

2006 - Issue 2

Brazil oil & gas

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President Lula starts P50 production.
Photo: Steferson Faria

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EPRASHEED

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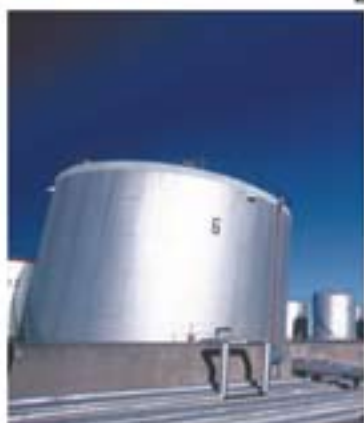
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Rio Oil & Gas Expo and Conference 2006

Brazilian Oil Self-Sufficiency: A new era of opportunities and challenges

OPMA



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Brazilian Oil self-sufficiency



President Lula wets his palms with Brazilian crude.
Photo: Steferson Faria, Petrobras.

A tribute to the myriad workers - Brazilian and visitors - that make production happen.

With an average production of 5,000 bopd exceeding demand, Petrobras and Brazil reached the historic milestone of oil self-sufficiency on April 21st 2006. By producing 1,795,000 bopd, April's production exceeded the previous highest production by 37,000 bopd.

Within 20 years, Brazil's dependence on oil imports for national demand has fallen from 80% to 0%. This places Brazil, as far as oil production is concerned in a select and fortunate position as it does not have to compete for crude on international markets.

In a ceremony on the P-50 Platform, both the Presidents of Brazil and Petrobras celebrated the event by highlighting the significance of self-sufficiency as a financial shield from oil-price volatility. Now, Petrobras must maintain a rigorous program of reserves replacement and production in order to sustain self-sufficiency.

Self-sufficiency shows just how far the Brazilian oilfield has come along since the market opened up in the late 90's. Majors come and go; but the real EP constant is Petrobras which has driven the industry to overcome the twin challenges of deepwaters and heavy oil.

This has been possible due to the myriad oilworkers from both the service companies and operators that make production targets happen. In this way, self-sufficiency is also a tribute to these people, Brazilian and visitors.

Our cover shot reflects this with a group photo of Petrobras and contractor workers in front of the P-50 platform.

Brazil Oil and Gas forms part of EPRasheed's signature series – a commitment to providing our readers with insight to handpicked key-global oil and gas markets.

It is satisfying to see issue 2 of Brazil Oil and Gas with such a strong editorial line-up. Our cover features are an extensive interview with Jose Sergio Gabrielli and a deepwater technology feature. The Petrobras President took time out during a recent visit to London and met with our international markets editor, Majid Rasheed.

The extended deepwater feature includes drilling, subsea and production analysis as well as interviews with PROCAP-3000 Manager Minami.

We also have a special interview with Marcelino Guedes, Pipelines and Terminals Director, Petrobras.

Looking ahead to future issues, there is an interview with Jose Luiz Marcusso, Executive Manager of the newly formed Santos Basin Business Unit-based in Sao Paulo. There is also an extended interview with Renato Bertani, President Petrobras USA. And of course our usual technology features.

Brazil Oil and Gas will be published quarterly, this is in accordance with the interest shown in the magazine by both Petrobras and other companies within the sector. Brazil Oil and Gas forms part of EPRasheed's signature series – a commitment to providing our readers with insight to handpicked key global oil and gas markets.

W Rasheed

Wajid Rasheed,
CEO and Founder,
Brazil Oil and Gas.



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2006

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PETROBRAS PRESIDENT INTERVIEW

During Brazil's recent state visit to the UK, Petrobras President, Jose Sergio Gabrielli, gave a private presentation to Financial Analysts at Deutsche Bank, London.

According to Deutsche's Head of Latin America Market Equities – Kerim Derhalli – Petrobras is one of the most exciting investors in the oil and gas sector and one of the leading lights in the sector. Following the presentation, Brazil Oil & Gas enjoyed Mr Gabrielli's company in an exclusive interview and gained a privileged insight into the world of Petrobras.

By Majid Rasheed (Editor, International Markets - Brazil Oil and Gas, London)

Self-Sufficiency

Q: Brazil Oil and Gas – Brazil and Petrobras have reached an historic milestone, what does self-sufficiency represent?

A: Jose Sergio Gabrielli – “First of all, self-sufficiency means we can provide the necessary amount (of oil) for the consumption of oil products in Brazil. Second, over a long-term view, it allows the possibility of growth of production, and management of reserves, because, as you know, oil is a long-term business, not short term. Third, is

the economic benefit, so that international price fluctuations do not affect the Brazilian domestic market. This is very important for us.”

Next decade

Q: Brazil Oil and Gas – Petrobras has evolved immensely over the last 10 years from state ownership to market privatisation. What does the next decade hold for the company?

A: Jose Sergio Gabrielli – “Up to now we have been focusing on production,

in the next few years we are going to increase investment and focus on exploratory activities. We have some very large national Projects planned for each consecutive year until 2010, and the following projects are now in their final stages: Albacora Leste, Jubarte, Piranema, Manati, Peroa-Cangoa, and Golfinho. Petrobras will also become more involved with the Bio-Diesel Programme. Not from an agricultural point of view ie buying land, but concentrating on the refining, production and exportation of Bio-Diesel.

Investment Strategy

Q: Brazil Oil and Gas – What is Petrobras business investment strategy?

A: Jose Sergio Gabrielli – Petrobras will be investing considerably in key strategic areas of its business, including international activities, and a total of US\$ 56.4 billion has been set for the 2006 to 2010 period. A few of Petrobras' future strategies are that we have an Investment Plan for the 2006-10 period which will see US\$ 56.4 billion invested. (See Investment Box Below)

E & P

Q: Brazil Oil and Gas – What are the acquisition/major E and P fronts for Petrobras?

A: Jose Sergio Gabrielli – “There have been no company acquisitions of late. However, our global activities are continuing to expand. Petrobras won a bid to explore and produce in Turkey and recently acquired 2 blocks for exploration there. Since establishing a foothold in China, with the May 2004 inauguration of its office in Beijing, Petrobras has been broadening its map of international activities through agreements and signed contracts in seven countries, across three different continents. The scenario looks promising off the Northwest coast of Libya, in the Mediterranean Sea, while new fronts are being opened up in the American sector of

the Gulf of Mexico, off the Tanzanian coast, in Colombian waters in the Caribbean, in the Persian Gulf and even in the interior of neighbouring country Uruguay. We have increased our production significantly, and Domestic production will grow at an average of 6.4% per year, from 1,684 boed in 2005 to 2,300boed in 2010. From 2006, light oil production from new projects will surpass 150,000 bpd and crude oil exports will reach 522,000 bpd.

From 2002 to 2005, there has been a 12% increase in production. We have now seen the P-50 – Albacora Leste (cap. 180,000 bpd) platform start production and later this year further production is slated for P-34 – Jubarte (cap. 60,000 bpd), FPSO Capixaba – Golfinho (cap. 100,000 bpd) and the SSP 300 – Piranema (cap. 20,000 bpd).

New finds

Q: Brazil Oil and Gas – What have been the new finds booked?

A: Jose Sergio Gabrielli – “We announced a new find in the Campos Basin a few months ago. It is in a deeper area than before, and although it is not large it is a significant discovery nevertheless. We are now in a commercialisation stage of different fields on a continuous base. Last year our reserve replacement ratio was more than 1 barrel per barrel used in our production.”

Reserves

Q: Brazil Oil and Gas – What is Petrobras' reserves to production ratio?

A: Jose Sergio Gabrielli – “We have a fairly stable reserve to production ratio. The Reserve to Production ratio is 19 years, and we want to keep it much more beyond 2010, to 15 years”

Lifting Cost

Q: Brazil Oil and Gas – What is the average Lifting Cost for Oil & NGL?

A: Jose Sergio Gabrielli – In 2005 the lifting cost was US\$ 5.73 against US\$ 4.28 in 2004, an increase of 34%. In Reais, this same cost was R\$ 13,83 against R\$ 12,30 in 2004, representing a 12% increase. Lifting cost increased in 2005 due to the appreciation in the Brazilian Real against the Dollar, higher chartering fees for rigs linked to increases in the international price of oil, higher expenses for transportation, underwater operations, restoration and maintenance, and chemicals used to unlock and eliminate toxic gases and increased salaries and benefits resulting from the collective labor agreements for 2004/2005 and 2005/2006.

Platforms

Q: Brazil Oil and Gas – What plans are there for new platforms/installations?

A: Jose Sergio Gabrielli – “We have several extensive projects coming along in 06, 07, 08 09, and 2010. Also, P-53 and P-54 are currently under bidding and we have started the bidding process for P-55 and P-57.”

Gas

Q: Brazil Oil and Gas – What part does Gas play in the company's plans?

A: Jose Sergio Gabrielli – “Gas plays a definitive part in our plans. For the first time, we have a very strategic plan for development of non-associated gas, now going to start producing a large volume of non associated gas from the Santos Basin, which was the first major

Petrobras investment

E&P - USD 34.1Billion (60%), Downstream - USD 11.4B (20%), G&E - USD 6.7B (12%), Petrochemicals - 2.1B (4%), Distribution - 1.0B (2%), Corporate - 1.1B (2%)

Expected Investments in 2006 - US\$ 15.4 billion (R\$38.5)

E&P 49%, Downstream 13%, G&E 17%, Distribution 2%, International 16%, Corporate 3%

Downstream

US\$12.9 Billion Refining / Pipelines, Terminals & Transport / Ship Transport / Petrochemical

US\$8 Billion in refining Diesel & Gasoline Quality / Extension / Maintenance & HSE / Conversion [using R\$2,50 per USD]

PETROBRAS PRESIDENT INTERVIEW

discovery for natural gas. As you probably know, the first major discovery for oil was the Campos Basin in Rio, which holds 85% of reserves. The three major areas are located thus – Campos – Rio, Santos – South of Brazil, Espirito Santos – in North. These locations across Brazil mean we have a wider area for production.”

R & D

Q: Brazil Oil and Gas – During the time when many IOC cut their R&D functions to reduce costs, Petrobras invested more in its R&D facilities and pioneered aspects of deepwater and heavy oil production. What are the future plans for R&D?

A: Jose Sergio Gabrielli – “We believe we are at the leading edge of offshore deep water production, and we want

to maintain this position. We are investing considerably in this area in order to ensure we secure our position at the forefront of this area. One of the main plans, and strengths, of Petrobras is continual investment. Particularly so in R&D and the Brazilian Labour force that we have: Training, Research and Development, and long term career development & opportunities, are all very important for Petrobras.”

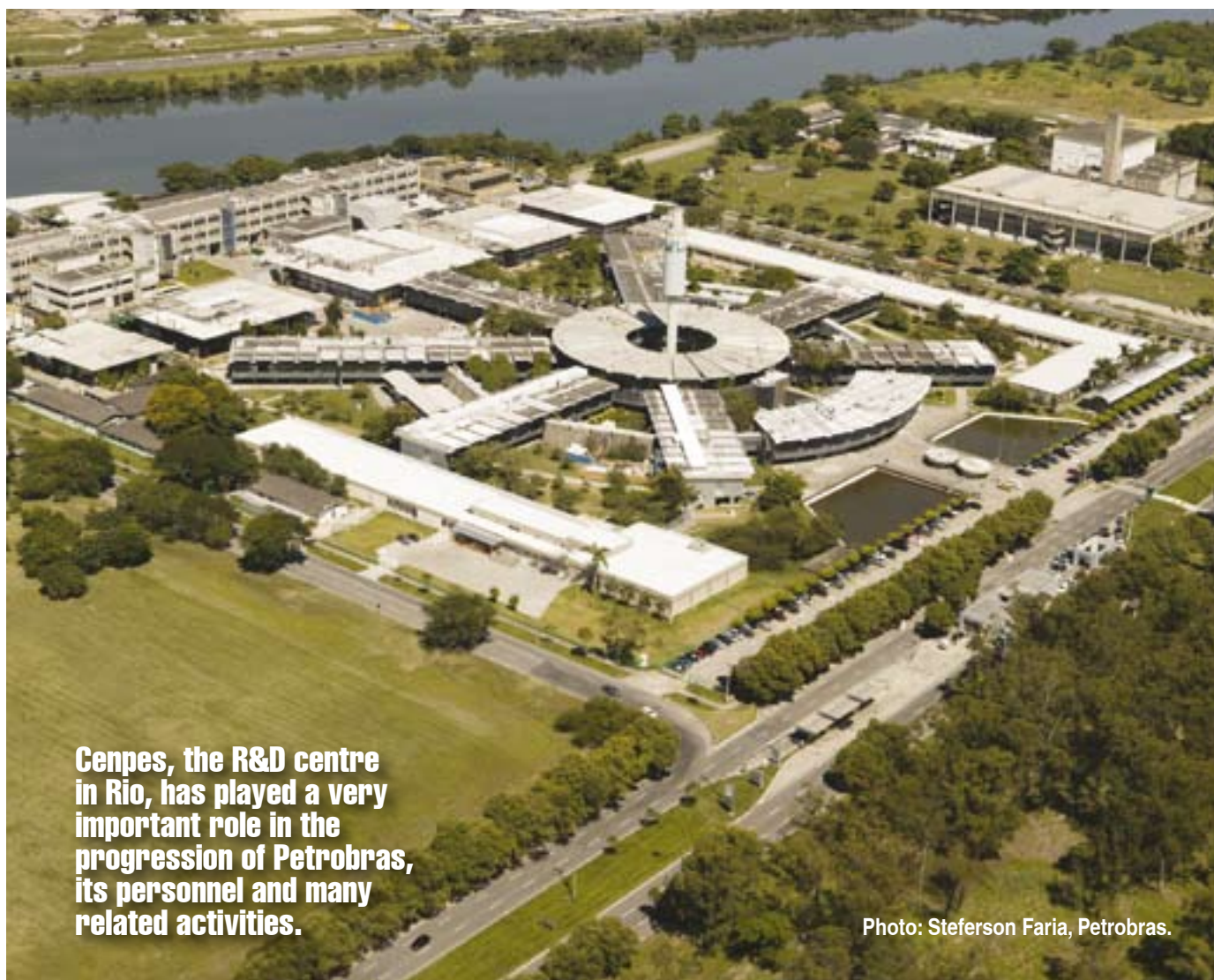
Q: Brazil Oil and Gas – Do you see Petrobras technology as a competitive advantage over IOC when dealing with potential foreign partnerships ie when bidding or negotiating for new acreage?

A: Jose Sergio Gabrielli – “Yes, I think in some countries it is advantageous, however in other countries the bid pro-

cess is more price oriented not technology oriented. So, in some countries to have good technology is beneficial, but not in all countries.

Q: Brazil Oil and Gas – What is the role of Cenpes, the R&D Centre in Rio?

A: Jose Sergio Gabrielli – Cenpes has been an important economic influence, helping the country’s balance of payments, for over 30 years. It has consistently achieved results with foreign reserves regarding technical assistance, purchasing designs and paying royalties. Cenpes also plays an important role in using raw materials, equipment and material manufactured in Brazil, and providing a genuine incentive for Brazilian manufacturers and companies to provide technical consulting services.



Cenpes, the R&D centre in Rio, has played a very important role in the progression of Petrobras, its personnel and many related activities.

Photo: Steferson Faria, Petrobras.

Downstream Strategies

- Domestic oil production will exceed throughput
- In 2010 oil products sales will be equal to throughput
- Increase of the domestic oil participation in throughput, reaching 91% in 2010

Cenpes coordinates three strategic projects, which are among the technological priorities of Petrobras: Technological Innovation and Advanced Development in Deep and Ultra-deep Waters, the Advanced Oil Recovery and the Strategic Refining Technologies Development. Another outstanding technological program run by Cenpes is the Offshore Technology Program, to upgrade offshore exploration, drilling and production operations. Cenpes also undertakes projects in partnership with other oil corporations and research and development centers overseas.

People

Q: Brazil Oil and Gas – What is the secret to Petrobras' success?

A: Jose Sergio Gabrielli – “People most definitely, as well as necessity, technology, and successful management. There are also three significant areas, which are not secret, but they are the main driving forces for Petrobras.

First, the commitment to the domestic market; in the beginning Petrobras had the responsibility to provide Brazil with oil products. Second, we have set targets that we have to meet, and in order to do that we consistently invest. Petrobras has always been committed to creating employment opportunities. There will be 10,000 new workers brought in from 2006 – 2008, across all our areas and departments. We have a very intense training system, and we have a very dedicated, motivated labour force. It's amazing! If you visit our R&D centre or go to our sites you can see that the

vast majority of personnel are Brazilian, trained by Petrobras.

The third thing is to remain adaptable and keep a very flexible adjustment to the conditions of the market. Petrobras really tracks the market, and different phases of the oil market in the world and in Brazil."

Training

Q: Brazil Oil and Gas – What training programs does Petrobras offer and what investments are being made?

A: Jose Sergio Gabrielli – “Although we have Petrobras Universities, we also



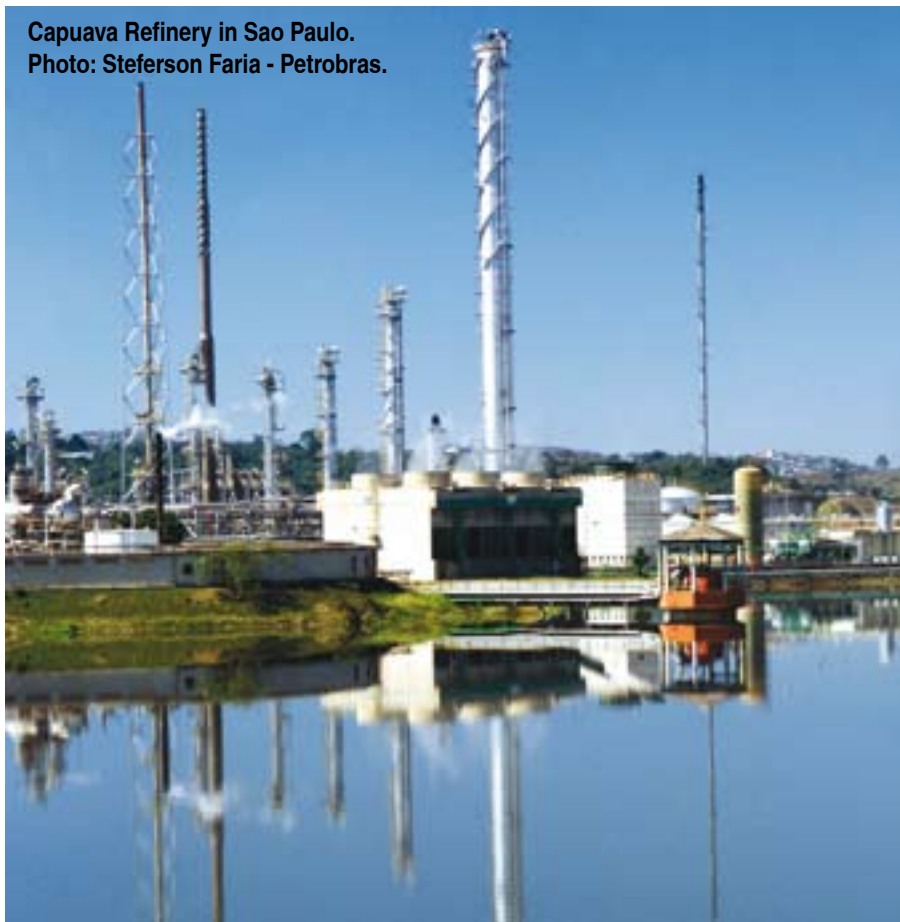
train people in the best place – where we can find the work, providing intensive training programmes for our dedicated and motivated labour force. Training, R&D, long-term career development and opportunities are all very important for Petrobras.”

The two Petrobras Universities are in Salvador and Rio. Cenpes, the R&D centre in Rio, has played a very important role in the progression of Petrobras, its personnel and many related activities.

Petrobras is investing in each and every area of personnel, focusing especially on Training and R&D"

PETROBRAS PRESIDENT INTERVIEW

Capuava Refinery in Sao Paulo.
Photo: Steferson Faria - Petrobras.



Refining

Q: Brazil Oil and Gas – What plans does the company have for new refineries?

A: Jose Sergio Gabrielli – Petrobras has approved the purchase of a refinery in Texas, continuing its expansion in the US.

Refineries

Q: Brazil Oil and Gas – What are Petrobras total number of refineries?

A: Jose Sergio Gabrielli – The refineries are the following:

1. Landulpho Alves Refinery (Rlam) – Mataripe, Bahia /
2. Presidente Bernardes Refinery (RPBC) – Cubatao, Sao Paulo /
3. Duque de Caxias Refinery (Reduc) – Campos Eliseos, Rio de Janeiro /
4. Gabriel Passos Refinery (Regap) – Betim, Minas Gerais /
5. Alberto Pasqualini Refinery (Refap) – Canaas, Rio Grande do Sol /
6. Paulinia Refinery (Replan) – Paulinia, Sao Paulo /

7. Manaus Refinery (Reman) – Manaus, Amazonas /

8. Capuava Refinery (Recap) – Maua, Sao Paulo /

9. Presidente Getulio Vargas Refinery (Repar) – Araucaria, Parana /

10. Henrique Lage Refinery (Revap) – Sao Jose dos Campos, Sao Paulo /

11. Asphalt plant in Fortaleza (Asfor) – Fortaleza, Ceara Petrobras industrial plants also include two nitrogen fertilizer plants (Fafen) in Laranjeiras (Sergipe) and Camacari (Bahia).

12 US, Texas, Pasadena refinery.

Q: Brazil Oil and Gas – What Awards has Petrobras received recently?

A: Jose Sergio Gabrielli – “Global Transparency Award 2005, and OTC Award for two consecutive years. Our Director is going to give the keynote address at the OTC Award. As well as receiving prestigious Awards from within the Oil & Gas sector, Petrobras has also been recognised for its on-going commitment to social programmes. It secured 2nd

place ranking in the ‘Young Citizenship Network Itaú-Unicef Award’.

Petrobras competed with 1,682 other registered initiatives of Brazil, and won the award for, among other things:

- *Displaying commitment with the development of children and teenagers;*
- *Stimulating learning in public schools;*
- *Respecting diversity and the promotion of equality between youngsters;*
- *Developing projects and with the community and schools.*

Q: Brazil Oil and Gas – Does Petrobras produce any other energy fuels?

A: Jose Sergio Gabrielli – Yes, In addition to helping to distribute anhydrous alcohol, Petrobras also produces shale oil, similar to petroleum. Brazil has the second largest shale reserve in the world.

Environmental & Social Responsibility

Q: Brazil Oil and Gas – Can you discuss Petrobras’ major social responsibility projects?

A: Jose Sergio Gabrielli – “Yes, we are the largest contributors to culture in Brazil! We have a large number of social projects. There are 2 different programmes focusing on social responsibility, Petrobras Social & Fome Zero (Zero Hunger). Petrobras also has a very large environmental programme. Our main focus over the last 2 years was the Water Management programme, which we continue to finance.

Petrobras also sponsors the following environmental education projects:

Brigada Mirim Ecológica (Children’s Ecological Brigade) in Angra dos Reis (Rio de Janeiro state), Cetaceans, on the Rio de Janeiro state coast Jubarte Whale, in the Abrolhos archipelago in Bahia.

The company also supports Ibama projects, such as the preservation of Monte Pascoal National Park and the Tamar project that protects sea turtles.

Petrobras is considered one of the most important sponsors in Brazil, and also

supports cultural, sports and community projects.

Petrobras also supports 'The Young Citizenship Network', promoted by Associação Imagem Comunitária (AIC).

Q: Brazil Oil and Gas – Apart from the regulatory framework what does Petrobras do to control the effect of its activities on the environment?

A: Jose Sergio Gabrielli – "Petrobras has a preventative approach regarding the environment. We recognise it can be a risky business, and we place the utmost importance on environmental responsibility to avoid the possibility of accidents"

"Petrobras has invested in many areas including Hardware ie pipelines and the latest equipment, but most important thing is to have a preventative approach. We have to always keep in mind that we are dealing with a very risky business, and the potential to have an environmental incident, and we have to avoid the possibility of any accidents at all costs.

"Over the last four years, after 2001, we have invested in environmental prevention. The environmental Programme of Excellence helps manage our systems to minimise leakage and the impact on our environment. We have a very good track record, in the last 4 years we have reduced dramatically our leakage."

Brazil Oil & Gas has always been impressed by Petrobras' transparency, the way it handles its business and continually invests to help reduce the environmental effects of its business while building local infrastructure. This goes back to 1999 when Wajid Rasheed first started working with Petrobras. Brazil Oil and Gas would like to acknowledge Anamaria Rossi for her help with this editorial feature.

Gabrielli on oil self-sufficiency

"First of all, self-sufficiency means we can provide the necessary amount (of oil) for the consumption of oil products in Brazil.

Second, over a long-term view, it allows the possibility of growth of production, and management of reserves, because, as you know, oil is a long-term business, not short term.



Third, is the economic benefit, so that international price fluctuations do not affect the Brazilian domestic market. This is very important for us."



PROCAP 3000

Kazuioishi Minami PROCAP 3,000 Coordinator spoke with Brazil Oil and Gas about Petrobras' ongoing technology commitment for deep and ultra-deepwaters.

By W. Rasheed

Q: Brazil Oil and Gas - What technologies would you highlight as being fundamental to maintaining self-sufficiency?

A: Kazuioishi Minami - Keeping Petrobras production above Brazilian long term demand will require business investments in exploration, new production development projects, and the proper operation of existing fields to halt their natural decline. Technology will be needed in all the three fronts. I am not covering technology related do Exploration because it is not my area of specialization.

For field development projects, an area that Procap-3000 has a strong influence on, I believe well construction technology, which allows large bore

size and long horizontal stretches, precisely placed in the reservoir, is a key to the success of reaching high throughput and good reservoir sweep. To do that, it is very important not only to have the technologies but also to have a well integrated technical team, composed of geologists, geoscientists, reservoir engineers and drilling experts, working together to design and execute the production and injection wells accurately. Drilling technology has advanced so much that today it is possible to drill 40,000 bpd producers and water injectors offshore Brazil, something unthinkable 15 to 20 years ago. Another technology that evolved significantly is the hull design and mooring for floating production units. The new hulls

and mooring are built to reduce movements, and thus, increase life span of risers, and to increase load capacity of the unit so that we can have larger processing plants and larger number of risers. The mooring technology we use today, based on polyester ropes and torpedo piles, is believed to support installation of floating units in water as deep as 3,000m.

For fields already in production, the key is to keep or increase throughput by using more efficient artificial lift and subsea boosting. For heavy oil and high water cut wells lifting the liquid stream becomes of paramount importance and these two technology are much better than gas lift from hydraulic performance. It will be important to develop technology to increase run life and decrease replacement costs.



The Procap-3000 comprises 17 systemic projects and 93 projects. We spent around USD 30 million in 2005 but we expect to increase this number by 30% in 2006.

A good portion of this amount will be directed to projects for well construction and subsea equipment development.

Petrobras overall R&D spending is increasing steadily.

2002 - US\$ 147 million

2003 - US\$ 201 million

2004 - US\$ 247 million

2005 - US\$ 399 million

2006 - approx. US\$ 500 million (budget)

Petrobras has two major initiatives for mature fields, the first one being the Enhanced Oil Recovery Technological Program, called PRAVAP, and the corporate RECAGE program to seek highest recovery factor from fields in advanced recovery stages. The first one is technology oriented, run from CENPES and involving all E&P business units, and the second is business oriented, run from headquarters, to implement necessary investments to keep the mature field alive as long as possible.

Q: Brazil Oil and Gas – What are current PROCAP 3000 Projects?

A: Kazuioishi Minami - The systemic projects are:

1. Wellbore Safety
2. Drilling Equipment

3. Deep Horizon Drilling
 4. Wellbore Stability
 5. Well completion equipment
 6. Deep and Ultra-deep Water Flow Assurance
 7. Artificial Lift and Subsea Boosting in deep waters
 8. Flexible Riser Systems
 9. Rigid Risers Systems
 10. Alternate Risers Systems
 11. Subsea Equipments for 3.000m Water Depth
 12. Non-conventional Subsea Systems
 13. Dry Completion Units for Deep and Ultra-deep waters
 14. Ultra-deep water mooring
 15. Ultra-deep water hull concepts
 16. Meteocean, geological and geotechnical Data Acquisition
- There is also the follow up on the Deepstar Phase VII project.*

Q: Brazil Oil and Gas – What are the new projects?

A: Kazuioishi Minami - These are related to mid-term E&P domestic and international scenarios. For example, in Flow Assurance, we are increasing our efforts towards gas and condensates in deep waters, wax and hydrate controls for light crudes in ultra-deepwater scenario. In the drilling area, we have added projects for hard formation drilling and drilling sub-salt. I can also say that to overcome overpriced rig costs, we are conducting several projects such as light interventions techniques, cable installed subsea equipment, and horizontal subsea trees for electrical submersible pumps. We are also looking at each project for the possible Gulf of Mexico scenario application, making the necessary adjustments.

Q: Brazil Oil and Gas – How will PROCAP3000 technologies be applied to new Santos Basin?

A: Kazuioishi Minami - Developing Santos will be a huge task to be carried out by the newly formed Petrobras Santos Basin Business Unit. The basin is relatively untouched with fields similar to those of the Campos Basin, such

as the heavy oil reservoirs in ultra-deep waters, but also with several fields very much different.

We are going to be developing gas and condensate fields such as Mexilhão, using multiphase flow in large diameter and long pipeline to shore (34in, 140km long). Since this trunk pipeline is going to operate at low flowrates for a couple of years, a lot of issues related to pigging and slug control will have to be dealt with. Another concern is the subsea development of Mexilhão, comprised of long tie backs to the host platform in shallow waters, which will require special care concerning MEG (monoethylene-glycol) injection to the subsea wells, for hydrate prevention, and its recycling at the host plant.

We have already discovered large volumes of heavy to extra-heavy crude in ultra-deep waters in Santos Basin. Therefore, in addition to the Procap-3000 projects, we are counting on technology being developed by the Propes - Offshore Heavy Oil Technological Program, similar to Procap, started three years ago.

Finally, we have great potential for light crudes from very deep reservoirs, below the salt layer, 6000m or deeper from sea level. They are very tight reservoirs that will require special wells, long horizontals, fractured or multi-lateral. The Procap-3000 systemic project Deep Horizon Drilling is very important for that matter. At the end of 2005 we have also included one systemic project under the Pravap (Enhanced Oil Recovery Technological Program) dedicated to Low Permeability Carbonate Reservoirs of Santos Basin.

In summary, Santos Basin will pose a lot of challenges which will require results from Procap-3000, Propes and Pravap to be successful.

Editor's note:

Kazuioishi Minami was recently named by Petrobras as the Drilling Manager for the Santos Basin Development. His successor at Procap 3000 is Mauricio Werneck.

VETCO GRAY

Slender Well Economical Wellhead System for Ultra Deep Water



By Carlos Eduardo M. Sequeira and Bruno Schauerte - Vetco Gray Brasil

This article is based on the original developmental work conducted as part of a technological agreement with Petrobras to design and test a 13" Subsea Slender Wellhead System for drilling wells in deep water. It describes the technological challenge and the solution adopted for each of the principal components during the design phase and how interfaces were defined. It also explains the various stages of the prototype test program and outlines the installation of the first system in the field. The article also describes how the Slender Wellhead System fits into a typical Slender Drilling System.

"The Slender Wellhead System permits the use of smaller or older generation drilling rigs (fitted with Slender Drilling System) in deeper waters, reducing the overall cost of the drilling operation. In today's tight rig market it opens up new options".

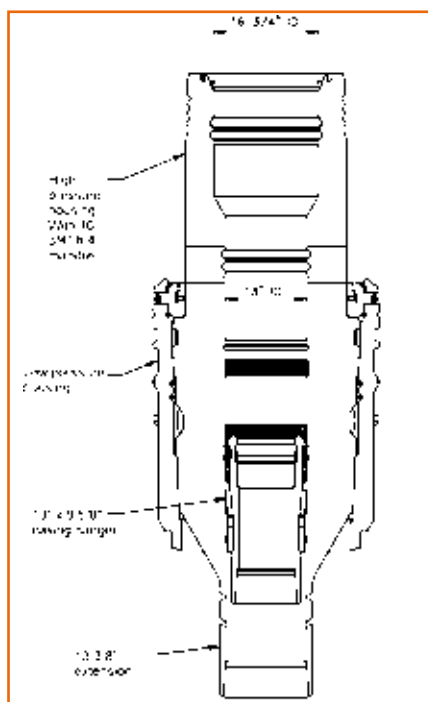
Slender Wellhead Technology Challenge

Slender Wellhead technology is based on the field proven 16-3/4" and 18-3/4" MS-700 system.

Because of the reduced diameter compared to an 18-3/4" or 16-3/4" system, various design challenges were identified and required innovative solutions for both equipment and tools.

Critical areas identified included the casing hanger load shoulder, the casing hanger neck, the MS-1 and MSE seal elements and the wear bushing lockdown mechanism.

To date, Vetco Gray has delivered 40 Slender Systems and installed 12 systems for Petrobras.



State-of-the-art engineering technology and computer modeling was used to design the system.

Slender Wellhead System Overview

- Slender Well configuration: 30" x 13-3/8" x 9-5/8" for 10,000 psi

MWP. Figure 1 exhibits the wellhead system stack-up.

- The low pressure wellhead housing is prepared for attaching a 30" conductor string to provide the structural integrity of the well.

The housing provides a dual socket, preloaded, fatigue-resistant connection between the low pressure housing and the high pressure housing with a capacity of 2.4MM ft.-lbs. identical to the 16-3/4" and 18-3/4" Petrobras system.

- The high pressure housing is provided with a 16-3/4" external H-4 mandrel profile and a standard 16-3/4" VX seal preparation to interface with existing 16-3/4" BOP equipment.

The 16-3/4" housing ID has been maintained on the upper end of the housing with a profile to permit the use of an existing 16-3/4" cam-actuated running tool, reducing to a 13" ID to set the casing hanger. Two seal bands of parallel "wickers" are provided to set, lock and seal up to two casing hangers and seal assemblies. The internal diameter allows the passage of a 12-1/4" bit with bore protector in place.

The lower end of the high pressure housing is provided with an extension for the 13-3/8" casing string.

- The system is rated to 1,530,000 pounds axial load, which corresponds to 400,000 pounds of casing weight plus a 10,000 psi pressure end load.

High Pressure Housing

The internal load shoulder to land off the primary casing hanger was

recognized as extremely critical to the overall integrity of the system, due to the high bearing load combined with the inherent diameter restrictions of a 13" system. This load shoulder interface therefore was extensively analyzed and verified with FEA.

The load shoulder provides the contact area in the wellhead housing for mating of the casing hanger load shoulder, achieving a system capacity of 1,530,000 pounds without the use of a separate load insert ring.

A specific lock-down groove is provided below the load shoulder for engagement of the spring loaded pins on the casing hanger.

Casing Hanger

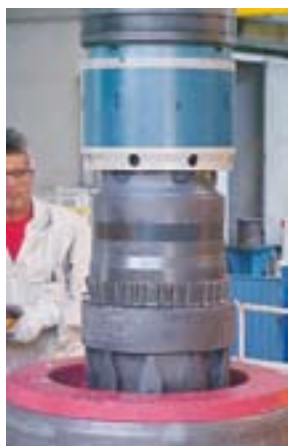
The casing hanger was optimized using FEA to maximize the radial and compressive load capacity of the hanger neck for the interface with the Universal Running Tool (PADPRT) and the MS-1 seal element.

The load shoulder is provided with a continuous 360 deg. contact area to maximize the load capacity of the system with generous flow-by area of 9.6 sq. inch and for a maximum particle size of 0.7 inch.

Spring loaded pins are provided to engage in the lock-down groove on the high pressure housing to confirm correct positioning of the hanger.

A generous debris collection area is provided below the metal seal element.

The hanger internal drift diameter of 8-3/4" allows passage of an 8-1/2" drill bit.



13" MS-1 Seal Assembly

The 13" MS-1 metal seal is designed to meet the rigors of offshore drilling.

It consists of an energizing ring between the metal "U" seal, expanding it into the "wicker" profiles of the wellhead housing and the casing hanger.

This 13" seal is a downsized version of the field proven 18-3/4" or 16-3/4" metal-to-metal MS-1 seal and fits into the reduced annular space between the hanger neck and the wellhead housing.

Extensive FEA analysis was performed during the design phase to ensure the structural integrity of the seal element and define reduced setting loads to an acceptable range to ensure maximum seal performance.



Bridging Seal

A bridging seal may be set on top of the primary casing hanger in the event of a MS-1/ MSE seal failure.

It is provided with a similar neck to the casing hanger in order to interface with the PADPRT and the MS-1/MSE seal element. The lower end provides metal-to-metal sealing against the ID of the casing hanger.

13" Emergency Seal Assembly (MSE)

The 13" MSE seal is designed to fit into the same space of the MS-1 seal element and is used in the event of drilling damage to the sealing surface in the wellhead housing.

The seal is provided with a soft inlay metal which flows into the wicker profile filling the original profile and the score damage. This 13" emergency seal is based on the field proven 18-3/4" or 16-3/4" MS-E seals.

13" Wear Bushing

Used to protect the sealing areas in the wellhead housing from damage during drilling operations.

Different to the conventional system, which uses a resilient lock-down ring, it is provided with a metal locking mechanism to secure the bushing in the casing hanger.

13" Universal Running Tool (PADPRT)

The single trip pressure assist drill pipe running tool (PADPRT) is a scaled down version of the 18-3/4" and 16-3/4" tools with similar features.

The tool is used to run and cement the hanger, set and test the MS-1 seal assembly. It is designed to permit energizing of the seal ring only after it has been positioned in the correct location.

Due to the reduced diameter and to maximize the tool capacity, extensive FEA was performed on all the critical load bearing components.

13" Isolation Test Tool (ITT)

The isolation test tool is a scaled down version of the 16-3/4" Petrobras tool.

It permits testing of BOP to 10,000psi only after it has been positioned correctly in the wellhead housing. Testing can be performed with or without bore protector or casing hanger in place.

13" Wear Bushing Running/Retrieving Tool (WBRRT)

Tool is designed to install and retrieve the bore protector and the wear bushing. Permits testing of BOP to 10,000 psi.

13" Seal Retrieval Tool (SRT)

The tool is designed to retrieve the MS-1 or MSE seal element in the event of leakage.

Prototype Qualification Test Program

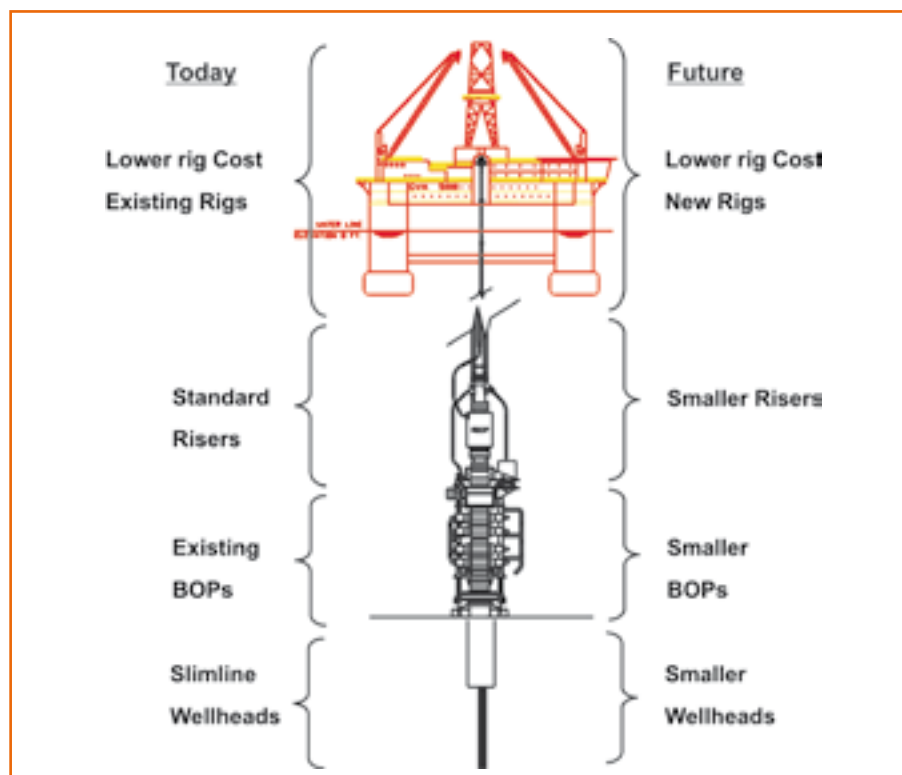
The purpose of this test program was to confirm that the criteria established in the design specification was met in accordance with the applicable standards and specification. The qualification consisted of integrity and functional testing followed by a complete system stack-up.

of 32 deg F (0 deg C) using the same test fixture of the pressure test.

Proof Pressure Test:

Consist of one pressure cycle to 1.5 times the maximum working pressure mainly to prove structural integrity of the seal element.

- Casing Hanger Test
- Wear Bushing Retrieval Test
- Isolation Test Tool Test (ITT)
- Universal Running Tool Test (PADPRT)
- Seal Retrieval Tool Test (SRT)
- System Stack-Up Test



Metal Seal Test

The first test was a pressure test to determine the metal seal's ability to reliably seal gas from the top and the bottom. Testing from the top was conducted at field rated working pressure of 10,000 psi. This test was to insure the basic sealing criteria and was conducted in a specifically designed test fixture.

Temperature Test

Consisted of several temperature cycles with an upper extreme of 250 deg F (121 deg. C) and a lower limit

Field Installation

The first system consisting of a 30" housing and a 16-3/4" x 13" high pressure housing was installed on a production well in approximately 1400m (4600 ft) of water depth in the Campos Basin, in the first quarter of 2004.

Subsequently, a completion base (Tubing Spool) was installed on the high pressure housing. The final drilling phase for the 9-5/8" casing through this completion base has yet to be performed.

Slender Drilling System Overview

The new 13" Slender Wellhead System now allows the entire drilling system to be scaled down, reducing cost, weight and running times.

The Slender Wellhead System described fits with a 16-3/4" H4 connector/ BOP stack and 18-5/8" riser system, rather than an 18-3/4" BOP stack and 21" riser system.

Work has already been done to develop, test and deliver 16" drilling riser systems (Figure 5), which can be used in conjunction with either 16-3/4" BOP stack or 13-5/8" BOP stack to further "slim down" the overall Slender Drilling System.

Conclusions

The results of the successful laboratory test program and the partial installation of the first system does indicate that the Slender Wellhead technology is a viable alternative for drilling in deep water.

The main advantages of the system are

- Permits the use of existing 16-3/4" BOP equipment.
- Allows the use of a smaller diameter drilling riser.
- Reliable metal-to-metal sealing system based on field proven technology.
- Reduced overall well cost.
- Lower rig costs and use of older rigs.

Acknowledgement

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The Mexilhao field is the largest undeveloped gas accumulation in the Brazilian Continental Shelf, located in Santos Basin, in water depths ranging from 320 to 500 m. The field is situated approximately 137 km from the coastline (see Figure below) and reserves are estimated to be 90 billion Sm³ of gas and 6 million m³ of oil range. The reservoir is a sandstone and the original pressure is 9,774 psi (67.4 MPa) at 4,656-m of vertical depth.

Mexilhao's development is based on the construction of seven subsea wells (6 horizontals and 1 vertical) connected to a subsea manifold that will be responsible for exporting the production to a fixed platform located in 170 m of water depth, at about 20 km from the field. The planned start of the production is scheduled for 2008, reaching the production peak of 10

million Sm³ of gas per day in 2009. Details of a typical horizontal well in the Mexilhao field are presented in a figure overleaf.

As Production flow rates of the horizontal wells may be higher than 1 million Sm³ of gas per day, drilling and production activities on the Mexilhão field are likely to encounter considerable safety challenges.

A comprehensive HAZOP, including risk assessment, was performed to minimize risk. Most of the practical implications of a blowout intervention project are addressed, including intervention strategy, pumping requirements, and mud storage. The paper also presents details of the blowout rate calculations and relief well kill requirements. It is worth mentioning that the drilling of a relief well would involve high pumping rates and challenging requirements.

Managing Blowout Risk

The uncontrolled production of hydrocarbons from a well, i.e. a blowout, is one of the most serious accidents that can happen while exploring or developing oil and gas fields. It represents a significant hazard to human life, material assets, and the environment. Blowouts are recognized as one of the main contributors to the total risk picture on the oil and gas offshore industry.

A study of historical data from the Gulf of Mexico and the North Sea confirms that, regarding loss of material assets, blowouts are, indeed, major contributors to the total offshore risk. In general, blowouts are very costly incidents. The installations are severely damaged or totally lost and enormous time losses are typical. Often, wells are plugged, abandoned and reconstructed. This data analysis also observes that offshore blowouts cannot be considered major contributors to the personnel risks. Other aspects such as occupational accidents, helicopter transportation and vessel stability are considered more relevant. Further, concerning the damage of the environment, the great majority of oil that enters the sea is caused by accidents with tankers or industrial runoff.

More than twenty professionals from five different companies are engaged in the HAZOP assessment activities, comprising the following tasks: (1) introduction to the HAZOP methodology; (2) technical review of the proposed plans; (3) review of the main hazards identified; and (4) HAZOP of the key components.

The Field of Mexilhao and the Coast of the State of Sao Paulo.



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Technical review

The technical review of the proposed plans identifies more than a hundred operational scenarios, which are evaluated and prioritized based on the use of a criticality analysis (2) using a variant of the traditional risk priority number (RPN) method. This covers the probability of event occurrence, the severity of the consequences and the potential for timely prior detection of the event.

The identified operational scenarios are classified in accordance with three levels of criticality that are presented in Table I, leading to the following result: (1) Level I – 37; (2) Level II – 70; and (3) Level III – 4 scenarios.

The scenarios rated level III, which deserve special attention in terms of planning and execution, are the following: (1) geological fault, connecting the reservoir to a shallower formation, meaning that the reservoir is exposed while drilling the 12-1/4" hole section; (2) well control event while drilling the 8-1/2" pilot hole; (3) well control event while pulling the string out of the well, and (4) well control event while performing a formation test.

The level III rated scenarios are submitted to a careful revision in which fault trees are constructed for identifying minimal cut sets and quantifying probabilities. Despite not being a new method for analyzing critical events^{1,3}, it is worth to describe briefly the main elements in a fault tree. A fault tree is composed of a top event, the and gates, the or gates, the intermediate events and the basic events. The combination of the events in accordance with the tree structure determines whether or not the top event will occur.

An illustrative example of a fault tree explains where the well control event while performing a formation test. The fault tree is a logic representation that is not only useful for quantifying probabilities

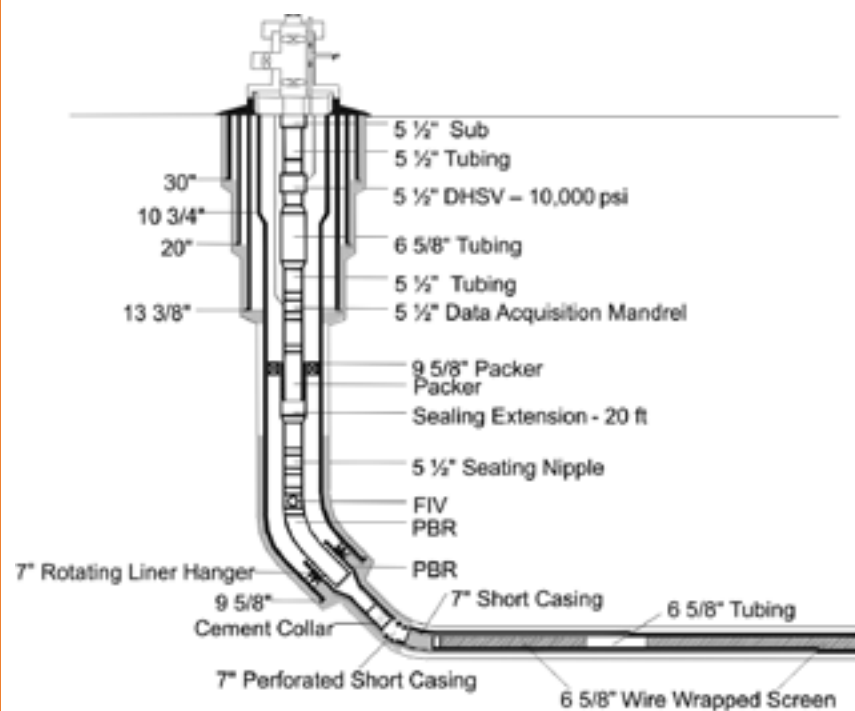
but also for producing a list of possible combinations of events that can result in the occurrence of the top event.

QRA of blowouts

QRA's of blowouts are traditionally based on historical data⁴. However, a common problem in QRA is that accident statistics are too general to be of significant value in a specific situation. Besides that, while dealing with well control events or kicks, the difficulties are even more relevant

extension of the Bayesian approach to population variability analysis, which involves the introduction of engineering judgment as an additional form of evidence used in the construction of population variability distributions. Consequently, as part of this quantification process, more than twenty experienced engineers, who are aware of the operations to be held in the Mexilhao field and experts in well control issues, are submitted to a consultation procedure.

A Typical Mexilhao Horizontal Well.



because reliable empirical data are rare. One usual procedure consists of making assumptions, which may be justified by experienced operational practice and engineering judgment. Anyway, in spite of paying special attention, the introduction of assumptions might affect the robustness of the results³.

Considering those difficulties, an innovative approach⁵ is introduced to combine the use of relevant empirical data with expert estimates and quantify the probabilities related to the basic events. This method is an

After constructing the distributions related to the basic events, it is possible to assess the probabilities of occurrence associated with the top events that are representing the level III rated scenarios. Subsequently, the probability of occurrence of a well control event is calculated based on the fault tree which stands for a kick control event while constructing a horizontal well in the Mexilhao field. Besides that, research also highlights the fact that the formation test scenario is the major contributor to a well control incident,



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meaning that special care must be taken regarding this operation. In other words, the probability of a well control event related to drilling is negligible compared to performing a formation test.

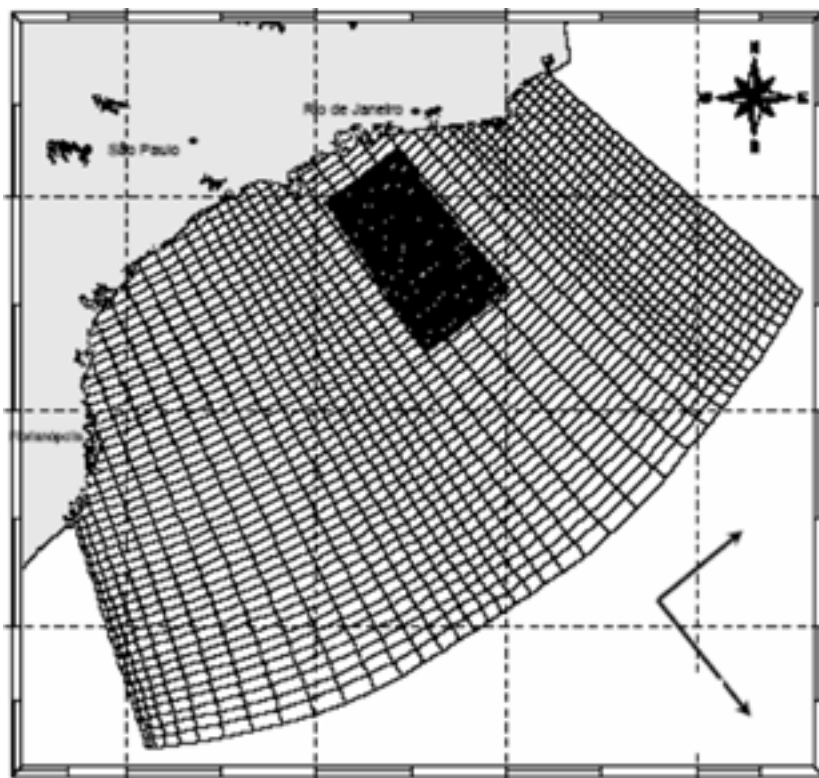
Further, results show a summary of the displacement results at the sea level. It is worth mentioning that the diameter of the bubble plume at surface corresponds to at about 50 m. Besides that, based on the results of the research show the best location for placing a rig to drill a relief well is at about 200 m from the wellhead of blowout well in terms of keeping a safe distance from the structure of the bubble plume.

Planning the Kill Operation

The majority of the well-known blowout control methods are limited in terms of working properly in deep water scenarios. The best options for killing a blowout well in deep or ultra-deep waters are centered on subsurface intervention techniques, requiring an effective flow link into the uncontrolled producer. However, as it is quite difficult to gain this straight access through the blowing well, the relief well technique is considered the best option for this particular scenario¹⁵. As a result, the planning activities for constructing horizontal wells in the field of Mexilhao include the design of a relief well. The relief well is planned to intersect and enter the blowing wellbore as close as possible to the producing zone.

Besides elaborating a preliminary plan for the construction of a relief well, it is necessary to study the hydraulics aspects associated with the killing technique involving the different well control scenarios previously identified by the HAZOP. Therefore, the OLGA14 computer program is used to calculate the transient multiphase flow that characterizes the killing process.

Horizontal view of the numerical grid.



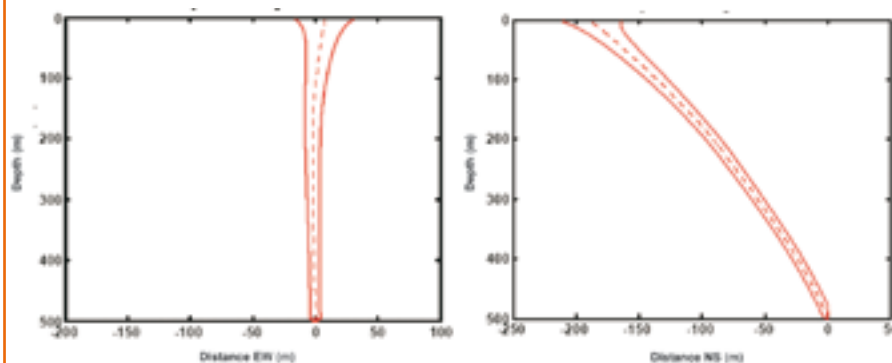
A complete set of transient multiphase simulations, involving the level III rated scenarios is performed. The multiphase calculation process starts simulating the blowout, which corresponds to the period from 0 and 5 hours in the graphics. According to Fig. 13, the well discharges 445 MM Scf/d (12.6 MM Sm³/d) of gas and 5,140 bbl/d (817 m³/d) of oil at the bottom of the ocean.

From 5 to 16 hours, seawater is

pumped down through the relief well and up the annulus of the blowing well with the injection rate of 80 bpm, but it is not enough. The blowing well does not stop the production, but the reservoir output is reduced.

Then, after this initial killing period, four distinct alternatives are used for stopping the production: (1) injection of 13.5 lbm/gal drilling fluid at the rate of 80 bpm; (2) injection

Evolution of the bubble plume.



of 14.3 lbm/gal drilling fluid at the rate of 76 bpm; (3) injection of 16.5 lbm/gal drilling fluid at the rate of 72 bpm; and (4) injection of seawater at the rate of 180 bpm. All those alternatives are effective in terms of stopping the blowing well.

Conclusions

A practical application of a methodology for elaborating a complete analysis of a blowout is presented through the illustrative example of Mexilhao, which is the largest undeveloped gas accumulation in Brazil. A comprehensive HAZOP is carried out leading to the identification of hundred and eleven operational scenarios, which are prioritized based on the level of criticality, resulting in four scenarios level III rated, which is the highest one.

A QRA process is performed to evaluate the risk of a blowout. It shows that the risk of having a blowout departing from a formation test operation is of the order of 3.33×10^{-4} , which is higher than the acceptance criterion (2.10×10^{-4}) defined by the Health & Safety Executive in Great Britain.

The influence of the sea currents on the bubble plume leads to the conclusion that the best location for placing a rig to drill a relief well is at about 200 m from the wellhead of the blowing well because it permits keeping a safe distance from the bubble plume.

The blowout resulted from a well control event while drilling, which is chosen based on the philosophy of worst case scenario, is used for sizing pumping capacity and mud storage. Computational calculations indicate that the best alternative for killing a blowing well consists of pumping heavy mud. Considering the injection of a 14.3 lbm/gal drilling fluid, 76 bpm of pumping capacity for a maximum pressure of 5,800 psi (40.0 MPa) is necessary for killing the blowing well with the use of a single relief well.

Acknowledgements

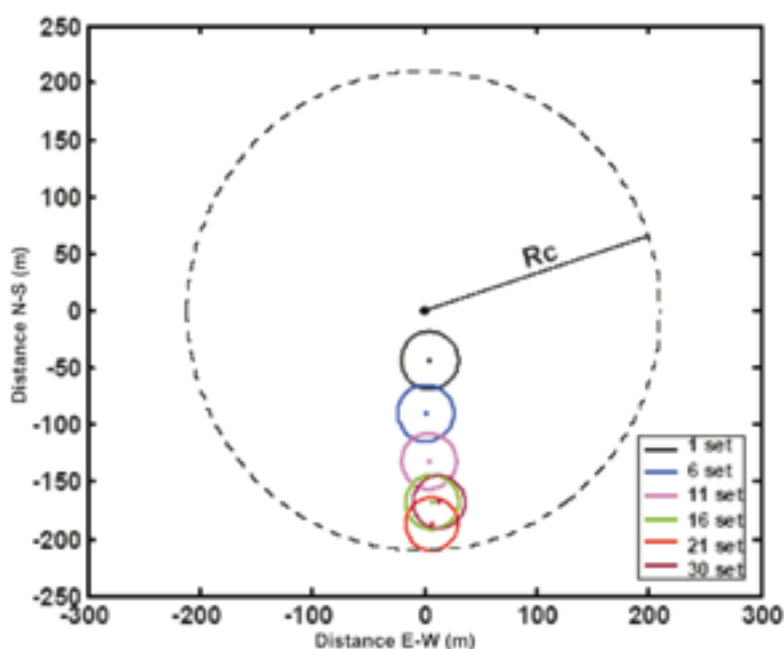
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Evolution of the bubble plume continued.



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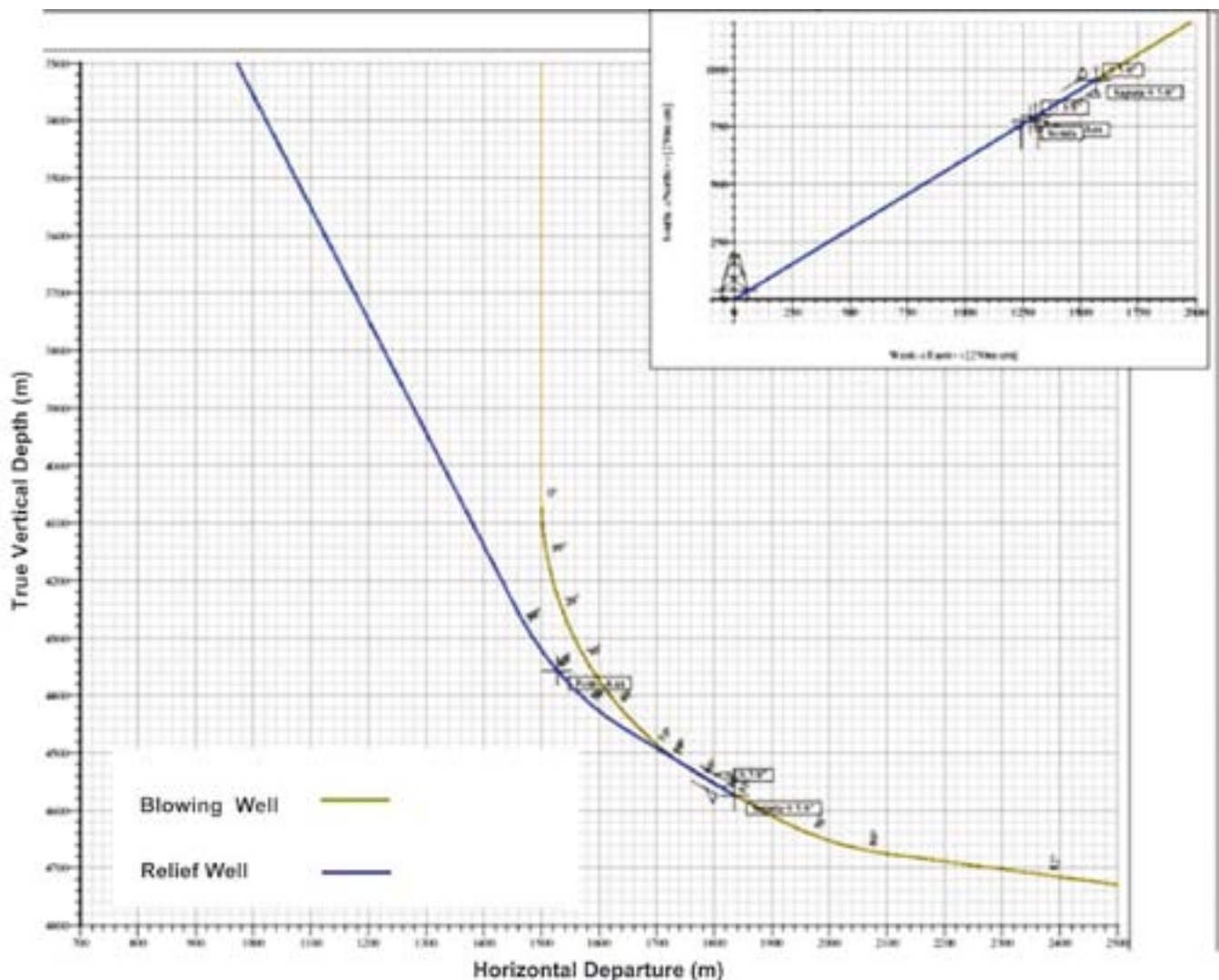
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SI Metric Conversion Factors

ft	x 3.048	E-01	= m
gal	x 3.785 412	E-03	= m ³
bbl	x 1.589 873	E-01	= m ³
in	x 2.54	E+00	= cm
lbm	x 4.535 924	E-01	= kg
psi	x 6.894 757	E+00	= kPa

Bottom hole pressure while killing the well.



Petrobras Sets Record Casing Run in Extended Reach Well

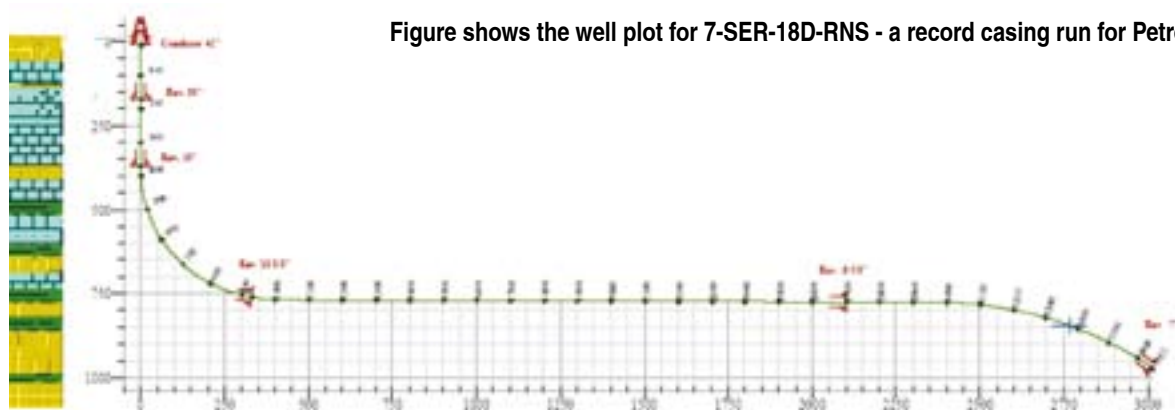
By Clovis Neves, Tesco do Brasil and Vicente Abel Costa, Petrobras

There are many reasons for drilling extended reach wells. In the case of the Serra field, which is located 200 km from Natal, in Rio Grande do Norte, extended reach wells are drilled because the shallow water depths are not good applications for offshore rigs. Therefore, wells are drilled from onshore locations to reach offshore reservoirs.

while running in using 22,000 ft/lb of torque. This reduced the axial drag component, resulting in a gain of 20,000 lbs hook load which was sufficient to allow the casing to reach TD. This was achieved using the Casing Drive System™ (CDS), a technology developed by Tesco Corporation. This equipment is linked to the Rig's Top-Drive and enables the

better casing centralization as well as breaking the gel force and the removal of drilling fluid which results in better cementing job quality.

The benefit of casing rotation was clearly seen in wells 7-SER-17D-RNS and 7-SER-18D-RNS, with the latter presenting a greater challenge in that the 7" casing was run and cemented at a measured depth of 3,655 m. This corresponded to a horizontal section of 3,022 m with a



Drilling and casing these types of wells is always challenging and this has led to Petrobras permanently seeking new technologies to overcome these challenges.

Well 7-SER-18D-RNS, was drilled by Petrobras using a water based fluid and the 9 5/8" casing string was run in to a measured depth of 2,708m. This corresponded to a TVD of 775m and a horizontal section of 2,113 m. In these conditions, drag forces generated by the casing as it rubs against the wellbore are so high that casing cannot be run conventionally. Simulators used by Petrobras indicated that the maximum depth that could be reached would be 2,600m. To overcome the depth limitation, it was necessary to rotate the casing

rig to run casing while rotating or circulating at any given time. This guarantees that casing will be seated at the planned depth.

To ensure the integrity of casing connections, Tesco's Multi-Lobe Torque Ring™, was placed on the internal connection of the API Buttress joint. This increases the torque handling capabilities of the connection by a factor up to 4 as compared to the original capability.

The CDS generated other operational benefits beyond the ease of running casing. During tripping in operations, the well can be circulated with fluid without downtime, because the equipment does not need circulating head or extra lines. While cementing, the casing can be rotated to enable

vertical depth of 960 m where casing rotation was a determining factor in a good cement job.

Due to these successful first runs and within the context of self-sufficiency, Petrobras already plans to set intermediate casing strings deeper in the Serra field while continuing to overcome its challenges in increasing oil production in the region.



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HEAVY OIL TECHNIQUES

Offshore Heavy Oil Recovery

Uncertainty Assessment Using Experimental Design and Risk Analysis Techniques

J.W. Vanegas Prada, J.C. Cunha and L.B. Cunha, U of Alberta

The rising difficulty of finding conventional reservoirs i.e. trapped in uniform structures, containing light oil, with high permeability, high pay zones and easy access, where the uncertainties to its development and associated risk are not too high, leads to increasing efforts to turn marginal prospects in economical ones.

Current high oil prices as well as technological advancements are also boosting these projects, in which the increasing complexity in its development is directly proportional to the increasing of its uncertainties.

In the particular case of offshore heavy oil scenarios, the difficulty to recover representative fluid samples,

due to the high fluid viscosities, conducts to unreliable information of the PVT properties. In addition, the highly unconsolidated formations, which are commonly associated with heavy oil, increase the difficulty to obtain representative core samples, leading to non-consistent measurements of petrophysical properties like absolute and relative permeability, fluid saturations and porosity.

Also, the high oil viscosities together with the high sand content make the well testing operations more complicated and consequently poor well potential information is obtained. In such cases, where the decisions about the entire field development process

have to be taken under strong conditions of uncertainty, a probabilistic analysis, instead of a deterministic one, is the natural way to proceed.

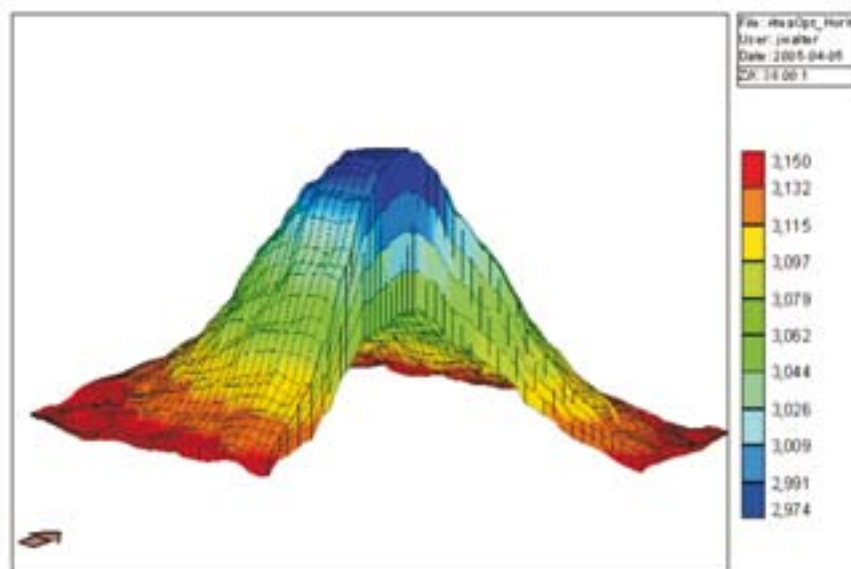
Based on that, this work aims to present an application example of the Experimental Design and Risk Analysis techniques to assess the uncertainty of the Net Present Value in a synthetic offshore heavy oil reservoir during its initial development stage.

The reservoir, located under a water depth of 1,500 m. and approximately 1,500 m. below the sea bed, requires, as any development in these conditions, a great amount of investment and therefore it is crucial to recognize and analyze each possible outcome for the field development in order to map the uncertainties and the resulting financial outcomes.

This work was oriented to assess uncertainty of the Net Present Value under different possible values of variables related to the reservoir characterization and production process during the earliest stage of the field development. For this reason, only constant values of porosity and permeability through the entire reservoir were considered and not a distribution of them, as it should be done when a more detailed study is conducted.

Besides porosity and absolute permeability, the reservoir area and relative permeability curves were chosen as uncertain "non-controlled" variables related to the reservoir characteriza-

3D reservoir model.



tion. Production scheme (horizontal or vertical wells) was chosen as the uncertainty related to the production process and therefore controlled by human decision.

This paper describes a methodology based on the screening study of uncertain reservoir variables using the Experimental Design technique to determine which variables and the interaction between them have the largest impact in the NPV, and based on this information establish the distribution of its uncertainty.

The black-oil reservoir simulator IMEX1 was used to estimate the monthly production of oil and water during 30 years and then, the NPV was calculated using some financial assumptions.

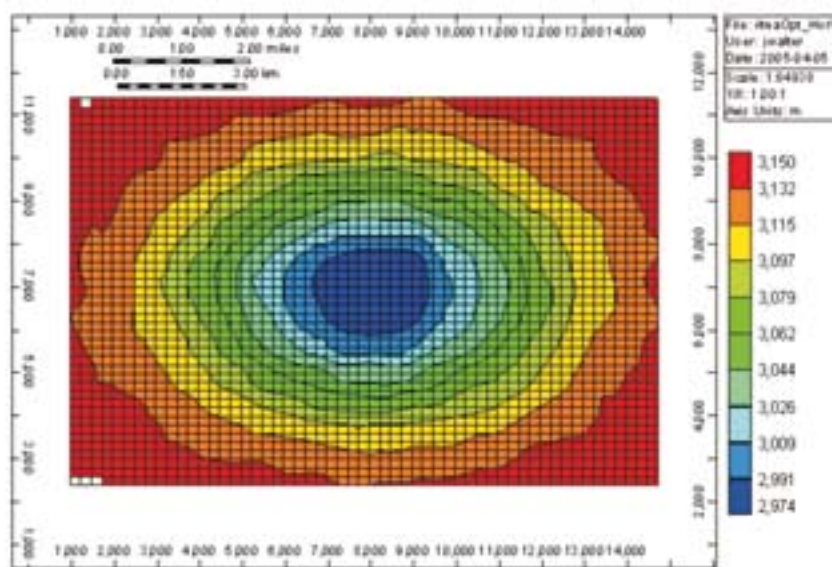
Methodology

Experimental Design is a statistical technique that allows obtaining the maximum information of a given process at a minimum cost. This methodology is used to determine the space variation of the result due to the variations in the input parameters of a given process.

The experiment has to be planned according to the final objective of the study; in general there are two types of purposes:

- Screening, where the aim is to know the input variables that have the largest impact in the result of the process. Most common designs to attend this purpose are two levels full and fractional designs^{3,4}. Levels are the values that each variable or factor can take when the experiment is being run.
- Modeling, where the aim is to construct a statistical model of the process. In this case the experiment is done using more than two levels, in order to capture the most probable variation of the result due to the variation of the input parameters. In this study the process is a flow simulation run whose result is used to calculate the NPV based on some

Optimistic area.



financial assumptions. The time chosen for the project was 30 years and the cumulative production for each month during this time was simulated. The input parameters are the uncertain variables chosen for this case. The choice of the input parameters and its range of variation is the most important stage in the uncertainty analysis.

Reservoir model and uncertain variables

The analysis was done on a reservoir model covering an area of approximately 123.5 km², with a maximum thickness of 100 m and anticline geometry. The figure on page 26 shows a 3-D image of the reservoir.

The production scenario is offshore with 1,500 m of water depth and 2,970 m. to the reservoir top. The production mechanism simulated was waterflooding.

The reservoir was modeled using a 55x45x4 grid, 9,900 blocks in total, and the average run time to simulate 30 years of production was 4 minutes in a Pentium IV PC.

The produced fluid was an oil of 13 °API and viscosity of 152 cp at surface conditions. The initial reservoir pressure was 314 kgf/cm² at 3003

m. and the reservoir temperature was 70 °C. A water oil contact was located at 3,140 m. depth.

The reservoir characterization variables, which are non-controlled variables, chosen to have a large uncertainty are: permeability, relative permeability curves, porosity and area of accumulation. The range of variation for absolute permeability, porosity and area were based on pessimistic, expected and optimistic values.

The reservoir area uncertainty is represented by three different maps.

The uncertainty in the reservoir area is justified by uncertainty associated with the seismic interpretation in which the precision to infer the reservoir thickness directly affects the area of the accumulation.

Analysis shows the differences of original oil in-place for all possible areas as well as the number of active blocks used during the simulations. The values of parameters used to create the 16 different tables of relative permeability curves can be found in the original paper.

16 different cases of the Corey model were used to construct the respective equiprobable tables of relative permeability curves.

HEAVY OIL TECHNIQUES

The uncertainty in the production scheme was defined using either vertical wells or horizontal wells. Since the productivity index (PI) of horizontal wells is a source of uncertainty it was decided to consider three possible cases for the productivity index of horizontal wells. Research shows the different possibilities used to map the uncertainty of the production scheme.

The number of wells and their locations were optimized for each possible reservoir area considering vertical and horizontal wells type of exploitation schemes. Thus, each area would be developed in the best possible way using vertical wells as well as horizontal wells.

The assessment of the Net Present Value uncertainties for an offshore heavy oil reservoir in its earliest stage of development was done by means of experimental design and risk analysis techniques.

In the vertical well type of exploitation, all injector and producer wells are completed in each one of the four layers, while in horizontal wells, the injectors are placed at the bottom of structure (layer 4) and the producers at the top of it (layer 1). The assumed average horizontal well completion length was 500 m.

Research shows the number of injector and vertical wells used to simulate 30 years of production for each reservoir area. The figure on page 27 shows as an example a 3-D map of the optimistic area and a horizontal well exploitation scheme.

In summary, there are 5 parameters with large uncertainty, 3 levels of porosity, 3 levels of absolute permeability, 16 tables of relative permeability, 3 different reservoir areas and 4 production schemes. This gives a total of 1,728 possible combinations.

Net Present Value (NPV) Calculation

NPV was selected as the financial criterion for the economical analysis. This analysis was done based on the results of the simulation runs. Each case was run to simulate a period of 30 years and the result of the monthly cumulative production of oil and water was the base to calculate the monthly net income.

Some financial assumptions were made in order to determine the NPV:

- All investments are done at the present;
- Cost of drilling and completion of a horizontal well is US\$ 15 MM;
- Cost of drilling and completion of a vertical well is US\$ 10 MM;
- Cost of surface facilities is US\$ 500 MM plus US\$ 5 MM per well for sub sea equipment;
- Cost of production is US\$ 8 per barrel of produced oil;
- Cost of water injection and treatment is US\$ 1.5 per barrel of produced water;
- The interest rate for investments is 12% nominal per year;
- Oil price is US\$ 25 per barrel;
- Taxes represent 42% of the gross income;
- Taxes begin to be paid only after the return of the investment;
- Before the breakeven the income is discounted to an interest rate of 6% per year.

Screening Analysis

The initial objective is to do a screening analysis to define which uncertain variables have a larger impact on the NPV.

This analysis was done using a full factorial experiment design at two levels. In this design, two values of each parameter are selected and a matrix containing all possible combinations of them is constructed, then the simulator is run using each combination. The values are selected to represent the entire range of variability of each parameter, in other words, the two extreme values of each uncertain variable are chosen. It is a common practice in experimental design to normalize the parameters to values -1 and 1, assigning -1 to the minimum and 1 to the maximum of the same parameter.

In this work the number of runs is given by 25, or 32 different cases are run to define the effect of each factor and the effects of the interactions between them on the Net Present Value. Research shows the matrix of runs used to perform the screening analysis. The values were assigned to 1 and -1 for each parameter.

In order to run and calculate the NPV for all combinations a program to manage the input/output files of the simulator was written. This program builds the matrix of runs, then for each row of the matrix or combination of the uncertain variables it opens and changes the keyword values in the simulator input file. Following, the program calls the black-oil commercial simulator and runs it using the input file. When the simulation is finished the program opens the simulator output file and collects the cumulative production of oil and water for each month. Finally, using the previous financial assumptions the program calculates the NPV. The NPV results for the screening analysis were presented together with the codified variables used in the simulations.

In order to determine the effects of each variable and the effects of the combination of variables on the NPV, it is necessary to construct the

so called matrix of contrast coefficients. This matrix is built by multiplying element by element the columns of the matrix of runs, in order to obtain new columns corresponding to the interactions between the variables⁴. Then, a column of ones is added at the first column. This column (M) is used to determine the mean of the NPV results. Research shows the matrix of contrast coefficients, where columns 1, 2, 3, 4 and 5 are related to the codified input variables: porosity, absolute permeability, relative permeability, area, and production scheme, respectively. The other columns are related to the interaction between the variables and the codes are determined by multiplying element by element the respective columns. For example, the column 123 is related to the interaction between porosity/permeability/relative permeability and the codes are found by the element-by-element multiplication of column 1, 2 and 3.

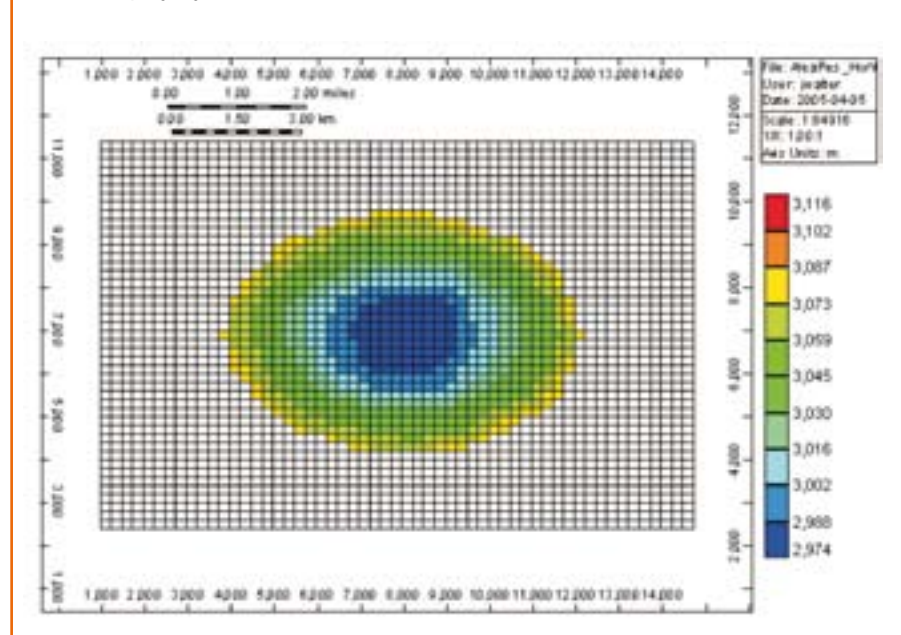
The remaining terms of D divided by $2n-1$ correspond to the vector of effects. In this case $n=5$ and the vector of effects is shown in Table 10.

As an example, we can see in this table that the effect of increasing the porosity from 0.24 to 0.32 is, in average, US\$171 MM in terms of NPV. In this table also is shown the effect caused by the interaction between variables, for example the effect of increasing the area and change the production scheme from vertical wells to horizontal well – good PI – is in average US\$158 MM.

It is important to note that by doing a full factorial design it is possible to determine all possible effects on NPV, i.e. 5 effects of first order, 10 of second order, 10 of third order, 5 of fourth order and 1 of fifth order.

In order to define which effects are really important it is necessary to construct a Pareto plot with a sig-

Pessimistic area.



nificance level of 95%. It means that only the effects, whose values are greater than the value corresponding to 5% of cumulative probability, are statistically important.

In the Pareto plot, where the value for P5 (five percentile) is US\$ 29.32 MM. It is noticeable that the most important effects over the NPV, in decreasing order, are:

1. Permeability;
2. Production scheme;
3. Area;
4. Relative permeability;
5. Interaction Permeability -Relative permeability;
6. Interaction Permeability - Production scheme;
7. Interaction Permeability – Area;
8. Porosity;
9. Interaction Area – Production scheme;
10. Interaction Relative permeability – Area;
11. Interaction Porosity – Permeability;
12. Interaction Permeability - Relative permeability – Area;
13. Interaction Porosity – Area;
14. Interaction Permeability – Area – Production scheme;
15. Interaction Porosity – Production scheme.

The previous result leads to the conclusion that, in this case, all the variables taken into consideration cause an important effect over the project's NPV; therefore they should be included when the overall uncertainty of the project is determined.

Following this premise, the next section illustrates an alternative to construct the uncertainty distribution of NPV for this project.

Uncertainty Analysis

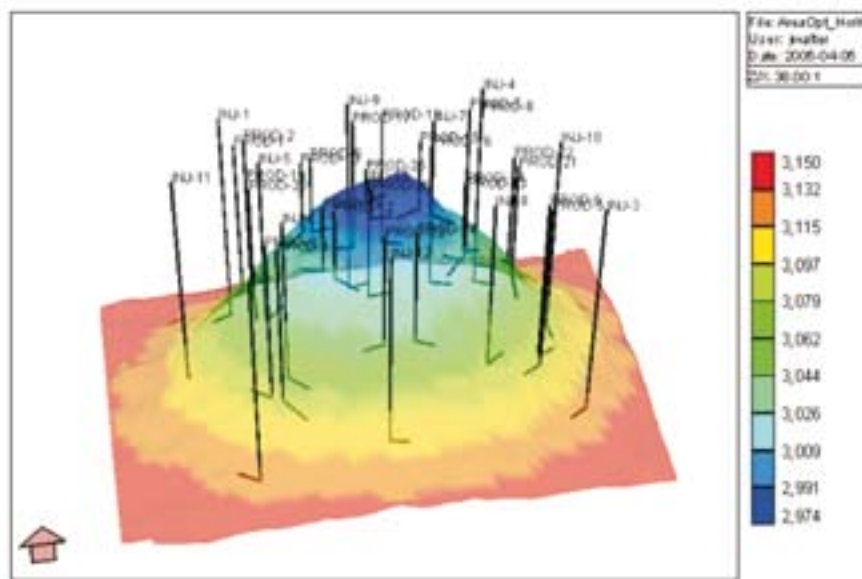
The uncertainty analysis aims to determine the Expected Monetary Value (EMV) for the development project. Two cases are considered; in the first, there is some information about probabilities of the uncertain variables and in the second there is no information about any probability.

For the first case, probabilities associated to the values of porosity, were calculated along with absolute permeability and area. For the relative permeability and production scheme, it is assumed each outcome being equiprobable.

A decision tree was constructed using this information. It can be seen that the total of all outcomes for the NPV

HEAVY OIL TECHNIQUES

Horizontal well production scheme.



is given by $3 \times 4 \times 16 \times 3 \times 3 = 1,728$. Using the previously explained program all the 1,728 cases were run and the NPV value was found for every possible outcome. The total simulation time was around 5 days in a Pentium IV PC.

Then, the Expected Monetary Value (EMV) was calculated assuming independence between the events of each variable. For example, the probability that the porosity assumes the value of 0.2 is not affected by any value that other variable can assume, in this case permeability, relative permeability, area, or production scheme.

For the second case, the assumption of no information about probabilities was used in the uncertainty analysis.

Considering that the values of each variable cover the entire range of variability, a histogram of the 1,728 possible results can give an idea of the NPV uncertainty distribution.

A histogram with 25 bins was created where the Expected Monetary Value was found by assuming the relative frequency as the probability of occurrence of the given value at

the interval center of its respective bin. The EMV calculated using the assumption of no information about probabilities is \$US 914 MM. This value confirms the one found in the case when some information about probabilities is assumed.

It is important to notice that the EMV in the first case depends on the probability values that the parameters can assume, but it is important to notice that for different values of probability tested the EMV was close to \$US 914 MM.

Illustrating this is the cumulative probability distribution curve of NPV for this project. Some useful points in this curve are P10 = US\$ 302 MM, P50 = US\$ 754 MM, and P90 = US\$ 1,560 MM.

From the previous analysis we can conclude that under the considered assumptions this project is highly profitable.

Conclusions

The assessment of the Net Present Value uncertainties for an offshore heavy oil reservoir in its earliest stage of development was done by means of experimental design and risk analysis techniques.

A screening analysis was performed to confirm that the chosen uncertain parameters caused a great impact into the NPV of the project. This analysis was done using a two level full factorial experimental design.

A program was written in order to use a commercial black-oil simulator for the uncertainty assessment of the Net Present Value through variations of some petrophysical and/or production parameters.

The uncertainty analysis was done, first assuming some information about probabilities of the uncertain parameters, and then assuming that there is no information about it. In both cases the result of the Expected Monetary Values was \$US 914 MM.

Considering the schemes as mutually exclusive events, the horizontal wells would be the best choice for the development of this reservoir.

One step forward in the field development study would be the implementation of a Monte Carlo methodology to better assess the NPV uncertainty, sampling the complete probability distribution for the uncertain parameters instead of simply assigning discrete values of probability for them.

Nomenclature

A = Area, m^2

EMV = Expected Monetary Value, \$US

K_{rw} = Water Relative permeability

K = Absolute permeability, mD

n_w = Coefficient of Corey model for water relative permeability

n_o = Coefficient of Corey model for oil relative permeability

NPV = Net Present Value

P = Probability

P.Sch. = Production scheme

S_{or} = Residual oil saturation

S_w = Water saturation

S_{wi} = Initial water saturation

ϕ = Porosity

DEEPWATER WELL CONSTRUCTION

Deepwater Feature

By W. Rasheed

It is fashionable these days to use the deepwater label to distinguish a particular type of drilling. But is this so different to shelf or onshore practices?

The common denominator of all drilling activities is the management of people, technology and locations. Customs, environmental, and legal issues exist also. And so does that detail of prospect selection. That's fine. But this logistical labyrinth is essentially the same whether you're sitting in a company man's office offshore Angola or onshore Azerbaijan.

Technology isn't exclusive to deepwater either. Smart completions using fibre optics and satellite communications are enabling the production of onshore production zones to be commingled and controlled. Acidification through water injection lines permits live well intervention without skidding land rigs. New gravel packing and filtering techniques can be used to control sand production in shelf fields. In fact, it seems an equally compelling case can be made for technology to be used in onshore or shelf locations to improve marginal economics as can be made for deepwater operations.

What really differentiates and impacts deepwater activities are the challenges associated with incredible sea depths. Of course, block size in deepwater frontier areas such as Brazil can reach huge proportions; 25,000 sq km (that's 1,000 GOM blocks). This makes picking and drilling prospects tough, irrespective of operator resources or experience. But it is greater water depth that leads to higher pressures and overburden and that's where the problems arise. The drilling engineer has to consider and

overcome bottom hole pressures that can exceed 22,000 psi and mudline temperatures that can fall as low as 35 degrees F.

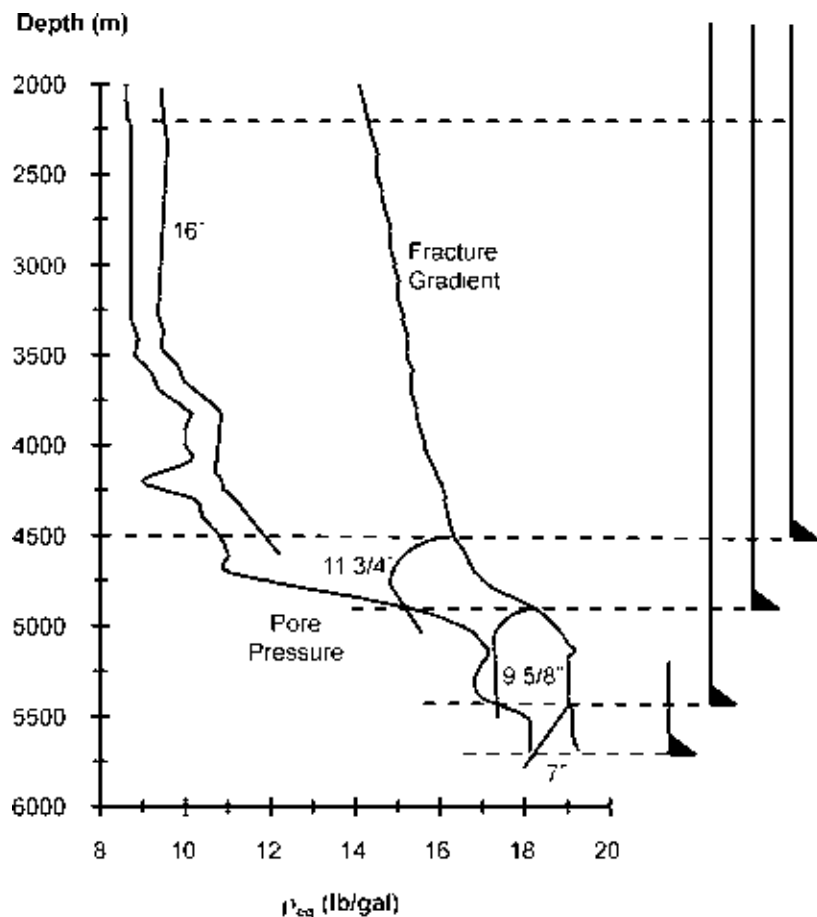
So where is the deepwater line drawn? According to Petrobras, waters between 1000-2000 m depth are classified as 'deep'. Beyond this are the ultra deep waters (this line goes to 3500m for the present). Deepwater definitions aside, deeper seas mean deeper pockets.

Deepwaters are characterised by strong currents which create a need for high specification rigs that are capable of maintaining station and in some instances of suppressing

Vortex Induced Vibration (VIV). Such rigs are expensive. Contracting one in the GOM can cost a cool \$400,000 per day. Deepwaters are also characterised by young depositional formations that differ from shelf and onshore scenarios. Exemplifying this is the typically narrow window between pore pressures and fracture gradient (ppfg). Low fracture gradients can necessitate lighter drilling fluids and lighter cement slurry. While rising pore pressures can often upset the delicate fracture gradient destabilising the well-bore and jeopardising the section, if not the entire well.

A consequence of narrow PPFG is the need for close tolerance

PPFG Example.



DEEPWATER WELL CONSTRUCTION**Deepwater rig in the Campos Basin.**

and contingency casing schemes. (Accompanied by a need for concentric underreaming. It's easier to set casing with gauge hole). A potential consequence of a tight ppfg is the requirement of contingency casing strings to isolate formations. In short, deepwater Operators must have an excellent knowledge of wellbore stability to avoid a formation influx (kick) or fracture the shoe which would result in losses. New well construction methods are being developed for just such an eventuality. These include the "dual gradient system". Petrobras is presently sponsoring a JIP that develops a subsea pump to control the pressure at the wellhead and studying gas injection systems. For this technology to work, risers must be resistant to collapse forces as soon as gas is injected into their bases.

Further engineering challenges are added by temperature gradients. A negative gradient runs from surface to seafloor but this turns positive below the mud line. Equations become more complicated as cooler surface mud alters the temperature profile as it pumped downhole. While gas hydrate formation is a common problem that is difficult to resolve. Hydrates trap natural gas inside water molecules and bond with metal. This can result in tubing blockages and affect valve and BOP operation.

Unfortunately, deepwater environments present the ideal combination of low temperatures, high seabed pressures, gas and water that cause hydrate formation. Extensive modeling is required to minimize hydrate formation. Low temperatures alter the properties of cement which mean new designs of cement slurries composition are required. Existing API norms do not cover low deepwater temperatures and stringent test procedures are now determining the properties of cement slurries in deep water operating conditions.

Riser manipulation is another challenge is found in ultra deep waters - 2000m and beyond. Research is being carried out on innovative lightweight risers. By reducing the weight of the risers and their joints, it should be possible to use lower cost fit-for-purpose rigs in ultra deep water. A parallel technology that has been developed is the 'Slender Well' concept to permit the use of smaller diameter wellbores and lighter risers.

A further innovation has been the torpedo pile, which is a torpedo shaped anchor that is dropped from a certain height to the seafloor. The resulting kinetic energy is sufficient to drive the pile 20 to 30 m down into the floor, providing the required vertical-load resistance. The torpedo subsea well base was developed based on the same concept. It

penetrates into the soil because of its own weight and then, if necessary, is hammered down to the final position. It is a new product and more than six torpedo well bases have been successfully deployed so far. It is possible cut drilling time by a day or two, per well, just by using this technology. Considering current rig rates, it represents a significant economy.

Undoubtedly, deeper waters add greater cost and complexity to operations. But expenses can be cut in three ways. Firstly, by simplifying well design. Well trajectories should not only be compared in terms of how effectively targets are reached, but also on their overall cost effectiveness. Secondly, by reducing casing strings. Casing can be set deeper, based on real-time pore pressure and fracture gradient detection. Accurate prediction will reduce contingency casing. Offset data can help to refine pore pressure models and enhanced pore pressure detection will make the best of the casing program while drilling. Modeling steady and dynamic state fluid behavior will reduce surprises. Last but not least, costs can be cut by contracting 'fit-for-purpose' technology, especially rigs.

Editors Note: Would like to thank Joao Carlos Placido and Antonio Lage of Petrobras CENPES.

SUBSEA

Subsea Equipment, Risers & Pipelines

Petrobras's long history of developing subsea completions shows how the company has constantly met new challenges when designing and deploying subsea production systems. A key foundation of the development strategy has been the generation of new technology ways and means in order to meet new application scenarios and keep costs from spiraling. The Subsea equipment, riser and pipeline project will enable E & P in water depths exceeding 3,000m.

The project is focusing on the following items:

- Subsea connection system for 3,000m water depth;
- Completion riser for 3,000m water depth;
- Guide lined installation procedures for 3,000m water depth.

Unconventional subsea production systems

Looking beyond conventional wisdom is the vision behind this project. The idea is to evaluate unconventional technologies according to their cost effectiveness when applied to the needs of deepwater, ultra-deepwater and marginal fields. These evaluations will also identify new technological developments to be 'launched' and make concrete recommendations regarding their technical and economical feasibility based on the needs of different fields. Promising technologies will then be developed as separate sub-projects. The technologies being considered are:



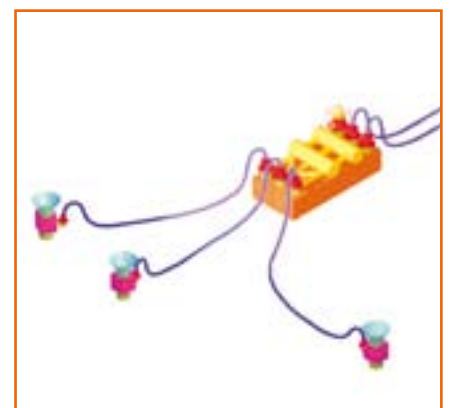
- Subsea water disposal
- "All-in-one" wet Christmas tree

Steel catenary riser systems for ultra-deepwater

Risers, flowlines and multifunctional umbilical cables are undoubtedly the most critical components of typical floating production systems in ultra deep waters.

The use of rigid flowlines or pipe-in-pipe and steel, composite, or hybrid catenary risers (SCR, CCR & HCR) are important options for the transportation of fluids in ultra-deepwater conditions. The SCR can be cost-effective and as yet is also the only field proven technical solution for large diameter hydrocarbon pipeline flows, especially from semi-submersibles or in ultra-deepwaters, when compared with traditional flexible risers. Their use in conjunction with FPSOs was the subject of a comprehensive study conducted by Petrobras and completed in late 1999; however, a prototype has not yet been installed.

Results from the monitoring system installed in the P-18 SCR (the world's first prototype of a SCR) have been systematically used to compare and calibrate Petrobras's SCR computer models. Presently, such models are being fine-tuned to enable the design of SCRs for Roncador and Marlim Suls module 4. The 'lazy-wave' configuration for SCRs is also being considered and the 'reel-lay' installation method for SCRs is undergoing a qualification process.



SUBSEA



Flexible riser systems for ultra-deepwater

Today's flexible pipe technology seems to have reached its operational limit. Although, it allows the use of 6 inch flowlines (static application) can be used in 2,000m water depth and 10 inch risers (dynamic application) can be used in 1,500m-water depth, Petrobras believes that flexible pipe technology has a long way to go before they can be used in deeper waters. This has given rise to the need for composite materials which may offer better thermal insulation, mechanical performance and novel riser configurations all the while reducing the weight of, and loading on the riser system.

Alternative riser systems for ultra-deepwater

To overcome the challenge of producing in ultra-deepwater, new technologies are being developed. Some of the most promising ones are the hybrid riser system alternatives, such as the Tethered Riser Buoy (TRB), the Self-Standing Riser (Riser Tower) and Single Line or Concentric Offset Riser (SLOR & COR).

The TRB consists of a combination of flexible and rigid sections with

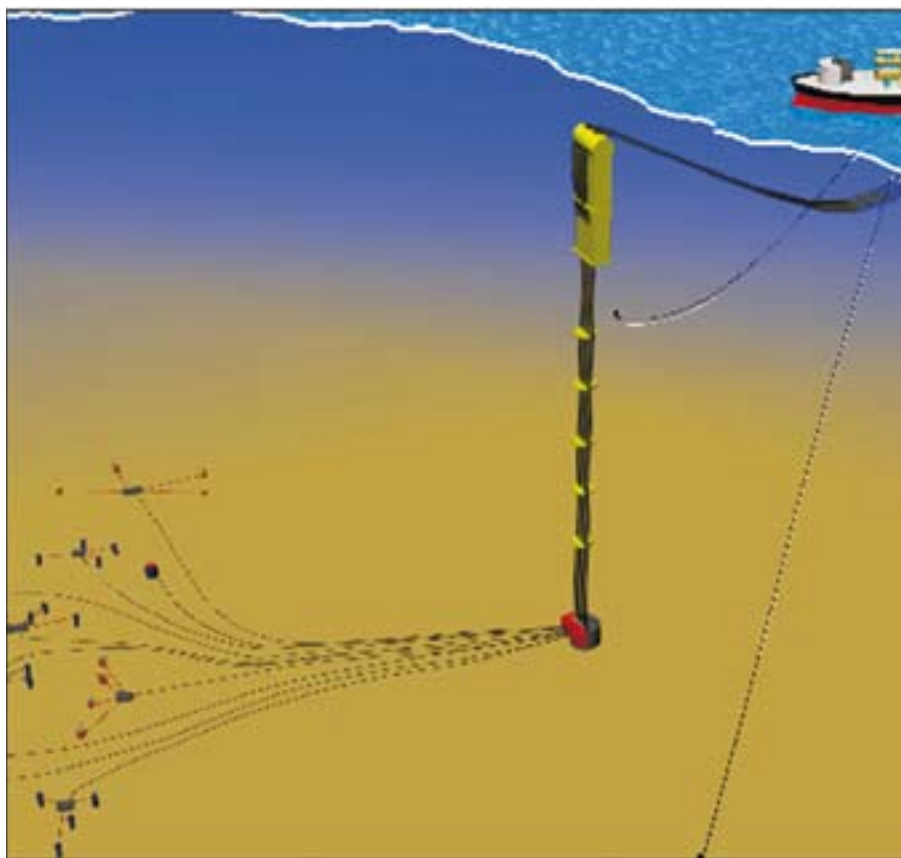
different configurations, one for the top and another for the lower part of the riser. The main concern linked with this system is related to installation procedures and buoyancy control. It has a major advantage in that it is a better overall (global) riser system when responding to dynamic excitation, that is to say that certain motions of the vessel are easily absorbed by the upper part known as a compliant structure while the lower part or the upright rigid riser takes almost none of the dynamic loading. Petrobras is pioneering this approach and plans to introduce this technology in its ultra-deepwater fields during the next few years.

While a related technology is the 'Self-Standing Riser' or riser tower which has been used in a West African field development. It presents advantages that are similar to the TRB but Petrobras are looking at performance of certain critical issues such as bottom connectors, vortex induced vibration VIV, buoyancy control, installation pro-

cedures and inner tube fatigue analysis. The research will concentrate on investigating the performance of this concept as it is particularly well suited to complex subsea layouts so characteristic of deep water Campos Basin.

Another group of related technologies are the SLOR or COR systems which are also similar to the Riser Tower. However, the concept was devised for one (SLOR) or two (COR) lines rather than for a bundle. Additionally, these solutions offer a mid-water subsurface connection that can link up with the floating unit through a flexible 'jumper'. Such systems have been approved to be installed in West Africa.

The performance of all these technologies is being assessed according to specific application scenarios defined by the PROCAP-3000 program. The technical feasibility and cost effectiveness of the various risers, pipelines and concepts will be analyzed in the context of the subsea layout and time-line for the wells and subsea pipelines.





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The Easy



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DIRECTOR INTERVIEW

Pipelines and Terminals

Petrobras Transporte SA Director Marcelino Guedes

By W.Rasheed

Q: Brazil Oil and Gas – What is the role of Petrobras Pipelines and Terminals in reaching self-sufficiency?

A: Marcelino Guedes – Petrobras Pipelines and Terminals is responsible for the transportation, storage, and treatment of the crude oil produced, refined and exported by Petrobras. In the short term, no change is expected in our operations. After our crude production and exportation increases we will probably enhance our facilities to accommodate the additional demand without causing any problem to the current supply to Brazilian market. This will also be repeated with our refined product transportation and storage operations in order to deal with the additional increase in Brazilian demand and international sales.

Q: Brazil Oil and Gas – What is the company's refining capacity today?

A: Marcelino Guedes – The total refining capacity of Petrobras is 2,114,000 bbl/d. In Brazil we refine 1,985,000 bbl/d. The remaining 129,000 bbl/d are processed in our facilities abroad.

Q: Brazil Oil and Gas – What are the major pipeline terminals?

A: Marcelino Guedes – The major marine and land terminals of the Petrobras Transport - Transpetro are:

- a) São Sebastião Marine Terminal – operation up to 4 ships simultaneously with maximum of 300,000 dwt and 2,100,000 m³ storage capacity.*
- b) Madre de Deus Marine Terminal – operation up to 5 ships simultaneously with maximum of 120,000 dwt and 670,000 m³ storage capacity. Handles oil, refined products, LPG and ethanol.*

- c) Angra dos Reis Marine Terminal - operation of up to 2 ships simultaneously with maximum of 500,000 dwt and 950,000 m³ storage capacity. Handles oil, refined products, LPG and ethanol.*
- d) Guararema Land Terminal - 840,000 m³ storage capacity and operations with oil, refined products and ethanol.*

- e) São Caetano do Sul Land Terminal - 205,000 m³ storage capacity and operations with oil, refined products and ethanol.*

The major pipelines of Petrobras are:

- a) GASBOL – Bolivia/Brazil natural gas pipeline connecting Santa Cruz de La Sierra (Bolívia) and Porto Alegre (Brazil), with 3150 km extension (Bolivia - 557 km; Brazil - 2,593 km) and diameters ranging from 32" to 16".*
- b) OSBRA – liquid product pipeline connecting Paulínia Refinery in São Paulo State to Brasília 980 km in length and diameters ranging from 20" to 14" transporting gasoline, diesel, kerosene and LPG.*

Q: Brazil Oil and Gas – What products does Petrobras refine?

A: Marcelino Guedes – Petrobras' main refined products are: LPG, petrochemical nafta, gasoline, aviation and illumination kerosene, turpentine, solvents, diesel, basic lubricant oils, paraffins, bunker, fuel oil, coke, asphalt and sulphur.

Q: Brazil Oil and Gas – What plans does the company have for new pipelines / new refineries?

A: Marcelino Guedes – Petrobras will invest US\$ 7 billion in transport pipelines (US\$ 4.5 billion in gas pipelines and US\$ 2.5 billion in liquid pipe-



lines) and US\$ 2.0 billion in distribution pipelines.

Petrobras will construct a refinery in the State of Pernambuco and another in the State of Rio de Janeiro.

Q: Brazil Oil and Gas – What is the total number of refineries and pipeline footage?

A: Marcelino Guedes – Petrobras owns 15 refineries: 11 in Brazil and 4 abroad.

Total length of Petrobras pipelines is 30,318 km, of which 10,000 km are operated by Transpetro.

Q: Brazil Oil and Gas – What is the history of the Williams formula 1 relationship?

A: Marcelino Guedes – The partnership between Petrobras and BMW Williams Fórmula 1 team was signed in 1998. It is Petrobras' responsibility to develop a high technology fuel allowing the BMW V10 engine to reach optimum racing performance. In the Petrobras Research Center (Cenpes) a team of 50 employees work in all as-

pects of fuel development including the supply of this special fuel to BMW Williams, a team that has won the world champion nine times - one of the most important and traditional races in car racing worldwide.

Q: Brazil Oil and Gas – What are the major social responsibility projects? How well do they integrate differing needs of society and development?

A: Marcelino Guedes – When adhering in 2003 to the Global Compact, one of the most important world initiatives of corporate social responsibility, Petrobras strengthened its principles of respecting human rights, labor and environment, and fighting corruption. A landmark of Petrobras performance in this area was the launch of the Petrobras “Fome Zero” Program back in 2003 with a forecast of R\$ 303 million investment by the end of this year to strengthen public policies to fight misery and hunger. A wide-ranging program is being implemented across Brazil with the direct participation of the communities. This contributes to the improvement of the quality of life of the population.

In the same way, social responsibility is strongly engrained in Transpetro's culture and performance. We have already developed many projects, especially in ecological agriculture, education and supporting population needs in poor areas. Currently we are structuring a department to deal with this subject.

In partnership with Petrobras, NGO “Instituto Terra de Preservação Ambiental” and NGO “Onda Verde”, we launched last year the “Right-of-Way Agro-ecological Family Farming” project. Its objective is to help families with low income in order to establish communitarian small production areas in the right-of-ways close to Duque de Caxias and Nova Iguaçu cities, located close to Rio de Janeiro. This auto sufficiency project will benefit 1,600 people who will cultivate 15 different organic products in 13,300 seedbeds. In a sec-

ond step family based agro-industries for production improvement are going to be established.

Q: Brazil Oil and Gas – What are the major pipeline technologies that Petrobras is pursuing?

A: Marcelino Guedes – Petrobras and Transpetro are investing in methodology, equipment and product research and development in the following areas:

- Cathodic protection systems
- Thermal Isolation of pipelines (including "in situ" repairing)
- Internal and external corrosion evaluation, monitoring and control
- New materials
- Leak detection systems
- Defects evaluation and remaining resistance

- Hydrostatic test
- Fatigue
- Pig Inspection
- Alternative technologies for inspection
- Operation optimization
- Monitoring and geotechnical evaluation
- Remote monitoring and geoprocessing
- Design and construction new techniques (no right-of-way pipelines, high strength line pipe, etc)
- Measurement and product quality

Guedes "Petrobras intends to invest US\$ 7 billion in Brazilian pipelines."



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