Knowledge is sovereignty and technology is an expression of knowledge. Over the last 60 years, Petrobras has built a trajectory of overcoming challenges. Established research as a basis for knowledge and development of new technologies and the result will come in the form of superlatives: we are the world leaders in technology for exploration and production in deep and ultra deep waters, where about 90% of our reserves can be found, and we have become one of the most innovative companies in the oil and power sector in the world. We register more patents, both in the country (1,543 patents) and abroad (2,850 patents), than any other brazilian company does. Over the past 12 years, we have had an average increase of 700% in investment in research and development (R&D), leaving from a US$ 160 million basis, which was the average from 2001 to 2003, to a US$ 1.24 billion basis, that represented the average from 2011 to 2013. In 2013, we maintained our commitment to invest in R&D, having invested US$ 1.1 billion, being the company with the highest investment in R&D in percentage of net revenue, compared to other majors.

In our opinion, the history of the company’s investments in R&D lies in the view that only innovation could bring a differential to the implementation of projects, as well as to the sustainable growth of Petrobras. Still in the 1950’s, when Petrobras was created, the first company leaders needed to create a structure of technical capability in the brazilian oil industry, able to design units and facilities that could meet the specific condi-
tions of the country. Thus, in 1956, the Center for Staff Improvement (Cenap) – a teaching and research body of the National Oil Petroleum Council (CNP) – was integrated into Petrobras and, in 1963, the Board of Directors approved the creation of the current Research and Development Center of Petrobras (Cenpes), in charge of the technology management of the company and whose 50 years were celebrated in December 2013.

The outcome of this business culture that seeks paths for innovation to overcome apparently insurmountable challenges is demonstrated by our findings of onshore or offshore fields, in places once considered difficult for production, as well as the extraction of oil and gas found thereof (with their subsequent treatment). In the early 1980s, for example, we performed great discoveries in unprecedented depths. At that time, there was no proven technology in the world to enable the production of giant oil fields in depths of over 1000 meters. Faced with this challenge, we sought international referrals, developed partnerships with suppliers, worked together with universities and research centers and developed our own technology. Today, Cenpes works in partnership with more than 100 universities and national research institutes, through 49 thematic networks. Thus, our experience has allowed us not only to find the pre-salt reservoirs, but also to figure out how to produce in these challenging reservoirs - located in water depths of approximately 2,200 meters and located 300 km off the Brazilian coast - reaching the mark of 500,000 barrels of oil per day in 2014, just eight years after the discovery of such reserves.

Just like the pioneers of the company, we continue to see into the future, by anticipating scenarios, by expanding boundaries and by diversifying energy generation using new raw materials and products. Our Strategic Plan 2030 has been developed taking into account medium and long term goals for production of 4.2 million barrels of oil per day in 2020 in Brazil, besides an increase in our refining capacity, reaching 3.3 million barrels, enough to meet our domestic demand.

This Petrobras Technology 2013 report brings together the major outcomes obtained by the areas of basic engineering research and development during 2013, pointing out solutions that demonstrate our progress in the energy industry. Our goal is the research-driven results. Therefore, with management focused on better performance, capital discipline and technological and operational excellence, Petrobras will lead the way in overcoming their challenges.

Maria das Graças Silva Foster
President of Petrobras
August 2014
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The premise of the Petrobras technological strategy is to meet the challenges set by the company, focusing on the direct applicability of the company’s business and the promotion of technological development with local content, comprising of the requirements and obligations of safety, environment and health. In addition, the commitments of the company are to anticipate scenarios and expand frontiers sustainably, based on the monitoring of trends and market opportunities.

To translate innovation into business results, Petrobras relies on resources capable of facing the challenges. Beyond the effect of highly qualified professionals dedicated to research, development and engineering, our Technology System comprises an extensive network of partnerships between universities, national research institutions and suppliers of goods and services. Petrobras investments in R&D over the last ten years show management focused on innovative solutions that meet the demands of brazilian and world energy, mitigating risks of industry activities.
HISTORY

In 2013, Petrobras celebrated 60 years and its history is directly linked to overcoming challenges. Since the discovery of the first well, in the state of Bahia, passing through pioneering refinery processes in the country, the technological domain in oil exploration in ultra deep waters up to pre-salt oil and gas production, Petrobras’ role has always been to take advantage of their opportunities, facing the unknown and seeking innovative solutions.

A technological base has always been off-stage for these challenges. In 1963, the Board approved the creation of the Center for Research and Development - Cenpes, responsible for the technological management of the company. The pioneers of the company had already foreseen technology as the key to the success in this industry, establishing a culture of innovation as one of the pillars for its growth.

Fifty years later, Cenpes has a history of victories, with the development of processes and technologies applied in a pioneering way, that have generated positive results for the company and for the brazilian oil, gas and energy industry as well.
Construction of the original Petrobras Research Center
Photo: Petrobras Archive (1972)
Ileana Williams, one of the first researchers of Petrobras in a laboratory
Photo: Petrobras Archive (1956)

Visit of then president of Petrobras Ernesto Geisel to Regap in 1970
Photo: Petrobras Archive (apr/1970)
Just one year after its founding, in 1954, Petrobras started its oil production at 2.6 million barrels per day, what represented approximately 1.7% of national consumption, and had a refining capacity of 41 thousand barrels per day. Until the mid-1970s, the implementation of the refining industry was the main direction of the company’s strategy, since Brazil was importing oil and the goal was to encourage domestic processing capacity and fuel production to supply the domestic market.

During this period, it was necessary to learn and assimilate the existing refining technologies in the world, and then adapt them to the domestic needs. In this context, in 1960, the first refinery built by Petrobras began operating – Duque de Caxias Refinery (Reduc) – and Cenpes was created, which now congregates all the research activities of the company.

In 1974, the Garoupa field, in the Campos Basin, marks the beginning of the exploratory boundary of the first high sea Petrobras fields. After the price increase due to the second world oil crisis in 1979, offshore production (at sea) on the international scenario was taking its first steps with the deployment of platforms in the North Sea (Norway and the United Kingdom), in Venezuela and the Gulf of Mexico.

The discovery of oil in the Campos Basin has changed the scenario of the oil and gas industry in the country, making Petrobras change its innovation strategy. Given the conditions found in this oil province, the company started to develop new technologies to enable, in a secure, efficient and
cost effective manner, the planned offshore extraction in increasingly deeper waters.

Thus, in 1986, the Deep Water Technology Program was created (Procap) in order to generate technological support to the production of Marlim and Albacora, enabling production in water up to 1000 meters deep. The second phase of the program began in 1992 with Procap 2000, focusing on the production of Marlim Sul and Roncador, this time with a water depth of 1730 meters, considered the greatest brazilian deposit until then. Already in its third and final phase, which started in 2000, Procap 3000 spawned technological support for the production of ultra-deep phases of Marlim Sul and Roncador.

With the discovery of the Lula field, in 2006, a new exploration frontier started for oil and gas in the pre-salt region. Again, Petrobras identifies a major growth opportunity for the company, with a significant step in the worldwide industry. With extensive experience in operating in ultra-deep water, Petrobras seeks technological solutions for the new scenario. Only seven years after the first discovery, the mark of 300 thousand barrels of oil extracted from the pre-salt per day, achieved in December 2013, confirms that the company not only acquired knowledge, but already implements it in production, in a time interval lower than that required to achieve the same level in other important areas of offshore production in the world.
Aerial view of the Petrobras Research Center

Photo: Rogério Reis / Petrobras Image Bank (mar/2012)
In December 2013, the Petrobras Research and Development Center celebrated 50 years of activity. In a celebratory event, some of the processes and technologies that made history were acknowledged for their relevance in the brazilian oil, gas and energy industry. In this celebration, which was attended by Petrobras’ president Graça Foster, professionals responsible for the award-winning technologies received honors. Also present were current directors of Petrobras and former directors of contact, as well as former superintendents and former executive managers of Cenpes.

Following, the award-winner processes and technologies shown during the Cenpes 50 years ceremony are presented. These technologies were selected according to the criteria of the company application scale and the consequent financial return.

GEOCHEMICAL CHARACTERISTICS OF BRAZILIAN SEDIMENTARY BASINS (1973)

In 1973, Petrobras started to evaluate the geochemical characterization of rocks, soils, oils and gases of sedimentary basins where the company operates. Since then, the analysis of the oil and rocks generated by these basins, integrated into the work of exploratory interpretation, create an important competitive advantage for the company in the oil industry. Such geochemical evaluations aim to support the strategies of exploration, production and preservation of the environment, being fundamental to the safe geological definition of project risk and contributing to the maintenance of high rates of success in the wildcats drilling by Petrobras.
“PASS” SYSTEM (1993) AND DEVELOPMENT OF HEAVY LOAD UFCCs

With the increased production of heavy oil from the Campos Basin in the 1990s, technologies to crack 100% of the atmospheric residue from these oils - which require special attention to minimize the formation of coke and combustible gas - were developed. Some of these technological, proprietary and patented solutions were applied in the creation of Petrobras model for cracking residue, PACRC (Petrobras Advanced Converter - Residue Cracking). Among these technologies the high efficiency load spreader Ultramist and the PASS system of rapid separation (closed cyclones) stand out. They are associated to the development of catalysts, help to facilitate the processing of loads with carbon residue of up to 10% by weight. The Petrobras Advanced Separation System (PASS) permits rapid and efficient separation of catalyst and reaction products and avoids the loss of these products to the regenerator. With this, the unit starts to generate more quality products such as LPG and gasoline. First applied in 1993 in Regap the PASS technology is capable of generating a profit estimated at US$ 200 million per year through the eleven units where it is installed. The PACRC, which is the result of a multidisciplinary development, has been deployed in three units of the company (Recap, RLAM and Refap) and amounts to 20,000m³/d of cracking residue capacity.

SUBMERGED CENTRIFUGAL PUMP (1993)

The method of artificially lifting crude oil, based on the installation of a centrifugal pump submerged (BCS) at the bottom of wells, is capable of doubling oil production when compared to wells equipped with a gas-lift, depending on the characteristics of the reservoir producer. The first installation of a BCS in a subsea well in the world was made by Petrobras, at the Carapeba field, in the Campos Basin in 1993. The company currently has about 20 high power systems (> 1000 hp) in operation, producing about 150,000 barrels of oil per day (bopd). The installation of 24 new similar systems is planned, 19 of which will make feasible the production of heavy oil from Papa Terra, Parque das Baleias and Marlim Leste fields, increasing it to 350,000 bopd. With new projects planned, a total of 44 systems will be installed, which can produce about 500,000 bopd, depending on the oil productivity of future wells.
ANCHORAGE SYSTEM (1996)

A submarine docking system, based on the joint use of torpedo stakes and polyester cables, is one of the technological applications that confirms the company’s position as the global benchmark in offshore production. Patented in 1996, the torpedo stakes use the energy of free-fall for its own staking on the seabed. The P-50 was the first platform anchored using such technology in 2006. Currently, there are about 1,400 torpedo stakes installed, with more than 700 on flexible lines, 200 on probes and more than 400 at fixed points in Stationary Production Units (UEPs). The use of polyester cables (more efficient and lightweight material compared to steel) allow anchor in a shorter radius and installation of floating production platforms in deep water.

PRA TECHNOLOGY - PORE REGULATING AGENT (1997)

Patented in 1997, the “PRA” technology is a process of catalyst preparation for FCC (Fluid Catalytic Cracking) with soluble carbohydrate (sugar) for easy removal, which increases its activity and confers porosity adequate for processing more heavy loads. Noteworthy is the rapid development and deployment of the technology in the company’s business, in just three years. Since the first test performed at Regap in 1998, when it was proven to increase conversion and yield of gasoline, its application has been expanded to eight more FCCs in the company and for about 15 years has resulted in a higher profit estimated at US$ 232 million. The excellence in innovation has been recognized by two awards received by the State Government of S. Paulo (2000) and by FINEP (2003).
GRAVEL PACK IN HORIZONTAL WELLS (1998)

The gravel pack system is conventionally used to control sand production during the drilling process in order to prevent migration of sand into the well. The technology was pioneered by Petrobras at the Marlim field in 1998, and was applied over large horizontal wells up to 1200 meters, which enabled control of sand production associated with oil at more than 380 wells. The implementation of this solution allowed the development of several deepwater fields in the Campos Basins and Espírito Santo. Such methodology positioned Petrobras at a level of technological leadership in the field of sand production control.

TOPSIDE OF REPLICANTS (2010)

The concept of replicating the same basic design of a modular plant for different production units within the same scenario is innovative in the oil industry. In that way, the basic engineering work is optimized, becoming more agile. Designs had been created for Floating Production Storage Offloading (FPSO) and transfer of petroleum, for units ranging from the P-66 to P-71, with the same processing plants being built in different factories in modules and integration sites throughout Brazil. The concept was developed to minimize the lapse between the discovery and the start of production in pre-salt fields.
Petrobras has a technological system established for over 25 years which allows
the development of technologies that enable to carry out its strategy plan, al-
lowing the company to be prepared to deal with trends and signs of technologi-
cal changes, at the same time. Cenpes is the unit responsible for conducting re-
search and development at Petrobras, which takes place in a shared manner with
business sectors, who happen to be both customers and users of technologies.
Research and technological development are made with selective involvement
of partners, which are mainly institutions of Science and Technology and nation-
al and international supply companies.

Technological development has its origins in the unfolding of both the Strate-
gy Plan and the Business Management Plan (PNG), as well as in the trends and
signs of changes that are recognized within the business environment. The R&D
projects are derived from a set of processes operated by the following structure
of committees:

• Technology-Orientated Corporate Process, operated by the Committee for In-
tegration of Engineering, Technology and Materials (CIETM), defines the Spot-
light Technologies, Technological Policies, Objectives for Technology Function,

• Technology-Orientated Process for segments, that generates – as from the
guidelines of the Company’s Strategy Plan, Business Management Plan, the
trends and signs of change in the technological environment, as well as prod-
ucts of Corporate Technology-Orientated – a set of prioritized technologi-
cal challenges, grouped in the form of programs and technology with their
goals. The Technology-Orientated for segments is operationalized through
the Technology Strategy Committees CTE, being one for each business sector
(Exploration & Production, Downstream and Gas & Energy). These committees
are comprised of Cenpes, Executive Managers, in conjunction with the Execu-
tive Managers of each business segment.

• Demand Management is the process by which project proposals are prepared
and analyzed, in order to face the technological challenges associated with
each technological program or area and which aims to meet technologies de-
mands of the Petrobras system. This process is operationalized by the CTOs
– Operational Technology Committees, which are organized by issue. Demand
Management can also provide referrals for proposed pre-projects, availabili-
ty of technology projects and assisted technical assistance. At the end, lists
of prioritized projects are generated, with their respective budget within the
PNG horizon.
From 2008 to 2013 R&D projects followed a strategy based on three axes of technological development of the company: Expansion of the Current Petrobras Business Limits, Adding Value and Diversifying Products, and Sustainability in the Energy Industry, which were grouped by technological focuses. At the end of the year 2013 a new review cycle of the Technological Direction was completed, generating new technology focuses, related to the Exploration & Production; Downstream, Transport and Distribution; Biofuels; Petrochemicals; Gas and Energy; Cross Technologies and Sustainability and Future Vision. From the new set of technological focuses, new technological challenges were developed, which guided the choices of technological projects for the cycle that began in 2014. In parallel, during the 2013 2nd semester, there had been a review of the Company’s Technology Management processes, resulting in an improvement to the governance model of the Technological System. The new model, to be implemented from 2014 onward, aims to improve the management of R&D and increase the contribution of technology to business outcomes through an Approval and Monitoring Systematic of R&D Projects.
In 2013, Petrobras invested US$ 1.1 billion in Research and Development (R&D) ranking, in a worldwide scale, among the largest companies to have invested in R&D for the energy field. The management of these resources is coordinated by the Research Center and Leopoldo Américo Miguez de Mello Development - Cenpes - and follows the guidelines set forth in the Company’s Business Management Plan (PNG). Most of this investment is destined to Exploration & Production area, which reflects the distribution of the total financial resources of Petrobras by business area, as foreseen in PNG.
R&D Expenditures at Petrobras

Average 2001/03
US$ 160 million

Average 2011/13
US$ 1,243 million

7.8x

Investments Planned by Petrobras for Business Segment (2014-2018)

Total Investment:
US$ 220.6 billion

Major Energy Companies Investments in R&D, as of 2013 *

* Percentage of investment in R&D in relation to annual net income.
Source: Evaluate Energy, 2014
The complex of buildings that forms Cenpes today occupies about 300,000 square meters, in University City, located at the northern region of Rio de Janeiro City. Inside its facilities of innovative architecture, with advanced eco-efficiency criteria, there are over 200 laboratories, experimental plants and the Center for Visualization and Collaboration (NVC) - which is used for studies in three-dimensional simulations.

In addition to the Rio de Janeiro facilities, there are five other experiment centers located near to business-related areas. At these centers, tests are conducted on a semi-industrial scale, a process fundamental to the scaling of technology and its future availability for use by the company.

In its research and development procedures, Cenpes had 1,959 employees at the end of 2013, being 241 PhD, 477 Masters Degree holders and 628 college graduates, as well as 613 technicians in laboratories and pilot plants.

Besides having their own infrastructure and personnel, Petrobras also has several partners that complement the resources necessary for carrying out its R&D activities.

In recent years, Brazil has become attractive to many suppliers of goods and services in the energy industry. With new opportunities in the domestic market, especially with the application of new products and solutions in the pre-salt region, companies are interested in generating local technology through centers of captive research and also in partnership with national institutions of Science and Technology (ICT’s), encouraged by the investments of the sector.
Some of these companies settled their research centers down at the UFRJ Technology Park in University City – a region strategically close to the Petrobras Research Center. Schlumberger, one of the biggest providers of specialized services in exploration and production in the world, was the first to open its research center in 2010.

In the following years, also moved into the UFRJ Technology Park, Baker Hughes, whose research focus is the optimization of production in deep-water and pre-salt reservoirs, as well as FMC Technologies, with its research center and experimental plants aimed at the development of subsea production and processing of oil and gas.

In 2013, another Petrobras’ associate supplier, Halliburton, has also opened its research center to develop technologies for exploration and production of hydrocarbons in deep water, also with emphasis on pre-salt. Another line of research will be based on the studies of drilling and completion of wells, reservoir characterization and production efficiency. Besides these companies, new facilities are planned for the ensuing years, such as General Electric and BG Group, both of which in 2014 will inaugurate their respective research centers in the UFRJ Technology Park.

Petrobras also has a wide network of collaborators, working in partnership with more than 100 universities and Brazilian research institutions through 49 thematic networks. In December 2013, Petrobras owned 954 terms of technological cooperation with 88 Brazilian institutions of Science and Technology. In 2013, US$ 266 million were invested in universities and national institutions, destined for Research & Development (R&D) projects, training of technicians and researchers and expansion of laboratory infrastructure.
In this report, we present some of the principal technology outcomes obtained during 2013 in both Research & Development and Basic Engineering activities. These outcomes are arranged according to three main axes of technological development of the company: the expansion of the current Petrobras business limits, adding value and diversification of the company’s products, and sustainability in the energy industry. To disclose them, Petrobras presents to its investors and partners some of the trends in which investments are made to ensure the sustainable growth of the company.
EXPANSION OF THE LIMITS

This axis comprises all projects for the expansion of conventional Petrobras business: exploring new frontiers; production optimization; pre-salt production; subsea production systems; unconventional reservoirs; natural gas logistics and commercialization; integrated operations logistics; supply and export of oil and derivatives; and refining pre-salt oil and rendering the refining park more flexible.

Next, are presented the results of the researchs dedicated to seeking new techniques and methods, besides the constant improvement of our processes in order to maximize business results.
From the test planned by Petrobras and performed in a pre-salt well, followed by laboratory tests and numerical modeling, it was possible to evaluate the chemical interaction between the reservoir rock (carbonate) and the injected water and check that the water produced in the polo pre-salt fields of the Santos basin will be less acidic than originally predicted. Thus, the effects of corrosion expected were also reduced. Hence, Petrobras could select a less noble metallurgy – like super-martensitic stainless steel instead of super duplex – for the next generation of non-injector pre-salt wells. The economy is conservatively estimated, at US$ 188 million for pre-salt development projects, considering only the cost of materials for wells.

Economy in the selection of materials for the pre-salt production wells

Schematic of a Polo pre-salt well producer, with application of stainless steel super-martensitic (SCR 13%) in the production column
Illustration: M Quatro Design
The lifting method employed in the Serraria field, located in the production-asset of Alto do Rodrigues, which belongs to the Operating Unit of Rio Grande do Norte and Ceará (UO-RNCE), is the mechanical pumping, greatly affected by scale, resulting in production downtime and need for intervention to exchange pumping equipment. In this field a pilot was performed in order to evaluate the performance of magnetic devices in the prevention of the formation of inorganic scale. The data collected pointed out a good performance from the magnetic device technology (DMA), developed domestically, which have been allowing the continued well operation in which it is installed, since August 2012. The average time between failures of the well before installing the equipment was 133 days, and after having the DMA installed, three well interventions have been avoided during 2013, as well as all declines in production thereof. The positive results obtained with the domestic DMA equipment in this well saved about US$ 185,000 and its application in pre-salt is being studied. Laboratory tests will be conducted under representative conditions using equipment mounted at the Institute for Technological Research-IPT and at UFRJ.
Applied in the Campos Basin, for the first time in the world, electro hydraulic bottom-well disconnection tool (WDT - Wet Disconnection Tool)

This tool, developed by the Halliburton-Petrobras partnership, can reduce by at least 20%, the intervention-time for replacing the column production in wells with intelligent completions compared with other interventions that don’t use this tool. Additionally, by reducing the number of operations on the critical path of intervention, it provides greater reliability and prevents these transactions from losing both control and monitoring of the well. This 3 ½ inches tool, has been tested as of January 2013, in the Carapeba field, located at Campos Basin. The intelligent completion requires the installation of various well monitoring sensors and valves with remote actuation in order to control the flow, either produced or injected. Since the electrical and hydraulic lines of this system can be damaged during removal of the completion columns for maintenance, to avoid this kind of damage, the WDT acts as a connector that divides the column into two parts, allowing a disconnection and reconnection of the top part and control lines that pass through it without the need to intervene at the bottom of the column, avoiding the inherent risks to this stage of the intervention. Besides teaming up with two other suppliers to develop it, Petrobras is adapting and qualifying the tool with Halliburton for the use in the pre-salt fields, where there are more severe conditions, such as higher levels of pressure and risk of scale. The application in the pre-salt of a 4 ½ inch tool by three suppliers (Halliburton, Baker Hughes and Schlumberger) is scheduled for mid-2017 and should be conducted in the Franco field.
MPD/MCD technology enables well drilling in Franco, reducing to zero the time wasted due to circulation losses

The well drilling in the Franco field was successfully completed in October 2013, using MPD/MCD (Managed Pressure Drilling/Mud Cap Drilling) technology. The application generated both a reduction of about seven drilling days and a US$ 7 million savings. The goal was to reach the 5788 meters depth pre-salt carbonate reservoirs. Due to the high risk of severe circulation losses during drilling of the reservoir, the use of MPD/MCD drilling technology was mandatory. This technique is recommended to mitigate operational risks during well drilling, with both post-salt and pre-salt objectives, with narrow pressure range. This was the first Latin America MPD operation in pre-salt and deep waters from dynamic positioning unit. By 2018, it is expected the drilling of 129 wells with this technique, in both exploratory and development wells, located at Santos Basin pre-salt polo (PPSBS), as well as in Equatorial Margin, Campos Basin and Espírito Santo Basin.
It had been possible to anticipate, in about five months, the uncertainty analysis for the Marlim Sul field thanks to the development of a new technique for historical adjustment stage in geological models and flow simulation in reservoir. This technique, based on Kalman filtering, is commonly used by meteorological and oceanographical science and was successfully adapted for production forecast systems of oil fields. The new technique allows the incorporation of fast forms, data on field production models, generating more reliable production forecasts. The system was also applied to history adjustment of the Jubarte field.
**Probe usage is reduced through the automation of monitoring the performance of drilling activities**

Through the use of automated monitoring sensors in 12 probes for a period during which two thousand connections were performed per probe on a monthly basis, it was possible to analyze the performance of each of them. In order to perform such analysis, a software called ProNova, from TDE company, was used for this analysis. This study supported the definition of the most effective type of probe and operating procedures, resulting in a 10.8% time reduction, measured between the placement of the wedge (a tool that supports the drill column during a connection) and its removal (time from wedge to wedge). In a given month of measuring, probe time was reduced by five days, which equates to approximately US$ 5.25 million, compared to the same month last year. Currently, 30% of the fleet is accompanied by the tool, which has received US$ 3.23 million of investment. The forecast is that in 2014, 100% of the fleet will be monitored by the control system.

**Redesign and qualification of EPR connectors system for long-term tests**

A multidisciplinary team from Petrobras and Weatherford conducted extensive work on the redesign and qualification of the modified solution for the threaded connectors of the Early Production Riser System (EPR), which is being used in long-term tests (LLT) in the area of Central Lula, in the Santos pre-salt Basin. In most fields of the pre-salt Santos Basin, the oil produced is rich in carbon dioxide (CO₂) and hydrogen sulfide (H₂S), forming an aggressive environment to the material used in this type of connector. This environment, in contact with areas of concentrated stress within the connection, causes the occurrence of cracking of the material, leading to breakage of the connector. The redesign prevents the access of aggressive fluids inside the connection, blocking one of the root causes of failures. The modified connector represented a solution without significant additional cost and no impact within the LLT. Modified by the system operator, Weatherford, new connectors have been qualified within the expected timeframe and are in operation in the LLT in well LL7 of Central Lula.
Optimization of the operations of scale-inhibitor pumping with Remote Operations Simulator (ROS)

The graphics on the right represent letters of flow and pressure provided by the ROS for a remote pumping operation in the Campos Basin. Illustration: M. Quatro Design

The pumping operation of the inorganic scale-inhibitor solution, in the post-salt well, was conducted in accordance with optimization simulations performed with the Remote Operations Simulator (ROS) developed by Petrobras. The optimization of the operation has tripled the pumping flow, having reduced pumping time from 27 to 9 hours with stimulation boat, generating a US$ 37,500 savings. Additionally, the reduction of production loss caused by intervention generated an anticipation revenue of approximately US$ 696,000. The use of the ROS tool to optimize operations can increase vessels availability and therefore reduce wasted probe time. The positive results show that ROS tool can bring substantial benefits to the company, which has motivated its use for optimization of future operations of inhibition or scale removal by Petrobras.
Application of new methodology in pre-salt for predicting risk of fracture formation during water injection

Methodology developed by Petrobras and applied in a pre-salt well allowed to predict the risk of fracture formation, to recommend reducing the flow of water injection and to indicate the best area for reservoir injection. For this, relevant parameters that directly influence the emergence of fractures, such as thermal effect created by the contrast between the temperature of the injected water and the reservoir, the variation of geomechanical parameters and different levels of water injection flow were incorporated into Propag programs developed by Petrobras in partnership with the State University of Campinas (Unicamp) and Pfrat, created by Petrobras. This methodology has already been applied in the Marlim and Marlim Sul fields in the Campos Basin, having predicted the appearance of fractures for high levels of flow injection, which were also reduced. Petrobras, in partnership with the State University of Campinas (Unicamp), Pontifical Catholic University of Rio de Janeiro (PUC-RJ) and Federal University of Pernambuco (UFPE), is developing a complex simulator, which integrates geomechanics and reservoir simulation, with completion scheduled for late 2015.
Increased flow and uniformity of flow to Jubarte wells

Based on previous study conducted to the Baleia Anã field in the Operating Unit of Espírito Santo (UO-ES), in which it was noted the great influence of the increased diameter of the sand containment screens in the productivity index (PI) of the wells, UO-ES requested a similar study to the Jubarte field. The results showed an expected average increase of about 10% in the IP of the analyzed wells. Taking as a basis the productivity of the wells of the field, the production gain corresponds to a gross financial gain of about US$ 700,000 per day. This increase in flow, from the economic standpoint, would cover additional cost entailed by installing larger diameter screens. It was also performed, such as the Baleia Anã well, a study of flow uniformization in three wells of the Jubarte field analyzed by using diversionary drilling. This technique was developed in Petrobras and has been successfully used in other fields operated by the company. Diversionary drillings were designed for screens which will equip three horizontal wells in Jubarte Field considered in this study. It is expected, with the diversionary drilling, to promote a delay in producing waster through the well, increasing thus its useful life.
The SEEDS program allows a quantification and minimization of the exposure time to hazardous conditions in the event of an emergency disconnection, allowing a proper choice of the probe that will execute the well. The program is already being used by Petrobras, contributing to identify improvement opportunities in the probes fleet and reducing the possibility of catastrophic events (blowout), which can harm the environment and can damage both property and the security of the crew. The SEEDS program – well construction schedule generator with EDS (Emergency Disconnection System) selection – automates and accelerates the generation of the document that contains the recommendations, standards and schedule of well construction operations, thus contributing to a better knowledge management and training of personnel in key issues related to well security. Petrobras, along with Inteli, coordinated the project and developed models of well operations sequencing and the choice of EDS.
Pioneering laboratory study, in the conditions of the Lula field, confirms potential for increasing the recovery factor by applying the Water Alternating Gas (WAG) injection method

Tests performed at the Petrobras Research Center indicate that the technique called Water Alternating Gas (WAG) injection method has the potential to increase the recovery factor in the pre-salt fields. By using fluids samples from the Lula field, in the field original conditions of pressure and temperature, an increase in oil recovery was observed in the laboratory compared to the value obtained with continuous water injection, which is the conventional method used for improving recovery of the field. These results reinforce Petrobras’ strategy to use the WAG method in pre-salt. This method is based on the injection of waves of a gaseous or supercritical fluid, preferably miscible with the oil, alternating with water waves, to ensure higher efficiency of displacement of the injected fluid. There were doubts about the behavior changes during injection cycles (water / gas), which were also clarified by laboratory tests, which increased the reliability of the method. The equipment used for testing, which is unique in the world oil industry, can simulate all operations involved in the WAG method in actual reservoir conditions, which will allow Petrobras to invest with greater confidence in this method, both in relation to the earnings recovery and to the operational issues.
Test with an FCC (Fluidized Catalytic Cracking) innovative technology allows the processing of heavier loads

FlexCool technology tested in the FCC at Presidente Bernardes Cubatão Refinery (RPBC), reduced regenerator temperature and consequently allowed the increased processing of atmospheric residue (AR), the oil heavy fraction, from 2,000 to 2,450 m³/d. In consequence of the higher processing of AR in the unit, it is possible to increase the production of diesel and reduce the production of fuel oil at the refinery, generating a potential gain of US$ 19.5 million per year.

The company FCC S.A (Fábrica Carioca de Catalisadores S.A), which launched the technology in the Latin American market with the name FlexCool, provided the product for field testing in RPBC and has produced more than 1,000 tons of it. Previously tested on a laboratory scale, pilot plant and demonstration plant SIX, the technology allows FlexCool to absorb the increase in temperature of the regenerator caused by processing a heavier load. New tests will be performed to prove the effectiveness of this new technology in other Petrobras refineries that have restrictions on the regenerator temperature, as is the case in the commercial test at Landulpho Alves Refinery (RLAM), whose completion is expected by the end of 2014.
Development of a model for integrated planning of São Paulo refineries

The model combines the production plans of the four refineries in São Paulo: Paulínea Refinery (Replan), Henrique Lage Refinery (Revap), Presidente Bernardes Refinery (RPBC) and Capuava Refinery (Recap), in an integrated plan that incorporates existing logistics networks between them and considers the market to be served in order to optimize planning decisions of the refineries together and maximize the overall result. Developed by Petrobras, the model considers the assumptions set forth in the Downstream Plan (Planab) for input and output of oil and its finished products in the region and allows identify and detail existing synergies between the refineries. Thus, decisions and adjustments are anticipated in planning of the production and movement, making it possible to predict and solve contingencies that affect regional production, establishing oil and its finished products supply logistics, taking into account economic criteria.

Implemented in the area of São Paulo in October 2013, the integrated plan was developed as part of the Production of Middle-Distillates and Gasoline (Promega) Program and generated, in the first month of use, a profit of US$ 3.4 million. It is expected that the methodology will also be applied in the Northeast region when the Nordeste Refinery (RNEST) comes into operation and the integration with Landulpho Alves Refinery (Rlam) and Potiguar Clara Camarão Refinery (RPCC) is made possible. In the southeast region, it is expected that production plans between Rio de Janeiro and Minas Gerais are integrated from the inauguration of the Rio de Janeiro Petrochemical Complex (Comperj), which will then be integrated into the Duque de Caxias Refinery (Reduc) and the Gabriel Passos Refinery (Regap).
Technologies applied in Atmospheric Distillation Unit increase the efficiency of desalination of pre-salt oil

The technologies implemented in the desalination unit at the Capuava Refinery (Recap) - internal brine recycle, fresh water reuse and injection point of dilution water variation - generated higher efficiency in the desalination process with a 75% reduction in chloride content of the top atmospheric vessel. These solutions were consolidated by Petrobras in the basic design developed for the unit, which works as a pilot for evaluating technologies that are being tested for optimizing systems that desalinate pre-salt oil. Until the second semester of 2014 the project will also select the mixing device and the pressure variation most suitable for more efficiently mixing water and oil in the desalination process and thereby further reduce the concentration of chlorides in the desalted oil.
Study development for selecting an alternative to adapt Mexilhão Platform (PMXL-1) in order to allow the outflow of 10 million m³/d of gas from pre-salt fields (ROUTE 1)

Petrobras has developed a study to select the best alternative to adapt Mexilhão platform (PMXL-1) in order to enable drainage of 10 million m³/d of gas from the pre-salt fields (Route 1), besides analyzing opportunities for adjusting this pre-salt drainage route. In order to achieve this, the alternatives identified for the adjustment of the PMXL-1 platform were qualitatively evaluated, meeting the requirements for safety and operational flexibility. This study provided information on the selection of an alternative for the later stage of FEL 2 (Front-End Loading or definitional requirements of a project).
Hull structural analysis presented in conversion projects of four VLCC (Very Large Crude Carrier) ships to be used in future Production Units (UEPs) from the Onerous Transfer of Rights Agreement, guaranteed, in a shortest amount of time, an increased reliability and structural integrity of the hull with less exchange of lower steel plates than that initially planned. In the P-75 platform, two thousand tons of steel were saved, the equivalent to US$ 16.2 million. For these analyses, it had been necessary to consider wave conditions more severe than those found in the Campos Basin. The consortium Indústria Naval, winning bidder who will perform the conversion, is implementing the necessary changes identified in the structural analysis. Petrobras is still working on the hulls of Floating Production Storage and Offloading (FPSO) in order to further reduce the use of materials. The converted P-75 and P-77 hulls are scheduled to be delivered on the second semester of 2015.
Reduction of 25% in manufacturing cost of anchor stakes for 15 production units

The new alternatives to torpedo stakes replace the mixed ballast (cylindrical block that ensures penetration into the soil, composed of lead and pig iron) with pig iron ballast, reducing the final cost by 25%. This cost reduction in scale represents huge savings for the company, since the new torpedoes will be used in 15 production units, being: eight replicating Floating Production Storage and Offloading (FPSO); four FPSO’s used in the Onerous Transfer of Rights Agreement, as well as the FPSO’s: Cidade de Itaguaí (Iracema Norte), Cidade de Maricá (Lula Alto) and Cidade de Saquarema (Lula Central). In each one of these units, 24 torpedoes will be installed. Geotechnical, hydrodynamic, structural, logistics and lifting were analyzed to ensure operational feasibility of type T-98 and T-120 torpedoes, with new material. The tube diameter, the ferrule and the pig iron ballast were standardized for both solutions, having their length altered in order to maintain the original stakes performance. DELP, winning bidder, manufactured a prototype of the new T-120 model, which will be tested with the lease of the pre-salt production unit of FPSO Cidade de São Paulo (Pilot Sapinhoá). The T-120 solution will be applied to the 15 units listed above, while the T-98 torpedo will be applied in long-term tests (LTT).
Laboratorial Development and selection of oil antifoam in order to increase the hydrotreatment (HDT) time in the refining units

Petrobras conducted the development and selected in the laboratory 16 oil antifoam with up to 72% less silicon in their composition. Some of these products have been field tested and showed the same efficiency as those currently used by the company. Silicon is one of the main agents responsible for the poisoning of the catalysts of Hydrotreating Units, shortening the lifetime of these units at the refinery. In a refinery such as Henrique Lage (Revap), it is estimated that the reduction in lifetime of one of the HDT units can result in a loss of profit of about US$ 46 million. The bidding for a product of lower silicon content in the Campos Basin Operating Unit (OU-BC) presented a cost reduction of 21% with the purchase of antifoams, generating a US$ 649,000 savings. The results presented at UO-BC motivated other Exploration and Production Operating Units in the Southeast region, to begin switching their antifoams for these products selected by Petrobras. It is estimated that by the end of 2014 all operating units of this region will have adopted products with lower silicon content from Bluestar and Dow Corning, the companies that won the bid for the Southeast, which will allow a reduction of 30% of the product price and savings of US$ 9.3 million for E&P. Petrobras will continue testing new suppliers in order to ensure competitive prices in the market.
Installation of the first Wet Christmas Tree system (WCT) with standardized interfaces at Sapinhoá and Northeast-Lula fields, in pre-salt wells

Petrobras has standardized the set of interfaces and connections of the equipment that make up the WCT system at Sapinhoá and Lula Nordeste fields, in pre-salt wells. This allows the use of interchangeable devices, enabling the involvement of several manufacturers in providing the same type of system. Thus, Petrobras gains flexibility in installation, operation and maintenance of underwater equipment. It also reduces costs by increasing competition and the availability of tools, which generates savings and convenience to the development of pre-salt wells. The pre-salt well WCT was created for 2,500 feet deep scenarios and a maximum of 10,000 psi pressure rating. The project had a pilot with the same type of equipment installed in the Lula field pilot and currently operates at eight wells. The main innovations of WCT at the Sapinhoá and Lula Nordeste fields are: column suspension interfaces, vertical connection modules with higher mechanical strength, equipment compaction for operating with the new pre-salt probes, qualification of new metal-metal and elastomeric, seals for high CO₂ concentrations, and qualification of new subsea connectors, among others. Around 180 new sets of pre-salt WCTs are being manufactured, which may be used in scenarios with the same conditions of pressure, of depth and of characteristics of the fluid produced whose class of equipment specification is met. Types of monitoring that will assist in the equipment installation and operation are also being developed.
Geochemical characterization of pre-salt oils and gases helps identify promising areas for exploration in the Santos Basin

The integrated analysis of geochemical oil, bitumen and gas data from about 80 wells in the pre-salt Santos Basin allowed the characterization of four petroleum systems responsible for the accumulations discovered to date in this region. The scenario of generation, migration and accumulation of oil, built from this data, was quite detailed, allowing the inference of possible hydrocarbons migration routes from the source areas towards the traps, where they accumulate. The integrated use of data from geochemical, geological and geophysical sources promotes continuous improvement of the understanding of the active petroleum systems in the area, aiming to identify prospects for lower exploration risk. This information is strategic to the business decisions of the company in future bids in the pre-salt region.
Main results of the Program for Production of Middle-Distillates and Gasoline (Promega)

The Program for Production of Middle-Distillates and Gasoline (Promega) aims to increase the production of middle-distillates (diesel and jet fuel) and gasoline from the current Refinery Park, based on increasing both the capacity and the efficiency of process units with low investment, reducing the import of derivatives and increasing the margin of Petrobras. The goal is to increase the daily production in 80,000 barrels of gasoline with and in 160,000 barrels of middle-distillates by December 2015.

To achieve this goal, Petrobras analyzed their process units to identify and eliminate chokepoints. The Petrobras Contributing to the results of Promega through the development and introduction of new technologies. Cepes already performed 30 different projects and several optimization initiatives in refineries.

Created in June 2012, Promega has already achieved significant results, increasing average gasoline production by 41 thousand barrels per day and diesel fuel by 81 thousand barrels per day, and has expanded refinery capacity by 69 thousand barrels per day as well as has used this capacity by 177 thousand barrels per day.

SUMMARY BY TECHNOLOGY FOR MAIN PROJECTS IMPLEMENTED

**DISTILLATION**

13 projects related to units adaptations, in order to increase the load to be processed, have been completed; the heat recovery in the preheating batteries have been increased, reducing power consumption in the furnace; desalters that process oil from pre-salt have been adjusted and fractionation have been improved, in order to increase the distillates production.

*Left Photo: Increased heat recovery in the Revap preheating batteries, reducing energy consumption in the furnace*

*Right Photo: Adequacy of Revap desalters, which process oil from the pre-salt*

*Photos: Deisi Spricigo (Jun/2014)*
DELAYED COKING

Three projects were completed related to improving energy efficiency, which will provide better heat recovery in batteries in preheat projects, reducing energy consumption in furnaces.

Replan Coke Unit is one of the units that received energy efficiency improvements
Photo: Marcos Perón (jul./2011)

FLUID CATALYTIC CRACKING (FCC)

Five projects were completed regarding the adaptation of the loads dispersers, to allow increased load to be processed and improvements in fractionation, and increase the recovery of gasoline and other products.

Adaptation of load disperser at Recap
Photo: Petrobras Image Bank (jul./2014)

HYDROTREATING (HDT)

Nine projects were completed related to replacements of internal parts of the reactors, which allows the performance improvement of hydrotreating units and adaptations of units to increase the load to be processed.

Replacements of internal reactors in Repar
Photo: André Valentim/Petrobras Image Bank (oct/2012)
In this axis, the projects aimed at expanding the diversity of energy sources and the products portfolio offered by Petrobras are outlined. Including the constant search for quality and performance in the development of new fuels, lubricants and special products; petrochemicals; ammonia and urea, used in the field of fertilizers; the development and improvement of biofuels and bioproducts; generation of energy from thermoelectricity and other renewable sources.
Automatic control of pH for the production of biodiesel

Installed in the Darcy Ribeiro Biodiesel Plant in Minas Gerais, the automatic pH control for the transesterification unit, when compared to the foreign technology used until then, will avoid a series of estimated annual expenditures, of US$ 463,000, in a lump sum. Among the benefits provided by the technology is: the reduction of repair, or replacement, of both equipment and piping, which suffered corrosion in high acidity environments; a reliability gain with the increase of the number of operating hours per year; a lower consumption of hydrochloric acid; a lesser demand for operational oversight and a reduction in losses of biodiesel production. Automatic control anticipates the characteristics of the currents to be neutralized, acting preventively in pH correction. The foreign technological used previously forecast an automatic operation, but it actually demanded constant adjustments and controls, with production halts and consequent economic losses. With the results achieved, Petrobras Biofuel already studies the necessary adaptations for deployment in other units. Automatic control has been installed in the Biodiesel Plant at Quixadá, in Ceará and should be implemented in two units of the Biodiesel Plant at Candeias in Bahia.
Development of new formulation for Podium S-10 diesel

A new additive package was balanced, based on S-10 diesel and in the addition of 10% (by volume) of biodiesel, for use in a new formulation of Podium S-10 diesel. With its proven performance in laboratory trials and tests on vehicles and engines, both in Brazil and abroad, the formulation developed, compared with regular diesel fuel currently sold, has a higher oxidation stability, which provides greater compatibility with engines with P-7 phase technology of the Air Pollution Control Program from Motor Vehicles – Proconve. A new generation of detergent/dispersing additives also gives a high detergency, to a level never before practiced by the company that reduces in up to 44% deposits on engines’ fuel injectors. Additionally, the optimization of cetane improver, the most expensive component of the package, allowed a cost reduction of up to 27% with additives.

The Implementation of an advanced control in urea production unit ensures greater energy efficiency

It is the first application of advanced control in a Petrobras urea production unit, in order to reduce process variability, maximizing the production of urea and energy efficiency. Deployed at the Nitrogenous Fertilizer Factory of Bahia (Fafen-BA) in September 2013, the system ensures constant monitoring of the plant through mathematical models developed especially for the unit, rejecting disturbances and respecting the constraints of the process. In an specific performance of this advanced control in the unit, preliminary results showed a 2% increase in energy efficiency, after a reduction in steam consumption per unit of urea produced. Currently, the unit produces around 1500 tons of urea per day and the advanced control system helps maintain maximum possible production. Since 2012, the system has been operating in the ammonia unit, one of the raw materials for urea production, also in Fafen-BA. The advanced control system is also being implemented in the ammonia unit at Sergipe Fertilizer Factory, with completion scheduled for 2014.
Performance tests attest the benefits of S-50 Gasoline

Some tests conducted by Petrobras proved that S-50 Gasoline promotes lower deposits formation on intake valves and in the combustion chambers, as well as reduced emissions of some legislated and not legislated pollutants, especially in newer vehicles, approved according to the criteria set for the L-6 phase of the Program designed for Control the Air Pollution caused by Motor Vehicles (Proconve). Among the legislated vehicle emissions, a reduction of nitrogen oxides (NOx) emissions by up to 59%, carbon monoxide (CO) by up to 46% and unburned hydrocarbons (NMHC) by up to 55% compared with common S-800 gasoline previously commercialized. In addition to the environmental benefits, the new gasoline has higher oxidation stability, extending the catalyst’s useful life and promotes the low deposit formation inside the engine, which contributes to obtaining the best performance of the vehicle. To produce the new fuel, about US$ 9.5 billion has been invested over the past seven years to build 21 units in the company’s refineries. Petrobras conducted the assessment of the pool of gasolines that came from different refineries in order to ensure compliance to the specification of automotive gasoline in 2014, identifying the best options to suit the gasoline production to new quality requirements.
Evidence of the technology to produce Arla-32 from solid urea close to major consumer markets

Arla-32 (Flua brand of Petrobras) is a reagent produced by Fertilizer Factories, which consists of a urea solution of 32% in water. It is used in the exhaust system of vehicles with diesel engines that conform to the Program designed to Control the Air Pollution caused by Motor Vehicles (Proconve P-7). It is used in conjunction with specific catalysts for abatement of nitrogen oxides (NOx) present in exhausts of these vehicles. Bench testing of the new process technology has demonstrated the feasibility of eliminating 100% of biuret, a by-product of the process of urea production that needs to be eliminated for the fabrication of the Arla-32 reagent. The development of this new removal process allows the dissolution of the solid urea in water – the manufacture of Arla 32 itself occurs close to consumer markets. Thus, urea can be transported in concentrated solid form to the consumer markets, with a significant reduction of the logistics cost. The removal process development was conducted in partnership with the Institute of Chemistry, State University of Rio de Janeiro (Uerj). By the second half of 2014 the process will be validated on an industrial scale, in the Bahia Nitrogenous Fertilizer Factory (Fafen-BA), and the technology evaluation for other applications such as removal of other substances and their application within the urea production process.
Fluctuations in electric voltage can occur both in industrial units and electrical systems that interact with eolian generation, due to the intermittence and random intensity of this type of generation. Petrobras has developed a Dynamic Reactive Compensator (christened Statcom-BR) in partnership with the Federal University of Rio de Janeiro (UFRJ) and has installed it for testing and evaluation in a Petrobras’ experimental Eolian Plant in Macau / RN, which has an interface with operational unit of Rio Grande do Norte and Ceará (UO-RNCE). The equipment prevented voltage fluctuations, caused by intermittency in eolian generation, from bringing about power outages and damages to equipments connected to the local network. Besides avoiding production halts, mainly in the Macau-A and Serra fields, the prototype has also reduced expenditures related to the electricity purchase, that supplied regional fields, whenever the voltage fluctuations put the eolian plant to a halt. By 2016 new features will be evaluated, such as the implementation of remote control functions that will remotely operate the equipment, as well as will assure its operational continuity. The increase in the reliability of this generated energy, as well as the operational continuity of plants connected to it, legitimise the feasibility studies of the Statcom-BR application in other Petrobras’ units.
First Anemometric Tower Installation in Brazilian marine environment

Eolian generation potential is typically gauged using anemometric towers, which are metal structures, measuring between 80 and 120 meters tall and containing instruments capable of measuring the wind conditions. Petrobras has over 40 airspeed towers installed throughout Brazil. In 2013, the first anemometric tower was installed in the marine environment of the country, in, to measure and evaluate the winds, aiming to generate electricity. This 80-meters tall tower was installed on the PAG-2 platform, located at 20 kilometers off the coast of Guamaré, in Rio Grande do Norte (RN).

Equipped with anemometers (which gauge wind speed), windsocks (which shows wind direction), barometers and thermo-hygrometers, the equipment will allow Petrobras to verify the offshore eolian potential of regions in Brazilian territorial waters and thus prepare technical and economic studies to evaluate power generation at sea. This tower will still enable to profile wind speed, which consists in an important factor to define how tall the wind turbines will be, an issue that causes a significant impact on the installation cost of future plants. Preliminary results indicate that producing energy offshore could surpass onshore production, even when using the same amount of power. Besides evaluating the potential for local eolian generation, the results presented over an year-long comprise an atlas of eolian potential of the Rio Grande do Norte coast and will verify the gain in relation to towers located on land. Anemometric data also serve to validate a portable measurement technology of eolian parameters, known as Lidar (Light Detection and Ranging), installed at the tower on the PAG-2 platform and represents a new methodology for measuring eolian potential. If approved, this technology will be applied on other parts of the coast. This project is developed by Petrobras in partnership with the Center for Gas Technology and Renewable Energy (CTGAS-ER).
The Mixed Fertilizer Pilot Plant (PPFM), installed at the Nitrogenous Fertilizer Factory of Sergipe (Fafen UP), is a Petrobras’ Research and Development facility that produces urea based nitrogenous fertilizers, containing other components in its formulation for tests of new higher added value fertilizer products. The first fertilizer batches with elemental sulfur and urea, or ammonium sulfate in the formulation were produced, as well as micronutrients such as boron, copper and zinc. These batches will be used in agronomic trials conducted in partnership with Embrapa, up until 2016, in the Northeast region of the country, in crop products, such as sugar cane, corn and cotton, to evaluate the performance of these new fertilizers and allow the recording of future new Petrobras fertilizer products. PPFM processes 500Kg/h, and uses innovative mixed fertilizers technology that provides and develops differentiated products with higher added value of urea, generates more uniform pastilles and provides a more homogeneous soil fertilization. It is estimated that the technology for making pastille mixtures, patented by Swedish company Sandvik, may represent a 30% production costs reduction in, compared to traditional granulation. By the end of 2014 more resistant materials will be selected for the production unit and the possibility of a future industrial unit will be assessed. Currently, Petrobras, the sole urea producer in the country, has three plants for urea production: in Laranjeiras (SE), Camaçari (BA) and Araucária (PR).
Development of high-tech coating for repairing thermoelectric plant gas turbines

Critical components in gas turbines are manufactured with metal coating with ceramic alloys to withstand the high temperatures inside these devices and require eventual repair to maintain the availability and reliability of Petrobras power plants. A new ceramic alloy, developed by Petrobras in partnership with the Institute of Technology for Development (Lactec), Federal University of Paraná (UFPR) and Federal Technological University of Paraná (UTFPR), is composed of different rare earths metals and chemical elements abundant in Brazil. Laboratory tests proved that, when compared to traditionally used materials - mainly Zirconia and Yttria, the inclusion of new elements resulted in an increase in resistance to high temperature in coatings for turbines used in power generation. Allied to this development, technology for the application and removal of ceramic and metallic coatings on turbine blades was successfully tested, located in an area with high temperatures (above 1100°C) and subjected to oxidation and corrosion of the material. High temperatures are directly related to the efficiency of the turbines, so that increasing strength of the material is an opportunity to increase the equipment’s efficiency. These developments are fundamental for Petrobras to dominate the maintenance technology of these equipments, thus, avoiding a delay of up to one year in shipping and receiving materials that have been sent for repair abroad. Applied to the blades, it is estimated that the new alloy will be tested in real conditions in a turbine by the end of 2015.
The Research and Development (R&D) projects included in this axis intersect those projects developed in the other two axes, aiming at sustainability in all of Petrobras products and processes. The goal is to mitigate potential impacts that may be neutralized or even turned into positive environmental and economic outcomes, with the conversion of waste and emissions into inputs that create value for the industry. The Water and effluents management, including CO₂ and other emissions, as well as projects for improvement of energy efficiency, R&D initiatives in the area of biodiversity and the search for solutions in the area of integrity, safety and reliability are included in this axis.

*Humpback whales in the Abrolhos National Park, south of Bahia. Thanks to the actions promoted by the Humpback Whale Project, sponsored by Petrobras, the cetacean that names the project was removed from the endangered species list.*

Photo: Petrobras Image Bank
Particulate material gauge in the turbo
generator located at a Catalytic Cracking Unit in
Fluidized Bed

The data generated by the new method and equipment developed by Petrobras helped diagnose the impact of the concentration of catalyst fines (microparticles derived from the catalyst breakdown which are not retained in the cyclones located at the industrial unit of Catalytic Cracking Unit in Fluidized Bed - UFCC-2) in the electricity generated by the turbo-expander. With this diagnosis, in order to double the power output, reaching 25 MW, the equivalent of spending US$ 21 million/year on the purchase of this energy by Landulpho Alves Refinery (RLAM), some necessary adjustments were performed. Until then, the measurement was not performed due to the risks involved in the execution, which happens at a temperature of 700ºC and at a pressure of 2.3 kgf/cm². The equipment can also be used in the refining units that are operating near the limit of emissions determined by the environmental agency, as it aids in the diagnosis of the FCC system to reduce particulate emissions. This equipment was developed in partnership with technicians and researchers of the Experimental Center of Refining Technologies, located on the SIX in São Mateus do Sul.
Probability definition for cyclone occurrences in the Santos and Campos Basins and confirmation of safety engineering parameters used at Petrobras

Petrobras has compared the parameters of winds used in technical specifications of the company’s engineering projects with the likelihood of extra-tropical cyclone occurrences and has confirmed the security of these values even in extreme tested scenarios – in case the predicted winds magnitude is maintained. Some research conducted have showed that, on a monthly basis, these events are less than 10% likely to occur and are distributed in a kind of evenly manner throughout the year, reaching an average of 14 cyclones in the Santos and Campos basins. In partnership with the Laboratory of Mesoscale Forecasts of the Rio de Janeiro Federal University (LPM / UFRJ), some climate information have been used and some data were generated by the use of numerical modeling to predict the origin and path of extra-tropical cyclones.
Qualified repair with composite materials in pipelines with dented weld

Petrobras conducted fatigue tests on pipelines with dented weld in order to evaluate the efficiency of composite material in the repair process. While the conventional process (dual-rail welding) requires high security parameters with high operating cost, whereas a cold operation, with the application of composite material, reduces both the repair time (from seven hours to one and a half) and the safety risks, since in both cases there is no interruption of the fluid passageway. During the test, conducted at the Rio Grande do Sul Federal University (UFRGS), the pipelines were repaired with composite blankets from three suppliers - Rust Engineering, OPTEC and TDW. The first two used an epoxy resin matrix reinforced with glass fiber while the latter used carbon fiber. The results proved the repair efficiency by the use of composite material up to the 6% depth limit of the dent in the weld, according to the criteria set by the BS 8010 standard (with a forecast of 100 years of the pipeline operating life). The technique was introduced in Petrobras Pipes Repair Standards for maintenance of onshore oil and gas pipes.
Energy efficiency increase at petrochemical plant in Argentina

Petrobras developed a simple solution to improve energy efficiency in preheating batteries in the naphtha hydrotreatment and catalytic reform units at the petrochemical plant of Puerto General San Martin (PGSM), located in Rosario, Argentina. After identifying gaps in sealing devices in the heat exchangers, which generated less efficiency than predicted, Petrobras has proposed the use of more modern and resistant seals, supplied by German company Kempchen, with an investment of US$ 60,000. Thus, the purchase of new exchangers was avoided, averting an estimated USD 2 million expenditure. As far as economic results concern, it is estimated a gain of US$ 2.5 million/year, including gains from product recovery (liquefied petroleum gas, benzene, paraffinic and aromatic solvents), besides the reduction in carbon dioxide emissions in 10,000 ton/year. The project is part of the program to improve the energy efficiency of the Petrobras facilities.
The Argus system provides critical information for monitoring the HDT and UGH units at the Petrobras refinery park in a standardized and online form, allowing continuous performance assessment of the units, contributing to increased reliability, operational efficiency, identification of improvement opportunities and effort reduction in monitoring the refining units. The system helped in monitoring the performance of the U-2800 (HDT) of the Duque de Caxias Refinery (Reduc) during industrial tests that sought to evaluate the possibility of increasing the volume of cargo processed in the unit for producing S-500 and S-10 diesel. The Argus pilot was launched on the U-3900 (UGH) and U-2800 (HDT) at Reduc and, with the results obtained, the system was expanded to other HDT and UGH units, being the cracked naphtha Hydrodesulphurization (HDS) units still in the first version of the system. In 2013 Argus was recognized as the monitoring system of refining units, having its extension requested to the processes of distillation, coking, catalytic cracking, sulfur recovery and lubricants. The next version will provide reports of the units monitoring at up to 50% of the time currently spent, as well as global consultations that will provide a comparison between the units’ key variables and references and metrics in addition to goal-setting.
Petrobras has finished the first stage of the environmental characterization of the Santos Basin, creating an extensive environmental database of the region that has been providing subsidies for the licensing of projects in the Santos Basin: Environmental Impact Assessment (EIA) of Phase II of the pre-salt, which contemplates 20 enterprises, Protection Plan for Oiled Fauna under the Emergency Oil Spill Plan (Pevo), and other monitoring projects conducted by the Operations Unit at Santos Basin (UO-BS). The study is an important support tool for Phase II of the Regional Characterization Plan of Santos Basin (PCR-BS), in negotiating with the environmental agency (Ibama). The study area will go from Cabo Frio (RJ) to Santa Catarina, at depths ranging from 25 to 2400 m, in a total of 350,000 km² (geographical area of the Santos Basin). With the completion of the PCR-BS, the company will have a robust environmental assessment with fundamental information for its environmental management, to support decision making in new projects in the licensing process and conducting environmental impact studies, in addition to meeting the Operating License for drilling activities in this region. In the first stage, the project included the collection and organization of about 790,000 records of structured environmental data by means of geographical information systems, which were previously scattered in various scientific publications and thus the provision of environmental information to the company has been optimized. The study involved researchers from the University of São Paulo (USP), the Rio de Janeiro Federal University (UFRJ), the Rio de Janeiro State University (Uerj), the Fluminense Federal University (UFF), University of Vale Itajaí (Univali), Paulista State University (UNESP), Campinas State University (Unicamp), Paraná Federal University (UFPR), Santa Catarina Federal University (UFSC), University of Southern Santa Catarina (Unisul) and the Fishing Institute of São Paulo.
Through the application of integrated methodology in the management of an area impacted by industrial activities, environmental, social and economic benefits are generated

Between 2003 and 2013, Petrobras applied integrated management methodology at impacted areas, to the remediation of Lagoa de Baixo, an area under influence of industrial activities, located in Rio Grande do Norte. With the application of this methodology, which is based on assessing the risk to human health, the company anticipated what was advocated in 2009, by the National Environmental Council (CONAMA). The project included the environmental characterization of the area, with the integrated assessment of chemical, physical-chemical, biological and microbiological data. Associated with conducting treatability tests, the study provided a technical foundation for understanding the scenario and decision making process along with the state environmental control agency, Idema (Institute for Sustainable Development and Environment of Rio Grande do Norte). Thus it has been defined a strategy for establishing the best cost/benefit ratio for the area recovery, removing hot spots (material with a greater concentration of contaminants between 2012/2013 and destined to cement fabrication) combined with monitoring estimated up until 2016. The adoption of this strategy has allowed Petrobras to retrieve the area, to fulfill the conditions with less environmental impact and to save an estimated a US$ 6.72 million, in addition to the gain in credibility - and consequent support for obtaining new licenses. A replication of this systematic is favorable, as it allows environmental management based on the following criteria: technical and social (reducing risks to human health), environmental (rehabilitation area with low impact) and economic (better resource allocation).
New tool enhances process of identification of contaminated areas in soils and reduces costs

Petrobras has successfully tested the Ultra Violet Optical Screening Tool (UVOST), from Dakota Technologies, which is able to detect the presence of oil and its products in the subsoil in real time. Besides providing better management of the remediation process, accelerated characterization in situ minimizes the uncertainty during investigation of contaminated areas, reducing the response time of chemical analyses by 50% and the research cost by up to 20%. Through the technique of Laser Induced Fluorescence (LIF), the organic compounds present in the contaminated subsurface emit radiation when stimulated by light, therefore, enabling being identified by its fluorescence. In partnership with Paulista State University (UNESP), bench tests were conducted to evaluate the equipment’s ability in detecting and differentiating types of oil, with varying degrees of API, as well as products marketed by Petrobras, such as diesel, gasoline, aviation kerosene (jet fuel) and biodiesel. From the results of the tests it was possible to evaluate their potential and include this tool as one of the investigation techniques to be used by the E&P area.
Garden of the Ilha d'Água terminal, having the Guanabara Bay in the background

Photo: Geraldo Falcão / Petrobras
Image bank (dez/2009)
Conclusion of environmental evaluation of Guanabara Bay

An important bibliographic review of environmental research and studies on impacts of economic activities in Guanabara Bay was conducted, in the period comprised between 1900 and 2007, being assembled in articles written by 77 authors from nine Brazilian universities: Rio de Janeiro Federal University (UFRJ), Rio de Janeiro State University (Uerj), Fluminense Federal University (UFF), Pontifical Catholic University of Rio de Janeiro (Puc-Rio), Federal University of the State of Rio de Janeiro (Unirio), Pernambuco Federal University (UFPE), Paraíba Federal University (UFPB), Pernambuco Federal Rural University (UFRPE) and University of Taubaté (Unitau). The environmental survey includes Physical-chemical and geological regional characterization data, which are associated to economic activities, as well as the biodiversity of the Bay and its ecological aspects. The acquired scientific characterization enables a more efficient environmental management by Petrobras, which includes greater flexibility for licensing units in the region. As a project final result, Petrobras released a book named: “Guanabara Bay – A Summary of environmental knowledge”, containing 816 pages divided into two volumes, a title that has a technical-scientific feature, which will serve as a reference material for the academic community. The book, sponsored by the company, will be freely distributed in educational institutions, libraries and consulting firms that operate in the environmental area.
GLOSSARY

**ANM**
Undersea equipment comprising a set of valves remotely operated by hydraulic triggers, pressure sensors and temperature sensors. It is installed on the well head of wet completion, on the seabed.

**CATALYTIC CRACKING**
Process through which the hydrocarbon molecules are broken down (cracked) into lighter fractions by the action of a catalyst.

**COMPOSITE MATERIAL**
Formed by combining two base materials, in which the material, called the reinforcement phase, is in the form of fibers, particles or plates embedded in another material called a matrix.

**DEEP WATERS**
Between 300 and 1,500 meters depth (984 and 4,921 feet).

**DISTILLATION**
The process by which liquids are separated and refined by vaporization followed by condensation of the vapors.

**FEED**
*Front-End Engineering Design*. Between the basic design and the work is the consistency analysis stage of the basic design and pre-drill.

**FLEXIBLE RISER**
Pipeline responsible for the connection between the well and the floating unit which, on account of its constitution, has greater flexibility than those made with hard metal pipes.

**FPSO**
*Floating Production, Storage and Offloading*. Floating production, storage and transfer of petroleum unit.

**GAS LIFT**
Production method based on controlled injection of gas into the production well.

**LNG**
*Liquefied Natural Gas* - Mixture of hydrocarbons (methane, ethane, propane and butane), usually containing carbon dioxide, nitrogen, sulfur, sediments and water and that in atmospheric conditions, presents in a gaseous state.

**LPG**
*Liquefied Petroleum Gas* - Mixture of saturated and unsaturated hydrocarbons, mostly three and four carbon atoms, used as domestic fuel.

**RECUPERATION FACTOR**
Ratio between the recoverable volume and the original, that is, the percentage of the original volume that is expected to be produced from a reservoir.

**TRAPS**
Geometric configuration of sedimentary rock structures that retain migrant fluid, coming from upflow of oil or gas, disabling their escape, forcing them to accumulate.

**ULTRA DEEP WATERS**
More than 1500 meters (4,921 feet) depth.
Measurement Units and Abbreviations

- API Gravity - OAPI - Standard Measure the density of oil developed by the American Petroleum Institute

- bbls – barrels

- blpd – barrels of liquid per day

- bopd – barrels of oil per day

- bpd – barrels per day

- kg/h – kilogram per hour

- kgf/cm² – kilogram-force per square centimeter

- m³/d – cubic meters per day

- m/h – meter per hour

- Nm³/d – normal cubic meters per day

- ppm – parts per million
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Petrobras Technology 2013 displays on its cover a representation of the map of Brazil, with emphasis on the Brazilian coast from its northeast part to its southeast, a region where Petrobras has major offshore production basins.

For this illustration, textures from the corresponding rock and fluid samples from the pre-salt area in southeastern Brazil were applied. These samples are part of the collection of the Rocks Laboratory – one of the leading laboratories at the Petrobras Center for Research and Development (Cenpes). In this laboratory, samples are studied by teams of geologists of the company in order to obtain parameters (rock type, porosity, permeability and others) to support the exploration (prospecting) and Exploitation (production) activities of Petrobras.

You could say that a geologist is a detective of the Earth and that in the context of Petrobras, he seeks to uncover geological processes that favor the occurrence of oil, in its generation, storage or extraction. Thus, behind a picture that refers to the map of Brazil, our researchers are able to look beyond, looking for clues in the rocks themselves.