Pazflor Project Pushes Technology Frontier

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In its latest campaign to push the deepwater technology frontier on Angola's prolific Block 17, Total has embarked on the Pazflor project. Proceeding under a concession granted by the Angolan national oil company Sonangol, and following upon industry milestones established by Total on the same block at Girassol, Dalia, and Rosa, Pazflor will feature several world firsts for subsea technology, including

- Full-field gas/liquid (G/L) separation and liquid boosting systems at the mudline
- Hybrid boosting pumps
- Vertical-separator technology

Located approximately 93 miles offshore Luanda and 25 miles northeast of the Dalia complex, in water depths of 2,000 to 3,900 ft, the Pazflor development will bring four fields into production, Perpetua, Acacia, Zinia, and Hortensia, which were discovered between mid 2000 and early 2003 **(Fig. 1).** The project derives its name from the initial letters of three of those fields (Perpetua, Acacia, and Zinia) and the similar-sounding Portuguese word *pasiflor,* for passion flower. Thus continues the floral nomenclature on Block 17 established by Girassol (translated: sunflower), Dalia, and the Jasmim and Rosa subsea tiebacks to Girassol.

Like the earlier core developments, Pazflor will be produced by means of a floating processing, storage, and offloading (FPSO) unit. The hull of this processing behemoth will weigh 82,000 tonnes, while its 15 topside modules will weigh an aggregate 37,000 tonnes. Combined, the weight of 119,000 tonnes will make this one of the largest FPSOs in the world. Holding accommodations for 240 per-

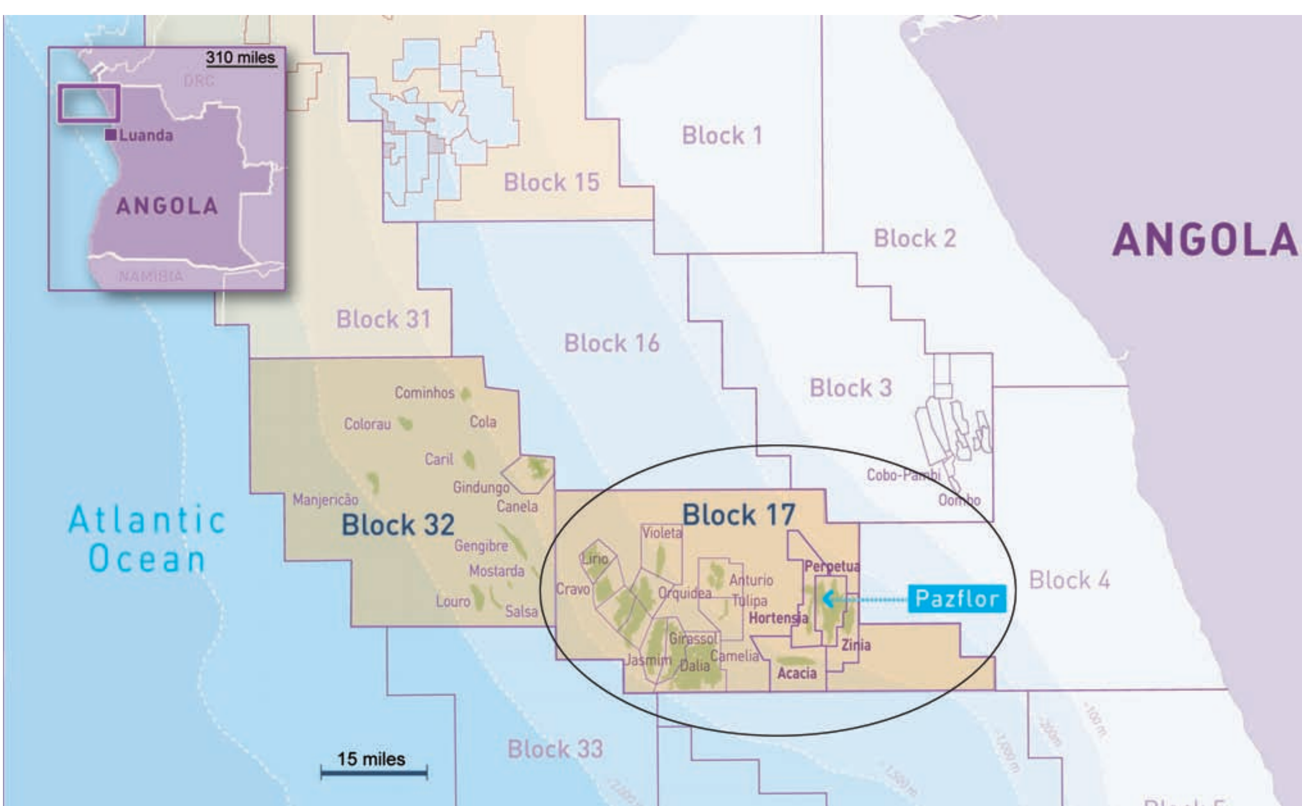

Fig. 1—Block 17 offshore Angola, with fields showing, including the Perpetua, Acacia, Zinia, and Hortensia fields comprising the planned Pazflor development. (All images courtesy of Total.)

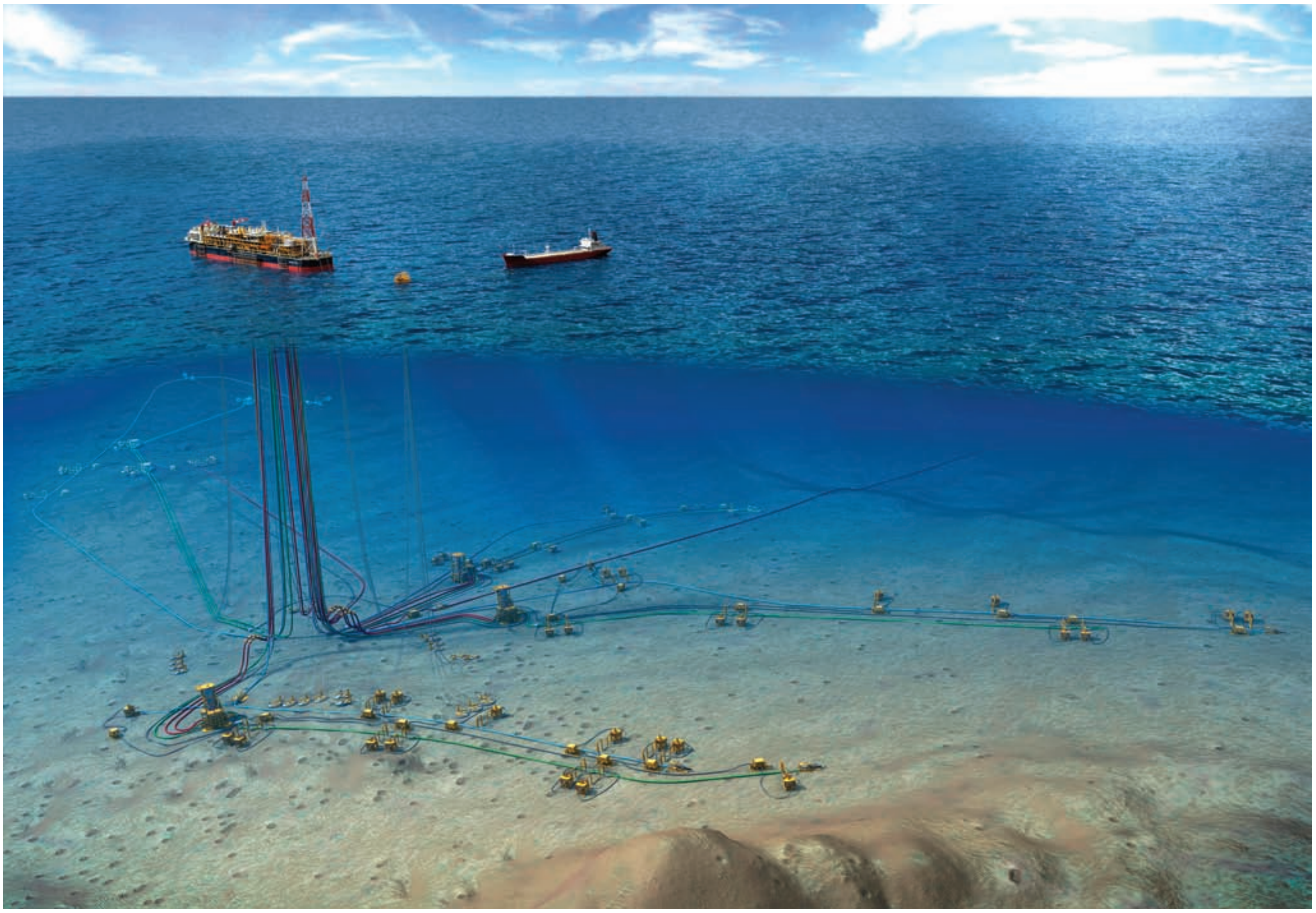

Fig. 2—A schematic shows the layout of production facilities planned for the Pazflor development.

sons, the FPSO will process the oil produced by a system of 49 subsea wells that includes 25 producers, 22 water injectors, and two natural gas injectors. The total subsea production system, linked by a network of 109 miles of pipelines and 51 miles of umbilicals, will be spread over a vast expanse of 232 sq miles—some seven times larger than the city of Paris—and have a north/south axis of 19 miles **(Figs. 2 and 3).** The FPSO will have an oil-processing capacity of up to 220,000 barrels per day (B/D) and storage capacity of 1.9 million barrels, bringing the installed production capacity on Block 17 to more than 700,000 B/D.

The Pazflor project carries a budgeted cost of approximately USD 9 billion. Total, as operator, holds a 40% share in the project, with the remaining interests held by StatoilHydro (23.3%), Esso (20%), and BP (16.7%). Major contracts have been awarded to Daewoo Shipbuilding & Marine Engineering to provide the FPSO; a consortium of SBM and APL to provide the buoy turret offloading system; FMC to provide the subsea separation and production systems; and a consortium of Technip and Acergy to provide the risers, umbilicals, and flowlines.

Two Very Different Kinds of Oil

Pazflor embraces the major technical challenge of producing two very different kinds of oil from very different reservoirs. Approximately two-thirds of the oil at Pazflor is heavy crude (17–22° API) produced from the Miocene reservoirs of the Hortensia, Perpetua, and Zinia fields. The rest of the oil is lighter crude (35–38° API) produced from the Oligocene reservoir of the Acacia field.

Oil from the Oligocene reservoir will be produced by means of a traditional production-loop system, with the fluids flowing from the subsea wells to the FPSO through two 10-in. flexible production risers, using the integrated-production-bundle technology pioneered at Dalia, with G/L separation occurring on the topside.

The Miocene reservoirs represent the biggest challenge and are driving the major technology breakthroughs at Pazflor. The heavy Miocene oil is very viscous (16–64 cp at 140°F), and reservoir pressure, at 200 bar, is low, compared with the Oligocene reservoir, at 350-bar pressure. To produce the oil from these reservoirs and assure fluid flow in an environment prone to generate gas-hydrate flowline blockages, Total will install three subsea separation units (SSUs). To be located near the initial production well at each field, to facilitate cold startups when needed, each SSU module will hold a vertical separator for G/L separation and two hybrid pumps for lifting the liquids **(Figs 4 and 5).** A hybrid pump combines helico-axial- and centrifugal-pump technologies, in that sequence, on a common shaft. These will be the first such pumps installed

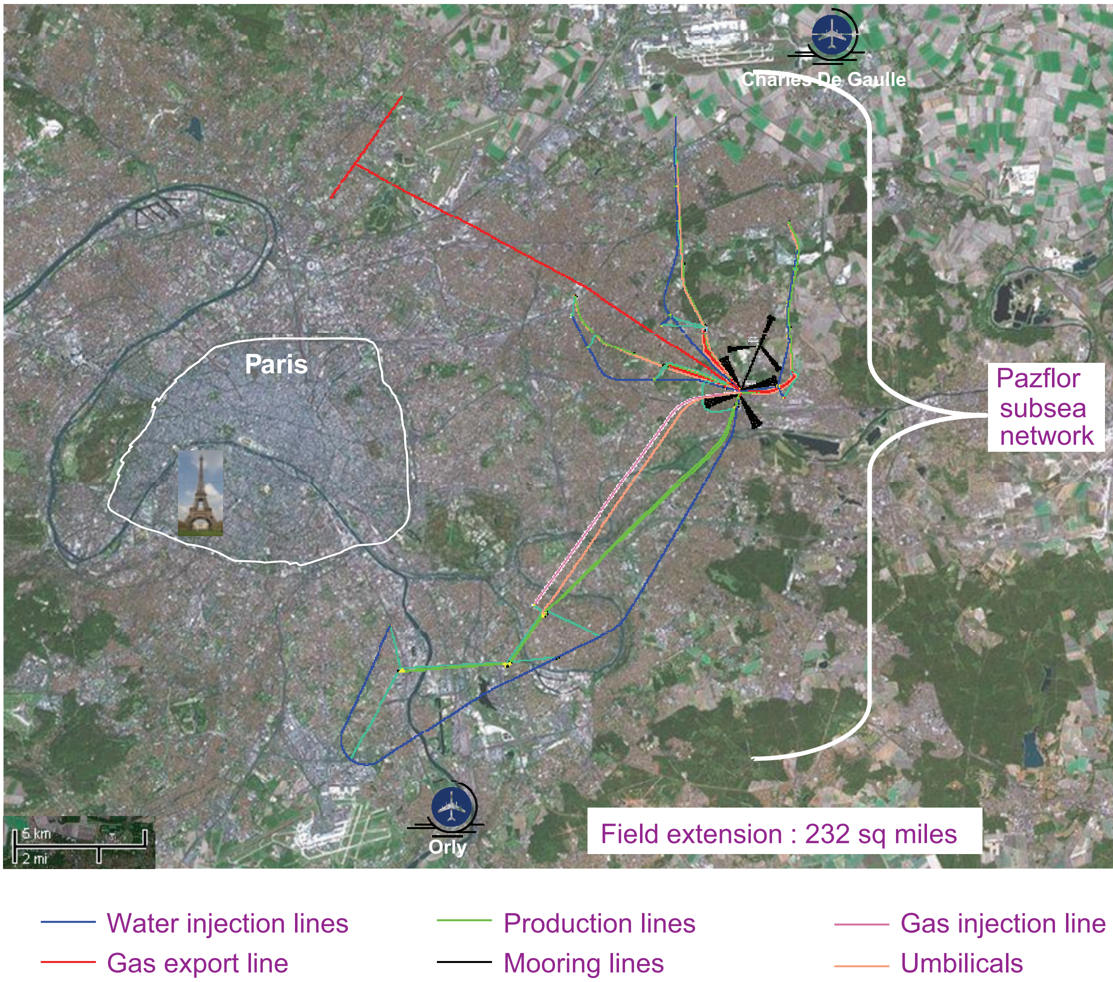

Fig. 3—The sprawling Pazflor subsea network covers an area some seven times larger than the city of Paris.

in the world. Production will flow from the SSUs to the FPSO through a total of three 10-in. flexible liquid-production risers and six 6-in. flexible gas-production risers.

The need to process two very different qualities of crude oil simultaneously is the essential reason for the tremendous weight of the FPSO. Not only does the heavier, more viscous crude require larger and heavier processing equipment onboard, but a record-breaking 120 MW of power-generating capacity (vs. 66 MW for Dalia) is needed to drive the subsea hybrid pumps in the Miocene fields. This power will be supplied by five 24-MW turbogenerators on the topside.

Subsea Separation, Hybrid-Pump Boosting

Subsea separation is a technology that so far has seen relatively few applications but is soon to see more, including combinations with subsea boosting. Seabed separating facilities have been installed in one Brazilian and two Norwegian fields (one along with multiphase boosting) to improve lifting at fields already in operation. For new fields, subsea G/L separation and boosting systems are planned at two developments (US Gulf of Mexico and Brazil) that deploy electrical submersible pumps within caissons that are driven more than 350 ft into the seabed. At Pazflor, the SSU modules will be installed at the mudline.

The need to apply artificial lift to Pazflor's Miocene production was critical because of the low reservoir energy and potential for high-friction pressure drops in flowlines, as a result of fluid viscosity. Surveying its options, Total looked at combining a bottom-riser-gas-lift (BRGL) system with the use of multiphase pumps, but noted the limited efficiency of BRGL methods in relatively shallow water, as well as potential problems handling viscous fluids and a number of well-operating issues involving gas lift. Furthermore, no multiphase pump had been qualified to a differential-pressure (delta P) attainment of more than 50 bar, and higher delta P levels would be needed to produce Pazflor's Miocene fluids.

"The challenge was to find a pump tolerant to free gas, capable of pumping very viscous oil, able to generate a high delta P, and that would be efficient," said Total's François-Régis Mouton, Partners/Sonangol Relations and Communication Manager for the Pazflor Project.

Indeed, the demanding pump specifications at Pazflor went well beyond ordinary requirements, whether subsea or topside. Pumps would need to generate a delta P of 105 bar for a suction pressure of 23 bar, while producing a flow rate of 15,900 ft^3/h with fluids at 185-cp viscosity, and be capable of handling viscosities of up to 4,500 cp during startups. Additionally, pumps would need to accommodate a gas-

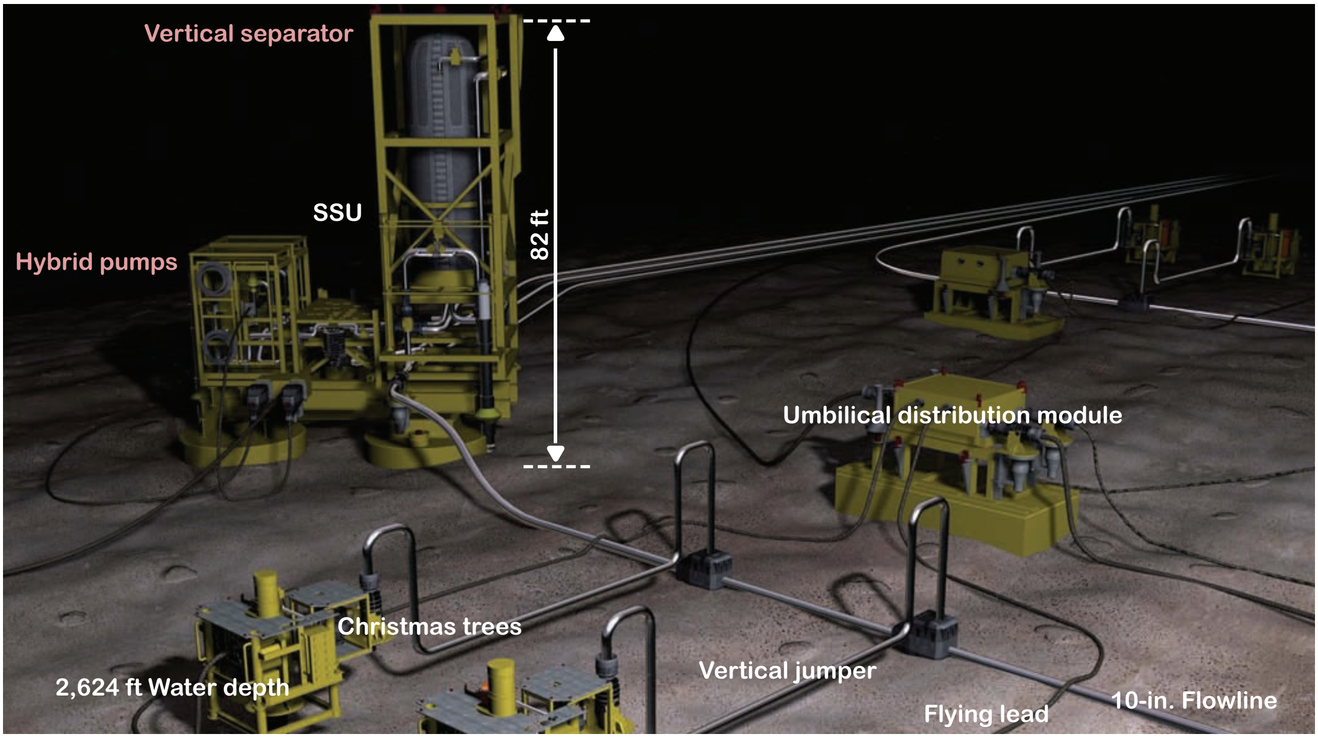

Fig. 4—Subsea production infrastructure for Pazflor Miocene reservoirs. Two production wells (Christmas trees) in foreground connect by means of vertical jumpers to a 10-in. multiphase flowline to the SSU, which includes a vertical separator and two hybrid pumps. Umbilicals carry electric, hydraulic, and chemical-injection lines that control well operations. The umbilical distribution module, connected to the Christmas trees by flying leads, ensures power distribution to the wells.

volume fraction (GVF) of 15% as a base case and 40% for unexpected fluid behavior.

As Total looked for the answer, it sought proposals from two suppliers and eventually settled on the hybrid pump being developed by Framo, which that company is supplying under Total's contract with FMC. "It is not a centrifugal pump; it is not a multiphase pump; it is both," Mouton said.

Operating at 23-bar pressure, the SSU assures that production fluids downstream of each separation unit remain outside the hydrate-formation window. Upstream of each SSU, preservation of the multiphase line is assured by a simple depressurization operation—with no chemical injection from the surface required—should there be an extended production shutdown. For the Oligocene reservoirs, the production loop will feature a pipe-in-pipe envelope, insulated by rock wool, to prevent hydrate formation in the flowlines during normal operations. The system will keep production fluids within a temperature window of 230°F upon departure from the wellhead and 104°F upon arrival at the FPSO. In the event of an extended shutdown, inert oil will be circulated to preserve the line.

The trailblazing subsea separation technology for processing the Miocene production has undergone a rigorous qualification program spanning 3 years, enabling the final design features and parameters to be established.

Beginning in 2006, tests were conducted with model oil (of 40–2500-cp viscosity) in a transparent scale unit at Cranfield University in the UK. Comparison of horizontal and vertical separator configurations resulted in selection of the vertical design because of superior sand-management suitability. Also determined at this stage of the qualification was the 15% GVF objective under normal operations.

Between January and June 2007, tests with an oil mixture from Dalia and Total's Sincor heavy-oil field in Venezuela were conducted under pressure at the Solaize (Lyon) facility of the French Petroleum Institute. The tests confirmed the previous results and the GVF objectives, the latter figures enabling decisions to be made on the hybrid pump design.

A final qualification phase is in progress at Solaize to confirm the results from the previous qualification round, and this time, some Pazflor Miocene oil taken from an appraisal well will be used.

Qualification of the hybrid pump took place at Flatøy, Norway, during late 2006 and early 2007. The hydraulics of the helicoaxial and centrifugal stages were otherwise field proven but needed and received qualification under conditions of relatively high fluid viscosity and/or GVF that have not been characterized by most field operations for these pump designs. The sensitivity of the helicoaxial impellers to viscosity and of the centrifugal impellers to viscosity and gas were successfully addressed, as was the design of the intermediate diffuser.

Environmental, Sustainability Initiatives

The Pazflor project has taken a number of important steps to limit the environmental impact of field activities and enhance the sustainability of operations. Gas flaring will be

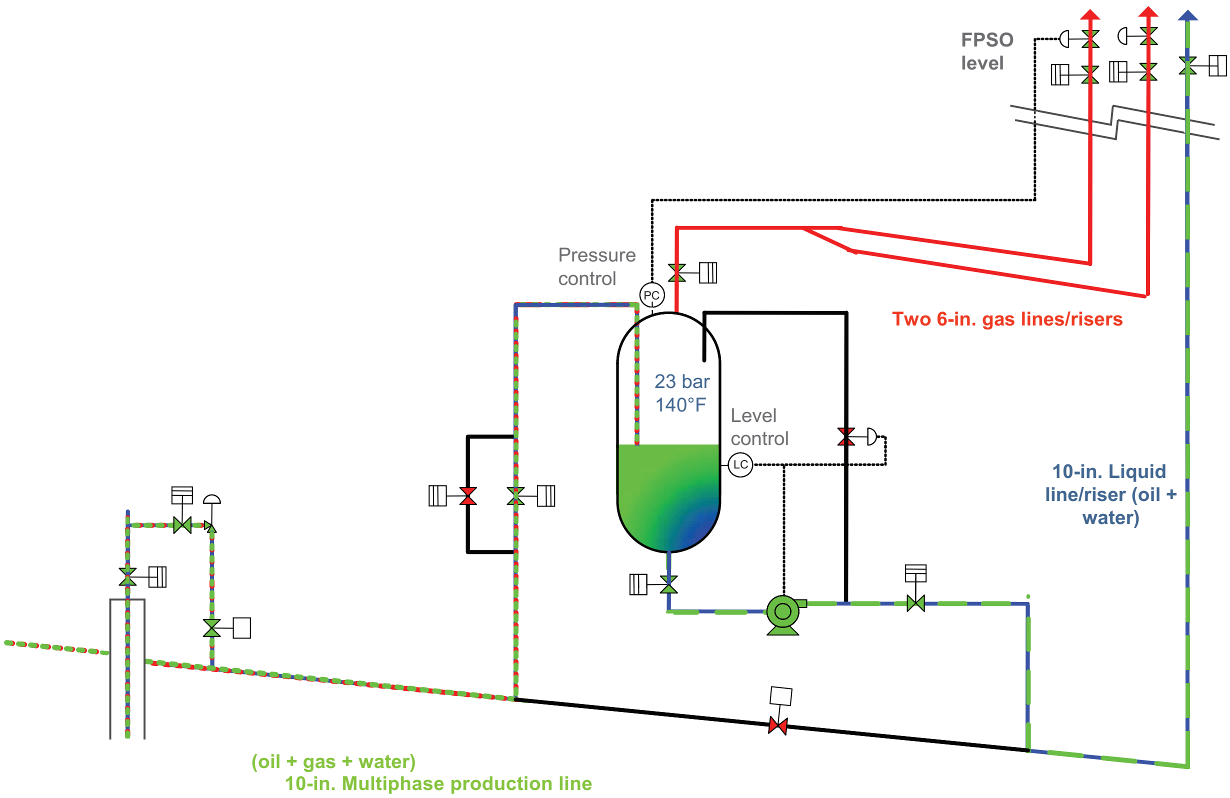

Fig. 5—The flow schematics of one of the planned SSU facilities at Pazflor are shown.

eliminated under normal operating conditions through the reinjection of associated gas into the reservoir. Eventually, associated gas could be exported to an Angolan LNG liquefaction plant under development and slated to begin production in 2012. Heat from turbine exhaust gases will be recovered, and turbine vent gases also will be recovered by means of a compressor. Produced water from the Miocene reservoirs will be reinjected into the formation, thus eliminating related disposal issues.

Pazflor is on track to produce first oil in the second half of 2011, with 23 wells to be drilled by then. Part of the drilling will be conducted from the Saipem newbuild drillship *S12,000,* now under construction. Major milestones along the way to initial production include

- FPSO hull launch, third quarter 2009
- First Christmas tree delivered to Angola, first quarter 2010
- Offshore installation startup, third quarter 2010
- FPSO sailaway to Angola, fourth quarter 2010
- First SSU delivered to Angola, first quarter 2011

Building and manufacturing operations for Pazflor are spread around the globe. A substantial portion of the work—representing approximately one-third of project capital spending—is taking place in Angola.

Beginning this year, Angolan yards will be making a significant contribution to the construction of project equipment. All three subsea manifolds for the Oligocene field, as well as the foundations for the three SSUs for the Miocene fields, will be manufactured and assembled at the Sonamet yard in Lobito. Certain components of the post-first-oil Christmas trees also will be made in Angola. Equipment for the network of flowlines and umbilicals will be manufactured or assembled at three Angolan facilities, including the Dande spool base and the Angoflex yard in Lobito—both joint ventures of Sonangol and Technip—and the Sonils logistics base in Luanda. This work includes the construction or assembly of subsea pipelines, flowline end terminations, in-line tees, and thermal insulation for the Miocene production flowlines, as well as the fabrication of riser anchor piles, jumpers, and virtually all umbilicals. The offloading buoy and its associated export lines also will be made in Angola, and several components of the FPSO—the helideck, anchors, boat landings, riser-protection structures, and mooring lines—will be manufactured at the Sonamet yard.

From the project's outset, Total has been engaged actively in recruiting Angolans and transferring knowledge to the local workforce. A significant number of Angolans—some of them employees seconded by Sonangol—are on the global Pazflor project team in France, Norway, the US, and other locations.

Those busy at work on this project, regardless of nationality and location, are well on their way to extending a record of meeting challenges of flow assurance, facilities scale, and new dimensions in world-class project management that has become a tradition on Block 17. From Girassol to Dalia, the page now turns to Pazflor. **JPT**