PETROBRAS TECHNOLOGY: A LEGACY OF SUCCESS

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Forced by national need to develop offshore Campos basin reserves, Brazil' s state oil company has a track record that prepares it well for coming ultra-deepwater challenges

Petrobras has been making important oil strikes in waters deeper than 300 meters over the past 10 years. This exploratory success is reflected by the Albacora and Marlim giant fields, and also by discoveries of other deepwater fields in Campos Basin, such as the recently announced Roncador Field.

The challenges of producing in deep water, 300 to 1,000m (980 to 3,280 ft), and ultra-deep water >1000m, in Brazil, had to be faced since it was the only alternative to reach production levels compatible with the country needs as well as the required development speed. To achieve the technological level that allowed Petrobras to develop the deep and ultra-deep water fields, a long path has been tracked.

This article is a brief review of the Brazilian offshore activities and the experience that Petrobras has acquired through more than 20 years of deepwater operations. It describes the main drivers to deep water and shows how PROCAP-2000, the strategic corporate R&D program, fits into this scenario. Technology trends, based on previous experience, as well as the future challenges to support the activities to be carried out in ultra-deepwater, are also discussed.

INTRODUCTION

The 1973 world oil crisis caused a tremendous economical impact on most countries, especially those with strong dependence on imported oil. This led to the increase in investment in oil and gas exploration and production worldwide, including the search for new technologies for producing fields located in hostile environment.

The first oil discovery in Campos Basin (**FIG. 1**), Brazil, occurred in 1974, just in the middle of the economical chaos created by the world oil crisis, which was worsened by the country's unfavorable external balance of payments. Therefore, although the discovery of hydrocarbon accumulations offshore Rio de Janeiro came at a very good time, just having the "oil in place" alone was not enough to lessen the increasing national foreign debt. Thus, the Brazilian Government urged Petrobras to find technical methods to produce the just-found oil in an economically feasible way.

However, not all of the required technologies had been field proven at that time. So, due to that circumstance, Petrobras decided to introduce several emerging technologies, mainly those related to deep water, to initiate the new oil production as well as implement and test new ideas.

Moreover, after the Albacora and Marlim discoveries, in 1984/1985, in water depths ranging from 250 to 2,000 m (820 to 6,560 ft) it was of paramount importance for the company to develop technologies fitted to its needs and peculiarities.

DEEPWATER PRODUCTION IMPORTANCE

The total Brazilian reserves of oil and gas equivalent reached 17 billion boe at the end of 1997. Of this, the oil reserves were distributed as follows: onshore, 13%; in shallow waters, below 400 m, 14%; and deep water, between 400 and 1,000 m, 28%. The remaining 45% were in ultra-deep water, i.e., beyond 1,000 m. But in this case, it has been necessary to both develop and extend technology to produce in such water depths. In short, the current Brazil oil and gas equivalent reserves in deep and ultra-deep water stand for 73% of the total.

At the end of 1997, Petrobras reached an average daily production of 1,000,000 bopd, with the following distribution: onshore 25%, shallow water 34%, and deep water 41%. This production is not enough to meet the Brazilian market demand, close to 1.6 million bopd. To increase its domestic production, Petrobras needs to produce from fields in deep and ultra-deep water.

The importance of the new technology is reinforced by the fact that more than 60% of the future oil and gas discoveries are expected to be located in deep and ultra-deep water. These figures reveal that Brazil's future, regarding oil production, is strongly related to offshore production in fields located in water depths beyond 400m.

In summary, to increase Petrobras' domestic oil production, its deepwater fields must be produced.

THE FIRST PROCAP

The economic significance of deepwater reserves determined the launch of Petrobras Technological Development Program on Deep Water Production Systems, the first PROCAP, in 1986. Its main objective was to improve the Company's technical expertise in oil and natural gas production in water as deep as 1,000 m, aiming at the Albacora and Marlim field developments.

The program also had the purpose of consolidating Petrobras' operational experience, mainly in Floating Production Systems (FPSs), to: 1) achieve cost reduction and reliability improvements, 2) extend shallow water offshore technology to deeper waters, and 3) develop new alternatives to improve deep water oil exploitation.

PROCAP was carried out in six years, and undertook 109 interdisciplinary projects. Its main result was full technological capability through the Floating Production System based on semisubmersibles, which helped Petrobras produce in water depths up to 1,000 m. This capability was really proved with a set of achievements such as :

1. Installation of the Marlim pre-pilot system, which started in March 1991, and lasted one and one-half years, using an adapted drilling rig (P-13) moored in 625-m water, with MRL-3 and MRL-6 wells onstream, in 721 and 752 m, respectively, and a monobuoy for oil offloading. Some world records were performed at that time, including:

· First purpose-built guidelineless diverless lay-away tree (MRL-3)
· Deepest wet Christmas tree (752 m WD)
· Deepest monobuoy (CALM type,400 m WD)
· Deepest flexible Line (752 m WD)
· Deepest floating production unit (625 m WD).

2. The installation of P-18 semisubmersible platform, in 910-m WD, which was the largest production platform in the world at that time. It was entirely designed by Petrobras with capability effort developed in the first PROCAP. It has been in operation, in Marlim field, since April 1994.

3. The completion of Marlim-4 well, located at 1,027-m WD which was put onstream in April 1994.

PROCAP-2000

The excellent results obtained in the first program and additional discoveries in deeper waters encouraged the Company to create, in 1993, a new program called PROCAP-2000, Petrobras Technological Innovation Program on Deepwater Exploitation Systems - far more challenging than the previous one. It has been implemented to give continuity to the efforts of the first program with the following two major objectives:

1. Enable Petrobras to produce oil and gas from offshore fields situated in ultra- deep water (1,000 to 3,000 m) aiming at incorporating the reserves located at these water depths.

2. Develop technological innovation projects aiming at reducing the cost of oil and gas production, in relation to current conventional systems, in fields located in ultra-deep water.

Petrobras has chosen 12 projects to be developed throughout five years, from 1993 to 1997. These projects represent the essential technologies to achieve the goals. To assure significant and effective results in these projects, the final products should be presented as prototypes, field tests, small scale models, computer simulators or basic design. The program endeavors to optimize know-how and resources available locally and abroad, to reduce deepwater development costs.

In this way, Petrobras has been intensifying its contacts with the international technical community, such as universities, research institutes, engineering consultants and foreign suppliers to access technologies not available in Brazil. Another important issue has been the monitoring of technology developments worldwide. Ways found to pursue this strategy are through Joint Industry Projects like DeepStar, Cooperation Agreements (Shell, BP/Statoil and Agip), and Service Contracts.

In mid-1996, some of the projects were concluded, so that new ones were incorporated into the PROCAP-2000 portfolio. The updated and extended portfolio, **table 1** reflects the current technology required by the company to achieve program goals and will be carried out from 1997 until 2000.

CAMPOS BASIN PRODUCTION EVOLUTION

Campos Basin, the main petroleum province in Brazil, lies offshore Rio de Janeiro state, on the southeast region of the country. Its area covers 100,000 sq km (38,600 sq mi) from shore to 3,400-m (11,152-ft) water depth.

Basin exploration began in 1968, and the first commercial discovery, Garoupa field, was hit in 1974 through the well RJS-9A. But production activity began in August 1977, at the second-discovered Enchova field, also in 120-m WD. There, a new concept, for Petrobras, was introduced, the Early Production System (EPS).

After installation of the first EPS in Enchova, several others were installed, relocated and demobilized. Presently, 21 FPSs are still in operation. Naturally, other improvements were introduced along the way, such as full conversion to Floating Production Unit.

Most of the production systems in use (or planned to be used) in Campos are basically extensions of the EPS concept. The typical scenario has changed in relation to the period in which it was conceived. The last-discovered significant fields are much larger in volume than those considered at the beginning of Campos development, and all of them are located in deep water. These factors have demanded much more complex systems in terms of number of wells, processing capacity, subsea layout and equipment, and production facilities. In addition, improvement of 3-D seismic technology has diminished the importance of the reservoir information given by the old EPS.

Simultaneous use of subsea well completions and FPSs has created an approach to oil/gas developments that has increasingly shown economic advantages in offshore fields worldwide.

Simple as it might sound, and confirming the concept that innovative design does not have to be complex, the heart of the Petrobras option to deepwater developments can be summed up in just three items: 1) surface controlled subsea wells, 2) floating separating/processing facilities - either ship-shape or semisubmersible, and 3) flexible risers and flowlines.

This preferred development scenario brings to the operator an extensive range of benefits, such as:

• Suitability of the system to the characteristics of Campos Basin reservoirs which are found at shallow depths

• Suitability of the system to the environmental conditions considered mild when compared with the Gulf of Mexico and the North Sea

• Possibility of using this system as a pilot unit in a scale lab for definitive systems

• Possibility of using the system to perform extended well tests to get better reservoir characterization to optimize the field exploitation design

• Phased development - revenues from one phase may finance the following ones, improving the cash flow and minimizing risks and capital exposure

• Fast deployment and high level of flexibility - short period from discovery to first oil, specially by conversion of available units and also easy and fast relocation of FPU's, bringing extra advantages for other field developments, and

• Field proven and reliable technology – our previous experience proved the reliability and cost effectiveness showed by these systems so far.

In short, the FPS is an excellent alternative for deepwater and marginal fields, according to a worldwide trend.

Table 2 demonstrates Petrobras' experience in this subject. The company has more than 288 subsea trees already on the seabed, 3,100 km of flexible lines and umbilicals laid, 49 subsea manifolds and 21 FPSs in operation. A significant increase is expected in the next 4 years.

Due to the systems' satisfactory performance record, Petrobras feels comfortable in planning to install some 14 deepwater production systems to develop its oil fields in the next four years, **Table 3**.

Two decades of operational field testing and experience have added continual incremental improvements as well as breakthrough innovations to the design and construction technology of a list of equipment, eventually making them industry standards. **Tables 4 and 5** summarize the main technologies implemented in Campos Basin during its 21 years of operation.

In August/1997 South Marlim Early Production System entered in production representing a milestone for the development of deepwater technology applicable to the profitable exploitation of fields in up to 2,000 m WD.

The main technologies fitted out were:

- Subsea systems:
  - Subsea Tree for 1,800 m;
  - Pig Cross-over for passage of multi-size pigs;
  - Dumping valves for reducing closing time of direct hydraulic controlled Subsea Tree valves;
  - Elimination of the well´s DHSV.
- Mooring systems:
  - Polyester ropes mooring system;
  - Development of high resistance polyester ropes standardized and certified for offshore use;
  - Adaptation of work boats to handle polyester ropes;
  - Polyester ropes installation procedures.
- Flowlines and risers:
  - 4 and 6" flexible lines for static operations in WD up to 2,000 m and dynamic operations until 1,500 m WD;
  - 12 hydraulic function control umbilical lines for static operations in WD up to 2,000 m and dynamic operations until 1,500 m ;
  - Use of High Collapse Resistant (HCR) hoses for ethanol injection ;
  - Lay away installation of flexible and umbilical lines to 1,800 m WD ;
  - Extension of the use of free catenary configuration for flexible risers down to 1,500 m WD;
  - Pull-in of "second end " in FPSO external turret ;
  - Bell mouth type connection in riser interface x FPSO external turret.
- FPSO:
  - Six-month period of adaptation to be installed in 1,420 m WD;
  - Production and Processing of heavy oil (16 ^{o}API) at low temperatures in ultra-deep water;
  - Hydrates and paraffins prevention methods.

This project is a multi-record holder: water depth for completions, the FPSO on production with the deepest mooring system, in 1,420 meters or 4,659 feet of water, the deepest installation of flexible lines and Control Umbilical, and the First Floater fully moored with the use of polyester ropes.

These issues have represented a fundamental step toward the development of other ultra-deepwater fields, mainly Roncador.

THE FUTURE - NEW DEEP AND ULTRA-DEEPWATER CHALLENGES

A series of challenges and constraints had to be faced and overcome to produce the deep and ultra-deepwater fields offshore Brazil. Although environmental conditions are milder, compared to the North Sea or the Gulf of Mexico, specific problems had to be solved before Petrobras could go ahead. Discussed here are several of these challenges.

Step-by-step development - The first rule was to get data in advance to avoid, or at least minimize the "surprises" during the field development. Use of pilot systems and step-by-step development (modular) is highly recommended and is a default procedure in the company. By these means, future problems or adjustments in development plans can be foreseen and their solutions provided for the next steps.

Some examples of this adopted strategy include: 1) detection of the possibility of both organic deposits and hydrates in flowlines in most deep water fields and development of problem solutions; 2) adjustment to the development plan of Marlim Field, without impairing the normal development plan, due to an increase in field production potential, and 3) suppression of the water injection wells due to better knowledge of the Albacora reservoir during the first module development.

Ultra-Deepwater reservoir characteristics - Most ultra-deepwater reservoirs have large extension area with small effective thickness, presenting low temperature, often varying along the reservoir extension and contributing to relatively high oil viscosity. This poses a new set of challenges. These reservoirs' characteristics may result in lower recovery factors than desired. Since we are aware that these fields restrict conventional EOR options, both economically and technically, they will require new approaches for the application of IOR (Improved Oil Recovery) techniques.

Drilling of extended reach and multilateral wells - For deepwater projects offshore Brazil, the wells and their respective flowlines are responsible for more than 50% of CAPEX. High well productivity will play a key role in this scenario, being the target of horizontal and non-conventional wells, such as multi-lateral and extended reach ones - the latter also increasing the attractiveness of dry completions.

Drilling and completion of wells in deep and ultra-deepwaters - Establish innovative and cost effective concepts for deep and ultra-deep water drilling and completion is a very important target to be reached.

Light-weight fluid drilling is one of the most promising techniques for application in deep and ultra-deep water scenarios. The greatest benefit of this technology is the potential for reduction of formation damage, specially in low pressure and depleted reservoirs. Thus, larger production rates and, eventually, larger recovery factors can be obtained. Additionally, a dramatic reduction on stimulation costs is anticipated. In Brazil, some deep water fields are already requiring the use of light-weight fluid due to pressure depletion.

Another interesting technology which is being addressed by Petrobras is the Slender technology. It is an integrated system involving drilling, completion , and intervention of wells in deep and ultra deep water. It is based in the reduction of diameter of the intermediary and surface casings without reduction of the diameter of the production casing.

The main objectives of the technology are: increase the availability of rigs for deep water due to the reduction of deck load as a consequence of reduction of diameter of the drilling riser (ID 14"), and reduce the costs of drilling, completion and intervention in deep water. Being able to use smaller rigs to operate in deeper waters due to the reduction in the diameter of the drilling riser it is expected a reduction in the rig daily rate of 25%, and five fold in the increase of the number of rigs available to work in deep waters with a minimum required structural upgrade.

For the next tree years Petrobras intends to drill 148 wells using this technology. It has been working with several companies all over to be able to develop the necessary equipment for application of this technology. All the major components are expected to be ready by the end of 99.

Production of low API oils - The forecast for relatively heavy oil production (15 - 19 degrees API) in ultra-deepwaters is another Petrobras concern. To assure the oil will flow throughout long distance subsea lines, under low temperature at sea floor, new subsea fluid-flow technologies will be required, as well as some innovation in the existing artificial lifting methods.

Design, construction and installation of lighter subsea equipment for ultra-deepwaters - Petrobras in its development of deepwater fields up to 1,000 m, uses the subsea drilling and production alternative almost as a standard. Ultra-deep water prospects will demand new technologies to keep the subsea alternative attractive. Developments of technologies aiming 1) cost reduction of subsea equipment, 2) optimization of installation resources, 3) optimization of subsea production systems and 4) availability of technological alternatives for ultra-deep water subsea installation is a must. In this way, Petrobras main challenges are:

- Development of horizontal Xmas-tree for water depths up to 2,500 m to minimize intervention time in the well.
- Use of alternative materials for drilling riser intending to minimize the deck load on the drilling rig.
- Reducing weight on deck, allowing small rigs to operate in deeper waters with a minimum upgrade.

Flow assurance issues, as wax and hydrate mitigation techniques - In deep water conditions, many operational problems and huge production losses may occur due to organic deposition and hydrate formation in flowlines in which low temperatures, in both subsea floor and reservoirs, are predominant. Alternatives for the mitigation of hydrate and wax deposition in subsea pipelines will remain of fundamental importance as we move to ultra-deep water.

Development of new mooring systems - As the subsea layout in most fields is congested, mooring is also a major concern. A large mooring pattern, normally required for deepwater mooring, can impose heavy costs to the subsea equipment if flowlines and risers have to go around them to reach their connection points. Also, it may impose the use of DP (dynamic positioning) vessels, as they would be only ones capable of operating in the nearby area.

Use of synthetic ropes in a taut-leg configuration for production units, not only will bring a sharp reduction on the mooring radius, it also will help optimize subsea layouts in crowded areas.

Two other issues shall be taken into consideration: Reduction on vertical loads due to mooring lines weight and use of Vertical Loading Anchors as an alternative for suction/grouted piles.

Ultra-deepwater risers and flowlines configurations and structures - To overcome the challenge of producing in ultra-deep water, new technologies for subsea pipelines, control umbilicals and diverless connections, considering all phases from design to installation, shall be developed. Therefore the following technologies are of fundamental importance:

- Development of flexible pipes, accessories and installation procedures for water depth up to 3,000 m, to both evaluate and validate new flexible pipe design criteria and new materials applicability.

- Establish a technical and economical evaluation methodology for rigid pipe, defining its applicability, limitations and interfaces with the subsea systems, to be used up to 3,000 m, aiming to have a competitive technical and economical alternative to the flexible pipe.

- Availability of steel risers, in a catenary configuration, to be used in FPU being a Semisubmersible or a FPSO/FSO.

- Development of riser system alternative such as Tethered riser buoy (TRB) which has as its main advantage a better dynamic riser behavior - vessel motions are almost completely absorbed by the flexible jumpers while the SCR's and flexible risers have very little dynamic response.

- Availability of an efficient subsea remote connection system, to be used in water depth up to 3,000 m.

High Costs - In addition to the above mentioned items, **costs** are undoubtedly a major concern. The necessity of new technologies to allow production in deep water must be linked to the need for keeping costs at competitive levels. Of course, in order to overcome those barriers, Petrobras is aware that in some cases, it must pay the price of being the pioneer mainly in the prototype phase of a new development.

PROCAP-2000 TECHNOLOGIES TO BE TESTED

Since 1977, Petrobras has been both introducing and testing new technologies in Campos Basin. This vocation will continue within the company, as new challenges will be shown up when designing and operating new fields in deeper and deeper water.

A series of field trials of new concepts for Campos Basin in the coming years is summarized in **Table 6** . They are not comprehensive. Only the main technologies are pointed out, especially those in the implementation stage.

Roncador Early Production System – Later this year Petrobras will be bringing onstream the first oil from Roncador, using the Dynamic Positioned Seillean FPSO as an Early Production System for two wells.

This unit with a 20,000 bpd processing capacity and a 306,000 bbl storage capacity is the only one of its type, worldwide, equipped with a Dynamic Positioning System (DPS) and will produce through a vertical rigid riser (Drill Pipe Riser) linked to one subsea well and another tied back one. The unit will be used initially for long-term test, in 1,853m establishing a new world record.

CONCLUSIONS

The true challenge in deep water is using technology to make the development economically sound but - if adequate planning and risk management are used, even with the presently available technologies- it can be successfully faced. A phased (step by step) development strategy, in which risks and capital exposure are minimized, is an interesting approach that also allows cash flow to finance the next phases. The use of FPSs based on subsea completions has proven to be both cost effective and reliable over the years.

Petrobras is trying to overcome technical barriers through focused R&D projects and aggressive technology programs. In them, the start is the lab experiment, but the final goal is always field implementation. This is the only way to make sure that innovation will actually contribute to domestic production. Programs like PROCAP - 2000 are good examples of such focused R&D projects.

With additional important new discoveries in even deeper waters, Campos Basin will continue being used as a real-scale lab for new technologies, for years to come. Experience acquired over the years; existence of a large resources infrastructure; a deepwater knowledge network that provides technical and operational support; and success of the focused deepwater R&D projects, all give Petrobras the tools and confidence to face future challenges in ultra-deepwater.

Tables attached

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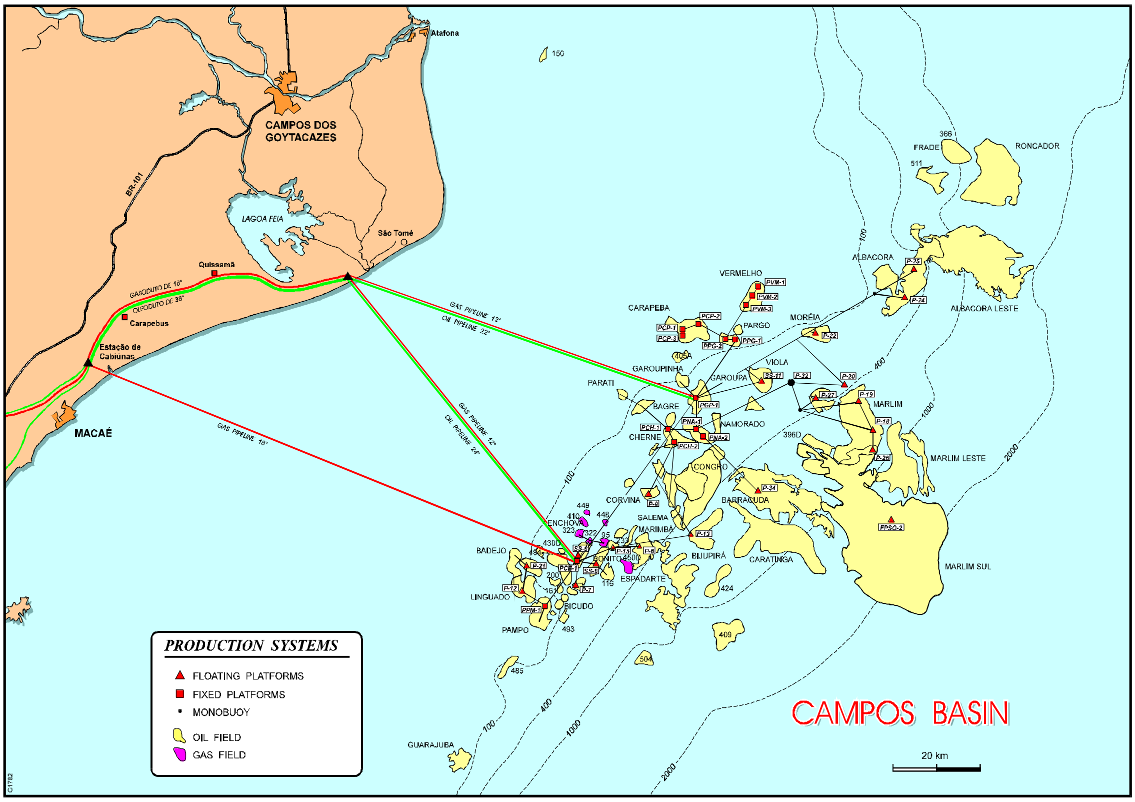

FIG 1 - Campos Basin Field Developments

Table 1. PROCAP-2000 Portfolio

Number	Project
1	Horizontal and Extended Reach Wells In Deep and Ultra-Deepwaters
2	Unconventional Drilling Techniques For Deepwaters (Offshore Underbalance and H.P. Jet Drilling)
3	Subsea Equipment For Ultra - Deepwaters
4	Electrical Submersible Pumps in Subsea Wells (ESPS)
5	Subsea Separation Systems (SSS)
6	Subsea Multiphase Pumping Systems (SMPS)
7	Flow Assurance in Deepwater Flowlines and Equipment - Phase Ii
8	Technology for Production, Transport and Processing of Heavy Crudes in Deepwater Scenarios
9	Stationary Production Units With Dry Completion
10	Deep and Ultra-Deepwaters Mooring Systems
11	Acquisition and Treatment of Geological, Geophysical, Geotechnical And Oceanographic Data
12	Deepwater Subsea Risers & Pipelines (Gathering, Sales and Control)

Table 2. Petrobras FPS Experience

Equipment	Installed	Planned (98- 2001)
Floating Production Units	21*	14
Subsea trees	288	158
Subsea manifolds	49	6
Subsea flexible flowlines (km)	1,954	1,201
Umbilicals (km)	1,205	498
Rigid pipelines (km)	1,300	600
Monobuoys	10	1

(*) 01 at Santos Basin

Table 3. Floating Production Units, Projects Under Development

FIELD	FPS	TYPE	WD(m)	START OF PRODUCTION
MARLIM	P-33 (H. Dias)	FPSO	780	Nov-98
MARLIM	P-35 (J. Bonifácio)	FPSO	850	Jul-99
MARLIM	P-37 (Friendship)	FPSO	905	Mar/2000
RONCADOR	P-36 (SANA 15000)	SEMI	1,340	Aug/99
RONCADOR	P-47 (Eastern Strenght)	FSO	815	Aug/99
RONCADOR	Seillean	FPSO	1,856	Nov-98
MARLIM SUL	P-40 (DB-100)	SEMI	1,080	May/2000
MARLIM SUL	P-38 (World Eminense)	FSO	1,020	May/2000
SALEMA/BIJUPIRÁ	P-45 (Jequitibá)	FPSO	675	Oct/2000
ESPADARTE	On Bidding	FPSO	940	Sep/99
BARRACUDA	P-41	TLWP/SPAR	815	Feb/2001
BARRACUDA	P-43	FPSO	805	Mar/2000
MARIMBÁ LESTE	P-21	SEMI	700	Nov-98
CARATINGA	P-48	TLWP/SPAR	1,040	Jul/2002
TOTAL	14 FPS	7 FPSO - 3 SEMI - 2 TLWP/SPAR - 2 FSO	700 - 1,856	Nov/98 - Jul/2002

Table 4 - Main drilling/production technologies implemented in Campos basin

Technologies	Field	W.D. , m	Date first application	Present status
Early production system	Enchova	120	Aug/77	Demobilized
Subsea atmospheric dry trees	Garoupa/Namorado	120/160	Feb/79	Demobilized
Atmospheric central manifold	Garoupa	120	Feb/79	Demobilized
First subsea diverless template/manifold	Bonito	190	1982	In Operation
Lay-away guideline completion (RJS-294)	Marimbá	412	1987	Installed
Electrical submersible pump	Northeast Pole	100	1989	In Operation
Offshore piles with conic shape toe	Northeast Pole	100	1989	Installed
First subsea horizontal well (BO-13)	Bonito	222	1990	Drilled
Muxcom (electro-hidraulic multiplexed control system)	Bonito	221	1990	In Operation
Lay-away guidelineless completion (RJS-298)	Marimbá	387	1990	Installed
SGN (Nitrogen Generation System)	Campos Basin	Several	1992	In Use
Vertical connection (MRL-20)	Marlim	610	Dec/92	In Operation
Pig crossover (AB-13H well)	Albacora	289	1993	In Use
Pig loop (Albacora Manifold)	Albacora	250	1993	In Use
ESP in subsea well (RJS-221)	Carapeba	86	Oct/94	Demobilized
ESP in Deepwater well (RJS-477A)	Albacora Leste	1,109	June/98	In Operation
Deepest Subsea production manifold (diverless guidelineless technology)	Marlim	822	June/98	Installed
Very soft density foam pigs	Marlim	1,027	1996	In Use
Direct vertical connection (Manifold- DL2)	Albacora	620	Mar/96	In Operation
Subsea Tree	Marlim Sul	1,800	Aug/1997	In Operation
Flowlines and risers	Marlim Sul	1,709	Aug/1997	In Operation
Slender Well	Campos Basin	692	Jan/1998	Drilled

Table 5. Types of mooring systems tested in Campos basin

Mooring leg	Year	WD, m	Platform	Field
Wire rope	1977	109	SEDCO-135D	Enchova
1st chain - wire rope - chain	1986	220	FPSO (P.P.Moraes)	Albacora
KEVLAR Aramid rope tests 1 million lb	1986/89	220	P-9	Corvina
Chain - wire rope - chain - 1st pre-laid (in platform)	1988/89	100	P-21	Trilha
Jacketed spiral strand (pre-laid)	1990	405	Monobuoy	Marlim
Polyester fibre rope - 400 t, catenary leg tests	1995/1997	220	P-9	Corvina
Polyester fibre rope 400 t, catenary leg tests	1995/1997	114	P-22	Moréia
Taut leg polyester w/ suction pile 700 t, 16 legs	1997	770	P-19	Marlim
Polyester catenary leg mooring	1997	1420	FPSO II	Marlim Sul
Deepest turret system	1997	840	P-34	Barracuda
Taut leg polyester with VLA	Apr/1998	530	P-27	Voador

Table 6 - Future drilling/production technologies to be implemented in Campos basin

Technologies	Field	W.D.. m	Date
Subsea multiphase flowmeter	Albacora	410	1998
Drilling in reservoirs with thin layers of sediments	Marlim Sul	1,130	1999
Subsea multiphase pumping systems	Marlim	660	1999
Steel catenary riser (P-18 semi)	Marlim	910	1998
Steel Catenary Riser (FPSO)	Campos Basin	1,000	2001
Tethered riser buoy (TRB)	Campos Basin	1,000	2000
Diverless Pipeline Repair System	Campos Basin	1,200	2000
Shared Actuator Manifold	Enchova Oeste	116	1999
Multilateral wells	Marlim Sul	1,500	1999
Extended reached wells (>4,000m)	Marlim Sul	1,200	1999
Drill Pipe Riser	Roncador	1856	1998
Subsea separation system (VASPS)	Campos Basin	430	1999/2000
Tension leg platform	Barracuda	815	2001
Spar buoy	Caratinga	1,000	2002
DICAS*	Bijupirá/Salema	675	2000
10" Flexible Riser	Roncador	1,500	1999
6" Flexible Flowline	Roncador	2,000	1998
Umbilicals	Roncador	2,000	1998
Deepest DP - FPSO	Roncador	1856	1998

*** Differentiated Compliance Anchoring System (DICAS)**