TOTAL

MOHO NORD

NEW ENERGY FOR CONGO AND BEYOND

TOTAL

SUPPLEMENT TO OIL&GAS JOURNAL Offshore


NW
SW

THIS PHOTO AND COVER PHOTO: DAMIEN MALFÈRE

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MOHO NORD

Here in the Gulf of Guinea, 75 kilometers offshore the Republic of Congo, is the Moho Bilondo field, site of the republic's largest oil project ever. Since 2008, Moho Bilondo has been producing from Miocene reservoirs to the floating production unit (FPU) Alima. And now Moho Nord takes the baton—the next major step to develop deepwater resources that will power the country's energy and economic growth in the decades ahead.

140,000 BARRELS OF ADDITIONAL PRODUCTION CAPACITY PER DAY.

1ST TOTAL TLP AND FPU COMBINED IN A SINGLE PROJECT.

12,000+ TONS OF EQUIPMENT FABRICATED LOCALLY.

PIERRE JESSUA
Managing Director, Total E&P Congo

YVES DUTEIL
Moho Nord Project Director

A SOURCE OF PRIDE

Moho Nord is a significant development for the Republic of Congo, adding economic value and executed with a continuous focus on safety and environmental protection. By enabling the production of untapped reserves in the Moho Bilondo field, this project reflects Total's commitment to ensuring a sustainable energy industry for the country, ushering it into the era of deepwater production.

Moho Nord required the building of new facilities and the expansion of existing ones—and it delivers major innovations. One is Total's first tension-leg platform (TLP) in the Gulf of Guinea, which can conduct both drilling and production activities simultaneously. Another is the all-electric floating production unit (FPU) Likouf, the largest unit of its kind in the Republic of Congo's deep offshore.

First oil—on March 14, 2017—brought this exciting collective undertaking to an official close. For several years, we worked closely with the Republic of Congo, our partners SNPC and Chevron, and the many local and international contractors selected for the project. All contributed their expertise and experience to ensure that Moho Nord would succeed.

As a long-term source of oil production, Moho Nord also propels development for the country. It has brought new opportunities and supported economic diversification by involving local businesses during construction, investing in long-term manufacturing facilities, and training skilled workers and specialized engineers.

We are particularly proud of the role we played in leading this development, completed in accordance with Total's own demanding standards and delivered on schedule and within budget, without any major incidents. In fact, everyone who participated should be proud too, and we thank them heartily for their contribution.

MOHO NORD

Doubling Total's Congo production, it sets the stage for the country's growth.

A DEEPWATER SUBSEA PRODUCTION SYSTEM

The new subsea production loop for the Miocene reservoir consists of four manifolds, 11 producing wells and six water-injection wells. The system comprises a 2- by 13-kilometer loop, producing 60,000 barrels of oil per day, pumped up to the FPU through risers.

FPU LIKOUF

The FPU extracts oil from Moho Nord's Miocene reservoirs (between 23 million and 5 million years old). With a total production capacity of 100,000 barrels of oil per day, it receives and processes all subsea and TLP production on two parallel trains.

March 2013

Final investment decision and start of engineering, procurement and construction.

December 2015

First oil from Phase 1 Bis.

SURFACE WELLHEADS ON THE TLP

Bringing 40,000 barrels of oil per day, the TLP is situated 350 meters away from and operated by the FPU, to which it is connected by six transfer lines. The normally unmanned TLP produces the Albian reservoir (between 100 million and 113 million years old) and, from the surface, enables coiled-tubing intervention. A significant innovation is the riser skidding system, which allows the drilling riser to be moved easily among the 27 slots, reducing the time lost between wells.

FPU ALIMA

On stream since 2008, the FPU Alima has been rescaled for the additional production brought by Moho Nord: 11 new wells (seven producers and four injectors) are tied back to the existing platform, which now can process an additional 40,000 barrels of oil per day.

TOTAL IN THE REPUBLIC OF CONGO

Nearly **50** years in the country.

The country's **Nº.1** exploration and production operator.

50% of the country's production.

1,000+ employees.

Market leader with **47** service stations.

118,000 barrels per day produced in 2016 by facilities operated by Total E&P Congo.

March 2017

First oil from Moho Nord Miocene.

May 2017

First oil from Moho Nord Albian.

PHOTO: JULIEN MUGUET

MOHO NORD
TEAMWORK AT ITS FINEST

Moho Nord, the biggest oil project to date in the Republic of Congo, assembled a broad range of expertise and capabilities from around the world. It was a one-of-a-kind, international, multicultural human adventure. Above all, it was an example of teamwork at its finest.

FINDING THE BEST SYNERGY OF SKILLS

A project of this scale requires every ounce of Total's expertise in the deep offshore, plus our extensive experience with complex projects. All of the stakeholders—partners Chevron and SNPC, contractors and local authorities—united to achieve the multiple goals of Moho Nord.

The success of the project hinged on finding the right risk-sharing balance with the contractors. Its successful execution was based on a carefully structured organization, well-proven management processes, trust and cooperation.

INTEGRATED, MULTIDISCIPLINARY, INTERNATIONAL TEAMS

Like a gigantic industrial puzzle, the multitudinous pieces of Moho Nord came from the four corners of the Earth. The umbilicals were fabricated in Great Britain and the USA; the TLP and FPU in South Korea; the subsea systems in Norway. Other elements came from France, China, Finland, Italy, Poland, the Netherlands, Germany, Argentina and Romania.

The people, likewise, brought their many-faceted skills: geologists, drillers, subsea and surface-installation experts, naval architects, construction managers and planning experts are just a few examples.

We leveraged our widely recognized skills in managing large-scale projects. These include:

- A strategic vision that enables us to make the right decisions and find the best solutions on time, adapting quickly to overcome changes

From Great Britain to South Korea, from the Republic of Congo to the United States, from France to China—and including Norway, Finland, Italy, Poland, the Netherlands, Germany, Argentina and Romania—the Moho Nord facilities were built in more than a dozen countries around the globe, involving more than 10,000 people during peak fabrication.

and challenges and yet maintain the schedule.

- Robust tools for managing projects of this scale.
- An organizational structure with clear objectives for everyone, combining active leadership with delegation of responsibility to the work sites.

At the height of our work on Moho Nord, the multidisciplinary and international project team comprised more than 500 people from 20-plus countries. Their jobs were to support the contractors in their endeavors on dozens of projects around the world.

Total's cohesive, self-sufficient and highly motivated team worked seamlessly despite the multiple distances that sometimes separated them: geography, time zones, cultures and nationalities. Together, they focused on safety, high-quality execution and compliance.


TOTAL
HSE ENGINEER
TOTAL
NARJIS 나지스
TOTAL
TOTAL
Electrical gloves
RED WING

SAFETY, ABOVE ALL

It is impossible to overstate Total's focus on safety: from the moment we launched Moho Nord, our top priority was the safety of everyone involved. It was a key criterion in our selection of contractors and was embedded in our culture, making it the primary concern for every team leader. Because we were uncompromising and vigilant at all times, we reached first oil with no major injuries or safety incidents.

Moho Nord developed and showcased a new behavior-based safety program called IMPACTS (IMProvement and ACts Together for Safety). Its aim is to create a climate of trust, thereby fostering safety and exemplary practices at every level of every operation.

We identified dozens of IMPACTS champions, on all of the main teams. These employees were not safety specialists, but they clearly showed exemplary behavior in these areas. They encouraged everyone to be attentive to others, and they assisted their colleagues in these efforts. As a result of their extraordinary determination, we did not experience a single major incident during the more than 50 million hours that more than 10,000 of us worked to acheive Moho Nord. Major milestones were marked by the signature of an IMPACTS passport by all participants.

20+
nationalities

10,000+
people around the world during the peak fabrication phase

500
people on the project team

50 MILLION+
hours worked

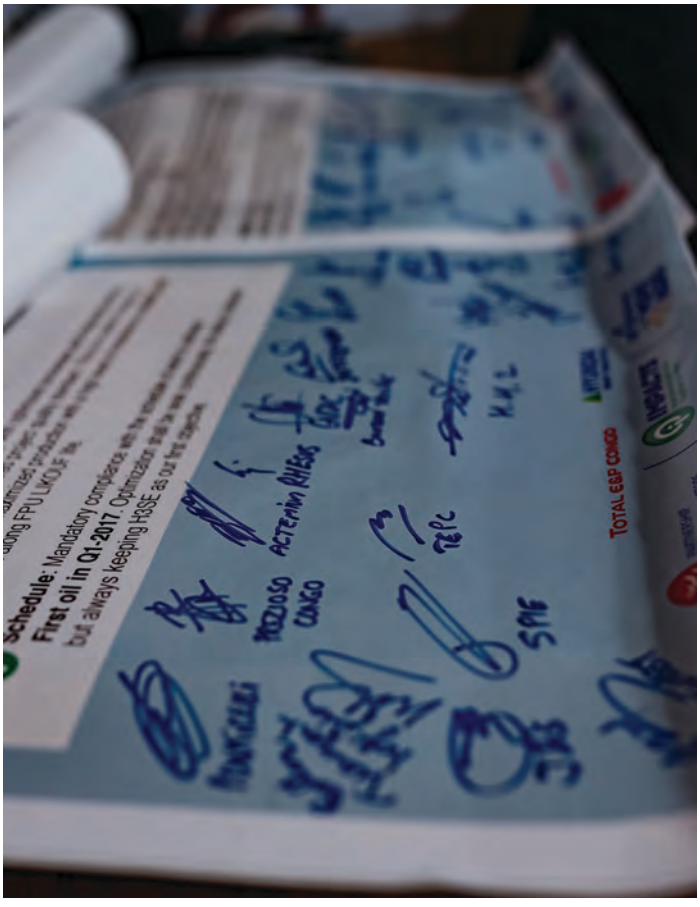


PHOTO: DAMIEN MALFÈRE

"Moho Nord is a high-stakes project that must comply with the most stringent standards and meet all contractual commitments. To my mind, however, it was only a complete success because there were no accidents."

—YVES DUTEIL
Moho Nord project director

TOTAL'S GOLDEN RULES FOR SAFETY

- RULE 1 — RISK SITUATIONS
- RULE 2 — TRAFFIC: MACHINERY/VEHICLES CYCLISTS/PEDESTRIANS
- RULE 3 — BODY MECHANICS AND TOOLS
- RULE 4 — PROTECTIVE EQUIPMENT
- RULE 5 — WORK PERMITS
- RULE 6 — LIFTING
- RULE 7 — WORK ON POWERED SYSTEMS
- RULE 8 — CONFINED SPACES
- RULE 9 — EXCAVATION WORK
- RULE 10 — WORK AT HEIGHT
- RULE 11 — CHANGE MANAGEMENT
- RULE 12 — SIMULTANEOUS OPERATIONS OR CO-ACTIVITIES

IMPACTS
Improvements and Acts Together for Safety

MOHO NORD SAFETY CULTURE PROGRAM

SAFETY FOR ALL IS A VALUE

PROJECT OBJECTIVES

Have an injury-free workplace
- zero accidents
- respect for the environment

All project team members **shall exemplify safety**

PROGRAM OBJECTIVES

DEVELOP A COMMON WAY TO WORK TO EMBED SAFETY IN ORGANIZATION AND BEHAVIORS

PROMOTES
- The involvement of all members (company and contractors)
- Active collaboration
- Open dialogue
- Reciprocal knowledge sharing

REQUIRES
- A proactive and positive attitude toward safety
- Collaborative mindset
- Mutual support
- Active reporting

SAFETY COMMUNITY

WORLDWIDE SAFETY COMMUNITY
Everywhere the project operates

200 MEMBERS

GATHERING PEOPLE FROM TOTAL AND CONTRACTORS:
- IMPACTS champions
- HSE teams
- Management

IMPACTS CHAMPIONS ARE DEDICATED AMBASSADORS

THEIR IDENTITY:
SKILLED AND MOTIVATED PROFESSIONALS

Non-HSE people recognized for their credibility in the field by the whole project team

Committed to safety culture and able to demonstrate it in the field

Supported by management and HSE department in their tasks

THEIR MISSION,
PROPAGATE SAFETY CULTURE AT ALL LEVELS OF THE ORGANIZATION

Share information: Organize safety moments, promote safety initiatives to teams

Leverage information: Communicate lessons learned and events and combine them with personal know-how to propose safety initiatives suitable for the context

Motivate teams: Promote safety on the site and provide explanations and tips

VISIBILITY AND LEADERSHIP

PERFORMANCE RECOGNITION

PARTNERSHIP WITH CONTRACTORS

TRUST ENVIRONMENT

COMMUNICATION


SOREL W.
TOTAL
E&P CONGO
SOREL W.

PHOTO: DAMIEN MALFÈRE

IN THE REPUBLIC OF CONGO

Building capacity and encouraging diversification

Total's goal, always, is to contribute to lasting economic progress in the countries where we operate. Moho Nord worked to develop local industry in the Republic of Congo, with two aims. The first was to build local industrial capacity during project development. The second was to contribute to the long-term growth of small businesses that would, in turn, help to build the local economy.

A PERMANENT MANUFACTURING BASE

To meet the requirements of Moho Nord, several industrial sites in the Republic of Congo made large investments, developing more than 120,000 square meters of industrial space and creating a dozen fabrication, maintenance and paint shops. Investors developed some 30,000 square meters of warehouses and open-air storage as well.

The ILOGS base in Pointe-Noire significantly increased its logistics and port capacity, with six hectares of service-center facilities, a 200-meter jetty extension and a new 23,000-square-meter metal-fabrication yard built by Friedlander. The BosCongo site installed two heavy-duty welding lines and a general welding and bending line. Total E&P Congo increased the storage capacity of its logistics base by about 10,000 square meters and built a new workshop to maintain subsea equipment.

These facilities form a powerful engine for developing the Republic of Congo's industrial capacity. Today, they are available for other projects and fabrication activities and will facilitate the country's access to new markets, including those outside the oil industry. Furthermore, the construction of maintenance shops by local businesses, their acquisition of machine tools, and their construction of heavy-duty production lines and new storage areas increase their chances of winning future contracts. These advantages will help competitive industry to emerge, supporting the Republic of Congo's economic diversification.

LOCAL-CONTENT REQUIREMENTS

We set local-content requirements for all major contractors—beginning with the call for tenders. To promote in-country fabrication, those contractors made binding commitments to award a significant share of their work packages to local businesses, who in turn committed to outsource some of their work locally. We re-scoped certain contracts to put them within the reach of local businesses.

PHOTO: JULIEN MUGUET

As a result of this cascading strategy, more than 12,000 local jobs were created by the 637 local businesses that participated. These Congolese workers fabricated 12,000 tons of equipment and structures at local yards.

We applied a similar strategy to high-value-added services and consultancies. Local companies such as Emexdis, a business specializing in detailed engineering, considerably strengthened their skills and workforce and ultimately diversified their activities in the space of just a few months.

DEVELOPING NEW EXPERTISE

The international companies involved also formed partnerships with local businesses to transfer skills and technology to the Republic of Congo. Their goal was to develop new expertise within Congolese businesses—especially those that operate in diverse industries.

To ensure that Congolese staff would hold management and supervisory positions, the

principal Moho Nord contractors also made firm commitments to undertake recruitment and training. More than 180 technicians and engineers were trained in a variety of project technologies in Europe, Asia and Africa—through total-immersion programs at the same companies that were fabricating equipment and maintaining facilities. These programs encompassed subsea production systems, instrumentation, operations and maintenance, and telecommunications. Proficient in their newly acquired, state-of-the-art skills, these trainees will continue to be more competitive—long after the Moho Nord development is complete.

As soon as the project began in 2013, Total recruited and trained new operators to run the Moho Nord facilities. The FPU Likouf personnel received comprehensive training that combined classroom teaching in the Republic of Congo with hands-on learning in South Korea. More than 60 Congolese engineers and senior technicians were also trained in France, South Korea and locally, learning how to operate the variety of systems on the FPU. The challenge for everyone was to be fully capable—from the first day of start-up.

> The training for business leaders gave me the skills needed to submit better bids during calls for tenders. Moho Nord especially helped us show what we are capable of providing. Our revenue rose by 40% in 2015 and doubled in 2016.
>
> **—SERGE MBERI**
> CEO, Chapet Congo

180+ direct local suppliers and

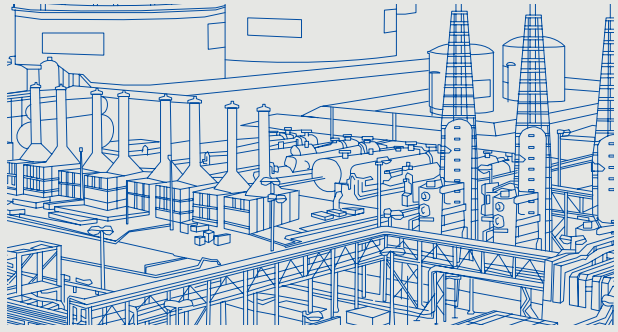
600+ local contractors

12,000+ jobs created locally

600,000+ hours of training for young Congolese professionals from local companies and 5,500 hours of support for small-business owners in the Republic of the Congo

180+ Congolese technicians and engineers trained in project technologies in Europe, Asia and Africa

THE DJÉNO TERMINAL: NOW READY FOR NEW OIL PRODUCTION



The Djéno terminal, connected to the FPU Likouf by a new 75-kilometer pipeline and equipped with heaters to render the oil compatible with the Djéno Blend, receives all oil from Moho Nord—after it is processed on the FPU Likouf. In preparation, Total built receiving facilities specifically for Moho Nord, including fiscal metering, heaters and a separate technical room.

MAXIMIZING LOCAL INDUSTRIAL CAPACITY

From the outset, one of our priorities was to involve as many local businesses as possible in Moho Nord. We addressed this priority in three major ways:

- Training Congolese technicians and engineers who could support capacity-building and diversification.
- Transferring skills and technologies to local businesses.
- Helping local workforces to improve their performance and broaden their opportunities.

PHOTO: DAMIEN MALFÈRE

WIDE-RANGING TRAINING STRATEGY

We extended our training strategy to the instructors of the future Congolese technicians and engineers. Nearly 50 lecturers from UCAC-ICAM, the Ecole Superieure Technique du Littoral and the Ecole Nationale Polytechnique at Université Marien Ngouabi, Brazzaville—three of the most prestigious schools in the country—completed the train-the-trainers program, carefully designed to align theory with practice in the oil industry.

A partnership with Actemium Congo and UCAC-ICAM led to the creation of a diploma in industrial maintenance tailored to the oil industry—the first of its kind in Central Africa. The diploma is awarded after two years, and students spend an additional year gaining field experience. The first class of graduates, comprising 48 young technicians, finished their course in 2016.

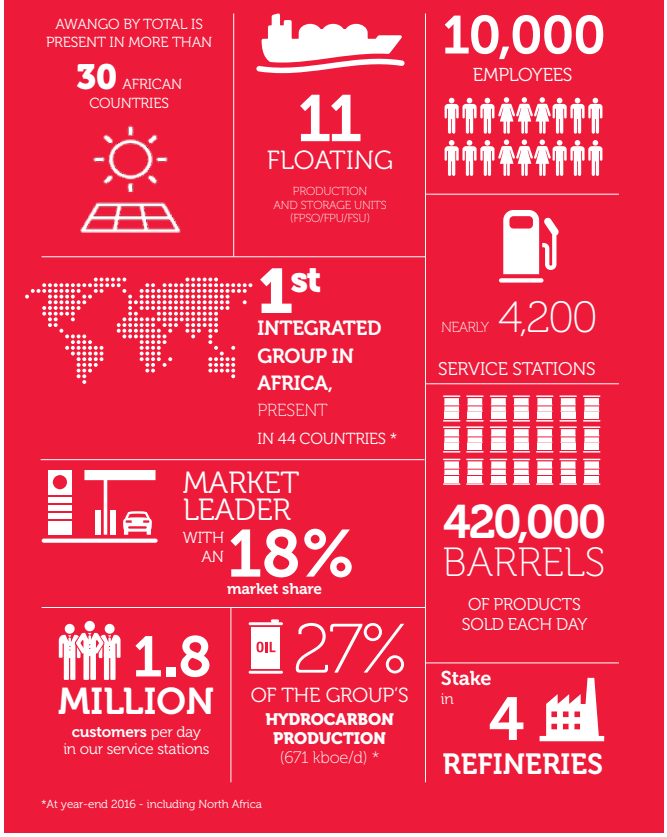
Since 2013, 25 Congolese companies have received business-management support from Total E&P Congo—through programs that focus on quality, HSE supervision and business management.

In the Republic of Congo, betosala means "working together" in the Kituba language. Our program of the same name aims to support Congolese entrepreneurs over the longer term—before and during Moho Nord's operation—to help them better secure their future. In a country that depends on oil for 70 percent of its gross domestic product (source: World Bank), it is important to help to diversify the economy. In the Republic of Congo, we encourage our partners to work with Congolese small business and set up programs to transfer skills.

TOTAL IN AFRICA

In 2016, Total's production in Africa, excluding North Africa, was 634,000 barrels of oil equivalent a day, representing 26 percent of Total's overall production.

In The Republic of Congo, Total operates not only Moho Bilondo, but also Kombi-Likalala-Libondo, Nkossa, Nsoko, Sendji, and Yanga. It holds a large share in Lianzi, Loango and Zatchi, as well.



*At year-end 2016 - including North Africa

1995 TO 2006
Discovery of Moho Nord Albian reservoirs.

1997 TO 2007
Discovery of Moho Nord Miocene reservoirs.

JULY 2011
Creation of Moho Nord project group and start of basic engineering.

MARCH 2013
Final investment decision.

OCTOBER 2013
Begin TLP hull construction.

JANUARY 2015
Launch FPU hull.

APRIL 2015
Complete TLP topsides heavy lift (over the hull).

APRIL 2015
Begin Miocene drilling campaign.

OCTOBER 2015
FPU Likouf hull sail-away from Mokpo to Ulsan, South Korea.

NOVEMBER 2015
Begin FPU module-lifting campaign.

OCTOBER 2015
TLP sail-away from South Korea.

DECEMBER 2015
First oil from Phase 1 Bis.

'THE ELEPHANTS IN THE SEA'

The TLP and FPU were built and assembled in South Korea. Delivery halfway around the world to the Republic of Congo was no mean feat for vessels that weigh 61,000 tons (FPU) and 16,000 tons (TLP). Measuring 250 meters long and 44 meters wide, the FPU Likouf is the largest delivery made to date by the Dockwise Vanguard, the largest heavy-lift ship in the world and the only one capable of transporting such a massive structure. Welded to the semisubmersible Dockwise Vanguard to ensure its integrity, the FPU departed South Korea, with 219 people on board—for Gabon, where it was refloated. After spending 40 days at sea and traveling almost 20,000 kilometers, the FPU was then towed to the Republic of Congo. The four-column TLP, measuring 62 meters square, took the same arduous route.

JANUARY 2016
TLP arrives on site (Congo).

MARCH 2016
TLP installation complete.

JUNE 2016
Begin Albian drilling campaign.

OCTOBER 2016
FPU Likouf sail-away from South Korea.

OCTOBER 2016
First production test for Alpha/Beta.

DECEMBER 2016
FPU Likouf mooring complete.

DECEMBER 2016
TLP completion certified.

MARCH 2017
First Miocene oil from Moho Nord.

MARCH 2017
Start-up of multiphase pump.

MAY 2017
First Albian oil from Moho Nord.

JUNE 2017
FPU completion certified.

DECEMBER 2017
Moho Nord at production plateau of 100,000 bopd.

ON TIME, ON TARGET, ON THE MONEY

We successfully completed Moho Nord on March 14, 2017, less than four years after we sanctioned the project—on time, on target and on the money, without compromising on safety or asset integrity.

PHOTO: DAMIEN MALFÈRE

A TRIUMPH OF INNOVATION AND TECHNOLOGY

With Moho Nord, the Republic of Congo has entered a new era of innovative deepwater development. The project was complex, conducted to meet the most stringent requirements for safety, quality of execution and environmental protection, and integrating many technical innovations.

At peak, the Moho Nord FPU will receive 40,000 barrels a day of light Albian oil from the TLP. The Miocene production to the FPU from the subsea network brings 60,000 barrels a day, giving 100,000 barrels of total production from the Moho Nord field.

BUILT FOR 30 YEARS OF RELIABILITY

One major challenge was to ensure reliable performance for the entire 30 years of expected operation. The subsea equipment, such as manifolds and wellheads, must be especially robust to withstand water temperatures 4 degrees Celsius in 1,000 meters of water. Therefore, its manufacture was closely supervised at Aker Solutions in Norway. Certain

2 distinct geological formations

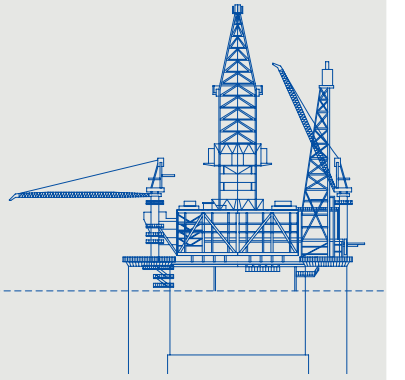
2 drilling strategies: Miocene reservoirs accessed by subsea wells drilled by dynamically positioned drillships; Albian reservoirs accessed from surface wellheads drilled from the TLP

45 wells: 30 producers and 15 water injectors

THE TLP: A MAJOR INNOVATION FOR TOTAL AND THE REPUBLIC OF CONGO

A development plan using a TLP and surface wellheads is a first for Total. It enables us to produce the Albian carbonate reservoir, whose deposits are very hard and require frequent well intervention.

Built by Hyundai Heavy Industries (HHI) in South Korea and delivered to the Republic of Congo, the impressive floating platform is moored with 12 tendons attached to piles driven into the seabed. We carried out this challenging installation with a crane vessel and remotely operated underwater vehicles. Our goal was to guarantee the unit's stability by controlling the movements caused by ocean currents, while ensuring a production capacity of 40,000 barrels of oil per day, with simultaneous drilling and / or well interventions.



key components were precisely fabricated—to the nearest micron—and tests often lasted several weeks.

Assembly was likewise complex for facilities such as the FPU. Composed of 13 separate topsides modules, it required extremely detailed calculations for correct assembly and installation.

The module-lifting operations were a major challenge: HHI chose for the task the biggest floating crane in the world, with a 10,000-ton capacity. Built by and for HHI, it was used—for the very first time—to lift the Moho Nord TLP deck.

WHAT GOES UP MUST COME DOWN

Even trickier was the procedure to lift the TLP's topsides onto the hull—considering that the topsides measures 56 by 55 meters by 16 meters high and weighs more than 5,000 tons. Preparations and simulations continued for several months before the heavy lift took place in April 2015. It was essential to eliminate any potential risks to workers and asset integrity posed by the possibility of tipping, the handling of heavy objects, or work at height.

The two-day operation—a formidable technological challenge—required 180 people, including naval and structural engineers, quality and safety officers, constructors, crane operators and vessel crew.

The topsides spent a full night hanging over the water before it found its permanent home, fastened to the hull at four connection points to within 2 centimeters—a resounding success!

Another particularly difficult operation was installing the deepwater facilities on-site. Aside from the inherent risks of working at sea, both the powerful currents in the area and the unpredictable weather conditions combined to shorten the windows for operations as the work progressed.

TECHNOLOGY THAT SAFEGUARDS THE ENVIRONMENT

The Moho Nord facilities were designed, from the beginning, to prevent routine flaring. There is no permanent flame. Instead, an innovative automatic system can ignite the flare if needed. This is a first for the Republic of Congo. Associated gas is reinjected or used to fuel power generation.

Reinjecting produced water

Another Total first is that all produced water is reinjected into Moho Nord's reservoirs. This offers two benefits: It maintains the pressure in the reservoir to optimize oil recovery, while it also prevents the discharge of any produced water into the sea—even if the water has been treated.

The smallest environmental footprint

The FPU Likouf is the biggest deepwater-production FPU in the Republic of Congo, but boasts the smallest environmental footprint. Highly energy efficient, it incorporates multiple technologies to limit the emission of greenhouse gases, such as a central management system for all energy needs, a venting recovery unit and a heat-recovery system for the exhaust produced by the turbine generators.

ZERO
routine flaring.

ZERO
discharge of produced water.

ALL-ELECTRIC
FPU.

PHOTO: DAMIEN MALFÈRE

A SHOWCASE OF INNOVATION

Pioneering technologies have distinguished Moho Nord from the outset. It is the first Total deepwater project to combine two floating units—an Floating Production Unit (FPU) and a Tension Leg Platform (TLP)—with two separate drilling strategies and production systems. This hybrid model is the key to developing several reservoirs in two distinct geological environments.

The light oil from the Albian carbonate reservoir is extracted by the TLP. This is a highly innovative technological concept using surface wellheads, deployed for the first time by Total in Africa.

The riser skidding system likewise is an important innovation, allowing the drilling riser to move easily among the 27 slots and reducing the time lost between wells. The Miocene oil is extracted using a standard subsea loop measuring 2 by 13 kilometers and tied directly to the FPU Likouf.

All production is gathered—via a system of risers from the Miocene reservoir and by transfer lines from the TLP—to the FPU Likouf. There, it is processed before export, by pipeline, to the onshore Djéno terminal, 75 kilometers away. The FPU Likouf is the largest deepwater floating production unit in the Congo, capable of processing as much as 100,000 barrels of oil per day from both reservoirs.

Technological breakthroughs

The decision to use a TLP—Total's first in West Africa—was based on geology: The carbonate reservoirs feature very low matrix permeability, as well as oil that is subject to asphaltene precipitation. This requires regular well intervention to promote productivity, such as injecting solvents to counter naphthenate buildup. For various technical and economic reasons, subsea development is not an option, due to the frequency of these interventions.

Wash tanks. *Total stands on the cutting edge of deep-offshore development and draws on extensive expertise in designing floating units, whether Floating Production, Storage & Offloading units (FPSOs) or Floating Production Units (FPUs). Since installing its first FPSO off the coast of Angola, Total has continued to improve the design of these floating systems. One recent development has made it possible to treat and remove water from the oil, in the hull, by using huge wash tanks. Carrying out this last stage of treatment in the hull rather than on deck has important advantages, such as limiting topsides weight while saving precious space to optimize layout. The Moho Nord FPU is the first floating deep-offshore unit to use this innovation off the Congolese coast.*

Hybrid loop. *The Moho 1 Bis Alpha Beta loop embodies a new Total concept in the design of subsea operations. In contrast to a conventional production loop, which connects two production lines to create two lines along which the oil can flow, the hybrid loop ties in a single production line and a service line filled with dead oil. In the event of extended downtime, this dead oil is injected into the production line to prevent hydrate buildup. In addition, the replacement of an insulated flow line with a service line that does not need insulation produces significant cost savings.*

Production capacity of 140,000 barrels a day

MOHO NORD

A new production hub to tap the northern zone of the Moho Bilondo permit:

- 1 FPU, connected to a subsea production loop
- 1 TLP supporting surface wellheads

MOHO PHASE 1 BIS

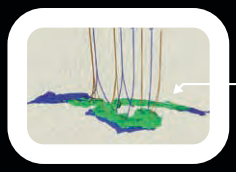
Developing the central zone of the Moho Bilondo permit from the Alima FPO

- Extending the existing production loop
- Creating a new production loop
- Debottlenecking the FPU

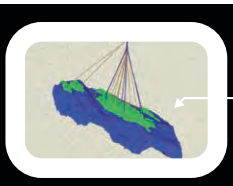
MOHO NORD, 2 DEVELOPMENTS IN 1

TECHNOLOGICAL BREAKTHROUGHS > GROWTH DRIVER FOR CONGOLESE PRODUCTION > RESPECT FOR THE ENVIRONMENT

TWO GEOLOGICAL ENVIRONMENTS



Miocéne: turbidite reservoirs; depth of 1,000 m; complex architecture; viscous oils



Albian: carbonate reservoirs; depth of 3,200 m; extremely heterogeneous sediment; light oils

VISCOUS OILS

PRODUCTION OF VISCOUS MIOCENE OIL FROM THE MOHO NORD (4 TO 13 CP) AND MOHO PHASE 1 BIS (UP TO 25 CP) FIELDS REQUIRES SPECIAL BOOSTING METHODS

- Downhole gas lift
- High-power subsea multiphase pumping for Moho Phase 1 Bis

INNOVATIONS AND TECHNOLOGICAL FIRSTS

TOTAL'S FIRST TLP IN AFRICA

TOTAL'S FIRST DEEP OFFSHORE PROJECT COMBINING FPU & TLP

FIRST DRILLING FROM A TLP

TOTAL'S FIRST HYBRID SUBSEA PRODUCTION LOOP FOR MOHO PHASE 1 BIS

MOHO NORD FPU: A SERIES OF FIRSTS IN CONGO

ZERO GAS FLARING DURING NORMAL OPERATIONS

REINJECTION OF ALL PRODUCED WATER

OIL/WATER SEPARATION AND DESALTING IN THE HULL

A LARGE-SCALE PROJECT

1 FPU FOR 2 DIFFERENT OILS

1 TLP FOR SURFACE PRODUCTION FROM THE DEEP ALBIAN RESERVOIRS

DRILLING

- Miocene: 18 producers and 10 injectors
- Albian: 12 producers and 5 injectors

FLOWLINES AND RISERS

- 39.7 km of production lines
- 41.1 km of water injection lines
- 19.6 km of gas injection lines
- 5.6 km of service lines
- 50.4 km of umbilicals
- 21 risers
- 1 gas import/export line (23.1 km)
- 1 oil export line (76.6 km)

SPS

28 Christmas trees
6 manifolds
18 production jumpers
2 multiphase pumps

PHOTO: DAMIEN MALFÈRE

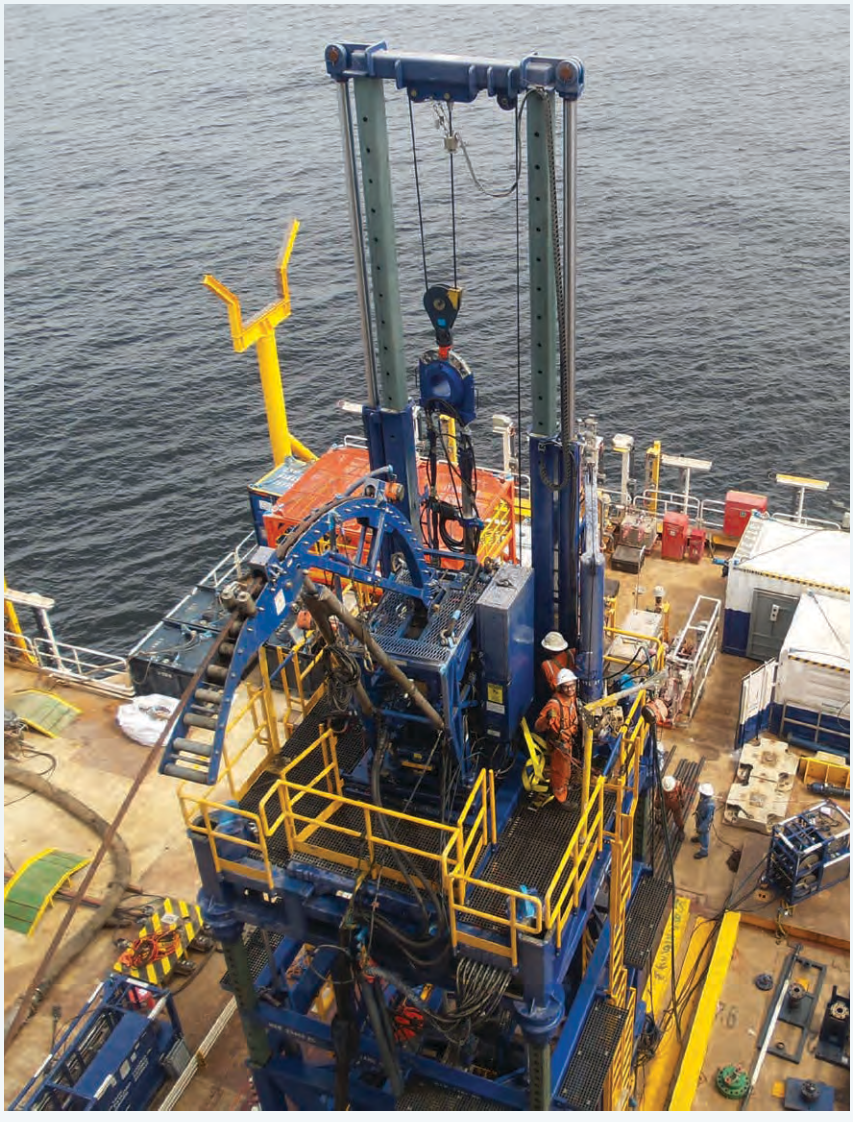

HD_S4

PHOTO: DAMIEN MALFÈRE

COMPANY PROFILES

Teamwork, Collaboration Deliver Technological Success for Complex Deepwater TLP Project

The Total Moho Nord offshore development and production project in the Republic of the Congo presents multiple technological and logistical challenges requiring customized solutions, strong collaboration between operator and service provider and a broad array of technical expertise and equipment. The development, when completed, will include 45 deepwater wells, 17 of which are designed with dry trees on a tension leg platform (TLP). Twelve of the TLP wells are oil producers with gas lift systems and the other five are water injectors to manage pressure.



The CT intervention tower, which included the first-time integration of a remotely operated CIRP completion insertion and removal under pressure system, is designed to insert and retrieve long gun strings under wellhead pressure. (Courtesy of Schlumberger)

For these wells, drilling operations using a mast equipment package (MEP) and various types of coiled tubing (CT) intervention, including perforating, must be run simultaneously. The TLP project began in June 2015 with an extensive design and planning phase addressing space, deck loading, weight and other parameters. The successful installation of the initial dry Christmas tree well two years later achieved several industry ‘firsts’ in technological innovations and applications. The project highlights the importance of ongoing teamwork between Total and Schlumberger.

The undertaking also reflects the commitment of Schlumberger to advance its expertise and technology by building capacity, developing infrastructure, and recruiting and training employees where it operates. With 80% of the Schlumberger local workforce involved in this project, the company seeks to develop a strong national employment base in Congo. To achieve this, Schlumberger has created a vigorous training program in Congo for each business function.

To assist development of the Moho Nord project, Total and Schlumberger launched the ‘Train the Trainer Program’ in 2015. Through the Schlumberger recruiting department, experienced industry professionals were invited to share operational knowledge with selected universities of the Republic of Congo. Thirteen days of training, totaling 90 hours, were conducted for 33 university professors on Schlumberger technology and best practices.

"Thank you for the training, it was excellent. I received very good feedback from the teachers who were invited, and all of them want to make this a common practice as it is really refreshing. We will debrief together and see how we can improve our lessons," said the Dean of Marien Ngouabi University.

Through the Schlumberger recruiting department, experienced industry professionals were invited to share operational knowledge with university professors. (Courtesy of Schlumberger)

Coiled Tubing Compensated Intervention Tower

The centerpiece of the first TLP dry Christmas tree is a custom-engineered CT intervention tower configured with a heave motion-compensating system. Designed specifically to fit on the limited-space deck of the TLP, the tower can skid easily from one well slot to another and convey a long string of perforating guns even while working below the MEP. For this first-ever global deployment, the CT tower was engineered to operate independently from the drilling activity and at its maximum-extension working height both underneath and alongside of the MEP. By enabling safer and simultaneous drilling and intervention operations, the tower delivered considerable time, cost, and risk reductions.

Advanced Fluids and Technology for Well Construction

The MHA1-01 well, an oil producer with gas lift, was drilled in 2016 in water depth of 780 m (2,559 ft) in the Albian age multilayer carbonate reservoir, which is characterized by high vertical heterogeneity. Continual communication between Total and M-I SWACO, a Schlumberger company, ensured selection of the optimal drilling fluid technologies and waste management services for both performance and efficiency. For example, the rig-based ENVIROUNIT* offshore slop water treatment system recycled the slop water to significantly reduce disposal costs over its 14-month deployment.

The M-I SWACO Wellbore Productivity team also saved two days of rig time by combining three operations—cleaning the internal diameter (ID) of the polished bore receptacle (PBR) to confirm top of liner depth, inflow testing the 4½-in liner and cleaning the wellbore—in a single run. The specially designed tieback mill used to drift and clean the PBR's ID was developed by M-I SWACO after performing multiple torque-and-drag and simulations from the VIRTUAL COMPLETION SOLUTIONS* completion fluid modeling software package to demonstrate operational feasibility.

Dual Completions with a 20-Year Well Life Expectancy

The first dual completion was installed on the Moho Nord TLP in March 2017. For this initial well, Total and Schlumberger Completions engaged early on to design a fit-for-purpose technology, incorporating multiple system integration tests (SITs) to achieve a 20-year well life expectancy.

The design addresses the TLP requirements and weight distribution of the completion and the challenging well architecture, with a 10¾-in × 7⅝-in casing scheme. Other issues include constraints associated with pressure and temperature variations due to production and injection cycles and corrosive produced fluid.

Key technologies introduced in the completion design include a tubing-fill test valve (TFTV) to enable filling and testing the tubing while running in the hole, a dual XMP premium multiport production packer installed below the mudline, a 7⅝-in XHP premium production packer, a tubing-mounted chemical injection mandrel, and a DCIN-II dual-check chemical injection nipple.

The completion hardware was also designed to accommodate other key components including subsurface safety valves and real-time monitoring with downhole pressure and temperature gauges.

Simultaneous Drilling, Intervention

On March 31, 2017, the intervention team positioned the CT intervention tower on MHA1-01 as the rig skidded to the next slot to begin drilling the second well. Simultaneously with the drilling operation, the team performed a cement bond logging run using Schlumberger ACTive* real-time

downhole coiled tubing services, which use real-time downhole measurements to interpret and optimize treatments while they are in progress.

Early in the project, Total had determined that customized engineering would be required to accommodate intervention operations on the TLP and achieve the key objective of perforating with up to 150 m (492 ft) of guns on CT conveyance to depth in a single run. Following perforating operations, the guns would need to be pulled out of hole in a live well condition without killing the well.

The solution to this challenge was a custom-built motion-compensated CT intervention tower, featuring the first-time integration of a remotely operated CIRP* completion insertion and removal under pressure system, which inserts and retrieves long gun strings under wellhead pressure. In addition to the customized tower dimensions, a 5/16-in braided wireline cable for gun deployment was integrated with the tower while an A-frame/gin pole crane facilitated gun deployment in the live well to meet the working height limitations below the MEP. A custom CT well control stackup that worked within the tower's dimensional limits was rigged up on top of the Christmas tree, as enabled by the motion-compensation system.

The initial SIT and factory acceptance test (FAT) of the CIRP system stack and CT intervention tower in Lafayette, Louisiana, validated tower functionality. A second SIT was performed in November 2016 at the Schlumberger base in Pointe-Noire, Republic of the Congo, to simulate the deployment under pressure functionality with the CIRP system and the braided wire using wireline pressure control equipment (PCE).

In February 2017, a final commissioning SIT was performed of all the components rigged up for the first time together on the TLP, including a full CIRP system gun deployment simulation and interference test with the MEP conducted simultaneously with MHA1-01 drilling operations. The offshore SIT validated the functionality and technical interfaces across the CT tower, CIRP system equipment, and braided wireline cable, and ultimately improved operational procedures by allowing application of lessons learned on the first well execution.

Engineers from multiple Schlumberger product lines are involved in the Moho Nord exploration and production project, providing opportunities for collaboration and sharing of lessons learned and best practices. (Courtesy of Schlumberger)

Single-Run Long Perforation in Deep Water

For the first well intervention operation, 81.8 m (269 ft) of perforating guns and spacers was deployed in hole on the braided line using the CIRP system and bowl/slips. The job marked the world's first CIRP system perforation operation on a TLP in deep water. The perforating guns were conveyed to depth using ACTive Perf* CT real-time perforating services in combination with ACTive GR* CT real-time gamma ray logging tool and casing collar locator for depth correlation.

The guns were activated on the first attempt using the eFire-TCP* tubing-conveyed perforating electronic firing head, as verified by ACTive services' downhole data acquisition. The CIRP system enabled perforation of 78 m (256 ft) of reservoir section in a single run and post-perforation retrieval with braided wire under live well conditions.

After an initial acid wash of the perforations was performed on the bottom 15 m (49 ft) of the reservoir interval, the well was handed over to the Schlumberger Testing & Process team for well cleanup and well testing. A memory production logging tool (MPLT) conveyed on slickline was deployed through the CT intervention tower at various stages of the well flowback operation. After conducting a larger acid stimulation operation, the team performed a second well test cleanup and MPLT run. All operations were executed simultaneously with the TLP drilling operation, with no HSE incidents.

Collaboration and the application of advanced technology and workflows for all phases, from planning and design through drilling, completion, single-run perforation and well testing, were instrumental in not only delivering the first Moho Nord TLP well in May 2017 but also ensuring long-term success of the Moho Nord campaign.

*Mark of Schlumberger or a Schlumberger company

Schlumberger

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Bureau Veritas: Premium classification and certification services for Moho Nord FPU and TLP

Bureau Veritas (BV) has been deeply involved from Total Moho Nord project's earliest stage, providing classification and certification services during the design and construction of FPU *Likouf* in HHI yards in Korea. Bureau Veritas offices all over the world have been involved in the classification process for more than 50 systems installed on the FPU, in addition to ten systems submitted for certification.

In addition to providing classification and certification services for the existing floater FPU *Alima* in Moho Bilondo field, BV has provided class in service for the FPU *Likouf* and for the TLP under transfer of class.

The classification and certification processes for the FPU and TLP are based on BV's extensive experience acquired through years of diverse services deployed across nearly 50% of offshore floating installations throughout the world. BV's classifications address construction integrity and design life on the operating site.

Bureau Veritas has been entrusted to provide these classification services as a result of its extensive presence in Africa, and Congo in particular, combined with an excellent track record and client satisfaction on previous such projects. The new solutions and concepts applied on the project have further diversified Bureau Veritas' portfolio in the offshore sector.

Indeed, as a classification society, Bureau Veritas assesses ships and offshore facilities for conformity with standards that mainly concern structural soundness and the reliability of onboard machinery. In addition, Bureau Veritas provides ship certification on behalf of flag administrations; independent verification of design and operations, as well as technical assistance services, including asset integrity management services.

Bureau Veritas provided a variety of classification services for Total Moho Nord's FPU and TLP.

Bureau Veritas, as a global leading provider in testing, inspection, and certification (TIC), offers innovative solutions that go beyond simple compliance with regulations and standards in order to help its clients meet their growing challenges of health and safety, security, environment protection, and social responsibility by reducing risks, improving performance, and promoting sustainable development.

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DORIS: Meeting engineering objectives from Conceptualization to Hook-up

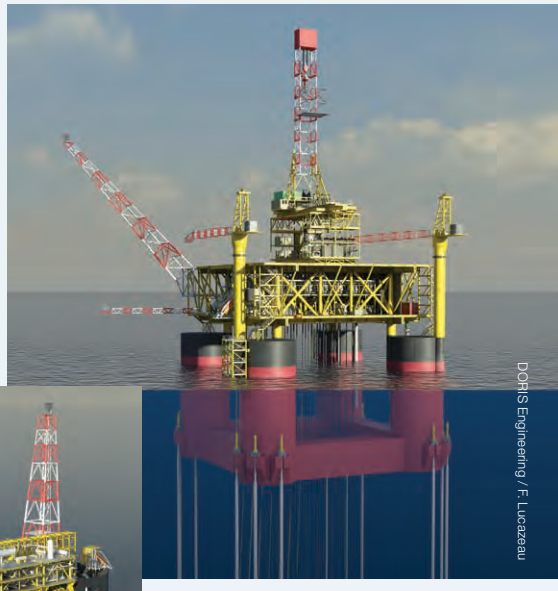
DORIS' involvement on the Moho Nord (MHN) field development covered all project phases (Conceptualization through Detailed Design to Hook-up and Commissioning), and the scope included three key components of the field architecture: the tension leg platform (TLP), the floating production unit (FPU) and the processing plant. This noteworthy commitment to the project and the close partnership developed with TOTAL resulted in the delivery of the project on schedule and within budget, while meeting all technical objectives.

Integrated engineering for a large-scale project

In 2009, after delineating the Moho Nord discovery, TOTAL contracted DORIS to perform conceptual studies to evaluate options for developing the field's distinct Albian and Miocene reservoirs. The pre-FEED studies rapidly led to an ambitious scheme including a TLP and an FPU. DORIS then developed preliminary designs for the TLP and FPU, as well as for the umbilicals, flowlines and risers (UFR) and the subsea production systems (SPS). Having the design of the whole field in hand, DORIS teams delivered an optimum layout to minimize overall transfer and interconnection costs.

Likouf FPU – A complete engineering development, one objective

DORIS' largest task on MHN was performed during the FEED studies of the Likouf FPU, which required more than 200,000 man-hours. DORIS provided project management, prepared tender documents for long lead items, and conducted basic engineering studies for the FPU hull and topsides, the UFR and for the SPS. Subsequently, as subcontractor to Hyundai Heavy Industries (HHI), DORIS performed the detailed engineering of the FPU topsides and mooring lines. DORIS achieved the main objective set by TOTAL which was keeping the FPU topsides below a weight limit target of 20,000 t.


DORIS Engineering / F. Lucazeau


DORIS Engineering / F. Lucazeau

MHN TLP, technical firsts with confidence

In parallel with the FEED for the FPU, DORIS contributed to HHI winning the design competition and was then responsible for the early detailed designs of the TLP topsides, risers, drilling interface and mooring system installation.

Designed to be a low-weight, small-footprint structure, the TLP would incorporate an innovative skidding system for the blowout preventer (BOP) and drilling riser to allow for quick transitions between wells during the drilling program.

After a handover period in 2013, with a DORIS team working at HHI's Ulsan yard in Korea, DORIS' involvement on the project was completed in November 2016 with the participation in the FPU hook-up and transition to offshore operations.

About DORIS Group

For more than 50 years, DORIS has been applying its expertise to provide first class engineering and technical services to enable the faster development and lower cost production needed by the oil and gas industry. In West Africa, DORIS has been involved on all major projects for TOTAL including the Moho Bilondo FPU in Congo and the Akpo and Usan FPSOs in Nigeria.

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Custom power packages from project planning to reliable servicing and maintenance

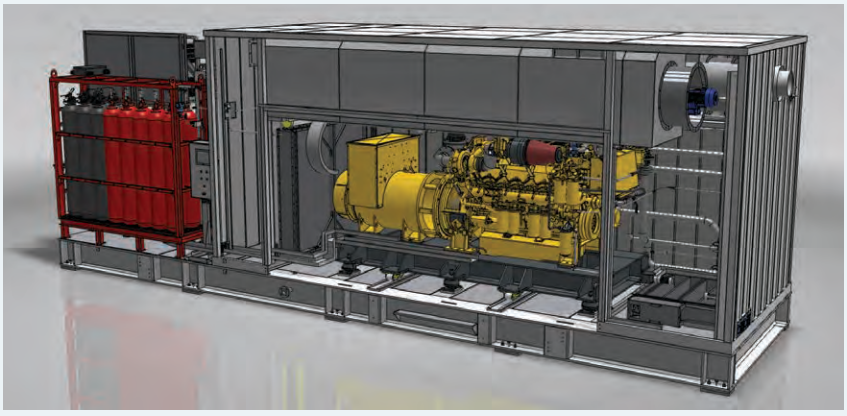
As official Caterpillar dealer, Eneria offers know-how and expertise to supply custom electrical installations for both onshore and offshore applications, integrating the best quality, reliability, and high flexibility of Caterpillar engines.

Applying exceptional technical skills, Eneria delivers EPCIC solutions for:

- Essential/emergency generator-set packages
- Fire pumps (NFPA) and hydraulic groups
- Caterpillar engines and transmissions for well servicing
- ATEX/IECEx packages for hazardous-area Zones 1 & 2

Comprehensive customer support. Eneria's engineering teams and specialists are available to provide expert advice throughout the life of the project. Eneria integrates specific technologies, such as F&G systems, type A60, H60 enclosures with fire and blastproof resistance and IP55 protection rating, and control system connected to critical safety systems on floating units. Eneria's power packages meet applicable regulations with ATEX and Marine Classification Society certifications, while operating under severe service conditions in extreme environments.

Reliable service and maintenance. The continuous operating requirement of the petroleum industry demands extraordinary reliability. Eneria offers expert intervention and service teams, rapid availability of genuine parts, and the ability to adapt to local conditions and constraints worldwide to ensure the best possible performance from each generator-set package.



For Total's Moho Nord TLP, Eneria supplied the emergency diesel generator to satisfy the 500 eKW power requirement.

Eneria's power package addressing the strictest TOTAL General and Project Specifications, while being compliant with ATEX/IECEx regulations and DNV GL rules.

Moho Nord TLP package. Eneria supplied the emergency power package (EMDG) consisting of C32 Caterpillar equipment to satisfy the 500 eKW power requirement. Unit Control Panels were designed to control the generator set.

This stand-alone EMDG package is certified by a Notified Body as a unit ATEX Ex'px zone 2, group IIB, temperature T3. The Moho Nord TLP package, also DNV GL certified, is equipped with an A60 stainless steel close-fit soundproof and pressurized enclosure, and a fire extinguishing water mist system, complying with NFPA 750 regulations, and electrical and hydraulic starting systems suitable for Zone 2.

Eneria's main challenge was to design the power package addressing the strictest TOTAL General and Project Specifications, while being compliant with ATEX/IECEx regulations and DNV GL rules.

Eneria CAT

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Delivering the industry's finest EPIC services and cutting-edge technologies for Moho Nord

Hyundai Heavy Industries CO., Ltd (HHI) is a major engineering, procurement, installation and commissioning (EPIC) company based in Ulsan, South Korea, offering a diversified range of offshore oil and gas and shipbuilding services.

Since the award of the AKPO FPSO project in 2005, HHI has been maintaining excellent working relationships with Total in performing EPIC services for a variety of offshore fixed platforms, FPSOs and FPUs. Prior to the Moho Nord project, HHI and Total had experience in working together in the Republic of Congo during the execution of the Moho Bilondo FPU *Alima*.

The Moho Nord TLP is Total's first TLP in Africa and the only one in the world to combine drilling operations, interventions on wells, and surface production. Incorporating the latest innovations in FPUs, Moho Nord FPU is the first 100% electric FPU, designed for minimum impact on the environment through processes such as zero gas flaring, reinjection of all produced water, and heat recovery.

Safety First

HHI considers safety as a top priority in its approach to every project. HHI and Total implemented various safety programs during the execution of Moho Nord project. These included programs such as the S1 (Safety First) program, IMPACTS program, HSE incentive program, plus Anomaly and Stop cards to enhance the safety culture. As a result, HHI is proud to have recorded only three minor lost time injuries (LTIs) although 22,000,000 man-hours were spent during the execution of the Moho Nord FPU & TLP project.

Engineering

One of challenges during engineering was the control of changes during the design phase. During the execution phase, methanol and LDHI module were newly added. In order to manage these changes during engineering, HHI and Total designated key design parameters, namely weight (topside and hull), electrical load balance, ICSS hardware I/O (topside and hull), and utilities. These key engineering parameters, so designated, enabled the monitoring and follow up of problems that may arise and the finding of technical solutions with the Total engineering team. HHI also actively followed-up vendor documentation, interface between hull and topside, freezing of ICSS data, and 3D model reviews.

Construction

For the execution of both TLP & FPU projects, HHI maximized the synergy effect by sharing of common procedures and common specifications of engineering and materials. From a project management perspective, these actions benefited not only HHI, but also Total in terms of cost savings and increased efficiency in the fabrication of the FPU and the TLP in the same yard.

HHI used the heavy lifting vessel *HD 10,000*, newly built by HSHI. The

Moho Nord TLP was the first project in Korea for the fabrication of both the topside and hull in the same yard.

The FPU achieved first oil on March 14, 2017. For both TLP and FPU, HHI maximized synergy by sharing common procedures and common specifications of engineering and materials to achieve significant cost savings and improve construction efficiency.

HD 10,000 is the biggest heavy lifting vessel in the shipbuilding yards, helping to make the integration of heavy modules on a hull safer and easier than any other methods. The *HD 10,000* was also used by HHI for the lifting of the topsides of the TLP, and also 14 topside modules of the FPU onto the hull, thereby improving efficiency by reducing the integration schedule as well as the cost.

Offshore hook-up and commissioning

After the TLP and FPU sailed away from HHI's yard on November 30, 2015 and October 1, 2016 respectively, HHI was actively involved in the offshore hook-up and commissioning phase with Total, other contractors, vendors, and local subcontractors. The HHI onshore team also supported the site team for the timely delivery of materials and the mobilization of various vendors and local manpower through active communication with all the parties. As a result, offshore installation, hook-up and commissioning of the FPU were completed successfully in four months, with first oil achieved on March 14, 2017.

HHI is pleased to have played a key role on the Total Moho Nord project. The inevitable risks and challenges were addressed with Total's continuous support and the cooperation of subcontractors and suppliers. With this project, HHI is continuing to play a key role as the leading EPIC contractor in the offshore market.

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PIH: Insulating pipe joints with thick-layer Injection Moulded Polypropylene (IMPP)

Pipeline Induction Heat Ltd (PIH), a Stanley Black & Decker company, provides field joint coating and other custom coating services to the onshore and offshore pipeline construction industry. The services include application of corrosion protection, foam infill and thermal insulation systems.

Historical track record. Through decades of experience, PIH has gained a global reputation for successful project delivery through a culture built on safety, passion for innovation, commercial competitiveness, specialist automated equipment, and highly trained personnel.

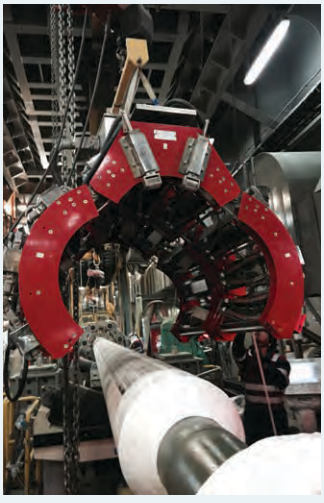
PIH services for Moho Nord. The project involved the installation of production flow lines, gas-lift lines, injection lines, and export lines of varying diameters from 6-in. to 16-in. onboard the TechnipFMC *G1200* S-Lay pipelay vessel, offshore Congo. The 9-in. and 10-in. diameter production flow lines were supplied with multi-layer polypropylene thermal insulation. PIH's critical scope of work was to install up to 115-mm thick IMPP to the field joint areas, with up to a 740-mm wide band.

PIH Engineered Services Team collaboration with the client commenced during tender stage to ensure the service offering met and exceeded the client's expectations. Post-contract award vessel visits were carried out to align equipment and processes to fit specifically in the "firing line" on the *G1200* vessel.

Limited space aboard the vessel, coupled with demanding cycle times, dictated a completely bespoke design for the IMPP coating equipment, built in and around the vessel infrastructure. New equipment enhancements allowed the IMPP machine to track any pipe movement, whilst still having the ability to quickly release the pipe should the pipe movement exceed the design parameters. Varying pipe heights, angles, and weld positions necessitated the IMPP equipment to move in the X, Y, and Z planes whilst having the ability to match the lay angle of the pipe.

PIH's scope also included the application of Heat Shrink Sleeves (HSS).

Project success. The project was rewarding and a successful campaign built on safety, collaboration and innovation.



Top left: PIH patented Solaris™ radiant heater. Top right: IMPP station. Bottom: IMPP joint transferring over the stinger

PIPELINE INDUCTION HEAT

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Brownfield Experience Is Key to Successful Topside Upgrade For Moho Phase 1 Bis

As part of the overall Moho Nord project offshore Congo, Total planned to expand the existing Alima floating production unit (FPU), already serving the Moho Bilondo field, by adding two major topside modules to handle production from new subsea wells in the Moho Phase 1 Bis development. A related challenge was performing the upgrade on the functioning FPU with only two scheduled production shutdowns.

Leveraging Ponticelli's Experience

Total needed help from an offshore construction contractor with significant brownfield experience in West Africa, so it selected Ponticelli as its lead topside contractor for Moho Phase 1 Bis. For the past decade, Ponticelli has built a successful track record performing work on tiebacks, platform revamps, and integrity management projects in Nigeria, Gabon, and Angola.

Scope Includes Two Large Modules

In November 2014, Total awarded Ponticelli a contract for the fabrication of two modules each weighing 300 metric tons, together with the prefabrication of 470 tons of structural elements and 2900 spools of interconnecting pipe. Ponticelli also would be responsible for transportation and installation of these elements on the Alima FPU. In addition, Ponticelli was contracted to install five additional I-tubes on the Alima hull, a task that would require marine operations, lifting and diving services. To implement the project, Ponticelli also set up a new 13,000 square meter yard in Pointe Noir with offices, workshops, and a logistics area.

Module installation on Alima FPU.

Integrated Team is Key Innovation

Because of the scope and complexity of the project, Total and Ponticelli established "The I-Team", an integrated project management group. The team was organized so that each aspect of the project was overseen by the individual from either company who was most qualified to manage that particular task. This approach enabled the team to achieve "fast-loop" decision-making, while improving the interface with and coordination between project subcontractors.

Successful Project Implementation

Ponticelli began working offshore on the Alima FPU in August 2015. The first production shutdown, originally scheduled for 28 days, was completed four days early on 10 October 2015. The second shutdown, planned for nine days, was completed in 8 days on 14 April 2016. Work was completed on the FPU in March 2017. During the 24 months of project implementation, a total of 400 Ponticelli employees were working offshore, contributing 1.6 million man-hours to the project. Ponticelli successfully met all of Total's objectives, including completion of both planned shutdowns ahead of schedule.

PONTICELLI FRÈRES GROUP
Vincent Ladougne
Business Development Manager

Vallourec provides full scope of tubular solutions to support Moho Nord Project

Building on experience supporting Total's operations in Angola, Nigeria, Gabon, and previous projects in Congo, Vallourec provided drill string engineering, high performance drill pipe, oil country tubular goods (OCTG), drill pipe risers, and welding services for the Moho Nord field, 75 km off Pointe-Noire, Republic of Congo.

Total planned the Moho Nord field to produce from two separate reservoirs. The Albian reservoir will be accessed by 17 dry tree wells on Total's first tension leg platform (TLP) in Africa. The Miocene reservoir will be developed with 28 subsea wells, including Phase 1 Bis. All of the Moho Nord wells will produce to the Likouf floating production unit (FPU), which has two separate processing trains (handling H_2S and $C0_2$ along with oil, gas and water) and the capacity to export 100,000 BOEPD via pipeline to Total's Djéno onshore terminal. Drilling began in 2014 and first production came ashore in March 2017.

Drill String Engineering

To prepare for the project, Vallourec's drilling experts began working with Total engineers in 2012 to design drill strings for the challenging wells that would be drilled from the TLP in 800 m of water, with departures as long as 6000 m and measured depth of 7500 m. Total engineers provided parameters for each planned well, including well architecture, trajectories, and mud properties to be used in each hole section. Vallourec engineers, with in-depth knowledge of drill string components and their application, used proprietary software to analyze torque, drag, tension, compression and well hydraulics to design the optimum drill string. Tapered strings with high strength mechanical properties would be required on most wells.

Total provided the resulting specifications to the rig contractors, and Atlantica was selected for the rig on the TLP. Atlantica acquired the entire drill string from Vallourec. This included the VM-150 DP high-strength drill pipe with the field-proven VAM® Express™ connection. This connection provides torque capacity that averages 150% to 200% of API connections, improved hydraulic performance, and quick makeup for improved rig floor efficiency.

Drill Pipe Risers and Casings viewed from the derrick of the Vantage Tungsten Explorer drill ship

Drill pipe stands on the Atlantica Delta rig

Oil Country Tubular Goods

The OCTG specifications for the Moho Nord project were very stringent on account of the reservoir conditions, requiring material to be both high strength, to support the well loads, and corrosion resistant (H_2S and CO_2). To confirm the high level of performance of connections and materials, Vallourec conducted specific laboratory tests at its dedicated Research Center in Aulnoye, France, including accelerated corrosion

testing using fluids from the Albian and Miocene reservoirs.

OCTG provided for the Moho Nord project was manufactured in France and Germany using Vallourec's super chromium proprietary grade VM 110 13 Cr SS as well as some high collapse sour service grades to withstand the corrosive fluids produced from the two reservoirs.

Moho Nord is one of the first major projects to take advantage of the high performance characteristics of Vallourec's latest generation of premium connections, the VAM® 21. Qualified to API RP 5C5:2017, the most stringent connection qualification procedure, VAM® 21 is gas tight and is as strong as the pipe body under compression and tension. VAM® 21 is now the reference threaded and coupled connection for deep offshore projects.

In addition to OCTG, Vallourec manufactured a variety of custom-designed accessories including pup joints and crossover subs for the project. Through innovative engineering, careful material selection, and in-house fabrication, Vallourec produced made-to-measure components that met the challenging specifications at significantly reduced cost for Total.

Drill Pipe Riser

Vallourec provided its high performance drill pipe riser, VAM® DPR HP™, as part of Aker's subsea package for the Miocene wells drilled in up to 1300m of water. Drill pipe risers provide an efficient means of installing upper completion, subsea trees and other components as well as performing well interventions. The VAM® DPR HP™ drill pipe riser incorporates a proprietary double-shoulder connection design, with a gas-tight metal-to-metal seal, and is rated up to 10,000 psi working pressure for safe operations on high-pressure wells. The 6 5/8" OD VAM® DPR HP™ drill pipe riser delivered to the project is manufactured using VM 105 DP MS proprietary sour service grade. It provides a quick, cost-effective means to connect service rigs to subsea assets to reliably install equipment and perform through-tubing or wireline operations. Total has already utilized the VAM® DPR HP™ drill pipe riser system on other deepwater fields including Usan and Egina in Nigeria.

Vallourec local inspection services

Local Services

Vallourec will provide over 20,000 metric tons of OCTG for the Moho Nord project between 2014 and 2019. To manage this quantity of OCTG, Vallourec helped Total optimize the operation of its large-scale pipe yard in Pointe-Noire. Vallourec experts audited the yard and made recommendations for its layout, equipment, and best practices for storage and handling with the objective of avoiding safety hazards, minimizing damage to the OCTG, and maximizing efficiency for the duration of the project.

Vallourec also trained all people involved with tubular management. Vallourec's local VAM® service licensee, SPIE Oil & Gas Services, and pipe yard personnel were familiarized with the new products, including the VAM® 21 connection. Vallourec experts also conducted training for the Total's drilling, subsea and QA/QC teams on the drill pipe, drill pipe riser and the OCTG. Vallourec also trained and qualified local inspection companies on how to inspect OCTG and drill pipe connections.

Welding on pipelaying vessel

In addition to providing tubulars used in Moho Nord's wells, Vallourec also contributed to the installation of the project pipelines. Working aboard the TechnipFMC Global 1200 pipelaying vessel, Serimax, Vallourec's pipe welding subsidiary, successfully performed approximately 20,000 welds on 225 km of line pipe.

Full scope helps meet tight schedule

Total brought the Moho Nord field on line from FID to first oil in less than four years. In the process, the operator leveraged Vallourec's international scope of technical and manufacturing capabilities. To date, Vallourec has met all scheduled deadlines on the project without any safety incidents, and has kept its tradition of designing quality products, testing them in real life conditions, and providing Total the quality products that perform in very challenging conditions.

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TechnipFMC's broad offshore portfolio delivers Moho Nord on target

Moho Nord is one of the largest projects undertaken by TechnipFMC to date. The company provided the UFR package—subsea structures, umbilicals, risers, and flowlines—for the Moho Nord and Moho Phase 1 Bis developments, including major upgrades on the existing *Alima* FPU, two riser pulling systems, installation of transfer lines between the *Likouf* FPU and the Moho Nord TLP, and offshore pipeline installation.

TechnipFMC installed 300 km of rigid pipe, umbilicals, and flexible pipe. In all, several hundred TechnipFMC personnel contributed over 10 million man-hours to the Moho Nord project.

Integrated offering keeps project on track

Total let the contracts for Moho Nord in 2013 during a busy period for the offshore industry, when marine assets were in short supply. By selecting TechnipFMC, the operator could rely on the full support of the company's in-house expertise, manufacturing capacity, and marine assets. This broad scope enabled TechnipFMC to adjust schedules to compensate for challenges in implementing the multifaceted project.

Large, complex UFR package

The project's design phase required four years of effort from TechnipFMC engineers, but fabrication and installation of the UFR package was the company's largest contribution to Moho Nord. Total specified a unique high-pressure gas lift riser umbilical, or GLU, that required careful design, thorough testing, and new manufacturing procedures. To fabricate the GLU and other umbilicals on schedule, TechnipFMC split manufacturing between plants in the United States and the United Kingdom, using the company's proprietary Vertical Helical Assembly Machine (VHAM).

The complex subsea infrastructure design required compact modules that could be handled by the available vessels, plus adaptation of wellhead connectors to perform in a small operating envelope.

The project included more than 50,000 metric tons of subsea structures, such as mud mats, manifolds, rigid jumpers, flying leads, and flowline end terminals.

Commitment to local content

To provide local content and meet the accelerated schedule, TechnipFMC worked with a subcontractor to establish a new facility in Pointe Noire to manufacture mud mat components and assemble subsea structures, providing jobs for Congolese workers and demonstrating the extent of Total's and TechnipFMC's commitment to the project.

A fleet of 34 offshore assets supported the Moho Nord project. Two new-build vessels were deployed, including the *Skandi Africa*, which is highly automated for efficient and safe flexible pipe-laying. The pipe-laying vessel *G1200* was extensively modified to handle multiple construction tasks in water depths ranging from just 3 m to 1,200 m. The *G1200* was used to perform an innovative dynamic positioning beach pull operation, bringing a pipeline to shore using thrusters, instead of anchors, to hold the vessel in position.

The pipe-laying vessel G1200 performed construction tasks in water depths ranging from just 3 m to 1,200 m and completed an innovative dynamic positioning beach pull operation.

Project management gets results

With close coordination with Total, TechnipFMC work was completed on schedule for first oil in March 2017. Notably, TechnipFMC achieved an excellent HSE record throughout a two-year offshore campaign.

TechnipFMC

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Successful delivery and integration of Moho Nord ICSS

Prior to the Moho Nord project, Yokogawa, a world leader in industrial automation and control, had already demonstrated its project management capabilities by providing its advanced integrated control and safety system (ICSS) for the ALIMA Floating Production Unit (FPU) for Total's Moho Bilondo field offshore The Republic of Congo. This success was an important factor in Total's selection of Yokogawa to provide the Moho Nord ICSS which is based on Yokogawa flagship control system, CENTUM VP.

The workscope included the following:

- supply of the new ICSS of the TLP platform and LIKOUF FPU of the Moho Nord development
- extension and upgrade of the existing ICSS of the ALIMA FPU to control the additional subsea wells brought online on the Moho 1 Bis development
- supply of the Subsea Control Units (SCU) to interface the Subsea Production System with the ICSS on both the Moho Nord development and Moho 1 Bis development
- supply of an Operator Training Simulator (OTS) aimed at preparing and qualifying offshore personnel to operate the control systems

One system split between different contracts

The main challenge for Total was to keep the integrity and design harmonization between the different parts of the ICSS which had to be delivered through different contractors but which in the end merged with each other at site to form an integrated system. Yokogawa helped Total to meet this challenge thanks to the mobilization of a core team responsible for its internal coordination across the various contracts. This core team also helped contractors to coordinate with each other.

Overall Control of Wells and Risers (OCWR)

The subsea system is fairly complex and difficult to control and this places a considerable burden on the operators. To help the operators, a set of advanced control algorithms were configured in the CENTUM VP system by Yokogawa experts. These algorithms automate certain recurring operational procedures for the subsea production and injection networks that are carried out from the Central Control Room.

Local content

To meet Total's local content requirements, Yokogawa hired four Congolese engineers and enrolled them in a five-phase training program. Through this program, the trainees were included in the engineering and programming team in France, then participated in onshore commissioning in Korea and offshore commissioning in Congo. Four years after the program started, the four trainees are today in the last phase of the program, providing maintenance services on the Moho Nord facilities.

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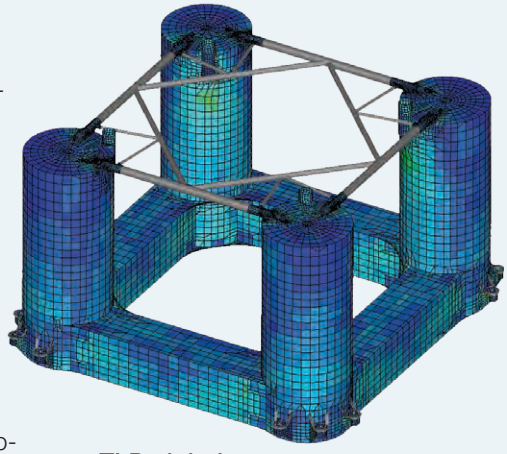
DNV GL: Assurance partner from concept to TLP certification

DNV GL provides classification, technical assurance, software, and independent expert advisory services. From project initiation to decommissioning, DNV GL experts enable oil and gas operators to make the right choices for a safer, smarter, and greener future.

For Moho Nord, DNV GL served as the assurance partner for Total from the earliest stages of the project—from concept stage approval, all the way to final TLP classification and certification. DNV GL provided the confidence required on the tendon system and components, by following up on the critical delivery to ensure project-specific compliance. Additionally, DNV GL performed independent verification of risers and mooring system.



TLP global structural analysis model

Proactive engagement was a must to ensure the success of this project. Challenges included addressing a parallel total quality and certification approach on the critical tendon components, as well as simultaneous operations with a tender-assisted, drilling rig. As a result of the Moho Nord project experience, DNV GL issued a new updated set of rules for the benefit of future TLP projects.

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Total Mpita service station, Pointe-Noire, Republic of Congo

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