CAIRU FPSO REQUIREMENTS AND DESIGN

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Abstract - Cairu FPSO is one of the five FPSOs\(^1\) to be installed up to 1998 at Campos Basin, Offshore Brazil. Designed to operate in Marlim Field for twenty years without docking, carrying out off-loading operations about each six days, and handling more than 150 000 bopd during its operational life, this unit, like the others to be installed by PETROBRAS\(^2\), has its conversion contract subject to basic requirements established in order to guarantee operational reliability.

Constructed in 1974 at Ishikawajima Shipyard, and pertaining to PETROBRAS fleet, CAIRU is a VLCC (Very Large Crude Carrier) with 280 000 dwt. Due to the absence of double hull and her high operational costs as an oil tanker, she was available to be used as a Production and Storage Unit. Allied to that, Technical and Economic Feasibility Study developed focusing oil drainage in Campos Basin has shown the advantages of employing oil storage units exporting via shuttle tanks over the option of constructing a pipeline network. Taking advantage of the installation of an oil storage unit, an oil treatment plant to process the fluid from P-18 and P-20 (semi-submersible platforms already installed at Marlim field) was also planned. In order to allow the mooring of this FPSO a turret system was incorporated in the design, providing also facilities for the connection of eight risers.

The aim of this paper is to present a brief description of the systems which compound Cairu FPSO, their main requirements, the most relevant difficulties and solutions adopted. Innovative solutions, such as the employment of cargo tanks as process coalescer tanks and crude oil as a combustible for boilers and furnace are also highlighted.
INTRODUCTION

Conceived to store oil from Marlim Field produced by semi-submersible platforms P-18, P-19, P-20 and from 4-RJS-377 and 4-RJS-403 well area produced by semi-submersible P-27, and also to treat oil from P-18 and P-20, CAIRU FPSO has been designed to operate for 20 years at a 160 m water depth, handling more than 150,000 bopd.

Like the other four FPSOs to be installed up to 1998 at Campos Basin, offshore Brazil, one at Barracuda Field (P. P. Moraes - P-34), one at Albacora Field (Vidal de Negreiros - P-31) and two more at Marlim Field (Henrique Dias - P-33 and José Bonifácio - P-35), Cairu FPSO (P-32) is based on the conversion of oil tankers pertaining to PETROBRAS fleet, which contracts are subjected to a quite extensive technical documentation generated by PETROBRAS. This Basic Design includes a General Technical Specification (GTS) with general requirements, such as design life and design operational and loading conditions and specific requirements concerned to the main systems to be constructed or to be subject to an overhaul. Besides GTS, Basic Design also includes: general and equipment lay-out; Process Flow Diagrams, Piping and Instrumentation Diagrams (P&IDs), equipment list, data sheets; specifications for safety, instrumentation, electrical, equipment, telecommunication and ventilation & air conditioning. Naval and structural design premises are also included in order to guarantee the hull performance in a new function, with new load conditions, taking into account the previous life of the available ships, as all of them are more than 20 years old.

The main purpose of this paper is to present a brief description of the systems which compound Cairu FPSO, and the corresponding most important technical requirements established. Difficulties and solutions, mainly related to lay-out definition, for some particularities of Cairu design are also shown. Innovative solutions, such as the employment of cargo tanks as process coalescer tank and crude oil as a combustible for boilers and furnace are also highlighted.

HISTORICAL BACKGROUND

Marlim Field, one of the Brazilian giant oil reservoirs, was discovered in 1985 in water depths ranging from 650 m to 1050 m. By the end of 1999, the total installed oil processing capacity will be around 650,000 bopd and the total gas compression capacity will be approximately 12,600,000 Nm³/d.

The first production Unit, a semi-submersible platform named P-20, was installed in 1991 as a pilot system, exporting its production to an oil tanker
(Horta Barbosa) permanently moored to a monobuoy. Processing 52,000 bopd, this platform has been incorporated to the definitive exploitation strategy.

The world largest new building production semi-submersible platform, P-18, was installed in 1994 at Marlim Field, in a water depth of 910 m, with a processing capacity of 100,000 bopd and 2,100,000 Nm$^3$/d of gas. The produced oil was exported to shuttle tankers alternating between two monobuoys.

As can be seen in Figure 1, Marlim Field exploitation scenario includes the installation of two more semi-submersibles (P-19 and P-26), and four FPSOs (P-32 (Cairu), P-33, P-35 and P-37). All Units are existing vessels, whose conversions are under development. Among all mentioned FPSOs, only P-37, the most recently contracted, was not previously owned by PETROBRAS.

![Figure 1 - Marlim Field and 4-RJS-377 & 4-RJS-403 well areas](image_url)

Placed northwest in relation to Marlim Field, known as 4-RJS-377 & 4-RJS-403 well areas, new fields discovered, respectively, in 1987 and 1989, will be exploited by semi-submersible platform P-27, which oil production, around 43,000 bopd, will be stored at Cairu.

All oil transference from Marlim Field will be based on storage units off-loading the oil to shuttle tankers, which provide the transport to shore. A reduction in
the necessary investments has been obtained, by eliminating the installation of
the offshore oil pipeline network and also due to the availability of ships from
PETROBRAS fleet which were supposed to be alienated. The absence of
double hull and the high operational cost are two reasons for the ship to stop
working as an oil tanker. Transportation via shuttle tankers also offers the
advantage of enabling unloading at any terminal, giving flexibility to the
refinery programming.

As mentioned before, Cairu FPSO was planned to receive and export oil from
platforms P-18, P-19, P-20 and P-27. In those platforms the associated gas is
removed and exported via gas pipelines. Taking advantage of the installation of
an oil storage unit, an oil treatment plant to remove water and salt from P-18
and P-20 oil was also included. This process comprises few equipment, as
follows: oil pre-heaters, separation tanks consisting of specially prepared cargo
tanks, oil heaters, oil dehydrators and hydrocyclones to treat oily water.

Besides the placement of a process plant, the conversion of Cairu into a FPSO
includes also the installation of an internal turret system, a helideck, three
cranes, an off-loading system and modification or repair of existing utilities,
accommodation and hull.

CONVERSION CONTRACT

Astilleros Españoles S. A. (AESA) has been contracted on February/1996 to be
responsible for all conversion work and detailed engineering design under a
lumpsum contract basis, meaning, as mentioned before, an obligation to follow
technical requirements established in PETROBRAS Basic Design. As the Main
Contractor, AESA sub-contracted other companies, as shown in sequence:

• BLUEWATER - Company qualified to design, purchase and assemble
turret systems, sited in Hoofdoorp, Netherlands, responsible to all aspects
related to the turret;
• ALLEN TANK INC. - American company in charge of process plant
design, purchase and assembly, including deck structure module;
• UTC - Brazilian design company, with the attributions to coordinate and
be responsible for the entire design compatibility, to perform naval and
structural analysis related to the ship hull, to generate documentation
about production facilities and ship utilities;

Under the responsibility of all presented subcontractors, as well as the main
contractor, there is another level of subcontractors, which leads to an enormous
interface relation. As established in contract, all suppliers should have design,
proceedings and construction process certified.
The original ship Classification Society, American Bureau of Shipping (ABS), has been maintained in order to count on hull historical background, to anticipate technical discussions and to have PETROBRAS basic engineering design certified.

**DESIGN PARAMETERS**

The most relevant design parameters are mentioned in sequence. They are mainly related to naval and structural aspects.

**Cairu basic data**

Cairu oil tanker was constructed in 1974 at Ishikawajima Shipyard. The following Table 1 summarizes the main ship and FPSO characteristics.

**Environmental data**

As a FPSO, Cairu hull integrity was checked and new structural systems were designed to withstand Campos Basin metocean conditions instead of being governed by unrestricted navigation conditions. A centenary metocean condition governs the verification of the ship hull for the new light weight and cargo conditions, and for the design of structural subsystems, mooring and risers. The exceptions are some structures submitted to specific environmental conditions in operation, such as pull-in winch and off-loading systems.

Besides centenary condition, the ship hull and other structures are also checked for a typical sea state that could happen, which consists of waves in a very regular shape, with heights around 3.5 m, that could reach the hull in a beam sea condition, if wind and currents have low intensities. This requirement has been established based on operational experience.

After defining the transportation route from shipyard to Campos Basin, the environmental conditions that the FPSO could be submitted to during the trip were also considered in the analyses.
### Ship characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deadweight</td>
<td>280,000 dwt</td>
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<tr>
<td>Displacement</td>
<td>320,000 t</td>
</tr>
<tr>
<td>Length between perpendiculars</td>
<td>320 m</td>
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<tr>
<td>Breadth molded</td>
<td>54.5 m</td>
</tr>
<tr>
<td>Depth molded</td>
<td>27.8 m</td>
</tr>
<tr>
<td>Maximum draught</td>
<td>21.62 m</td>
</tr>
<tr>
<td>Steam production capacity *</td>
<td>120 t/h</td>
</tr>
<tr>
<td>Electric power generation</td>
<td>2<em>1800 kW + 1</em>1500 kW</td>
</tr>
<tr>
<td>Number of cargo and ballast pumps</td>
<td>4 cargo + 1 ballast</td>
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<tr>
<td>Accommodation</td>
<td>44 persons</td>
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<td>Water depth</td>
<td>160 m</td>
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<td>Treatment plant</td>
<td>100,000 bopd</td>
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<tr>
<td>Process plant deck area</td>
<td>1200 m²</td>
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<tr>
<td>Number of mooring lines</td>
<td>8</td>
</tr>
<tr>
<td>Number of risers attached</td>
<td>6 + 1 umbilical **</td>
</tr>
<tr>
<td>Risers diameter</td>
<td>5 x 12” + 1 x 8” + 1 x 4”</td>
</tr>
<tr>
<td>Turret upper bearing diameter</td>
<td>5 m</td>
</tr>
<tr>
<td>Turret lower bearing diameter</td>
<td>7.1 m</td>
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<tr>
<td>Off-loading flow rate</td>
<td>150,000 m³ @ 24 h</td>
</tr>
<tr>
<td>Accommodation</td>
<td>91 persons</td>
</tr>
</tbody>
</table>

**Table 1 - Cairu basic data**

* Assumed in Basic Design, 60 t/h per boiler; the original was 80t/h per boiler
** There are 8 guide tubes for 6 lines, 1 umbilical, 1 spare line

### Design life

Fatigue life and anti-corrosive protection system, i.e. painting and cathodic protection, should be compatible with 20 years operational life without docking. The possible previous damage related to the life of the ship as an oil tanker during the last 20 years, should be taken into account in the investigation of structural details likely to present fatigue problems.

As a consequence of the ship's long service life at sea, all remaining equipment is being overhauled to achieve an 'as new' condition.

### FPSO DESCRIPTION, REQUIREMENTS AND DESIGN SOLUTION

The main systems adopted in Cairu FPSO are discussed in sequence together with the most relevant requirements and design solutions.
General lay-out

The conversion of Cairu follows a premise to minimize changes in the original hull. The superstructure with accommodation and the engine room with utilities are located at the stern. Considering the benefits to safety in maximizing the separation between accommodations and major hydrocarbon release hazards, the process plant is positioned at midships as far aft as possible, and the turret at the bow, as it can be seen in Figure 2.

![Figure 2 - General arrangement](image)

The turret location at the bow provides great weathervaning capability, without reducing tank capacity and minimizing structural reinforcements. The Basic Design documentation allowed for both internal or external turret installation, as the water depth and number of risers are not so big. The contracted turret designer has chosen the internal turret concept, which gives an advantage of protecting turret structure and equipment from wave slamming, green water and collision.

Compared to the available deck area, process plant deck area of Cairu is small, and could be arranged in a single module elevated around 5 m above the main deck to eliminate the possibility of green water and also to ease cargo piping maintenance.
The adopted concept for off-loading, based in our environmental characteristics, is a shuttle tanker moored in tandem, at the stern of the FPSO. So, the off-loading system area is located at the stern, behind superstructure.

The helideck is positioned above the off-loading system, at a height of 10 meters above the main deck. The rear location is the safest because of the distance of cargo tanks and process plant, and the protection given by engine room and the superstructure. Additionally, there is the advantage of the accommodation proximity.

**Hull**

The requirements concerning the hull are related mainly to naval and structural verifications and anti-corrosive protection system. The naval verifications are basically trim and stability analyses for the new loading/unloading conditions and Campos Basin environmental data. A motion analysis is also required as input to new structures dimensioning. The hull structural verifications include steel plate replacement, longitudinal hull girder strength and local verifications.

The required scantlings shall take into account the premise of 20 years without docking. Corrosion margins that reflect an average overall corrosion wastage of 20 years in service have been established, assuming good maintenance schedules, an effective system for coating protection in ballast tanks and previous experience with oil tankers. These corrosion margins shall be considered in addition to the renewal thickness fixed by the Classification Society (CS) for different parts of the hull, as a criterion for plate replacement.

The longitudinal hull girder strength analysis shall be performed according to CS values, taking into account all loading and unloading conditions, considered in the Trim and Stability Booklet. Care shall be taken for the inspection loading, in order to maximize the cargo capacity and be compatible with the design allowable stresses. Loss of storage capacity means an undesirable time reduction between off-loading operations. Efforts have been made in order to reduce the high time expended in inspection due to tank washing and gas venting to put the tanks in a free for men condition, including facilities inside the tanks to enable future inspections as wire ropes, stairs, padeyes, etc.

The hull reinforcements due to all new structures added, such as process plant deck, cranes, off-loading equipment etc., shall be calculated.

**Turret**

Figure 3 shows a general schematic view of the turret installed in Cairu. Turret conception has been let to turret designer, provided some fixed requirements were met. These requirements were mainly related to risers arrangement, number and pattern of mooring lines, main bearing type, equipment to be fitted.
in decks, as well as the operations to be done related to oil process and installation procedures.

A passive mooring system consisting of a symmetric catenary mooring pattern with conventional mooring radius and composition was adopted. The mooring legs are composed by top and bottom segments of stud link chain, intermediated by spiral strand wire rope and a High Holding Power anchor. To complete mooring dimensioning, a model test was performed at MARIN (Maritime Research Institute Netherlands), where the behaviour of the FPSO coupled to an off-loading shuttle tanker was also investigated.

A cylindrical surface of 8.4 m diameter plus a conical upper part, known as moon-pool or casing, is the structural interface between the turret and the ship.

The turret shaft, also a conical structure, performs the load transference of the mooring lines, connected to its lower part called spider, and the risers, connected at connection deck, to the ship hull by means of two levels of bearing. A tri-roller bearing, installed at the intersection of the top of the casing and the top of the shaft, is designed to receive all the vertical loads and also the horizontal and tilting moment loads due to the turret decks. A sliding bearing, consisting of an inconel surface at the bottom of turret shaft running in contact with bronze blocks held by casing, transmits the horizontal forces imposed by mooring and risers to the hull keel plate.

The most peculiar characteristic of the turret deck system is the space reserved to the pig receiving operation. Due to the use of long (about 15 km) rigid pipelines to transfer the oil from production platforms to Cairu, their thickness should be periodically inspected by intelligent pigs, which length is much bigger than that of regular cleaning pigs. Seven receivers for intelligent pigs, also capable to handle cleaning pigs, are arranged horizontally along two decks together with check and ball valves. Due to operational preferences, the pig receivers had to be horizontally arranged.
The turret deck module contains also one level for swivel stack. Composed by six oil paths, one fire water, one service air, one pneumatic, one electrical and one optical path, this equipment reaches about 8 m height and 80 t weight. Among the six oil paths, two of them are stand-by paths.
A main winch for 150 t, employed in mooring and riser installation, is located below the lower deck. An auxiliary 10 t winch is also employed for the same purpose.

Another singularity that affects turret lay-out is the requirement for installation and removal of a 2 m diameter diver cage through the turret. That equipment, as well as the diver cage winch, is supplied by a diving company, which is responsible for their maintenance.

To allow cargo handling inside the turret decks one monorail with 5 t hoist is installed over each of the two manifold decks. A gantry crane is the handling system adopted at the swivel stack area. Both systems allow load transference between turret and a lay-down area at the ship main deck, within reach of the ship’s forward crane. Shakes, shackles, padeyes and ladders are installed to allow risers and mooring lines pull-in and pull-out operation.

The access from the ship main deck to all turret levels is made by a framed structure called tower support structure, which besides allowing people circulation also supports piping and swivel gantry crane.

**Accommodation**

The accommodations had to be totally changed due to increase of FPSO crew, as a consequence of 20 years of operation without any docking. The crew was increased from 44 to 91 people for operation, maintenance and inspection activities, leading to an increase of collective rooms, such as the library, dining room, galley, living room, game room, etc. All the deck accesses to the stairways had to be closed by A60 bulkheads with one door by deck.

After changing old rooms into new ones, changing floor, linings, bulkheads and scuttles, the finishing would be different. The existing B15 linings, using oily naval wood were different from those found in the market nowadays, using steel plate with fiberglass coating and synthetic wood. The solution adopted was to renew the existing lining and cover it with wall paper similar to the new one. As the aisles are escape routes from the accommodations, these changes had to be submitted to the Classification Society and were accepted by the surveyor. All furniture had to be replaced by new one, because of the necessity to install four berths, where the old ones couldn’t fit in the new layout.

**Process plant**

Since all gas is removed from the oil in the original production platform before reaching Cairu, the process plant become very simple although processing large volume of oil. The untreated oil is transferred from the riser installed in the turret to the ship, via a swivel path, after being manifolded. At the process plant deck, it is pre-heated to around 40°C, by the oil which leaves the dehydrators,
and directed to the coalescer tanks. Pumped to the heaters, the oil reaches 90°C to enter the dehydrators, where the water and salt are removed, to levels of 1% BSW and 200 ppm of salt. Finally, the treated oil is directed to the cargo tanks through the cargo piping header. The remaining water is treated in hydrocyclones to be disposed to the sea with maximum of 15 ppm of oil.

The heating process consists of heat exchange between crude oil and hot water. To heat the water, three furnaces are installed. During start-up, the furnaces burn diesel oil and after reaching operation temperature change to crude oil. That operation is automatic and performed by the automation system.

Utilities
To transform Cairu into a FPSO many modifications were required in the ship utilities systems. The main one consisted in changing the boiler combustible from fuel oil to crude oil. This equipment is critical to the FPSO continuous operation, because all main power generation and all main pumps are steam-turbine driven. To perform that important change the original boiler combustion system manufacturer was contracted, due to the knowledge required to carry out this modification. A completely new burners and fuel feeding skid with new pumps and instrumentation was designed.

With the removal of the propulsion system all steam condensing system had to be resized. The main condenser was removed and a new auxiliary condenser was installed to guarantee the correct and safe boiler operation.

The lower deck of engine room was replanned to permit a better equipment lay-out and maintenance space during FPSO operation.

All remaining auxiliary systems of the ship had to be repaired and conditioned in a fully 'as-new' state to guarantee 20 years operation with minimum stopping for maintenance. In general, these systems include:

- diesel oil for emergency fire water pumps, auxiliary and emergency generator;
- lube oil for boilers, generators and pumps;
- service pumps, i.e., cooling water, bilge, ballast and lube oil;
- cargo pumps;
- hydraulic system to cargo valves;
- power generation system, i.e., 2 steam turbines generators, 1 diesel generator and all panels.

The electrical system was reason for a large impact in the design, due to new loads resulting from new systems of the FPSO. The power generation is compatible with the loads, but the philosophy of 20 years of continuous
operation required some changes in the existing panels. The increase in short circuit current was not accepted by PETROBRAS engineers. Modification of the existing main panel was not a good solution, due to the requirement of a new certification for that panel. The adopted solution was to design a new panel for managing the main loads of the ship. The emergency generator was changed for a new one due to the new emergency concept and consequent new loads.

The control/service air system was changed for a new one, due to the new critical functions assumed by instrumentation system in the FPSO and the air driven equipment in the turret. The existing system consisted of 3 reciprocating compressors driven by diesel engines and had no components for immediate delivery. The new one consists of 2 screw compressors driven by electrical motor that are more reliable and demand less maintenance.

All cargo valve system was renewed with all hydraulic tubing changed and all valves repaired. Valve repair consist of changing seat rings and repairing the obturator. The panel of solenoids was completely changed due to no availability of parts and high integration required by the new supervision and control system.

**Automation system**

Another significant modification in the conversion of Cairu into a FPSO was the new automation system to be installed. Composed by Digital-Alpha workstations, running VXL process control software, this system is called ECOS (Central Station of Operation and Supervision) and is responsible for supervising all PLCs (Programmable Logic Controllers), receiving data and sending commands to them.

To permit that high degree of automation, all existing equipment had to be modified, receiving new sensors to support stop and run commands and automatic supervision throughout alarm and trip resumes.

The new philosophy in the FPSO operations is to concentrate few operators in the central control room and let the ECOS system supervise all FPSO systems. All new systems to be installed, i.e., turret, VAC, fire detection, process plant, off-loading, boiler burners and electric panels will be fully controlled by PLCs and supervised by ECOS system.

**Off-loading system**

The Basic Design documentation required an automatic way to store the off-loading hose, allowing the choice of a drum, a chute or a basket. The Contractor in agreement with PETROBRAS operational team decided for a storage chute installed along the length of the hull main deck, providing best
conditions for inspection and maintenance, and avoiding interference with the helideck. The substitution of any section of the hose, can be carried out by the cranes of the ship. Maintenance of the chute is more simple than the drum and access of all parts is easier.

An alternative option was designed to enable the oil transfer to the shuttle tanker if the off-loading system fails. There will be a pneumatic winch to pull a spare hose from a supply boat to be connected to the cargo line. After that connection, the supply boat will help the connection of the spare hose to the shuttle tanker.

Off-loading in normal operational condition is defined to occur in no less than each six days.

**Cargo handling system**

All existing cranes were removed and three new were designed to be installed one at the bow, one amidships and one at the stern. To reduce maintenance costs and noise, hydraulic cranes driven by electrical motor were adopted. The new cranes have increased boom length to transfer loads 20 meters from the hull.

As the work area of one crane doesn’t reach to other crane, Basic Design proposed the installation of a trolley system to transport the loads from one crane to another or to any point along the deck. This equipment reduces the use of the cranes, increasing its life time and turns the operation safer. The trolley has an independent traction system, using a diesel engine driving a hydraulic motor. The trolley will run over rails along the deck and was designed to 15 t of capacity.

The bow crane is responsible for transferring the loads from the turret lay-down area to the trolley and serves the pull-in operations. The stern crane is fitted to handle stores and provisions from a cargo area near the superstructure, and also loads from the off-loading system. Installed starboard, this crane makes possible to transfer loads to a supply boat when the approximation is only possible by this side or to the trolley. The middle crane is responsible for handling the loads of the process plant and between FPSO and the supply boat when the portside loading station is used.

**INNOVATIVE SOLUTIONS HIGHLIGHTS**

Among the design solutions adopted, two are highlighted here because of their innovative aspect not considered in the other FPSOs to be installed by PETROBRAS.
Cargo tanks as process tanks
Oil/water segregation in cargo tanks during oil transportation trips is a well known process. As this phenomenon is exactly what was requested to get the correct specification for the untreated oil, two pairs of wing tanks were converted into separation tanks. Stability and longitudinal hull girder analyses have shown that operating with wing cargo tanks 3A and B and 6A and B permanently full is a possible cargo condition at the minimum draught, meaning that no storage capacity would be lost with this condition. This being the case, two tanks operate simultaneously as flowing separation tank, while the other two normally operate as cargo tanks, substituting the first pair if any repair/cleaning is needed.

The residence time achieved in those tank is calculated to be more than 30 hours, much higher than could be reached by conventional gravity separator vessels, and much more efficient to allow breaking emulsion.

Each separation tank is provided with internal heating system, using hot water as heating medium, to compensate heat loss. To avoid short circuit paths inside the tanks, that could shorten the effective residence time, a feed distributor over the whole width of the tank and some baffles in its interior were placed. Added to the convective flow due to heating, the installed equipment will be enough to avoid this problem.

ABS has been consulted and has no objection to the new function of these converted process tanks.

Crude oil as boilers and furnace combustible
Production platforms installed in the Brazilian continental shelf normally employ gas originated from oil separation process for their own consumption, as, for instance, electric power generation, exporting the excess. As Cairu FPSO does not handle gas in its process plant, the crude oil was considered as combustible for boilers and furnaces. Combustible gas would need to be imported and would increase conversion costs due to the installation of high pressure gas swivel path, flare system, etc.

Studies and queries to boiler burner suppliers were made to assure the possibility of the crude oil utilization without any previous treatment. Exhaust gas emission was also evaluated. The conclusion was for the feasibility of crude oil employment.

As crude oil originates hazardous areas, it was not possible to install daily storage tank inside the engine room. A special tank constructed inside the slop tank solved the problem. All oil piping was place inside ducts.
CONCLUSIONS

Cairu FPSO installation at Marlim Field is the beginning of a new era in Brazilian offshore oil exploitation, based on converting VLCCs into production and storage units. Although Cairu does not represent a typical processing platform at Campos Basin, the experience obtained in mooring and riser installation, as well as with off-loading operation, will be very useful. When operational feedback begins to be consolidated, better design specifications could be formulated for future projects.

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REFERENCES
