and the Sector Manager of Petrobras. This type of assembly began in 2014;

(iv) Monitoring Operational Meeting (ROA), with monthly frequency and participation of the operations management of the FPSO CDSM (BW) and sectoral management and SMS OU-ES Petrobras;

(v) Quarterly meeting of BW Brazil, held in the office of Rio de Janeiro; and

(vi) Critical Analysis Meeting (RAC) of SMS, with six-monthly frequency and with the participation of BW Operational Management, the Sector Manager and the General Manager of Petrobras Organizational Unit in the Espírito Santo Spirit (OU-ES), both from Petrobras.

Monitoring of more specific situations, such as planning for correcting problems in the cargo transfer system, indicated in item 6.7 of this report, was made in internal meetings of BW. Petrobras has followed the progress of corrective actions by schedule assessment of corrective actions in meetings between BW and Petrobras. A weekly meeting between BW and Petrobras was created in 2014 and this meeting was weekly monitored the progress of corrective actions of maintenance of the load transfer system valves.

Petrobras, in addition to the weekly meeting, there was the daily meeting videoconference with Petrobras' Fiscal aboard the FPSO CDSM to monitor the fulfillment of contracts with the site operator.

It is emphasized that Petrobras performed the monitoring of indicators monthly and interpreted the follow-up of ANP Resolution No. 43/2007 was made by BW. Monitoring the implementation of SGSO it was done by examining the internal audit reports conducted by BW and monitoring the implementation of the action plan[58].

When considering the results of the internal meetings of BMW presented by the company, it appears that the annual assessment of the management system implemented in the FPSO CDSM was the staff position on board the unit. This review only described the flaws and there was no specific monitoring indicators. In turn, the monthly follow-up pertaining to the safety indicators was manager responsible for operations, maintenance and human

[58] Letter UO-ES 0528/2015, of 03/06/2015

resources, among which are: (i) injuries with lost time, (ii) number of high potential for accidents, (iii) gas leaks number, (iv) number of fires, (v) number of lifting incidents, (vi) number of object falling incident, (vii) number of security notes, (viii) delays in maintenance critical equipment, (ix) board leaks number, (x) number of unplanned emissions, (xi) number of management changes postponed priority 1 and (xii) staff turnover on board.

It was observed that over the years some indicators showed performance fall short of the target set, however it was not possible to identify specific corrective action for poor performance. When asked about the review of the management of BW these indicators, Petrobras transferred to ANP documentation BW Offshore where you can not show that this fact critical analysis occurred.

When evaluating the monthly follow-up meetings made between Petrobras and BW, it is observed that during the year 2014 there was an improvement in monitoring questions related to operational security, but the follow-up of FPSO CDSM indicators was still in its infancy, without contemplating the indicators defined by BW for monitoring the operational safety[59]. In the meeting minutes were not reported or evidenced corrective actions for situations considered inadequate. The latest monthly meeting between Petrobras and BW before the accident, Petrobras management requested to be included with Resolution ANP service index indicators No. 43/2007 (SGSO), which includes the actions mapped in risk analysis and equipment inspections recommendations.

During the investigation conducted by the ANP, several failures of evidence were identified in implementing the Operational Safety Management System for the FPSO CDSM, namely: (i) lack of monitoring the implementation of safeguards and recommendations of risk studies; (ii) lack of periodic risk review; (iii) changes in procedures, people and systems without the change management process; (iv) lack of training in operational procedures; (v) failure to implement operating procedures; (vi) failure monitoring and continuous improvement, among others.

[59] Item c from Letter UO-ES 0528/2015, as of 03/06/2015 (pgs. 558 to 561)

Petrobras planned to hold SGSO audits in chartered platforms, which included an audit on the FPSO CDSM in 2015, which did not occur. We began to evaluate one of the other monitoring mechanisms and continuous improvement, auditing SGSO.

4.2.4. Internal Audits Diligences as per ANP Resolution No. 43/2007 (SGSO)

Since the beginning of its operation it was conducted two internal audits of SGSO the FPSO CDSM in 2012 and 2014.

The 2012 audit pointed out ten non-compliances as follows:

"1- Head of Department did not have access to the Safety Case and its action plan;

(...)

7 (..) All procedures related to operations (ie starting equipment, equipment failure, system insulation). must be updated "

During the investigation there was evidence found from these non-conformities still to be present, i.e. the operations manager had no access to the action plan arising from the recommendations of the Safety Case and operational procedures needed to be updated.

In the last internal audit at the FPSO Cidade de São Mateus, held on 23.10.2014, all non-conformities were registered in the internal control system called Synergi. Each non-compliance was spun off in the objective evidence and, in turn, was registered as "actions" to be monitored through the system. For each registered share, the period of 18.02.2015 for completion was set.

Thus, from the Internal Audit report, it was opened 29 (twenty nine) shares to follow in Synergi, which at the time of internal audit, fourteen were classified as "Implementing" and fifteen with status "completed".

Regarding actions with status "Implementing", it was found that some had already been completed, but their status was not updated in the system and the evidence sanitation were not recorded, demonstrating a lack of structure in monitoring and updating about information preventive / corrective actions.

Among the actions that were still classified as "Implementing" two deserve special mention, namely:

"Action 17: It was not possible to show the management of the documents in BW Offshore system, among the list of FPSO CDSM procedures, identification of procedures which are Operational Safety named as critical, as described in the Safety Case 384-HS-0501-RPT -015 Rev.0, of 12/12/08, item 6.4 Safety Critical Tasks".

"Action 18: It was filed the records of Implementation Manual Safety Case 000-HS-DOC-002 Rev.1 Report of 29..05.2019 and 384-HS-0501-RPT-015 Rev. 0 of 12/12/08 referring to the unity of risk analysis which is outdated, according to the five-year review ".

Regarding the action number 17 as the migration process procedures of Prosafe for BW, although started in 2011, had not yet been completed, critics procedures for the FPSO CDSM had not been identified. Thus, to purify unidentified compliance in internal audit remained pending the completion of the migration procedures for the Setup Operator documentation system. In regard to action 18, it was settled a review schedule of the Safety Case, having started the schetch of the safety studies, named HAZID (completed in October 2014) and HAZOP Unit topside (completed in November 2014). This review began in October 2014 and it took twenty weeks for completion.

Regarding the fifteen actions with the status of "completed", it was observed that twelve of them, the actions taken were only off towards providing treatment to objective evidence, without having been taken comprehensive and preventive measure to avoid recurrence as pointed deviation in non-compliance. This, in line with the understanding shown by the representatives of BW ground crew during the presentation of sanitation of non compliances as demonstrated by the lack of understanding of the purpose of the Technical Regulations of the Operational Safety Management System (SGSO) ANP establishing the need to take corrective action to eliminate the cause of non-compliances identified and preventive actions to eliminate the cause of non-conformities in order to prevent the occurrence. Moreover, this fact reinforces the perpetuation of a practice already observed in the audit of 2012 of which did not result in corrective actions in order to eliminate the cause of the identified non-compliances.

In addition, the BW published a guideline for all the company's fleet in the country in view of SGSO audits to include the closing of nonconformities from previous audits. If for any reason the corrective action was not completed in the audit, it would be reopened in the BW system and appropriate remedial actions would be defined.

5. Storage operation system and cross docking load of FPSO Cidade de São Mateus

5.1. Cross docking load system components of FPSO CDSM

The main components for the cross docking system in the FPSO CDSM can be observed in piping and instrumentation diagrams (P & ID - Piping and Instrumentation Diagram) below, once adapted from unit project documents[60,61]:

[60] P&ID Cargo System in Pump Room – Doc. n° 384-33-W-DWG-100_001 Rev. Z – Issue Date: 03/03/2009

[61] P&ID Cargo System in Vessel – Doc. n° 384-33-W-DWG-100_002 Rev. Z – Issue Date: 03/03/2009

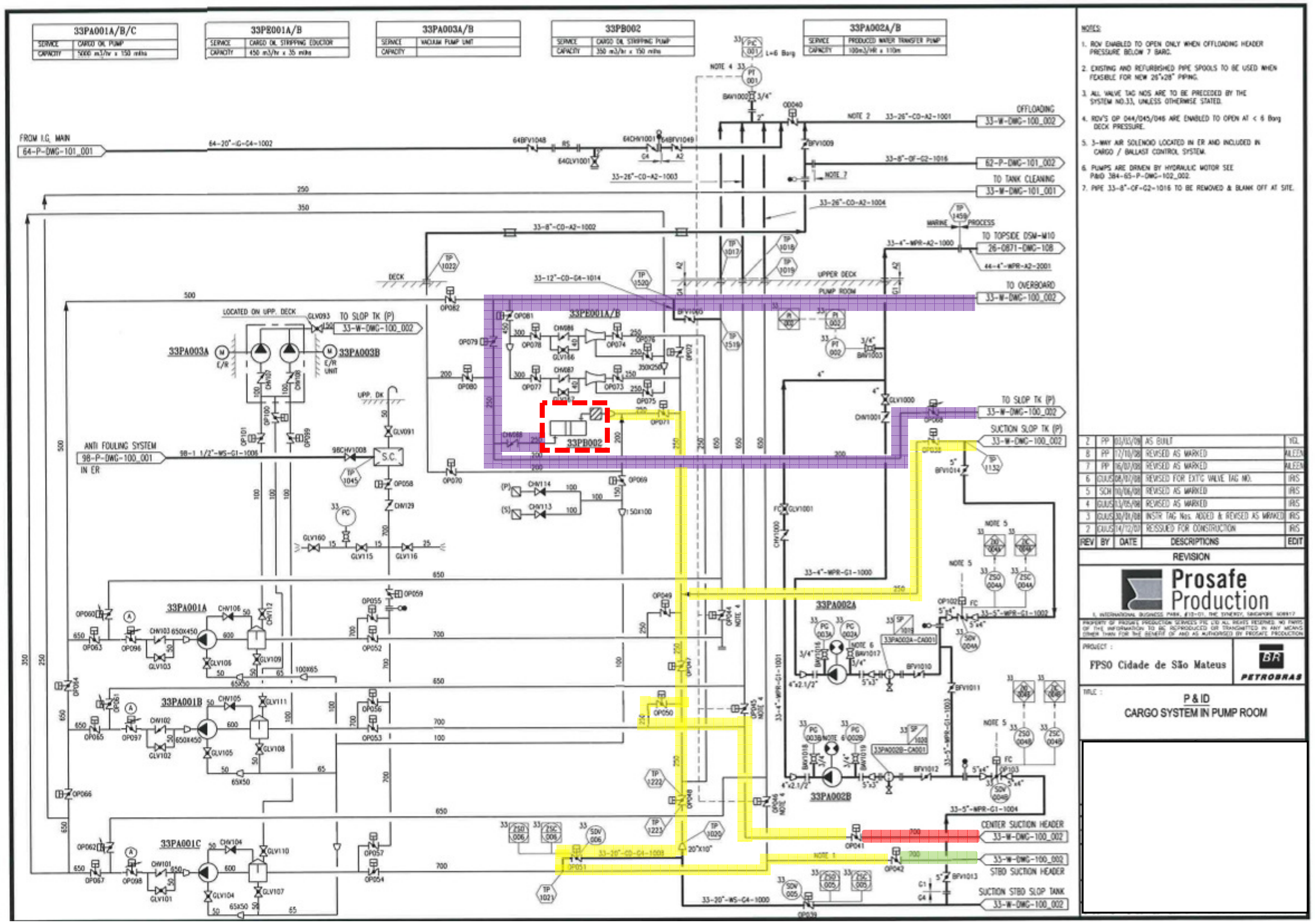


Figure 3 – P&ID of the Pumps Room and *Upper Deck*

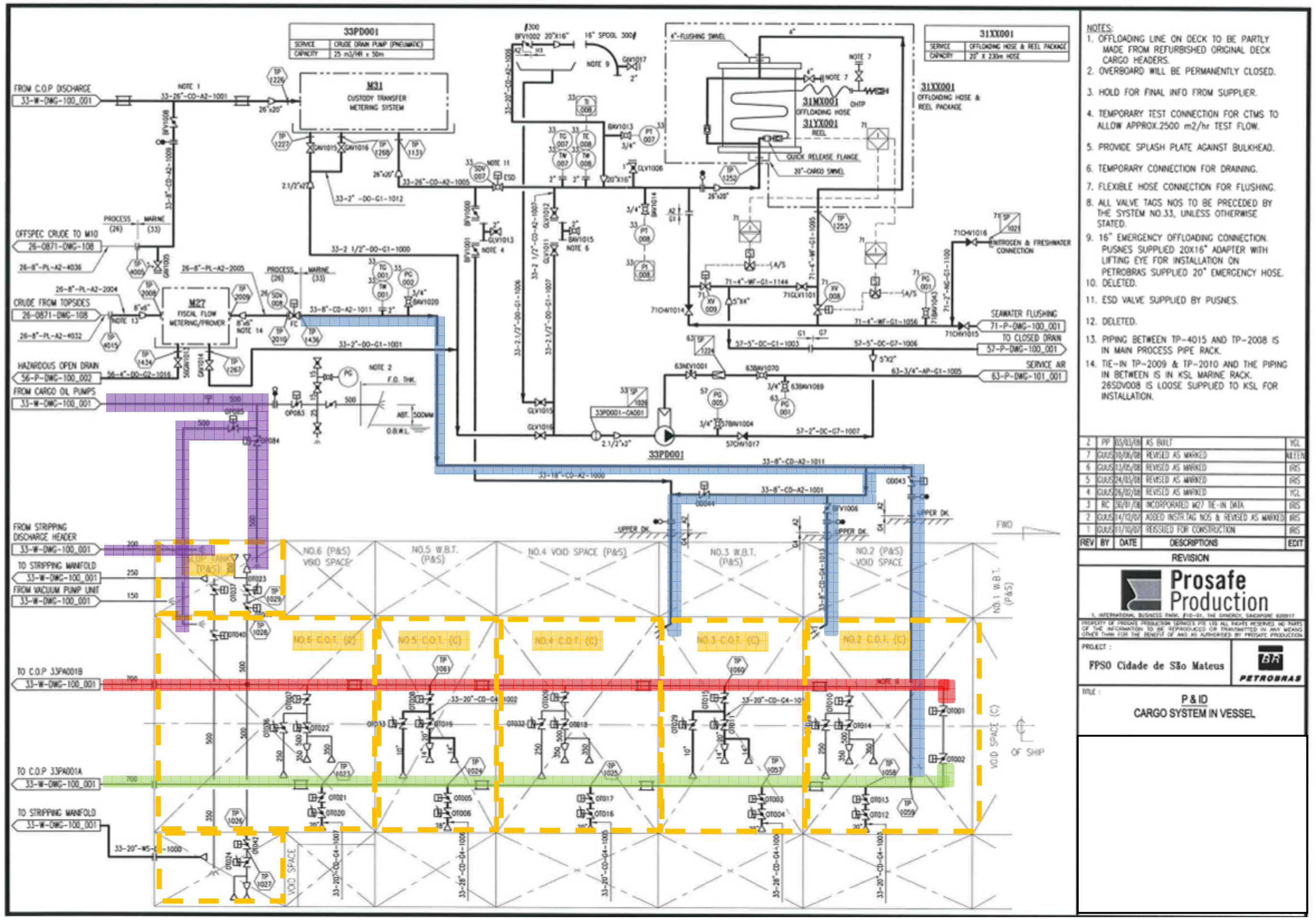


Figure 4 – P&ID of the *Upper Deck* and Storage Tanks

The cross docking system in question does not cover the ballast system or the gas system. The main components of the cross docking system to be observed in this report is as follows:

a) The finish line of production in the storage tanks (run down line): blue;
b) The collectors (headers) fund from the storage tanks, the main header (red) and starboard header (green);
c) The five storage tanks (2C, 3C, 4C, 5C and 6C): dashed orange;
d) The two slop tanks, port and starboard: dashed orange;
e) The pump of 33PB002 drainage (pump stripping): Red dashed;
f) The OP valve (located in the house pumps);
   The OT valves (located inside the cargo tanks);
g) The OD valves (located on the upper deck);
h) The BFV valves (butterfly valves) manuals;
i) Alignments of interest to the suction of the stripping pump: yellow;
j) Alignment of interest of discharge of the stripping pump: violet.

Below follow pictures of some components which are located on the upper deck.

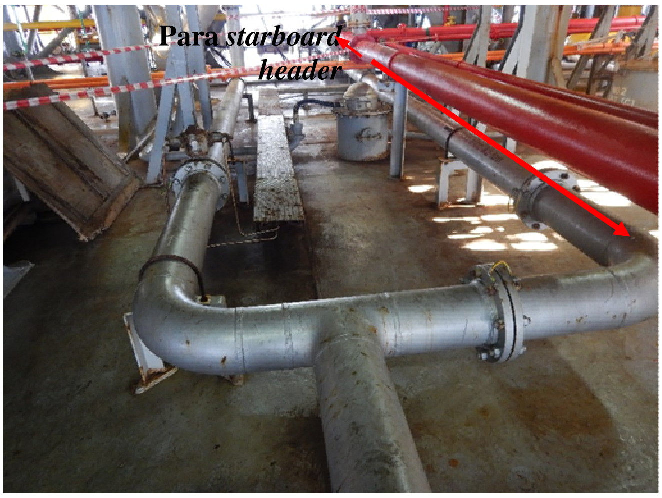


Figure 43 – Run down division through the line to the tank 2C, 3C tank and the starboard header

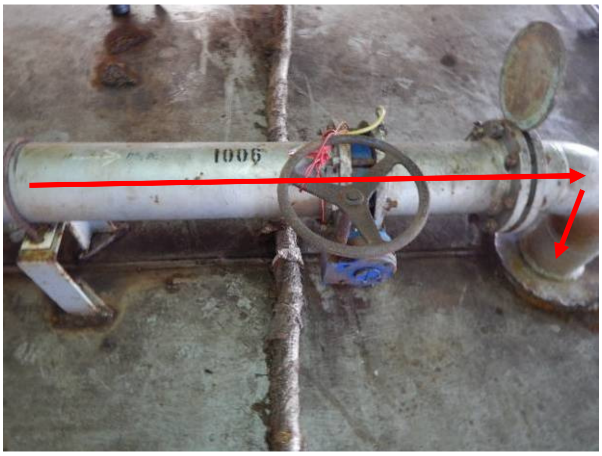


Figure 44 - Branch line to run down the 2C tank, through the BFV-1006

Figure 45 - Branch run down the line to the tank 3C

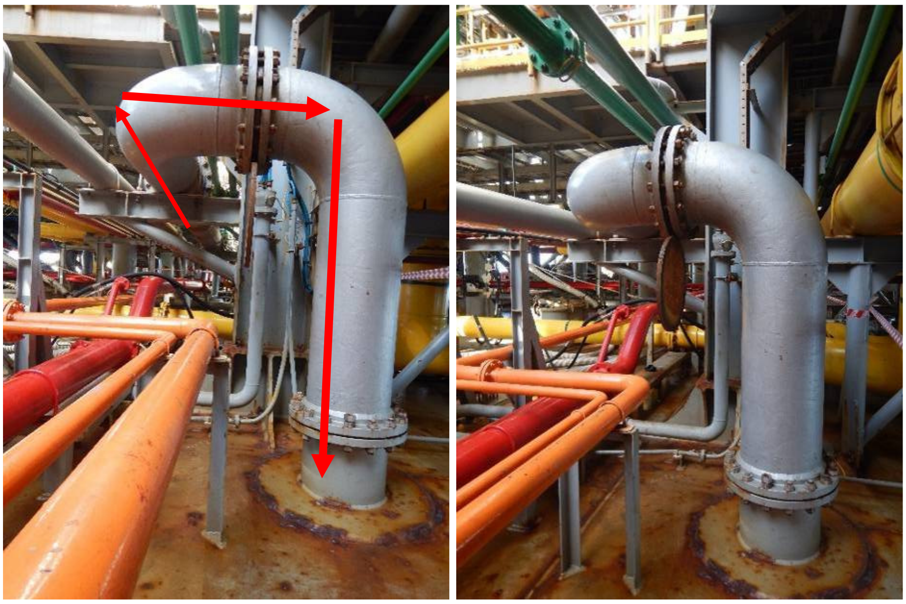


Figure 46 - Branch run down the line to the tank 3C, through a "Figure 8"

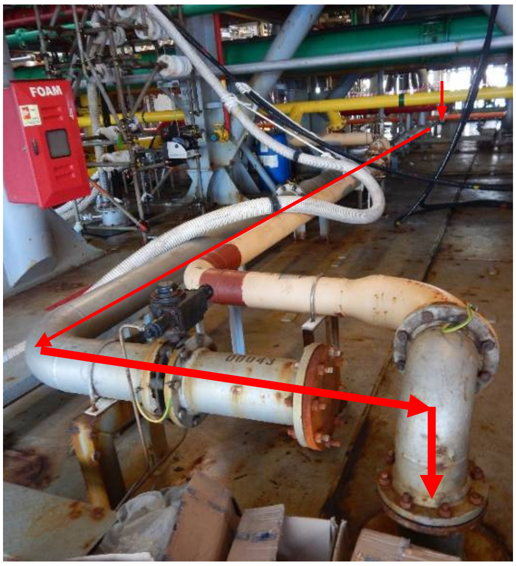


Figure 47 - Gangway line to the starboard header past the OD-043

5.1.1. FPSO Pump House in the Cidade de São Mateus

The pumps's room was located between the cargo tanks and the engine room, as shown in below Figure 48[62].

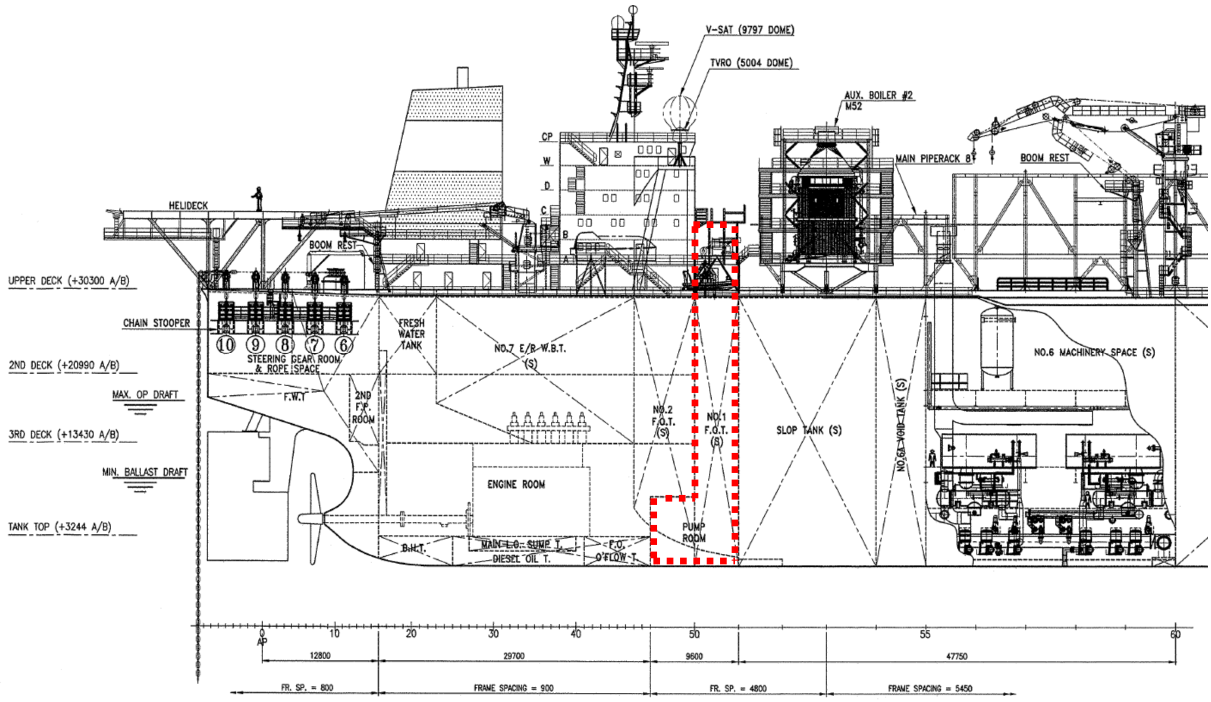


Figure 48 - Position of the pumps room

The pump was located in the stripping vessel pumps the house ward background, as shown in Figure 49, removal of the 3D model of the installation[63]:

[62] *FPSO General Arrangement - Doc No. 384-01-G-DWL-002_001 Rev. Z - Issue:.12/12/2008 (252 pgs)*

[63] Received by Charter OU ES-231/2015 of 03/20/2015 (pgs. 189)

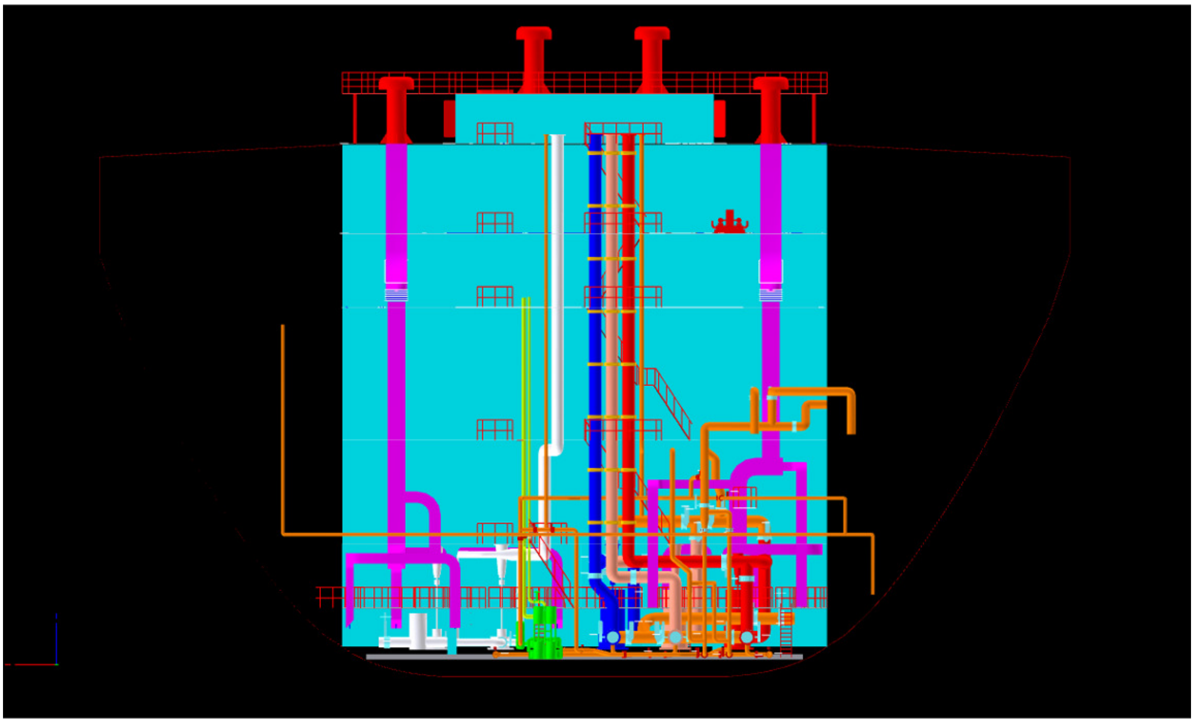


Figure 5 – *Stripping* pump (green) at the inside of the cargo door

There were three gas detectors (tags 73AB326, 73AB327 and 73AB370) located on the lower floor of the pumps room. Additionally, in each of the two outputs of the pumps room exhaust system had a gas detector (tags 73AB368 and 73AB369). The air exhaust system is illustrated in Figure 50 hereinafter by ducts violet color and the arrows indicating the flow inlet and air outlet.

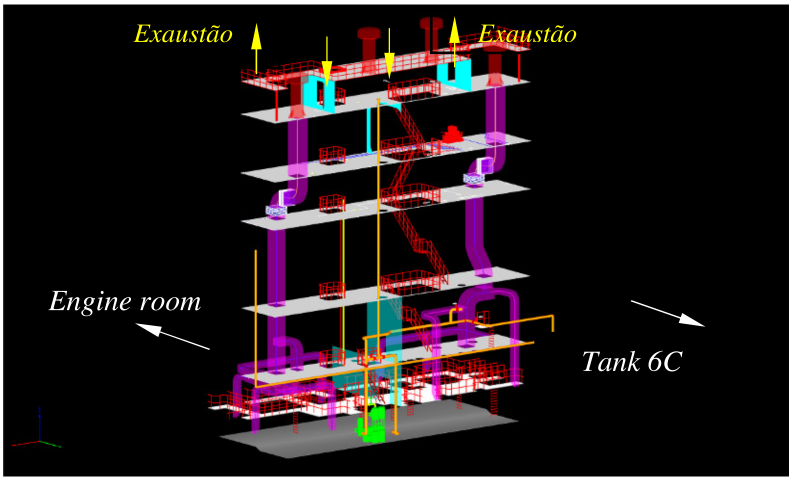


Figure 50 – Representation of exhaustion in the pumps room

The pumps room has two doors on the main deck, on opposite walls, facing the side of the ship. The following photo shows one of the doors and the hoods.

Figure 51 - A door and an exhaust of the pumps house

Both cameras in closed streaming video which record images of the spillage and visual alarm from the gas leakage on the day of the accident (cameras 4 and 5) were in the next highest to the lowest floor of the pumps room.

Aside from the stripping pump, the pumps room gathered three cargo pumps (tag 33PA001A /B/C), both produced water pumps (tag 33PA002A/B) and the two platform ballast pumps (tag 52PA001A/B). The cargo and ballast pumps were driven by steam turbines, located in the engine room. The axis of the pumps crossed the engine room to the pumps room. Unlike the pumps of cargo and ballast, the stripping pump was driven by steam supplied directly to the pump through the steam line coming from the engine room.

The main electrical equipment installed in the pumps were: lighting, emergency lighting, audible alarm, light alarm, telephone, two video cameras and gas detectors.

As for the electrical classification area, the pumps room was classified as Zone 1[64]. The area classification drawing tells how the reference standard for its preparation to API RP 505

[64] Hazardous Area Classification Layout – Main Deck – Doc. n° 384-01-G-DWG-005_001 Rev. Z – Issue date: 31/08/2009

standard[65], which states that this type of area classified ignitable concentrations of flammable gases and vapors can often exist or occasionally, due to operational conditions, repair or maintenance, breakdown or failure of equipment or due to the communication area with an area Zone 0, in which ignitable concentrations of flammable gases and vapors are present continuously or for long periods. The standard indicates that the Standard Classification Zone 1 includes locations where volatile flammable liquids or liquefied flammable gases are cross dockingidos from one container to another, pumps inadequately ventilated rooms for flammable gas or for volatile flammable liquids, among others. The cargo tanks and slop storage tanks were classified as Zone 0.

Figure 52 below, extracted from API RP 505 illustrates the area of typical rating for FPSOs. It can see that the pumps house is typically classified as zone 1, and that the pumps in this area are driven by motor located outside the same.

[65] API RP 505 – Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2

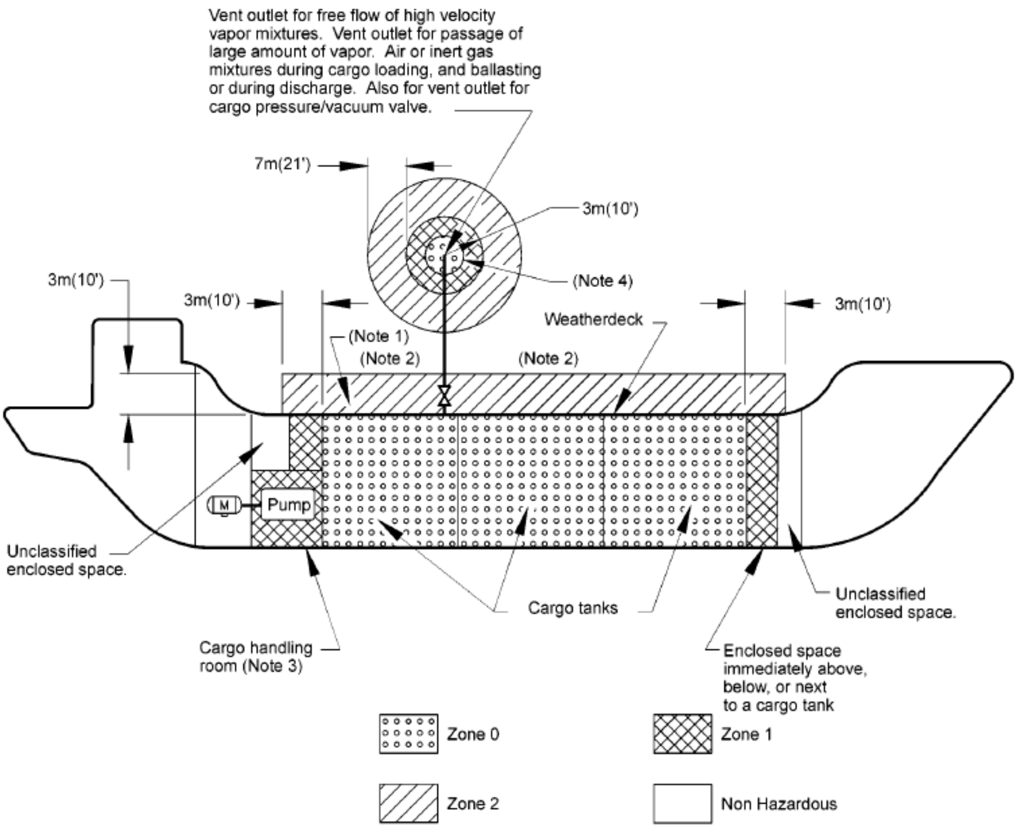


Figure 52 - Typical Area Classification for FPSOs as per API RP 505

The area classification is focused on the selection, design and installation of electrical equipment as suitable for environments where it can potentially accrue explosive atmosphere material.

According to IEC 60079[66], which establishes the requirements for electrical equipment in explosive atmospheres where electrical equipment is installed in areas in which explosive concentrations and quantities of flammable gases or dust may be present in the atmosphere, protective measures are applied to reduce the likelihood of explosion due to ignition by electrical arcs, sparks or hot surfaces, produced by both normal operation or under specified fault conditions of own electrical equipment.

66 IEC 60079 – Explosive Atmospheres

Thus, still according to IEC 60079, the electrical equipment installed in hazardous areas must be certified as containing one of the protection types defined in this standard to meet the security levels appropriate to each area.

5.1.2. The stripping pump and its protection project

The stripping pump corresponds to PH 350 model manufactured by Shinko Company. This was a double-acting pump alternatively with steam actuation, located in the pumps room background. The pump was equipped with pressure relief valve, supplied by the manufacturer. The documentation provided by the manufacturer refers to this valve as an "escape valve". The valve was connected to the air chamber and directed to fluid offload to the pump suction.

Figure 53 shows the assembly of this valve in the stripping pump assembly settings according to the technical specification of the manufacturer[67].

[67] From the site http://www.shinkohir.co.jp/en/digitalbook/kph_r-1002k_e/, acessed on 31/07/2015.

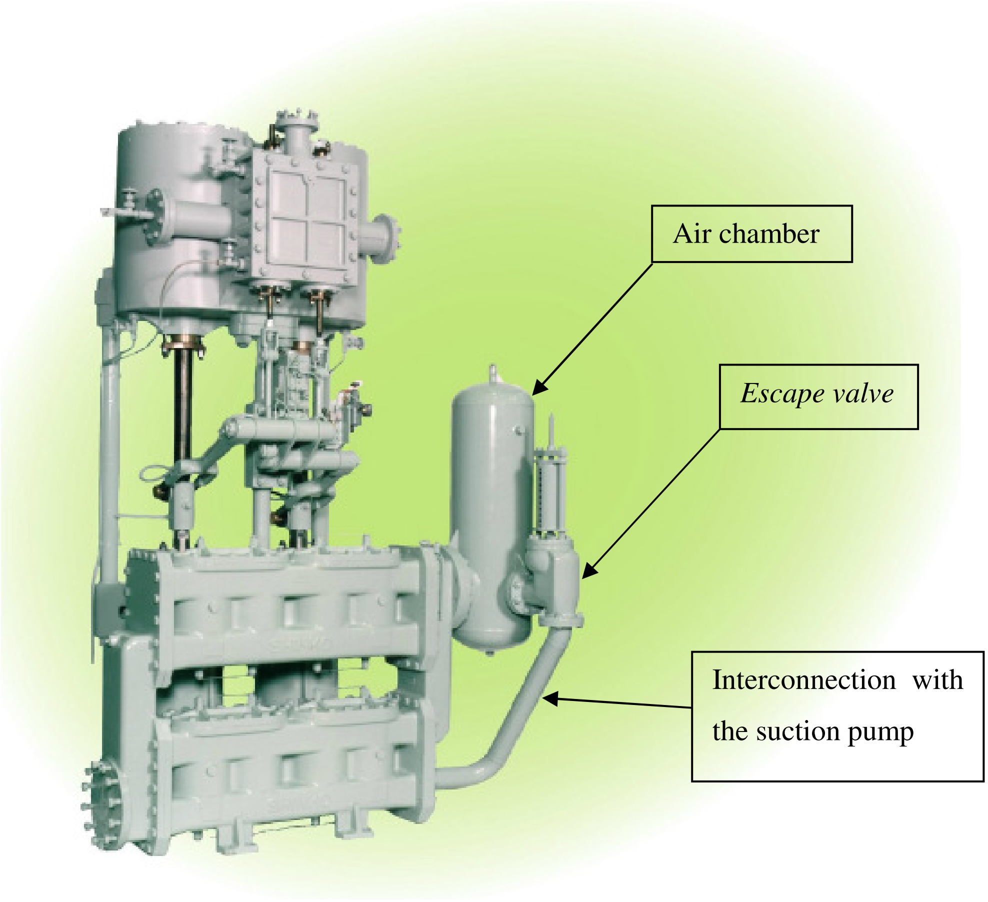


Figure 53 - Assembly of the release pressure valve stripping pump

5.2. Monitoring, controll and cross docking load system operation

The control and monitoring of the plant were carried out through a kind of HMI (Human Machine Interface), as part of the supervisory system load cross docking system.

The charge transfer system was monitored from the marine control room (CCRM), which was located on the houses adjoining the process plant control room (CCR). The main screen of the HMI in CCRM was a juxtaposition of diagrams (P & ID) of the charge transfer between tanks system (previously shown in Figure 41 and Figure 42) and is illustrated in the following figure.

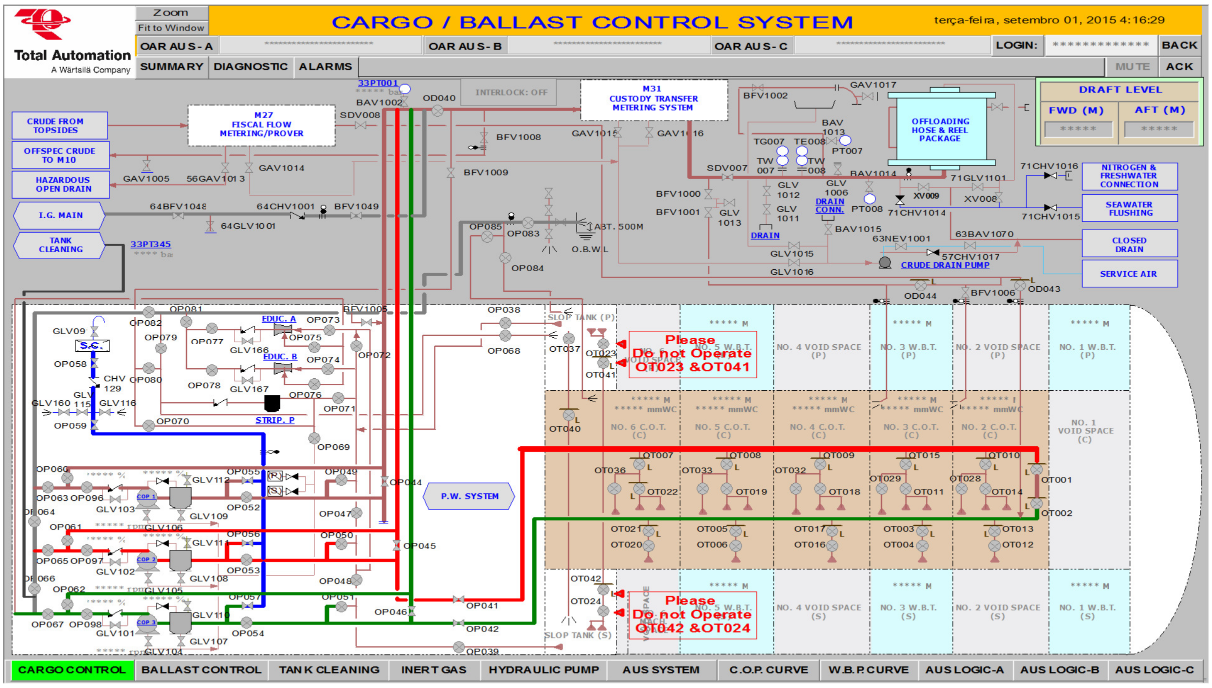


Figure 54 - IHM screen of the Supervisory System in the CCRM

The operation of the charge transfer system was conducted by marine operator (operator position), supervised by marine superintendent, who reported directly. In total, there were four marine operators in the FPSO CDSM, two expatriates and two Brazilian nationals. Every shipment worked a double, consisting of an expatriate and a Brazilian.

Although they occupy the same position, there was a hierarchy among the expatriate marine operator and the Brazilian, in which the Brazilian played mainly only functions related to the issuance of documents, while expatriates played operational functions. The difference between people functions occupying the same position was due to the fact that expatriates marine operators were more experienced than those Brazilians.[68].

In other units, the marine operator can be called a marine operator/ballast or craft operator.

Figure 55 below shows the team composition on board of the FPSO CDSM by function and number of employees on board for each function, according to current organizational chart at the time of the accident.[69].

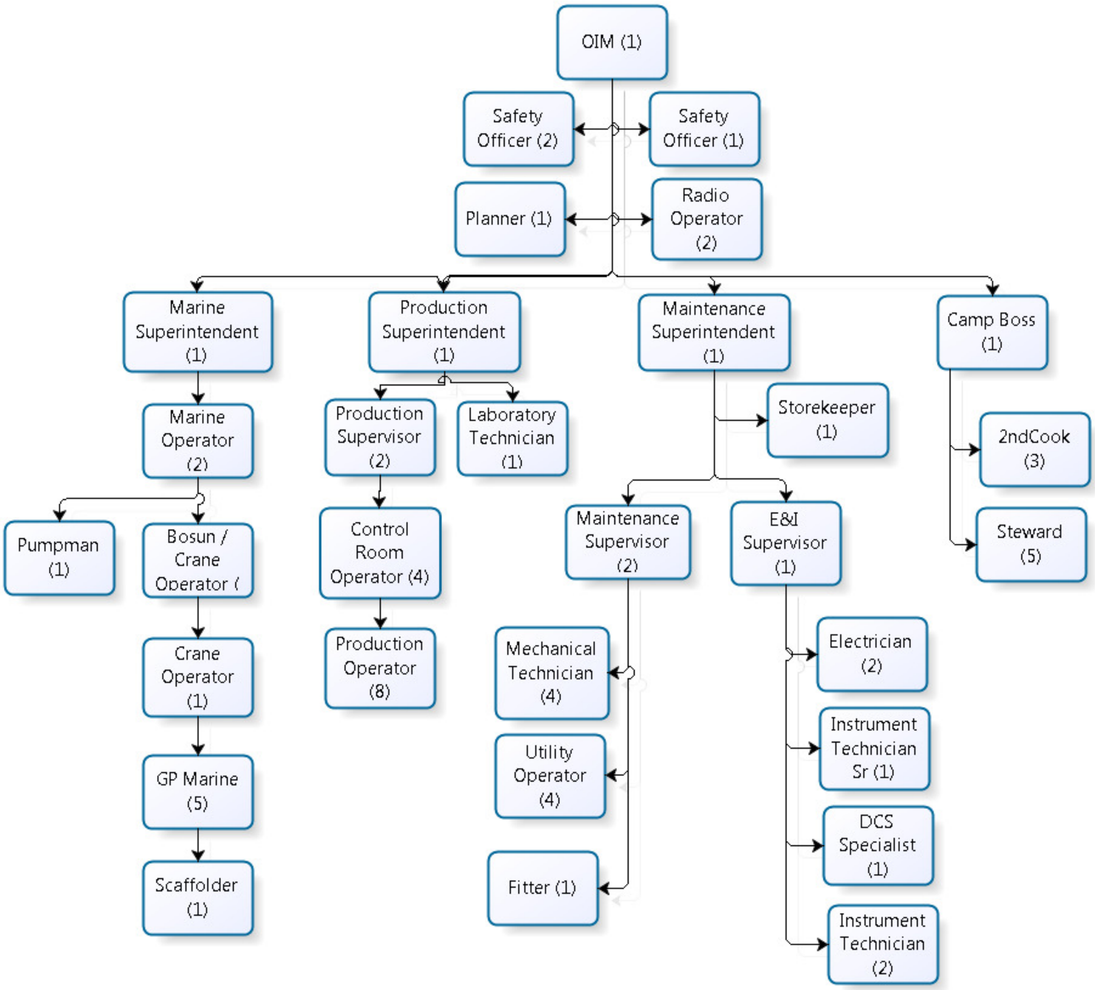


Figure 55 - board chart of the FPSO CDSM

[68] Logbooks and Rotation Handover Report – OIM - Doc nº OIM Handover 2015 01 04 – Issue date: 04/01/2015

[69] File CdSM - Offshore Organization Chart 10_02_2015.pdf

In the meantime as much of the load cross docking system valves were controlled through the supervisory system in CCRM the marine operator, some valves were controlled by hand controls in the upper deck and on the first floor inside the pumps room[70]. Figure 56 shows the levers to the operation command of some valves whose drive was located in the upper deck (main deck).

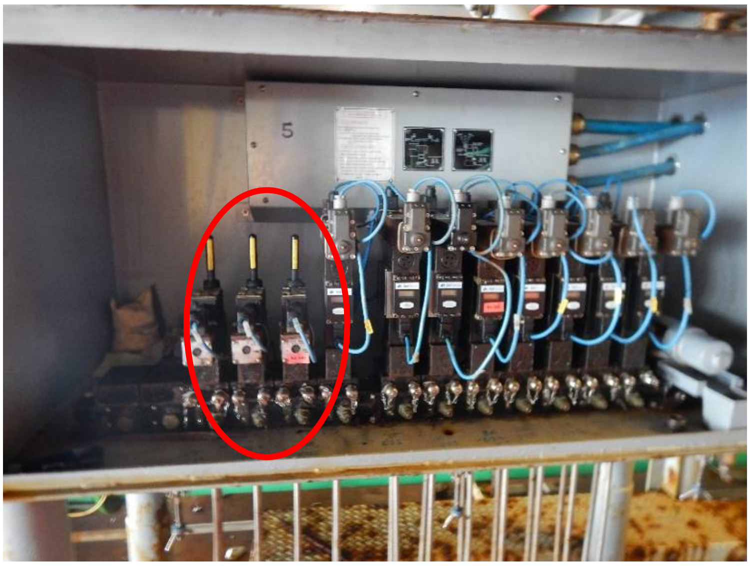
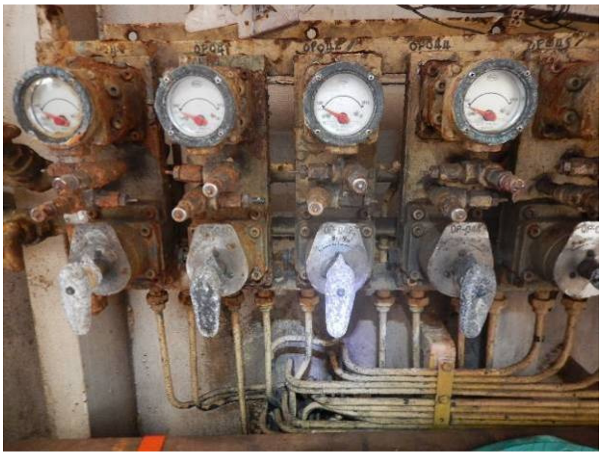


Figura 6 – Acionamento de válvula por meio de alavanca no *upper deck*

Figure 57 shows the keys with positions "open", "closed" and "neutral" for the valve operation that had driven through controls that were located on the main deck level and within the pumps room.



[70] Known informally by staff on board as "*pump room top*"

Figure 57 - Valve Drive through the pump room top key

The levers and pulling switches of local operated valves were in boxes known as solenoid boxes, see Figure 58.

Figure 7 – *Solenoid box*

The local operation of valves was performed by the pump operator (pump man), to receive specific order of marine operator. The valves of the fluid handling system driven off the HMI, some automatically sent to the CCR status information of its position (open or closed) and others may not.

For these, the marine operator must enter the valve position information after clicking on the screen on top of the valve. All valves OP, OT and OD of interest to this report were hydraulically operated valves, while the BFV valves were manually operated.

The Table 8 as below identifies the location of where it was thrown each considered important valve for such report. For valves with command type "Open/Close", the opening operation or closing a valve was performed through the HMI in CCRM by clicking on the valve and choosing the "open" or "close".

For valves with type "Setpoint"of command, the operation was made in HMI through the valve opening percentage setting. "Toggle" means that the valve position status was switched manually by the operator in marine HMI, and not automatically.

Table 8 - Control of the valves of the type cross docking load system by CCRM.

TAG	IHM Type of Command	TAG	IHM Type of Command
OT-001	No command	OT-042	No command
OT-002	No command	OP-038	*Setpoint*
OT-003	No command	OP-039	*Setpoint*
OT-004	*Setpoint*	OP-041 [(71)]	*Toggle*
OT-005	No command	OP-042[84]	*Toggle*
OT-006	*Setpoint*	OP-044 [84]	*Toggle*
OT-007	No command	OP-045 [84]	*Toggle*
OT-008	No command	OP-046 [84]	*Toggle*
OT-009	No command	OP-047	*Open / Close*
OT-010	No command	OP-048	*Open / Close*
OT-011	*Setpoint*	OP-049	*Open / Close*
OT-012	Setpoint	OP-050	*Open / Close*
OT-013	No command	OP-051	*Open / Close*
OT-014	*Setpoint*	OP-052	*Open / Close*
OT-015	No command	OP-053	*Open / Close*
OT-016	*Setpoint*	OP-054	*Open / Close*
OT-017	No command	OP-068	*Open / Close*
OT-018	*Setpoint*	OP-069	*Open / Close*
OT-019	*Setpoint*	OP-070	*Open / Close*
OT-020	*Setpoint*	OP-071	*Open / Close*
OT-021	No command	OP-079	*Open / Close*
OT-022	No command	OP-080	*Open / Close*
OT-023	*Setpoint*	OP-081	*Open / Close*
OT-024	*Setpoint*	OP-082	*Open / Close*
OT-028	*Setpoint*	OP-083	*Open / Close*
OT-029	*Setpoint*	OP-084	*Open / Close*

[71] The valve position (open or closed) is not automatically updated in the CCR.

TAG	IHM Type of Command	TAG	IHM Type of Command
OT-032	*Setpoint*	OP-085	*Open / Close*
OT-033	*Setpoint*	BFV-1005	No command -
OT-036	*Setpoint*	BFV-1006	No command -
OT-037	*Setpoint*	OD-040	*Open / Close*
OT-040	No command	OD-043	*Open / Close*
OT-041	No command	OD-044	*Open / Close*

Figure 59 below shows a window example for clockwork valve operation in the IHM. The operated valves outside the CCRM had another kind of pop up window in the supervisory system, as shown in Figure 60. There was still pop up windows for monitoring the levels, temperatures and pressures in the center tanks (load) and slop tanks, as shown in Figure 61 and Figure 62, respectively.

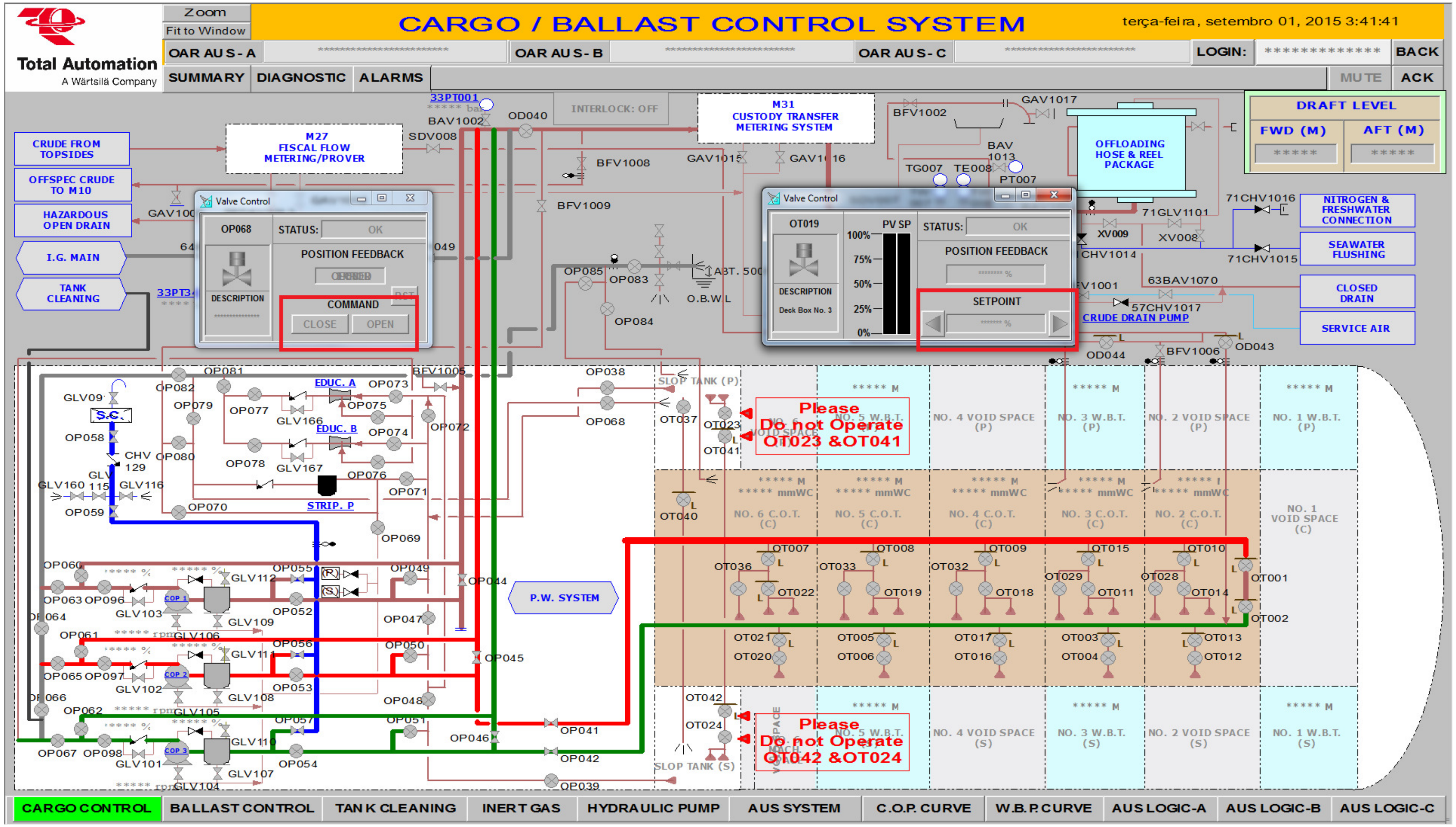


Figure 59 – Windows pop up in the HMI supervisory system for operating the valves

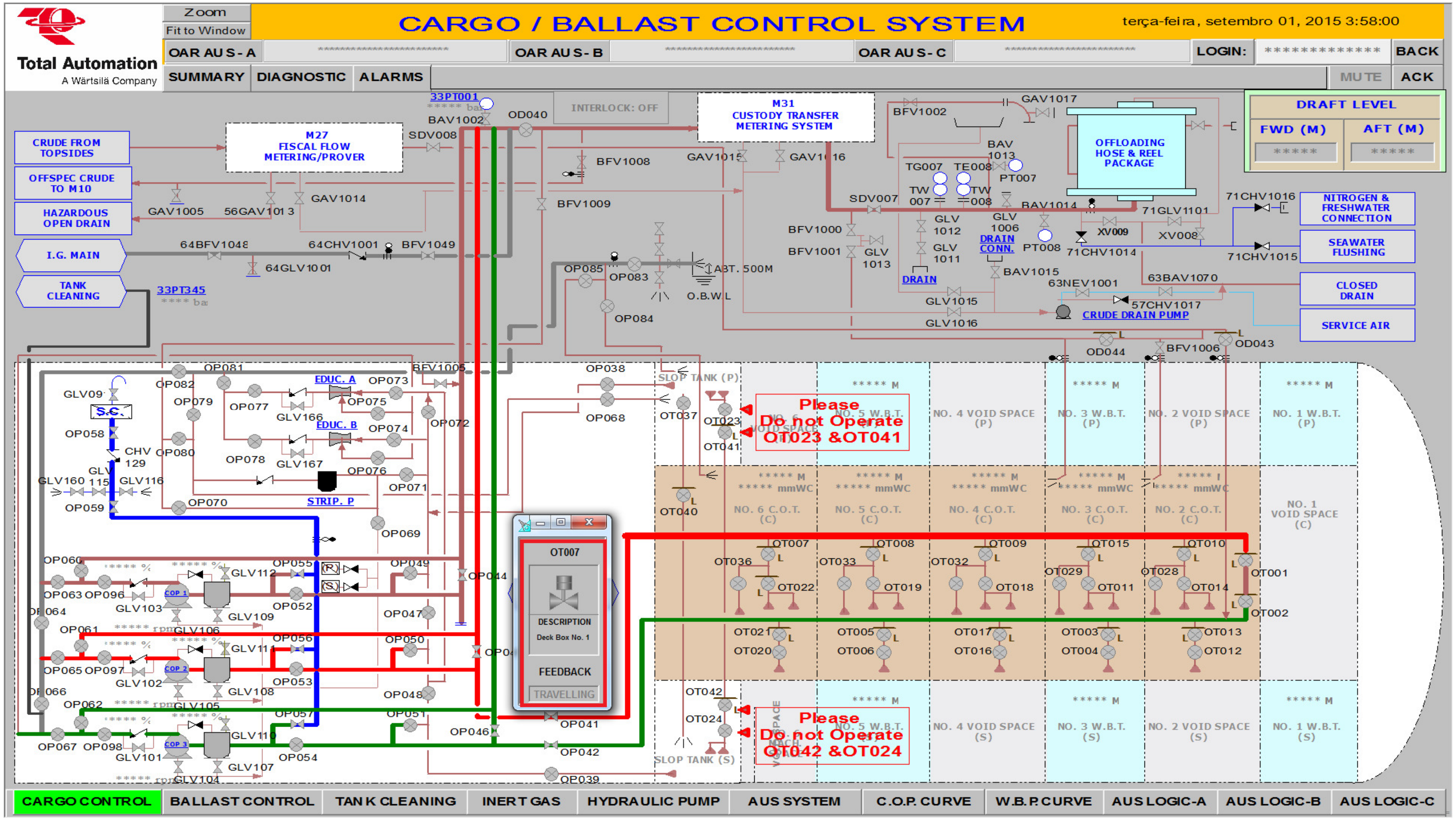


Figure 8 – Windows pop up in the HMI supervisory system for controlled valves outward CCRM.

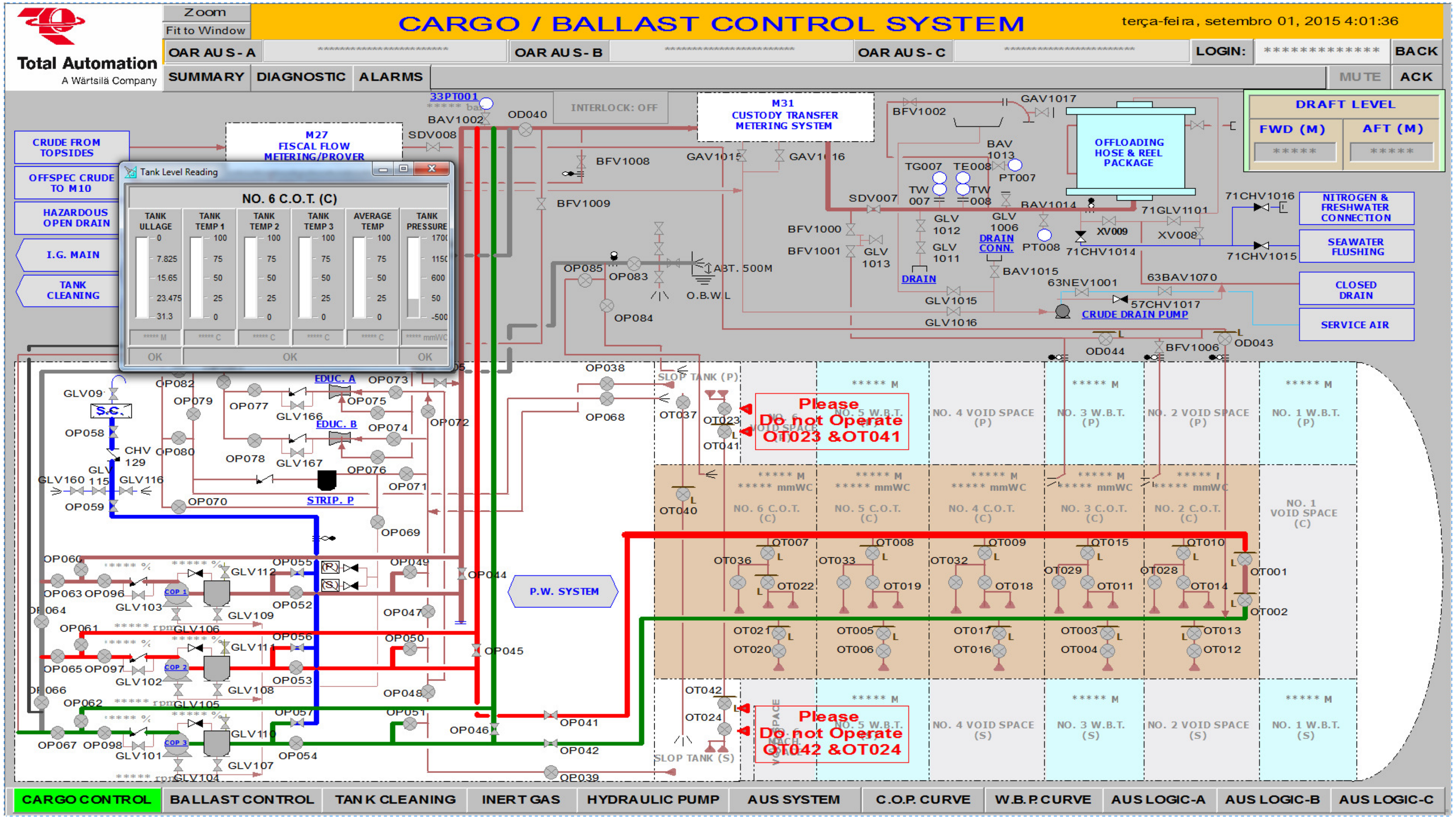


Figure 61 - Windows pop up in the IHM supervisory system for central tanks.

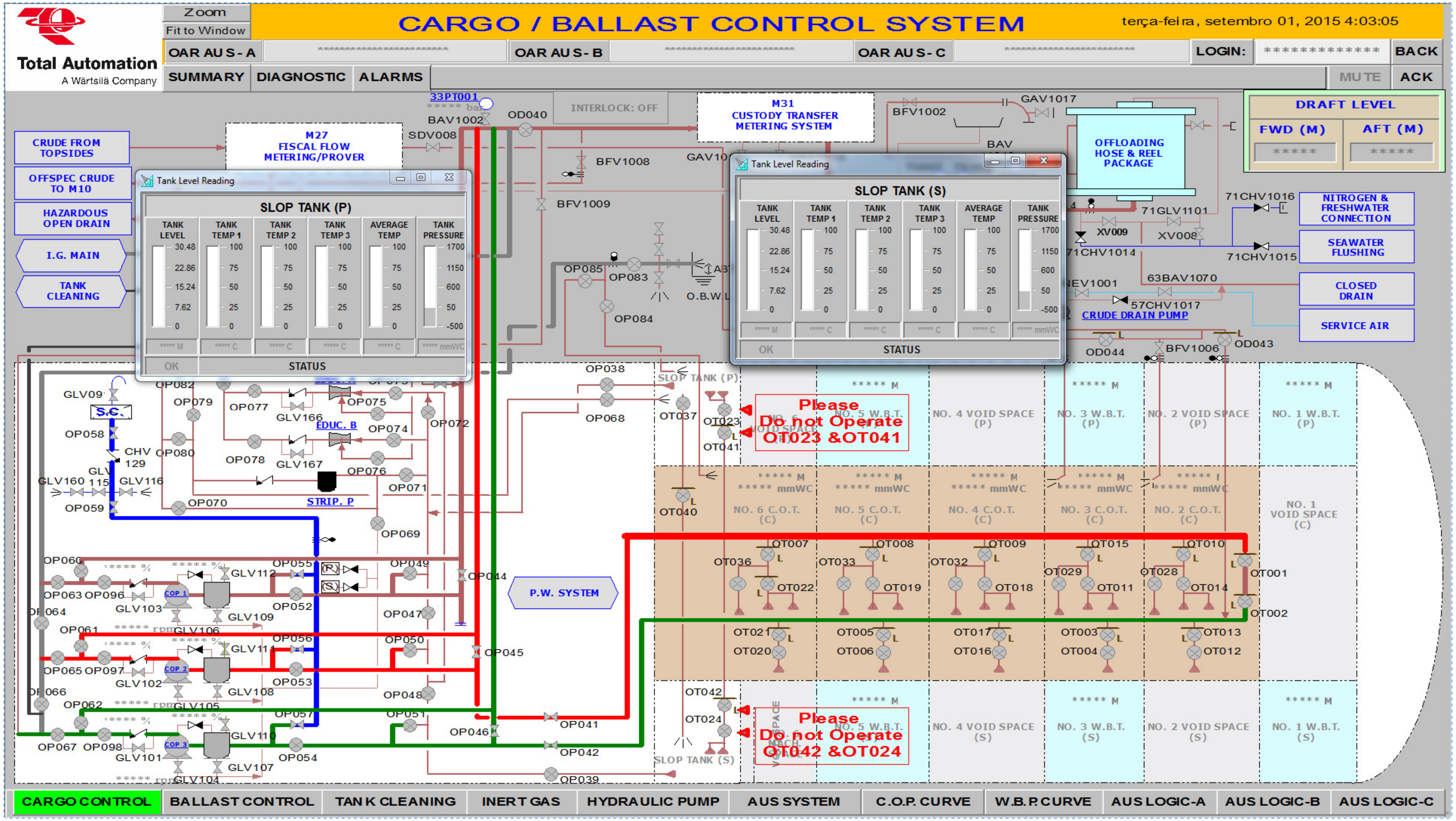


Figure 62 - Windows pop up in the HMI supervisory system to slop tanks..

The pump supply vapor stripping was done by means of a vapor pipe with admission to the home pumps, controlled by a manual valve located in the engine room. The vapor supply was the responsibility of the engine room personnel (engine room) and if there was need to operate the stripping pump, the navy personnel requested the opening of the vapor supply.

The operation of the stripping pump was controlled by opening and closing a power vapor control valve pump, located at the home of pumps. This enabled the adjustment valve opening percentage between 00 and 100%.

The pump's operating manual indicated the holding of local actions to be performed during starting operation or pump failure, but there was no formal documented procedure for pump operation. As testimonies collected, these transactions were carried out as follows:

• The pump operator should be next to the pump in order to perform specific actions drainage during the match as well as to monitor and report the condition of the equipment for the marine radio operator.

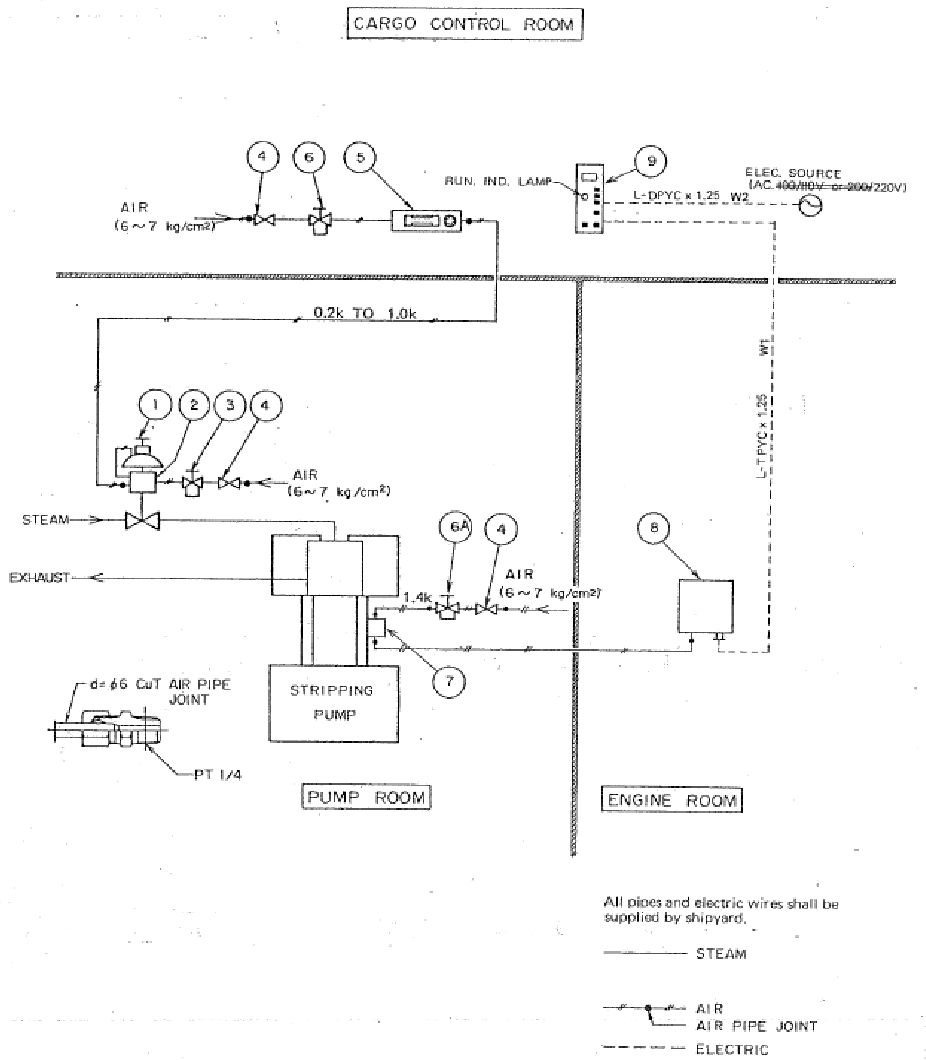
• For starting the pump, the marine operator warned the staff of the engine room to provide vapor. Within the pumps room, the pump operator when maneuvering the drain valves of the pump the water in the system was expelled and waiting for heating the pump. The pump operator communicated during this period with the marine operator via radio. During drainage and heating pump, the marine operator kept the vapor control valve pumps slightly open house, worth about 5%.

• After heating the pump, the pump operator visually accompanied the beginning of the movement of the machine's pistons, next to the stripping pump. The pump began to show its motion when the opening of the vapor control valve was adjusted to between 7% and 10%. With the information coming from the pump operator that the pump operating normally, then the marine operator used to gradually increase the opening of the vapor control valve to a value between approximately 30% and 35%.

• The pump stop was conducted by the speed reduction, then the following actions in order: closing the suction line valve to prevent reverse flow, full stop of the pump by adjusting the opening of the vapor control valve to 0%, warning the control room of the house ward which it was stopping machines drainage operation, the pump operator on-site confirmation of the fact that pump stopped and closing the discharge line valves. If there was a change in the discharge line first opened up new alignment of the valves, valve opening was confirmed locally, the discharge pressure was monitored and finally the previous alignment valves were closed.

Such practice, however, was not formalized in any operating procedure and dependent on the experience and knowledge of marine operator.

The Figure 63 below illustrates the pump control scheme, detached from the data sheet. Figure 64 shows the screen on which the marine operator commanded the vapor control valve of the CCRM.



NO.	NAME OF PART	QTY	REMARKS
1	STEAM CONTROL VALVE	1	
2	POSITIONER	1	
3	FILTER REGULATOR	1	
4	STOP VALVE	3	PT1/4"
5	MANUAL LOADER	1	
6 / 6A	FILTER REGULATOR	1 / 1	WITH PG
7	AIR RELAY.	1	
8	TRANSMITTER	1	PNEU.→ELECT.
9	STROKE COUNTER	1	

ITEM NO.	
ORDER NO.	
REMOTE CONTROL SYSTEM FOR CARGO STRIPPING PUMP	
MODEL	KSC
DRAW. NO.	KS - 27500 A

Figure 63 - Control scheme of the stripping pump

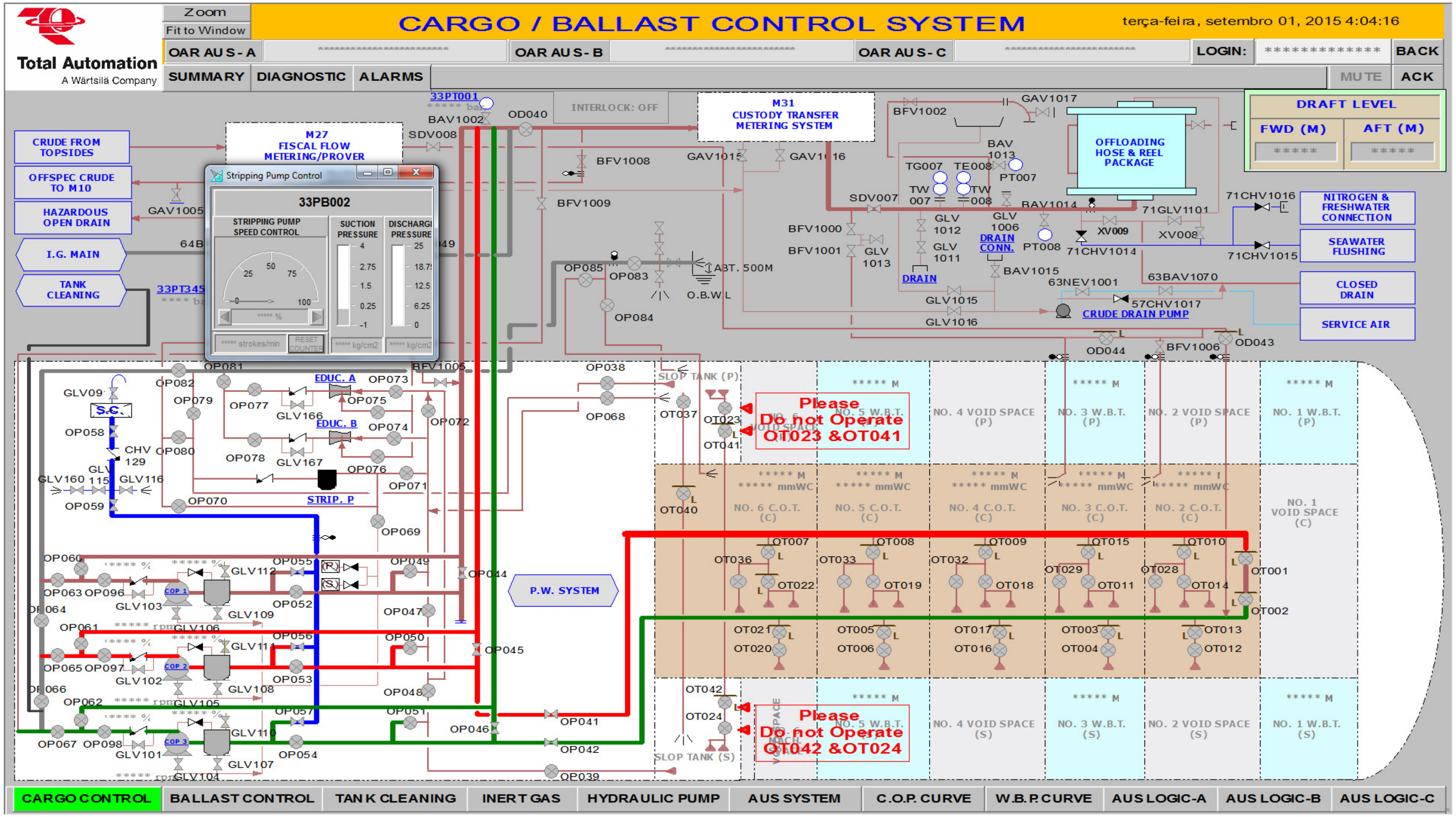


Figure 64 - Screen control and monitoring of stripping pump

In the meantime the pump operator was in the pumps room, he had the access to the vapor pressure information, pump suction pressure and offload pressure of the pump through local indicators, as shown in Figure 65.

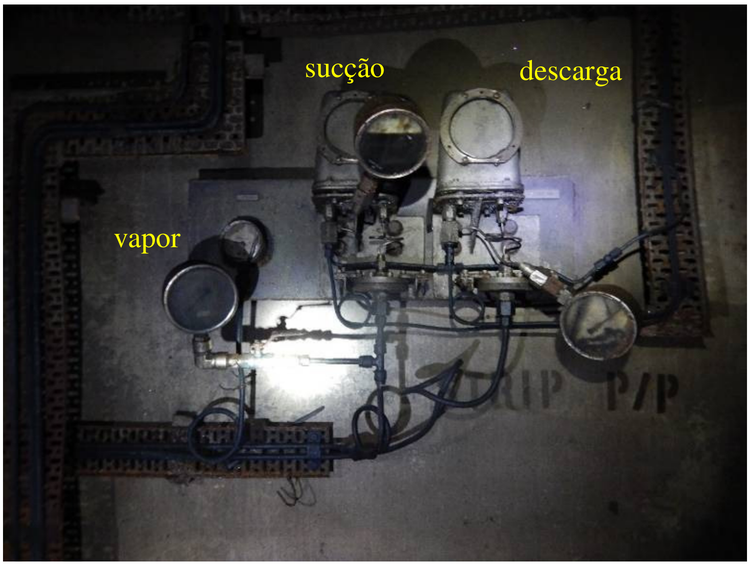


Figure 65 - Pressure Gauges vapor, suction and offload stripping pump at the pumps room

The information available in CCRM for marine operator were: (i) the percentage of opening of the vapor control valve, (ii) suction pressure and (iii) the offload pressure. The stripping pump was endowed with by minute strokes counter (strokes / min) as its datasheet, and had the foresight to display the amount of strokes per minute (strokes / min) of the stripping pump on screen HMI, but this information was not available to the marine operator.

In regard to the monitoring offload pressure, there are records of such pressure to reache a value of 4.4 bars at a 30% opening of the vapor control valve. Additionally, there is instruction register[72] for the marine operator to reduce the opening of the control valve or even shut down the pump if the offload pressure reached 5 bars.

5.3 Record analysis upon cross docking load system operation

[72] Cargo log book – marine department in 04/11/2014 (fls. 839)

The marine department team recorded the activity and parameters of the cross docking load system into three main documents: cargo log book, daily tank report and handover report.

In the cargo log book, exemplified in Figure 66, it is found recorded the main activities that took place during the day as well as measurements of tanks taken to the ICU instrument (ullage-temperature-interface). This instrument was used to measure the height of the empty space inside the tank, the height of the interface between fluids (water condensate) and the temperature of the fluid and is shown in Figure 67.

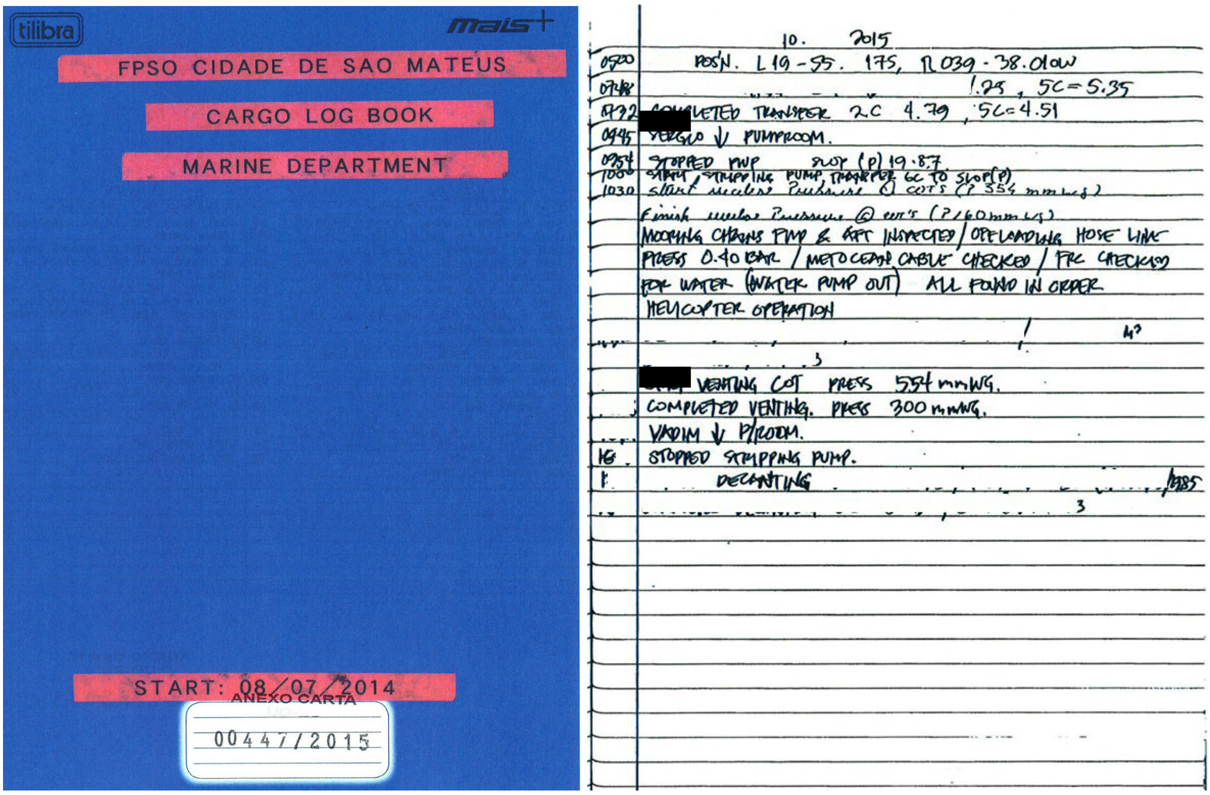


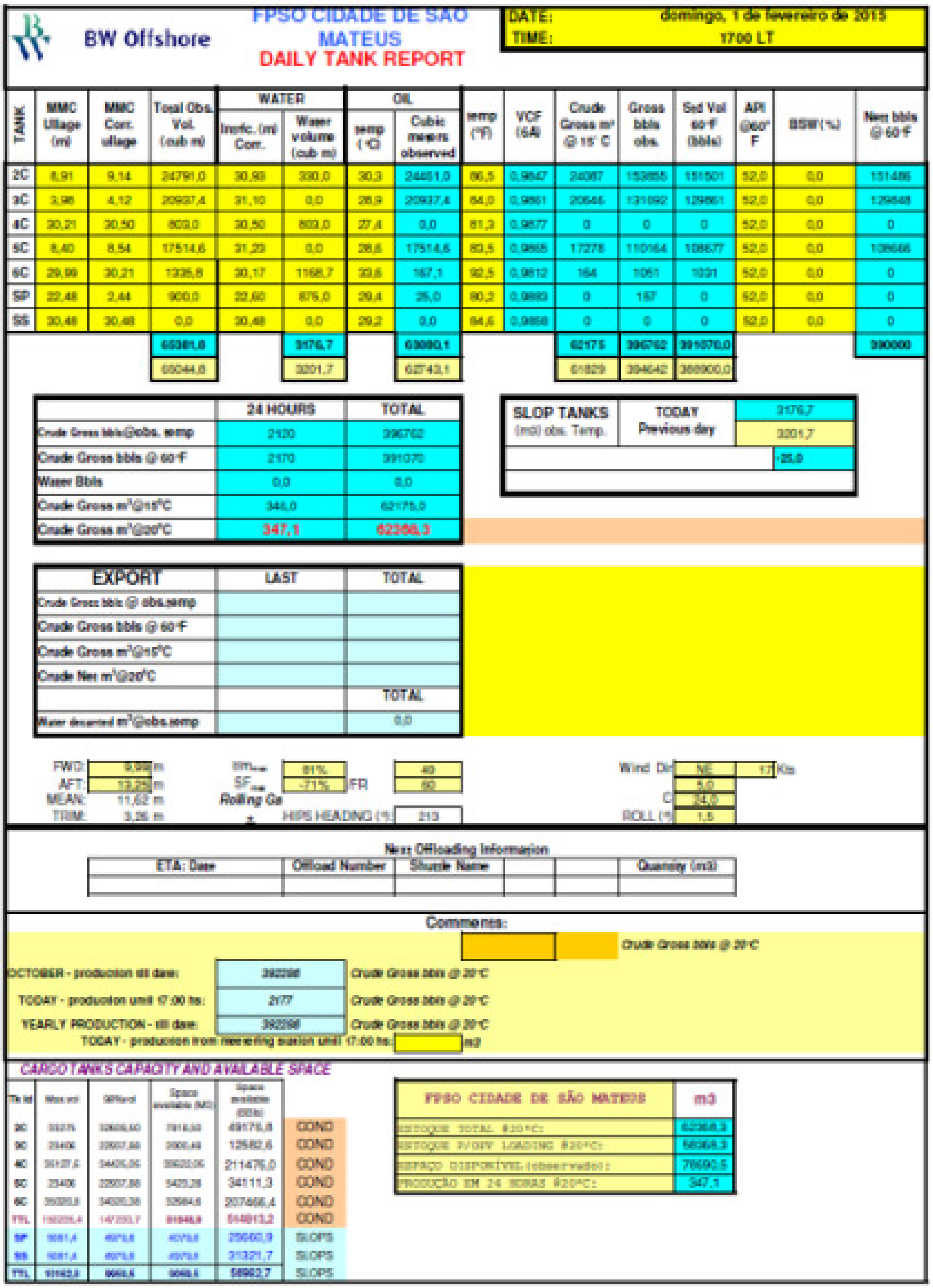
Figure 9 – Example of cargo log book

Figure 67 - Photos front and side of the ICU meter

• The ICU connection in each tank was held in the upper deck of the ship, as shown in Figure 68.

Figure 68 - ICU Connection 4C tank

In the daily tank report exemplified in Figure 69, it is basically recorded levels, volumes and temperature of fluid in each tank as well as the daily production.


BW Offshore

FPSO CIDADE DE SAO MATEUS

DAILY TANK REPORT

DATE: domingo, 1 de fevereiro de 2015

TIME: 1700 LT

TANK	MMC Ullage (m)	MMC Corr. ullage	Total Obs. Vol. (cub m)	WATER Interfc. (m) Corr.	WATER Water volume (cub m)	OIL temp (°C)	OIL Cubic meters observed	temp (°F)	VCF (6A)	Crude Gross m³ @ 15° C	Gross bbls obs.	Std Vol 60°F (bbls)	API @60° F	BSW (%)	Net bbls @ 60°F
2C	8,91	9,14	24791,0	30,93	330,0	30,3	24461,0	86,5	0,9647	24087	153855	151501	52,0	0,0	151486
3C	3,98	4,12	20937,4	31,10	0,0	28,9	20937,4	84,0	0,9661	20646	131092	129661	52,0	0,0	129648
4C	30,21	30,50	803,0	30,50	803,0	27,4	0,0	81,3	0,9677	0	0	0	52,0	0,0	0
5C	8,40	8,54	17514,6	31,23	0,0	28,6	17514,6	83,5	0,9665	17278	110164	108677	52,0	0,0	108666
6C	29,99	30,21	1335,8	30,17	1168,7	33,6	167,1	92,5	0,9612	164	1051	1031	52,0	0,0	0
SP	22,48	2,44	900,0	22,60	875,0	29,4	25,0	90,2	0,9680	0	157	0	52,0	0,0	0
SS	30,48	30,48	0,0	30,48	0,0	29,2	0,0	84,6	0,9658	0	0	0	52,0	0,0	0
			65381,0		3176,7		63080,1			62175	396762	391070,0			390000
			65044,8		3201,7		62743,1			61829	394642	388900,0			

	24 HOURS	TOTAL
Crude Gross bbls@obs. temp	2120	396762
Crude Gross bbls @ 60°F	2170	391070
Water Bbls	0,0	0,0
Crude Gross m³@15°C	346,0	62175,0
Crude Gross m³@20°C	347,1	62368,3

SLOP TANKS (m3) obs. Temp.	TODAY / Previous day	3176,7 / 3201,7
		-25,0

EXPORT	LAST	TOTAL
Crude Gross bbls @ obs.temp		
Crude Gross bbls @ 60°F		
Crude Gross m³@15°C		
Crude Net m³@20°C		
		TOTAL
Water decanted m³@obs.temp		0,0

FWD: 9,99 m; AFT: 13,25 m; MEAN: 11,62 m; TRIM: 3,26 m

SF: 81% / -71%; FR 40 / 60; Rolling Ga

HIPS HEADING (°): 213

Wind Dir NE 17 Kts; 5,0; C 24,0; ROLL (°) 1,5

Next Offloading Information

ETA: Date	Offload Number	Shuttle Name			Quantity (m3)

Comments:

Crude Gross bbls @ 20°C

OCTOBER - production till date: 392298 Crude Gross bbls @ 20°C

TODAY - production until 17:00 hs: 2177 Crude Gross bbls @ 20°C

YEARLY PRODUCTION - till date: 392298 Crude Gross bbls @ 20°C

TODAY - production from metering station until 17:00 hs: m3

CARGO TANKS CAPACITY AND AVAILABLE SPACE

Tk id	Max vol	98%vol	Space available (M3)	Space available (BBls)	
2C	[illegible]	[illegible]	[illegible]	49176,8	COND
3C	[illegible]	[illegible]	[illegible]	12582,6	COND
4C	[illegible]	[illegible]	[illegible]	211476,0	COND
5C	[illegible]	[illegible]	[illegible]	34111,3	COND
6C	[illegible]	[illegible]	[illegible]	207466,4	COND
TTL	[illegible]	147200,7	[illegible]	514813,2	COND
SP	5081,4	4979,8	4979,8	25660,9	SLOPS
SS	5081,4	4979,8	4979,8	31321,7	SLOPS
TTL	10162,8	9959,6	9959,6	56982,7	SLOPS

FPSO CIDADE DE SÃO MATEUS	m3
ESTOQUE TOTAL @20°C:	62368,3
ESTOQUE P/OFF LOADING @20°C:	56368,3
ESPAÇO DISPONÍVEL (observado):	78690,5
PRODUÇÃO EM 24 HORAS @20°C:	347,1

Figure 69 - Daily Tank Report

In marine service crossing report there had certain sections on situations related to personnel safety, offloading system, docking system, equipment for oil pollution, waste management, cranes and lifting equipment, structural maintenance, spare parts and storage class certificates, statutory certificates, inspections and additional information.

Handover Report – Marine Superintendent

Name of FPSO/FSU: **Cidade de Sao Mateus**	*Date for Handover:* **21/01/2015**

Marine Superintendent Leaving: **Armando Rex Michael Salvador**	*Marine Superintendent Joining:* **Bernard Vinas**

Item/System	Comments
1. Crew issues	**All personnel are Filling up their Own Time sheet and Hours of Rest now - They were advised to have their Overtime Request Form filled up and Get signed on a daily basis / immediately the next day after doing the overtime. No Overtime will be be allowed without prior approval.** **New Vacation Plan in being implemented to avoid lack of personnel** **New Training matrix sent by Caroline**
2. Safety Issues	**During Gas Free-ing of Slops Pumproom doors as well as the accommodation doors to be closed at all times to avoid any ingress of Gas inside.** **The Use of Safety Harness is mandatory in using any of the vertical access ladders onboard.** **ISPS Drill (Table top) was held yesterday, 20th Jan - This is to be done on quarterly basis** **Monthly Departmental Safety meeting not done yet - complete this before month end.**
3. Cargo offloading system, including lines, valves, pumps and COW system.	**Valve change out details and photos of JSMEA number are saved - see attached link.** **P:\Common\Cargo Department\M&S Superintendent\Cargo Valve Change Out.** **The flow meter was leak / pressure tested with fresh water up to 7 bar no leaks were found.** ****IMP - If you open these valves then they need to be closed by hand pump as they do not close fully :(** **a) OT-014** **b) OT-029** **c) OT-019** **d) OT-006** **e) OT-004 does not open from CCR. E&I can check it out, but ONLY after the off-loading.** **3P and 5P ballast tank overboard valve are leaking, so keep an eye on the stress/bm.** **THE NRV on MOC-091 line needs to be turned 180 deg if 6C has to be loaded. Blow the line from forward of the pump room with Nitrogen, then close the manual valve then turn the valve. Isolate the gas detectors before proceeding with this task.** **Gas freeing of Slop S was started but the Hydrocarbon levels are not going down. attempt to Purge both Slops also did not work.** **The closed drains from process were diverted to 4C via flexible hose connected to the cow line.**

MS-FR00916 Rev. 00

MS-FR00916-00 Rotation Handover Report - Marine Superintendent 21Jan 2016 Page 1 of 4

Figure 70 - Example of marine superintendent service crossing report

6. Operational issues upon load handling system

6.1. Recommendations and safeguards not implemented

Based on October reports relating to HAZOP as per the marine recommendations, once prepared in 2007, here follows the Table 9 regarding some conclusions about the implementation of recommendations and safeguards identified in this study.

Table 9 - Monitoring Risk Analysis recommendations of the Marine HAZOP

Recommendations of Marine HAZOP	Log in to the Close out report	Comments
SS-1: Review the life extension plan useful for load transfer system valves to ensure that all critical valves were included in the general program of maintenance.	Recommendation closed on 07/12/2007. The description of the close in October says the service life extension plan was in progress and that the personnel involved in the commissioning and operation would be overseeing the renovation of existing valves.	1) The recommendation is pending status, but with the closing date of registration. 2) The description in close in October shows that the recommendation had not yet been completed. However, no action was recorded later. 3) It was also found that one of the safeguards for this scenario is not implemented. Safeguarding said that all the charge transfer system valves need maintenance or should be exchanged.
SS-7: Ensure all couplings load transfer system to undergo to general maintenance during the period of repair / service life extension.	The close out was not presented.	1) It was shown that such a recommendation has been implemented.
SS-13: Consider the configuration of PAH in each cargo tank.	Recommendation was answered on 05/02/2008. The description of the close in October only says it should be installed PAH.	1) There had no record of the recommendation closing date. 2) It was shown that such a recommendation has been implemented.

Recommendations of Marine HAZOP	Log in to the Close out report	Comments
SS-15: Review resources to promote positive insulation (paddle and blind flange) of the cargo tanks and slop to ensure that the positive insulation could be used depending on the security requirements of the Prosafe management system.	Recommendation closed on 07/12/2007. The description of the close in October said that the lines of charge transfer system above the deck had arrangement that enable the installation of spades . For the lines of this system background, the positive insulation should be done through the CCR panel through the valve closing.	1) The recommendation remains as pending over status, but with the closing date of registration. 2) The *close out* counteracts the insulation procedure[73] adopted by BW says the insulation in the bottom lines of charge transfer system must be accomplished through double lock.
SS-35: Ensure that the PSV of stripping pump can be removed from the pump and calibrated.	The close out was not presented.	1) It was shown that such a recommendation has been implemented. 2) It was also found that one of the safeguards for this scenario is not implemented. Safeguarding consisted of the preventive maintenance plan and it was noted that for PSV stripping the pump, the maintenance program was not implemented.
SS-36: To ensure that operating procedures include requirements for the safe departure of the steam pumps in the pump house and engine room.	Recommendation was answered on 05/02/2008. The close out description in October said the requirements for starting the steam pumps correctly were included in the 384-OP_MDK_201 procedure.	1) It was observed that the procedure cited in the close out fact does not establish requirements for starting the pump in terms of steam provision.

[73] *PTW System – Procedure – Insulation – Mechanical* – Doc. n° MS-PR00840 Rev. 1 – Issue Date: 07/08/2013 (pgs. 859)

Recommendations of Marine HAZOP	Log in to the Close out report	Comments
SS-38: To ensure that the reform plan for the pump house includes all the instrumentation associated with the stripping operation in order to ensure reliable and safe operation.	Do not close was presented in October.	1) It was shown that such a recommendation has been implemented.

Thus, it can be concluded that the failure to implement safeguards and recommendations identified in the analysis of risks associated with the lack of real control status of the implementation of actions during the unit operation stage took the platform to a risk condition uncontrolled and above all acceptance criteria that could be considered as a good practice. Such behavior is basic and catastrophic failure regarding minimum practices in risk management, and contributes to the degradation of the operational safety of the FPSO CDSM.

6.2. Flaws in the systems commissioning wise

On 17/10/2009, while the operation in FPSO CDSM was still held by Prosafe Company, was issued a Change Management form[74] of Cargo & Ballast control system (Full Commissioning).

The description of the problem addressed by the change management description that the control system of the charging system and ballast is commissioned partially left in the conversion phase, there is a need to complete such a commissioning. It was also recorded that such a system has not been completed in Singapore because its completion would take place only after the arrival of unit in Brazil. As justification and benefit of change management was written System not yet commissioned, No control in the CCR (system not yet commissioned, with no CCR control).

Additionally, it was reported that the control system configuration was not checked during the installation phase and the actions to be taken to complete the commissioning of the load control system and ballast were postponed because they were not considered priority[75] in view of achieving to obtain the first gas operation, even with the technical unit in a position to carry out such activities.

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[74] Change Management Form – Cargo & Ballast Control System – Doc. n° CMR / CDSM / 0012 – Issue Date: 15/12/2009

[75] E-mail 13/07/2009 senior engineer instrumentation and control Prosafe to the Operations Manager FPSO Cidade de São Mateus, annexed to Change Management Form – Cargo & Ballast Control System – Doc. n° CMR / CDSM / 0012

The same change management contains a list of thirteen (13) disputes related to: (i) conversion of some valves for automatic control (OT-022, OP-044, OP-045 and OP-046), (ii) Installation emergency trip the cargo pumps, (iii) to make field information reached the HMI, (iv) as well as making that IHM command were respected by actuators in the field.

Update P & IDs was also acquired as a result of the changes that would be implemented. Stand out from the service list two examples of interest to this incident investigation process items 3:12:

> *"03 controls and pressure transmitter of stripping pump yet to be commissioned."*
>
> *"12-some valves were not properly commissioned."*

During the investigation, it became clear that for item 03 there was an incomplete commissioning and, for item 12, the commissioning was done in the wrong way.

Regarding item 12, the main valve OT-022 6C tank (control valve remotely operated under P & ID) was commissioned as fully open or closed position indicator and yet to be commissioned valve. Nonetheless, a designed project document[76] indicated that the OT-022 valve should have control position.

Regarding item 3, about the stripping pump controls, there is in one of the annexes of the finished work scope form[77] confirming that no leak was found in the measuring lines of suction and discharge pressures of the stripping pump and such information were available at the IHM. However, regarding the strokes count information was reviewed by instrumentation supervisor that the engineering team would bring a suggestion for the feedback from stroke ("1. Our Engineering Team to come with suggestion for stroke feedback").

When asked if the strokes indication per unit time of stripping pump has ever been available to the marine operator through the supervisory system screen at some point the phase of unit operation and for what period, the concession operator answered following[78]:

[76] Piping Diagram of Cargo Oil and Water Ballast System – Doc. n° 2T-7412-001 – Issue Date: 30/05/1987

[77] Annex 384-Cargo & Ballast Control System Scope of Work Finalized do CMR / CDSM / 0012 – Issue Date: 12/03/2010

[78] Carta UO-ES-0757/2015, as of 06/08/2015

"The BW Offshore informed the answer is negative and the details of the strokes of information per unit of the stripping pump timeframe was not available to the marine operator through the supervisory system screen on the unit operating phase."

The appointment of counting strokes / minute to be displayed on the HMI screen of the marine operator was never available during operation of FPSO CDSM.

Regarding the OT-022 valve control of the 6C tank, valuable to note from P&ID[79] and as illustrated in the identification section of the charge transfer system, the valves OT-020 and OT-036 (also from the 6C tank), valves OT-006, OT-019 and OT-033 (tank 5C), valves OT-016, OT-018 and OT-032 (4C tank), valves OT-004, OT-011 and OT-029 (3C tank), valves OT-012, OT-014 and OT-028 (tank 2C), all similar to OT-022 em t in terms of access to the storage tanks are valves that had control position.

It is worth mentioning that there is record[80] with the information that the logic implemented for the OT-022 valve was the local drive only and that there was need for the valve to be operated remotely in the same way that all other valves of the cargo tanks, because otherwise, during operations load would no control over the 6C tank:

"*Please note this valves needs to be remote operated like all the other cargo tank valves, otherwise during cargo operations we will not have any control over tank 6C*").

However, it is noted, the screen HMI with representation of the feedback from the OT-022 valve collected in audit, the OT-022 valve was still up to the date of the accident as a valve without position control, i.e. the related modification in item 12 of the change management has not been implemented.

6.3. Poor information reliability upon the CCRM and steam leakage

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[79] P&ID *Cargo System in Vessel* – Doc. n° 384-33-W-DWG-100_002 Rev. Z – Issue Date: 03/03/2009

[80] Email the marine superintendent for the engineer assigned to serve the preparation of modification statements and to coordinate technical issues on suppliers related to instrumentation and control, dated 13/12/2008, annexed to Change Management Form – Cargo & Ballast Control System – Doc. n° CMR / CDSM / 0012

By analyzing data from the cargo system, there were several incidents that cast doubt on the reliability of information and commands in CCRM. Below are listed the records of marine operator on the reliability issues of the cargo handling system of FPSO CDSM:

- In 21/08/14, it was recorded that although the OP-valve 051 was fully opened at the site in CCRM panel was shown as closed.
- In 25/09/14, the water pump produced PWP B could not be stopped from the CCRM panel.
- In 30/09/2014, It was recorded for the 4C tank that OT-018 indicated valve opening 10% in CCRM though it was 100% closed and the OT-016 indicated valve closed in CCRM though it was 100% open.
- In 18/10/2014, the OT-019 valve remained 17% open when commanded to close while the OT-006 valve showed 100% opening to be controlled in 88% of opening from CCRM.
- In 27/10/2014, the OD-044 valve was locked in place but appears in green (open valve indication) from CCRM.
- In 16/12/2014 the valve indicator OP-054 presented problems.
- In 09/02/2015 it was found that the gauges in the discharge of ballast pumps did not indicate the same pressure shown in CCR.
- Valuable to note, therefore, a lack of reliability of the information available on the CCR for the marine operator.

Additionally, the dates 13/09/2014, 19/09/2014, 25/09/2014 and 28/09/2014 steam leaks were reported as responsible for moving the stripping pump. The leakage from 25/09/2014 was classified as severe. After repairs, the pump was tested on 16/10/2014 and only returned to be used on 23/10/2014.

6.4. Degradation of the seat rings over the condensed material

Other data obtained during the investigation was the report that presents the condensed characteristics. This is obtained for the report "Evaluation of failure in the sealing ring of the tank valve" issued in 21/10/2014[81]. This reports the tests on the seal (seat ring) of the tank valve which failed in service, in order to characterize the seal material and assist in the evaluation of the possible causes that led to its failure.

Tests performed in the rubber seal where the failure occurred showed that it was made of elastomeric material with absorption characteristics of a Nitrile Rubber (NBR), being a remarkable

[81] Document sent as an annex to DF 458830 240715 called RT37914.pdf

fact from its composition with 9.8% of volatile materials. The report indicates this is a relatively high amount of volatile materials which can be associated with the condensate absorbed by the elastomer.

Figure 71 - Seal assembly Aspect received for analysis - photo contained in the report

Figure 72 - Macroscopic appearance of a failed gasket seal, showing cracks in the longitudinal direction and next fracture contact transition region with fluid and with the external environment

Figure 73 - Macroscopic appearance of a failed gasket seal, showing cracks in the longitudinal and transverse direction and next fracture contact transition region with fluid and with the external environment

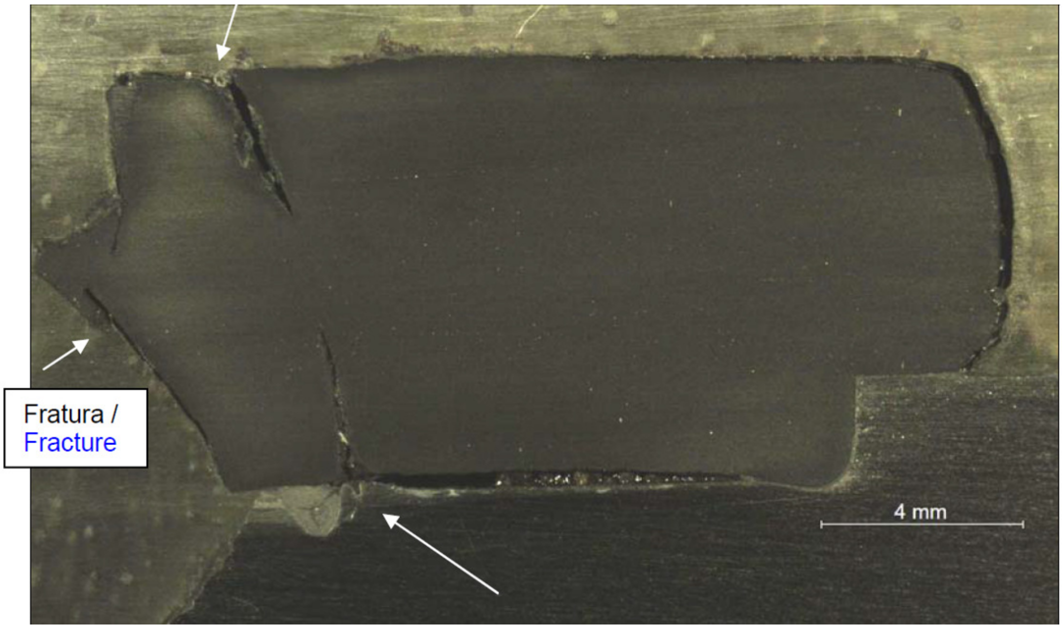

Figure 74 - metallographic appearance of the cross section of the seal, showing internal and surface cracks located in the region of contact with the fluid

The results presented in this report showed that the seal failed due to the presence of longitudinal and transverse cracks caused probably by a chemical attack of the internal fluid to the ring associated with operating voltages, generating the loss of system sealing.

6.5. Triggered valves enabled for crossing flow even in sealed mode and the resulting modification introduced in cross docking load system

After the start of production of gas and condensate storage in the FPSO CDSM, it was identified in December 2011 that some valves of the system allow passage of fluid, even when in closed position[82]. Such a situation initially causes operational problems because the product stored in the tanks, initially with low water content and ready to export was contaminated with water, then, leaving specification. Thus, new measures were needed to return the condensate to the initial specification of storage.

After identifying the occurrence opened a change request on 10/12/2011 by the staff on board of FPSO CDSM (MOC-CSM-069)[83], with priority 2 (operational impact), for manual valves were installed on the system, to allow insulation between double lock slop tanks and the load. On this occasion, it had been identified to occur starboard slop tank contents move to the 2C tank and passing the port slop tank contents into the tank 6C, even with the valves of closed tanks.

The change request for the installation of five manual valves (on the suction of the slop tanks, and between the port slop tank and 6C tank) was approved by the Operations Manager in February 2012 and evaluated by the engineering sector of BW Offshore. The valves were purchased in 09/10/2012[84] and embedded in the unit, but by the time of the accident it had not been installed, as shown in Figure 75.

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[82] Modification Request, Modification Notice & Deviation Request - Install manual butterfly valves in pump room on Cargo System - MOC-CSM-069 – Issue Date: 10/12/2011

[83] Modification Request, Modification Notice & Deviation Request - Install manual butterfly valves in pump room on Cargo System - MOC-CSM-069 – Issue Date: 10/12/2011

[84] "Valve MOC 069 certificate.pdf" – Quality certificate number 09.10-40 / 2012, NF 9965 of 09/10/2012, taken from marine superintendent of the computer in the audit. Information collected together the representatives of BW and Petrobras for inspection activities conducted by ANP in the CDSM and FPSO BW's office in Vitória in the period between 13 and 17/7/2015.

Figure 75 - Manual valves not installed inside the pump house

Parallel to the application open installation manual valves, in December 2012 was recorded new request for change (MOC-CSM-91)[85] on-board staff, with priority 1 (direct impact on safety and production), which indicated that 2C tanks, 3C, 4C and 5C had suspected problems in passing in its valves and their Dresser couplings - elastic joint that allows the union of plain end pipes, eliminating flange, welding or thread and absorbs vibration, small axial and angular movements. This problem led to the migration of content between the tanks. According to the deck design, the liquid products produced to be stored in the cargo tanks from the production could be designed to 2C and 3C tanks and then to the other through the use of headers at the bottom of the tanks. However, since it was necessary to enter 2C and 3C tanks to carry out the necessary maintenance, there was a need to allocate production to another tank.

Thus, this request was so that production could be allocated to 6C tank using an inert gas drying line was not in use on the main deck of the platform and other adaptations. Valuable to note the change of plan considered to export condensate produced directly by the gas export line, without storing it. The alignment of production to the 6C tank will be left prepared in case of a problem in the direct export of condensate by pipeline. However, the inert gas line would be used to transfer the contents (remaining after offloading) of 2C to 5C tanks to 6C tank, with the aid of submersible pumps and portable stripping pump.

[85] Modification Request, Modification Notice & Deviation Request – Modification of Condensate Run Down Line – Doc. n° MOC-CSM-091 – Issue Date: 24/12/2012

Figure 76 - Submerged pump used for load transfer between tanks during temporary change

However, it was identified that it was necessary for the manual valve installation in constant OP-084 the area in the previous change request was made before the conclusion of the routing change of condensate. This insulation was considered necessary because there was a possibility from the condensate to migrate to the slop tank P (port) by the problems presented by the storage system valves.

The use of inert drying gas line located on the main deck to achieve the complete emptying of the tanks instead of using the collectors (headers) at the bottom of the tanks was due to the problem of passage in the valves installed in the headers. Besides inert gas drying line, temporary alignment was made of submersible pumps inside the tanks, manual valves and hoses flexíveis3. These valves have their sealing seals (seat rings) exchanged in order to solve this problem of sealing.

It is emphasized that the description of the change management MOC-CSM-91 had an indication that the effectiveness of this temporary change was to allow the entry of people in cargo tanks so that the necessary maintenance to be made, namely: exchange of shaft seals (seat rings) of internal and external valves to the tanks and repair of Dresser couplings. Such request for change was demanded by the personnel on board the FPSO CDSM and approved for further study by the Operations Manager in December 2012 and approved for implementation in February 2013.

As indicated by the MOC-CSM-091, while the repairs of the valves of tanks 2C, 3C, 4C, 5C and slop port were made, direct export of condensate through the pipeline, would be taken together with the natural gas. This procedure, referred to in unit design, used three pumps located on the main deck, which were designed from the beginning of the FPSO for such service[86].

[86] General Technical Description – Doc. n° I-ET-001-Gas Rev. 0 – Issue Date: 10/08/2006

If any difficulties were encountered during the service inside the tanks, there would be a line ready to move production directly to 6C tank with the aid of a temporary alignment. This alignment was provided with the installation of pipe sections, valves and mechanical insulation, on the main deck[85].

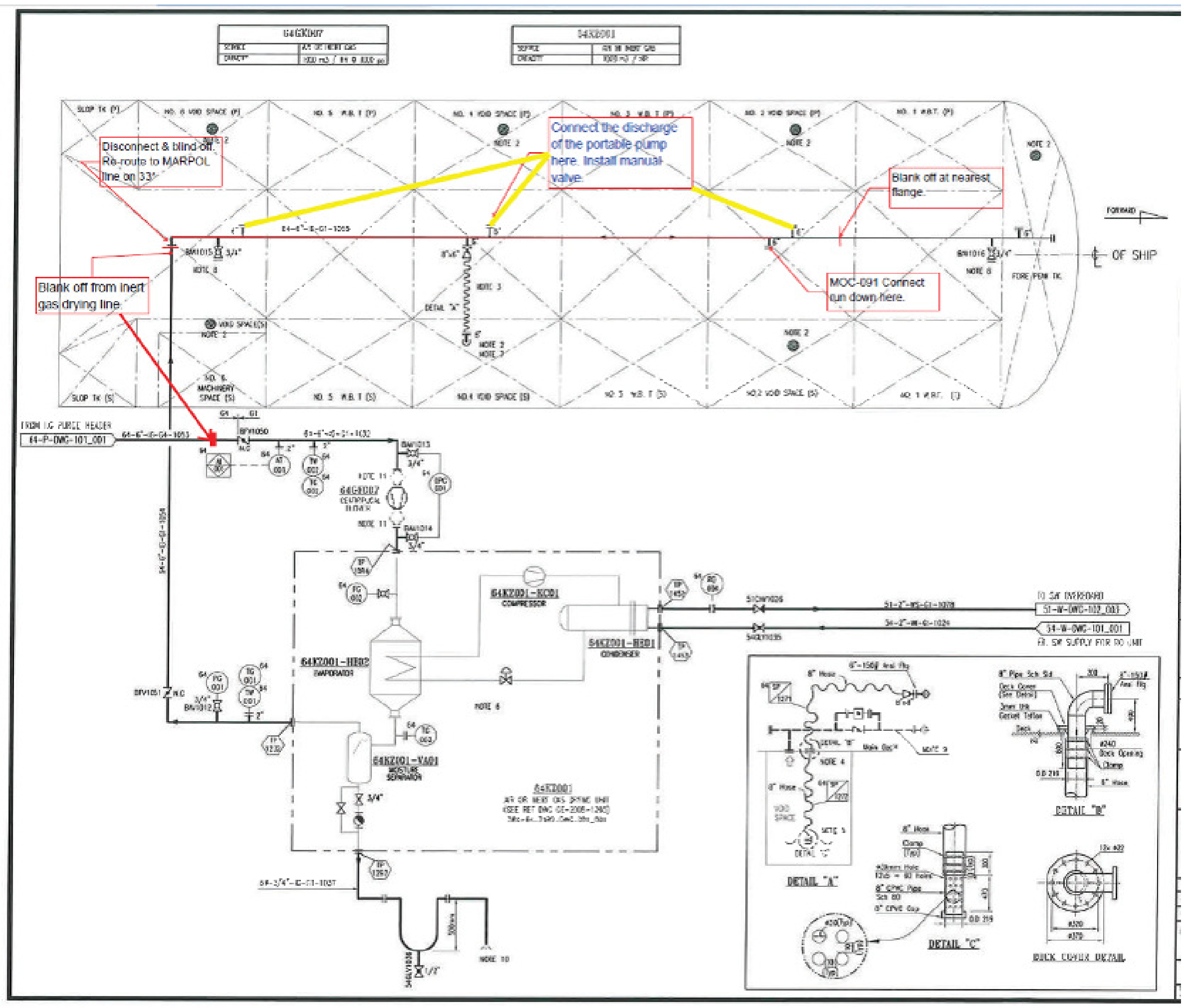

Figure 77 - P & ID with connection of submersible pumps with temporary line

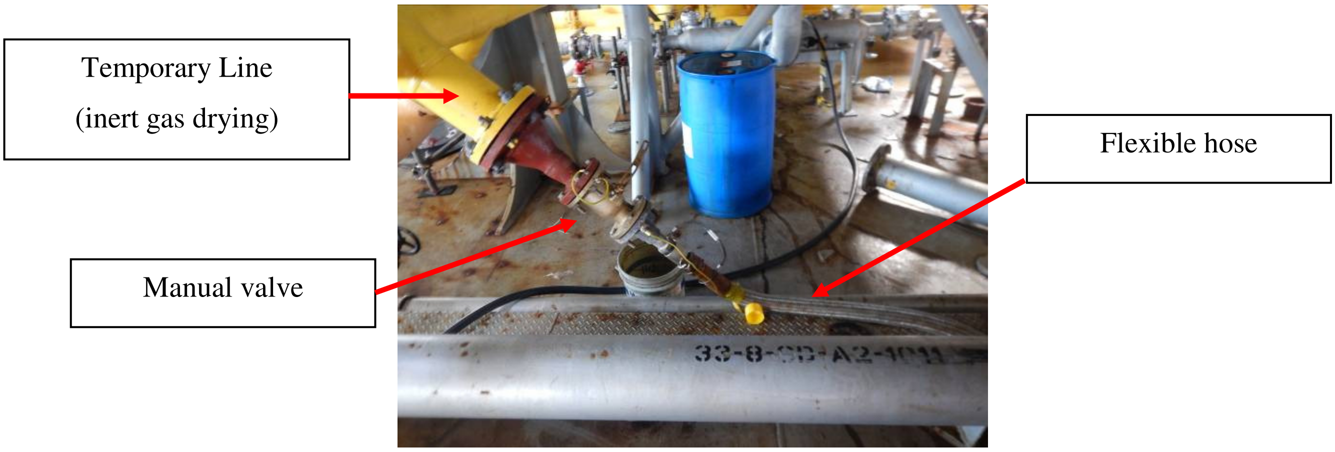

Figure 78 - Connection of submersible pumps with inert gas line

For emptying the port slop tank, would be used to pump stripping with alignment with OP-038, located in-line separate from the headers that contain faulty valves.

In order to prevent a counter flow during the use of the stripping pump, or prevent the contents of the tank port slop tanks were to 2C to 5C[87], It was installed a check valve (check valve) in the temporary line (inert gas drying line). In the check valve, a manual valve in the temporary alignment was inserted, which prevented the production 6C reached the drying tank by the inert gas line.

Then, for emptying the slop tank port to the tank 6C, it was not necessary the use of inert gas drying line, for the entire transfer would be in line inside the tank and pump house using valves OP-038, OP-071, OP-079 e OP-085. The OP-084 should guarantee the proper tightness in order to condensate material not to pump back to the proper port slop tank.

[87] Annexes to Modification Request, Modification Notice & Deviation Request – Modification of Condensate Run Down Line – Doc. n° MOC-CSM-091 – Issue Date: 24/12/2012

Figure 79 - Check valve which was installed (the line removed after the accident)

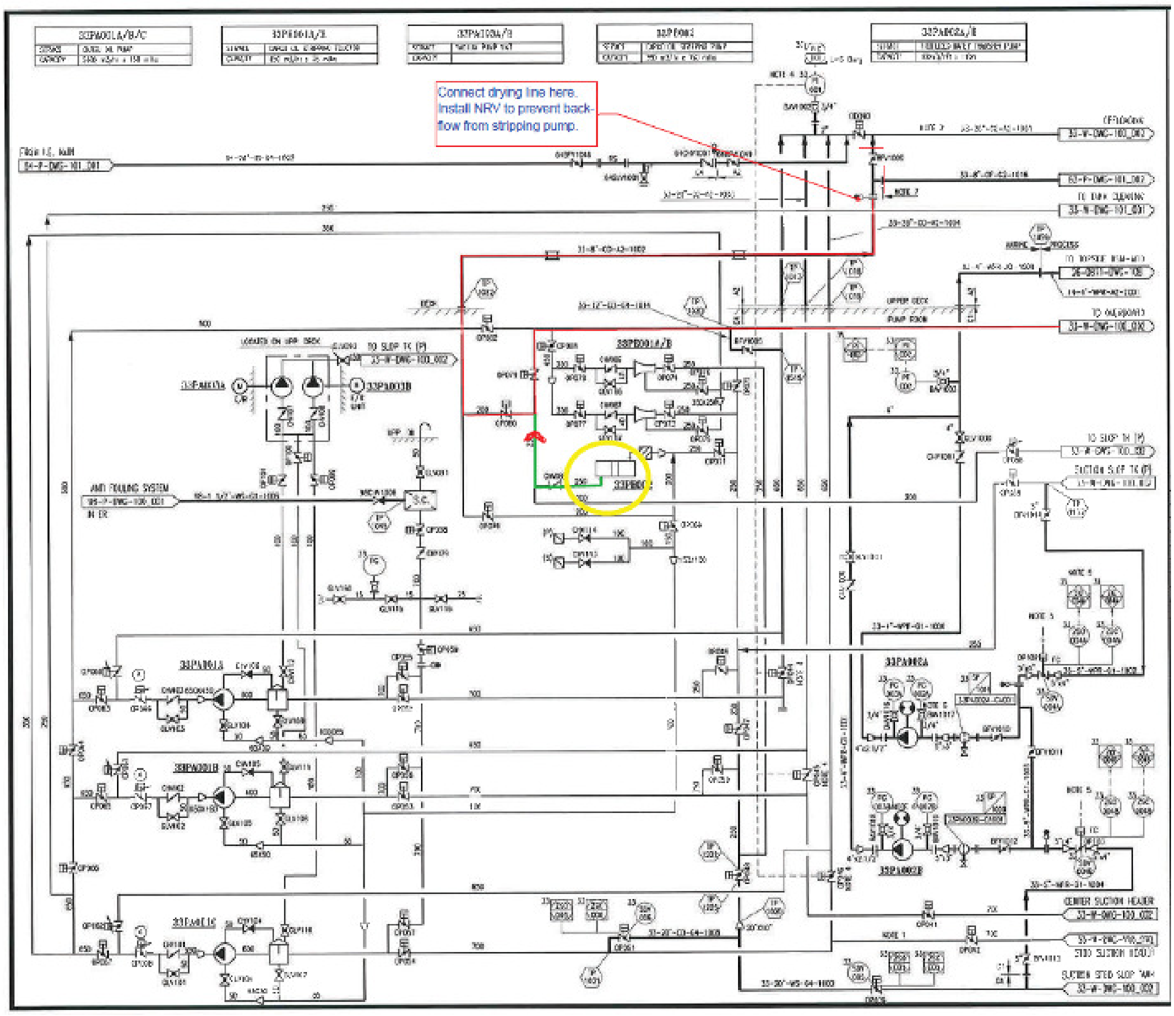

Figure 80 - indication of the need for the check valve installation [88]

Change management for alternative alignment fixture to 6C tank contains diagrams (P & ID) and photos with markup in which contained indications of insulation, connection points, installation of pipes and accessories. Thus it was prepared planning for entry into tanks 2C to 5C and slop tank port. Figure 81 shows schematic drawing containing bonding scheme.

[88] Design mark, annex to Modification Request, Modification Notice & Deviation Request – Modification of Condensate Run Down Line – Doc. n° MOC-CSM-091 – Issue Date: 24/12/2012.

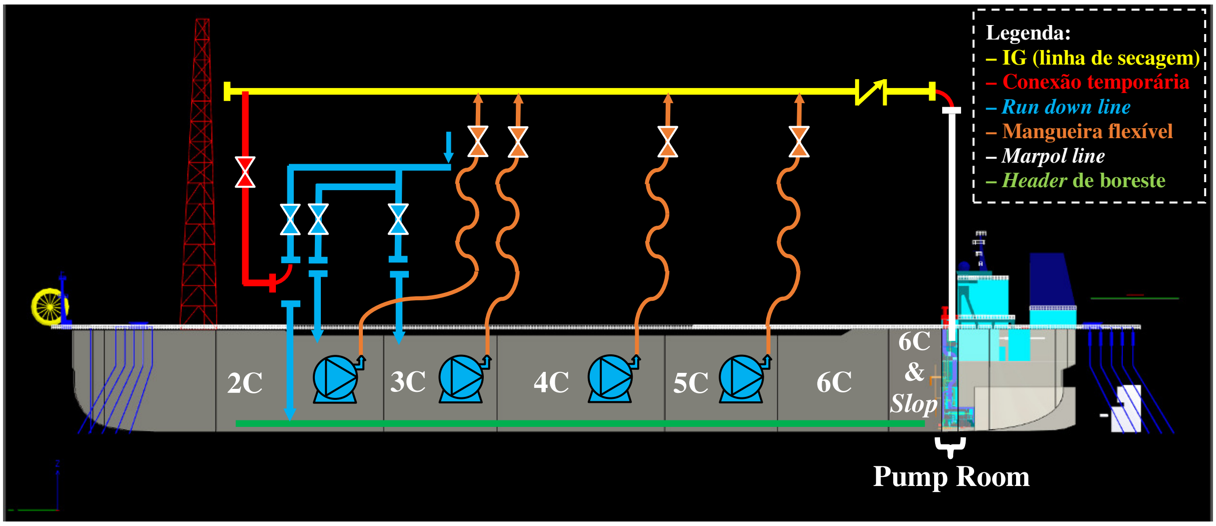

Figure 81 - Wiring plan, MOC-CSM-091[89]

However, there is no task scheduling description, modifications and isolates was registered with the MOC-CSM-091 to allow entry into the tanks and slop 6C starboard. In no other document was the description of such planning. In addition, it is emphasized that the MOC-CSM-091 in fact been issued for entry into the slop tanks 6C and starboard. As nothing was described on the tasks required for emptying the tank 6C and slop starboard, it was expected that the emptying of these tanks occur by traditional methods, ie through offloading, transfer between tanks by gravity or with the pump job and the line own drive system.

In turn, the change request for the installation of manual valves (MOC-CSM-069) was recorded in November 2013 that the discovery of aromatic content (BTEX - benzene, toluene, ethylbenzene and xylenes) in the stored condensed the FPSO CDSM demanded a reassessment of the change of plans so that only two valves were installed to allow the separation of slop tanks P (port) and 6C tank and prepare for future interventions in cargo tanks.

On this occasion, it was indicated that planning for intervention in the system that had lasted for a long time, has been changed so that there was an exchange of shaft seals (seat rings) valve to a more resistant polymeric material to chemical attack caused by presence of high levels of condensed aromatics in the unit.

[89] Source: Petrobras, adapted by ANP

In November 2013[90] the planning to install two valves was postponed and the first exchanges of system valve seals, being followed by a campaign of exchange of valve seals were made. This campaign was initiated by the interior of the pump house, providing the possibility for the board to create personal routes for condensate flow and isolate parts of the system, making it possible to perform interventions and other regular maintenance activities. Some of shaft seals (seat rings) are replaced shown in Figure 82.

Figure 82 - Some of the shaft seals (seat rings) substituted with the goal of correcting the problems of the charging system valves.

Figure 83 shows the result of the exchange of sealing seals service.

[90] E-mail between the marine superintendent and process engineer, dated as of 23/11/2013, annex to Modification Request, Modification Notice & Deviation Request - Install manual butterfly valves in pump room on Cargo System - MOC-CSM-069 – Issue Date: 10/12/2011.

Figure 83 - Left, valve seat ring degraded and right valve seat ring replaced.

The plan to install manual valves postponement was due to the inability to perform the activity without emptying and degas the adjoining tanks in performing the activity. For such was contemplated including the use of positive pressure ventilation generated by the pump house and the use of self-contained breathing apparatus for the maintenance team. However, this activity was considered high risk and was not approved.

In 04/02/2014, the marine superintendent added to the change of management of content MOC-CSM-091 that in order to prevent condensate migration to the tanks by headers collectors, the seat rings were replaced from the following valves as per Viton Material: OP-070, OP-077, OP-078, OP-079, OP-080, OP-081, OP-082, OP-084, OP-085, OP-064, OP-065 and TCV-002.

In this case, the marine superintendent also mentioned the difficulty of changing the shaft seals (seat rings) of OP-068 valves and BFV-1005 and therefore spades were installed[91] these valves as a way of isolating the same.

During the investigation it was shown that the exchange of the seal of OP-068 valve seals was not implemented due to the liquid level inside the port side slop tank overcome the valve elevation degree.

In addition, there is sufficient evidence to state that the spades installed to insulate the OP-068 valves and BFV-1005 were not appropriate to the service, because in the FPSO CDSM operations had

[91] Cold Work Permit n° 34850 – Issue Date: 12/01/2014 (pg. 281)

control failure in the inventory management of spare parts, practice to manufacture racquets on board[92] and lack of foresight in off project for spades installation in the cargo transfer system [93].

The flange connection in which was installed the spade for the insulation of OP-068 valve was condensed leak point in this accident. During the investigation of the ANP, after the accident, there was high risk of removing such a spade in the situation where the FPSO CDSM was. Thus, the ANP did not have access to the spade and the analysis of the piece in question properties will be made as soon as made available by the companies involved. The outlook for business is that the withdrawal of the spade occurs when the unit is under cross docking, as the situation has not been scheduled to occur.

Figure 84 - Spade installed for valve insulation OP-068

[92] Item 3, 8th comment of Rotation Handover Report – Marine Superintendent – Doc. nº MS-20082014 – Issue Date: 20/08/2014

[93] Item 15 (Insulation Philosophy) from Process Engineering Design Criteria – Doc. n° 384-20-DOC-001 Rev. 0 – Issue Date 26/11/2008.

Figure 85 - Spade installed for valve insulation BFV-1005

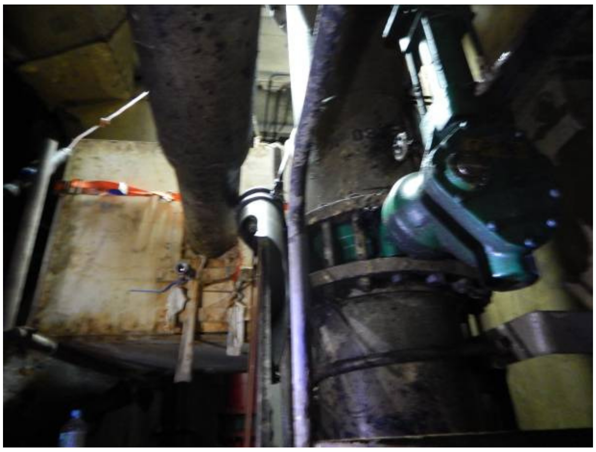

Figure 86 - Insulation (post-accident) in concrete box around the spade to installed valve insulation OP-068

It adds that, although the installation of spades for insulation of OP-068 and BFV1005 valves were registered in the drawing to change management MOC-CSM-091, such insulations were recorded in long-term insulation of control[94]. It is analyzed below in detail as were the controls and the procedures set out guidelines for insulation systems and insulation control long-term FPSO CDSM.

[94] Long Term Insulation Register, valid as of 11/02/2015

6.6. Installation issues on spades in load storage system

BW had a procedure for the mechanical installation of insulation[95]. The procedure requires that all mechanical insulation should be documented in Mechanical Insulation Certificate and that all insulation certificate should be accompanied by flow charts pipe (P&IDs) with insulating points properly indicated.

The insulation field certificate contained in the description / include: (i) requesting, (ii) the work permit number associated, (iii) design of the area where the insulation occur; (iv) the equipment to be isolated; (vi) insulation of the subject; (vii) the authorization and approval; (viii) insulation medium (blind flange, spade, figure 8, etc.) and insulation sequence.

Another requirement of the procedure was that the process line should be inspected to confirm that the P&ID reflected faithfully the physical configuration of the insulation, the modified design should be submitted to IOM for approval and, following approval, the P & ID should be forwarded to the corrections "as built" (as-built). In addition, the insulation certificate should always accompanied by the respective valid permission. The mechanical insulation procedure defined four methods not approved insulation (via check valve, pressure relief valves, valve "open failure" and control valves) and three possible methods of insulation:

- Method 1 as of single and drain block;
- Method 2 as of double and drain block; and
- Method 3 as of positive insulation.

For method 3, positive insulation, it is stated that:

> *"This is the highest standard of insulation, performed by the installation of plates or blind flanges or by removing a short section of the pipe and the installation of blank flanges".*

Specifically on the method 3, the procedure mentions that the following points should be taken into consideration while conducting positive insulation:

(i) All the blank flanges and gaskets must be specified for flange class;

(ii) All blank flanges and gaskets are made from material appropriate for the application (e.g. lines with acid products etc.); and

(iii) The thickness of the flange is according to the document: Calculation of Blank flange.

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95 PTW System – Procedure – Insulation – Mechanical – Doc. n° MS-PR00840 Rev. 1 – Issue Date: 07/08/2013

Although there is mention of a document "Flanges Calculation Blind," there was no field work permit application or the mechanical insulation certificate that made reference to the need to calculate or specify the spade to be installed. According to testimony, there was no requirement on board the FPSO CDSM to the record in the work permit (PT) the defendant's pressure rating for the paddle and the executor of the work permit, after approval for execution of the service, should look to pressure class pipe to choose the spade or request its manufacture.

It must be noted that, according testimonials, there were few spades available for standard flanges JIS (Japanese Standards Identification), the most common type for flanges and fittings of the FPSO CDSM charge transfer system. There is evidence, as in marine service overseer crossing report[96], that is commonly make such type of board the spade in the workshop when máquinas3 court was not a spade. It is noteworthy that there was greater availability of standard spade ANSI (American National Standard Institute), which was the most common type of connection to the other drive systems.

The mechanical insulation procedure considered that the insulation of ballast / cargo tanks it was a critical and complex activity. In this case, an additional permission, specifically for the insulation of activities could be considered during the working meeting of risk analysis (JSA - Job Safety Analysis).

As for the selection of the insulation method to input service cargo tank, was setting the method 3 (positive insulation) should be adopted for deck lines and Method 2 (double block and bleed) should be used for bottom lines of charge transfer system. As for the length of a mechanical insulation for longer time the validity of seven days of a work permit, there were two possibilities:

(i) To issue new work permit immediately after the expiration of the initial permission and in this case, the procedure stated that the insulation certificate could be transferred to the new work permit; or

(ii) To register the mechanical insulation in Long Insulation Control Duration (LTI).

The Long Last Insulation Control Duration (LTI)[97] It had a procedure on requirements in order to verify that the insulation were working as insulation certificate, check that locking devices and warnings were running in good condition, and to inform the crew about the LTIs.

[96] Item 3, 8th comment of *Rotation Handover Report – Marine Superintendent* – Doc. nº MS-20082014 – Issue Date: 20/08/2014

[97] System PT - Sub Document - Long-Term Insulation – Doc. n° MS-PR00847 Rev. 02 – Issue Date: 07/01/2015

The installation of the spade (positive insulation method) in January 2014 in a position upstream of the OP-068 valve, namely, the point of leakage, contrary mechanical insulation procedure, which provided the insulation method of double block and bleed for the bottom lines of charge transfer system.

On the occasion of the installation of the aforementioned spade, was issued a work permit, with mechanical insulation certificate[98] and certified instrumentation and control system insulation[99] attached. The three documents had the same title: "install spade in OP-068."

Insulation certificate instrumentation and control system referred to the insulation of the five gas detectors pump house, in order to facilitate the installation of the spade. In turn, the mechanical insulation certificate referred to the closing of the OP-079 valve, OP-080, OP-071, OP-069, OP-083, OP-084 and PB-085, all the suction and discharge stripping pump, in order to facilitate the installation of the spade.

The P&ID[100] accompanying mechanical insulation enhancement certificate contained in said valve, but not the racquet indicated position, upstream or downstream of OP-valve 068, as shown in Figure 87.

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[98] Insulation Mechanical certificate No. 20101 of 12.1.2014, attached to the Work Permit (Cold Work Permit) No. 34850 - Issue Date: 01/12/2014

[99] Insulation System certificate Instrumentation and Security Control No. 20403 of 12.1.2014, attached to the Work Permit (Cold Work Permit) No. 34850 - Issue Date: 01/12/2014

[100] P&ID Cargo System in Pump Room – Doc. n° 383-33-W-DWG-100_001 Rev. Z, attached to Cold Work Permit n° 34850 – Issue Date: 12/01/2014

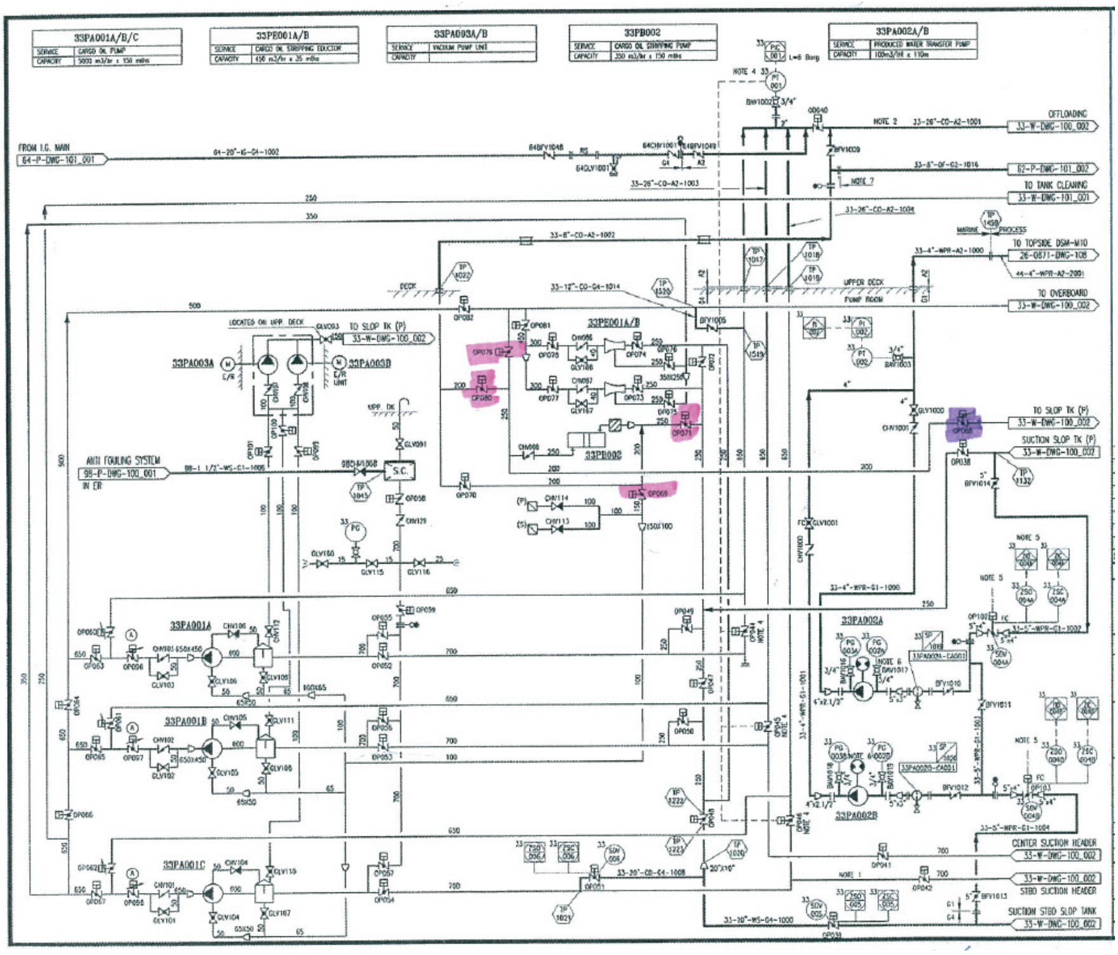

Figure 87 - P & ID marked, but without the spade identify the amount of OP-068

However, no certificate has been issued considering the spade itself as a mechanical insulation. Ie the spade itself was not recorded in the sequential list of insulation Mechanical insulation certificate issued, as shown in Figure 88.

MIC No.: 20101

MECHANICAL ISOLATION CERTIFICATE

1. Isolation requested by: [redacted]

2. Initial / Subsequent Permit No.: CWP 34850

3. Drawing No.: 384-33-WS-DWG-100-001 / 384-33-WS-DWG-100-002

4. Equipment to be Isolated - Tag No.: OP068

5. Reason For Isolation: Install spectable blind in OP068
Instalar raquete na OP068

6. Authorize and Approval | HOD of the system | I have reviewed and approved this certificate and authorize isolation to proceed.

Name: [redacted] Sign: [redacted]

7. Isolation

Key Method	(A) Immobilization	B. Block	C. Bleed
D. Spade	E. Spectacle Blind	F. Blind Flange	G. Spool Disconnection

Seq. No.	Isolation Point Tag No.	Normal Position	Isolated Position	Method	Isolated SR	Field Key No.	Checked WRP	Control Key No.	EFT HOD	De-isolated SR	Checked HOD
01	OP079	CLOSED	CLOSED	A							
02	OP080	CLOSED	CLOSED	A							
03	OP071	CLOSED	CLOSED	A							
04	OP069	CLOSED	CLOSED	A							
05	OP083	CLOSED	CLOSED	A							
06	OP084	CLOSED	CLOSED	A							
07	OP085	CLOSED	CLOSED	A							

Figure 88 - Mechanical Insulation Certificate, no spade ID in the sequential list

Therefore, when the spade install the final, on 01/13/2014, both the work permit as both insulation certificates were closed. Thus, the Long Insulation control Duration (LTI) was not duly updated because there is no insulation certificate considering the installed spade.

Another document that has not been updated considering the installation of the spade was the P & ID, which, according to procedure, should have been updated to include the changes made (as-built) and duly approved.

Meaning that the marking of the location of the spade installation was only made in the P & ID attached to the change management process MOC-CSM-091. Such marking was not done in P & ID accompanying the certificate of insulation, either in the design made available to the general staff through the computerized system for documentation management.

6.7. Repair execution of the storage system valves in the load tanks inlet

In 2014, after about two years since the first identification of problems in the storage system valves, which had fluid passage even when in closed position, the problem had already reached advanced level of system degradation, becoming a widespread problem the storage system valves. Even in this context, it was decided to maintain production while isolating the tanks to entry for service. According to records of the BW, only 6C tank valves had no such problem[101].

In April 2014 opened a new change request (MOC-CSM-129), registered as a client request (Petrobras) for the exchange of the seals of the valves of the cargo tanks, the pumps and the deck house were executed main.

The new seals should be made of other material, Viton (fluorine elastomer) instead of NBR (Acrylonitrile Butadiene Rubber) material used in the valve system loads since its construction.

In describing the MOC-CSM-129 change management were identified all valves whose shaft seals should also be replaced. You can see that this relationship valves were not in the OP-068 valves and BFV-1005 pump house or the OD-043 and OD-044 valves of the main deck, which during the investigation[102] found to have been treated for an oversight.

Such modification was approved for implementation in June 2014. However, the exchange of campaign Stamps storage system valves also began in early 2014 and no further evaluation was done within the change management process by security personnel and engineering.

To implement the plan of insulation tanks, 01.04.2014, the produced condensate began to be exported by the natural gas using the pipeline connected to the unit. On 02/04/2014, the offloading was performed, with a consequent reduction of the levels of tanks 2C, 3C, 4C and 5C[103]. Between 04/09/2014 and 04/21/2014, the annual shut down for maintenance was carried out, which was not in its scope the exchange of sealing valve seals.

On 04/24/2014 alignment planned in MOC-CSM-091 was completed. From this same day we began the transfer of the content is left in the tanks 2C to 5C after offloading to 6C tank.

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[101] Modification Request, Modification Notice & Deviation Request – Modification of Condensate Run Down Line – Doc. n° MOC-CSM-091 Rev. A – Issue Date: 05/10/2014

[102] Interview with marine superintendent. Information collected together the representatives of BW and Petrobras for inspection activities conducted by ANP in the CDSM and FPSO BW's office in Vitória in between 13 and 17/07/2015

[103] Offloading History - FPSO Cidade de São Mateus

During the transfer was Necessary to gather and further decline of submersible pump in the tank for several Reasons and on 05.31.2014 was started inserting water in the tanks, provided for in the change management MOC-CSM-091. During this period, at least in days 29/05/2014, 08/06/2014 and 05/07/2014 and the production was directed to 6C tank.

In 06/15/2014 was recorded emptying the slop tank port to 6C tank, as planned in the change management, i.e. using the stripping pump.

In the days 09/07/2014 and 12/07/2014 were recorded Confined Space Entry in the port slop tank, having yet registered for the day 29/07/14 the repair of valves slop tank port was completed, test with "OK" the OT-041 valve. The T-valve 023 was tested on 27/07/2014.

On 08/04/2014, the closed and open drains that were aligned to starboard slop tank, due to the insulation port slop tank, they could be returned to normal alignment, i.e., to port slop tank. On the same day moved slop water from starboard to port side slop.

On 11/08/2014, he started to use the stripping pump to move the water from the starboard slop for the slop of port. In 08.13.2015 started the process of making the slop of free gas starboard (gas freeing). On 09/02/2014 it was announced that the inserting of slop starboard was completed.

On 26/08/2014 there was a return of production to the tanks, with the condensate export and stop before the end of repair of the valves of the tanks 2C to 5C. It is noted in passing service between marine superintendents on 20/08/2014[104] mention to customer pressure (Petrobras) and Operations Manager (BW) so that production back to be stored in tanks 6C and 2C. In this same passage service it was announced that the port slop tank had problems, with migration of content to 5C, even after the renewal of the valves OT-041 and OT-023 port of the slop tank.

Additionally, it was registered in the same passage of service valves and couplings Dresser of 2C and 3C tanks had not yet been repaired. So while the repairs were not completed and problems were also identified in the repaired items, it was decided to return to the condensate storage on the ship, disregarding the initial planning done to repair the valves before the condensate storage return in cargo tanks.

In 03/09/2014 was recorded test valve 3C of the tank, wherein the valve OT-004 did not respond to commands of CCRM or the local command. Manual pump use was required. The OT-029 valve would not close completely the CCRM, only through the local command.

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[104] *Rotation Handover Report – Marine Superintendent* – Doc. nº MS-20082014 – Issue Date: 20/08/2014

On 08/09/2014 the production happened to be directed to the 2C tank and on 11.9.2014 was directed to the 3C tank.

On 13/09/2014 the check valve installed in the inert gas drying line is reversed by setting a modification in relation to the MOC-CSM-091. In the marine superintendent of the Service Form November 2014[105] was recorded 6C that the tank had to be loaded (condensate production), then the line check valve MOC-091 should be inverted. Since then, the flow direction changed to the opposite in inert gas drying line, that is, through the course of the pump house to the cargo tanks, as illustrated in Figure 89. This change to the management MOC-CSM-091 change was made without hazard assessment and the overall impact on activities before implementation. The operation performed on this day was the use of stripping pump for transferring the contents of the slop tank port to 3C tank, by opening the valve in the OD-043 line run down.

Additionally, it was found that, during and after repair of the valves of the tanks 2C to 5C and slop tank port, activities were carried unplanned changes that used in relation to own MOC-CSM-091[106], distorting the originally intended use of the alternative alignment installed.

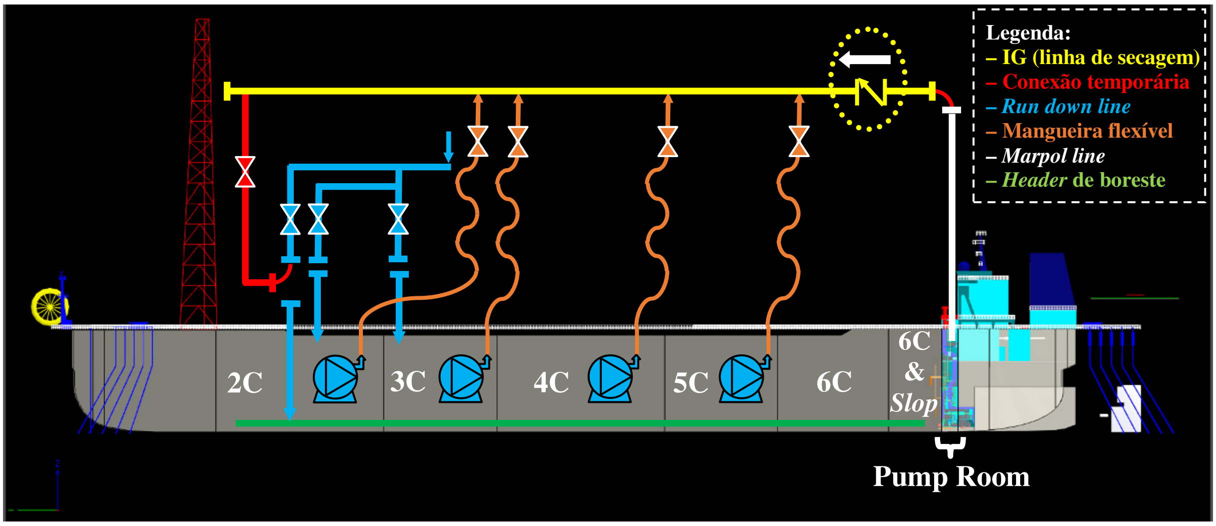


Figure 89 - Change in the MOC-CSM-091

Important to note that the demand is maintained to proceed to the emptying port slop tank, valves which had been repaired but has problems remained. Another aspect observed was that for carrying out the emptying of the slop tank port was decided to use the inert gas drying line in a direction opposite to the planned on MOC-CSM-091 instead of the alignment performed earlier to take the

[105] Rotation Handover Report – Marine Superintendent – Doc. nº MS-19112014 – Issue Date: 19/11/2014

[106] Cargo log book (cargo log book – marine department)

contents of the slop from port to 6C tank, using a pump stripping, with alignment only by lines and valves inside the pump house, as planned in the MOC-CSM-091.

The following day, 14/09/2014, started the inverting process slop tank port. In 19/09/2014 and 25/09/2014, there record of the stripping pump was used again to remove contents of the slop tank port through the inert gas drying line and opening the valve OD 043 run down the line.

In late September the stripping pump could not be used due to failure to provide steam. Only in late October 2014, the stripping pump was again used to remove the contents of the slop tank port. On 31/10/2014, there was record of a purge of slop tank port and the next day, the tank was measured and recorded as dry. On 11/03/2014, there was water transfer Registration 6C tank to the slop of port. In the marine superintendent service day pass on 19/11/2014[107], it was announced that "try to purge and make the slop tank of gas free port, but the OT-037 and OT-040 are giving way and hydrocarbon gas entered the port slop tank". It was also recorded in this same passage service the starboard slop tank still needed to seat rings replacement on its valves.

At the end of the transfer 6C water to slop port from the stripping 04/11/2014 pump was used to transfer condensate 6C to 2C, using alternate alignment of MOC-CSM-091.

08/11/2014 6C in the tank was reported empty and the stripping operation has ended. However, the day after stripping pump again used for the same operation, ie transferring the condensate to 2C 6C, by means of inert gas drying line. Also on 09.11.2014, the starboard slop tank was emptied with the stripping pump and registered as empty. On 11.12.2104 was recorded early purge the starboard slop tank. Therefore, 6C tanks and slop starboard were being emptied, while the MOC-CSM-091 had not been issued providing this task.

Even after emptying the tank 6C, on 11.12.2014, no employment record of stripping pump transferring contents of the slop tank port to 6C tank. However, this time we used the alignment inside the pump house with the aid of OP-085 valve.

Only on 21/12/2014 was recorded entering the 4C tank for final inspection and 25/12/2014 5C tank returned to store condensate, condensate and received the 2C and 3C tanks.

In early January the stripping pump was again used to transfer 6C content to 2C by inert gas drying line and also to empty the slop tank starboard.

Besides the new attempt to empty the tank 6C and starboard slop tank started emptying the slop tank port, which presented problems as previous service passage reports. It turns out that with the simultaneous deflation of the two slop tanks, the unit needed to direct the drains elsewhere, which was

[107] *Rotation Handover Report – Marine Superintendent* – Doc. nº MS-19112014 – Issue Date: 19/11/2014

held on 12/01/2015 for the 4C tank. This is another change that took place without prior assessment of hazards and global impact on activities.

The contents of the port side slop tank was being directed to the tank 4C using the stripping pump and, therefore, it was necessary to use the washing line 4C tank (4C aft COW line). This alignment with COW line with installing insulation to isolate the 4C of other tanks, shown in the following figures, is yet another modification that occurred without prior assessment of the dangers and the overall impact on the activities, i.e., without using the tool change management.

Figure 90 - Flexible hose connection points between closed drain and 4C aft COW line

Figure 10 – Insulation of 4C *aft COW line*

It was shown that in this period in January, the situation of use of inert gas drying line connected to 4C tank as well as the direction from the drain to the 4C tank was as follows.

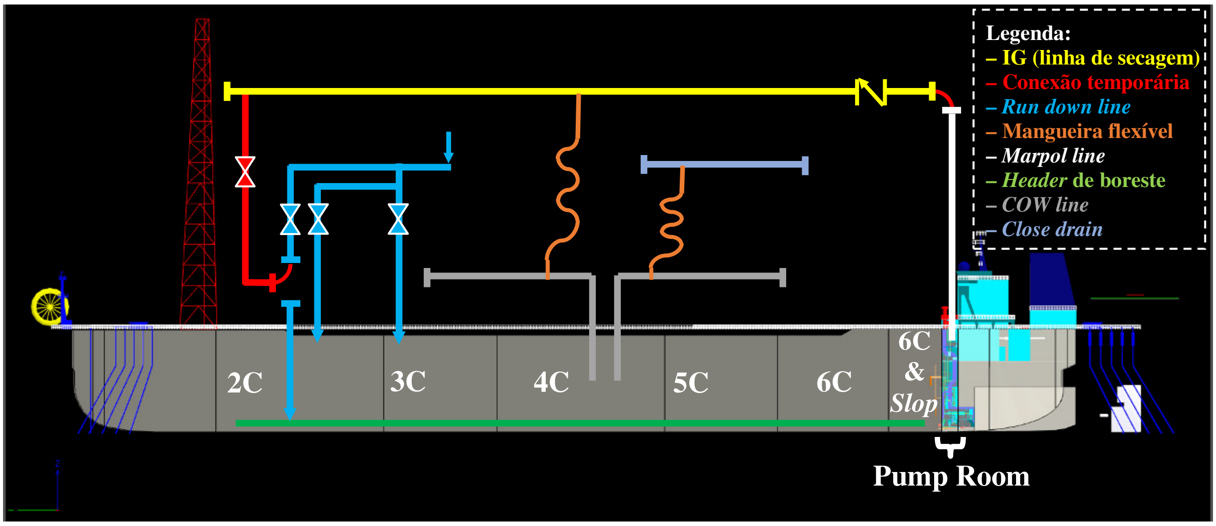


Figure 92 - Wiring diagram of flexible hoses to the tank 4C

As evidenced in audit, on 17/01/2015 it was started this a try operation 6C empty the tank through the condensate vaporization. This shutdown was initiated due to the difficulty to empty the tank with the stripping pump. The objective was to heat the water inside the tank 6C utilizing the existing steam line within the tank. This operation was evidenced by the early 6C tank temperature record in office log book to book, which so far contained no temperature record in this tank.

Figure 93 - Valves in the upper deck of the heating line (steam) of 6C tank

The expected result was that the condensate layer above water was sprayed at about 35 ° C. Vapors were continuously vented by the vent riser (shown in Figure 94) daily, the day shift, with inhibition of gas detectors on the main deck, in the area near the exit of the vapors. The scheme used to blow the gas is shown in Figure 95.

Figure 94 - Vent riser, the ship's starboard side

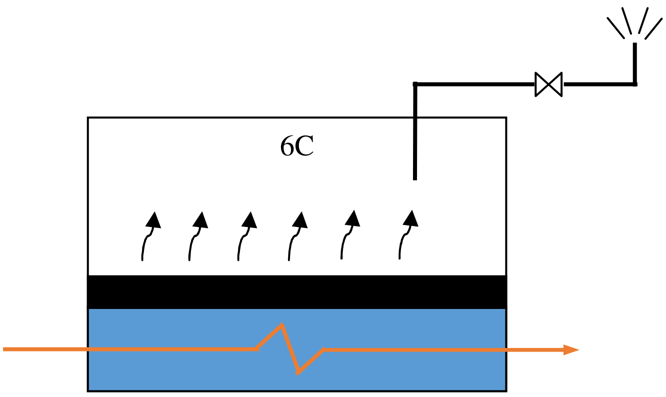


Figure 95 - Simplified scheme condensate vaporization operation

This task was also not assessed by change management and was not part of MOC-CSM-091 records. On the day of the overseer service passage 21/01/2015 this operation were recorded, there was approximately 130m3 condensate, and that the temperature should be maintained at 35 ° C, with the recommendation that did not exceed 40 ° C.

Between 20/12/2014 and 31/01/2015, the unit had been no marine superintendent, getting the marine operator accumulating its function with the superintendent. Thus, vaporization operation was delivered in progress to other marine operator on 21/01/2015.

The service crossing report there was mention of the alignment of the drain closed for 4C tank. A flexible hose line between the inert gas drying and other cleaning line (line COW) 4C tank for water transfer purposes to 4C tank was also registered in the service passage report has been installed. However, it was not registered, the reason these alignments, such that the ratio has not been registered to have the two slop tanks out of operation.

Not to mention as listed service crossing report the difficulty of making the slop tank of gas free starboard, such as hydrocarbon levels not lowered. There was an attempt to purge the two slop tanks simultaneously, but without success. It should be noted that in previous service passes, had already been registered difficulty in relation to purge the slop tank port.

In 20/12/2014 was recorded in the service passage that slop tank port was not fixed, to avoid using the port side bottom header to transfer load, since the load migrate into the slop tank port. However, this information was not kept in the day of the service pass 21/01/2015.

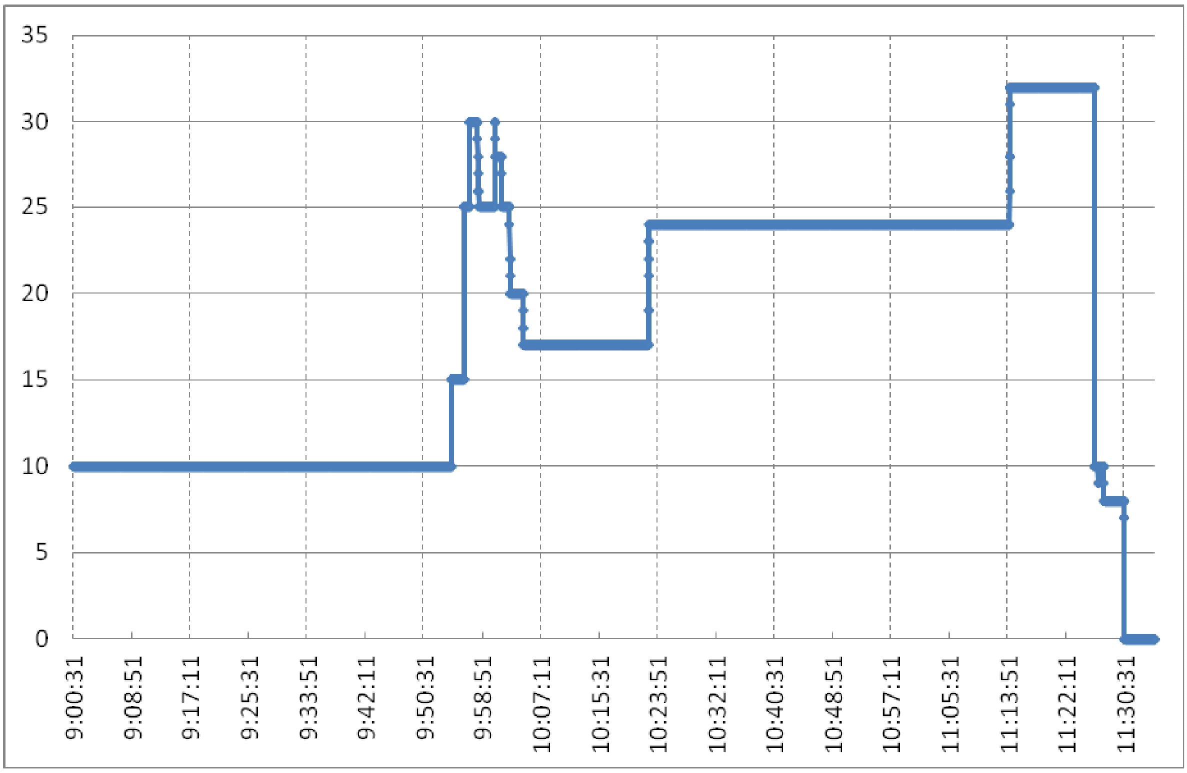
Anyway, on 23/01/2015, there was use of stripping pump to transfer the cargo port of slop to 6C tank. On this occasion, the slop tank port was measured with gap (ullage) of 22,09m height, and the tank has a height of 30m order of magnitude, i.e. there was a significant content in this tank. Therefore the slop tank port has already been put into use after two days of service passage.

After repeated unsuccessful attempts to vaporize the condensate tank 6C, in the days 02.05.2015, 02.09.2015 and 02.10.2015 the stripping pump was used to transfer 6C contents into the slop tank port.

Although there offloading schedule for the month of February and despite all the difficulties encountered in a complete draining of 6C tank during the month of January and early February, the team on board was still trying to empty the 6C tank on 11/02/2015, date of the accident.

The only written record in the book of marine department records for the day 02/11/2015 was the starting information of stripping pump to 9:50 a.m. the morning. Described "early stripping pump to drain the header port" (start stripping pump to strip port header). In depoimento3, drainage was reported that this was necessary because of the day before the line have been used to transfer water by gravity from the tank to 5C slop tank port, as written in the marine department logbook.

According to digital information recorded by the supervisory system, on 02.11.2015 the supply of steam for stripping pump was started at 09: 00 am, with an opening percentage of the control valve by 10%, as shown in Figure 96 as follows.



Between 20/12/2014 and 31/01/2015, the unit had been no marine superintendent, leaving the operator.

Also according to the information saved by the supervisory system before the opening of the control valve is adjusted to 10%, around 08: 53h, there was alignment of the discharge of stripping pump for slop tank port (opening of OP-079 valves and OP-084) and alignment suction pump for stripping 6C tank (OP-opening valves 041, PB-050, PB-047 and PB-071). Remember that this alignment for emptying the tank 6C had been tried unsuccessfully in January.

Thus the content of 6C tank was transferred to the slop tank port during the morning of 02.11.2015, until 11: 27h, when the suction and discharge were closed (closure of the OP-041 and OP-84 valves) with the pump still operating, 7% and 8% opening of the steam control valve.

In deposition, it was reported that there exchange header used in the suction port slop tank and exchange alignment 2C discharge into the tank. The new alignment of the suction involved the opening of OP-042 valve. Meaning that the OP-042 valve was operated by pumping outside the marine control room (CCRM), but marine operator informed the supervisory system when the valve opening. There is no record of the opening OP-042 in the supervisory system for the day 11/02/2015. The new alignment on the discharge pump would use the stripping inert gas drying line. Remember, the alignment of 6C tank discharge into the tank 2C using the inert gas drying line had already been tried unsuccessfully in January. To align the exhaust stream of stripping pump, one of the necessary maneuvers was the opening of OP-084 valve for marine operator in CCRM, but there was no record of this opening in the supervisory system. Also, to use inert gas drying line, pumping should open the manual valve to the main deck.

In testimony it was reported that at the end of the attempt to empty the tank 6C to the slop tank port on 02.10.2015, by identifying loss of efficiency in the transfer, it was thought that there would be leakage into the slop tank port for the header port. It is worth mentioning that on the marine superintendent of service crossing report 20/12/2014[108] It was reported that if the slop tank port was not fixed, then it was necessary to avoid the use of port side bottom header to transfer load, since the load migrate into the slop tank port. However, this information lack of tightness between the slop tank port and the port's header was not passed in the service passage occurred in January.

[108] Rotation Handover Report – Marine Superintendent – Doc. nº MS-20122014 – Issue Date: 20/12/2014

7. Causal factors and root causes inured by the accident

To identify causes of the accident, we used the methodology of identification of causal factors using fault tree and, subsequently, identifying its root causes using the root causes of map-related SGSO requirements, as it presented in the Integrated Operational Safety (SISO) and as indicated practice of Guidelines for Investigating Chemical Process Incidents (AIChE, 2003).

Causal factor is any negative occurrence or unwanted condition that would, if eliminated, would prevent the occurrence of the incident, or reduce its severity. In turn, the root cause is the absence, negligence or deficiency of management systems that enabled the occurrence of equipment failure / systems; and / or determining human errors investigated for the occurrence of the incident.

The event was considered condensate leak followed by explosion in FPSO CDSM the pump house that caused the death of nine people twenty-six wounded, seven serious damage to the installation, partial flooding and interrupting the production of two production fields indefinitely without damage to the environment.

For the accident FPSO Cidade de São Mateus, Figure 97 represents the sequence of causal factors identified in this investigation. For a better understanding of the public not knowing the SGSO, the root causes have been reported both in general appearance (proximate causes), as related to SGSO requirements (root causes), with the respective item infringed management indicated in bspades .

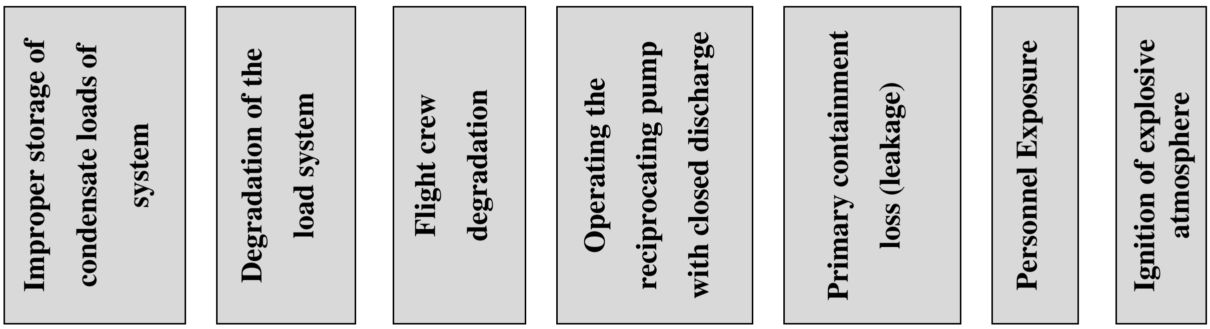


Figure 97 - causal factors of the explosion accident in the FPSO City of St. Mateus on 11/02/2015

7.1. The timeline of the accident

Table 10 and Table 11 presents the decisive events for understanding the causal factors and causes of the accident that occurred respectively before the day 02.11.2015, and this day.

Table 10 - Relevant events occurring before 11/02/2015

Date	Preceding Events and Conditions which could promote the accident
06/08/1998	Petrobras signs the Camarupim concession contract.
28/09/2001	Petrobras signs the Camarupim Norte concession contract.
10/08/2006	Petrobras issues the Technical Overview (General Technical Description - GTD) FPSO's CDSM with provision for the possibility of production of gas and oil. Condensate Storage forecast only if oil storage.
22/12/2006	Declaration of commerciality of Camarupim field.
22/01/2007	Forecast expansion of the UTG Cacimbas contemplated within the scope of PLANGAS.
16/04/2007	Prosafe (PRS) issues the first safety study of FPSO CDSM.
14/06/2007	PRS sends to Petrobras the preliminary report of the HAZOP scoped topside FPSO CDSM.
29/06/2007	Petrobras and Prosafe sign contracts for chartering and operation and maintenance of FPSO CDSM.
Outubro de 2007	Petrobras Prosafe refers to the possibility to stock only condensate without storing oil.
06/12/2007	ANP establishing the Operational Safety Regime for the publication of ANP Resolution No. 43/2007 establishing the Technical Regulations of the Operational Safety Management System (SGSO).
Junho – agosto de 2008	PRS agrees to operate in the early years the FPSO Cidade de São Mateus (FPSO CDSM) with the condensate storage without oil production. PRS obvious caveat that the condensate was exported by pipeline along with the natural gas processed by the unit.
21/08/2008	PRS delivery to the Emergency Response Plan of the CDSM FPSO for Petrobras.
02/09/2008	Petrobras declared the commercial viability of the North Camarupim field.
12/12/2008	PRS emits Safety Case for the FPSO CDSM, which consolidates all unit safety studies. This Safety Case was in effect on the date of the accident.

Date	Preceding Events and Conditions which could promote the accident
10/06/2009	FPSO CDSM starts production without the installation of the systems provided for in the project, such as strokes counter the stripping pump in the supervisory system of marine operator screen. The unit risk analysis has not been revised to incorporate the change in the allocation of condensate.
05/09/2009	FPSO's CDSM interconnection pipeline with the extension of Cacimbas UTG is commissioned. From this date the produced condensate happens to be exported by pipeline.
14/09/2009	FPSO CDSM stops the export of condensate through the pipeline. From this date, the condensate export becomes sporadic.
17/10/2009	PRS initiates change management in order to complete the commissioning of storage and ballast systems that were provided by project but were not installed. This change management was not completed by the date of the accident.
25/11/2010[109]	BW Offshore (BW) acquires the PRS, which does not start managing the changes resulting from the installation operator change.
25/05/2011	BW implements changes in the Operational Safety Management System FPSO CDSM due to the acquisition of PRS. Formal process of change management is not used.
10/12/2011	BW identifies problems in the storage system valves, which had internal fluid passage even when closed. Proposal for manual valves facility in order to establish Double locking.
24/12/2012	BW plans entry into tanks 2C, 3C, 4C and 5C for repair of valves and couplings inside the tanks. Highlighted the need to repair a widespread problem in the storage system, with the forecast of export condensate by pipeline during repairs. In case of problems in this export, planning includes the creation of an option for the condensate production could be allocated to 6C tank instead of 2C and 3C tanks.
20/12/2013	Manual valves installation is re-evaluated, and prioritized the exchange of shaft seals (seat rings) some valves of the pump house (OP-084 and OP-085).
13/01/2014	Spade installation flange in the amount of OP-068 valve within the pump house. There is no evidence that this spade met the system pressure class in which it was installed. The OP-068 is located between the discharge of the stripping pump and slop tank port.
27/01/2014	Replacement of shaft seals (seat rings) other valves inside the pump house. There

[109] Letter from UO-ES 0744/2015, as of 03/08/2015

Date	Preceding Events and Conditions which could promote the accident
	was still a need for service of other valves, both within the pump house, and throughout the cargo transfer system.
04/02/2014	Port side slop tank repair inclusion in planning the scope of the charging system tanks.
01/04/2014	The produced condensate begins to be sent directly by pipeline (without storage) to the UTG of Cacimbas to allow the repair of tanks of the FPSO CDSM.
03/04/2014	The condensate inventory stored in the tanks is drained to a tank ship (offloading). Last offloading before the accident.
09 to 19/04/2014	Shut down for maintenance of the FPSO CDSM. The valves and the couplings within the storage tanks were not in scope and have not been repaired at this time.
24/04/2014	Implemented change with the possibility to allocate production to 6C tank with the use of an inert gas drying line if there were problems in condensate export gas pipeline into the tanks during repairs.
30/04/2014	Related valves of the charge transfer system that should have their shaft seals (seat rings) substituted resistant material of the condensate effects. Some valves of the charge transfer system have not been included in this relation, for example, OP-068. As of the date of the accident, not all of the charge transfer system valves had their sealing seals (seat rings) replaced.
29/07/2014	Complete maintenance on the slop of port (P slop). Remains the paddle upstream of OP-068 valve. The gasket seal (seat ring) of OP-068 valve is not replaced.
20/08/2014	Registered in the service passage of marine superintendent pressure management operations BW and Petrobras for there to be a return to the condensate storage before the end of repair of the storage system valves. The port of slop still has valves crossing problems, even after repair of their valves.
26/08/2014	Condensate Storage return on FPSO CDSM after the repair of tanks 2C and 3C (recipients of production). After about five months, the export condensate plan directly by pipeline during the repair in the tanks is left without repairs are completed in all tanks.
06/10/2014	Petrobras sent to ANP updating the Operational Safety Documentation (DSO) with the installation operator change to BW after notification from the ANP.
17/10/2014	Resignation of one of the two superintendents of marine FPSO CDSM. In off the remaining marine superintendent, the marine operator expatriate who was on board

Date	Preceding Events and Conditions which could promote the accident
	also accounted for that function. Expatriates operators did not have the requirements to assume the post of marine superintendent.
28/10/2014	BW requests the offloading December scheduled to be delayed by problems in the measurement system. The offloading is rescheduled for February.
07/12/2014	The only remaining marine superintendent promoted to platform manager (OIM) of another unit of the BW fleet.
20/12/2014	Marine superintendent of the service pass promoted to a marine operator who accumulates marine superintendent function.
21/12/2014	4C entry into the tank for final inspection.
25/12/2014	5C tank back to store condensate.
Beginning of January 2015	Slop emptying the start port and retry emptying the starboard slop tanks and 6C simultaneously to entry for service. Previous emptying attempts the slop tanks starboard and 6C (since November 2014) using the stripping pump proved to be fruitless because the communication between the tanks slop and between the slop tank port and 6C tank. This information was not registered with the service pass.
12/01/2015	Drains directed to the 4C tank while the two slop tanks were unavailable. At this time, the cargo tank 4C becomes the single tank intended for produced water and drains.
17/01/2015	Start heating to attempt to vaporize condensate tank 6C difficulty in emptying by using the stripping pump. Vapors were continuously vented by the vent riser during the day.
21/01/2015	Service passage between the marine operators expatriates who accumulated marine superintendent function. The communication problem between the port of slop and slop starboard was not migrated from the previous service crossing report.
23/01/2015	Port slop tank is transferred to the water tank 6c using the stripping pump.
31/01/2015	Probable heating interruption 6C tank.
31/01/2015	Passing gas problem identification between the tanks 3C and 6C at the entrance of inert gas line.
31/01/2015	Marine superintendent new boarding to take on board the role of FPSO Cidade de São Mateus after a month and a half without person who was attending this function.
05, 09 and	6C tank emptying attempt to port the shop with the use of stripping pump.

Date	Preceding Events and Conditions which could promote the accident
10/02/2015	
10/02/2015	Finding inefficiency of transferring between the tanks and slop 6C P in the central use header stripping using the pump. The problem is discussed between the marine superintendent and OIM FPSO CDSM later in the day. The IOM remembers previous problems in the valves between the P slop tank and the central header.

Table 11 - Event-related loss of containment, the explosion and the damage resulting from the accident occurred on 11/02/2015

Time	Event
8:33[110]	Class exchange. The OIM who discussed the ineffectiveness 6C tank transfer to the port side slop tank with marine superintendent arrives and a new IOM boards the FPSO CDSM. The helicopter bringing the new IOM is the same that takes the IOM we landed. Of the ten people embedded in this exchange group, seven had roles in emergency response actions, of which four died. The other three were the last to leave the unit, given that two of them had primary role in emergency response structure.
09:00:31	Pump start using the central header and stripping pump to the tank contents transfer 6C to the slop of port, as in previous days.
9:30 – 10:40	Videoconference between the office operational management personnel in Vitória-ES and train crews. Participate in the IOM which entered service, the marine superintendents, production and maintenance, and technical safety and maintenance planner.
11:26:41	Decreased from 32 to 10% opening of the steam supply valve that drives the stripping pump.
11:27:22	Manual record[111] the Human Machine Interface (HMI or marine operator control panel display) the closing of the suction pump stripping. Started changing the central header for header starboard.

[110] All times given in time order: minute come from data unrelated to the detection systems of records (fixed or portable), valves and CCTV, like testimonials, toil frame (frame containing the marine team everyday tasks) and other records. All data that display the time format: minutes: seconds come from records of the aforementioned systems.

Time	Event
11:27:48	Closing the discharge from the stripping pump through the valve closure located in the slop tank inlet port.
11:29:50	Opening of the suction pump stripping the starboard header, admitting fluid 6C tank.
11:30:30	Opening percentage of the steam supply valve that drives the stripping pump is set at 0% through the supervisory system of marine operator screen.
11:30:33[112]	Opening of the stripping discharge pump through the valve opening in the slop tank inlet port.
11:31:42	Confirmed finding gas in the pump house by the detector 73AB370. High level alarm (10% LEL) in the HMI. As Cause and Effect Matrix, among other automatic actions, audible and visual alarms are triggered in the CCR.
11:31:56	Confirmed finding gas in the pump house. 73AB370 detector indicates 20% LEL (very high level). As Cause and Effect Matrix, among other automatic actions, audible and visual alarms on every platform are triggered, the exhaust pump house is stopped, the dampers of Electrical Power Module (M80) are closed and the HVAC system (ventilation and air conditioning) enters the M80 recirculation mode. The production plant is still in operation, as production stopping depended on a manual action in accordance with an assessment of the emergency command.
11:35:37	73AB370 detector has its extrapolated detection limit (100% of LIE)113.
11:36:44	All three gas detectors located in the pump house background (73AB326, 73AB327 and 73AB370) indicate the presence of gas.
11:38:12	All three gas detectors pump house have their limits extrapolated detection.
11:40 – 11:42	Team meeting out with the participation of the FIM, the marine superintendents, production and maintenance, and others of the crisis command. It was decided to send a team to the pump house to investigate, stop the bombs ballast and closing of the charge transfer system valves.

[111] The pumping is who triggers the closure of the OP-041 valve panel located inside the pump house, on the main deck level. The time indicated refers to the inclusion of the manual valve position information made in the IMH.

[112] At this event, the adopted schedule of reference is the records of the supervisory system for valves and pumps (office & ballast). After this event, the adopted schedule of reference is the records of the closed circuit TV system (CCTV). It was not possible to reconcile the two references and cannot say whether the opening sequence of the discharge and the reduction to 0% of the pump occurred before or after the first finding.

[113] The measuring range of the fixed gas detectors is between 0 and 100% of the lower explosive limit. Above this value, it means that the gas concentration is within the explosivity range.

Time	Event
11:44	Alarms are silenced to improve communication during emergency.
11:44:04	The 73AB326 gas detector is inhibited by CCR operator114.
11:44:06	The 73AB370 gas detector is inhibited by CCR operator.
11:44:19	The 73AB327 gas detector is inhibited by the CCR operator, getting the three sensors inhibited.
11:45[115]	The basic operation in Vitória BW (ES) is informed of the gas alarm. Petrobras representative on board informs the Petrobras Emergency Center.
11:49	Meeting conclusion in points against.
11:49	First team enters the pump house, even with gas detection confirmed that environment. The first team had two members of the brigade and a member of the technical team of emergency response.
11:54	Out of the first team of the pump house.
11:56	The leader of the brigade collects the gas detectors and heads to the control room to talk to the IOM. Reports was leak that liquid, in the form of drip, forming a pool of approximately two square meters below the flange.
12:00:42	The 73AB326 gas detector is removed from inhibition.
12:01:41	The 73AB326 gas detector indicates very high level of gas. This indication remains until the time of the explosion.
12:02	Slop pressure reduction port by the technical team member action emergency response.
12:03	Air conditioning (HVAC) of the Electrical Power Module (M80)[116], was put into normal operation, undoing automatic action of the Cause and Effect Matrix.
12:03	Second team sent to assess the required maintenance even with confirmed gas detection in that environment.
12:07	Second team enters the pump house, even with confirmed gas detection in that environment. The second team was a member of the brigade and two members of the emergency response technical team.

[114] Inhibition of the detectors keeps the visual alarm on the HMI screen, but does not cause the purposes set out in the Cause of Mother and effect, if new detection.

[115] Situations related to the same event were recorded in both automated systems and in emergency status frame. For aligning schedules between the two types of records, schedules status table have been adjusted.

[116] During the emergency, after the increase recorded temperature within the M80, through the CCR supervisor, a technician was sent to reopen the dampers, undoing an automatic claim arising out of the Cause and Effect Matrix. Within this module are electrical panels of production systems and the generation of primary energy.

Time	Event
12:10:21	First measurement portable gas detector [117] (16% of LIE) one of the victims member of the technical team of emergency response during the evaluation of the second team.
12:11:51	The portable gas detector measures 100% LEL.
12:11:51 – 12:12:41	Second team calls, radio, tools (keys) and ladder.
12:12:41 – 12:15:41	Climb the second team to breathe fresh air.
12:15 – 12:20	Leader of the brigade and the emergency response technical team member talk to the IOM in CCR.
12:20 – 12:27	Two members of the emergency response technical team provide absorbent blankets the SOPEP kit.
12:20 – 12:27	IOM calls the operations manager and report on the spill-shaped drip.
12:20 – 12:27	Partial demobilization of meeting places for lunch.
12:27:21	The third team down, even with confirmed gas detection in that environment, with absorbent blankets the SOPEP kit, firefighting hose, ladder and tools (keys). Absorbent blankets and hose had the objective of site cleanup. The ladder and tools would be to repair the connection in which there was a leak.
12:28:21	The portable gas detector measures 100% LEL.
12:28:21 – 12:38:05	The third team consisted of three members of the emergency brigade and two members of the emergency response technical team. The tools and the stairs were used in an attempt to repair. The blankets were used without success. There was the connection of a new stretch of 15 meters of fire hose, cleaning began with water jet. It was prompted increased pressure firefighting hose.
12:38:05	Explosion.
12:38 – 12:46	Observe three deaths on the main deck, wounded and missing, damage to the engine room and damage to houses, including the infirmary. Among the dead and missing, they found themselves the only commander on the scene and all the two leaders of the brigade teams.
12:46	Petrobras representative on board tells the Emergency Center and the Sector Manager of Petrobras Production Operations worsening of the situation and requests support aeromedical.
	Sector Manager of Production Operations Petrobras reported on complications of an

[117] Portable detector (247010610 Identification Number) found by the civil police of the Espírito Santo on the body of one of the victims.

Time	Event
12:46 – 13:00	accident to the CDSM FPSO BW Operations Manager.
	IOM calls the manager of BW operations for support aeromedical.
13:00 – 14:00	Shutting down the fire pump by the production superintendent, as the disruption of the fire lines near the pump house flooded the pump house and nearby areas.
	Heard on the radio, missing person's distress call.
14:00	Descent from the starboard lifeboat.
14:00 – 14:53	Identification of the existence of nine missing.
	Output by own means of the pump house of a member of the brigade, the only member of the third team to come out alive from this site.
14:53	The first helicopter landing in the CDSM FPSO. The helicopter was to carry passengers and was adapted for redemption.
14:53 – 15:25	IOM's request to book flashlights and radios, because we knew we embark firefighters.
	Rescue two people from within the lift debris in the roof top of houses. These people were the doctor and the stretcher team, led by the nurse. The effect of the explosion, the elevator was designed against the last top level of the houses.
15:25	The second helicopter landing in the CDSM FPSO. The helicopter was the type MEDVAC. This MEDVAC took off from the PGP-01 platform in the Campos Basin, as was medical care at the time of activation. The MEDVAC dedicated to the region of the Espírito Santo Basin was unavailable because it was undergoing maintenance.
15:44	Landing of the third helicopter in FPSO CDSM. The helicopter was the type MEDVAC.
16:18	Landing of the fourth helicopter in FPSO CDSM. The helicopter was to carry passengers and was adapted for redemption.
16:35	Landing of the fifth helicopter in FPSO CDSM. The helicopter was regular for passenger disembarkation.
16:50	The sixth helicopter landing in the CDSM FPSO. The helicopter was regular for passenger disembarkation.
16:50 – 19:00	Note that there was increase in the water level in the square of unknown source machines.
19:00	Location of utilities operator in the control room of the engine room without possibility of access for rescue.
23:00	Landing of the helicopter of the Marine of Brazil with the team of firefighters from the state of Espírito Santo.
23:22	Use of portable gas detector with hose to monitor the engine room environment. Indication of 7.8% LEL.
23:22 – 01:00	Note the existence of another body on the main deck.

Time	Event
	Ransom for utilities operator's body fire in the control room the engine room.
	Meeting of firefighters and crew members to plot strategy for entry into the pump house searching for the four missing.
	Personnel on board receives order from Petrobras' crisis command via the FPSO City of Vitória, to immediately leave the unit for risk of structural damage.
12/02/2015 01:00	Abandonment of unity for the whaling port, without the location of the four missing.

7.2. Causal Factor n° 1: Inadequate storage of the condensed material

The first causal factor identified by the ANP refers to a change in use of the FPSO CDSM still made in the conversion installation design phase. Initially, the FPSO CDSM only store condensed case oil. However, during project discussions, Petrobras requested the Prosafe to assess whether the condensate was stabilized to be stored without being mixed with oil. By agreeing to this alternative without proper risk management introduced by this change, the chain of events began which culminated in this accident.

Despite this, there is another opportunity to correct such deviation, since there was a requirement that risks were reviewed at the beginning of the production phase. This review could not be evidenced during this investigation, since the safety studies issued at the design stage were still in force on the date of the accident, also considering the initial specification of not stock condensed without being mixed with oil.

Hence, it is found that, due to the lack of a change management process before the unit operation and lack of risk review at the beginning of unit operation as described in the following sub-items, was stocking inadequate condensate on the platform..

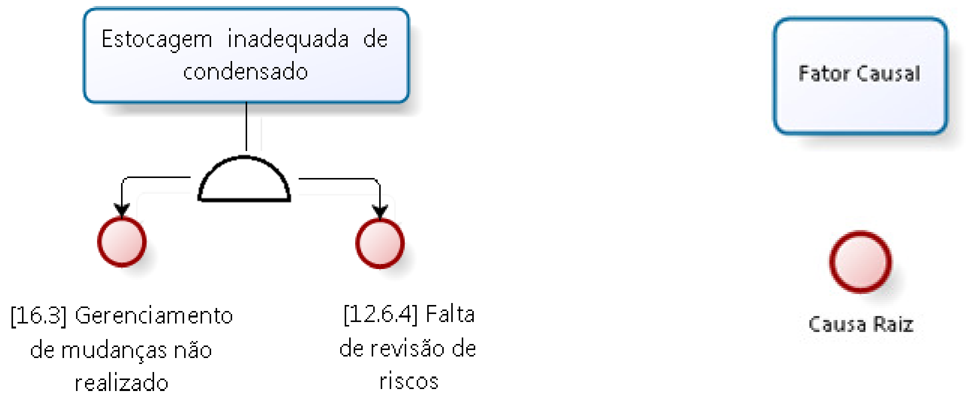


Figure 98 - Causal Factor # 1: Inadequate Condensate Storage

7.2.1. Root Cause n°1: [16.3] Management of of Change not performed

During the bidding phase of Charter Agreements and operation of Services for the FPSO Cidade de São Mateus, was drawn 0 revision of the document containing basic design specifications[118], offered to participants of the bidding companies.

One of the mandatory requirements of this document concerns the allocation of condensate produced:

1) In case of crude oil, condensate must be separated from natural gas and water, and then sent to the oil processing module[119];
2) If there is no oil production, condensate should be separated from the natural gas and water, and subsequently directed to the pipeline to export natural gas, for later separation Cacimbas.

It occurs that Petrobras decided to link the platform only Wells Camarupim and Camarupim North Campos, both gas producing fields non-associated. The change occurred caused Petrobras, in 2007, consult the company responsible for the conversion and engineering design, Prosafe (PRS) on the condensate obtained could be stabilized for subsequent storage in their tanks. Evidenced email from Prosafe, in October 2007, in response to Petrobras on adjustment of simulation models for the case of "start-up"[120].

As of June 2008 month of the[121] meeting minutes indicates that Prosafe said it would be possible to send the condensed to the cargo tanks via M10 (modulo 10, oil processing) for stabilization. However, this very minute to Prosafe warns that despite the offloading pumps are suitable for pumping condensate, the preferential export method is to direct the condensate to the export pipeline.

In August 2008, Petrobras requested the Prosafe that satisfied the impacts on the first gas if it were decided to direct the condensate to the separation module / oil treatment [122]. The Prosafe said he started the study so that the compositional data and the first well gas production profile were sent.

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[118] General Technical Description – Doc. n° I-ET-001-Gas Rev. 0 – Issue Date: 10/08/2006.

[119] In this module, it would be fewer and, after processing, the mixture would be stored in tanks.

[120] E-mail of 17/10/2007, annex 1 "OCT 2007 HYSYS WORK FOR CONDENSATE STABILISATION ON M10", do documento Start up Simulation and Operating Configuration Report - Doc. n° 384-20-RPT-001 Rev. 0 – Issue Date: 25/08/2008

[121] Minutes of Meeting – Operations Meeting – FPSO Cidade de São Mateus – 23 to 24/06/2008.

[122] Minutes of Meeting – Progress Meeting – FPSO Cidade de São Mateus – 14 to 14/08/2008.

Prosafe prepared a report[123] describing all of Petrobras requests history as well as the technical basis for the answers, containing e-mails as an attachment, cases modeled simulation software aid procedures and tables containing operating parameters to be followed so that they reach the condensate stability in module 10.

This report is evidenced Petrobras' refusal to provide some reports of Prosafe the gas wells to support the modeling claiming confidentiality.

One of the conditions laid down in such a way was to reach a condensate stabilization, getting a pressure Reid steam, PVR[124] of 10 psia to 37,8°C.

Below, the path of gas from the condensate is introduced as a very simplified diagram based on the engineering drawings:

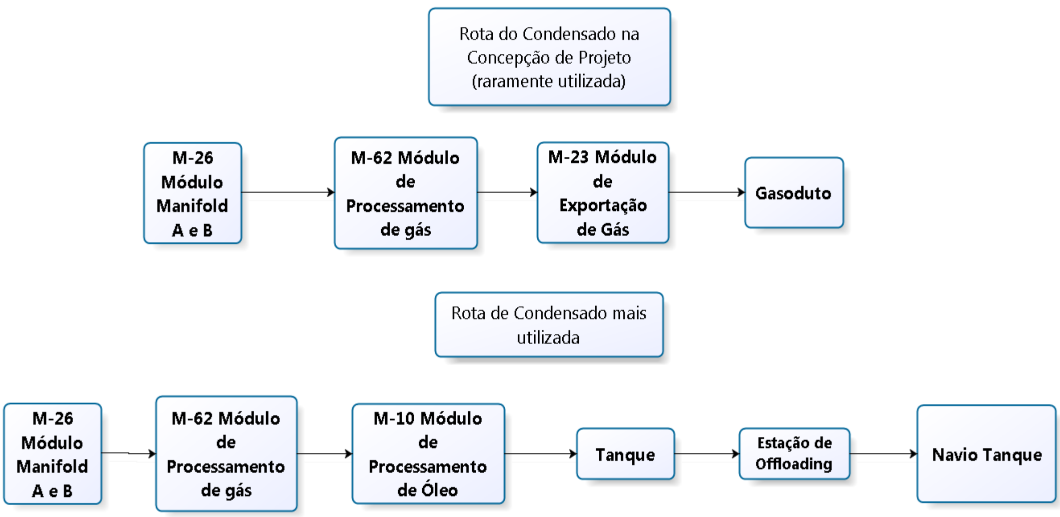

Figure 99 - condensate simplified processing route from gas

Since the beginning of the design of this installation, was the interconnection of this platform prediction with the Gas Treatment Unit (GTU) of Cacimbas through a new pipeline, designed under the PLANGAS, a project created to improve the national energy system reliability and anticipate the availability of natural gas for thermal power generation.

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123 Start up Simulation and Operating Configuration Report - Doc. n° 384-20-RPT-001 Rev. 0 – Issue Date: 25/08/2008

124 "Reid vapor pressure (RVP): resultant total pressure reading, corrected for measuring error, of a specific empirical test method (Test Method D323) for measuring the vapor pressure of gasoline and other volatile products."

During the inspection[27] it was unclear whether the initial motivation for condensate storage was due to a possibility of postponing the operation start of the FPSO CDSM by not installing new pipeline Camarupim, or the lack of initial capacity of the Gas Treatment Unit (GTU) of Cacimbas of the quantity or characteristics of condensate that would be received.

Nor is it known what caused the change in the initial design of interconnecting oil wells as it could have been connected to this platform wells Golfinho Field.

Thus, the platform came through storing condensate, since the platform started production on 10/06/2009[125], three months before the completion of the installation and commissioning of the pipeline, on 05/09/2009[126]. During this time there was the commissioning of the compressors when all inventory produced gas was taken to the flare for burning and the amount of condensate produced "by-product" of gas production, was stored in tanks.

Prosafe fact is that the report indicates the understanding that the condensate storage was a temporary change, to register that would be in the early years and that there would be a few times when the condensate would be exported by pipeline but stored in tanks. In practice, what would be temporary has become an established practice, for the period from June 2009 to July 2015, for a total of 1988 days of production by 187 days there were export condensate by pipeline in 1777 days there were storage and 24 days were devoted to scheduled production stops. Between the days when the unit exported condensate, 136 days were used for the entry and repair of tanks to correct the problems posed by the cargo transfer system valves[127].

Despite the above numbers, revision B of the General Technical Description (GTD), issued in 2013 with the unit already in operation and without ever being connected to any pit oil, makes no mention of this change on the condensate storage.

Therefore, we can conclude that it was not issued at the design stage or after FPSO document input operation that showed a Change Management process, which would produce practical effects such as reassessment of the risks that the facility would be submitted to the store condensate.

About Change Management in the design phase, it is emphasized that there was the identification and recognition of the potential impact of the change. However, the change was not managed by both companies - the contractor and the contractor. Thus, it was observed that the written procedures of both companies instruct management on the operational phase - not in the design phase.

[125] Commissioning information of turbochargers in the months of June and July 2009.pdf

[126] Pull-in gasoduto.pdf information

[127] Evidence collected during the tax audit meters.

A formal process would have required the production of a risk analysis. As a risk analysis study shall be done with a multidisciplinary team, it is possible that someone in this team had pointed the possible condensate attack on valves (more precisely, the sealing material of the valves).

About Change Management in the operation phase, it is necessary to report that the staff on board often operated with permissions of work for almost daily use of vents of the inert gas system to depressurize the tanks. The pressure increase in cargo tanks was coming from the detached gas condensate and for carrying out the activity was needed inhibition of gas detectors topside near these vents. This common practice can also be seen in books bypass records. Still, the flight crew did not identify that this could be occurring due to a change in project parameters.

It was evident during the investigation that the improper storage of condensate was known both as BW Offshore Petrobras, as it indicates presentation by BW Petrobras Operational Meeting Monitoring (ROA) of 01.26.2015. Figure 100 shows the slide with pain points indicated by BW.

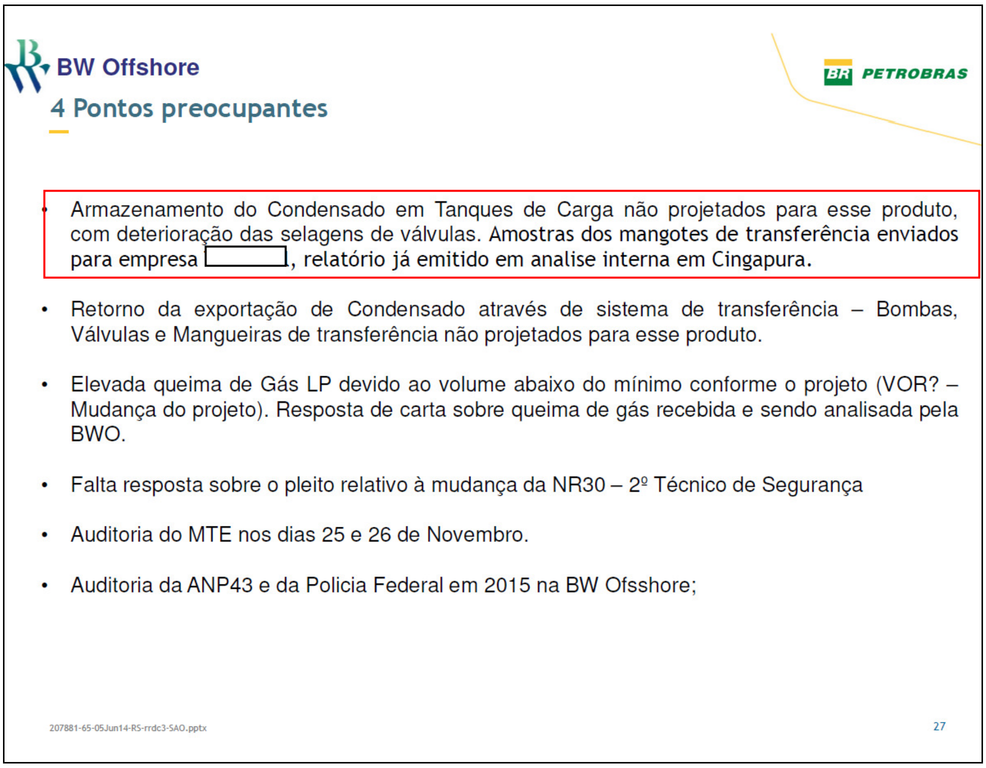

Figure 100 - BW indication Petrobras that the condensate storage in the FPSO CDSM was done improperly

Another point to note is the discrepancy between the operating parameters of the project and those performed on board. For this they compared the operating parameters recorded for each process equipment (eg temperature and pressure) on the record sheets of the operation team with the reported parameters in the Operational Configuration Report required for the condensate to reach a lower PVR value to 10 psia 37.8 ° C.

This may indicate a failure in the passage of responsibilities and project personnel information to the operating personnel and failure structure for maintaining process parameters within the limits previously established. He drew the attention of the investigation team the absence of engineering support structure and local security to support the operation. Every time the ANP research team demanded clarification of design information and operating parameters, BW had to resort to conferences with its office in Singapore.

So, if the risk controls members of the change management process were used, it was expected that: (i) the rationale for the change would be recorded; (ii) the implementation of the changes would only be made after evaluation of hazards and the global impact on activities; (iii) there would be updating the procedures and documentation affected by the change; (iv) take place training and communications to all personnel whose job is impacted and, finally; (v) the authorization for the proposed change would be issued by an appropriate management level.

In this sense, it can be seen that neither the operator nor the installation of the Concession Operator used their change management procedures. Such failure is considered one of the root causes Causal Factor "inadequate Storage condensate" and contradicts all control procedures set out in item 16.3 of SGSO.

7.2.2. Root Cause n° 2: [12.6.4] Lack of hazards review

The Safety Case developed during the unit's design contains the description of the operational scenario as "the hydrocarbon condensate can be injected into the gas export line downstream of the pig launcher - this system is only used if the condensate can not be mixed with crude oil due to restrictions of high values of Reid vapor pressure[128]". In other words, safety studies carried out during the design phase did not consider that there would be pure condensate storage unit in the cargo tanks.

It should be noted that the plant operator the procedure on the preparation and review of Safety Case[129] It provides a period of updating of security studies from the design phase and operation, during which it could have been identified the need for revision of the safety studies. Although this assumption has yet been changed during the design phase, the safety studies have not been updated to incorporate this change.

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[128] Item 2.6.1.3 from Design and Operations Safety Case for FPSO Cidade de São Mateus – Doc. n° 384-HS-0501-RPT-015 Rev. 0 – Issue Date: 12/12/2008

[129] BW Offshore Safety Case Guidelines – Doc. n° MS-MP01453 Rev. 2 – Issue Date: 06/05/2015

In addition, this procedure requires the Safety Case must go through a cycle of mandatory review every five years or in the event of significant change in the unit. Hereunder, any change that generates impact must (i) be identified and reported in accordance with the management system controls or a change management procedure or Request Enhancement action and (ii) generate the Safety Case Review and their further studies.

Figure 101 then removed from the procedure, shows the need to update the security studies and the Safety Case review.

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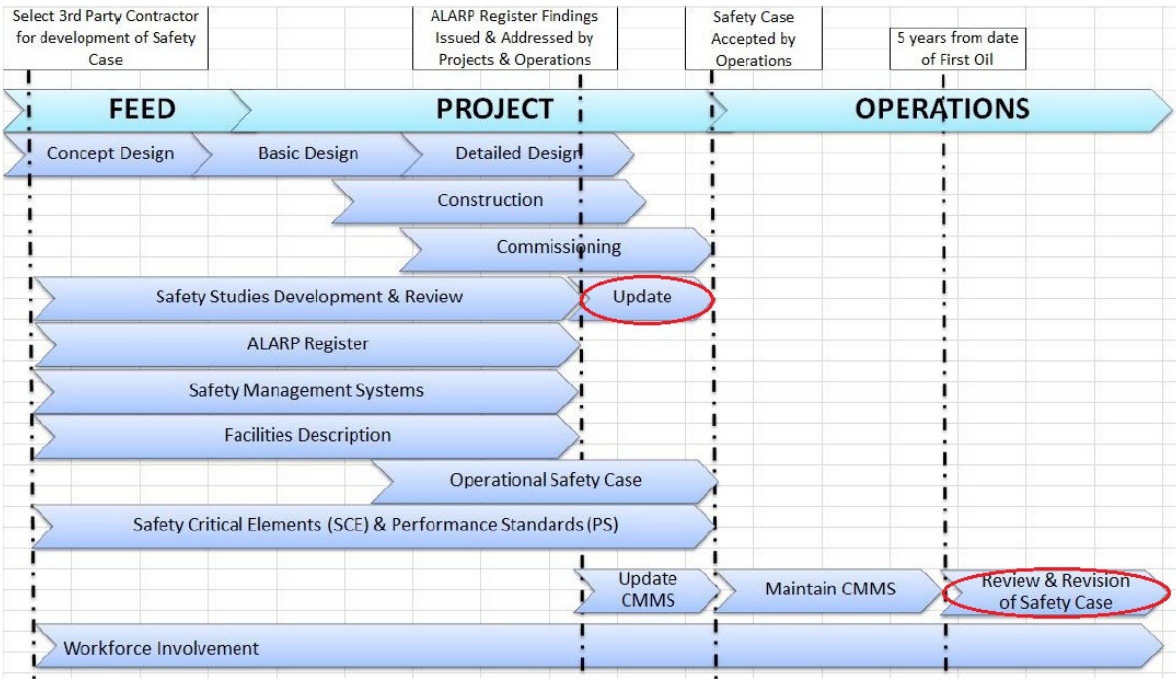

Figure 101 - Updating safety studies and Safety Case Review

In the manual are still some examples of specific changes that should trigger changes in the Safety Case: design changes and structure of operating parameters and process, maintenance, inspection and experiences from testing of safety critical elements (SCEs), changes in installation (including SCEs), changes and behavior of the critical elements of security, historical incidents and abnormal events, new knowledge and understandings, changes in safety standards and changes in the security and management aspects of human factors affecting the facilities. It is worth noting that the document mentioned as a specific example of changes in the Safety Case which would require a revision of this document relating to design changes and operational parameters "life due to fatigue and corrosion of topside and hull."

Additionally, the procedure establishes that, in order to determine whether a revision of the safety case is required, should be carried HAZID and HAZOP studies based on change areas identified and the decision whether or not to revise the Safety Case should be documented.

In addition to the own forecast update of the Safety Case appear in that BW procedure, it should be noted that some standards also indicate the need for risk analysis of the review in certain circumstances, as transcripts below:

> *"A general risk analysis is only valid as a basis for decision-making as the basis for the analysis (e.g. his method, models, inputs, assumptions, limitations, etc.) is evaluated as valid. Any deviation from the analytical basis should therefore initiate an evaluation of deviation from its effects on risk and / or the validity of the analysis and its results, considering that it intends to-use analysis for future decisions. "(NORSOK standard Z-012, Edition 3, October 2010 Risk and emergency preparedness assessment)".*
>
> *"The hazard identification and risk assessment may need to be reviewed and updated if significant new situations are identified or if significant changes are made in the facility." (ISO 17776, First Edition, 10/15/2000 - Petroleum and natural gas industries - Offshore production installations - Guidelines on tools and techniques for hazard identification and risk assessment)".*

According to information[130], provided during the audit, was in progress to update the Safety Case of FPSO CDSM. Initial activities for updating the Safety Case are shown in Table 12.

Table 12 - Activities revision of the Safety Case

Deadline	Scope
January to March / 2014	Scoping, sending documents to the companies participating in the drafting of the proposal and clarification meeting.
April and May / 2014	Shut down and activities after shut down.
June to September / 2014	Alignment of proposals and award of ABS company.
October / 2014	Meeting the day to check all the MOCs (Management of Change / Change Management), implemented in the FPSO CDSM since the beginning of

130 *E-mail* enviado pelo Engenheiro de Segurança aos representantes da Petrobras em 18/12/2014

	operation and realization of the Kick of Meeting in Vitória Office.
November / 2014	Board the FPSO CDSM for review of HAZID
December / 2014	Meeting during the period from 01 to 11/12/14 with representatives from areas: Production, Maintenance, Marine, Utilities, HSE along with two experts of ABS in risk analysis for HAZOP review.
January / 2015	Scheduled for 12 to 01/16/2015 the end of HAZOP review with participants from areas: Marine, maintenance and HSE.

The review of the safety studies was initiated in October 2014 and had planned duration of twenty weeks as per schedule to be followed to carry out[131], such a review, soon expected to be completed with the issuance of the Safety Case was revised in February 2015. It was reported BW by representatives of the HAZOP (first study to be revised as scheduled) would already be finalized, with the validation phase for catering teams. The Safety Case revised, however, it had not been issued to date of the accident, although the BW procedure provides that the review of the Safety Case should be held no later than five years after the first oil, i.e. in the case of FPSO CDSM to deadline would be 10/06/2014.

It was observed also that the description of the unit shown in HAZOP drafted in 2007 during the detailed design for the charge transfer[132] systems contained the following text:

> The FPSO Cidade São de Mateus is a spread-moored FPSO. It will receive well fluids from deepwater wells (gas/condensate, and crude oil), which will undergo gas/liquid/water separation. Gas is dehydrated before high pressure compression, and is then transferred to shore via subsea pipeline, together with any dry light condensate from the process. Produced water is treated before discharge overboard. The crude oil/condensate undergoes stabilisation and dehydration before storage in vessel cargo tanks. Salt water is treated for water injection purposes (with high pressure pumps). Crude oil is offloaded to tandem shuttle tanker by using a retractable floating hose station located at the bow of the vessel. Facilities are provided for the injection of ethanol, MEG, and hot Marine Diesel Oil (MDO) to sub-sea wellheads.

Figure 102 - Marine HAZOP Excerpt (2007)

[131] CDSM Schedule *Safety Studies 20 Weeks* (pgs. 958 to 960)

[132] *Hazard and Operability Study (HAZOP) Report for Ship Systems* – Doc. n° 384-HS-RPT-004 Rev. 0 – Issue Date: 03/09/2007.

The HAZOP topside, first issued in 2008 and revised in 2015, contains the following highlighted text:

> O FPSO Cidade de São Mateus é um FPSO spread-moored (navio ancorado pelos quatro quadrantes, com alimentação dos risers pela lateral) que está instalado na costa do Brasil, no desenvolvimento do campo de Golfinho. Ele foi projetado para: receber fluidos de poços em águas profundas (gás / condensado e petróleo bruto), e realiza um processo de separação líquido/gás/água. O gás é desidratado antes de ser comprimido a alta pressão e transferido para terra através de gasodutos submarinos. A água produzida é tratada antes da descarga no mar. O óleo bruto / condensado é estabilizado e desidratado antes do armazenamento em tanques de carga da embarcação. A água salgada é usada para fins de injeção de água (com bombas de alta pressão), e envolve diversas fases de tratamento. O petróleo bruto é descarregado em um navio-tanque de transporte (também chamado de navio aliviador) através de uma mangueira flutuante. A plataforma é equipada com instalações para a injeção de: etanol, mono-etileno-glicol (MEG), e óleo diesel marítimo aquecido (MDO) para todas as cabeças de poço submarinas.

Figure 11 – HAZOP text from the topside (2015)

The text of the Figure 103 mentions that the condensate storage would be held together with crude oil in cargo tanks, which did not represent the actual operation that was practiced in the unit (pure condensate storage in cargo tanks).

Although the unit never operated with crude oil, which configured a change assumption that need to be evaluated for their impact in cargo transfer system, it was only revised the HAZOP for the unit's topside and has not been revised HAZOP for the load transfer system of the FPSO CDSM, which found itself outside the scope of the five-year review. The safety study “CFD Gas Dispersion Modeling for Gas Detector Location” and “Fire Propagation and Structural Protection Analysis” also not part of the scope of review provided for in the schedule.

Thus, it can be seen that:

(i) It could not be demonstrated that there was the unity of the Safety Case review at the end of the design phase, because there was only one version of the Safety Case [133] issued on February 2009. If such a review had taken place, there was the possibility of identifying significant changes in operating assumptions of the FPSO CDSM also decided during the conversion phase;

(ii) the mandatory cycle of revisions every five years for the Safety Case was not done on time;

[133] Design and Operations Safety Case – Doc. nº 384-HS-RPT-024 Rev. 1 – Issue Date: 11/02/2009

(iii) the revision cycle that was in progress when the time of the accident did not include the review of all safety studies that had their premises changed since the last issue.

In addition, the operator of the concession could have identified the need to update the risk studies, as provided for in GTD the need for Petrobras to receive and approve the risk studies and the HAZOP developed in the project detailing phase should be updated in the operational phase, as quoted below:

> *"17.1 - Both the Risk Assessment Study as the Risk Management Program should be submitted to Petrobras for approval. (...)*
>
> *(...)*
>
> *17.2.2. Operational Phase*
>
> *At the beginning of the operation phase the study of hazards and Operability (HAZOP), prepared during the detailing phase should be reviewed considering the "as built" of Piping and Instrumentation Diagrams (P & ID). The operating personnel should participate in this task. The HAZOP should also be revised to incorporate the design changes made throughout the operation phase "*

When the ANP research team questioned the Petrobras representatives regarding the approval of risk assessment studies, it was sent the following response as e-mail the day 07.16.2015 sent to the ANP:

> *"Petrobras clarifies that because it is chartering project, not performs design approvals and risk analysis. The project is the Contractor's responsibility and is prepared based on a functional specification (GTD) that allows the adoption of technical solutions by the Contractor, who is responsible for the chartering, operation and maintenance of the unit. According to item 1.3 of GTD, the Contractor is required to hire a Classification Society for approval of the entire project, from the basic design to decommissioning. The purpose of the hiring of the Certification Company, as described in item 1.3 itself., Is to ensure that all steps necessary for the design, construction and operation of Unit comply with all applicable laws, including those related to security. Thus, the use of the term "approval", in English, aimed to enable the Project Coordination Technical intervene if necessary.*

The approval of the project and study the various stages of the project by the Classification Society is legal requirement for the design certification and the classification unit and later get the Marine authorization to operate in Brazil. To maintain legal compliance of the unit during its operational life, the Classification Society conducts periodic inspections (annually) to ensure the renewal of Class and Statutory certificates every five years, and the Marine conducts periodic inspections (annual) to Statement of annual renewal Compliance Unit "

Although Petrobras has claimed that in case of charter, it is for the installation of the Operator approval of projects and risk analysis, it is worth noting that in item 13.2 (Diligence in Conduct of Operations) of the Concession Agreement for Exploration, Development and production of Oil and Natural Gas entered into between the ANP and Petrobras in 1998 (IDB 0), the dealership also has obligations with respect to operational safety of the unit, as outlined below.

"The Dealer plan, prepare, perform and control the Operations in a diligent, efficient and appropriate, in accordance with the best practices of the oil industry, while respecting the provisions of this Agreement and the laws, regulations and other rules, including those on operations issued or that may be issued by the ANP, and not performing any act which would or could constitute a violation of the economic order. Based on this principle, and without limiting its application, the Concessionaire required to adopt, in all Operations, the necessary measures for the conservation of reservoirs and other natural resources, for the safety of people and equipment, and environmental protection, pursuant to Clause Twenty, and to obey the rules and technical procedures, scientific and relevant safety, even as the recovery of fluids, the prudent management of Production and control of reserves depletion."

Thus, in addition to the explicit requirement in GTD unit that the Concessionaire must approve the studies of the risk assessment, the Concession Agreement itself also states that the dealer is responsible for adopting measures to ensure the safety of people, equipment and the protection of the environment.

In this sense, it can be seen that the operator of the installation and the Licensor shall not systematically evaluated the risks during the phases of the facility lifecycle. Such failure is considered one of the root causes Causal Factor "inadequate Storage condensate" contrary to item 12.6.4 of SGSO.

7.3. Causal Factor n° 2: Operational degradation of cargo system of FPSO CDSM

The charge transfer system was originally ship's construction of tank that was converted into FPSO therefore dated 1989. During the ship's conversion step, significant changes were not made in order to upgrade the system or ensure that it obeyed the same standards and design requirements to which the processing plant should meet. This fact is supported by the isometric drawings of the system piping, which are original to the building of the ship and suffered no review for status "as built" during the conversion step, demonstrating that have not made significant changes that deserved record in the system documentation.

In this way, by storing different fluid other than that for which it was designed without there being previous change management to identify and mitigate the impacts, the FPSO storage system was to be degraded over time in relation to its design condition.

The degraded state of the charge transfer system restricted common transfer operations between tanks and drainage tanks, so that means were used that introduced risk and some unfit for operations as inadequate spades and the use of a pipe for condensate which had been designed to conduct inert gas.

The actions taken to try to correct the degradation of cargo transfer system without the machine operator was paralyzed were sometimes made without risk analysis or any evaluation of hazards and the global impact on activities before the change implementation. In addition, some of the changes to the project were not adequately documented and relevant information for operating the system have not been reported in the service passage. These factors contributed to the accident and their causal factors are described below.

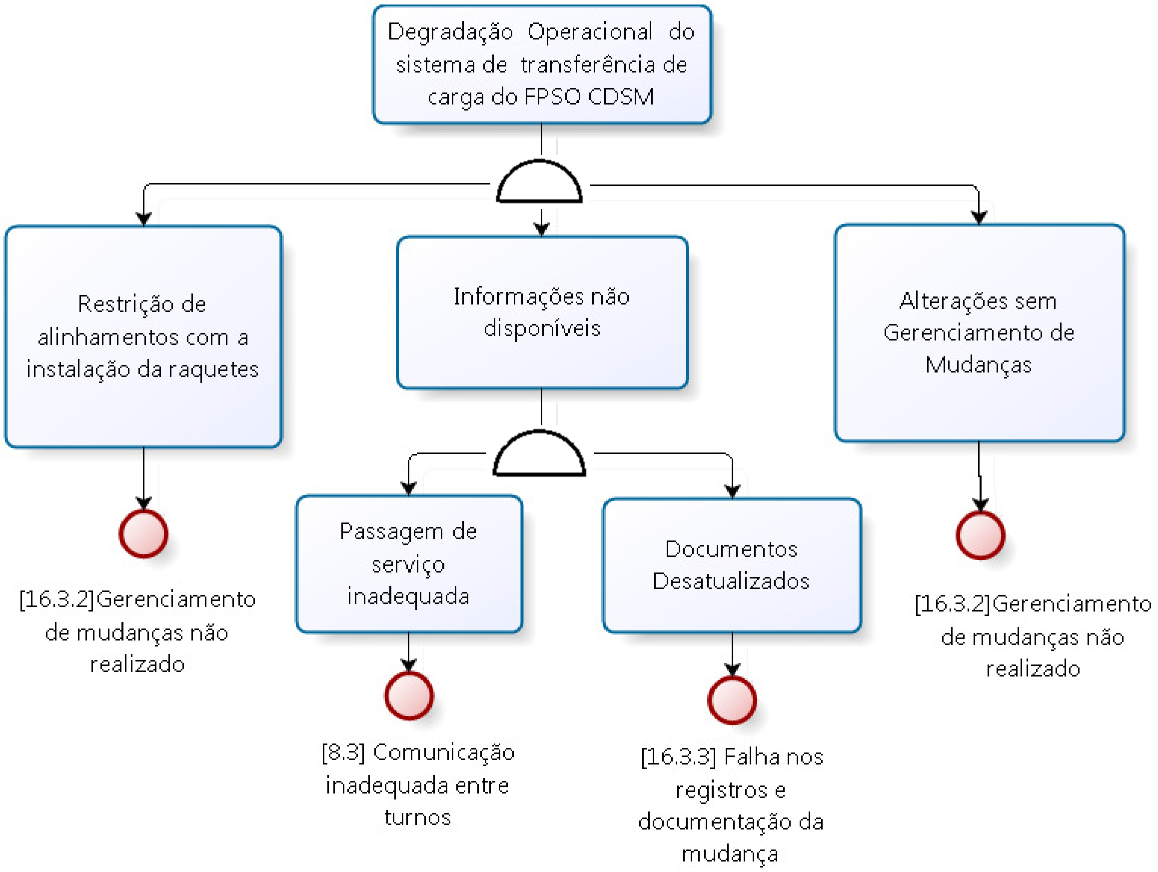

Figure 104 - Causal Factor # 2: storage system degradation FPSO CDSM

7.3.1. Root Cause n° 3: Restriction alignments with spades installation / [16.3.2] Management of change not performed

In 2011 it was identified water passage of slop tank port to 6C tank and slop tank starboard to 2C tank. A change management form was issued with MOC-CSM-069 code for installing manual valves in order to establish a double lock.

In 2012 such valves had not been installed and opened new change management, MOC-CSM-091, to allow the repair of valves and couplings within the 2C to 5C tanks and slop tank port. A condition for entry into the tanks was that MOC-CSM-069 have been completed for a particular valve, OP-084. Figure 105 shows the OP-valve 084 before and after the accident..

Figure 105 - PB-valve 084 before and after the accident

MOC-CSM-091 is the temporary installation of pumps, valves, pipe segments, spades , hoses and the use of inert gas drying line, to allow the condensate transfer between tanks. That is, the degraded state of the charge transfer system restricted common transfer operations between tanks and drainage tanks, such that means were used that introduced risk and some unsuitable for operations such as inadequate spades and employing a pipe for condensate, but had been designed to conduct inert gas.

Instead of installing manual valves as had been proposed in change management MOC-CSM-069, various valves of the pump house had their exchanged seals, including OP-084 as diagrams P & ID marked attached to MOC-CSM-091. In these diagrams are shown for the insulation-068 and PB-1005 BFV valve.

The installation of the spade in the discharge line of the pump limited stripping alignment possibilities. The shortest route between the stripping pump and slop tank port was precisely the line of OP-068, since that was the only valve in this line between the pump and the tank.

It was shown that during audit spade installation upstream of the OP-068 valve was required for the replacement of the seal of this valve was not possible due to the liquid level within the port slop tank is higher than the valve position.

It turns out that the team that performed the activities planned in the MOC-CSM-091 made entry[134], there was no planning for it to be removed spade in the discharge line of reciprocating pump and to perform repair of the OP-068 valve.

[134] Cargo log book (*cargo log book – marine department*) as of 29/07/2014 (pg. 839)

The spade was installed in January 2014 as evidenced in work permit and mechanical insulation[135] certificate. The change management MOC-CSM-091 was issued[136] in December 2012, but was revised in February 2014, covering the spade installation information.

However, the paddle stay in line with OP-068, located in the discharge of stripping pump was not included in risk analysis or any other hazard assessment and the overall impact on the activities before the change implementation. This failure in the application of hazard identification mechanisms and / or risk analysis prior to implementing change is considered one of the root causes Causal Factor "storage system degradation FPSO CDSM", contrary to item 16.3.2 of SGSO.

7.3.2. Root Cause n° 4: Inadequate service crossing / [8.3] Inadequate communication between shifts

On 20/08/2014, it was recorded in the service passage[137] marine superintendent that while the shaft seals (seat rings) of OT41 and OT-023 port of the slop tank valves had been renovated, the tank still had communication problem with the tank 5C:

> *"5c was pumped out completely. Port slop was reinstated after completion of works, but liquid was draining into 5C. Since then, we are maintaining 5C as a carry over slop tank. No gas reading there yet, we purge port slop from time to time. Priority is to complete stbd slop inspection for Class certification, then transfer 5C to stbd slop.*
>
> *Seat rings of OT41, OT23 (port slop), OT12, OT13, OT28 (2C) renewed."*

On 11.19.2014, it was registered in the passage of marine superintendent of service[138] the replacement service of 5C tank valves sealing seals had been completed. However, it was registered an issue of slop tank port communication, this time with the slop starboard, quoting the OT-037 valves and OT-040, both belonging to the line that communicates the two slop tanks, were with passing problem.

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[135] Cold Work Permit) n° 34850 – Issue Date: 12/01/2014

[136] Mechanical Insulation Certificate n° 20101, de 12/01/2014, attached to Cold Work Permit) n° 34850 – Issue Date: 12/01/2014

[137] Rotation Handover Report – Marine Superintendent – Doc. nº MS-20082014 – Issue Date: 20/08/2014

[138] Rotation Handover Report – Marine Superintendent – Doc. nº MS-19112014 – Issue Date: 19/11/2014

> *"We tried to purge & gas free port slop tank, but OT-037 & OT-040 are passing & hydrocarbon gas came into port slop.*
>
> *We could not purge & gas free starboard slop tank as the wind direction was not conducive. But that tank needs to have the seat rings replaced on valves."*

Although the T-valve 040 operates to communicate between the two slop tanks, it was located inside the tank 6C, according to the P&ID[139].

In 20/12/2014, the information cited in the day of service 11/19/12 passage on the slops tanks were kept [140], with the addition of information that slop tank port was not fixed, then it would be necessary to avoid the use of port side bottom header to transfer load, since the load migrate into the slop tank port. It was recommended its use only in case of need for a tank drainage operation.

> *"##If the port slop tank is not fixed, avoid using the port side bottom header to transfer cargo as it will drain into the port slop tank. Use only if you have to strip any tank."*

In January, there was an attempt to empty the slop tank port, along with the starboard slop tank and 6C, as job log book records. Such activity was not registered in the naval superintendent service crossing report on 21/01/2015[141]. Although this activity has not been recorded in the service crossing report, the result of the simultaneous emptying of the slop tanks was recorded, which was the alignment of the drain to the tank 4C:

> *"The closed drains from process were diverted to 4C via flexible hose connected to the cow line."*

The information on the motivation of the emptying of the tanks, namely, the problem of communication between the tank bottom and instructions use the header has been removed from the service passage report. The only additional mention of the slop tanks was that there was a failed attempt to purge the tanks:

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[139] P&ID *Cargo System in Vessel* – Doc. n° 384-33-W-DWG-100_002 Rev. Z – Issue Date: 03/03/2009

[140] *Rotation Handover Report – Marine Superintendent* – Doc. nº MS-20122014 – Issue Date: 20/12/2014

[141] *Rotation Handover Report – Marine Superintendent* – Doc. nº MS-21012015 – Issue Date: 21/01/2015

"Gas freeing of Slop S was started but the Hydrocarbon levels are not going down. attempt to Purge both Slops also did not work."

During the investigation it was evident the impossibility to pump the condensate tank 6C situation recorded in the service passage report in 21/01/2015[142], due to the fact that there is communication between 6C tanks and slop tank port. It is worth noting that in the long term insulation registration [143], had insulation note in OP-038 for exchanging the seat ring in the slop tank port. These motivations for emptying the port side slop tank were not registered in the service crossing report.

Even so, after the service passage 1/21/2015, slop tank port was put back into operation, including the use of stripping pump to transfer fluid from the tank to 6C slop tank port. Ie the team that won the previous service failed to consider the plan to repair the slop tank valve port and tried again transfer fluid 6C tank to the slop tank port, an activity that had previously been regarded as impossible by the previous staff due to communication between the tanks, all occurred in the light of information that were not registered or were removed from service crossing report. Lack of access to information necessary for executing the jobs that should be included in the service ticket report for their relevance, sets an unsuitable communication between shifts. Such failure is considered one of the root causes Causal Factor "storage system degradation FPSO CDSM" and contrary to item 8.3 of SGSO.

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[142] Rotation Handover Report – Marine Superintendent – Doc. nº MS-21012015 – Issue Date: 21/01/2015

[143] MIC 21928, in reference to CWP 39894 de 29/10/2014 in Long Term Insulation Register, valid in 11/02/2015

7.3.3. Root Cause n° 5: Outdated documents / [16.3.3] Fail in records registration and modifications

The MOC-CSM-091 has diagrams (P&IDs) in its annexes[144] presenting markings of the points of temporary connections and insulation installation points made to enable the desired changes. These drawings marked remained only as an annex to MOC-CSM-091, that is, the design made available to the general staff through the computerized system management designs and flowcharts (Proarc) was the original design without the markings on the changes made.

The work permit[145] and the mechanical insulation certificate[146] relating to the installation of the paddle upstream of OP-068 valve have not been entered into the control of isolations records of long-term[147], contrary to the operator of the facility isolation procedures.

As per BW procedure[148], the long-term isolation of records should be checked on a monthly basis in order to: (i) verify that the insulation are working as insulation Certificate; (ii) verify that Lock & Announcements devices are working and in good condition; and (iii) ensure awareness of long-term insulation between the crew. Also according to the procedure, the record date of insulation should be kept in electronic copy on your computer and in print under the control of work permits coordinator and should be replaced every update. Finally, this procedure also stipulates that the insulation that remain in place beyond the validity of their work permit must be recorded in long-term isolation control list[149].

It was shown that long-term isolation of control has not been updated with the paddle upstream of OP-068 valve. It turns out that, even though it was open a work permit for the installation of the spade, isolation certificate associated with this permission considered as insulation only the closing of valves necessary for the installation of the spade. The racquet itself was not considered as mechanical isolation in the isolation certificate, so that the spade of the final installation, the insulation had recorded on the certificate of release authorization. In other means, from the release, the valves that had been placed in the closed position to allow the racquet facility could be operated again and

[144] P&ID: "384-33-W-DWG-100_001" & "_002"; "384-64-W-DWG-102_002"; "384-62-W-DWG-101_002"

[145] Cold Work Permit n° 34850 – Issue Date: 12/01/2014

[146] Insulation work permit n° 20101, de 12/01/2014, as to Cold Work Permit n° 34850 – Issue Date: 12/01/2014

[147] Long Term Insulation Register, valid on 11/02/2015

[148] PT System – Doc. n° MS-PR00847 Rev. 02 – Issue Date: 07/01/2015

[149] PTW System – Procedure – Insulation – Mechanical – Doc. n° MS-PR00840 Rev. 1 – Issue Date: 07/08/2013

allowed to work with its mechanical isolation certificate to be filed. Thus, the presence information of the spade in the system was not transcribed in long term isolation control.

The mechanical isolation procedure also provides that, in case of isolation of a process line, such isolated line should be inspected to confirm that the P & ID faithfully reflect the physical configuration of the insulation and that any discrepancy is marked in red color in the P & ID. The same procedure also stated that the modified design was submitted to the IMO for approval and subsequent submission of the P & ID for corrections "as-built". The update of the drawings is required for the knowledge of the current status of the installation, so that the daily operational decisions or in an emergency can be taken safely.

However, although the spade remained installed for over a year, the P & ID was not updated with the insulation information. In the investigation it was shown that during the emergency was used by the IOM P & ID diagram that contains the valves of the pump house. But the design used, taken from the production superintendent computer did not contain the markings, either indicating the existence of the flange or spade installed it. It was also evident in other hearsay that there was doubt about the actual point of leakage.

The understanding of the situation at the time of emergency was hampered by the failure of the registration and documentation changes. Such failure is considered one of the root causes Causal Factor "storage system degradation FPSO CDSM" and contrary to 16.3.3 of SGSO.

7.3.4. Root Cause n° 6: Alterations without management of change / [16.3.2] Management of change not performed

The management MOC-CSM-091 change contains diagrams (P & ID) and photos with marking of insulation indications, connection points, installation of pipes and accessories. Thus it was prepared planning for entry into tanks 2C to 5C and slop tank port.

However, it was evidenced that during and after repair of the valves of tanks 2C to 5C and slop tank port, unplanned activities were performed using modifications regarding their own MOC-CSM-091. Such changes without proper change management are described below.

On 09/13/2014 the check valve (check valve) installed in the inert gas drying line (temporary line MOC-CSM-091) was reversed by setting a modification in relation to the MOC-CSM-091[150]. Since then, the flow direction changed to the opposite in inert gas drying line, ie, starting to flow from the pump house to the cargo tanks. With this configuration, the production could not be more taken

[150] Cargo log book (*cargo log book – marine department*) in 13/09/2014

directly to 6C tank. It appears that the marine superintendent of Service passage of November 2014[151] It was recorded if the instruction that 6C tank had to be used for storage of production, the return line valve MOC-091 should be inverted. This change from the change management MOC-CSM-091 was conducted without hazard assessment and the overall impact on activities. The reversal of the backflow preventer possible the emptying of the slop tank port through the inert gas drying line on the main deck in a direction opposite to the planned on MOC-CSM-091. In earlier days, to transfer the port of slop content to 6C tank using a stripping pump and in the absence of the line of OP-068, the used and planned alignment was by lines inside the pump house through the OP -079 and PB-085 valves and the downstream of the stripping pump.

After repair of valves OT-041 and OP-023 inside the port slop tank, the tank still presented problems, as recorded in the service passage between marine superintendents in 20/08/2014[152]. As job log book records, in January 2015 there was emptying the slop tank starboard. In January there was a simultaneous emptying of both tanks slop, so that the tubes were directed to the tank 4C in 12/01/2015[153]. This is another change that took place without hazard assessment and the overall impact on activities prior to implementation.

The contents of the slop tank port was directed to the 4C tank using the stripping pump and, therefore, it was necessary to use the cleaning line 4C tank (4C aft COW line) and inert gas drying line (temporary line of MOC-CSM-091). For this alignment with COW line (crude oil washing - crude oil wash) was necessary to hose installation in the upper deck and insulation in cleaning line to isolate the 4C of the remaining tanks. Such modifications configure other change that occurred without hazard assessment and the overall impact on the activities, before implementation, ie without use of change management tool.

Also in January 2015, it was found the pumping impossibility of this condensate in 6C tank, setting the superintendent registered service crossing report in 21/01/2015[154] using the term "pumpable condensate" (unpoppable condensate). To circumvent the situation, was carried out heating operation tank 6C, is expected to result in the vaporization of the condensate and the consequent removal of the tank. The same service crossing report was no record of this transaction, there were approximately 130m3 of condensate, and the temperature should be maintained at 35 ° C with recommendation not to

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[151] Rotation Handover Report – Marine Superintendent – Doc. nº MS-19112014 – Issue Date: 19/11/2014

[152] Rotation Handover Report – Marine Superintendent – Doc. nº MS-20082014 – Issue Date: 20/08/2014

[153] Livro de cargo log book (cargo log book – marine department) in 12/01/2014

[154] Rotation Handover Report – Marine Superintendent – Doc. nº MS-21012015 – Issue Date: 21/01/2015

exceed 40°C. Vapors were sold daily by the vent riser daily during the day shift and inhibition of gas detectors in the upper deck, in the area near the exit of vapors:

> *"Presently heating up 6C to evaporate the unpumpable condensate from the tank. for this, the temperature had to be maintained @ about 35*C. heating temp. should not exceed 40*C. the Vent riser continously open during daytime. there is approx 130m^3 of condensate. 1.2m sounding of water is kept inside the tank for this (…)"*

Thus, the use of MOC-CSM-091 change management was distorted and all these modifications described were identified in a formal process of change management in order to be hazard identification and assessment of the overall impact on activities prior to implementation of modification. Therefore, there was failure in the application of hazard identification mechanisms and / or risk analysis prior to implementing change. Such failure is considered one of the root causes Causal Factor "storage system degradation FPSO CDSM" and contrary to item 16.3.2 of SGSO.

7.4. Causal Factor n° 3: Degradation of marine staff of FPSO CDSM

Once a system with operating restrictions, it is expected that all resources were provided so that the risk caused by this change in the operations to be minimized. These resources include technical, human and proper qualification for people on board were able to perform their activities safely.

In this way, the operation of a platform is only effective in safety by ensuring not only the maintenance systems (focus on engineering) but also maintaining a solid and experienced technical team knowledgeable of the foundations and rules for the performance of their functions. It is for the operational safety management system implemented by companies establish requirements and provide funds for minimally be affected the reliability of people and systems, subject to continuous improvement.

The moment degraded systems are operated by a degraded staff, without proper management of people, there is increased probability of failure. Thus, the accumulation of functions, the loss of knowledge about the current system status, lack of updated procedures and training existing mechanisms, the overload caused by systemic problems and failure in training contributed to the occurrence of contention loss.

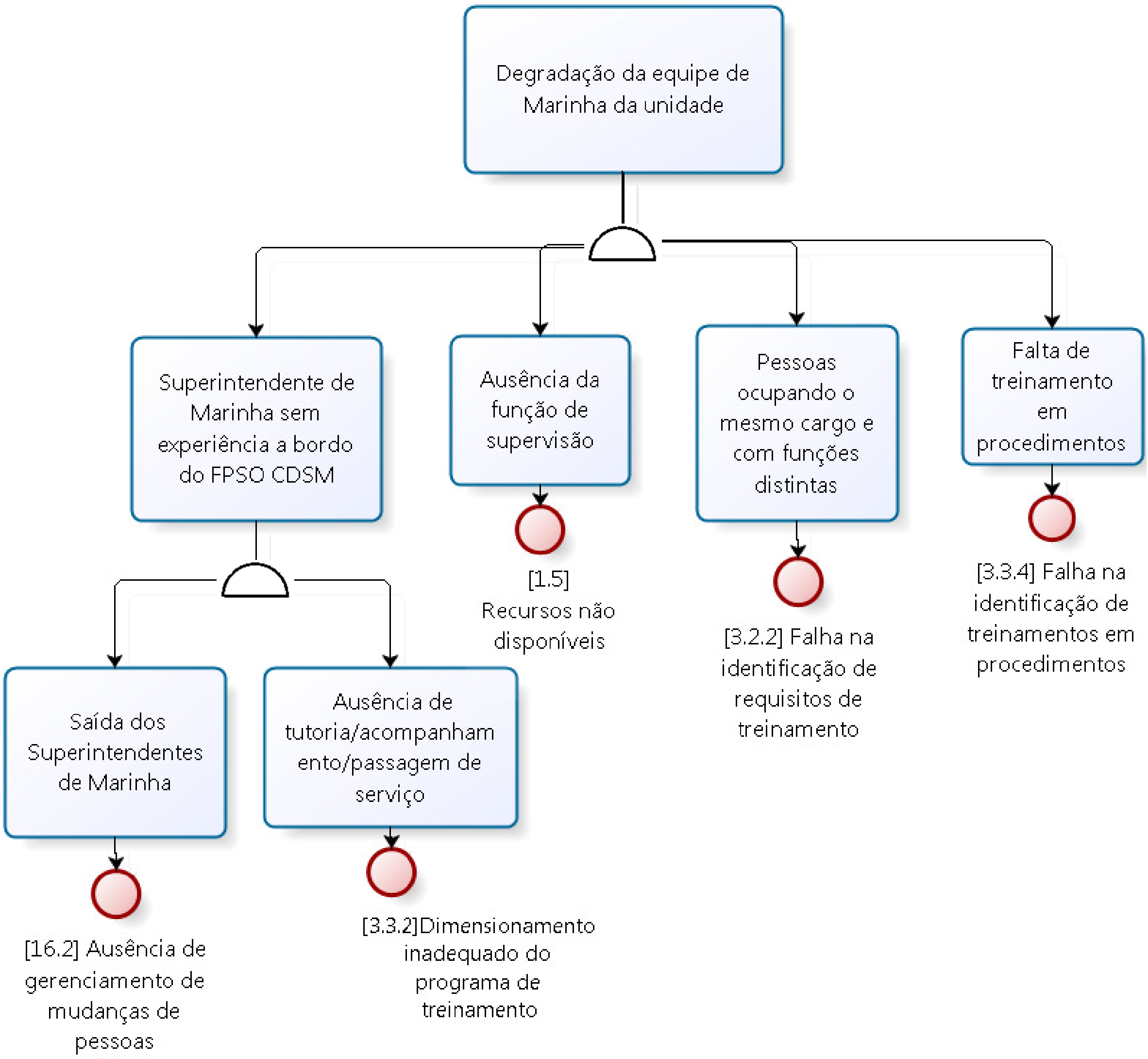

Figure 106 - Causal Factor 3: Marine team degradation of FPSO CDSM

7.4.1. Root Cause n° 7: Lack of marine superintendents / [16.2] Lack of staff management

The organizational structure of FPSO Cidade de São Mateus, had two marine superintendents who took turns with each other, leaving only one on board. That is, while one was boarded, the other was in non-working time. So were the cargo operators: there were four turns shipments, i.e., while two were picked up, the other two were off. The position of marine operator was in FPSO CDSM, the rank immediately below the marine superintendent.

About four months before the accident, in 17/10/2014[155], one of the marine superintendents resigned. The BMW company failed to immediately reset his absence and, therefore, the most experienced cargo operators (one per shipment) began to accumulate their duties with the superintendent function - turns the gate scale to the marine remaining superintendent.

About two months before the accident, on 07/12/2014, the only remaining marine superintendent in charge also turned away from the FPSO - once it has been approved to take the IOM function (Platform manager) on another platform BW Offshore in Brazil (the FPSO City of São Vicente).

It was found that this approved following the flow proposed in procedure [156] Career Development BW company, through competition and detailed assessment of their competence and performance evaluations[157] performed by higher courts BW. However, analyzing the flow of information in this assessment, at no time discussed the impact that his absence would give the FPSO CDSM or who would take over his position.

From this date, as the BW company did not immediately put back this marine superintendent position, the two most experienced cargo operators (one per scale boarding) began to take turns in both their original functions as the marine superintendent . Finally, eleven days before the accident, on 01/31/2015, embarked on a new FPSO CDSM marine superintendent who had previous proven experience of eighteen years in similar facilities[158], all Group BW. As per these eighteen, about ten years served as marine supervisor about four years as a marine superintendent.

However, this was his first embark on this FPSO and therefore was still in familiarization phase in relation to operating systems, modification, and ongoing operations, the type of fluid transferred in cargo movements, procedures practiced in the unit and the new team.

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[155] CSM – Dismissal Report, Transfers and Assets CSM (2009-2015)

[156] *Career Development & Promotion* – Doc. n° MS-PR01382 Rev.3 - Issue Date 29/01/2015

[157] MS-FR00507-04 Interview Guide; OCS-HR-1004 curriculum vitae;

[158] Testimony collected from ANP (pg. 650 to 657) and resume OCS-HR-1004, as of 16/07/2015

During audit, it sought to determine whether there was a context analysis of the absence of superintendents and the consequent accumulation function practiced by freight operators.

It was identified in the change management procedure Operator BW Installation[159], effective on the date of the accident, which had forecast personnel changes in management, including linked to temporary repositioning process functions that could affect the safety of operations.

According to this procedure, the flow of personal change management would be approved by the Division of Human Resources of the company - but should be opened / started by a requester, approved by the IOM of the FPSO and reviewed / approved by the Operations Manager, as illustrated in Figure 107, removal of the change management procedure. However, it was evidenced both by testimony and by historical service ticket and performance evaluations that all Marine and OIMS team knew the lack of marine superintendent position, however, there was no opening of a Change Management form by no "requesting" (the identifier change agent)..

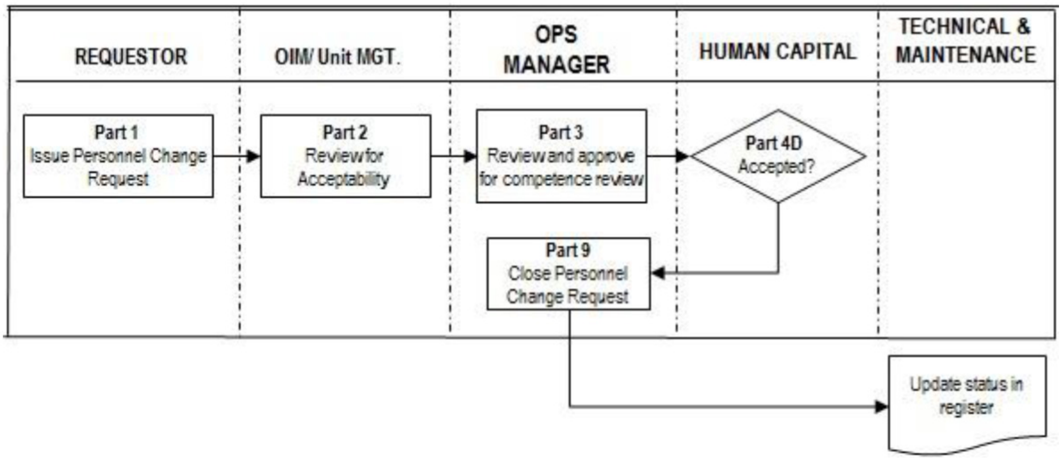

Figure 107 - Flow management change people contained in the BW procedure

Additionally, it was observed in audit that this procedure was not being applied in any case of change of people in the FPSO CDSM and was conducted either at the output of marine superintendents.

Besides the increased workload due to the accumulation of functions of the operators who took the superintendent function, another issue to be evaluated in this process would be the responsibility of these operators to assume that function.

[159] Management of Change - Operations - Doc. n° MS-PR00157 Rev.04 – Issue Date: 05/12/2014

In its last performance evaluations[160], held in October 2014, these expatriates operators were very highly rated, but was suggested by its evaluators to reach vacancies “Supervisor”[161] and “Senior operator” – since both require a license ("higher marine license") and certificate ("master's certificate of competency") so they could be promoted to the post of marine superintendent. Yet for one, was added the comment that he had acted several times as marine superintendent.

In addition, it is observed that the performance of marine operators expatriates as marine superintendents would be a promotion and, as such, should have been assessed following the entire flow required by the BW Career Development procedure.

For these reasons, it can be said that there has been deterioration in the quality of the work done by the Marine team due to the departure of marine superintendents without immediate replacement, still causing the accumulation of tasks that an expatriate marine operator held on board - beyond absence of proper evaluation and certification for the post.

In this sense, it could be seen that the installation operator has not evaluated nor managed this or any other change of form of personal that the risks arising from these changes remain at acceptable levels. Such failure is considered one of the root causes Causal Factor "Marine team Degradation of FPSO CDSM" and contravenes the provisions of item 16.2 of SGSO.

7.4.2. Root Cause n° 8: Lack of tutorial / monitoring / [3.3.2] Inadequate dimensioning of the training program

On the date of the accident, the new marine superintendent, embarked on 01/31/2015 was still familiarization process with the Cidade de São Mateus FPSO systems. There are reports that some operations accompanied by the marine operator on board, which accumulated before the superintendent role, but the reports were inconclusive on this received tutoring.

However, it is certain that there was any kind of mentoring between the new superintendent and an effective marine superintendent who had already worked on the FPSO CDSM. There was a scheduled tutoring to occur during the offloading operation between 21 and 24 of February 2015[162] – authoring chosen the former superintendent who IOM from another platform was promoted.

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[160] MS-FRO2535-00 Performance Appraisal Form – Offshore

[161] MS-JD01517, Rev.0, 12.11.2013

[162] Rotation Handover Report – OIM - Doc nº OIM Handover 2015 02 11 – Issue Date: 11/02/2015

It was also not prepared any class of ticket report (handover) to the new marine superintendent, who embarked on 31/01/2015, which is oriented to use the previous handover that was on the computer, dated 21/01/2015 - last exchange group among marine operators.

It should be noted that between November 2013 and the date of the incident, there was also a change in platform OIMs. The OIM with whom the new marine superintendent spent most of their boarding also had little experience on this platform, having been leased in unit 18/11/2014 having done so, only two shipments FPSO CDSM. This IOM landed early in the morning on the day of the accident. The OIM who took the platform on 02/11/2015, therefore, that is, was there a few hours onboard when the accident occurred, given that met the new marine superintendent that morning.

During the investigation it was possible to demonstrate the effective performance of marine superintendent in making decisions without having full knowledge of the conditions of systems and specific features of the FPSO CDSM. For these reasons, it was found that the training was not planned or effective for new marine superintendent and the passage of inefficient service.

In this sense, it can be seen that the installation operator not scaled the training program in accordance with the classification of functions and tasks relating to the post of marine superintendent. Such failure is considered one of the root causes Causal Factor "Marine team Degradation of FPSO CDSM" and contravenes the provisions of item 3.3.2 of SGSO.

7.4.3. Root Cause n° 9: Lack of supervision / [1.5] Resources not available

The organizational structure of the FPSO CDSM, there are three superintendents to subordinate IOM: (i) oversight of production, (ii) maintaining oversight and (iii) marine oversight. Subordinate to superintendents of production and maintenance, there are supervisors and subordinates to these there is an operational team. However, there is no supervisor in the FPSO CDSM marine team and marine operators respond directly to the marine superintendent.

During the accident investigation, it was found to exist in the BW management system, a "job description" (description of the tasks linked to the function with responsibilities and authorities) to marine supervisor[163], with some tasks and responsibilities in the existing "job description" of the marine operator[164] and the marine supervisor[165]. In addition, some BW platforms operating in Brazil and in the world have this post of marine supervisor.

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[163] Offshore Marine Supervisor – Doc. MS-JD01517 Rev.0 – Issue Date: 12/11/2013

[164] Offshore Marine Operator – Doc. n° MS-JD01515 Rev.02 – Issue Date: 31/12/2014

[165] Superintendente Marítimo *Offshore* – Doc. n° MS-JD01516 Rev. 02 – Issue Date: 31/12/2014

It was examined further that there is a contractual requirement with Petrobras establishing a minimum quantity of embarked personnel. This requirement appears in one of the Annexes to the established Service Agreement with Prosafe[166], as per the Figure below.

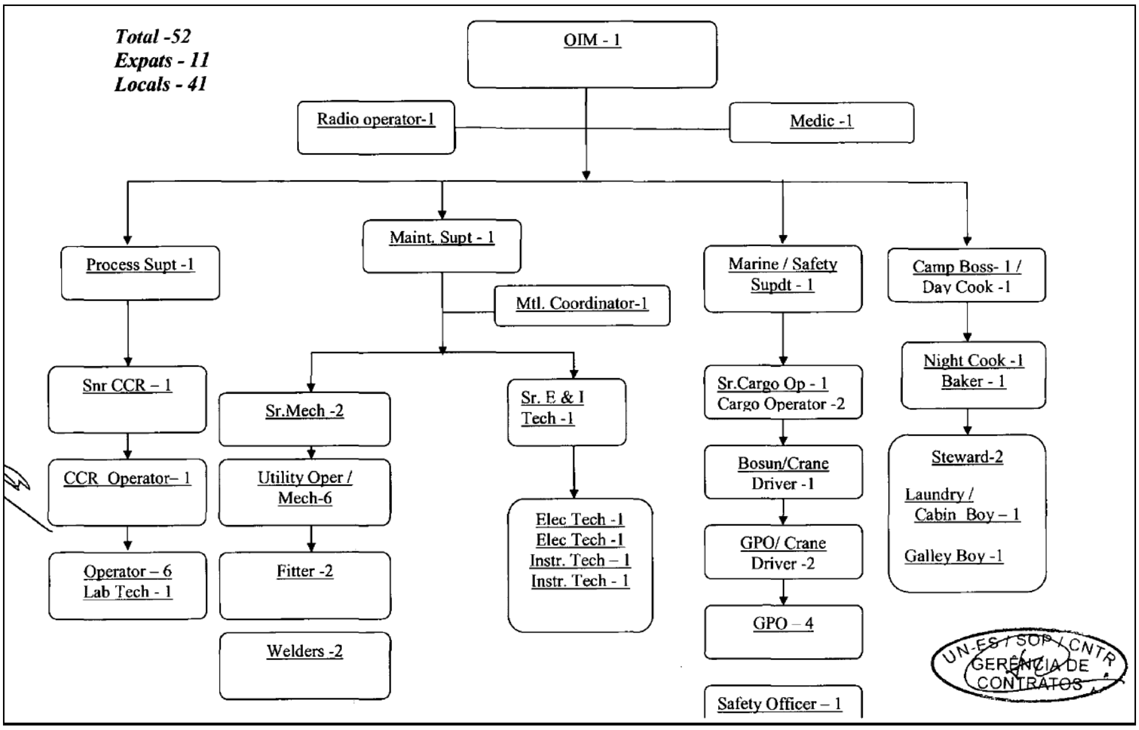


Figure 108 - Organization Chart minimum required in contract

This annex, it was possible to ascertain that there was no post of forecast "supervisor" for any of the three teams, but there was the appointment of a senior technician to each - indicating that this senior technical exert function similar to that of a supervisor.

However, only the marine team did not exist or supervisor or either "senior post operator" - and, according to the chart provided in the agreement, there should be for this team a 'senior position operator "and two" cargo operators "on board. Nothing was reported by inspectors on board the contractor about this absence. The current organizational chart at the facility when the accident can be seen in Figure 109 (adapted installation of the chart) and Figure 110 [167].

[166] Contract for Provision of Operation Floating Production Unit Services Oil Storage and Transfer (FPSO) n° 2300.0028837.07.2

[167] The figures were adjusted to preserve the names of employees.

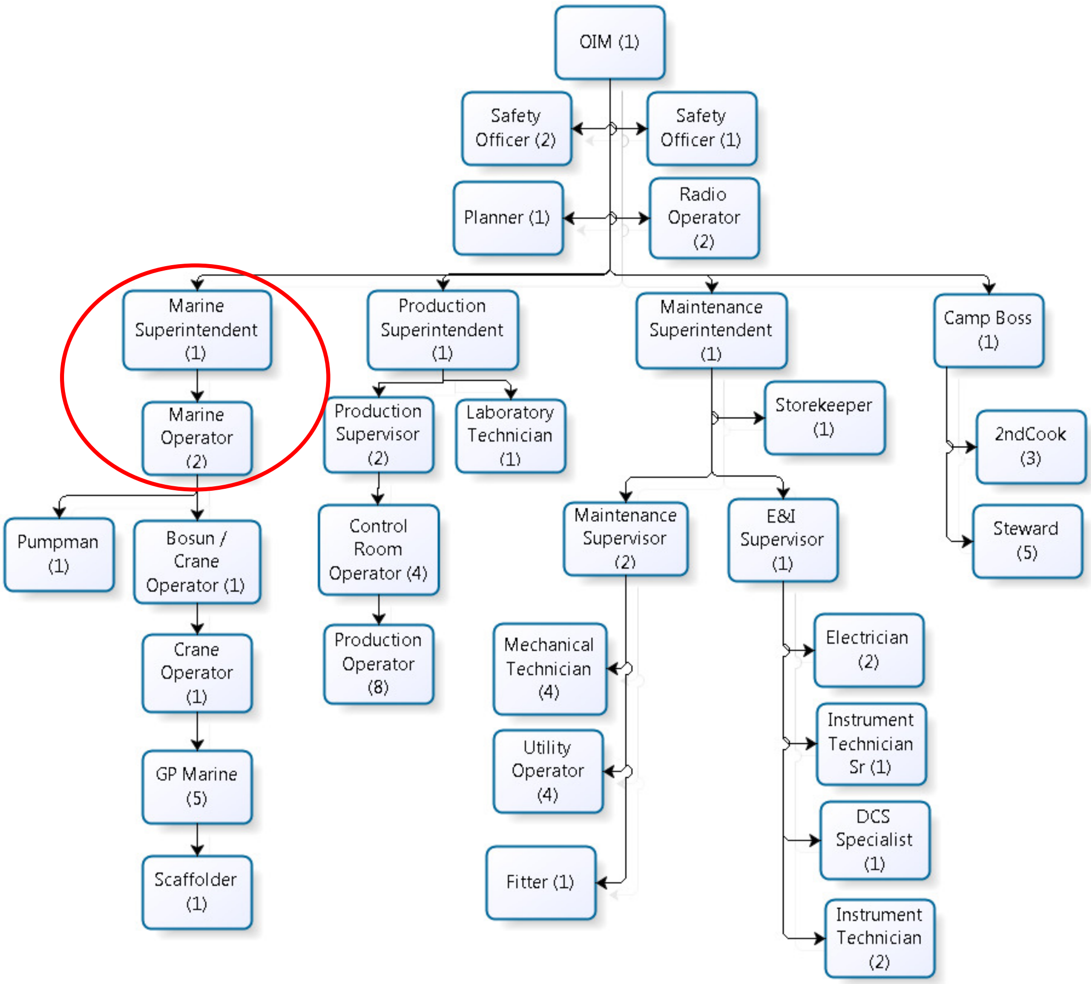


Figure 109 - Installation Organization Chart

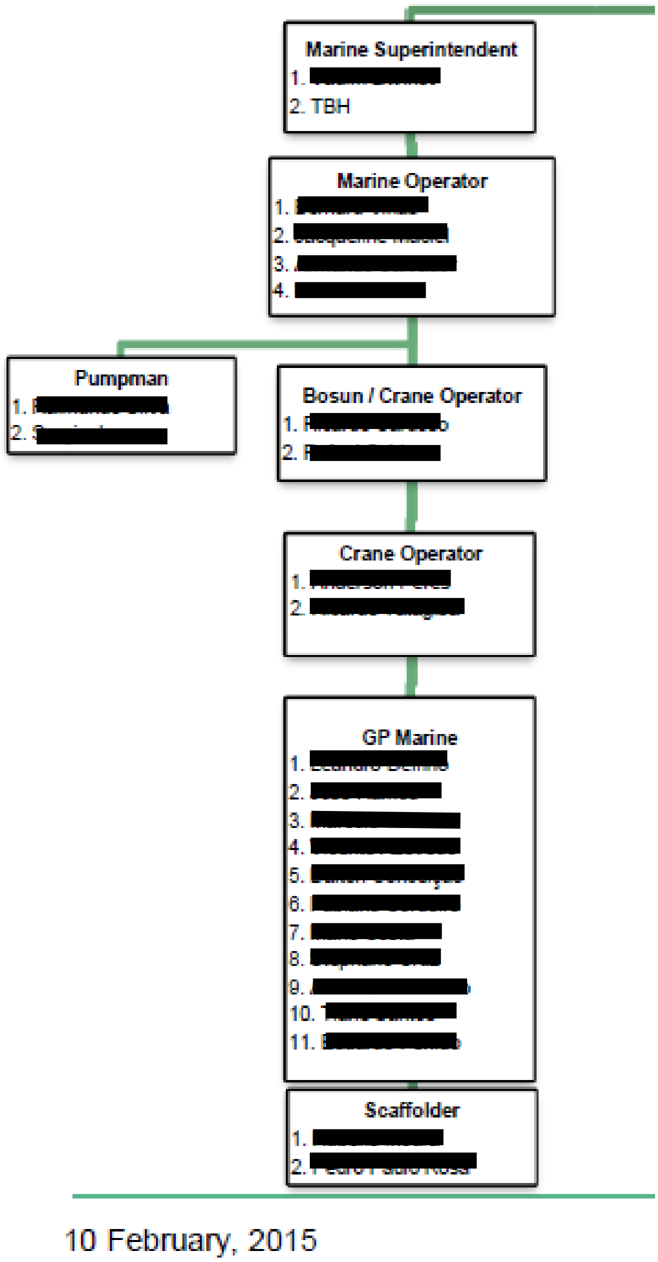


Figure 110 - Marine Team Organization Chart [168]

For these reasons, it was found that each shipment should be three marine operators, one being the supervisor or a senior marine operator, as provided in the contract signed with Petrobras. However,

[168] TBH means to be hired.

this had only two FPSO marine operators per shipment - neither had oversight function or was a senior.

During the investigation, it was found that lack of appropriate supervision also contributed to discontinuity of service information and passing control of charge transfer operations. The functional disparity between the superintendent positions and marine operator, added to the excess of activities required for the maintenance and operation of the charge transfer system were conducive to the emergence of failures in performing tasks and procedures for lack of adequate supervision.

In this sense, it can be seen that BW did not provide the resources needed for the implementation and operation of operational safety management system, as well as the Concession Operator failed to not evaluate the Setup Operator's performance. Such failure is considered one of the root causes Causal Factor "Marine team Degradation of FPSO CDSM" and contravenes the provisions of item 1.5 of SGSO.

7.4.4. Root Cause n° 10: Employees with the same attribution performing different functions / [3.3.2] Failure to identify training/qualification requirements

Besides the fact discussed in the item above, that there should be three on board marine operators - one being supervisor or senior - when in practice there were only two, there was still a complicating factor: one of the two marine operators on board seemed to be overwhelmed in relation to operational tasks.

Theoretically activities on marine operator function should be performed by all of this function, but it was evidenced via testimonials, which was consensus among marine operators and marine superintendent of respondent’s Brazilian marine operators and expatriates occupied the same position, On the other hand, they played different functions.

On board the FPSO CDSM, there were always two marine operators: a more experienced (expatriate) and other less experienced (Brazil). The testimonies and documents examined (such as resumes, performance reviews, permissions of work and service passages of OIMS) indicate that expatriates operators were responsible for the "operations" and the Brazilians with "administrative tasks". It is understood as "operations" tasks such as alignments used for cargo handling and operation of the valves for the HMI screen and "administrative tasks" the offloading of occurrence records and fill permissions work, especially the services performed on deck. Such disparity created a different workload between people occupying the same position, and the marine operators’ expatriates had more demand both in the operation of the systems, in control of ongoing maintenance activities in the planning and accumulation in attribution of marine superintendent.

The motivation for this difference is unclear, but there is evidence that they are linked to the long experience in the offshore area (expatriates had about 10 years longer than the Brazilians) at the time of experience in FPSO CDSM (expatriates had two years more than Brazilian), the different times of departure (expatriate Brazilians were 28 days and 15 days), and fluency in the English language (a language spoken by superintendents and OIMS).

In Table 13 below, a comparison between the duties of Brazilians and expatriates marine operators:

Table 13 - Comparison between the duties of Brazilians and expatriates marine operators

Brazilian Operator	**Expatriated Operators**
Daily Reports	The supervisory screen monitoring
Work Permit Issuance (PT) when there were crane drive including loads of these changes in the machines Square	Alignments between the tanks used for cargo handling
Monitoring of work permits on the part of the Marine, eg paints and scaffolding on deck	Reading and interpretation of P & IDs
Communication with the pumping over the interface of the tanks	Starting and stopping of the cargo pumps
During offloading, just as the occurrence of documentary records and ETA.	Communication with the pumping over the radio during opening operation and closing of valves
	Knowledge of existence spade valves
	Helicopter operations
	Maintenance of boats and lifeboats and deck equipment

In a statement, it was said that: (e) expatriates operators were but the service often for lack of time and that when the Brazilian tried to follow a process altogether, the superintendent the requested another job and (ii) only when the Marine team ran out superintendent and expatriates marine operators took the function is that they began to teach more operational service to Brazilians (as an example ballast tank of the movement, disposal or produced water circulation).

It has been found through performance evaluations and turn passes this fact, labor absorption referring to all the operational part for only one of onboard marine operators, was fully aware of both crew members, as OIMS and superintendents as well as management of BW operations. It was found that there was a demand for new expatriate cargo operator and pumping again.

The service crossing between OHMs report of 11/02/2015 is recorded on the specific problem of Brazilian marine operators and the proposed solution of the problem:

> *"I would strongly recommend to get rid of both (..) we have on board as Marine Operators. They do not show an interest in their work and not willing to learn. Unit's operations and procedures knowledge is not sufficient for their position. (..) plans to shorten one Marine position on board"*

This problem also affects the pumping function, such that transcription from the same passage service below:

> *"(...) also agreed to get 2 expats pumpman replacing Brazillian, so it worth to remind him of the current status"*

For these reasons, it was found that each shipment there were two marine operators occupying the same position but with different functions, possessing levels of knowledge in completely different systems and procedures. Added to this fact the accumulation of marine superintendent function - and sometimes even as bombeador3 when the holiday one of the pumpers - showing a workload and responsibility in a function considered of great impact on the operational safety of a unit floating production.

In this sense, it can be seen that the installation operator did not identify the levels of training, expertise, skill and knowledge specific to the function, which enables the employee to perform the tasks pertaining to the post occupied by him. Such failure is considered one of the root causes Causal Factor "Marine team Degradation of FPSO CDSM" and contravenes the provisions of item 3.2.2 of SGSO.

7.4.5. Root Cause nº 11: Lack of training in operational procedures / [3.3.4] Failure to identify training/qualification requirements in operational procedures

At the time of the accident there was a training matrix for all on board the workforce of the FPSO CDSM for training considered mandatory by the Operator Installation (NR-10, NR-34, CBSP, HUET, among others). However, it had not been implemented a training matrix in operating procedures for teams aboard the FPSO CDSM, although there is evidence that this matrix was in preparation and close to being finalized.

In addition to this matrix, which is a control of the training tool, has still not been implemented by the time of the accident, there was no training records in specific operational procedures for the Marine team. In some testimony was reported ignorance of the written procedure for charge transfer between tanks and the lack of formal training in this procedure for this unidade3.

During audit diligence there were evidenced that marine team members had training certificates in some procedures related to operational safety, such as: mechanical insulation, Work Permit and Task Risk Analysis (Job safety analysis and Risk Assessment - JSA) plus some Forms compliance checks with procedure for Simultaneous Operations Helicopter and offloading operations. However, it was not observed any kind of training to transfer load between tanks involved with this operation (pumping, marine operators or new marine superintendent).

For these reasons, it was found that there were no training features at all operational procedures that impact the operational safety as well as there was, at the time of the accident, any control to ensure that the workforce remained trained in the procedures.

In this sense, it can be seen that the installation operator did not establish the skills and training as much as needed to carry out the activities under operational procedures. Such failure is considered as one of the root causes of the Causal Factor "Degradation upon the marine team of FPSO CDSM" as it opposes the provisions of item 3.3.4 of SGSO.

7.5 Causal Factor n° 4: Operating the stripping pump with the offload sealed

The control of the operation of the stripping pump was made by the marine operator through the Human-Machine Interface (IHM) on the load cross docking system, located in a room adjacent to the process plant control room, and through the percentage adjustment opening the steam valve and monitoring the offload pressure. The IHM of the load handling system is the supervisory system display where the marine operator visualize/modify the position of the remotely operated valves, is displays the valves with a simple statement of position and controls the operation of the system pumps. In general, the confirmation of operation, triggering operations and stop pump were assisted by the pump operator.

The monitoring parameters through the opening percentage of the vapor control valve and offload pressure led to the failure of interpretation of the operating condition of stripping pump because they are indirect measures of alternative pump displacement. The number of strokes is a direct measurement of the pump displacement.

In the meantime, in order to evaluate the operation of the pump based on the percentage of opening of the vapor control valve, it should be considered the pump can be changed by the following conditions: i) different steam facts provided, i.e. temperature and pressure imply differences in the operation of the pump; ii) the opening of the steam lines of drains to influence the steam supplied by the pump; and iii) there is a different relative displacement of the pistons for different pumped fluids.

To rely on the marine operator's interpretation of the ratio between the percentage of opening of the vapor control valve and the number of strokes, considering the different process variables causes high probability of errors since the operation is no longer based on direct parameters of the operated process and is now carried out according to the marine operator's as by own experience. It should be noted the indication of the number of strokes per minute was provided in the stripping pump project but has not been implemented yet.

For the composition of the system operational overview, the marine operator then needed to establish the percentage of openings of the vapor control valve and to observe the pressure at the offload from the pump in order to infer directly in the stripping operation of the pump.

The purpose of the offload pressure indication of the stripping pump in IHM turn out to aggregate into the increased possibility of error from marine operators since the information pump offload pressure as then now represented by a pop up window, or to be omitted in the operation of other systems. Even watching the pressure in the offload, the scale presented was considered inadequate by the present values above the Maximum Feasible Operating Pressure

(PMTA) of the system, which made the pressure reading to depend on the visual acuity of the marine operator. As per such view there was also no indication of Maximum Operating Pressure (PMO) and system PMTA.

In this scenario, an operating procedure would be essential for the control of operational hazards and the performance of the functions of cargo operators, given that, for example, describe the charge transfer operation between tanks with use of stripping pump, define issues related to check valves and lines, as well as explicit prohibitions.

However, there was no operational procedure to indicate the parameters and procedures to be followed by the marine[169] operator and by pumping in maneuvering change collectors and how to operate the stripping pump.

Continuous monitoring of stripping pump to be done by pumping throughout its operation, which was appointed in HAZOP safeguarding of marine systems, was not reflected in any formal written from the operator site.

Nevertheless, it was found during the hearings provided to ANP that during the starting operations and stop the stripping pump, there was the practice of the pumping be next to the pump in order to perform specific actions drainage during the match as well as to monitor and report the condition of the equipment for the marine radio operator.

Additionally, the practice and procedure of load[170] cross docking devices operations indicated the operations of the storage system valves to be monitored by pumping, when possible, which prevented the physical presence of the pump installation site at all times.

It was then found that the operation that caused the loss of containment, the pump operator found stripping away of the pump as it performed the activities necessary for the new alignment[1].

In addition, management failures the procedure of cargo transfer equipment operations established by Prosafe was not continued and updated by BW, becoming uncontrolled

[169] *Hazard and Operability Study (HAZOP) Report for Ship Systems* – Doc. n° 384-HS-RPT-004 Rev. 0 – Issue Date: 03/09/2007

[170] Operational Management system - the Cargo Equipment Operations – Doc n° 384-OP-MDK-201 Rev.1 – Issue Date: 19/02/2008

document outdated and unused. Lack of knowledge in operating procedures is supported by the absence of a training plan in operational procedures.

There are differences in the testimonies of those who in fact, are the marine operator or marine superintendent, attended the maneuver valves which shut the pump offload. However, when evaluating system operation data, it was found the pump operation with closed offload occurred in other situations days preceding the accident.

Such associated facts led to the situation where it is allowed to operate a reciprocating pump with its offload lines closed, a fact crucial to the accident. This causal factor and their causes, which are described below, are indicated in Figure 111.

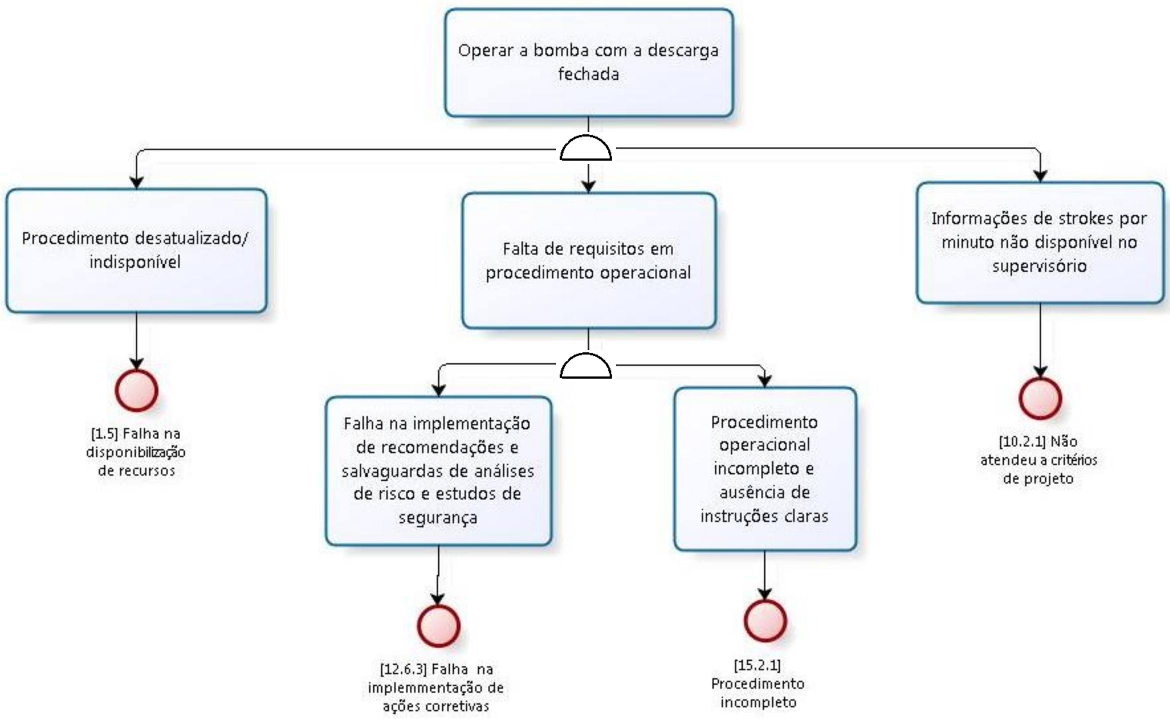


Figure 12 – Causal Factor n° 4: Operating the stripping pump with the offload sealed

8.
9.
10.
11.
11.1.

11.1.1. Root Cause n° 12: Outdated/unavailable procedure / [1.5] Failure to furnish the resources

It was found by consulting the tracking spreadsheet migration procedures[171], that several procedures had not yet been evaluated and migrated to the document control system - Management System (MS). Among them is the procedure "Operational Management System - Operations of Cargo Equipment", which describes and defines the step by step of the procedures for the operation of the Load System equipment and applies to the FPSO Cidade de São Mateus[172].

According to interlocutors of BW Offshore, as an alternative to the lack of evaluation of some Prosafe operating procedures for migration and inclusion in documentation control system BW Offshore (MS), it was decided to make available the old procedures of the unit, which had not been updated in the internal network to the FPSO Cidade de São Mateus, outside the established document control procedure in the company.

Among these, the procedure was made available by "Operational Management System - Operations of Cargo Equipment". However, since the BW had no training process that includes training in operational procedures, there is no evidence that the FPSO CDSM navy team had domain of the requirements of this procedure.

It was found that the applicability of the procedure "Operational Management System - Operations of Cargo Equipment" had not yet been evaluated by the team of BW Offshore and it still had to identify the "Prosafe Production".

Corroborating the fact that it had not yet gone through the Prosafe migration to BW Offshore, in that procedure included the cover of Prosafe logo and the following warning:

[171] OMS Procedure review log CDSM (Master Copy) – Issue Date: 01/02/2014

[172] Operational Management System - Operations of Cargo Equipment - Doc No. 384-OP-MDK-201 Rev.1 - Issue: 02/19/2008

WARNING

THIS PROCEDURE AND ITS REFERENCES ARE UNDER DEVELOPMENT, READ CAREFULLY AND SPEAK WITH YOUR SUPERVISOR BEFORE USE.
USE THE JSA AND THE MINUTES OF SAFETY MUSTER BEFORE PERFORMING THE TASK AND MAKE COMMENTS IN THE WORK PERMITS (PTW) IN REGARD TO SAFETY ISSUES WHICH MAY NOT HAVE BEEN MENTIONED IN THIS PROCEDURE.
THE ACCURACY OF SUCH PROCEDURE MUST BE ANALYZED IN PLACE AND A FEEDBACK FOR IMPROVEMENT MUST BE GIVEN RIGHT AWAY TO THE ON SCENE SUPERVISORS/OIM WHEN THE TASK IS CONCLUDED

Figure 112 - Warning contained on the cover of the operating procedure of charging system

Additionally, in this procedure, the section in which is described the charge transfer operation in an emergency situation, there is described below acknowledgment confirming that the procedure was obsolete:

5.2 CROSS DOCKING LOAD OPERATION IN EMERGENCY CONDITIONS

THIS PLAN HAS BEEN THROUGH SIGNIFICANT MODFICATIONS, STRUCTURAL DETAILS AND OPERATIONS ARE NOT AVAILABLE IN THE PRESENT MOMENT YET. SOME PROCEDURES WILL BE INCLUDED AFTER THE EQUIPMENT COMISSIONING AND DURING ITS VALIDATION ON SITE.

Figura 13 – Item referente à operação de transferência de carga em situação de emergência

These inserts capitalized in operation, associated with lack of control of the information by using different means to control information set by BW Offshore discourages its use, making it inefficient. Such a condition was considered analogous to the lack of operating procedure, since such a risk control mechanism was not kept by the BW and its use was discouraged by the procedure itself.

In this sense, it can be seen that the installation operator did not provide resources for the development, implementation and updating procedures of operational safety management system of the FPSO Cidade de São Mateus, in order to properly manage operational risks. Such failure is considered one of the root causes Causal Factor "Operate the stripping pump with offload sealed" and as it may contravene upon the provisions as set forth in item 1.5 of SGSO.

7.5.2 Root Cause n° 13: Failure to implement the recommendations and hazard analysis of safeguards and security studies / [12.6.3] failure to implement corrective actions

The Marine HAZOP[173], still performed in the unit's design phase in 2007, set for the diversion of "no flow" in the drainage operation of the cargo tanks, the following causes: (i) failure stripping pump, (ii) hydraulic valves closed stripping the offload pump, or (iii) closed hydraulic valves or locks the stripping suction pump. For this scenario classified as high risk, the following results were listed: (i) damage to the pump, (ii) delays the stripping operation, and (iii) pressure in the lines due to the locked offload, resulting in loss of containment and the possibility fire in the pump house.

Thus, it was found that the draining operation with the offload of the closed bomb had yet been studied in the design phase and the consequences associated with this practice had been identified. However, it was found that one of the safeguards associated with this scenario (closed valve in the offload of stripping pump to the final destination) was not implemented, namely: "the presence in the pump house throughout the time during stripping operations."

It is noteworthy that such protection requires the permanence of a person for long periods in the pump house, exposing it to the risk scenarios identified in this part of the installation. This is due to the maintenance of older operating systems, arising from the time the unit was an oil tanker, which have not been modernized in his conversion to the platform.

The operational practice established in the FPSO CDSM did not include all operating phases of the stripping pump, only the starting and stopping of the pump, and it was not reflected in a procedure / formal education. The operation procedure of loading equipment, in turn, limited the implementation of safeguarding the monitoring valve positioning and further brought the proviso that such monitoring would be done "if possible", except that it is not consistent with the protection, described above.

In this sense, it can be seen that the installation operator did not ensure the implementation of safeguards from risk analysis. Such failure is considered one of the root

[173] Hazard and Operability Study (HAZOP) Report for Ship Systems – Doc. n° 384-HS-RPT-004 Rev. 0 – Issue Date: 03/09/2007

causes Causal Factor "Operating the stripping pump with a closed offload" and contravenes the provisions of item 12.6.3 of SGSO.

7.5.3 Root Cause n° 14: Incomplete operating procedure and lack of proper instructions / [15.2.1] Incomplete procedure]

It was found from the data extracted from the Supervisory System (*Cargo Ballast System*)[174] that the performance of the freight operators in relation to the steam provision for the departure of stripping pump was not standardized as shown in the graphs below.

[174] Cargo Excel spreadsheet Ballast-- Supervisory System (pages 103).

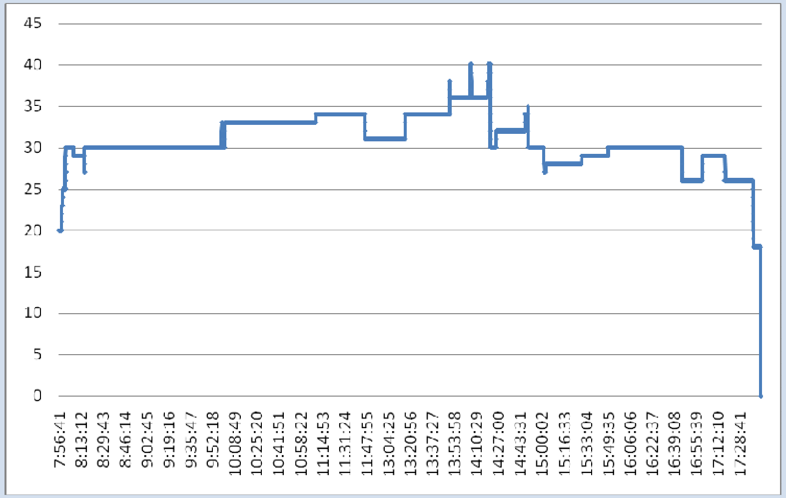
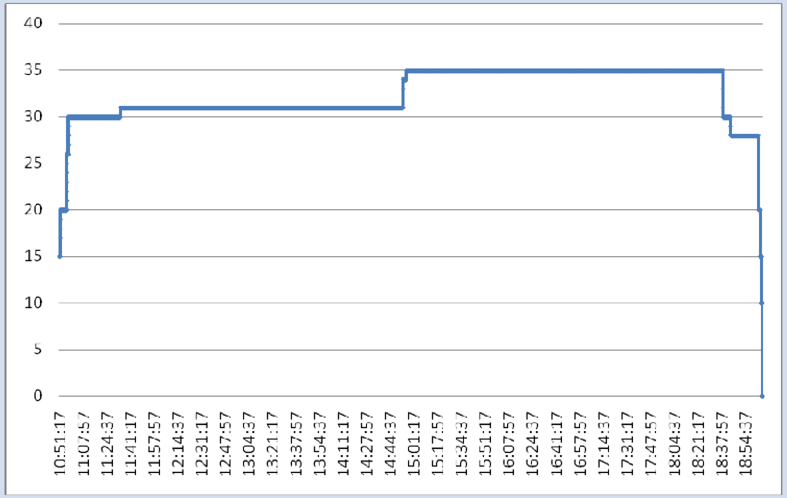
05/01/2015	08/01/2015
	

Figure 114 - Steam Flow charts for the stripping pump

14/01/2015 **23/01/2015**

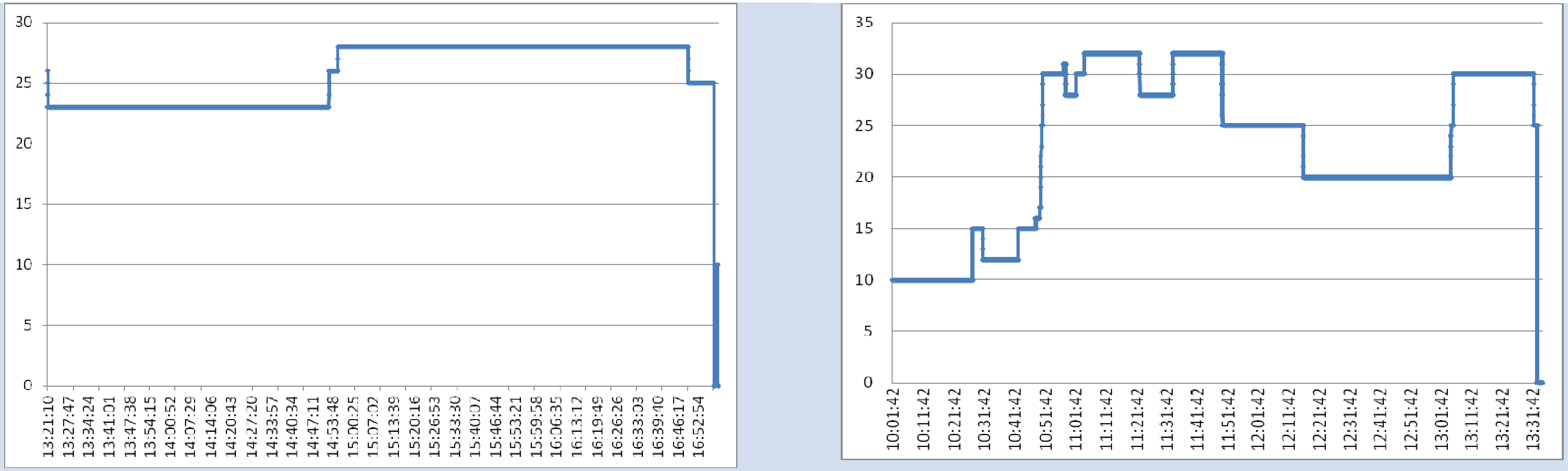


Figure 115 - Steam Flow charts for the stripping pump

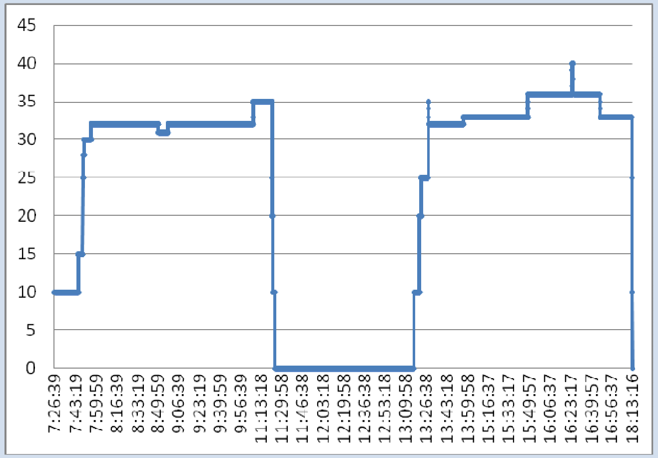
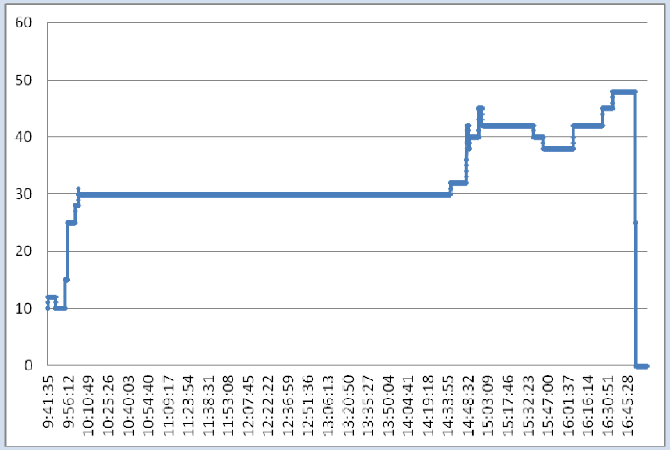
05/02/2015	10/02/2015
	

Figure 116 - Steam Flow charts for the stripping pump

As can be seen in the above figures, during the months of January and February, the percentage of opening of the steam control valve fitted to match the pump ranged from 10% to 25%. In addition, it is noted that on some days this provision was carried out gradually and on other days it happens instantaneously, although it was highlighted in testimony provided to the ANP, the way to provide pump steam would be according to the experience the marine operator.

Additionally, the differences in the ways of operating the stripping pump were also observed in relation to the actuation of the valves upstream and downstream of the pump. On the basis of supervisory data, it was found that, on some days, stopping the pump was preceded by closing the offload valve when it was still operating, while on other days the closing of the offload occurred only after stopping the pump.

The lack of standardization in closing the offload of the pump while this work was observed in the supervisory system data, although it has been highlighted in testimonials for a reciprocating pump such that the stripping pump, the correct would not operate it with a closed offload .

The Table 14 below shows the periods in which the stripping pump operated with the offload line valves closed during the month of February 2015.

Table 14 - period with the stripping pump valves sealed

Date	% Opening of the steam control valve	Period with the stripping pump valves sealed (h)	Working hours of the stripping pump valves sealed (h)
05/02/2015	10%	00:05:53	07:26:39 to 07:32:32
09/02/2015	10%	00:12:12	09:01:43 to 09:13:55
10/02/2015	10 to 12%	00:09:33	09:41:35 to 09:51:08
11/02/2015	8 to 7%	00:02:42	11:27:48 to 11:30:33

The divergence shown above procedures, is due to the fact that the procedure "Operational Management System - the Cargo Equipment Operations[175] " It was still incomplete by not explaining which bans would apply to the operation of stripping pump more explicitly by not mentioning the fact that the offload line valves stripping pump should not be closed before the pump stopped or in any situation there was flow. There is also no mention in regard to the adjustment of the percentage of opening of the steam control valve in the phase between starting and normal operation and does not address the procedures and parameters to be followed in the event of a change in the alignment of the suction or offload.

In turn, when assessing the stripping pump manual, the only mention of the closing of the pump offload is made in its item 3, which deals with the stopping of the pump, where there was the statement that: "after the parade pump, close the suction and offload valves. " The context of this statement is related to the total stop of the pump, unlike the alignment change of situation that was held by the Navy team FPSO CDSM. No mention of the ban of pump operation with a closed offload was made at any operating procedure.

In this sense, it can be seen that the installation of the operator did not have complete and clear operating procedure with regard to the prohibitions and restrictions for the use of systems and equipment in order to maintain control of risks. Such failure is considered one of the root causes Causal Factor "Operating the stripping pump with a closed offload" and contravenes the provisions of item 15.2.1 of SGSO.

[175] Operational Management System - Operations of Cargo Equipment - Doc No. 384-OP-MDK-201 Rev.1 – Issue date: 02/19/2008

7.5.4 Root Cause n° 15: Information of pump strokes not available in supervisory system / [10.2.1] Noncompliance to project criteria

During the investigation it has evidenced the existence of an informal procedure of starting and stopping the stripping pump. For the document analysis, it was concluded that the pump instruction manual[176] It was used as the reference procedure for starting operations and equipment failure. The instructions in this document for the operation of the pump refer to strokes rate (strokes) which is a direct measure of the pump, as shown in Figure 117 below, which shows part of this document in which reference is made to strokes rate bomb as "required revolutions" and "rated revolutions".

(5) Open the steam valve gradually until the steam pressure reaches required pressure at required revolutions, and begin operation if no abnormal point is seen in the condition of running.

(6) When steam or liquid leaks excessively from the glands, tighten the glands further and keep a tiny amount of liquid leaking from the pump glands.

(7) In case the extent of steam valve opening is kept constant during the operation the revolutions will rise or fall in accordance with the variation of the liquid end pressure, but the operation must be carried out at the rated revolutions by adjusting the extent of steam valve opening. In case the speed exceeds 125% of the rated revolutions there will be a fear of abnormal wear in the steam cylinder and piston rings.

Figura 14 – Stripping pump manual extract

It was observed in audit that the pump manual indicates the basics of starting, stopping and operating the equipment, but the operators were acting according to their previous experience and without the use of strokes counter information.

According to data sheet stripping pump[177], it could provide information of strokes count for CCR. The circuit diagram can be seen in Figure 118.

[176] *Instruction Manual of Steam Driven Piston Pump* (KPH), Shinkokinzoku Industries Co., LTD.

[177] The Cargo Data Sheet Stripping Oil Pump, Hull No. 606-7, 623-4, Hyundai Heavy Industries Co. LTD.

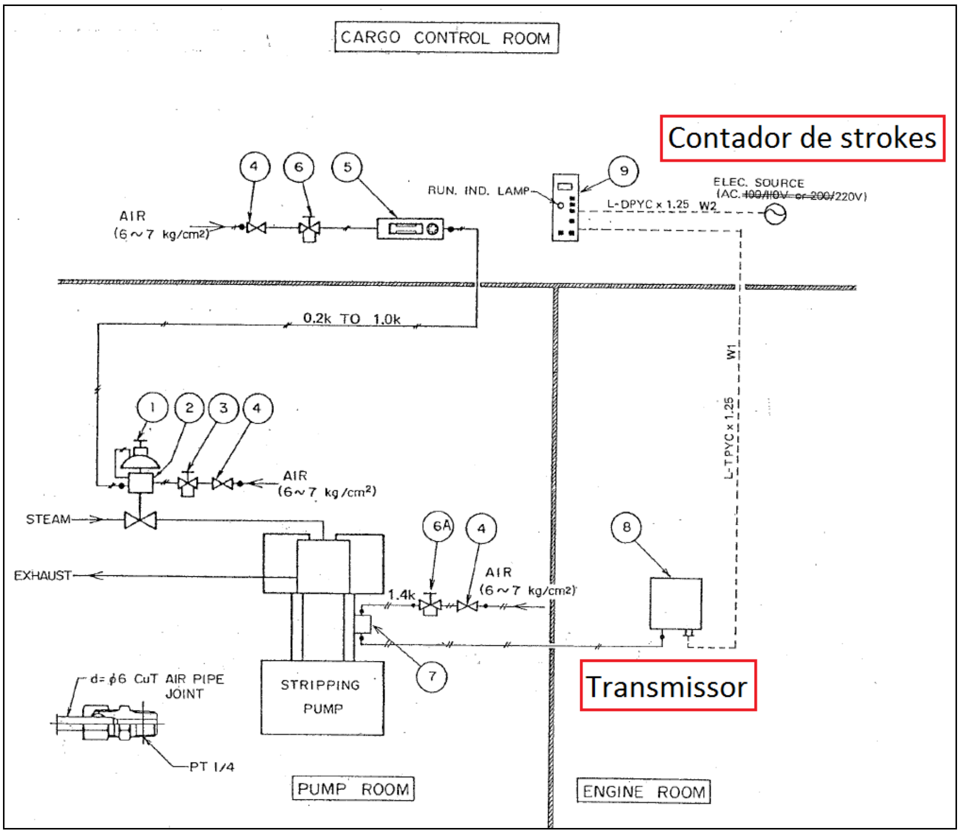


Figure 118 - Wiring diagram between the stripping pump and the CCR for the transmission of strokes count

The supervisory system was designed to provide information of the number of strokes / minute as shown in Figure 119.

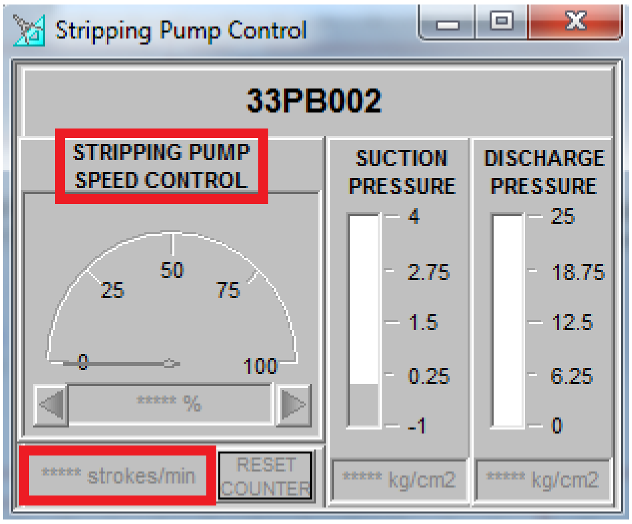


Figure 119 - supervisory system of the window where stated field to pump reading speed in strokes / minute

The strokes counter was not available to the marine operator since the commissioning of the unit, as (i) information provided by the plant operator[178], (ii) audit evidence and (iii) change management on incomplete commissioning of the charging system and ballast control system and (iv) evidence obtained through hearings.

Reading the strokes count, being a direct information of the operation of stripping pump, allow an unambiguous assessment about stopping the pump for marine operator.

Thus, the availability information of strokes count for the marine operator of the unit since the beginning of the operation due to lack of commissioning load control system and ballasting[179], is evidence that the operator did not meet the design criteria and not considered good engineering practice in the planning stages of construction and platform installation. Such failure is considered one of the root causes Causal Factor "Operating the stripping pump with a closed offload" and contravenes the provisions of item 10.2.1. the SGSO in noncompliance with design criteria.

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[178] Letter E&P-CORP/SMSCL/RA 0562/2015, de 06/08/2015

[179] *Change Management Form – Cargo & Ballast Control System* – Doc. n° CMR / CDSM / 0012 – Issue Date: 15/12/2009

11.2. Causal Factor nº 5: Loss of primary condensed material

In systems where there are devices that perform work on fluid, such as pumps and compressors, there is the possibility of pressure downstream and therefore critical procedures and systems are established so that, with this, safety barriers prevent loss of containment . With respect to positive displacement pumps, to operate with a closed offload, there may be a break weakest point in the system downstream of the pumps.

The system downstream of the outlet cylinder of the stripping pump had as single barrier overpressure against safety valve (PSV), physical barrier recirculating the pumped fluid to the pump suction, however this valve lacked a calibration routine, which made their uncertain reliability.

How much of the load transfer systems was originally from the time of construction of the oil tanker and its conversion into platform did not observe the safety philosophy applies to the processing plant, the system was kept obsolete without alarms, and interlocks, contrary standards and good engineering practice.

The containment point loss (leakage) occurred in a flange where a spade, possibly manufactured board. By not meet manufacturing standards that ensure its suitability to the system pressure rating, it may not need to insert the spade introduced a weakest point in the system, decreasing the Maximum Operating Pressure Allowable (MAWP) of the same.

As the leak point was concreted to prevent further leaks, it could not perform analyzes of the spade properties and their respective failure mode. On request to BW Offshore companies and Petrobras, the determination of the pressure reached in the offload of the pump proved to be uncertain, it is not possible to say that the pressure reached by the system exceeded or not the MAWP.

It is noteworthy that assess the PSV bench may prove incompatible with the valve of the situation at the time of the accident, making the results of this purely speculative assessment. Thus, it is considered that the full details of the causes of this causal factor can only be concluded after the analysis of the properties and the spade failure modes, which will only be possible after the unit is placed in the yard without term situation set to occur.

It was considered then, conservatively, that the possible causes are related both to the failure of the spade in a position above or below the system MAWP, for failure to design and update the load transfer system for unit conversion and various managerial failures that led to the leak in the pump house.

Above the MAWP, considers the absence of PSV calibration routine (critical system) and no alarms and interlocks as possible causes. Below the MAWP, it was found that the unavailability of type JIS spades (Japanese standard), the lack of space (allowance) for the installation of pressure class spades appropriate to the system, the lack of spades installation control procedures and improvisation spades are possible causes. These causes are detailed as below.

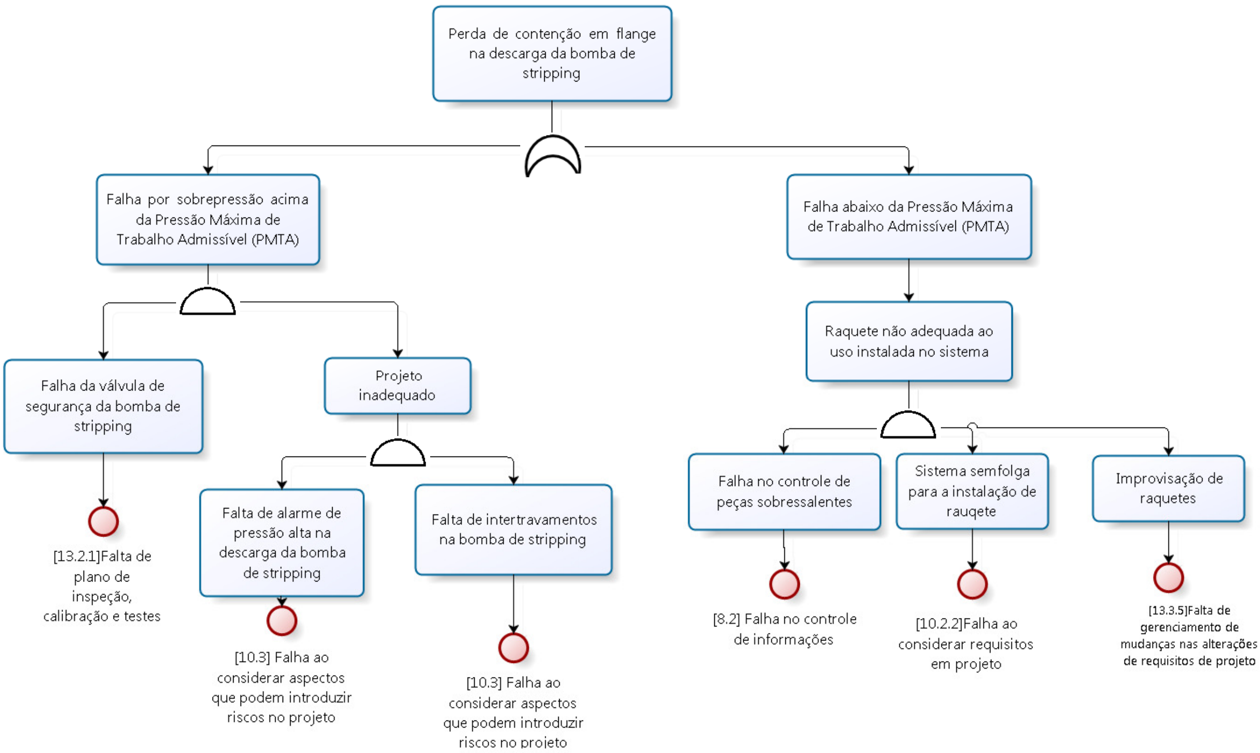

Figure 120 - causal factor 5: primary containment loss condensed material

11.2.1. Root Cause n° 16: Lack of inspections, calibration and tests plans to ensure minimum reliability for the safety valve from the stripping pump / [13.2.1] Lack of inspections, calibration and tests plans

The opening pressure (set pressure) of the safety valve design stripping pump was 16.5 kgf/cm 2g, indicated in the data sheet stripping the pump, as shown in Figure 121 below. The design pressure of the cargo transfer system according to the project documentation[180] is 16 kgf / cm2 g, lower than the valve opening pressure. The value of opening pressure of the project so contrary design criterion which states that the pipeline design pressure must not be lower than the opening pressure relief valve[181].

1. PARTICULARS OF PUMP MODEL KPH 350

CAPACITY	350 M3/H	NO.OF DOUBLE STROKE	31 RPM
TOTAL HEAD	150 M	ESCAPE V.SET PRESS.	16.5 KG/CM2G
SUCTION HEAD	-5 M	STM CONSUMP.AT RATED	5780 KG/H
PUMPING LIQUID	CRUDE OIL & S.W.	HYDROSTATIC TEST PRESS.	
MAX.STEAM PRESS.	18 KG/CM2G	STEAM SIDE	36 KG/CM2G
INLET STEAM PRESS.	15 KG/CM2G	LIQUID SIDE	30 KG/CM2G
EXH.STEAM PRESS.	1 KG/CM2G		
EXH. ENTHALPY	643 Kcal/kg		

Figure 121 - Project Opening pressure of pressure relief valve stripping pump

As for its maintenance and calibration, it is known that as good engineering practice, a pressure relief valve must be periodically inspected and calibrated to ensure a minimum reliability. During the investigation it was shown that there was no existing relief valve calibration routine stripping the pump set on the unit's maintenance system (MAXIMO). When notified to present calibration history of the evidence of the offload of the pressure relief valve stripping pump since the start of production of the FPSO Cidade de São Mateus to the date of the accident, the BW presented two documents: (i) inspection certificate held on 08/07/2008 at the shipyard[182], displaying a set pressure adjusted to 16.5 kgf / cm2; and (ii) another document 02/08/2010[183] has an opening pressure set to 16 kgf / cm2. In the latter document, the field "Next inspection" in this document is not filled.

[180] Item 7 Piping & Valve Material Specification document for Marine & Utility Systems - Doc No. 000-EG-SPC-031 Rev. 0 - Issue:. 10/08/2010

[181] Item 6.1 of Process Engineering Design Criteria document - Doc No. 384-20-DOC-001 Rev. 0 -. Issue 26/11/2008

[182] Inspection relief valve on estaleiro.pdf

[183] PSV - Report from calibration in 2010.pdf

There was, therefore, change the valve set pressure of 16.5 kgf / cm 2 to 16 kgf / cm2. When asked about the reason for this change of valve set pressure, the operator of the facility said it does not have evidence or reasons for a possible change in the set pressure safety valve stripping pump.

Widely used in industry, API RP 576 standard does not prescribe a schedule for carrying out inspection and calibration of pressure relief valves, however, it recommends that a set interval of time for each pressure relief device to be established[184].

It was informed during inspection operation [185] initially the valve maintenance and calibration was held mandatory when performing inspection by the NR-13 on the suction filter of the stripping pump (33PB002-CA001). However, because of regulatory changes on such this standard, periodic inspection routine was abandoned and hence the valve no longer kept being inspected and calibrated.

Since there is no inspection routine and test and considering the long period between the last adjustment of the set pressure of the stripping pump relief valve, there is no way rule out the possibility of failure of this device if the pressure reached downstream of stripping pump has exceeded the MAWP.

It can be said therefore that there was no plan and procedures defined for inspection, testing and maintenance for the valve in question. Such failure is considered one of the root causes Causal Factor "primary containment loss condensed material" and contravenes the provisions of item 13.2.1 of SGSO.

11.2.2. Root Cause n° 17: Lack of interlocks in stripping pump / [10.3] Failure to consider certain aspects which may introduce hazards to the project

[184] Item 6.4.1.2 of API RP 576 - Inspection of Pressure-relieving Devices

[185] Interview maintenance engineer. Information collected together the representatives of BW and Petrobras for inspection activities conducted by ANP in the CDSM and FPSO BW's office in Vitória in the period between 13 and 17/7/2015

The API RP 14C compliance rule[186] suggests a way to provide the shutdown of flow supply in case of overpressure (pressure above the MAWP) of a system or equipment. This recommendation is further enhanced in the same standard to address the specific security systems for hydrocarbon pumps. The standard recommends that hydrocarbon pumps are equipped with interlocking device (SDV - Shut Down Device) that interrupts the flow and stop the pump, both in case of high pressure as in the case of low pressure. In case of high blood pressure, loss of containment is avoided by shutting down the equipment before the pressure reaches excessive levels. The low pressure actuation rejoining equipment subsequently to the occurrence of rupture and consequent loss of containment minimizing the amount of spilled hydrocarbon.

The interlock device is considered by the API RP 14C the form of primary overpressure protection. Additionally, the standard indicates that the security system is to act primarily through the automatic tracking operation by automatic protective action in the event of an abnormal condition detection sensor operation.

It is valuable to note the safety philosophy of the unit lists upon the API 14C among the list of codes and standards should be observed during the implementation of all phases of the project[187].

Other interlocking recommended in good engineering practice is the interlocking of the possible leak of gas supply due to a gas alarm. The API RP 14J determines that gas detection systems should alert the staff through audible alarms and / or visual and activate valves to turn off gas supplies in the event of detection[188], and mentions the API 14C as a source of recommendations for the detection system.

The APIRP14C, in turn, reinforces this recommendation, adding the alarm should be activated in maximum 25% from the LIE (Lower Explosive Limit) and automatic corrective actions, such as closing shutdown valves in the sources of gas and disconnect the power

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186 Item 4.2.1.1.3 of API RP 14C - Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms

187 Item 1.2.4 of the document Safety Philosophy – Doc n° I-ET-004 Rev. 0 – Issue Date: 03/02/2006

188 Item 4.2 of API RP 14J – Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities

supplies of equipment not suitable for hazardous areas, should be started no more than 60% from LIE[189].

Documents established during the unit's design phase predict, to the area of the pump room, alarm in case of 10% LEL gas detection and shutdown (shutdown) in case of gas detection 30% LEL. This action is expected, for example, in case of unit Safety[190] and specification of the fire detection system, heat and gas[191], which appoints to the matrix cause and effect as a reference for automatic actions triggered by the fire and gas detection system.

After a matrix of cause and effect[192] in order to check how the automatic actions were implemented, it is possible to verify that the actions planned for gas detection if 20% LEL in the pump room include stopping the pumping of the charge pumps (33PA001A/B/C). In the pump room, in addition to cargo pumps, the pumps were located ballast and stripping pump. It is not provided for any action concerning the stripping pump (interruption of the drive or closing admission).

As the stripping pump also moves hydrocarbon, in case of gas detection in the pump room, this pump could also be the source of the gas flow, so only paralyze cargo pumps did not meet fully the shutdown criterion of the pump room .

The implementation of the shutdown of actions recommended in best practice and set out in project documents proved incomplete because it was not envisaged the total shutdown of the pump room equipment, since the stripping pump was not contemplated. It notes that the gas detection systems and shutdown to address critical safety systems.

Thus, were not considered in facility design all aspects that could introduce risks to operational safety. Such failure is considered one of the root causes Causal Factor "primary

[189] Item C.1.3.3 of API RP 14C - Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms

[190] Item 2.12.1 of the document 384-HS-0501-RPT-015 Rev. 1 – Design Operation Safety Case

[191] Item 7.1.2 of the document MS-MP03048 Rev. 0 – Fire Alarm System, Heat and Gas – Cidade de São Mateus

[192] ESD, Fire & Gas System Cause and Effects Matrix – Doc. n° 384-79-DOC-003 Rev. Z0 – Issue Date: 14/10/2013

containment loss condensed material" and contravenes the provisions of section 10.3 of SGSO.

11.2.3. Root Cause n° 18: Lack of the high pressure alarm in the stripping pump offload / [10.3] Failure to consider certain aspects which may introduce hazards to the project

The APIRP14C compliance rule[193] establishes protective actions to be triggered manually by the operator in case of unsafe condition of observation or alert alarm as one of the modes of operation of offshore production platforms security system. It notes that the safety philosophy of the unit lists the API RP 14C among the list of codes and standards that should be observed during the implementation of all phases of the project[194].

As to the stripping pump, there is as unsafe operating condition a offload pressure value greater than the maximum permissible system. As already discussed, the HMI displayed the offload pressure of the stripping pump in a pop up window and the pressure display range was inadequate and did not explain the value of the maximum pressure system operation. Additionally, there was no document setting out the maximum pressure value operation of the system of charges that should be observed by the operator. Such information was not in the operational procedure in the cargo system.

Thus, the observation of this operation parameter and the identification of the occurrence of an unsafe condition were uncertain, requiring the implementation of a high pressure alarm on pump offload to ensure compliance with the requirement of the standard.

The terminal was not equipped with high-pressure alarm in the pump offload to alert the operator of an unsafe operating condition and trigger response actions in an attempt to avoid overpressure. The lack of alarm, once increasing the risk of operation, in the meantime allocating a dependent evaluation barrier operator, the identification of the deviations in the process parameter depended on a constant monitoring of the offload pressure and an assessment of the marine operator. This review considered prior knowledge of the maximum pressure value system operation and identification of the pressure had exceeded the maximum recommended value. Depending on the marine operator, the action was adopted or not.

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[193] Item 3.3 of API RP 14C – Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms.

[194] Item 1.2.4 of the document Safety Philosophy – Doc n° I-ET-004 Rev. 0 – Issue Date: 03/02/2006 (pg. 622)

For these reasons, it appears that were not considered in the design of the facility, specifically in the charging system HMI design and security system design, all aspects that could introduce risks to operational safety. Such failure is considered one of the root causes Causal Factor "primary containment loss condensed material" and contravenes the provisions of item 10.3 a of SGSO.

11.2.4. Root Cause n° 19: Failure in the control of spare parts / [8.2] Failure to control the information

It was observed in audit that the MAXIMO system was used to track inventory on board. The parts request registration on the MAXIMO system was carried out in accordance with the minimum inventory definition registered in the system itself, or according to request on-board staff. Initially, the storekeeper was solely responsible for this activity. Later, the responsibility was shared with supervisors and superintendents of onboard departments who had less knowledge of the system usage, leading also to a lack of standardization in requests.

It had been found before the accident that the inventory record was not consistent with the items physically present on board. This inconsistency led to the presence of a person on board the Singapore office to make the conference and adjust inventory, and in the day of the accident this activity was running.

As for the inventory control spades , once evidenced in the hearing between the availability of the spade on the platform and the manufactured spade on board. Although there were on board an inventory of the type of the spades rendered for the process plant, when a spade was not found the employees used to manufacture racquets in the workshop at the engine room. There is spade manufacturing evidence in marine service crossing report[195].

Evidence shows that, as evidenced from the audit diligence, the door of the warehouse, located in the space before the entrance of the engine room, had its torn protective screen.

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[195] Item 3, comment 8 from Rotation Handover Report – Marine Superintendent – Doc. nº MS-20082014 –Issue Date: 20/08/2014

Figure 122 - broken screen on warehouse gateway

It became evident during the audit the screen had been installed in order to keep out strangers without the presence of the person responsible, but that even with the installation screen people continued to raid the warehouse.

It has been found, the operator did not have strong control system information on spare parts available in the unit. Such failure is considered one of the root causes Causal Factor "primary containment loss condensed material" and contravenes the provisions of item 8.2 of SGSO.

11.2.5. Root Cause n° 20: System without backlash for spades installation / [10.2.2] Failure to consider requirements for the project

According to the document containing the design criteria for process modules[196], the process plant (topside) should have permission to install insulation elements, is through the use of flanges with spacers that provide the necessary clearance for insertion of a spade in the line, either through use of a flange-like "figure 8" that can take open or closed position.

It was found that the layout of the pump house lines had no prediction for the installation of insulating elements, which implies the absence of play (allowance) for installation in a standard thick spade for line pressure class[197]. Audit, it was evident that the difficulty of

[196] Item 15 of the document *Process Engineering Design Criteria* – Doc. n° 384-20-DOC-001 Rev. 0 – Issue Date 26/11/2008

[197] Item 3 of the document *Handover Report – Marine Superintendent*, as of 20/06/2014 (pgs. 958 a 960)

installing a suitable thickness spade in marine pipe line caused the installation of possibly inadequate flange spade on the amount of OP-068 valve.

Therefore, it is concluded that the lines of the charge transfer system did not meet mandatory requirements for the process plant lines, although all these pipes work with hydrocarbons.

The lack of gaps in the lines of charge transfer system meant that the crew members could not properly carry out the insulation in the flange to the amount of OP-068 valve, then proceeding isolation with a spade with a thickness possibly less than that required for line pressure class.

The Figure 123 shows an example spade installed in-line load transfer system. You can see that its thickness is notably much lower than the flanges, showing that it is probably spade not specified for the line pressure class.

Figure 123 - Example of installed spade Online load transfer system

Failure to apply for the pump house the same engineering standards used for the process plant for the conversion project prevented the installation of proper spade, contributing to the insertion in line with a permissible pressure element probably below the MAWP system. Such failure is considered one of the root causes Causal Factor "primary containment loss condensed material" and contravenes the provisions of section 10.2.2 of SGSO.

11.2.6. Root cause n° 21: Spades improvisation / [13.3.5] Lack of management in changes of projects requirements

It was found that there were practical manufacturing spades on board. During the hearings it was stated that at first, these spades were made for short interventions, whenever the closing of a line, but without the forecast of pressurizing the same was needed. However, no record in marine superintendent of Service passage[198] which occurred the spade manufacturing on board to be installed between flanges for long term operations.

Racquets for use in the cargo transfer system lines should address the ongoing standardization in the project document which defines the material specifications for valves and pipe the marine systems and utilities[199]. However, there is evidence that the production of shipboard spades follow any standardization of engineering.

It should also be noted that, according to the document on Safe Practices insulation work, albeit confusing content in Portuguese, we recommend the use of physical disconnection whenever "reasonably practicable", justifying it would be simpler monitor the removal of a section of the pipe to check if a spade or a figure eight was installed correctly[200]. It is worth mentioning the spades for BWV-1005 and the OP-068 were installed in place where there was fairly short pipe section between the valve and the spade so that the removal solution pipe section could have been adopted , freeing up space for installing blind flanges or double locks on the ends of the line. The piping runs between spade and valve are shown in the following figures.

[198] Item 3, comment 8 of Rotation Handover Report – Marine Superintendent – Doc. nº MS-20082014 – Issue Date: 20/08/2014

[199] Piping & Valve Material Specification for Marine & Utility Systems – Doc. n° 000-EG-SPC-031 Rev. 0 – Issue Date: 10/08/2010

[200] Item 5.3.1 of the document Operations Management System - Safe Practices insulation work – Doc. nº 384-OP-HSE-018 Rev. 1 – Issue Date: 22/11/2012

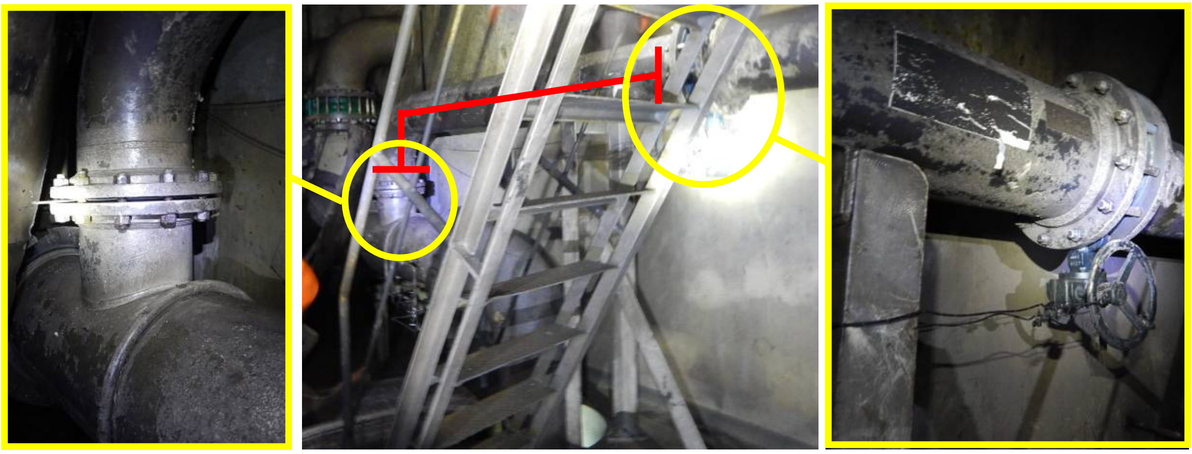

Figure 124 - Excerpt pipe installed between the spade and BFV-1005 valve

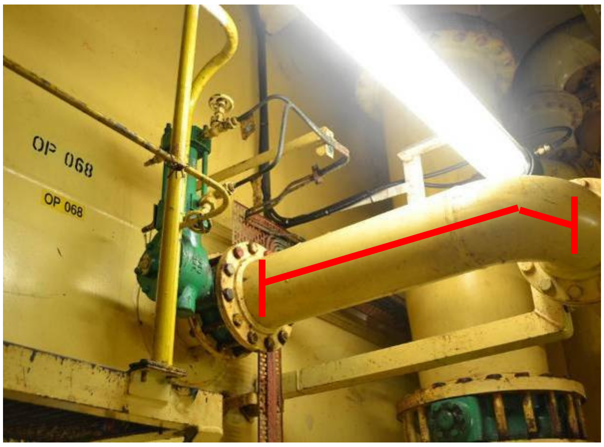

Figure 125 - Excerpt pipe installed between spade and OP-068 valve[201]

The mechanical isolation procedure[202] defined three possible methods of isolation: (e) simple blocking and bleeding; (ii) double block and bleed; and (iii) positive isolation. For positive isolation method, it was stated that: "This is the highest standard of insulation, performed by the installation of plates or blind flanges or by removing a short section of the pipe and the installation of blanks".

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[201] Previous photo of the accident provided by Petrobras on 05/03/2015

[202] PTW System – Procedure – Isolation – Mechanical – Doc. n° MS-PR00840 Rev. 1 – Issue Date: 07/08/2013

As to the selection of the method of isolation for incoming service cargo tank was defined as the positive isolation method should be adopted for deck lines and the double lock method and bleed should be used to rows background.

During audit it was informed that the spade was installed upstream of the OP-068 valve due to the fact the liquid level inside the port side slop tank exceeds the share of OP-068 valve. It was alleged that it was not safe to replace the seat ring of OP-068, was soon installed the spade. That is to say therefore that this scenario should also be considered if the pipe section to be removed. In any event, the port slop tank was emptied for repair, at which time the spade could have been removed or in which the pipe section could have been taken to improve the quality of the insulation.

The lack of sufficient slack in the load transfer system for installation of a spade with adequate thickness, the decision not to carry out the isolation removing pipe section and the possible unavailability of appropriate spare parts on board favored the isolation of the drive line flange loads the amount of OP-068 valve with an improvised spade, made on board, possibly inadequate to the line pressure class without prior assessment of hazards and global impact on activities.

The plant operator has not ensured that the use of isolation with distinct feature of the design specification were addressed through the practical requirements of Change Management. Such failure is considered one of the root causes Causal Factor "primary containment loss condensed material" and contravenes the provisions of section 13.3.5 of SGSO.

11.3. Causal Factor nº 6: Exposure to Personnel

In the event of a leak in potentially explosive atmospheres in training indoors, it must consider the possibility of event escalation to a fire scenario and / or explosion. Thus, systems and procedures should be provided for once there is the formation of an explosive atmosphere, there are conditions for the crew can act to control the situation, mitigate the risks of escalation, eliminating the explosive atmosphere for recall to return the operational routine.

For the success of mitigation actions, emergency procedures and resources for emergency response should be pre-planned, drawing on the use of all available resources, including the time of assessment of scenarios, always scarce resource for teams response to accidents on board the platforms.

Institutional support should outline how to act in various possible emergencies at the facility and should be described in the Emergency Response Plan of the unit. However, it could be seen that failed in assessing the risk scenario and emergency response that caused the accident, maximizing the effects of an occurrence of an explosive atmosphere rather than mitigate them, due to the absence of clear instructions and definition of accident scenarios in the Emergency Response Plan of the unit that did not include scenarios identified in the unit risk study.

Without identifying the Emergency Answers to plan the necessary resources to the incident scene, the crew aboard the FPSO CDSM at the time of crisis, could not adopt appropriate solutions to mitigate the explosive atmosphere scenario, leading to exposure of people board dangerous situations, in which the likelihood of scale and the potential severity were increased significantly.

This exposure of persons, whether belonging to the brigade teams or the other response functions for emergency, resulted largely from the resulting victims of this accident, ie the spill response incident led to an increase of the damage caused by the event as a whole.

Low operational discipline also demonstrated clear when there was the creation of a technical team to support the emergency response team, without this team was provided or possessed assignments in the Emergency Response Plan. During the incident, even with the knowledge that there were gas detection using fixed sensors installed at the bottom of the pump house, some people who formed the technical staff were sent along with the firefighters to evaluate the scenario in an explosive atmosphere. Another symptom that confirms the low operational discipline was the partial or total demobilization of the people of the respective meeting points, even with the permanence of confirmed gas detection.

Another cause of the danger people from exposure due to the setting of the meeting points for people with response function to the emergency, made without being considered safety studies of FPSO CDSM therefore without proper assessment of the effects of a possible explosion scenario in the pump house (or staggering) about the points against. It is noteworthy that one person was killed and others were injured as they stood in their respective meeting points.

The causal factor called exposure of individuals is shown in Figure 126 and their causes are shown below.

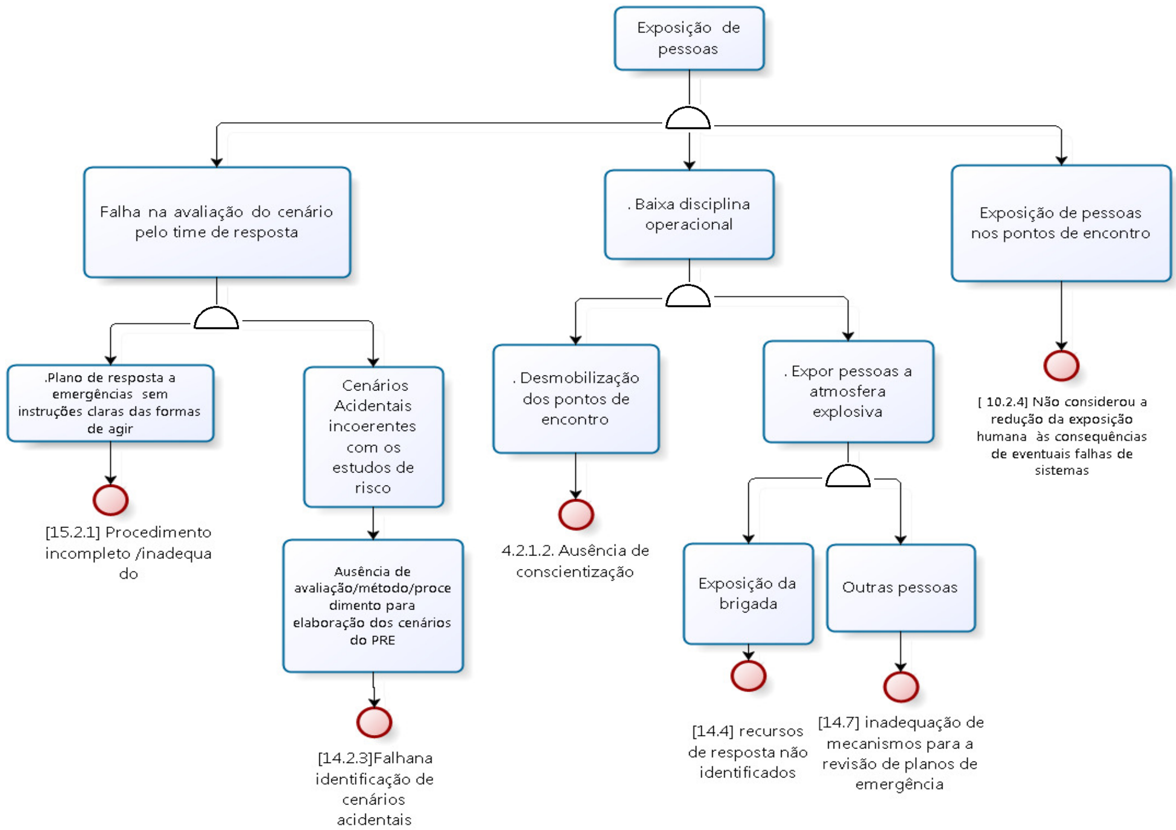

Figure 126 - Causal Factor 6: Exposure to Personnel

11.3.1. Root Cause n° 22: Lack of proper instructions upon emergency procedure / [15.2.1] Incomplete / inadequate procedure

As a response to the emergence of BW philosophy[203], the Emergency Response Plan (ERP) should be prepared during the detailed design phase and should be implemented during the operation phase. The plan must contain at least the guidance on training requirements and skills, often simulated and testing the response of structures to the emergence and procedures and responsibilities to be followed in various emergency situations, including response activities to emergency and plans action.

The PRE[204] presented the FPSO response structure in emergency situations, distinguishing the functions and their meeting places in many unit points, either in the CCR (Central Control Room), on the ward, in the control room of the engine, the boat of rapid rescue, the local brigade with equipment and in the cafeteria (temporary refuge). However, it was not presented to the ICT structure (Incident Command Team), i.e. who should be part of the incident command team.

Within the categorization of incidents by severity, to the level of incident categories II (major) and Level III (catastrophic), was provided for in the procedure for the mobilization of an emergency the response team in the MECC (Main Emergency Control Centre) with following leaders: Operations Manager, Human Resources Manager, Manager in Charge and SMS Manager. However, it was found that this procedure provided for in the structure was not compatible with the structure set up by BW Offshore, a fact that also reflects a system adopted by Prosafe. For example, do not exist in the structure of BW Offshore in Brazil the Charge Manager functions and SMS Manager and is not intended to MECC.

The Emergency Response Plan FPSO CDSM[205], it were displayed by "memory cards" (prompt cards) for cases of gas leakage, fire and explosion. These cards are shown in Figure

[203] Emergency Response Philosophy – Doc n° 4119-BWO-S-FD-00006 Rev. 0 – Issue Date: 11/12/2013

[204] Item 4.1 of document Emergency Response and Contingency Plan FPSO Cidade de São Mateus – Doc. n° MS-MP01279 Rev.1 - Issue Date: 13/01/2015

[205] Item 6.1 of document Emergency Response and Contingency Plan FPSO Cidade de São Mateus – Doc. n° MS-MP01279 Rev.1 - Issue Date: 13/01/2015

127 and, as can be seen, contain only the preliminary actions to be taken for each type of occurrence.

6.1 UNIGNITED GAS LEAK, FIRE OR EXPLOSION

COMMUNICATIONS/NOTIFICATIONS
Obtain Visual Report – Location of fire, flame impingement, gas plumes and effectiveness of containment (If feasible) ☐
Missing Persons – Check Permits, Contact Supervisor, Establish Cabin Number, Initiate Accommodation Check (Not during accommodation Fires) – Last Known Location ☐
Initial Time Out ☐
Initial PA Announcement ☐
Initial Call to Duty Incident Commander ☐
Subsequent Calls to IMT ☐
Silence General Alarm ☐

RESPONSE TEAM LEADER BRIEFING AND FEEDBACK
Is it necessary to respond? ☐
Number to respond (Two for visual check or Full Team) ☐
Location of Forward Control Point ☐
Route to follow ☐
Objective of response ☐
Restrictions re exposure of personnel ☐
Level of protection required ☐

UNIGNITED GAS RELEASE SPECIFIC CONSIDERATIONS
Consider isolation of non-certified equipment ☐
Monitor size and movement of Gas Cloud ☐
Monitor levels, pressures and temperatures in Process and Storage Vessels ☐
Monitor HVAC inlet and Damper status ☐
Electrically isolate incident location (Post Blow-down and Gas Dispersal) ☐
Refer to relevant ERP ☐

PROCESS / UTILITIES FIRE SPECIFIC CONSIDERATIONS
Monitor levels, pressures and temperatures in Process and Storage Vessels ☐
Attempt to reset flame detectors. ☐
Deluge initiated? ☐
Consider operating deluges above and adjacent to the fire location ☐
- both fire pumps may be required
Incident contained? ☐
Monitor Fire Main pressure ☐
Vessel Report – Deluge cover, location of jet fire impingement, lifeboat and helideck status and progress of fire ☐
Electrical Isolation of Incident Scene (Post Blow-down for Process Incidents) ☐
Refer to relevant ERP ☐

ACCOMODATION FIRE SPECIFIC CONSIDERATIONS
Establish incident location – First Detector and Extent of smoke detection ☐
Consider if Control Room requires to be evacuated – Relocate to Heli-admin of Lifeboat? ☐
Electrically isolate incident scene ASAP ☐
ERT to respond to incident location immediately – Utilize external door with the most direct access in to fire location. Smoke detection may increase as teams enter and search the accommodation ☐
Consider early ventilation (Open external doors on affected level) ☐
Determine if missing personnel are off-shift, Galley Crew or Stewards. (Cabin numbers of missing personnel **may** be useful) ☐
Refer to ERP ☐

Figure 127 - Memory cards contained in PRE for gas leakage, fire or explosion situation

The only mention of the explosive atmosphere scenario (gas leak not fired) cited within the PRE was contained in the title of these memory cards, which indicate the actions provided for an assessment to be made by team leader[206] in relation to whether or not to answer. In the case of an assessment would be required to respond to the event, had a time of mounting prediction, further indicating the existence of visual verification procedure.

Additionally, in case of a single gas detection or sensing confirmed the initial actions that should be taken were presented in the control room operator the memory card[207]. Table 15

[206] During the investigation it was not possible to identify to whom it refer to the term "team leader".

[207] Item 7 of the document Emergency Response and Contingency Plan FPSO City of St. Matthew - Doc No. MS-MP01279 Rev.1 - Issue Date:. 13.1.2015 (pages 958-960.), specifically in items 7.2 (single detection) and 7.3 (confirmed detection).

shows the comparison between the memory cards for single gas detection and confirmed detection.

Table 15 - Comparison of memory cards for single gas detection and detection confirmed

Detecção Única (Item 7.2 do PRE)	**Detecção Confirmada (Item 7.3 do PRE)**
DETECÇÃO ÚNICA	DETECÇÃO CONFIRMADA
AÇÕES INICIAIS	AÇÕES INICIAIS
• Enviar um Operador equipado com um Detector de Gás Portátil para Investigar ❑	• Iniciar ou Confirmar Alarme Geral ❑
• Anúncio no PA – "Attention all personnel we have an unconfirmed indication of a FIRE / GAS RELEASE in_____________. All personnel are to make their work site safe and leave the area while the incident is being investigated (Repetir) (Repetir em Português) "Atenção todo pessoal, temos uma indicação não confirmada de um INCÊNDIO / LIBERAÇÃO DE GÁS em . Todo pessoal deve tornar seu trabalho seguro e deixar a área enquanto o incidente está sendo investigado (Repetir) ❑	• Anúncio no PA – "Attention all personnel we have an indication of a FIRE / GAS RELEASE in_____________. All personnel proceed to their muster point and act under the instruction of their Muster Checker" (Repetir) (Repetir em Português) "Atenção todo pessoal, temos uma indicação de um INCÊNDIO / LIBERAÇÃO DE GÁS em . Todo pessoal deve proceder para seus pontos de encontro e aguardar as instruções de seu Inspetor de Ponto de Encontro" (Repetir) ❑
• Informar o OIM / Supervisor de Produção dos Detalhes ❑	• Confirmar quaisquer Paradas Automáticas Esperadas ❑
NOTA – Tratar dois Detectores de Gás ou dois detectores de incêndio em uma Zona ou um detector único onde não haja nenhum princípio de votação como uma Detecção Confirmada	• Preparar relatório verbal para o OIM ❑

There is the note applies only to detect if that states: "treat two gas detectors or two fire detectors in a zone or a single detector where there is no voting principle as a confirmed detection". In fact, at this point the PRE is confused when considering early voting in emergency response procedures, as to minimize the risk of response teams, any detection should be considered real, regardless of the voting principles of instrumented systems safety.

It is noteworthy that the FPSO CDSM accident response actions should consider that there was confirmed gas detection in the pump house because: (i) throughout the occurrence always at least two detectors presented indicating the presence of gas; and (ii) there was a visual confirmation of hydrocarbon leakage to the offshore incident command, so confirming the gas detection.

However, when evaluating only detection condition as shown in Table 15, it was deemed appropriate by the company that had sending operator equipped with portable gas detector to investigate the situation indication of the presence of gas through a single detector. In addition, the PRE over your text does not indicate additional procedures to drive the general alarm in case of detection confirmed, leaving the responsibility that in time of crisis, the offshore incident command on the FPSO CDSM assess, planned, identify the response resources and take decisions.

Such lack of procedure is reflected in the absence of explosive atmosphere scenario in Incident Management Guides, the FPSO CDSM PRE members, who had the accident scenarios and a specific checklist for each, containing the full detail of the subsequent actions. Figure 128 presents an incident management guide example contained in PRE for the fire scenario in the engine room. Thus, despite the setting of the presence of gas will not be triggered contemplated in memory card, detailed procedures for this scenario were not made explicit through an incident management guide.

8.8 ENGINE ROOM FIRE

SCENARIO SPECIFIC CHECKLIST

- Refer to Drawings for fire Zones and equipment locations. ❑
- Confirm / Initiate General Alarm ❑
- Make PA of Engine Room incident nature and location ❑
- Consider depressurizing oil system(s) within Engine Room ❑
- Start Fire Pump ❑
- Run Bilge transfer pump to avoid machinery space flooding ❑
- Notify Emergency Manger/DPA and request logistic support)– Request all available Helicopters and Medical Assistance s ❑
- Start Emergency Generator ❑
- Isolate HVAC to incident area ❑
- Close HVAC Dampers manually if necessary ❑
- Electrically isolate Incident Area once safe to do so ❑
- Obtain Muster Result – Determine locations for missing personnel. (Check permits, contact Supervisors) ❑
- Consider searching unaffected areas for missing personnel ❑
- ERT to respond to Identified Incident ❑
- Stem fuel leak and extinguish fire ❑
- Search for notified missing persons ❑
- Transfer casualties to Medical Centre ❑

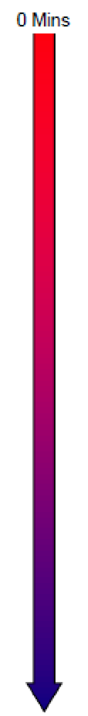

Figure 128 - Example incident management guide contained in PRE for the fire scenario in the engine room

Thus, the incident offshore decided to send command to the pump house persons, even with confirmed gas detection at that location. It is emphasized that this was an action provided for PRE to another scenario and that this document contained no explicit prohibition to do so.

It is considered a basic condition for the development of any emergency response plan that earlier actions to mitigate events, should be considered to minimize the exposure of people to possible effects of the event in progress. In this context, the scenarios should be clearly defined and response procedures shall indicate the objective actions and explicit prohibitions, in order to minimize exposure of people to unmanaged risks.

In this sense, it could be seen that the plant operator not prepared and documented operating procedure with clear and specific instructions to carry out the activities safely, in order to minimize human exposure to risks arising from the response to the emergency by setting failed development control and operational procedures. Such failure is considered one of the root causes Causal Factor "People Exposure" and contravenes the provisions of item 15.2.1 of SGSO.

11.3.2. Root Cause n° 23: Accidental scenarios in the PRE of installation operator does not include the outcome over the study of Hazards of the Unit / [14.2.3] Failure to identify accidental scenarios

The *Safety Case* document[208] It contained examples of potential identified emergencies that should be covered in the emergency response, among which figured as the first item listed, the "hydrocarbon leak resulting in fire / explosion."

There is therefore a discrepancy between the reported accident scenarios in the Safety Case and the assumptions made in the Emergency Response Plan and were not disclosed during the investigation records of how, from the accident scenarios identified in the Safety Case or other procedures, standards or best practices in Engineering: (i) the Emergency Response Plan reached 25 (twenty five) scenarios presented in the response procedures to emergencies, (ii) what criteria used for the selection of the scenarios presented in the PRE and

[208] Item 3.7.6 from Design and Operations Safety Case for FPSO Cidade de São Mateus – Doc. n° 384-HS-0501-RPT-015 Rev. 0 – Issue Date: 12/12/2008 (pgs. 958 to 960)

(iii) as to why some scenarios, like the gas leak and explosion scenarios in the pump house and engine room were not covered comprehensively (through incident management guide containing detailed actions) in that procedure.

In addition, the Safety Case also enlists[209] the recommendations from the fire and explosion assessment study (FEA - Fire and Explosion Assessment), among which worth mentioning Recommendation 7:

> *"[7]to ensure that the results of the FEA are considered and included in the Emergency Response Plan (ERP) in order to be taken all reasonable action to limit the consequences of dangerous events. The FEA information can help emergency the response team (p. Ex. Fire brigade) to understand the risks of such scenarios and to prevent injury to team members in the exercise of its function during accidents. The ERP installation should include the following procedures:*
>
> - ***Not to send the fire brigade to an area in which the scaling potential is still present;***
> - *Correct use of radio and / or speaker systems device to alert the staff, especially the brigade firefighting, potential sudden combustion scenarios ("flash fire") and gas cloud explosion due to delayed ignition flammable cloud. This is particularly critical during low wind speed conditions, when high pressure systems releases have demonstrated the potential to generate flammable clouds able to cover the entire FPSO; (...)*
> - *Training and regular exercises for emergencies based on a range of scenarios, as shown in FEA.*

Since: (i) the PRE contained no explicit prohibition of dispatch of the brigade area with staggering potential; (ii) the warnings set out in PRE for gas detection scenario contained

[209] Item 5.8.3 of *Design and Operations Safety Case for* FPSO Cidade de São Mateus – Doc. n° 384-HS-0501-RPT-015 Rev. 0 – Issue Date: 12/12/2008 (pgs. 958 to 960)

no explicit warning of the risk of ignition and explosion of the gas cloud; (iii) was not included in PRE conducting training for the explosion scenario; it can be said that the migration failed the guidelines contained in the unit's safety studies, including the Safety Case.

In addition to this fact, we have that as response philosophy to the emergence of BW, the Emergency Response Plan (ERP) should contain at least the guidance on training requirements and skills, often simulated and tests the response to the emergency structures and procedures and responsibilities to be followed in various emergency situations, including emergency response activities and action plans.

The Emergency Response Plan comes to training and simulated in three of its items (4.1.5, 4.1.6 and 9.3), however, does not define the frequency of simulations to be performed, thus contradicting response philosophy of requirement to the emergence of the company itself. Furthermore, the drill scenario and exercises schedule[210], contained only a list of the same scenarios that comprise incident management guide. As mentioned earlier, the explosive atmosphere scenarios (gas not activated) or explosion did not appear among the scenarios expected to be simulated by the emergency response team because they were not contemplated herein.

Another important fact established during the investigation[211] conducted by ANP was to verify the absence of simulated records for scenarios which required the drive of external resources to the unit such as those indicated in PRE Grade II and III.

In this sense, it could be seen the installation operator not adequately identified from studies of safety standards and good engineering practice, the accident scenarios for which should prepare, establishing procedures, resources and simulation. So there was a failure in planning emergency situations. Such failure is considered one of the causes from the Causal Factor "Personnel Exposure" and contravenes the provisions of item 14.2.3 of SGSO.

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[210] Item 9.3 of Emergency Response and Contingency Plan FPSO Cidade de São Mateus – Doc. n° MS-MP01279 Rev.1 - Issue Date: 13/01/2015

[211] Information collected together with the representatives of BW and Petrobras for inspection activities conducted by ANP in the CDSM and FPSO BW's office in Vitória in the timeframe between 13 and 17/7/2015.

11.3.3. Root Cause n° 24: Demobilization of gathering points / [4.2.1.2] Lack of awareness

After returning the second team of the pump house and before the third team entry, there was a partial demobilization of meeting places so that people could have lunch. This order came from the offshore incident command and was published on the platform from the public announcement system, commonly known as "iron mouth." There are versions of this demobilization was also made by telephone to muster stations with emergency functions or the guidance of demobilization it was only for the people who had emergency functions and who were in the cafeteria. The fact is that people, both with emergency response functions as housed in a temporary shelter, were demobilized as the emergency unfolded yet.

Most striking in this finding is that the decision to demobilize the people was taken while the fixed gas detector (73AB326) indicated very high level of gas in the pump house and upon the confirmation by the previous teams that had gone to the house of pumps, that the situation in that environment was real. Collected evidence indicated that the measuring of the second crew member's portable detector registered 100% LIE. Thus, all data showed that there was an emergency situation.

As the unit had a rule que people would not eat lunch with the overall service, people went to Their accommodations to ACCOMPLISH the change of clothes. People in the coffee shop meeting place near Were Their accommodation When the explosion occurred and several Were injured, with and without gravity. Two other people in the ward staff were inside the elevator que as a result of the explosion, was released to the roof top of houses, Causing serious injury to the occupants.A decision to demobilize meeting points for the emergence showed low operational discipline and awareness of board leaders about situations and conditions that could provoke or escalate the ongoing emergency situation. The conduct of demobilize meeting places made people to be exposed to risks not captured by the study for the establishment of temporary shelters[212] and acted contrary to typical prohibitions for emergency cases, like the use of elevators.

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[212] Escape, Temporary Refuge, Evacuation and Rescue Analysis – Doc. n° 384-HS-RPT-002 Rev. 1 – Issue Date: 22/05/2008

Thus, based on guidance from the offshore incident command, the meeting place of temporary refuge (cafeteria) was demobilized and the meeting points of the infirmary and the engine room control room were partially demobilized. The position of the temporary refuge of the meeting point is shown in Figure 129.

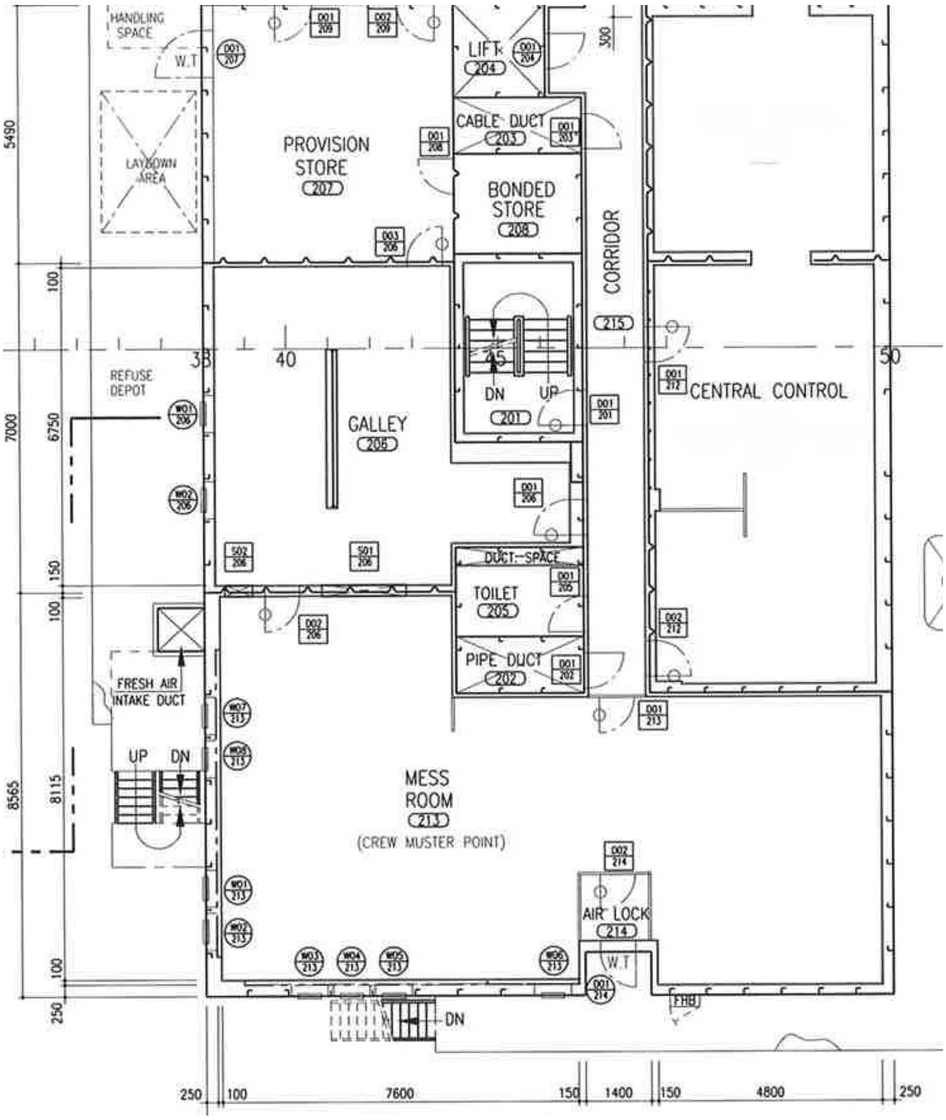

Figure 129 - temporary shelter position and response command to the emergence of FPSO City of St. Mateus

In this sense, it could be seen that the installation operator did not promote the awareness of the workforce involved in the operation and maintenance on the situations and conditions that could cause incidents, setting up failure in the awareness of the workforce. Such failure is considered one of the root causes Causal Factor "People Exhibition" and contravenes the provisions of item 4.2.1.2 of SGSO.

11.3.4. Root Cause n° 25: Failure to minimize the personnel exposure upon the hazards during the emergency response / [10.2.4] Disregard of reduction of human exposure to the consequences of eventual failures of systems and structures

As already mentioned, to identify an emergency situation, people should go to their respective meeting points. People in emergency response functions should go to locations outside of the temporary shelters, to be ready to act to mitigate the ongoing event. This fact demands that in the emergency response plan of the planning is done analysis for the risks of exposures to humans are minimized.

In the accident in question, the rupture of the bulkhead between the pump house and engine room caused the death of an operator in their meeting point in the engine room control room (ECR). In the upper deck, two people were injured seriously in their meeting point to be affected by pressure near the fast rescue boat.

The location of the ruptured bulkhead and access to pump room located on the upper deck of the installation are shown in Figure 130 and Figure 131, respectively.

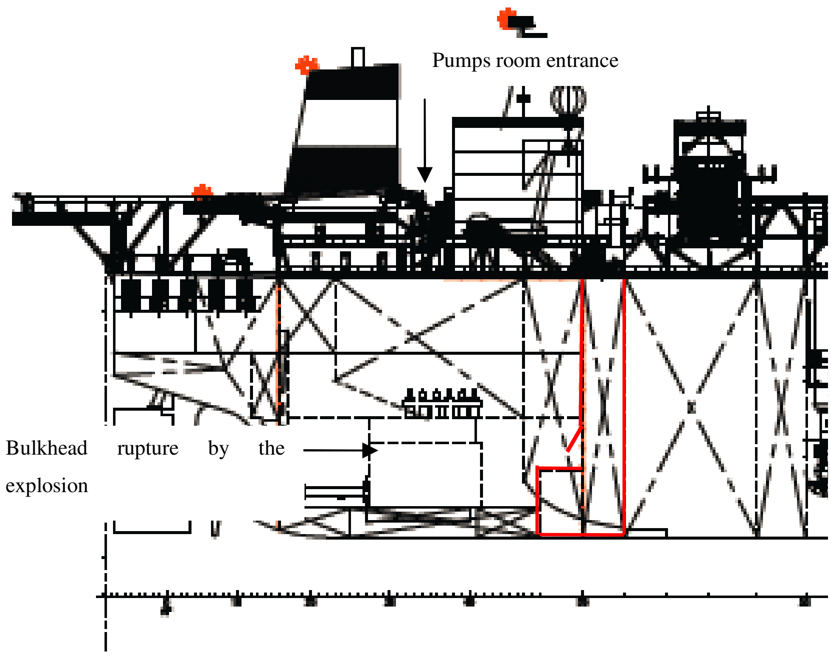

Figure 130 - Indication of the pump house on the FPSO City of St. Mateus

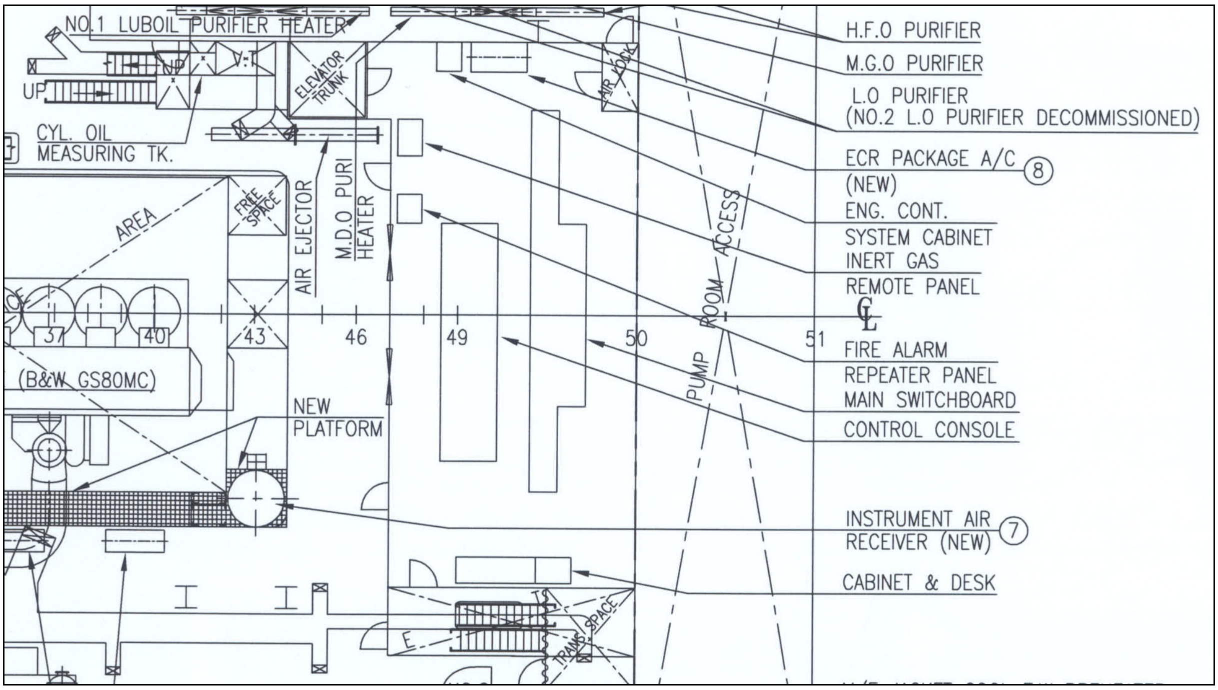

Figure 131 - Location of access to pump room in the upper deck installation

During the investigation of the incident it was not possible to demonstrate that the planning for response to accidents considered the need to minimize the exposure of individuals to risks during response procedures to emergencies, thus avoiding an escalation of the accident scenarios. In this sense, it was not possible to demonstrate the existence of studies to assess the safety of the meeting points for people with emergency response function against the possible accident scenarios and indicate the alternative meeting points for cases in which the meeting points set the Security Plan (Safety Plan) of the unit were considered unsafe.

Hence, it is found that the installation of the operator did not consider the need to minimize human exposure to a result of possible system failures. Such failure is considered one of the root causes Causal Factor "People Exhibition" and contravenes the provisions of item 10.2.4 of SGSO.

11.3.5. Root Cause n° 26: Brigade exposure / [14.4] Unidentified response resources

It was observed that, after being taken actions in order to stop the equipment and carry out the closing of the cargo handling system valves, the unit did not have systems and procedures previously established for the control and elimination of explosive atmosphere. For example, the only asset available in the pump house for emergency control system was the CO2 system was assigned to the fire scenario, with no provision for use for explosive atmospheres. There was also the ventilation system of the pump house that was stopped automatically in the event of gas detection in this environment. Thus, there was no system previously dimensioned to act in the event of an explosive atmosphere in order to reduce it or eliminate it.

Once the emergency situation it was not a fire (scenario set out in PRE) and due to lack of definition of resources and mitigating actions to the explosive atmosphere scenario in PRE, fell to OIM (offshore incident commander function) decision making at the time of emergency, the latter decided to send three teams successively to the pump house for site assessment.

PRE unit establishes the responsibilities for Commander Incident Offshore, calling it "strategist". Among these responsibilities, it must: (i) conduct the analysis of the situation based on the information and resources available; (ii) control events to prevent their escalation; (iii) maintain communications with the Operations Manager (when possible); (iv) minimize the risk to personnel, among others.

It is noteworthy that there was no provision in PRE for external support to the actions unfolded on board and that the drills only contemplated the unit features drive, without being trained or evaluated the relationship between Commander Incident Offshore and other external actors the FPSO CDSM.

According to testimonies collected by the ANP, the use of the brigade team for the evaluation of gas detections was common in any environment, both in the process plant as indoors.

Thus, the decision of sending response teams to the pump house was taken with the acceptance of the risks involved with the use of available resources on board and where we highlight the following facts:

- The first team was sent to pump house for conducting the investigation of the leak point, despite the confirmed gas detection at the room (all three detectors located in the pump house background had alarm).
- After returning the first team of the pump house, the leader of the brigade reported to offshore incident commander that there was leakage of liquid in the form of dripping, forming a pool of about two square meters below the flange. Even after confirmation of the actual situation, the decision was made the second team sent to the pump house to assess the required maintenance;
- The second team returned from the pump house to breathe fresh air, aware of the information that the portable detector had measured 100%from the LIE;
- A third team was sent to the interior of the pump house with absorbent blankets the SOPEP kit, already pressurized fire hose, ladder and tools.

In the case of a leak with explosive atmosphere training indoors, there is a possibility event scheduling scenario to fire and / or explosion. Therefore, resources should be provided (systems and procedures) so that once there was such an event, there are conditions so that the crew can act to control the situation by eliminating the explosive atmosphere for subsequent return to routine operations.

Ensuring availability of response resources, upon the prior identification of accident scenarios is shared responsibility between the Concessionaire and the operator of the facility as companies with established safety management systems. It is the workforce have adherence to the practices and policies of the company, through training and availability features that ensure that management systems are in fact implemented. It is not for one or a few people on board of a facility, set in the middle of an emergency how best to act.

In this sense, it can be seen that the Concessionaire and the installation operator failed to identify the necessary response resources, including systems and equipment, and the adequacy of existing resources has not been certified. Such failure is considered one of the root causes Causal Factor "People Exhibition" and contravenes the provisions of item 14.4 of SGSO.

11.3.6. Root Cause n° 27: Exposure to third party detached from the brigade towards the explosive environment / [14.7] Inadequate mechanisms for the review of emergency response plans

The emergency response technical team is an existing resource in other platforms operated by BW *Offshore*[213]. According to the testimonies collected by the ANP, the role of this technical advisory team was that the Incident Commander Offshore take off doubts about specific topics.

The assembly of the team response technical emergency was carried out informally, on 08/02/2015, without changing the procedures, including the Emergency Response Plan unit, conducting adequate training and formalize the team, a fact that is another sign of the low operational discipline to follow the plans and established procedures. Thus, the duties of Time emergency response technician were unclear and people who had response function were not used to this response structure.

It was shown on hearings that the technical team was created at the suggestion of new IOM, who previously worked on a platform operated by BW Offshore that had such a team in your response structure. As the FPSO CDSM was originally operated by Prosafe, the answer structure did not provide such a feature.

Despite the meeting point in the CCR (control room) to be close to the Incident Commander Offshore, the members of Team emergency response brigade Technical accompanied the three teams that entered the house of bombs and explosive atmosphere. To do this, other firefighters gave their brigade costumes for the members of Team emergency response Technical and thus other people besides the firefighters were exposed to the scenario unfolding.

Creating a team emergency response technician is an organizational and operational change that affects response procedures and therefore demanded that the Emergency Response Plan was revised to the proper implementation of the new response structure. Accordingly, it can be seen that the requirements for response plan review to the emergency installation operator proved to be inadequate. This inadequacy is considered one of the matrix

[213] Station Bill P-63, collected in the diligence of SGSO_2015_028.

causes Causal Factor "People Exposure" and contravenes the provisions of item 14.7 of SGSO.

11.4. Causal Factor nº 7: Ignition of the explosive environment

By combining a source of ignition in an explosive atmosphere, lots of chemical energy was released due to combustion reaction. By the effects of the geometry of the environment and the characteristics of the potentially explosive atmosphere, the resulting pressure, drag forces and the projectiles were able to cause harm to people, to installation and equipment.

The mixture of fuel and oxidizer in flammable proportion is called the explosive atmosphere. Each fuel has its explosive range, located between the lower explosive limit (LIE) and the upper explosive limit (LSE). The explosive atmosphere was achieved through the mixture of oxygen from the ambient air to the gaseous fuel derived from the variation of pressure imposed on the condensed while leaked. The response actions and condensate mixing characteristics are factors contributing to the increase in fuel gas concentration in the explosive atmosphere.

For the occurrence of explosion, besides the geometry of the environment and potentially explosive atmosphere, a sufficient energy source to initiate the combustion reaction is needed. This source of energy is known as ignition source.

When seeking data on sources of ignition explosion accidents, a publication of *Health and Safety Executive* (HSE)[214], which cites data from five other databases or previous publications, which presents in 46% of cases explosion of vapors or gases ignition sources are unknown.

As searched reference which deals with control and mitigate fire and explosion in production facilities *offshore*[215], possible ignition sources for a burst can be divided into: (i) calls, (ii) hot surfaces, (iii) Chemical reactions, (iv) compression heat, (v) atmospheric discharges, (vi) arcs and electric sparks (vii) mechanical sparks and (viii) static electricity.

For the high percentage of accidents in which it is not possible to determine the source of ignition, one has to take into account that those sources of ignition that are not easily viewed

[214] Worsell, N. :' Risk of ignition of explosive atmospheres', Health and Safety Laboratory Report RAS/96/13, 1996

[215] ISO 13702:1999 - Petroleum and natural gas industries- Control and mitigation of fires and explosions on offshore production installations- Requirements and guidelines

or perceived contribute significantly, and between these electrical or mechanical sparks and static electricity its best representatives.

Considering that the determination of the source of ignition is not immediate and demand analysis of various elements, the mechanisms of action of each ignition source, having considered several facts that support or refute the possible scenarios were studied. The facts considered concern condensate characteristics stored, House Design features of bombs and data on human action (decisions and actions taken during the emergency response).

Importantly, that, according to data shown in the accident timeline, the concentration of flammable gases had already reached 100% of the lower explosive limit (LEL), increasing the range of explosion, prior to the time of the explosion. As this detector it was a portable detector used by one of the members of the emergency response team, cannot be said that the environment gas concentration left the explosive range between detection of 100% LEL and another because Such variation may be due to the displacement of the person who carried the detector. In addition, by holding that there was a stop ventilation of the house pumps, the entire inventory of gas condensate produced by the leak was still on site.

In this way, it was considered unlikely the ignition sources listed below:

(i) Flame

Such ignition source is the existence of combustion reaction, heating the flammable gases to temperature above its ignition temperature. All ignition sources most likely would be subject equipment to flame, such as flare, process furnaces, heaters or the flame boilers, internal combustion engines, welding or cutting, cooking facilities or smoke (cigarette lighters or matches).

There was no equipment subject to calls inside the pump room (blast site). The pump was driven stripping steam, therefore there is no internal combustion engine in place. There was executing cutting or welding operations on site of the explosion and no fire report observed within the pump room prior to the explosion.

For these reasons, it is considered such a source of ignition as unlikely.

(ii) Hot surfaces

Hot surfaces can be a source of ignition, since the surface may be at a temperature higher than the ignition temperature of the flammable gas. To consider a hot surface as a likely source of ignition must be taken into account, so the gas ignition temperature in question. Figuring among the possible situations that can facilitate the formation of a hot surface: the welding activities, combustion gases from equipment subject to flame or the exhaust motor, incandescent lamps, equipment and hot process pipes, frictional heat from rotating machines poorly lubricated, among others.

When analyzing the pump room design, it turns out that did not exist internal combustion engines, equipment subject to flame, incandescent or rotating machinery inside. Also there was welding operation taking place inside at the time of the explosion. It was concluded that the only possible source of heat would be the power the steam stripping pump.As per API RP 2216[216] it states that, in general, Hydrocarbon a hot surface ignition is only plausible if the surface temperature is at least 180 ° C higher than the minimum ignition temperature of the hydrocarbon concerned.

In order to determine the properties of the fluid that leaked it was conducted by an analysis operator[217] of the condensed material stored in tanks 2C, 3C and 5C, after the accident. Since the leaked fluid on the day of the accident also consisted of condensed material produced in the unit, it can be said that the composition of the contents of these tanks similar to the fluid that caused the accident. The result of analysis is shown in Figure 132 below. As can be seen, the auto ignition temperature was found to be 244 ° C for the sample tank of 5C and 245 ° C for samples 2C and 3C tanks. Thus, this source of ignition is sustained only if hot spots are evident at a temperature range of 425 ° C or more.

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[216] Item 5.2 do API RP 2216 - Ignition Risk of Hydrocarbon Liquids and Vapors by Hot Surfaces in the Open Air

[217] Attached document from SISO in 19/08/2015

According to information provided by the plant operator [218], steam was fed at a temperature of 205°C. Thus, one can rule out the hypothesis of a steam leaks have caused the ignition of the condensed vapor.

CONDENSADO CAMARUPIM
FPSO CIDADE DE SÃO MATEUS

	Amostras/Samples				
Propriedades	**2C**	**3C**	**5C**	**Properties**	**Method**
Densidade (°API)	56,7	57,1	55,8	API Gravity (°API)	
Massa específica a 15 °C (g/mL)	0,7518	0,7498	0,7550	Density at 15 °C (g/mL)	ISO 12185
Densidade relativa a 20/4 °C	0,7477	0,7458	0,7510	Specific gravity at 20/4 °C	
Ponto de fulgor (°C)	< -30,0	< -30,0	< -30,0	Flash point (°C)	ISO 13736
Pressão de vapor Reid (kPa)	59,4	61,2	51,1	Reid vapor pressure (kPa)	ASTM D323
Destilação (°C)				Distillation (°C)	
ponto inicial	32,4	31,8	35,2	initial point	
5% vol.	61,5	60,0	59,3	5% vol.	
10% vol.	73,0	71,1	72,8	10% vol.	
15% vol.	82,6	80,8	82,2	15% vol.	
20% vol.	89,7	88,9	89,5	20% vol.	
30% vol.	102,0	101,4	102,3	30% vol.	
40% vol.	114,2	113,1	114,4	40% vol.	
50% vol.	128,1	127,1	128,7	50% vol.	
60% vol.	147,2	146,4	146,5	60% vol.	ASTM D86
70% vol.	170,4	169,4	171,4	70% vol.	
80% vol.	205,0	202,6	204,7	80% vol.	
85% vol.	227,8	224,7	228,3	85% vol.	
90% vol.	257,7	254,1	247,7	90% vol.	
95% vol.	-	-	-	95% vol.	
ponto final	299,7	299,6	297,9	end point	
recuperado (% vol.)	94,0	94,8	94,3	recovered (% vol.)	
resíduo (% vol.)	1,7	1,4	1,7	residue (% vol.)	
perdas (% vol.)	4,3	3,8	4,0	loss (% vol.)	
Temperatura de Autoignição (°C)	245	245	244	Autoignition Temperature (°C)	Conf. ASTM E659

Figure 132 – condensed material test result

(iii) Chemical reactions

This form consists of ignition in the presence of exothermic chemical reactions. The heat generated by such reactions constitute a source of ignition for the combustion reaction. It stands out among the reactions known for the offshore environment the reaction between iron sulfide and air. Iron sulfide is steel corrosion product in the presence of hydrogen sulfide (H_2S).

Second reference that recommends best practices for cleaning of oil storage tanks[219], wet the surface containing iron sulfide formed dissipates heat and insulates the iron sulfide deposits from the air, thereby reducing the possibility of spontaneous ignition.

[218] Item h from Letter UO-ES 0771/2015, of 12/08/2015

Furthermore, the condensed material produced in the unit does not contain H2S, so this hypothesis ignition source was considered unlikely. Upon the hearings, the explosion occurred as he was used water jet on the location of the pool. Therefore, it is considered the source of ignition unlikely chemical reaction, since water would have absorbed the heat from an exothermic reaction.

(iv)Heat compression

Such ignition source was the rapid compression of the flammable mixture (fuel-air mixture), similarly to what occurred in the cylinder of an internal combustion Diesel engine cycle. The volatile hydrocarbon leaked to the environment, then the fuel gas was at atmospheric pressure. The stripping pump, which constitutes the only possible source existing compression in the environment, was stopped at the time of explosion. Therefore, it is considered that source of ignition, such as unlikely.

(v) Atmospheric discharges

Such ignition source consists of incidence of an atmospheric discharge (lightning) on a location in which there is the presence of flammable mixture. It can be discarded as an ignition source, since the area in question is housed and there is bad weather record with the incidence of rays on the incident. In addition, reference surveyed said that the offshore project is usually able to ensure that lightning does not constitute a relevant risk source, except for some well operations involving explosives or gases released by atmospheric vent, situations that have no correlation with the accident in question.

(vi)Ignition by arcs and electrical sparkles

As per ISO 13702[220], an electric spark is a discharge of electrical current through the gap between two objects with different electrical charges. Electrical sparks can originate in

[219] Item 8.2.2.1 of API RP 2016 - Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks

[220] ISO 13702:1999 - Petroleum and natural gas industries- Control and mitigation of fires and explosions on offshore production installations- Requirements and guidelines

electrical equipment and may contain enough energy to ignite flammable mixture. Electric arcs occur when an electrical circuit driving current is interrupted. Among the sources of sparks and arcing, stand out electric motors and generators, circuit breakers, relays, batteries, ignition mechanisms for equipment exposed to flame, internal systems of internal combustion engines, electric lamps, cathodic protection systems with impressed current and malfunction of electrical equipment and wiring.

When considering the possibility of ignition equipment present inside the pump house should be borne in mind that it was hazardous area zone type 1, according to area classification drawing[221], based on API RP 505[222].

Thus, if the equipment inside were suitable for use in such an environment, they had been designed, constructed and installed so as to minimize the risk to constitute a source of ignition.

Stationary equipment with electrical circuits in pump house were: three fixed detectors, two CCTV cameras (4 and 5) audible and visual alarm signal, landline and fixtures normal fluorescent lamps and emergency. Portable equipment present in the pump house at the time of the explosion were portable gas detectors and communicators radios. It was found that all were rated for use in potentially explosive atmospheres, in accordance with policies and standards, particularly European.

Therefore, considering the equipment in conditions "as good as new" equipment present in the pump house should be safe for use in explosive atmospheres and do not constitute an ignition source, except in the case of having some damage to their protection.

As the equipment of the pump house, for the most part, have been severely damaged due to the explosion, one cannot determine whether any equipment was damaged before the explosion, which could have been a source of ignition.

[221] Hazardous Area Classification Layout – Maindeck – Doc. n° 384-01-G-DWG-005_001. Rev. Z – Issue Date: 31/08/2009

[222] API RP 505 – Classification of Locations for Eletrical Installations at Petroleum Facilities Classified as Class I, Zone 1, Zone 1 and Zone 2.

Additionally, the presence of an explosive atmosphere for a prolonged period of time, with no explosion makes it more likely that the source of ignition has occurred due to a condition or event that developed in the pump while home environment before the explosion, so if the ignition was caused by sparks or electrical arcs resulting from damage to electrical equipment present in the pump house, this damage must have occurred moments before the explosion is caused by the action of people who were present there at the time.

The facts collected during the investigation did not show the damage to the equipment during the response actions to the condensed material leak, either to refute. Therefore, this hypothesis was considered unlikely.

(vii) Ignition source by mechanical sparks

As per ISO 13702[223], a mechanical spark is the energy generated by mechanical friction created by mechanical tools and by falling objects. Other references relate this type of ignition to action belts or other moving parts of equipment poorly lubricated, allowing metal-to-metal friction.

Analyzing House Project pumps and the events on the day of the accident, it is concluded that a probability for this type of ignition source was probably caused by the use of inappropriate tools to hazardous environment. Maintenance staff was sent to the pump house in order to tighten the flange bolts where the spill occurred, and to do so, it took several tools for this environment.

It was shown that the tools taken to the pump house were not suitable for use in hazardous areas [224]. The tools were taken into the pump room by the maintenance crew consisted of two wrenches, one chrome and one common carbon steel. Because it is ferrous alloy, these were not adhering to the standard tools of tools do not generate mechanical spark. Such tools when used to effect the desired repair, or even accidental drop thereof, may have caused a spark ignited flammable mixture. In this way, due to some mechanical ignition spark is considered

[223] ISO 13702:1999 - Petroleum and natural gas industries- Control and mitigation of fires and explosions on offshore production installations- Requirements and guidelines

[224] Testimony collected by the ANP

probable and its cause is related to the action of people during incident response, due to the use of inappropriate tools for use in explosive atmospheres.

As per publication of OSHA[225], of iron or steel tools can cause sparks which may be a source of ignition in the presence of flammable substances. Where this risk exists, should be used to spark resistant tools made of non-ferrous materials which are stored or used explosives, flammable and highly volatile liquids, tools manufactured with non-ferrous metal alloys reduce the risk of power generation ignition, either by impact or by friction.

[225] OSHA (Occupational Safety and Health Administration) publication 3680 – Hand and Power Tools

(viii) Ignition source by static electricity

The ignition by static electricity occurs when two objects move relative to one another with a certain proximity, with the electric charge due to friction or induction. Thus, electric charges may be generated through flow of gases and liquids or by rubbing and friction created by the activities performed by the people within an explosive atmosphere. If objects are not grounded or electrically connected so as to remove the electric charges generated, these accumulated charges can be downloaded in the form of an electric spark. This spark may be able to trigger a flammable mixture.

The reviewed literature makes extensive reference to the dangers related to static electricity created by friction as the costumes, when walking. It is noteworthy among the static electricity-generating potential situations in which there is a flow of a conductive fluid through the hose or tube, such as filling operations containers or tanks, supply vehicles, washing with hose, etc.

Analyzing the events in the accident in question, there is one of the situations that constitute a potential source of static electricity: the use of fire hose to wash the place where had formed the condensed material pool.

The facts that occurred prior to the explosion show great probabilistic relationship between sources of ignition from static electricity, for two reasons:

(i) as the story of one of the witnesses, the explosion occurred immediately after request was made for the increase in water pressure in the hose used to clean the condensed material pool in the pump house floor;

(ii) the simulation of dispersion and explosion[226] performed by the utility indicates the position just above the condensed material pool as a likely location for the ignition of the flammable mixture. This position is consistent with where would possibly focusing the jet hose.

Thus, if the ignition source in this case is by static electricity, the ANP research team found that it is more likely that this ignition source is related to the use of water jet using the fire hose.

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[226] Simulation of dispersion and explosion, conducted by Det Norske Veritas for Petrobras.

When reviewing the documentation of the unit to find mention of the risk of ignition from static electricity, mismatched information between two documents were found. The document recommends safe practices insulation work[227] relates to static electricity as a danger. In the item referring to the identification of hazards associated with insulation failure, static electricity is listed as a danger:

> *"The vessel cleaning using high pressure water, solvent or steam blasting can create static electricity hazards. Guidance and advice on how to control the generation of electrostatic charges due to blasting and other activities are described in British Standard Electrostatic, Code of Practice to avoid hazards due to static electricity".*

Said British Standard (European Code CENELEC TR 50404[228]) states:

> *"Nonconductive hoses are not recommended if a flammable atmosphere can be present."*

According to the data sheet of the hoses firefighting[229], the same were made of synthetic rubber tube, so its material was non-conductive. Thus, its use in flammable atmosphere was not recommended.

So the lack of knowledge about the dangers associated with the use of flammable atmosphere in hose denotes at least unfamiliarity with good security practices.

In spite of these documents mention the dangers related to static electricity, the work permit procedure BW[230] reinforces this lack of technical knowledge on the subject. In this document are mentioned as examples of jobs that do not involve ignition sources work blasting water / sand and clean with, or blasting water.

Figure 133 and Figure 134 show the excerpts of the document that make such a claim:

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[227] Item 5.2.7 of the document Managing Operating System – Safe Practices Insulation Work – Doc. nº 384-OP-HSE-018 Rev. 1 – Issue Date: 22/11/2012

[228] Item 5.5.5.c of CENELEC TR 50404 – Electrostatic - Code of Practice for the Avoidance of Hazards Due to Static Electricity

[229] Data Sheet – Portable Extinguishers, Fixed Fire Fighting and Foam Equipment – Doc. n° 384-72-2851-DSH-001 Rev. 3

[230] PTW System – Procedure – Work Permit – Doc. n° MS-PR 00845 Rev.02 – Issue Date: 22/07/2014

Trabalho a Frio: qualquer tarefa de natureza não-rotineira que apresenta um risco, mas que não envolve fontes de ignição, positivos ou potenciais, incluindo as que envolvem:

- A exposição dos trabalhadores a ambientes potencialmente perigosos, tais como: espaços confinados, trabalho em altura ou trabalho por cima do mar;
- Liberação em potencial de pressão ou de energia elétrica;
- Liberação em potencial de produtos químicos ou substâncias perigosas;
- Manuseio de substâncias perigosas;
- Montagem ou desmontagem de andaimes;
- Trabalhos com rotas de escape restritas;
- Jateamento de água / areia;

Figure 133 - Extracted excerpt from Work Permit Procedure (Part 1)

- Trabalhos que afetam a disponibilidade de sistemas de segurança;
- Operações complexas de movimentação de carga e provas de carga em gruas;
- Operações de mergulho e trabalhos submarinos;
- Lançamento do bote salva-vidas até o nível do mar ou testes no mar;
- Testes de loop;
- O uso de ferramentas elétricas em áreas não-perigosas;
- Limpeza com, ou jateamento de água;
- Qualquer trabalho que exige o isolamento de equipamento;
- Trabalho que requer o teste ou monitoramento de gás.

Figure 134 - Extracted excerpt from Work Permit Procedure (Part 2)

This statement that operations with use of water jets are not sources of ignition as well as being in conflict with information contained in another document, it is not compliant to several references of good practice, including the standard ISO 13702:1999[231] and the European Code CENELEC TR 50404[232]. Both cited fluids with high-speed outputs (the high pressure water sprays, the gas jets) as a potential source of static electricity sufficient to

[231] ISO 13702:1999 - *Petroleum and Natural Gas Industries- Control and Mitigation of Fires and Explosions on Offshore Production Installations- Requirements and Guidelines*

[232] CENELEC TR 50404 - *Electrostatic-Code of Practice for the Avoidance of Hazards Due to Static Electricity*

promote ignition of an explosive atmosphere. Therefore, the procedure for Work Permit, which was a document widespread within the work team, contained incorrect information about the dangers associated with the blasting of water.

For the analysis of the information collected on each type of ignition source, we used the tool "matrix of facts and hypotheses", presented in the methodology used [233]. In the rows of the matrix were the various assumptions related to the ignition source that caused the explosion; the columns were related analyzed facts that corroborate or refute each hypothesis, all of them identified by the ANP research team throughout the research process. For each intersection "hypothesis x fact that" the correlation is analyzed between the two, providing for: if the fact supports the hypothesis (+) if the rejects (-) was no apparent relationship between the two (NA) or lack of information available to decide on this fact (?). The situations and facts that were considered irrelevant or unlikely to define the sources of ignition have been omitted from that table. The resulting matrix of this analysis is presented in Table 16.

[233] Guidelines for Investigating Chemical Process Incidents, AIChE, 2003.

Table 16 - Matrix of facts and hypotheses for the ignition source

Fact or condition → / **Hypothesis ↓**	**Lack of internal combustion engines in the pump house**	**Lack of equipment subject to flame in the pump house**	**Utilization of hose spray to "wash" the condensed material pool**	**Explosion occurred after pressurization increased request of the water in the hose**	**Pump house is required and there is no bad weather record with incidence of rays on the day of the incident**	**Auto ignition temperature of the condensed material (245 ° C)**	**Equipment house suitable pumps for hazardous area**	**Tools taken to the pump house were not suitable for use in hazardous areas**	**Stripping pump stop at the time of the explosion**	**Breakdown in equipment pump house by human action**
Flame	-	-	-	-	NA	NA	NA	NA	NA	NA
hot surfaces	-	-	-	-	NA	-	NA	NA	-	NA
Chemical reactions	NA	NA	-	-	NA	NA	NA	NA	NA	NA
Heat compression	-	NA	NA	NA	NA	NA	NA	NA	-	NA
Atmosferic discharges	NA	NA	NA	NA	-	NA	NA	NA	NA	NA
Arcs and electric sparks	NA	NA	NA	NA	NA	NA	-	NA	NA	?
mechanical sparks	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**+**	**NA**	**NA**
Static electricity	**NA**	**NA**	**+**	**+**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Legend: (+) the fact supports the scenario; (-) The fact refutes the scenario; (NA) the fact is apparently unrelated to this case, neither supports nor refutes; (?) There is insufficient information to decide on this fact.

Regarding the data from the analysis arranged in the matrix, it was possible to classify each hypothesis for the source of ignition according to the following criteria:

- Likely Source: there are facts that support this hypothesis;
- Unlikely source: there are no facts that support this hypothesis.

After the analysis presented, they remained as probable cases: a mechanical ignition sparks or static electricity.

Analyzing together the mechanisms of action of these sources of ignition and the greater likelihood that the ignition occurred due to some condition or event introduced in the bomb moments home environment before the explosion, it is concluded that the ignition source was caused or at least enhanced by the response actions of third team that entered the pump house, even with explosive atmosphere in that environment.

Additionally, the results of CFD simulation (computer fluid dynamics) held by Petrobras to analyze the explosive atmosphere and the explosion aboard the FPSO CDSM indicated two most likely locations for the source of ignition, one being the place where the staff worked immediately before the explosion.

By the facts, it was concluded that the root cause for the ignition source of this accident was introduced by the action of people in potentially explosive atmospheres.

The Causal Factor called "ignition of explosive atmosphere" is shown in Figure 135 and its cause is presented below.

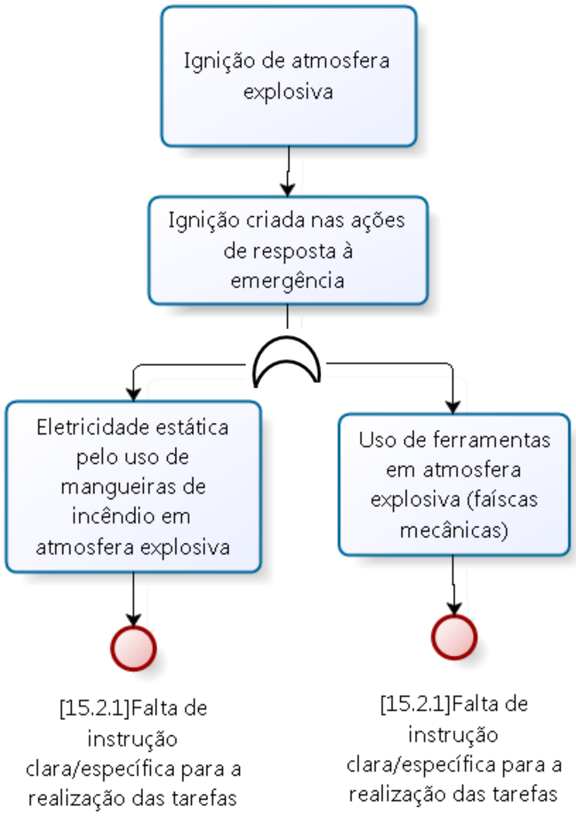

Figure 135 - causal factor # 7 - ignition of explosive atmosphere

11.4.1. Root Cause n° 28: Ignition source introduced triggered by the action of people inside the explosive environment / [15.2.1] Lack of proper/specific instructions for the tasks performance

For these reasons, whether the source of ignition was caused by mechanical spark or static electricity, the immediate cause for both hypotheses now considered more likely is the action of people in potentially explosive atmospheres, and the root cause for both cases is the same: the lack of clear / specific instructions for carrying out the tasks of emergency response teams. In the absence of such instructions, the emergency response team established procedures and used equipment or tools not suitable for use in explosive atmosphere.

As the occurrence of a gas leak it was an emergency situation, the actions to be taken to mitigate this situation not constitute an escalation risk should be included in the Emergency Response Plan. The lack of this information in the Emergency Response Plan sets is therefore a lack of clear and specific instructions for carrying out the activities safely at odds with paragraph 15.2.1 of SGSO.

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12. Mitigation action analysis

The emergency response structure previously established for the FPSO City of St. Matthew, which can be mobilized in the event of emergency, in order to define responsibilities and actions to be taken to the emergency control and mitigation of its effects, as it can be synthesized from Figure 136.

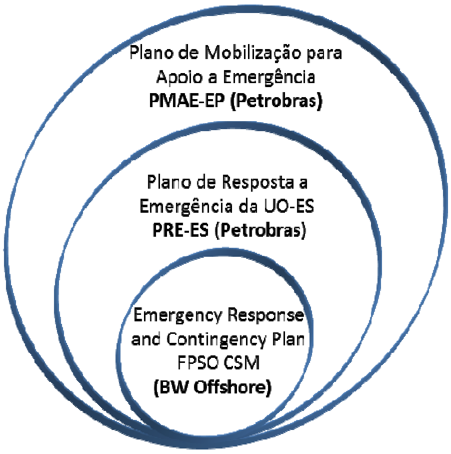


Figura 15 – Estrutura de Resposta à Emergência

The first level of response is the Plan Response Unit Emergency - PRE-CSM (Emergency Response and Contingency Plan - FPSO CSM), which was prepared by BW Offshore, aiming to protect the assets of the company and shipboard personnel possible damage from incidents.

PRE-CSM defines three categories of incidents (1-lowest, second-largest and third-catastrophic) for which it should be triggered. For the category of incidents 2:03, the procedure indicates that Petrobras must provide any additional external resources to the installation that are needed to manage the emergency. Such request must be made by the Audit Committee of Petrobras on board at the request of OIM.

The second level of response is the Response Plan for Emergency Operating of Espírito Santo – PRE da UO-ES[234] which adds response structure to the emergence available on the

[234] Plan Emergency Response OU-ES - Doc No. PP-3E6-00476 Rev. P - Issue Date:. 06/10/2014.

drive and aims to establish procedures and actions that can safeguard the lives, stabilize and reduce the consequences of the incident and protect the environment and assets.

The third level of response, which can be triggered by UO-ES depending on the emergency features, it is the Mobilization Plan for Support to Emergencies - PMAE-EP[235]. This plan aims to establish mobilization of corporative area shares of E&P and integration with other areas of the Petrobras deal to supply specialized features of E & P to Operations and Services when exhausted the remedies provided in the Response Plan for Emergency Unit.

The response actions to the accident after the explosion showed that it was classified as Category 3. It is observed that even the PRE taking its structure and its responsibility for setting the involvement of Petrobras in response to accidents Category 2 or 3, it was not possible to observe the formal establishment of this liability in contracts between BW and Petrobras or even that the PRE has been approved by Petrobras.

12.1. Organizational Structures Response Features - BW Offshore

BW Offshore had a corporate procedure for emergency response[236] which governs the structured response to an incident or crisis in an offshore unit or office on the ground of the company. This procedure establishes guidelines for the preparation of emergency response plans for its facilities, covering both the situations where the company leads the emergency response as in where the company only provides support your contractor. The same procedure cites the structuring of response actions in addition to the emergency response plan of the premises.

The corporate procedure classifies incident on three levels (1, 2 and 3). Level 1 incidents are processed in the framework of the platform and the respective emergency response plan itself, not requiring the activation of external resources of the BW response. Fall into this level event less likely to damage to life, environmental impact, damage to assets or the

[235] Mobilization Plan for Support to Emergencies - PMAE-EP - Doc No. PP-1E1-00256 Rev. D - Issue Date:. 09/09/2013

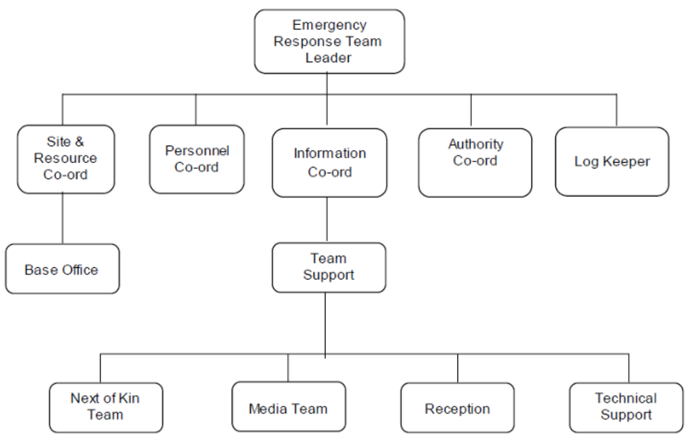
[236] BW Offshore Emergency Response Plan – Doc. n° MS-MP01168 Rev.02 – Issue Date: 03/03/2014

company's reputation. In the procedure are listed as examples MEDVAC, smaller fires and leak contained hydrocarbons. The actions demonstrated in response to accident FPSO CDSM between the gas alarm and explosion demonstrate that the incident during that time interval is treated as 1 level.

Incidents of type 2 are the events that are managed the edge of the platform, but with possible technical assistance from onshore staff, that does not necessarily require the activation of all the emergency structure in offices ashore. They are identified as incidents where there is a possibility of damage to life, environmental impact, damage to assets or the company's reputation. They are exemplified as charts of process plants, blackout, controllable fire and lower release of hydrocarbons or chemicals. Analyzing the settings for the accident levels 1 and 2, there is considerable similarity in the definitions and boundaries are not clearly established classification.

In turn, to level 3 incident (emergency or crisis), there is total mobilization of emergency response teams on the ground, both as contractor of the BW, in addition to internal and external support services. In the procedure are some examples of this type of incident, such as an explosion or fire large, multiple fatalities or serious injury, compelling security threat, ship stability loss, among others. After the explosion, the shares showed that the incident was classified at level 3.

The response structure for the emergence of BW level 3 incidents is shown in Figure.



137.

Figure 137 - Response Structure BW Offshore

Under the procedure, the BW Offshore Singapore is the main emergency source of support to the entire fleet of BW. The office of BW Offshore in Oslo provides support services to the BW Singapore, particularly with regard to assistance to families of relatives of BW employees domiciled in Norway and Europe.

The leader of the emergency response management team (ERMT) has the initial allocation, during the emergency in the first meeting with the team, confirming the role to be played by BW in emergency, can the company exercise the organization's leadership role or support to the contractor.

The operational offices in the country of origin of the facility involved in the accident, in turn, will have as its main task the customer contact and support for ERMT in Singapore. The roles and responsibilities of each office vary in the specific case of the office that provides support to the FPSO CDSM expected execution holder as signaled in Figure 138.

Unit/Country	Operations/Base Office	Main area of responsibility
Sendje Berge and ABO / Nigeria	Lagos / Port Harcourt	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support.
Berge Helene / Mauritania	Nouakchott	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support.
YÙUM K'AK'NÀAB / Mexico	Ciudad del Carmen	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support, Media and Information surveillance and local media contact.
BW Cidade de Sao Vicente/Polvo/ Peregrino / Cidade de Sao Mateus / Petrobras 63 (Brazil)	Santos / Rio de janeiro, Vitoria	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support, Media and Information surveillance and local media contact.
BW Joko Tole / Indonesia	Singapore / Jakarta	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support.
BW Pioneer / USA	Houston / New Orleans	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support, Media and Information surveillance and local media contact.
BW Athena / UK	Aberdeen	Overall responsible for Crisis Management in conjunction with Petrofac
Azurite / Congo (Brazzaville)	Pointe Noire	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support, Media and Information surveillance and local media contact.
Espoir / Ivory Coast	Abidjan	Client Interfacing, logistics, personnel and Next of Kin, Site information, medevac support, Media and Information surveillance and local media contact.

Figure 138 - Operating Office Support

In the accident FPSO CDSM response structure on land BW was thrown and locally concentrated in the company's office in Rio de Janeiro, because during the investigation process ANP noticed a clear deficiency in the BW office structure in Victoria, with only three people with technical bias in its structure. Thus, the BW Petrobras support structure was based on the presence of Operations Manager in response activities that were carried out in the crisis room mounted at Petrobras headquarters in Victoria (OU-ES).

The BW's corporate procedure for emergency responses indicates the need for periodic simulated accidents level. During the investigation it was shown that the FPSO CDSM performed only under simulated installation and in the case of oil discharge scenarios (environmental requirements of the authorities). There was the simulated planning to respond to events with multiple injuries and fatalities, that is, this structure had not been tested or established.

12.2. Organizational Structures Response Features - Petrobras

The Emergency Response Plan OU-ES presented as additional documents, the Emergency Response Plans of some units operated by Petrobras[237,238] and also presents the following statement about emergency scenarios considered:

> *"The accident scenarios have been described based on risk analyzes stored in SINDOTEC in SMSNet records in contracted emergency plans in the historical accident of the OU-ES interface and emergency plans."*

Contrary to this claim, the risk analyzes and plans for response to emergencies FPSO CDSM have not been approved or stored by Petrobras procedures or systems not being considered when planning for emergencies of the Espírito Santo Basin.

Corroborates the fact that Petrobras response plan not considered as a supplementary document or reference the Emergency Response Plans to the chartered units, including the

[237] Plano de Resposta a Emergências de P-34 - PP-5E6-00068

[238] Plano de Resposta a Emergências de P-57 - PE-5E6-00581

Emergency Response Plan for the FPSO CDSM, developed by BW and expressed Petrobras responsibilities. It is noteworthy that the Emergency Response Plan to the OU-ES is considered a complementary use of existing units in the sea and therefore should be considered in defining the necessary response resources such as recommended by the ANP Resolution No. 43/2007 .

The Plan of Emergency Response OU-ES presents a breakdown of the communication structure should be established during an accident and the organizational structure of response should be triggered, as shown in Figure 139 and Figure 140, respectively.

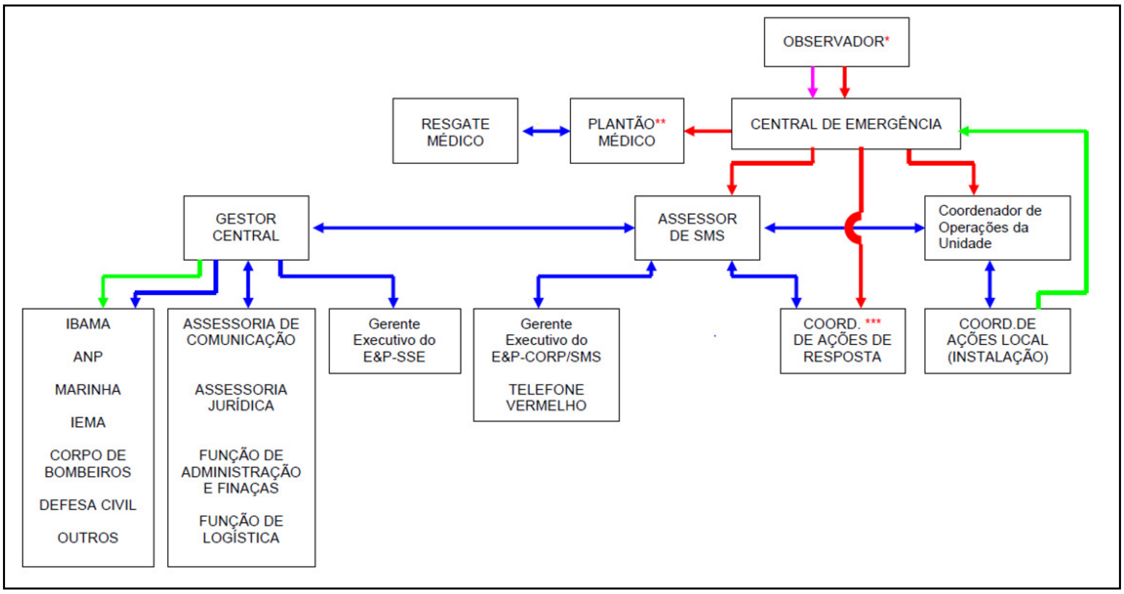


Figure 139 - Flowchart of Communication - structure should be established during an accident

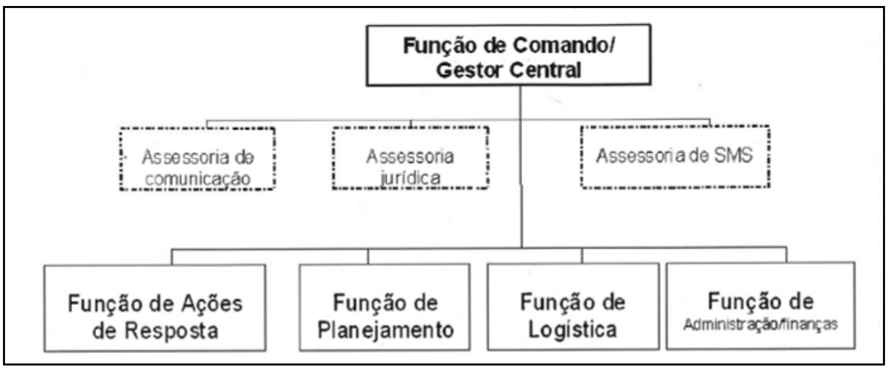


Figure 140 - Communication Flowchart - organizational structure of response should be triggered

PRE OU-ES also presents the following information about the structure of communication and organizational response structure:

- The initial report of the accident to the Organizational Structure Response (EOR) must be made immediately by the Emergency Call Center that communicates the receipt of information to the ER, Integrated Coordinator of Operations (CIOP), Unit Operations Coordinator, Response Actions coordinator (in case of oil spill) and the Advisory SMS.
- In case of platform, the observer is the maritime unit Manager or Petrobras Inspector.
- The initial communication is understood as preliminary in nature, ensuring the immediate activation of the Emergency Plan of the OU-ES and ensuring speed at the beginning of the response actions.
- When the plan is triggered, the Central Manager of EOR is the representative of the Operations Unit (UO-ES) and takes over the operation as a whole, is responsible for directing all activities related to the incident.
- In Annex A of the plan is described who can perform each of the eight roles of ROS in terms of the organizational structure of Petrobras (name and position of the person).

However, it was observed that in Figure 140 is not in the role of the Integrated Operations Coordinator (CIOP), although it provided the actuation by the Emergency Call Center and it has been triggered during the emergency of the day 02.11.2015.

In addition, as can be seen in Figure 140, Unit Operations Coordinator function is not included as part of the EOR and the PRE OU-ES does not provide the definition of who should exercise this function, only consisting on such attribution in the structure of communication of the accident (Figure 139). However, it was observed that the Operations Coordinator of the FPSO CDSM attended the EOR in managing the accident on 02.11.2015.

The lack of alignment of procedures to conduct carried out in practice was justified during the audit by representatives of Petrobras as follows: When a unit is operated by Petrobras itself, the Unit Operations Coordinator function coincides with the Equity Coordinator function Response (Installation). Whereas, in the case of chartered units, this coincidence of positions does not occur, it was that the latent Response Plan Emergency OU-ES is not fully adjusted to the situations in which the units are not operated by Petrobras.

This lack of OU-ES PRE adjustment was also observed with regard to planning functions, Logistics and Administration. This is because in such a plan these functions are described as taking place only represents Petrobras, which applies to cases where the units are operated by Petrobras. In the case of chartered units, as performed during the audit explanation, the functions are exercised both by Petrobras as the operator of the installation, unlike what is provided in the Plan.

Another point worth mentioning is that, considering the two response structures set up by the operator of the installation (Figure 137) and Petrobras (Figure 140), could not be identified to establish an interface between the two structures that demonstrate a systematic action joint between the two companies to manage the crisis.

Regarding the definition of resources necessary for emergency response, it is noteworthy that the PRE OU-ES has, as a reference document, the Standard Compliance N-2644[239], which rules on the content of Petrobras' contingency plans. Said standard establishes minimum criteria for the preparation of emergency response plans for the units, Petrobras facilities and activities.

According to the standard, the plan should provide the material and human resources as follows: *(i) "To be related the equipment, response material and human resources, consistent with the actions necessary to control emergencies, in its various types, dimensions and emergency scenarios"; (ii) "The list must contain both resources belonging to the installation and those outsourced" (iii) "Material resources must be related: a) type and operational characteristics; b) quantity available; c) location; d) the estimated maximum shift time to the place of use; e) people required for operation "and (iv)" Human resources should be related: a) expertise; b) quantity available; c) location; d) Maximum estimated time of travel to the place of use. "*

[239] Criteria for Contingency Plan Development - Petrobras - N-2644 Rev. C – Issue Date: 11/2008

Accordingly, the PRE OU-ES has the material resources and human resources, as shown in the following table:

Table 5 – Available resources

Recursos Materiais e Humanos
Material Resources
Existing equipment in the UO-ES stored in vessels of Oil Recover, the support base of CPVV and Emergency Response Centre (ERC), located in the administrative base of the asset northern Espírito Santo (ATP-NC) and UTGC in Linhares.
Equipment and CDA-ES response materials (Environmental Defense Center) and the facilities of the OU-ES (registered in InfoPAE).
Permanent virtual room, exclusively for emergencies.
Human Resources
Members of EOR
Triggered resources according to the PRE Unit

As can be seen from the analysis of material resources listed in the table, all appeals are exclusively environmental focus, i.e. they are resources for the management of potential environmental problems. Resources for other emergencies are not listed, which goes against the norm of the company and demonstrates that the OU-ES does not guarantee the availability of controllers for all accident scenarios. Moreover, as the PRE OU-ES is a unit PRE complement, should present the resources available to each of the scenarios identified in the PRE CDSM, which did not occur.

In addition, the PRE OU-ES, the Central Manager of EOR has the responsibility to drive the PMAE-EP to enlarge the resources available to control the emergency. Once triggered the PMAE-EP, functions triggered the plan will be part of the EOR unit that coordinates and oversees the emergency response. All corporate emergency support should be built according to his specialty the EOR that is acting in response. The response actions and resources are set out in PRE each unit, leaving the PMAE-EP actions complement or assist the actions developed there.

12.2.1. Aeromedical Aid

In specific regard to air medical transport resources, the PRE OU-ES presents as supplementary document, the procedure comes to attending emergency cases and medical emergencies in the Facilities UO-ES[240] and also, in Annex H (Operational Response Procedures) provides that the aircraft available for emergency use should have his Victory exit to the fire and explosion scenario, as shown in Figure 141.

description of accidental scenarios				
Cenário Acidental	Instalações	Ações	Localização dos Recursos	Comunicação Externa (CADINC, FAX ou TEL)
1 . Incêndio ou Explosão	Marítima	- Comunicar - Deslocar recursos e pessoas - Resgatar vítimas - Prestar socorro médico - Combater o incêndio - Articular com Órgãos - Estabelecer logística do material recolhido (resíduos)	Brigada de Emergência (Local) Embarcações de Apoio Sala de Emergência (Vitória) Aeronave (Vitória)	Capitania dos Portos ANP CGPEG (IBAMA)
	Terrestre	- Comunicar - Deslocar recursos e pessoas - Resgatar vítimas - Prestar socorro médico - Articular com Órgãos - Estabelecer logística do material recolhido (resíduos)	Brigada de Emergência (Local) CRE (São Mateus) Sala de Emergência (Vitória) Aeronave (Vitória)	Corpo de Bombeiros ANP IEMA IBAMA-ES

Figure 141 - Location of Resources for Fire and Explosion Scenario

However, it could not be identified in any of the two documents (procedure that deals with air medical care and Annex H of the PRE OU-ES) availability requirements of these aircraft, for example in terms of minimum required quantity, availability criteria of aircraft , criteria for substitution and maximum time for arrival at the offshore units.

Thus, since there are no pre-established requirements in these documents, the charter agreements helicopters MEDVAC[241] became the mandatory documents for establishment of the availability of aircraft criteria, getting the contract manager's job understanding the safety conditions associated with the resources listed in Table 18.

[240] Medical Contingency Operations in the OU-ES - Doc No. PP-3E6-00447 Rev. H - Issue Date: 07/31/2014

[241] Contract 2050.0072291.11.2 - Annex I - Chartering Terms of Aeromedical Helicopter Midsize (HMP) - Issue Date: 01/06/2015

Table 6 – List of MEDVAC Acfts.

Acft Registration Number	Base of Operation
PR-OMQ	Vitória
PR-OMA	Macaé
PR-OMB	Jacarepaguá

In Table 19 are summarized the main features of the charter party of MEDVAC helicopters.

Table 19 - Charter contract helicopter aeromedical features

Criteria	Features
Availability of Aircraft	- Exclusive use of the Petrobras System; - The contractor shall keep the aircraft linked to the contract available every day of the month, for 24 hours a day; - In the case of continuous availability of the aircraft, the contractor shall provide as soon as possible its return to operating condition or its replacement.
Operation of Aircraft	- The aircraft linked to the contract should be ready to take off to meet a medical evacuation in 25 minutes after Petrobras notification.
Maintenance Planning	- The allocation of time to perform maintenance actions shall be agreed between the contractor and the supervision of Petrobras. - The contractor shall provide monthly to inspection by Petrobras a breakdown of the scheduled maintenance plan of the aircraft.
Aircraft Replacement	- If the aircraft replacement, the replacement aircraft must be of the same technically equal or superior model or model of the specified contract.

Due to lack of Obligations to the dealer, were unclear forms of action as to the availability of aero-medical aircraft in periods when one of MEDVAC helicopters are in service or out of the base of operation. In such cases, there is no obligation to provide an equivalent replacement aircraft.

In fact, the PRE OU-ES, the PMAE-EP and its related documents did not describe the resources necessary for emergency response for each of accident scenarios and therefore cannot guarantee availability.

12.3. Accident troubleshooting capability

As already mentioned, there was response elaboration organization on board of the FPSO CDSM which provided a command structure, headed by OIM as the Offshore Incident Commander (CIO). It was found that, despite the involvement of many people in the response structure aboard the FPSO CDSM, training to deal with major emergencies of BWO was concentrated in the IOM, through training courses as "Major Emergency Management" and "Crisis Management".

The brigade, in turn, had forecast courses as: (i) advanced firefighting; (ii) course of survival and rescue boats, (iii) team maneuvers and combat aviation fire; (iv) first aid and (v) fast rescue boats.

In assessing the response to the accident structure provided by Petrobras, it reported that on 02/11/2015 initially adopted a response system that was not organized as the Incident Command System (ICS), as is provided in its existing procedure in occasion. However, visualizing the consequences of the accident and the difficulties presented for the control of the event, it was decided that the response structure should be organized as established in the ICS[242].

[242] Information collected in an interview during diligence action.

On the first day of the incident the post of command of response actions was played by Petrobras official in the Central Emergency Manager function (GCE), like Petrobras provided the procedure in force, the latter has been occupied by three different people. On the second day, the position of GCE becomes the role of Incident Commander (IC) and starts the use of forms of ICS protocol. It is noteworthy that since the arrival of ANP team on the Vitória crisis room late in the evening of the day of the accident was observed structuring and acting as advocated by the ICS, although Petrobras representatives have stated that the ICS not fully be implemented.

For more refined analysis using an emergency response system the presence minutes were recorded in the area on Vitória contingency / ES, containing the names of persons who have functions in the structure. In terms of education / training, of a sample group of eighteen people selected from those who had prominent roles in the ICS structure (adviser SMS, planning, logistics, operations and command), only 55% of them took part in course on the subject with an average time of training of thirteen hours.

One of the people who took over as CI had a capacity of only four hours, since Petrobras procedure established that some of the company management positions could not overcome this training time. Of the four who took CI forward crisis environment, it became clear that only two of them counted on training in emergency response or had taken part in some simulated.

In regard to past experiences as obtained during simulation, it can be grasped as of the sample group as previously shown, only five had such an experience and only by simulation offload oil, as demanded by IBAMA, the Table-Top type (without any actual triggering resources), Level 3. Valuable to note, despite such experience, some of these people remained only 1h30 at the site of the simulation between its input and output.

As per all forwarded and analyzed material, both with respect to people onshore or offshore of installation operator and concessionaire, it highlighted the need to review and improve the related training systems and simulated thoughts to service major accidents and the necessary diversification of established scenarios, verifying that currently simulated major emergencies (levels 2 and 3) mostly related to oil spillage in the sea.

4. Recommendation

The accident investigation process identified twenty-eight Root Causes, all of them correlated with the requirements established by ANP Resolution No. 43/2007 of 06/12/2007 (SGSO). In addition, sixty recommendations to establish additional requirements have been set by the ANP investigation team. The recommendations are directed to all oil production industry and offshore natural gas in order to avoid the recurrence of similar accidents and their implementation to be mandatory. The recommendations are intended to prevent the recurrence of similar accidents. Besides the continuous improvement, it was proposed certain recommendations addressed to ANP.

4.1. Recommendation for the Industry

As per the root causes identified, the ANP's investigation team identified the necessary recommendations in order to prevent certain recurrence of similar accidents. The Causal Factors and its root causes are related to their recommendations as presented in Table 20.

Table 7 – Recommendation for the Industry

Causal Factor	**Cause**	**SGSO/CR Item**	**Recommendation**
FC01: Inadequate condensed material storage	CR01: [16.3] nonperforming modification management	16.3	R01: Ensure that the change management practice is carried out at all stages of a drive life cycle, including its design, construction and commissioning. R02: Monitor continuously during the operational phase, the process parameters and fluid composition comply with the limits established in the design phase. R03: To ensure the availability of information necessary for the fulfillment of SGSO, including data required for the preparation of technical studies.
	CR02: [12.6.4] Lack of risk review at the beginning of the	12.6	R04: Review the platform risk assessments before the start of the operation, in order to consider the changes implemented and the characteristics of the finished unit. This review should consider the participation of project teams and unit

	operation		operation (crew and office staff) and supervision of the concessionaire, in the case of chartered units. This review should be highlighted. R05: The dealer must participate in risk assessments of chartered production platforms and approve them. Such approval must be in management level compatible with the design of resources for the full implementation of the needs identified by these studies.
FC 02: Storage System Degradation of FPSO CDSM	CR03: alignments restriction by installing spades / [16.3.2] Change Management unrealized	16.3	R06: Plan actions, prior to the implementation of temporary changes, until the return to the final condition of the system. This planning should be in the change management process.
	CR04: Passage of inadequate service / [8.3] inadequate communication between shifts	8.3	R07: Reassess the change management process whenever there is a change of premises, scope, purpose or planning considered.
	CR05: outdated documents / [16.3.3]	16.3	R08: Establish written procedure service ticket that ensures at least the record written format, as well as access and knowledge changes, insulation and

	Failed in the records and documentation of change		operating conditions of the system affects every function, before taking the job on board. This should define the roles for which there should be simultaneous landing and which functions should be dialogued and replaced.
	CR06: Changes without change management / [16.3.2] Change management unfulfilled	16.3	R10: Identify, establish and implement means to ensure that the workforce has theoretical and practical training in the execution of change management procedures, ensuring periodic retraining.
FC 03: Marine Team degradation of the FPSO CDSM	CR07: Absence of marine superintendents / [16.2] Absence management of change people	16.3	R11: Ensure the implementation of the process of managing change of people, including cases of reduction, increase and accumulation functions, entry and exit of people.
	CR08: Lack of mentoring / monitoring / [3.3.2] inappropriate dimensioning of the training program	3.3.2	R12: Implement mentoring process and monitoring of new people as part of the management process people, before you make the change.
	CR09: Lack of oversight	1.5	R13: The Concessionaire and the installation operator must ensure human

	function / [1.5] unavailable Resources		resources for the implementation of the organizational structure necessary for the fulfillment of SGSO. R14: The operator shall ensure the implementation of the charter contracts of safety requirements and / or operation and maintenance established to comply with the security provisions of the concession agreements.
	CR 10: People with same job performing different functions / [3.3.2] Failure to identify training / qualification requirements	3.2.2	R15: Establish objectively requirements to guarantee the minimum training for each position, with theoretical evaluation and mandatory practice, subject to regular training program, the verification of compliance procedures and periodic retraining. R16: Ensure that all occupants of the same position are able to exercise all the functions assigned to his office.
	CR11: Lack of training in operational procedures / [3.3.4] Failed in identifying education / training in operational procedures	3.3.4	R17: Establish ongoing training program in operational procedures, and the frequency of recycling in different critical procedures.

FC04: Operate the stripping pump with offload closed	CR12: Procedure outdated / unavailable / [1.5] failed in providing resources	1.5	R18: Ensure that changes to the management of operational safety arising from acquisitions, exchanges and Installation Operators mergers are valued at change management process. The change management process should consider existence, migration, upgrade, availability and applicability of operating procedures and set deadlines and responsibilities. R19: Plan and provide the necessary resources for the implementation of operational procedures, ensuring that they are current, available and appropriate. Features include operational structure aboard and offices, considering that the structure of the board has focused on the operation and the technical and administrative infrastructure on land has size compatible with the level of unit activities.
	CR 13: Failure to implement recommendations and risk analysis of safeguards and security studies / [12.6.3] Failure to implement corrective	12.6.3	R20: Implement all safeguards (Operational Safety Critical Elements) provided in the risk analysis and safety studies before the start of the operation. The implementation of all safeguards must be verified during the audit of Operational Safety Critical Elements. R21: Define those responsible to ensure the availability and integrity safeguards. Ensure that the said persons are aware of the risks involved in case of safeguards degradation.

	actions		R22: Continuously monitor in appropriate management level, availability and integrity of all safeguards, considering the information provided by those responsible. R23: The implementation of the recommendations arising from risk analysis and safety studies must be managed by competent hierarchical level, with definition of responsible and deadlines consistent with the level of risk. R24: Establish performance indicators to monitor the implementation of all SGSO practices to be monitored regularly by the installation operators and dealers. Periodic results of this monitoring should be part of the review meetings, to establish corrective and preventive actions when found insufficient performance.
	CR14: Some operating procedure and lack of clear instructions / [15.2.1] incomplete Procedure	15.2.1	R25: The operational procedures should set clear instructions and prohibitions to be observed by all who use them as a criterion for control of operational risks. R26: To ensure the integrity and clarity of information in the translation of operating procedures. R27: Establish written procedure in the limits and values of available handling operating parameters to be considered in the operation of systems for the control of operational risks. These procedures should be considered as Operating

			Procedures Critics.
	CR15: strokes Information not available on the supervisory system / [10.2.1] Do not call the design criteria	10.2.1	R28: All systems required for the start of operation of the unit must be adhered to the project, completely installed, commissioned and available before the operation. The adequacy of these systems should be checked during the audit Management Practice # 10: Design, Construction, Installation and SGSO Disabling before the operation.
FC05: Loss containment flange at the offload of the stripping pump	CR16: Lack of plan for inspections, calibration and testing to ensure minimum reliability for the safety valve of stripping pump / [13.2.1] inspection plan Lack, calibration and testing	13.2.1	R29: Include equipment information and Critical Systems arising from safety studies in computerized integrity management systems before the operation. Critics Procedures related to maintenance, inspection and testing should also be included. R30: Updating the previously existing systems in converted ships to platforms at the time of conversion, considering the same design criteria and safety philosophy of the processing plant. R31: Alternative pumps for oil transfer must have its offload protected by interlocking and alarm systems. R32: Contemplate on maintenance plans and defined periodicity, inspection and testing all pressure relief systems, alarm and interlock.

	CR17: interlocks loss at stripping pump / [10.3] Failed to consider aspects that can introduce risk in the project	10.3.a	R20, R30, R32
	CR18: Alarm Lack of high pressure in the offload of stripping pump / [10.3] Failed to consider aspects that can introduce risk in the project	10.3.a	R28, R30, R32
	CR19: Failure to control spare parts / [8.2] Failure to control information	8.2	R24 R33: Educate staff involved in the operation platform on the impact of inventory management in operational safety, aimed at improving operational discipline. R34: Studies for the minimum inventory identification must be included in the design of the facilities and the inventory should be available throughout the

			operational phase.
	CR20: system with no backlash for installation spades / [10.2.2] Failed to consider requirements for project	10.2.2	R23, R30
	CR 21: Improvisation spades / [13.3.5] Lack of change management changes in project requirements	13.3.5	R09 R35: not manufacture the parts board, including spades , requiring quality certificates of the material. R36: Treat through change management replacement or installation of parts, including spades , which have distinct characteristics of the design specifications.
FC06: Personnel exposure	CR22: Lack of clear instructions in response to the emergency procedure / [15.2.1] incomplete / inappropriate Procedure	15.2.1	R37: emergency response procedures in the various levels of response, should establish clear instructions and prohibitions, complete and not conflicting. R38: Prohibit exposure of people, including the brigade, explosive atmospheres. R39: Set in a specific document the responsibilities and interfaces of all organizations involved in emergency response actions.

	CR23: accidental scenarios at the installation operator PRE does not include scenarios of Risk Studies unit / [14.2.3] Failure to identify accident scenarios	14.2.3	R40: Establish criteria and procedures for the migration of risk scenarios identified in the risk analysis and safety studies for emergency response plans. In addition to the selected scenarios, the procedures should contain scenarios that represent challenges to response actions, such as fatalities, multiple injuries, among others, albeit with risks considered tolerable or ALARP region. R41: Establish periodically simulated emergency covering all identified accident scenarios, including scenarios with multiple injuries and fatalities. Such simulations should include the activation of external resources to form platform that response structure is effectively tested and that corrective measures arising from simulated ensure continuous improvement of the response actions of all entities involved.
	CR24: Demobilization of meeting points / [4.2.1.4] Lack of awareness	4.2.1.2	R42: Periodically coordinate all staff regarding the hazards involved in the assumptions made in the response procedure to the emergency unit. R43: Prohibit the release of people to normal activities before the full control of the emergency. R44: To evaluate the temporary shelters and ward (s) in the design phase to protect against the effects of overpressure.
	CR25: Failed to	10.2.4	R45: Consider the design of the units to reduce exposure of people meeting

	minimize the exposure of individuals to risks during emergency response / [10.2.4] did not consider the reduction of human exposure to the consequences of any failure of systems and structures		points to the risks of accidental or possible escalations scenarios. The meeting points must be identified on the unit's response plan. R46: Set of alternative meeting points in case of risk from the point of primary meeting be affected. The alternative meeting points must be identified in the response plan of the unit.
	CR26: Brigade Exposure / [14.4] Unidentified response resources	14.4	R38 R47: To ensure that all functions involved in emergency response, including land, have periodic theoretical training in emergency response procedures. R48: Contemplating the design of the units the systems and procedures for response to all accident scenarios to be considered in response to the emergency procedure of the unit. R49: Set in the emergency response plan the available material and human resources, in quantitative and qualitative terms, to the response of each accidental

			scenario and at all levels of response.
	CR27: Exposure others outside the brigade to the explosive atmosphere / [14.7] inadequacy of the mechanisms for review of emergency response plans	14.7	R19, R38, R42
FC07: Ignition of the explosive environment	CR28: Ignition Source introduced by the action of people within explosive atmospheres / [15.2.1] Lack of clear / specific instructions for carrying out the tasks	15.2.1	R38 R50: Prohibit the use of non-conductive hoses in environments where a flammable atmosphere is present and there is no flame. R51: To review the procedures related to emergency response and safe work practices considering the possible ignition sources identified in existing rules. R52: Conduct regular awareness activities for the entire workforce on possible sources of ignition. R53: Ensure the availability of appropriate tools to use in normal maintenance activities in hazardous locations.

4.2. Additional Recommendations

As per the research process, other cases were identified in which preventive actions are required both for operational incidents to be avoided/better mitigated, in order to facilitate future processes of incident investigation. Such measures are as follows:

R54: The dealer must participate in the development of emergency response procedures to the chartered production platforms and approve them. Such approval must be in management level compatible with the design of resources for the full implementation of the needs identified by these procedures.

R55: The installation operator must establish organizational structure and resources in Brazil that have person (s) responsible (s) for operational security in order to create an equalization of power between decisions related to the operational activities and risk management operational safety and ensure that risks are considered in the decision-making process of the company with equal importance to technical and economic evaluations.

R56: To establish organizational structure in Brazil for the response to the emergency command, to be exercised by the Concessionaire and / or by the installation operator. People members of this structure must first be defined and have the authority and capacity to drive necessary resources.

R57: To ensure the availability of at least one aeromedical aircraft dedicated by sedimentary basin where the dealer has ongoing operations. In the case of unavailability of aeromedical aircraft, equivalent aeromedical aircraft must be provided.

R58: To ensure that all parameters indicated in supervisory systems are registered and subject to further consultation.

R59: To install the control rooms of video platforms closed system (CCTV). Images should be subject to further consultation.

R60: To consider, in the emergency response procedures, conflicts between assignments to the whaling operation and other response functions in order to minimize damage to the abandonment in the event of injury to persons.

R61: Assess, for each response function to the emergency, the relevance to attend this function in the days of departure and arrival, considering the impact of human factors in the evaluation and implementation of emergency response activities.

5. Conclusion

The occurrence of major accidents gives us the evidence when it is held in synchrony, the management failures resulting from a poorly implemented or non-existent hazard management system result in great losses.

The accident which took place on board of the FPSO CDSM evidenced the scenarios identified in the hazard assessments were indeed real and the implementation of safeguards and hazard analysis of recommendations would have been useful in order to achieve the objective of controlling operational risks. It was also evidenced the bureaucratic approach towards risks identification and registration without the adoption of the requirements of operational safety management system does not fit into the demands of safety culture for operations in Brazilian waters.

As it indicates the requirements of ANP Resolution No. 43/2007 and other references in the safety subject, activities related to the platforms of operation should be monitored proactively in regard to the implementation of risk management systems.

In this sense, it does not establish methods for identifying latent failures of the safety management system nor to establish their respective continuous improvement actions consisting in mere passivity onward management issues, therefore, it awaits the occurrence of accidents and operates in violation of current legislation in the country. This legislation and the terms of the concession agreements establish overlapping responsibilities in respect to operational safety, both for the dealer and for the installation's operator, and these cannot be delegated and indeed mandatory.

The lack of minimum requirements for risk management, as acknowledged in such report, caused the accident FPSO CDSM on 11/02/2015. It is expected that situations, conditions and recommendations as evidenced by ANP in such report may indicate to the oil industry the importance of continuous improvement of safety requirements and typical proactivity of a good safety culture, which, in addition to ensuring human protection and the environment, tend to come to terms with the requirements for a socially responsible industry.