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Status and challenges of Chinese deepwater oil and gas development

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Abstract: There have been nearly 33 oil and gas fields with billions bbl resources found in deepwater areas all over the world since 1970, so deepwater areas are of prime importance for petroleum exploration and development. With the achievements of a series of deepwater petroleum exploration technology projects in the USA, Europe and Brazil, the GOM, Brazil and West Africa are becoming the focus of deepwater oil and gas exploration. The oil productivity derived from deepwater areas exceeds that of shallow water areas in GOM and Brazil since 2001. Deepwater is becoming very important for petroleum industries and the top area of technology innovations. On the basis of analyses of world deepwater technological innovations, this paper briefly introduces the history of the China National Offshore Oil Corporation (CNOOC), and then presents the status and challenges of Chinese deepwater oil and gas development.

Key words: Deepwater, subsea production system, semi-submersible units, pipeline-laying barge, flow assurances

1 Introduction

With the rapid development of the Chinese economy in the last twenty years, the conflict between energy demands and energy supply is increasing. Reducing the shortages of oil and gas is becoming more and more urgent. China's crude oil productivity has not met domestic market demand since 1993, when China changed from a net oil-exporting country to a net oil-importer. In 2010, China's crude oil imports reached 239 million tonnes and the shortage of oil is becoming a major factor constraining China's economic development. In 2010, China overtook Japan to become the second highest oil importer in the world, behind only the USA. From 2006, a series of national deepwater projects supported by the 11th and 12th Five-Year Program have been going on, in order to strengthen the exploration technology for developing deepwater oil and gas resources.

CNOOC was founded in 1982. There are about 52 offshore oil and gas fields developed from Bohai Bay, East China Sea to South China Sea. The oil and gas resources have produced more than 50 million tonnes oil equivalent and offshore oil and gas production has become one of major parts of Chinese oil and gas incremental production. The South China Sea, the largest sea area in China, is one of the 4 largest oil and gas regions in the world. However, more than 75% of remaining oil and gas reserves are in deepwater areas. From 1990, CNOOC began turning its eyes to deepwater areas, and in 1996, 1997, the biggest oil fields LH11-1 and LF22-1 where the water depth (WD) exceeds 330 m were developed with innovative deepwater technology, including the subsea production system, semi-FPS and so on. At present, the deepwater exploration and development (E&D) technology and deepwater vessels are being developed. However, domestic technology and facilities for deepwater oil development are still at a low level, perhaps 15 to 20 years behind advanced world technology. So utilizing the deepwater oil and gas as soon as possible is the most important task, which is one of the best way to improve continuing energy supply, and to solve the growing energy crisis in some extent.

2 World deepwater technology status and trends

2.1 World deepwater oil and gas resources

Deepwater is a concept depending on technology level, generally, the continental shelf deeper than 300 m is defined as the deepwater area for oil and gas development, and those deeper than 1,500 m are called ultra-deep waters (Zhang, 2005). According to statistics in the Oil and Gas Journal, as of 1 January 2006, global offshore oil resources were about 135 billion tonnes, and the proven reserves about 38 billion tonnes; offshore natural gas resources were about 140 trillion cubic meters, and the proven reserves about 40 trillion cubic meters (Tian and Yang, 2006). At present, global offshore proven reserves are still dominated by shallow water reserves. Proven deepwater oil and gas reserves are approximately 10 billion tonnes oil equivalent, mainly distributed in the U.S. Gulf of Mexico (GOM), the Brazil Sea

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and West Africa. Since the 1990s, it is estimated there are close to 100 global deepwater oil and gas reservoirs, among which the reserves at the level of 100 million tonnes exceed 30%. In 2004 alone, global offshore oil and gas exploration found 20 major deepwater reservoirs (Pan et al, 2006) with reserves of over 100 million barrels, and now there are nearly 33 huge discoveries in world deepwater areas (see in Fig. 1) (Li, 2006). According to the U.S. Minerals Management Service (MMS) statistics, the Gulf of Mexico is one of the single largest suppliers of oil and gas to the U.S. market, with continued interest and activity in deepwater areas of the GOM, oil production will continue to be strong with a large portion of production coming from projects in deeper water depth. Deepwater supplies about 70% of the oil and 36% of the gas from the GOM. There are 7,310 active leases in the U.S. GOM, 58% of which are in deepwater, respectively (2009-2018 MMS 2009-012, Gulf of Mexico oil production forecast to reach record high). Now deepwater is becoming the main area of offshore oil and gas development (Fig. 2).

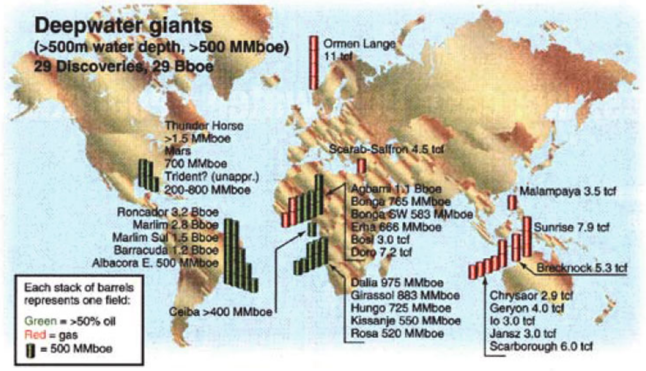


Fig. 1 World deepwater oil and gas reservoir discoveries (after Li, 2006)

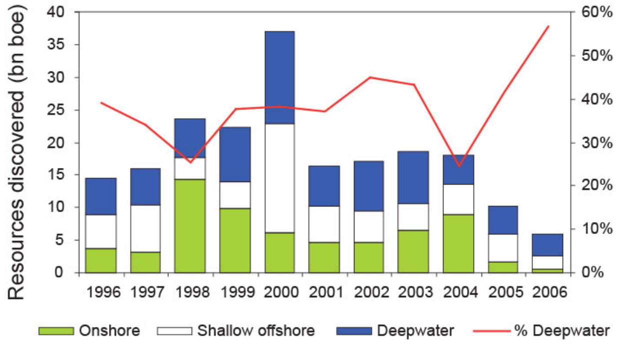


Fig. 2 Offshore fields resources

2.2 Deepwater technology

The characteristics of deepwater oil and gas E&D include high risks, leading innovation technology and huge investment.

The world's first deepwater exploration well was successfully drilled in 1970 in the GOM, the long-term national research projects such as European Poseidon Project, Brazil PROCAP, PROCAP 2000, PROCAP 3000 are underway in the GOM, North Sea and Brazil since the 1980s, in order to develop drilling and production units and technology for deepwater E&D. Through these systematic studies great achievements have been obtained and the sixth-generation drilling facility which can operate in a water depth of 3,000 m has been built. Different kinds of deepwater engineering technologies have been developed, there are about 240 units of various types of deepwater floating platforms such as CPT (compliant piled tower), TLP (tension leg platform), Spar (deep-draft single column platform) and Semi-FPS (large multi-functional semi-submersible platform) are operated in world deepwater areas (seen in Fig. 3). Meanwhile, subsea production technologies have experienced a rapid development. There are over 6,000 completed subsea wells. The world record depths change very rapidly, the deepest offshore oil production is currently in a water depth of about 2,743 m (the deepwater oil and gas research report, 2010) and the longest tied back subsea production system is near 143 km. Now the petroleum industry has turned its eyes to a water depth of 3,000 m. Deepwater is the leading edge of offshore activity and technology innovation.

However there are still some deepwater challenges, as follows:

Low margin drilling conditions;

How to reduce well, flowline & platform costs?

Fig. 3 Deepwater drilling rig and SPAR

How to increase flow distances?
How to minimize deepwater intervention costs?
How to handle associated gas?
How to develop deepwater marginals?
Environment risk.

3 Status of CNOOC and Chinese deepwater

3.1 History of CNOOC

Since CNOOC was founded in 1982, about 52 offshore oil and gas fields have been developed from Bohai Bay, East China Sea and South China Sea and these depend on innovation and technology. Chinese fabrication time of a FPSO is a world record; the offshore anti-vibration platform for sea ice had being successfully used in Bohai Bay and the longest subsea pipeline which transports heavy oil and water, 70 km was built in SZ36-1 oil field.

The South China Sea, rich in oil and gas resources, is one of the 4 world-renowned offshore oil and gas regions. A preliminary estimate of the geological oil resources in the deepwater totals 8.7 billion tonnes, with the expected recoverable resources at 2.7 billion tonnes; the geological natural gas resources are expected to total 6.0 trillion cubic meters, with recoverable resources reaching 3.7 trillion cubic meters. Deepwater oil and gas discoveries in the South China Sea by adjoining countries (among others, the 864-m Malampaya offshore oil and gas field and 350-m Linapacan oil field in Palawan, Philippines; the 885-m Seno offshore oilfield in East Kalimantan, Indonesia; the tectonic F6 Field and Kikeh oil field offshore Sarawak, Malaysia) indicate good prospects for oil and gas exploration in South China's deepwater areas. The distribution of China's offshore oil and natural gas are mainly in deepwater areas. In 1996, the biggest oil field in the South China Sea, LH11-1, was developed using 24 completed subset wells, a FPSO and a semi-FPS, 7 innovations had been used in this project, the most famous is subset ESP (electrical submersible Pump) and WMEC (wet matble electrical connect) whose water depth is 310 m. In 1997, the LF22-1 oil field, whose water depth is 333 m was developed using 5 completed subsea wells and a FPSO (seen in Fig. 4), which is the cost effective deepwater marginal field development case. In 2006, the LW3-1-1 well was successfully drilled, water depth is 1,480 m, deepwater gas field development is becoming a fact.

3.2 Challenges for Chinese deepwater development

The complexities of extreme environment conditions and the geological conditions in the South China Sea bring large challenges for the development of deepwater resources. The main challenges for China's deepwater oil and gas industry are:

Shortage for deepwater technology, facilities and experiences;

Extreme environmental conditions;

Complicated seabed topography;

Deepwater flow assurance due to complicated reservoir parameters;

Deepwater engineering and deepwater intervention.

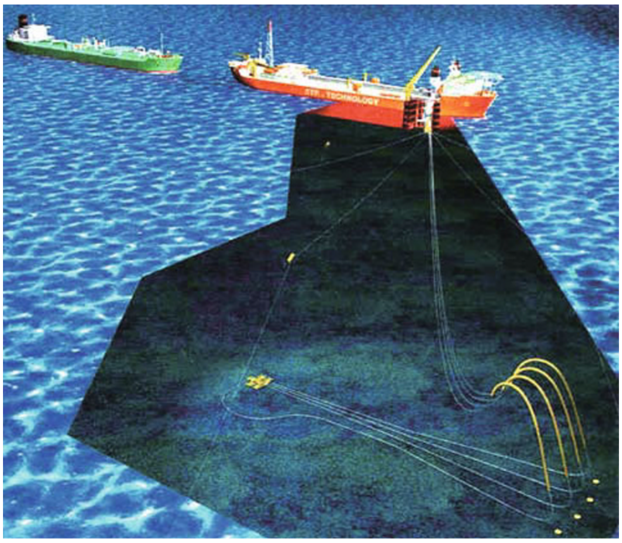


Fig. 4 LF22-1 oil field development methods

3.2.1 Advanced technology gaps

The WD record of offshore drilling in the world is 3,107 m, (http://www.physorg.com/news/2011-04-transocean-sea-depth-oil-drilling.html) and 1,480 m in China; the WD record for a developed field is 2,743 m and only 333 m in China; deepwater heavy-lifting and pipe-laying vessels can operate in depths over 3,000 m, and the biggest weight-lifting capacity reaches 14,000 tonnes, while in China, offshore engineering equipment can operate only within 150 m, and the largest weight-lifting capacity is only 3,800 tonnes. China's deepest oilfield is located in waters of 330 m operating with foreign partners. A huge technological gap has become a constraint to China's deepwater oil and gas resources E&D (Liao and Cao, 2005). For China to reach international deepwater technology levels is a big but important challenge.

3.2.2 Extreme environmental conditions

Frequent typhoons in the South China Sea. Globally, about 79 typhoons form each year, with the greatest and strongest number occurring in the northwestern Pacific Ocean and South China Sea region. Between 1965 and 2008, this area saw the formation of 1,189 typhoons, an average of 27 to 35 per year; more than half occurred in July, August and September, with most occurring in August.

Maximum typhoon wind speeds can reach 120 knots (222 km/hr). The Hagupit Typhoon, which occurred in the South China Sea region on 24 September 2007, is characteristic. Fig. 5 shows a satellite photo. In 2006 the riser of the FPSO used by the Lh11-1 oil field was destroyed by Typhoons.

Typhoons have resulted in great damages to offshore installations and are a principal hazard to offshore operations and platforms in the South China Sea. Serious damage even leads to stoppage of oilfield production; stricter design standards are under consideration.

Internal wave. These are gravity waves that oscillate within a fluid medium rather than on its surface. They arise from perturbations to hydrostatic equilibrium, where balance is maintained between the force of gravity and the buoyant restoring force. A simple example is a wave propagating on the interface between 2 fluids of different densities, such

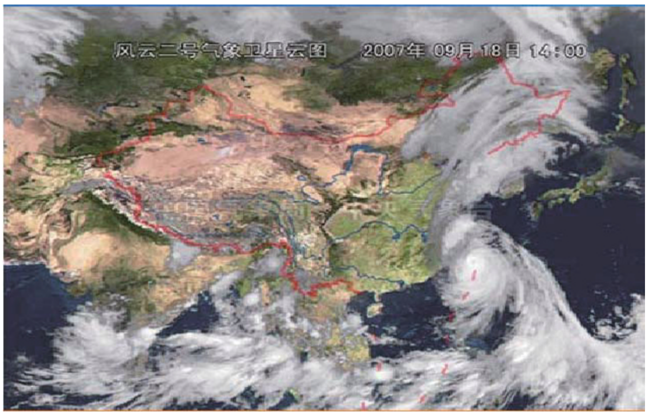


Fig. 5 Typhoon cloud satellite photo: Hagupit Typhoon

as oil and water. Internal waves typically have much lower frequencies (or longer periods) and larger amplitudes than surface gravity waves.

Internal-wave flows with a maximum speed of 2 m/s occur very frequently in the South China Sea. Fig. 6 shows a typical example.

Internal waves also cause great damage to offshore platforms and subsea equipment.

Sand wave and sand ridge. There some moving "sand-hill" on the seabed. These form the most disastrous geologic body which may destroy the subsea pipeline and facilities. The current velocity of seabed reaches a maximum of 84 cm/s in the South China Sea; the velocity of a sand wave is estimated at 330 m/s.

Like typhoons and internal waves, sand waves and ridges can result in damage to offshore platforms, subsea equipments, pipelines and risers, and the like.

Fig. 6 Typical internal wave in the South China Sea

Environmental conditions and design standard. In the 2000s, because of the greenhouse effect, the frequency and intensities of severe environmental conditions have overcome the established design standard. It is very important, indeed necessary, to revise existing deepwater engineering design standards so as to counter extreme environmental conditions such as hurricanes, typhoons and the other extremely adverse conditions.

3.2.3 Complicated seabed topography

In the South China Sea, the seabed landform is relatively smooth and stable in shallow waters, but becomes very complicated and steep in deep waters. For example, the distance of the 300-m water depth from onshore to offshore is over 300 km, while the distance from 300 to 1,500 m can be less than 60 km.

Complicated and steep seabed landforms will bring the following disadvantages:

Undulating seabed terrain can lead to a difficult pipeline route.

A difficult pipeline route can cause serious flow-assurance problems for a long tieback.

Undulating seabed terrain can result in increased investment and more complex operations.

3.2.4 Deepwater flow assurance

Because of high static water pressure, low temperatures, the composition of the fluids, long tieback distances, the flow-assurance problem becomes even more serious, as shown below.

Gas hydrates will form in subsea trees, subsea pipeline and riser, and can result in hydrate blockages due to high fluid pressure and low temperature.

Slugging is formed in flowline and riser because of steep landforms and long tieback distances. Slugging can result in a large pressure drop and may affect the process system.

Solids such as wax, sand, asphalt and scaling are often deposited in subsea equipment and flowlines, and a high wax content in the crude oil and gas/condensate systems increases the risk of wax deposition.

Corrosion commonly occurs along the pipeline, greatly damaging the equipment as well as the pipeline.

Emulsion will commonly occur in crude oil pipelines, causing large pressure drops and affecting the process system.

Fig. 7 summarizes the deepwater flow-assurance problem.

4 CNOOC strategies for deepwater development

China aims to explore and develop oil and gas fields at a water depth from 1,500 to 3,000 m in the South China Sea before 2020, with production of 50 million tonnes oil equivalent from these deep waters. All those challenges and difficulties mentioned above shall have solutions in 10 years, especially the big problems with typhoons, internal waves, and turbidity currents. The CNOOC is carrying out comprehensive planning and deployment regarding deepwater equipment and technologies. The specific objectives of the CNOOC deepwater development are as follows:

Develop offshore engineering facilities to build the

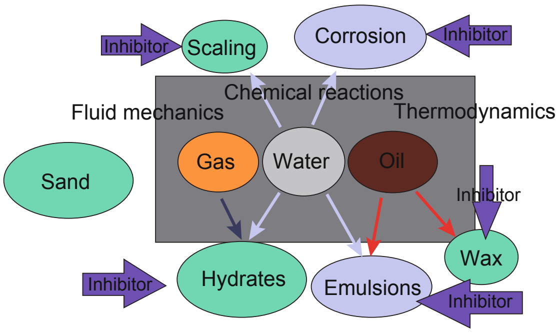


Fig. 7 Deepwater flow-assurance problems

deepwater offshore shipping equipment;

Master 5 key technologies.

Master 2 pioneering technologies.

Build a deepwater engineering construction yard.

Establish a deepwater engineering test basin.

4.1 Heavy facilities

Deepwater equipment is the basis for deepwater oil and gas E&D. In the past, China's offshore oil and gas field development has been mainly focused on the shallow water region, and China's deepwater engineering equipment and supporting fundamental technologies have been relatively ignored. Right now, the CNOOC's heavy investment is focused on forming a 3,000-m deepwater operational capacity through the development of a deepwater semi-submersible drilling rig, a deepwater heavy-lifting pipe-laying vessel, a deepwater geophysical-survey vessel, a deepwater engineering-survey vessel, and a deepwater high-power multi-functional supply ship.

4.1.1 Deepwater semi-submersible drilling rig

The HYSY-981 (Offshore Oil 981) is the 6th-generation advanced deepwater semi-submersible drilling rig. Its main operating areas are the South China Sea, but the rig will also cover the deep waters in Southeast Asia, West Africa, etc. The platform has both DP-3 dynamic positioning and mooring positioning functions, the maximum variable load is 9,000 tonnes, deepest operating water depth is 3,000 m, and maximum drilling depth is 10,000 m. It has drilling, completion, testing and well-repairing functions. At present, the HYSY-981, first deepwater drilling rig in China, which can operate in 3,000 m water depth, and drill through 11,000 m has been built and is to be in operation after 2011.

4.1.2 Deepwater, heavy-lifting, pipe-laying vessel

Two kinds of vessels and the corresponding technologies are being studied.

Phase I: 3,000-m water depth (WD), heavy-lifting, pipe-laying vessel. By cooperating with GUSTO, a Dutch company, and by using its DPV7500 design as a mother ship, the design and construction of DPV7500C, a deepwater, heavy-lifting, pipe-laying vessel are completed. Main dimensions are 204 m × 39 m × 14 m, using the S-type pipe-laying method. The pipeline diameter varies from 6 to 60 in, and pipe-laying speed is about 5 km/day (48-in tube). Lifting capacity is of 4,000/3,500 tonnes (stern fixed/full-rotary mode). The vessel is equipped with stinger, lifting crane, pipe-laying operation system, deepwater piling equipment, deepwater pipe recovery equipment, deepwater ditcher, deepwater subsea equipment, and DP-2/3 level dynamic positioning system (weight-lifting/pipe-laying). This vessel is to be in operation after 2011.

Phase II: 3,000-m deepwater semi-submersible, heavy-lifting, pipe-laying vessel. The target operating waters of the platform are the deepwater areas in the South China Sea, West Africa, the GOM, etc. Main dimensions are 220 m × 88 m × 44 m; maximum operating depth is 3,000 m; maximum speed is 15-20 km/day; and maximum weight-lifting capacity is 16,000 tonnes (dual cranes). The vessel uses the J-lay pipe-laying mode, and the maximum diameter of the laying pipe is 32 in.

4.1.3 Deepwater geophysical survey vessel

The first international, advanced deepwater geophysical-survey vessel with 12 cables is to be developed in order to have deepwater large-area and high-precision 3-D seismic acquisition capacities. The vessel will be 100-110 m long, 24-28 m wide, 9.5 m deep, with 16-knot design speed, unlimited operation zones, over 60 days' endurance capacity, 5-knot speed, 12 × 8,000 m cable (spacing: 100 m), and 8 ranked gun array.

4.1.4 Deepwater engineering geological-survey vessel

A world-class deepwater (500-3,000 m) engineering geological-survey vessel is being developed. This vessel is 104-110 m long, 20 m wide, 9.5 m deep, with 15-knot maximum speed, and 16,000 nautical miles in endurance capacity; it is self-sustaining for 70 days. Rigging capacity is 3,200 m (3,000-m WD plus 200-m hole depth), –20°-+45° in adapting operating temperature, –4°-+35° in adapting water temperature. Through its dynamic positioning system, the vessel can carry out subsea geological drilling or seabed surface sampling operations in 3,000-m WD, 7-class wind, 3-m significant wave height, and 3-knot current speed.

4.1.5 Deepwater large-power multi-functional supply ship

The host power of a deepwater 3-functional supply ship is generally greater than 20,000 HP, and the mooring force is greater than 250 tonnes. The main service target is to operate as workboats of 500-600 tonnes' power, mainly for long-distance towing, deepwater anchor-lifting operations, ocean engineering support and other services. The planned deepwater large-power multi-functional supply ship is 93.4 m long, 22.0 m wide, with 18-knot maximum speed, 3.0×10^6 tonnes in the biggest dolphin drag force, and 3,030 km in endurance capacity; it is self-sustaining for 60 days.

4.2 Five key technologies

Here we discuss the 5 key technologies for South China Sea deepwater oil and gas development.

4.2.1 Special environments of South China Sea

Forecasting and observation of the special environments in the South China Sea have been performed to support deepwater engineering design, installation and safe operation. There has been a great amount of research on the internal wave formation law, distribution characteristics and its mechanism with structures, the deepwater, seabed-current characteristics, the interaction mechanism of underwater biological attachments with structures, and the deepwater geological survey.

4.2.2 Deepwater oil and gas field exploration technologies

These have to be developed to carry out seismic acquisition and treatment at great depths, amid the difficulties presented by the continental slope and rugged seabed, and the large size required of a single exploration-target reserve. Large deepwater oil and gas basin slope accumulation theory and evaluation technology systems are very important in providing geological and geophysical technology support for the discovery of deepwater oilfields. Seismic imaging technology breakthroughs in a rough seismic seabed shall also be achieved, and scientific methods shall be proposed for the distribution prediction of marginal deepwater basin tectonic evolution, the thermal evolution of hydrocarbon source rocks, the causes of far-source classic reservoir and formation conditions, and large and midsized oil and gas fields in the South China Sea.

4.2.3 Deepwater geological reservoir engineering technology

Large-scale reservoir identification and integrated interpretation and evaluation technologies are to be developed for the complex geological structures in deepwater areas, fine imaging of complex structures, reservoir description, and oil and gas reservoir prediction. Analysis of oil geological conditions in deepwater areas and deepwater oil and gas migration shall be performed for hydrocarbon accumulation. Research on gas traps containing oil, deepwater geological reservoir characterization and geological evaluation, and reservoir description, as well as the original geological reserves, evaluation technologies of technically recoverable reserves, etc., are to provide technical support to the deepwater oil and gas reservoir development.

4.2.4 Deepwater drilling and completion technologies

Focused on the prediction of stratum drilling pressure in the deepwater region of the South China Sea, and on the deepwater well structure optimization, drilling and completion technologies are to be developed for deepwater mud drilling systems, hydrate inhibitors and debris removal, and deepwater as well as shallow-level low-temperature well-cementing slurry systems. Studies are being carried out on deepwater smart-completion technology, deepwater drilling and well control methods and techniques, deepwater subsea drilling equipment operation and monitoring technology, deepwater drilling wellbore pressure control and testing technologies. A deepwater drilling completion technology system is also set up to provide technical support for drilling and completion.

4.2.5 Deepwater engineering technology

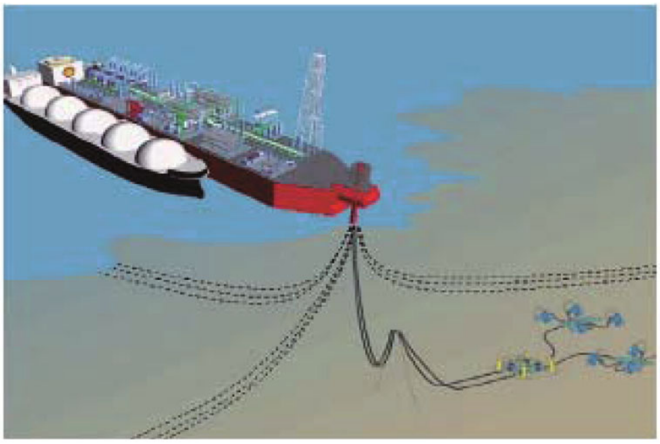
Focused on deepwater structure engineering, subsea production systems, flow assurance and such, deepwater engineering technologies are studying the mobile security control of flows and hydrate risk-control, deepwater subsea pipelines and risers, and the like. The CNOOC is planning in the 12th Five-Year Program to initiate China's first demonstration project of deepwater oil and gas field development.

4.3 Two pioneering technologies

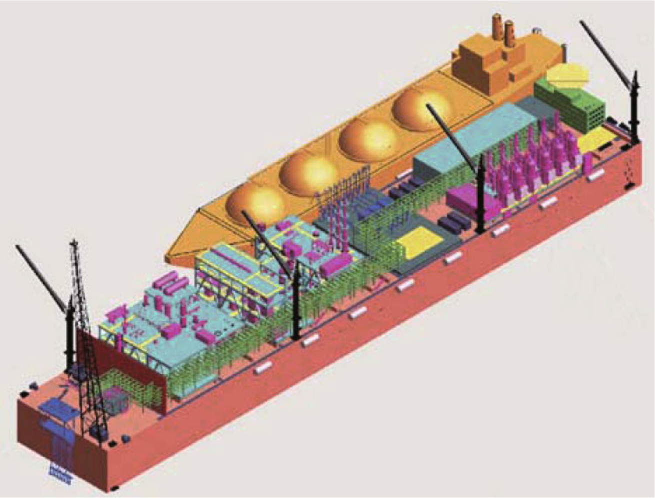
4.3.1 New deepwater equipment and innovative solutions

To hasten China's deepwater oil and gas exploration, and to better develop deepwater and marginal oil and gas fields, especially when a long distance (300 km or more) from the shore, new equipment and innovative solutions, such as FLNG/FLPG and FDPSO, are essential. The floating liquid natural gas (FLNG)/floating liquid petroleum gas (FLPG) are the kinds of FPSO that can receive gas production offshore for processing, and liquefy the gas into LNG/LPG (Fig. 8). The floating drilling production storage and offloading (FDPSO) is a kind of FPSO with drilling capabilities. It incorporates a design that is cost-efficient and effective for drilling and producing deepwater fields. Other new types of deepwater facilities, application technologies and supporting programs, etc. are also being stressed.

The world's first FLPG, for operation offshore Angola, started production in that country's SANHA offshore oil-field on 14 November 2004, with a daily production capacity of 6,000 m^3 and storage capacity of 135,000 m^3. The world's first FDPSO (total cost is US$640 million), owned by Prosafe Production, left Keppel Shipyard in Singapore on 24 January 2009. However, due to the high cost and advanced technologies, FLNG is not in production in the world; in recent years, it has been reported that it might possibly become operational in a huge gas field in the Browse Basin,



(a) FLNG/FLPG



(b) FDPSO

Fig. 8 Schematic diagram for FLNG/FLPG and FDPSO

Western Australia.

FLNG/FLPG/FDPSO are most applicable when no pipeline network is available or if the distance from the shore is relatively long. The 3 new vessels can be most useful to deepwater and marginal oil and gas field development in the South China Sea.

4.3.2 Deepwater natural gas hydrate exploitation and development technology

Natural gas hydrates are ice-like cage-shape crystals generated from natural gas and water at a certain temperature and pressure condition. In natural gas hydrates, the gas is mainly composed of methane (>90%). In standard conditions, 1 cubic meters of methane hydrate decomposition can produce 164 cubic meters of methane gas. Thus, natural gas hydrates are considered to be a potentially important resource for the future. Earth is rich in natural gas hydrate reserves, around 20% of the land (most of which lies in the permafrost layer) and 90% of the waters have natural gas hydrates (Sloan and Koh, 2008). The land-based natural gas hydrates exist in the permafrost at a depth ranging from 200 to 2,000 m, and under average ocean conditions, the water depth of the methane hydrate formation ranges from 600 to 3,000 m, while the stable depth of hydrates under seabed sediments ranges from 0 to 1,000 m. Organic carbon in natural gas hydrates is 53.3% of global organic carbon, which is twice the total carbon from coal, oil, gas and other fossil fuels (Li and Zeng, 2011) and is one kind of promising clean energy. In May 2007, gas hydrate samples were successfully collected from the northern part of the South China Sea. China is the fourth country after the United States, Japan and India to arrive at such a technological achievement. Initial estimates indicate the potential volume of gas hydrates around the area's continental slopes exceeds 100 million tonnes oil equivalent. The samples were collected from 2 different stations in the Shenhu (Magic Fox) continental slope on 1 May and 15 May 2007. At present, the CNOOC has built a series of experimental facilities to physical simulating development methods of Natural gas hydrate.

Gas hydrate development methods can be divided broadly into 3 categories: depressurization, thermal stimulation and inhibitor injection. In the depressurization method, pressure of the fluids in contact with the hydrate is lowered by production, pushing the hydrate out of its stability region and leading to its decomposition to methane and water. In the thermal stimulation method, heat is introduced into the reservoir, causing destabilization of the hydrate. In the inhibitor injection method, the injection of inhibitors causes decomposition of the gas hydrate by shifting its thermodynamic equilibrium curve. Most of these production techniques are conceptual and have not been tested on a large scale. With the exception of the reported history of the Messoyakha field, reservoir tests for the production of gas from hydrates are in their infancy.

4.4 Deepwater engineering construction yard

The Qingdao construction yard is one of the largest deepwater fabrication yards in the world, which has the ability of processing 200,000 tonnes of structure steel at present, and Zhuhai construction yard, another deepwater fabrication is been built now. Its products will cover the whole of China for various shallow and deepwater oilfield projects, and also radiate to various other markets, in Oceania, Southeast Asia, the Middle East, West Africa, South America and elsewhere.

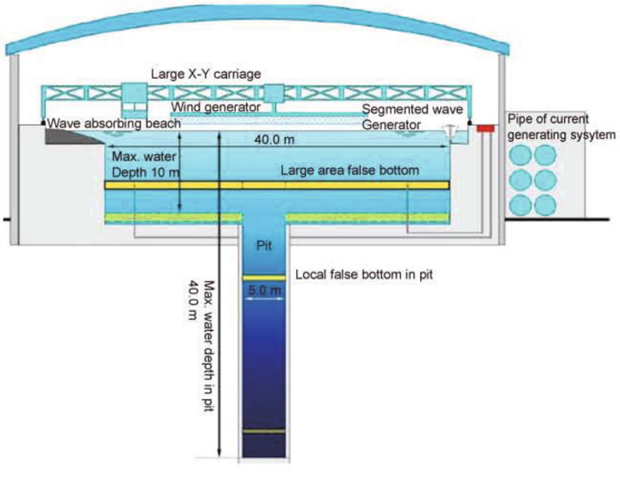
The completion of the Qingdao construction site will lay a solid foundation for enhancing the manufacturing ability of the CNOOC and for facilitating its march towards deepwater operation.

4.5 Deepwater engineering test basin

Through the deepwater engineering projects some deepwater lab facilities are built, such as deepwater test basin, multiphase flow loop with high pressure and low temperature, VIV equipment for subsea pipeline and riser.

The deepwater test basin (Fig. 9) is built to provide the necessary research tools for deepwater technology research. The main parameters of the basin are: Main body, 50 m long × 40 m wide × 10 m deep; deep well, 40 m in depth; maximum simulation water depth, 4,000 m.

CNOOC has signed strategic framework agreements with outstanding universities and institutes, such as Shanghai Jiaotong University and the China University of Petroleum in order to establish a deepwater engineering and technology research platform, to make great improvements in deepwater engineering technology by 2020.



(a) Schematic diagram of deepwater test basin

(b) Facility for riser and flow assurance experimental study

Fig. 9 Schematic diagram of deepwater test platform

5 Opportunities for China's deepwater development

5.1 Huge deepwater oil and gas resources in South China Sea

There may be many deep submarine fans with excellent prospects for hydrocarbon exploration in the South China Sea.

The deepwater area is estimated to be about 1,540,000 km^2, which is 75% of the total area; the oil geological resource is 87×10^8 tonnes; the oil recoverable resource is about 27×10^8 tonnes; the gas geological resource is 6.0×10^{12} m^3; and the gas recoverable resource is about 3.7×10^{12} m^3.

5.2 Discovery of LW3-1 deepwater gas field

The LW3-1 deepwater gas field was discovered in June 2006. It is in the Pearl River Mouth Basin, 250 km from Hong Kong. The first well was drilled at a water depth of 1,480 m. Fig. 10 shows the development plan of the LW3-1 gas field. At present, the LW3-1 gas field will be developed using a 10-well subsea production system, 79 km multiphase flow pipeline and shallow water platform.

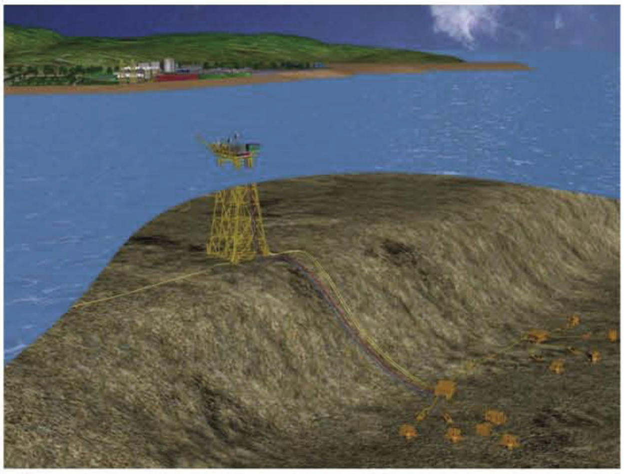


Fig. 10 Development plan of LW3-1 deepwater gas field

5.3 Exploration and development prospects

The LW3-1 gas field increases confidence in the discovery of even larger deepwater oil and gas fields in the South China Sea in the near future. The CNOOC will make many more investments in the exploration and development of deepwater oil and gas resources, and it will continuously seek international cooperation with more and more countries.

The CNOOC has formulated detailed prospects as follows:

1) Deepwater blocks: 98 blocks and 0.36 million km^2

2) Contract blocks: 13 blocks and 0.24 million km^2

3) Potential resources: $1{,}167\times10^8$ tonnes (oil equivalent)

4) Reserves targets: 19×10^8 tonnes (oil equivalent)

5) Geophysical exploration: 2-D (17,700 km), 3-D (3,813 km^2) (north of South China Sea)

6) Number of exploration wells: 619

7) Investment in exploration: $1{,}691\times10^8$ RMB

8) Production target: 50 million tonnes (oil equivalent)

9) Investment in engineering equipment: 354×10^8 RMB (not including supporting cost)

10) Investment in engineering yard: 301×10^8 RMB

11) Total investment cost: over $3{,}000\times10^8$ RMB

Table 1 illustrates the CNOOC oil and gas production growth prospects in 2010 and the coming years.

Table 1 The CNOOC oil and gas production growth prospects

(Unit: millions of tonnes)

Year		2010	2015	2020
Domestic production	Offshore	50	55	55
	Deepwater		25	50
Overseas production		25	40	50
Total production		75	120	155

6 Conclusions

Chinese deepwater has potential gas- oil reserves, existing opportunity and great challenges, with our best efforts, and extensive international technology cooperation, we can realize the CNOOC's deepwater development objective, up to 2020 is to be able to develop oil and gas fields in waters from 1,500 to 3,000 m in depth, and to reach 50 million tonnes of oil equivalent production, thus bringing the country's deepwater exploration and development technologies to the advanced world level.

In near future, Chinese deepwater will be not only the leading edge of Chinese offshore activity, but also will have reached international standards of technology.

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