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Emerging Technology to Enhance Production From Mature Offshore Fields

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Summary

Most of the world's oil production comes from mature fields, and increasing production from these fields is a major challenge for the E & P companies. Arresting production decline in mature fields needs induction of new technologies with bold investment decision. A judicious mixture of classical and New technologies have created the opportunity for new life for the mature offshore reservoirs of India.

Mature field development practices can be divided into two major groups, Sub-surface / reservoir engineering and Surface / well engineering. Robust static geological model which integrated the legacy data was developed for the 3D reservoir simulation model. Facies analysis, log derived permeability transform and karst mapping have helped in introducing reservoir heterogeneity in the model. Geo-statistical techniques were used to populate properties throughout the reservoir. The history matched dynamic model has helped to identify the area of bypassed oil.

Horizontal sidetracks offer a very viable technique instead of cost intensive new wells drilling through new platform for exploiting these bypassed oil. Modern tools and technology have come in handy in achieving this goal and appropriate technology application to our need has paid rich dividends. LWD- Geosteering with online monitoring and 3D visualization at base have improved the well placement in sweet zones. Introduction of advance tools like rotary steerable system, expandable tubular, whipstock, synthetic oil base mud system have provided encouraging solution for drilling through the problematic shales and differentially depleted pay zones. Use of Cased hole formation resistivity, measurement of pressure while drilling, Down hole fluid analyzer etc have also helped in placement of wells for exploiting the by passed oil. Advance well completion like level-3 completion has been adopted to control individual reservoir performance. Extensive use of swell packers for segmented completion were used to control water production. The paper discuss the results of the application of these technologies which has helped in arresting production decline in mature offshore fields of India. The experience provide confidence to draw the redevelopment programme for arresting the decline and also to improve reserves portfolio.

Introduction

Most of the world's oil production comes from mature fields, and increasing production from these fields is a major concern for the E & P companies. From mid 1980 to 2003, low oil prices has reduced the opportunity to invest in brown field development. Additionally, new discoveries have been declining over the past few decades. Boosting oil recovery from mature fields needs bold investment decision and induction of new technologies.
Present paper will discuss mainly how induction of different technologies has helped in arresting production decline from offshore fields of western offshore,India. These fields are 20-30 years old and contributing major amount of countries production.

Major issues

- Decline in pressure and reserve
- High water-cut
- Poor permeability leading to limited areal sweep.
- Poor cement behind casing leading to water channel from aquifer
- Inadequate water injection management
- Large well spacing
- Fields with old infrastructures

Field Management

To improve the performance of the field in the most

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economic way, plans were made to best utilize the state of art technology to identify by-passed oil and to intervene the existing wells. A multifaceted approach was adopted to rope in advanced technology in G & G, drilling , drilling fluid, well placement through state of art logging technologies and completion to produce best results. A work programme to arrest production decline and increase ultimate recovery was drawn up under redevelopment scheme for the fields and is under implementation.

G & G Technology

Advances in G & G technology plays a key role in finding oil within a producing field calls for much improved data quality, where there is minimum margin of error in interpretation. Geoscientists continually work to develop new ways to combine and use data from diverse sources in order to form a highly accurate picture of an area's subsurface geology. This results in improved recovery factor, faster development and greater efficiency of the oil field. This also requires analysis and interpretation at a different level consisting of multidisciplinary teams involving data from production, reservoir, petro-physics etc.

The issues in redeveloping a mature field are more because we know a lot more thing about the field, which were not known at the time of initial development. Reservoirs once thought to be relatively homogeneous often display their true characters during the course of initial development. Reservoir heterogeneities are one of the most vital data which is generated during the course of field development and production history. Any successful improved oil recovery scheme in a mature field essentially depends on the knowledge gained on the extent of reservoir heterogeneity, identifying the potential areas of bypassed oil and accurate well placement to exploit this oil.

To capture the fine scale heterogeneities of reservoir and to identify the bypassed area, Improved reservoir description was achieved through integration of available geo-scientific data.

The seismic interpretation was integrated with electro log and core data and the team of geo- scientists made a fairly detailed geological model incorporating the complex reservoir features of sub- layered structure, major faults, heterogeneity and fluid distribution.

Development of Permeability Transformation

Permeability prediction is one of the most critical parameter of any reservoir description. Degree of uncertainties is probably the highest in permeability propagation in developing a model. Availability of core permeability is normally few in any field and one mostly relies on derivations from porosity logs. In clastics, these derivatives are reliable to certain extent as the depositional model is predictable. But in a carbonate environment, permeability prediction has remained a difficult task owing to random development of dual porosities. An attempt has been made to derive permeability function by making use of all available well log suits and then comparing the results with core derived permeability and well test data.

Reservoir Simulation

Fine scale Geocellular model was prepared incorporating the reprocessed log and 3-D seismic data. The model was upscaled to cell size of 100m x 100m and cell thickness varies from 1 to 3 m. The permeability distribution through out the field was generated with the help of above permeability transform. All the property maps like porosity, saturation and permeability were generated using geostatistical software. Rock and fluid data generated in laboratory have been used in the model.

Well wise monthly allocated oil, water and gas data were used as inputs for history matching. Rock and fluid data generated in laboratory have been used in the model.

The study envisages two prong strategy viz. Brown field development through existing wells and Green field development through new wells. Under Brownfield development, the major areas of focus are enhancing the production from sub-optimally producing wells by sidetracking to a better saturation area, relocation /replacement of injectors for proper distribution of injection water for pressure maintenance and better sweep. After obtaining good history match several simulation runs were made for optimizing the variant. In prediction run sub optimal Wells were placed as horizontal drain holes in better oil saturation area mainly in the top part of the reservoir. Similarly water injectors were converted into drain holes along the strike direction in the lower part of the Bassein pay to improve sweep efficiency.

State of Art Drilling Technology

Conventional methods of workover for water shut off or gas shut-off were slowly discontinued. A series of changes were inducted in the old well management. Efforts were made to mitigate the decline in oil through suitable well intervention. The low performing wells were put back on production through side-tracking the existing wells by incorporating State of art drilling technology.

Whip Stock Technology

The magical deviation tool of 'Whip stock' was extensively utilized in directing wells in different directions from the existing positions. Whip stocks of different sizes, mainly; 7", 9 5/8" and 13 3/8" were used depending on the desirability of well deviation. Setting up of whip stock in 13 3/8" casing after retrieving 9 5/8" casing and deviating from shallow depth, helped in drilling a well in Long Distance. Similarly, if a Short Distance Side Track was desired, wells could be deviated by setting 9 5/8" whip stock. This job could be accomplished in a shorter time and had a great utility value.

However, effectiveness of 7" whip stock was most observed, in terms of application and increasing oil production in quick time. No wonder, majority of the wells were subjected to deviation from the production casing by setting whip stock against pay zones. The purpose of 7" whip stock was more relevant, when coupled with modern downhole motor drilling tools like, MRDH and SRDH.

This state of art drilling equipments had tremendous value in increasing oil production from the offshore fields. The wells drilled and completed in the initial phases of development were of conventional completion. The wells were drilled with angles mostly between 40 to 50 degrees. Moreover, a very small part of reservoir gets exposed to production in conventional completion. The problem was more acute, in poor reservoir facies area; the well productivity was minimal from beginning. In addition, the significant rise in oil water contact reduce the pay exposure.

The Medium Radius and Short Radius Drain Hole (MRDH/SRDH) tools became very useful in recompleting these conventional wells as better producers. In the application front, the conventional wells, which were in poor reservoir areas or, water level, had become shallower were chosen as the candidate. The 7" whip stock was set against the pay zone and drain hole is drilled by MR/SRDH tools. The tools help in building the angle quickly to horizontal and 200m to 500m horizontal well has been drilled by this tool. The process increases the reservoir contact manifold and enhances drainage area substantially.

Well Placement Technology

Well placement with Logging While drilling (LWD) technology has been used in critical wells, where the development of reservoir facies have not been precisely and in thin reservoir beds. Some of the wells have been completed successfully by online monitoring of drilling data at base and superimposing it on seismic.

Examples #1

The challenge was to place a horizontal well across the faults and drain the by passed oil from both the side of the faults. In this complex horizontal well, improved version of LWD and Rotary steering (RSS) technologies were employed to meet the challenge of maximizing the exposure to the best facies in the reservoir and identify faults. Continuous real-time monitoring enabled informed steering decisions and RSS enabled precise control on the trajectory to remain in the desired formation. LWD Images allowed for fault identification as soon as it was encountered. In addition to real time benefits, LWD technologies also aided in geological understanding of the area. The LWD spectroscopy measurements indicated the presence of dolomite at the top of the reservoir layer, which removed the ambiguity in the interpretation using the conventional measurements. The fault interpretation shown below (fig-1) is based on the dips picked from recorded density image and correlation with offset wells in this area.

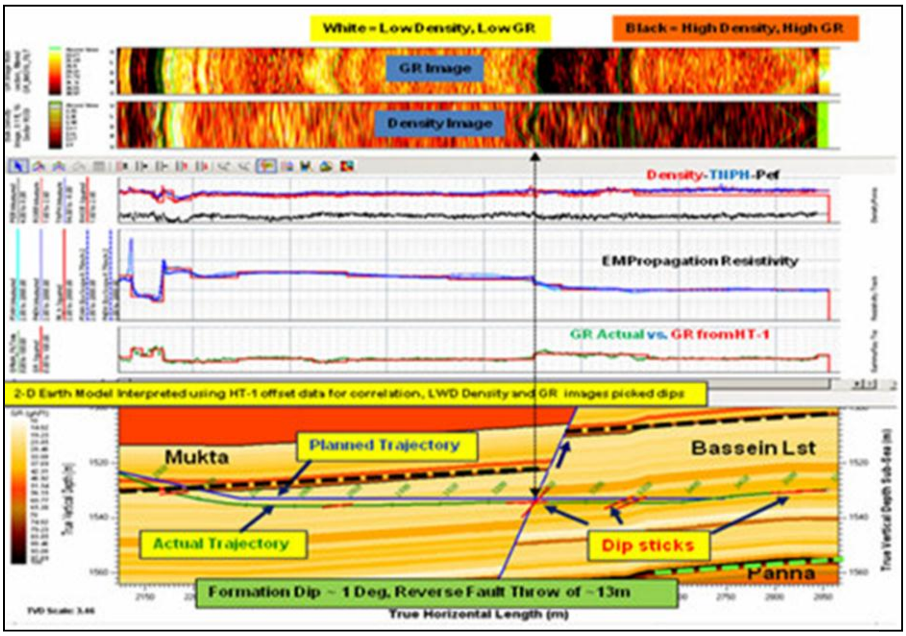

Fig- 1 : Well placement across fault.

Examples #2

The plan was to drill a long drain hole in a thin tight reservoir with the objective to get better production. Along with LWD constant imaging of bed boundary tool was utilised to place the hole in the sweet zone. Compounding the difficulty were other challenges like lateral heterogeneity, frequent local dip variation and gradational decrease in resistivity at reservoir top and bottom which posed a serious challenge to the resistivity based boundary detection capabilities of the tool. However,

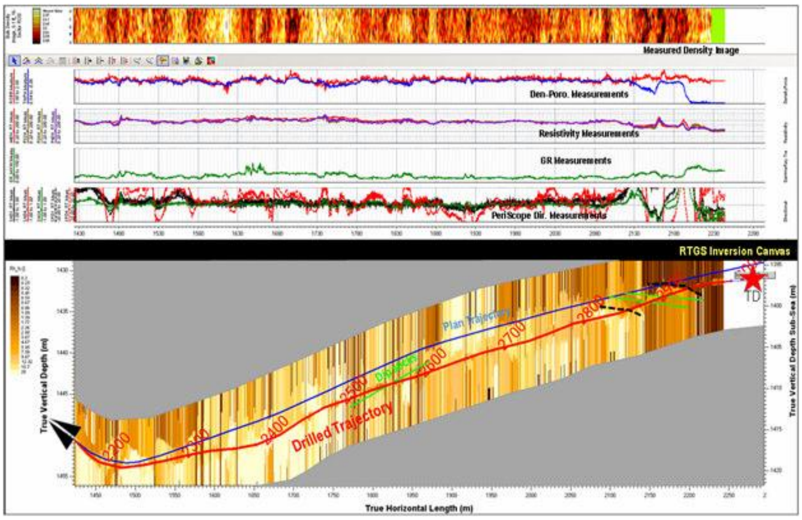

Fig-2 : Well placement using LWD & Imaging of bed boundary

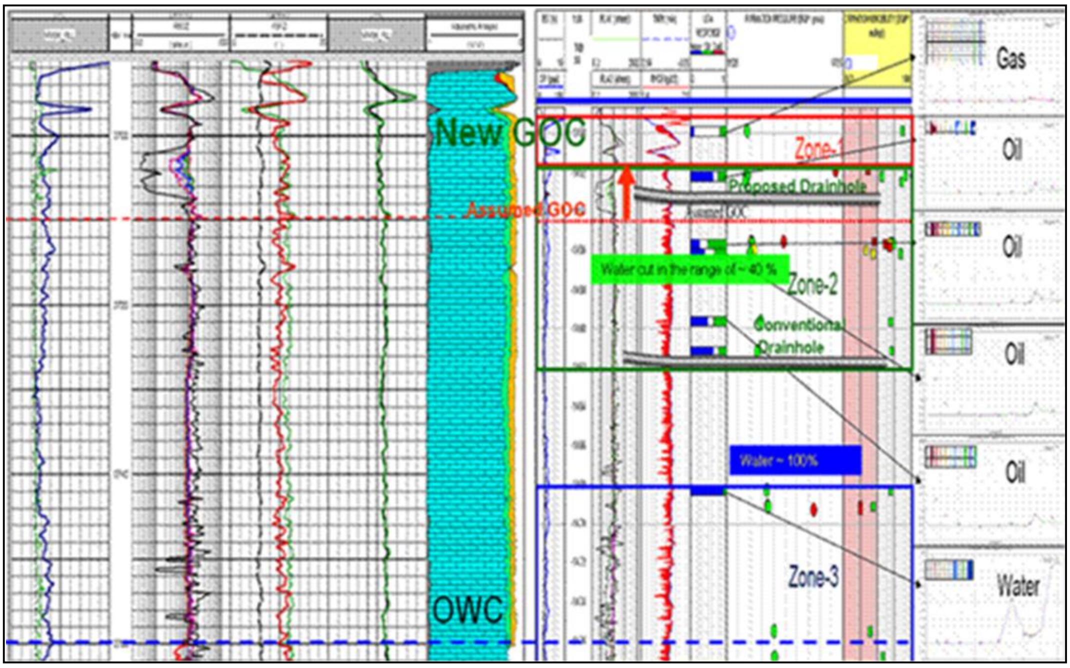

Fig-3 : Well placement using WFT and DFA

careful planning and continuous real time monitoring of the data successfully detected reservoir bottom from a distance of 1m and even mapped the interlayer minor resistivity variation accurately to explore the sweet zone within reservoir (fig -2). The well was drilled successfully with NTG of approx 93%. A total of 833 m of the reservoir section was drilled of which 773m was placed in the sweet zone. High quality azimuthal density image was used to pick dips of the beds and validate the structural trend showed by DTB Inversion. The well has started with 750 bopd and finally sabilised at about 500 bopd.

Examples #3

Reservoir simulation studies clearly indicate that more than 50% of gas cap has been produced along with oil which has resulted in oil migration in the gas cap area. This along with large water production has made the fluid distribution uneven and resulted in shifting of fluid contacts. Conventional Open Hole log interpretation for estimation of saturation is complicated in this field by the complex distribution of connate and injection water, as well as by varying levels of drilling fluid invasion. As a result of these, water production in new drain holes is sometimes higher than anticipated.

To address the problem of optimum drain hole placement, a new methodology was adopted in which Down Hole Fluid Analysis (DFA) in combination with pump out module have been added to the conventional Wireline Formation Tester (WFT). The DFA utilizes down-hole optical technique to analyze fluids as they flow through the WFT tool. This methodology is depicted in the Fig. 3

Water Injection Management

Water injection is in progress mainly through peripheral and pattern injection. Injection are mostly through commingled conventional completion. Effect of water injection is not uniformly felt in all parts of the field. In some areas with good injection support, the layers with relatively high permeability get the water injection effect early while the tighter ones continue under depletion mode. A considerable amount of pressure gradient exists from the periphery to the updip part of the reservoir. Higher pressures around the injectors indicate poor dissipation of injected water towards producing area. Redistribution of water injection was carried out in regular intervals based on, well wise and sector wise analysis.

To avoid early break through of water and to achieve uniform vertical sweep, horizontal drain holes were drilled in the lower most part of the tighter pay in Heera field. Horizontal hole helped in injecting sufficient quantity of water in tighter part of the reservoir. Based on the encouraging results of Horizontal water Injectors 19 horizontal drain holes are placed underer Heera redevelopment project. Presently water injection is in progress through 52 injection strings @ 1,52,765 bwpd for voidage compensation and pressure maintenance. IVC and CVC are 110-117 % and 69.2 % respectively.

Project Implementation

The Redevelopment project was initiated in 2006 and it is at final stage of completion. The programme envisages two prong strategy : brown field development through sidetrack existing low producing wells and drilling of 33 new well from three unmanned platform and connected pipelines, state of art facilities at the unmanned platform.

The over all recovery from the fields are estimated to increase by 4 to 5% of OIIP.

Production Performance

In one of the field the implementation of the above technologies not only arrest the production decline but also help to increase the production. The oil production performance from the beginning of the programme ie from 2005 to date is shone in fig.-6.

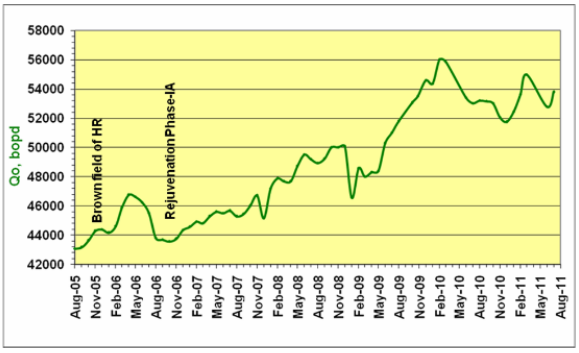

Fig.-6 : Oil production Performance of one of the offshore field

Conclusions

A multi–discipline and truly synergetic approach remain most effective rout for our project planning. The success of these effort is shown by improving field performance.

An integrated approach has been adopted to define the reservoir heterogeneity, hydrocarbon storage and flow units as the conventional approach of preparing the maps showing reservoir property distribution often fails to capture fine scale variations because of averaging.

Areas of leftover oil saturation have been identified and wells suitable for sidetracking as well as new wells have been identified to produce the unswept oil.

Modern tools and technology and its appropriate application to our need has paid rich dividends.

Fine grid simulation with detailed geological model has helped to identify the bypassed oil. The infill locations are optimized based on the current oil saturation. It is expected to improve overall recovery factor by 5% over the current estimates of about 28 %.

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