

Improved Water-flood and Adoption of Advance Drilling and Completion technology Pays Rich Dividend in Mumbai High North Field

Rudal Singh, T.E.Shivramkrishnan and S.K.Verma

Mumbai High Asset, ONGC, Vasudhara Bhavan, Mumbai, India

Presenting author, E-mail: rsingh53@hotmail.com

Abstract

Mumbai High North field, the northern part of major offshore oil field Mumbai High, was discovered in 1974. Multilayered carbonate reservoir NL-III is the main producer and has been on production since 1976. Water injection was commenced in the field in 1984. Being on continuous production for last 34 years, the field is in mature stage of its producing life. The oil production rate from the field was of the order of 130000-bopd during 1982 to 1989. During early and mid nineties the field had entered a crucial decline phase and production level dropped to about 63000-bopd by Dec.1993 due to rise in GOR, injection water break through and closure of some high GOR and high water cut wells. Various remedial measures such as installation of gas lift, water and gas shut off jobs and reopening of some wells showing reduced GOR resulted in improving the production level to around 78000 bopd by Dec.1999. Further implementation of redevelopment project of Mumbai High North field initiated in 2000 resulted in improving production which reached to the level of 100000-bopd in Jun, 2005.

The unfortunate fire accident at MHN process platform on 27July, 2005 caused major disruption of offshore production systems of Mumbai High field. Restoring the oil production without having new process platform within a short period became a major challenging task. The systematic actions taken in the field restored the production level to 80% within six months. Focused water flood management keeping layer specific requirements and successful implementation of NA1 layer development scheme helped in further improving oil production to the level of 92000–bopd (restoring 92% oil production) in Sep.2007. The oil production currently being maintained at around 80000 bopd. The paper highlights the integrated Asset approach in reviving and improving oil production from the field after MHN accident. The adoptions of new techniques and technologies have further added in rejuvenation campaign of the field. With the implementation of current development plan and improved water flood strategy, oil production is likely to be enhanced further and this would help in achieving oil recovery to 33% from main reservoir of the field.

Introduction

Mumbai High field is the largest offshore oilfield of India located about 160 Km west-north-west of Mumbai city in the Arabian sea at a water depth of about 80m. The field has an aerial spread of about 1200 sq. Kms. The multilayered carbonate reservoir, L-III, is the main producer and has been on production since 1976. The northern and southern sectors are divided by an east-west impermeable shale channel. The field has been developed through various field development schemes drawn and implemented at various stages. Water injection initially through peripheral row of injectors was initiated in 1984 in North field after a brief phase of natural depletion. Injection was later augmented through central and up dip row of injectors. During mid and late eighties oil production level of around 5.5 MTPA (Fig.-1) had been maintained from Mumbai high North field. With rise in water-cut and gas-oil ratio the production level dropped significantly by middle of nineties.

In order to control the declining trend and to improve the reservoir performance of Mumbai high North field, a comprehensive review was carried out through integrated analysis by multi-

disciplinary teams. Pilots were conducted to assess the potential of by-passed oil areas and to examine the feasibility of oil drainage from the considerable area below the gas-cap. A 'redevelopment plan' aimed at better reservoir drainage through additional wells was drawn considering techno-economically viable options. A continuously improving learning curve has helped to overcome setbacks and hunt for better alternatives resulting in assimilation of effectively applicable technology.

The improved understanding of reservoir complexity through use of new generation tools, integration of geo-scientific data, refined reservoir simulation and 3D visualization have provided higher degree of confidence to assess the potential reserves of by-passed oil. Poor producers were analysed for cost effective option of side-tracking for better reservoir drainage. Advance techniques in drilling, mud system, logging and well completion were used for improved productivity from new wells. A noticeable turn-around in field performance was already visible. Various measures taken under the redevelopment projects exhibit the improved reservoir health conditions also. The field GOR level which had increased to over 500 v/v in early nineties is consistently coming down and presently the GOR is around 254 v/v. Water-cut has been stable at around 60% during the last eight years (Fig.-2). These measures taken in field led to further enhancing oil production rate to the level of 100000-bopd in Jun, 2005.

A major accident took place at BHN Process Platform in July 2005. The process platform was completely destroyed in fire without any physical remains above sea. There was significant damage to process platform NNF and moderate damage to the well-cum-process-platform NNA & gas-compressor-cum-water injection platform-MNW. The accident resulted in total loss of oil and gas production from Mumbai North field. Multi disciplinary team of Asset systematically devised and executed revival plans for restoring Mumbai High North field production. The Revival plans envisaged resumption of production by surface facility modifications, diversion of fluid lines, creation of fluid handling capacity at NNA platform, enhancing water injection to match voidage created, execution of NA1 development plan and further redevelopment plan of field.

Mumbai High North Production Revival Milestones

The accident had incapacitated key production systems of Mumbai high North. Multiple actions were consolidated and put in place to recommence the production. A brief recount of activities is given below:

Resumption of NNQO production. Prior to accident, from NNQO platform oil production @ 68000 b/d was being dispatched to trunk line through the main oil line pumps of MHN platform. High pressure gas was fed directly to the main gas trunk-line. Restoration of NNQO production could be accomplished through hooking up oil export facilities of NNQO to new MUT line with modifications of NNQO platform's oil pumping facility. The work was completed within 30 days by the dedicated efforts of in-house teams, engineering consultant and offshore contractors.

Diversion of well platforms of BHN to NNQO and NMH South. Another priority task was to divert maximum number of well platforms connected with the ill-fated BHN complex to nearby process platforms through the existing network of subsea lines with some modifications at surface. BHN's four well platforms NNV, NNJ, NNC & NN11 were diverted to NNQO after surface modifications at well platforms, interconnecting pipelines and converting the water injection lines to gas injection lines. This exercise led to a production gain of about 14000 b/d. Fig. 3A and Fig. 3B shows the schematic of field diversions.

Re-commissioning of NNA Platform. The re-commissioning of NNA – an old well cum process platform of the BHN complex involved modifications for crude processing and

evacuation through SBM-tanker mode. The processing facilities of NNA which were not operative since long, were made operational by installing Process Control room at the rig Sagar Samrat and connecting the same to NNA through a bridge. In this manner, the revival of production from four well platforms, NNA, NNB, NN5 and NNU was completed by December 2005 and oil from NNA was dispatched to tanker moored at NNA SBM. The re-commissioning of NNA platform added oil production to the tune of 8000 b/d.

Diversion of NN1 & NN2 platforms to NNQO. NN1 and NN2 well platforms were connected to NNQO by using pipelines which were going to the BHN platform. The partly damaged underwater pipelines were located and repaired. In this way, production from two platforms NN1 & NN2 were diverted to NNQO after underwater hook-up of the existing NNQG- NNF gas lift line with NN1-BHN well fluid line. The wells of NN2 platform started flowing through NN1 platform to NNQO. The production gain from this diversion was 3500 b/d.

Revival of NN9 platform. The revival of these platforms were difficult due to the remote location of platform and non-availability of suitable pipeline hookups for diverting the well fluid line. In this set of activities, the sub-sea tie-in of BHN pipelines was involved. NN9 platform was put on production through NNQO by sub-sea tie-in of BHN-NNV & BHN-NN9 lines. The well fluid was taken to NNQO through NNV.

Revival of NMNW platform. NMNW, the new process platform commissioned in 2004, was bridge connected to BHN. MNW had certain structural damages due to the severing of the bridge. The water injection plant of NMNW was commissioned in May-June 2005. NMNW facilitated water injection and gas compression. The gas compressor was receiving gas from erstwhile BHN platform. Newly constructed MUT pipeline was also originating from NMNW. Due to the fire accident the gas input to MNW was cut off. NMNW revival scheme was designed to recondition the platform for power generation and water injection. Gas compression was required to arrest the gas flaring of NNA. By restoring NMNW gas compression, 1.9 MM m³/d gas was fed to the gas lift grid and sales.

These aforesaid actions taken in the field restored the production level to 80000 bopd within six months.

NA1 Development Plan Implementation

Based on the success of horizontal wells in the periphery area of NMHN, a development scheme for NA1 reservoir was conceived with 19 new development wells through three light weight bridge connected platforms NN2, NNEA and NNHA and six clamp-on wells from existing NNU and NN1 platforms. All the inputs of the scheme are in place and the project has been completed successfully. With the implementation of this scheme oil production has reached to the level of 92000 bopd by Sep. 2007 (Fig.-4).

Improved Water Flood Performance of Main Reservoir

Water injection rate in NL-III reservoir was around 310000 BWPD in Aug 2002. Due to leakages in some of the pipe lines water injection was suspended in some of the injectors and the injection came down to around 180000 bwpd. Injection was further affected due to conversion of some of the lines to gas injection after BHN accident and the voidage replacement ratio (VRR) remained at around 60-70%. From Aug 2006 onwards efforts were made to improve the water injection scenario through laying of new pipelines and opening of closed injectors. Water injection was redistributed in needy reservoir layers through profile modifications, stimulation of injectors, conversion of new injectors and regulation of water injection to control break through in nearby producers. With all these efforts the injection level has improved to around 315000 bwpd and VRR around 98% (Fig.-5). Bubble map of current water injection in MHN L-III is shown in (Fig.-6) which indicates the distribution of water

injection rates through out the field. The distribution pattern of injection water which initially started with peripheral injection wells, got significantly modified to balance the withdrawal rate from individual layers in different part of the field.

Productivity enhancement - Horizontal Well

Marked improvement in productivity has been achieved in the low permeability west flank area by resorting to horizontal wells. A similar enhancement has been achieved in case of low permeability lower zones in the crestal part of the reservoir.

Use of horizontal wells and multi-laterals has led to economic development of thin layers particularly in the fringe area with sweet zone as low as 3m. Horizontal well placement in these complex geometry reservoir layers is being carried out with the help of fine scale geological earth modeling and geosteering with logging while drilling tools. Wells with drain hole length upto 1100m horizontal section have been drilled in the thin oil column. The horizontal wells completed in thin layers have offered advantage of accelerated production with less draw down and delayed water production. The average production from the horizontal wells is about 2 to 3 times higher than the average productivity of the conventional wells in the same layers (Fig.7) realizing early oil gain.

Improved Well Production -Multi Laterals

In structurally high eastern part of the field, major portion of L-III reservoir is gas bearing and the lower layers hold significant untapped oil saturations. The conventional wells in this area had problems of poor primary cementation in the shale section and across the pay zone. The wells completed produced with high gas cut due to channeling, cusping / coning affecting the well productivity. Low pay thickness of the layers with deteriorating petro-physical characteristics deterred the initial development of this sector and contributed to overall lower recovery factor.

Encouraged with the primary success of horizontal wells in thin upper layers in the peripheral areas, the technology has been extended to oil bearing lower sub-layers beneath the gas-cap. A number of horizontal wells have been successfully placed in these zones using LWD-Geosteering. Wells recently completed in eastern part of field have produced with better initial oil rates with normal GOR.

Multi-lateral drilling in multi-layers recently attempted to address two and more layers through dual completions in some of the wells has given encouraging results. Multi-lateral completions using swell packers and dual completions is providing better management of reservoir layers separately. The completion sketch of a specific well is presented in (Fig-8).

Redevelopment Phase-2

With the objective of the production enhancement and further improvement in recovery from the field, Mumbai High North Redevelopment Phase-II is conceived. The development plan envisages integrated development of NL-III, NL-II and NL-I reservoirs of MH North. The envisaged inputs are drilling of 52 wells from five new platforms, 21 wells from existing free slots and 3 wells from clamp-on with 38 side-track wells. The cumulative oil production works out to 206.91 MMt and incremental oil gain with respect to Base variant is 18.555 MMt. Oil recovery is 31.7% (FIG-9). The oil recovery of L-III reservoir is likely to be 33%.

Conclusions

- The inherent strength of the Asset was fully exploited for production revival and as a result, the production was restored 85% within two months of BHN accident.

- Successful implementation of NA1 layer development in the field has further accelerated the production to current level of 92000 bopd within two years despite offsetting the natural decline and fluid handling constraint in the field.
- The Focused layer wise management of water injection commensurate to withdrawal has helped in controlling water cut, reducing GOR and maintaining base production from the field.
- Hi-tech Horizontal and multi-lateral infill drilling with new generation tools and improved mud system with new completion techniques has helped in improved productivity of wells.
- Adoption of the evolving technologies is expected to continue to provide leverage for further boosting of production and improvement of recovery from the field during proposed implementation of phase-2 redevelopment scheme.

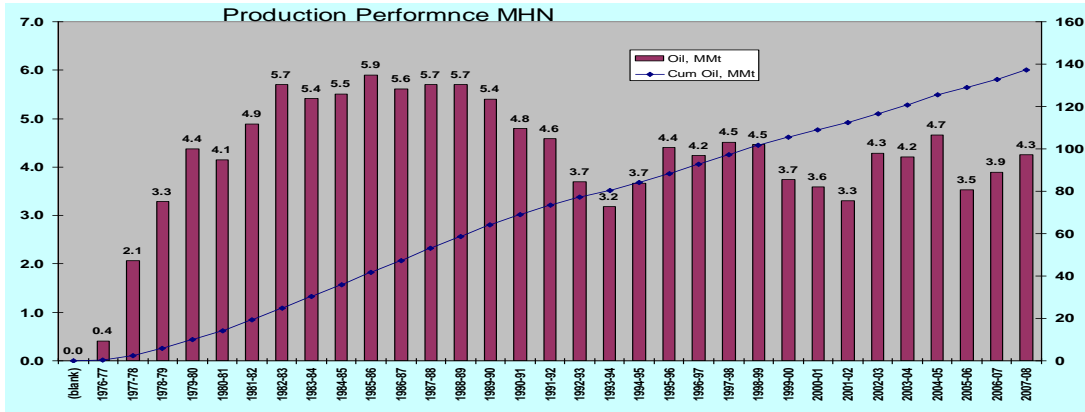
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Fig-1



Production Behavior of MHN Field up to Jun 2005

Fig-2

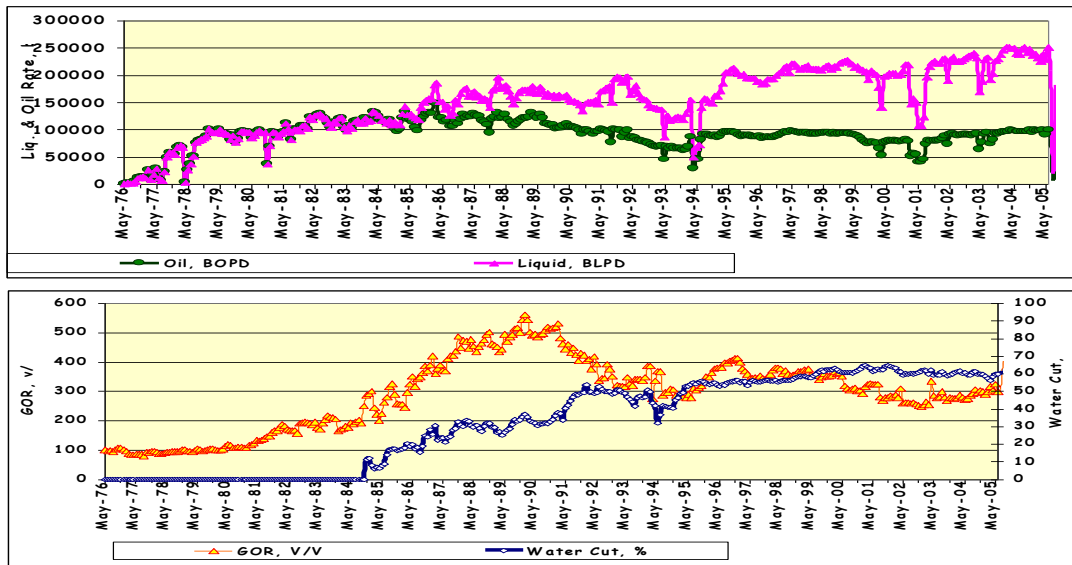


Fig. 3A: DIVERSION OF WELL PLATFORMS TO NNQO

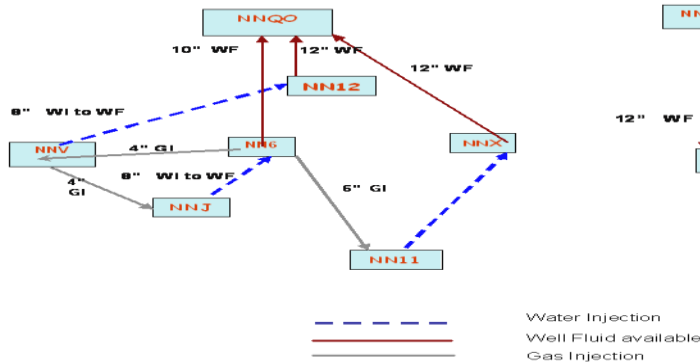
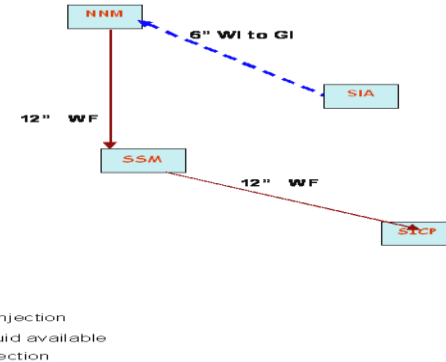


Fig. 3B: DIVERSION OF NNM TO SICP



Production Behavior of MHN Field after Jun 2005 till date

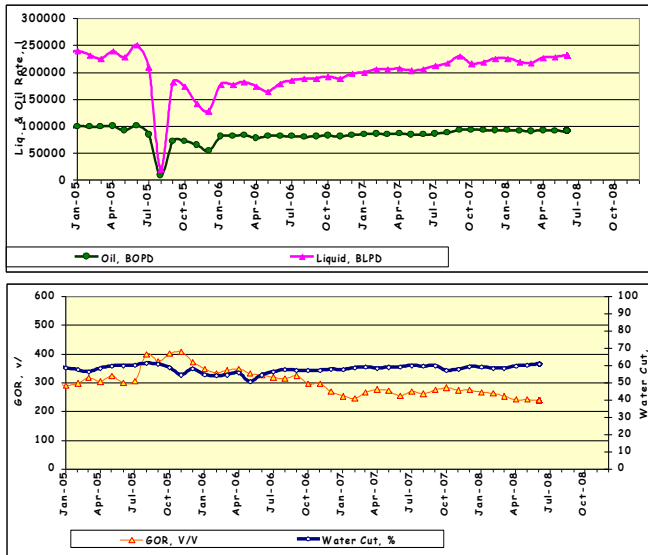


Fig-4

Water Injection Performance of MHN Field

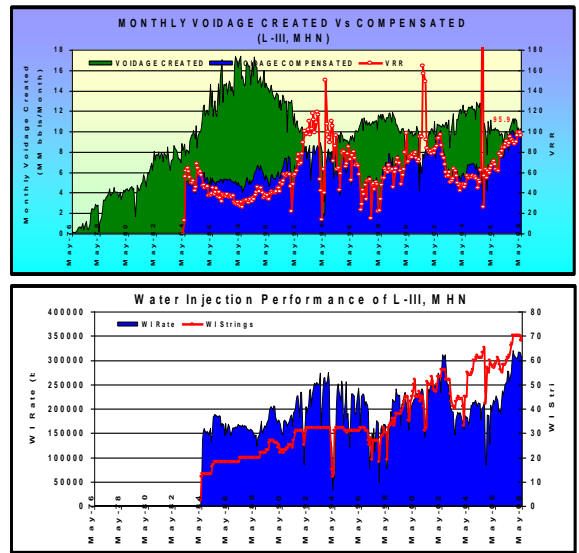


Fig-5

WATER INJECTION RATE BUBBLE MAP

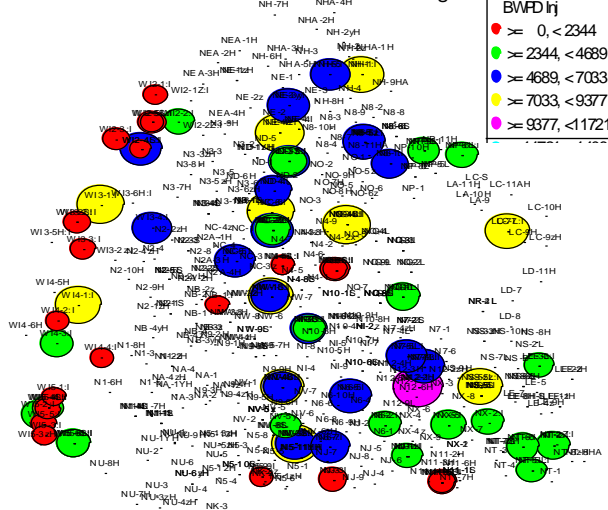
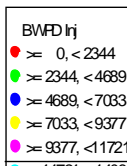


Fig-6



productivity of horizontal to conventional for NA1 layer

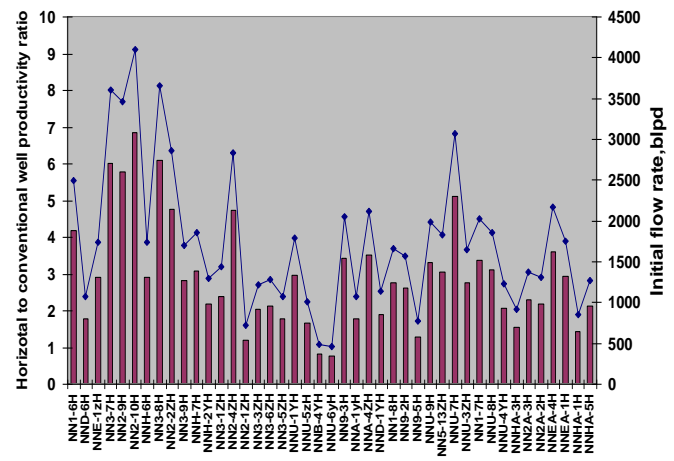


Fig-7

Multilateral Completion of Well NN-11H

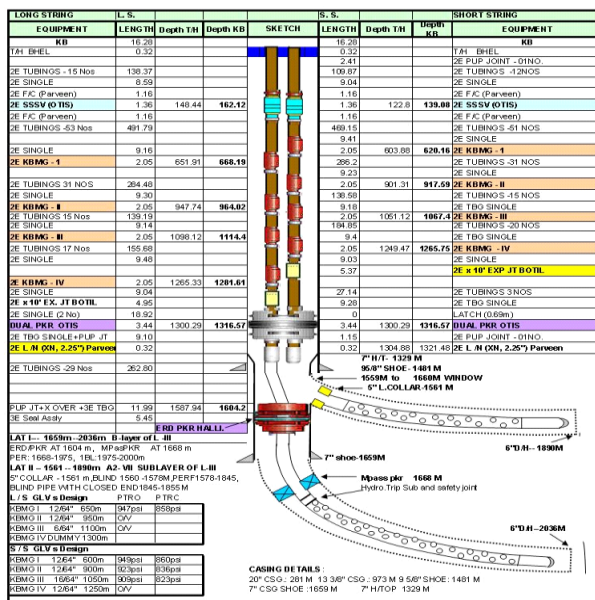


Fig-8

Production Profile (Base Vs Incremental), FR-Phase-II

Fig-9

