

Chapter 7

Impact of inadequate water injection

Failure to maintain the planned quantity and desired quality of injection water adversely impacted the voidage compensation and consequently the decline in reservoir pressure and ultimately the crude oil production. As the reservoir pressure goes down, gas starts evolving from the reservoir thereby reducing the oil permeability.

7.1 Reservoir health and monitoring

Since inception of fields, due to inadequate water injection, there was continuous decline in reservoir pressure which impacted crude oil productivity and its ultimate recovery.

Audit observed that reservoir pressure in Mumbai High, Neelam and Heera fields has been on continuous decline from its initial pressure level. The initial reservoir pressure at the time of commencement of production in Mumbai High field was 2,250 psi³⁵ and reservoir pressure at the start of water injection was 2,100 psi. The reservoir pressure in major oil producing layer of Mumbai High North (L-III) declined from 1,625 psi in 2014 to 1,585.2 psi in December 2019 and in Mumbai High South (L-III), it declined from 1,562 psi in 2014 to 1,551.7 psi in December 2019. In Heera field, reservoir pressure dropped from initial reservoir pressure of 2,100 psi to 900-1,200 psi in November 2019. The initial pressure at Neelam field was around 2,100 psi, which declined to 1000-1520 psi in November 2019.

Decline in reservoir pressure due to deficient water injection is further accentuated by higher gas production from the gas cap in the reservoir. Increasing Gas/ Oil Ratio³⁶ is an indication of reduced reservoir pressure. As the reservoir pressure goes down, gas starts evolving in the reservoir, thereby reducing the oil permeability.

External domain experts/ consultants engaged by the company and its internal task force/ committees (1990-2019) had highlighted (**Annexure-XIII**) the decline in reservoir pressure and reiterated the need to address low pressure areas, improve voidage compensation and thereby reservoir health.

Ministry through its technical arm, Director General of Hydrocarbons (DGH) has also periodically raised concern over insufficient water injection and its impact on reservoir health and well productivity. In its periodical production review meetings, DGH had also stressed upon importance of water injection and maintenance of reservoir health as mentioned below:

³⁵ *Measurement unit of pressure - Pound per square inch (psi).*

³⁶ *Gas/Oil ratio is the ratio of volume of gas that comes out of solution, to the volume of oil at standard conditions (vol./vol.).*

- Reservoir management is poor in Mumbai High and Heera; pressure drop is observed in Mumbai High fields. The water injection is not successful due to poor areal³⁷ distribution and inadequate quantity. Uneven areal spread of water injectors/ water injection rates resulted in pressure sinks in reservoir while inadequate water injection/ low voidage replacement ratio is responsible for decline in average reservoir pressures. Pressure sinks/ reservoir pressure depletion results in well productivity decline. Thus, water injection does not support the reservoir as envisaged. DGH suggested (April 2018) improving areal distribution by suitable pattern between the injectors and the producers.
- Oil production in Neelam-Heera field was constrained due to pressure sink in north Heera area (May 2017) and DG-DGH observed (August 2018) that '*despite high quality reservoirs of Neelam-Heera, production has been hampered due to mismanagement of resources*'.
- Pressure in Mumbai High and Neelam-Heera fields has dropped significantly. The prime reason for alarming fall in productivity of reservoirs of Mumbai High/ Heera fields is attributed to sharp decline in reservoir pressure due to low cumulative voidage compensation. Once pressure is low, water injection does not get effective in terms of sweeping the oil to producers and it short circuits to the nearby producer. With irregular/ insufficient injection, the objective of maintaining reservoir pressure was not achieved. Total water injection rate may have to be increased substantially and reservoir pressure has to be restored adequately (February 2021).

Had the above recommendations been implemented fully, it would have helped in maintaining the reservoir pressure.

Management/ Ministry stated (February/ June 2021) that in Mumbai High during last two years concerted action has been taken and as a result water injection level was increased from 7.5 lakh bwpd in June 2018 to 9.5 lakh bwpd in April 2020 and the water injection plan is to increase to 11.5 lakh bwpd by March 2021. It was also stated that wells with high Gas Oil Ratio were closed as part of reservoir management.

Management/ Ministry reply needs to be viewed in the light of the fact that actual water injection in Mumbai High during 2019-20 and 2020-21 was also less than the plan. During 2019-20, as against average water injection of 11.31 lakh bwpd in annual plan, the actual average water injection achieved was only 9.35 lakh bwpd (17 per cent deficit). Similarly, during 2020-21 as against average water injection of 10.51 lakh bwpd planned in build-up plan, the actual average water injection was only 8.86 lakh bwpd (15.76 per cent deficit).

³⁷ Areal distribution – geographical spread.

Further, the in-house committees³⁸ as well as consultants³⁹ have repeatedly recommended increasing the water injection volumes to augment the reservoir pressure.

Considering the delayed commencement of injection, with the continuing gap between redevelopment scheme injection levels and actual injection, ageing infrastructure and well maintenance issues, it is uncertain that the company would be able to achieve voidage replacement of 100 *per cent* in near future and maintain the envisaged pressure levels and reservoir health.

Recommendation No. 17

Company may devise a time bound action plan to address pressure sinks by ensuring injection volumes to redevelopment scheme levels and avoid uneven areal spread of water injection.

7.2 Performance benchmarking

The performance benchmarking group of the company was created in March 2002 and its main functions were to develop and monitor performance contracts⁴⁰; developing benchmarks for activities of the company with world's leading exploration and production companies. The benchmarking group identifies Key Performance Indicators (KPIs) of each Strategic Business Unit (SBU) within the company. KPIs flow from the MoU parameters with the Ministry and include other SBU critical parameters. The KPI of 'reservoir health' includes targets for 'water injection' and 'reservoir pressure maintenance' (this was introduced from 2015-16 onwards). Performance of KPI of 'reservoir health' is evaluated based on the target proposed by the SBU (Asset).

Audit observed that the benchmarking group did not benchmark all the above KPIs with world's leading exploration and production companies. With regard to the KPI on reservoir pressure in performance contract, the company maintained static target of maintaining reservoir pressure only at 70 *per cent* of the pools/ reserves.

Management stated (June 2020) that considering the achievement history, a SMART (Specific, Measurable, Achievable, Relevant, Time-bound) KPI of 70 *per cent* was fixed in 2016-17. Management/ Ministry further stated (February/ June 2021) that due diligence over benchmarking KPIs with world's leading exploration and production companies would be taken up.

³⁸ *Multi-Disciplinary Team (MDT) report on 'Facility cost optimisation and water injection improvement in Mumbai High'- July 2012, Task Force Report on 'Augmentation and redistribution of water injection in MH field'-October 2018.*

³⁹ *International consultant M/s Gaffney, Cline & Associate was engaged for consultancy work for implementation of MH redevelopment schemes since 2000 and international petroleum consultants William M Cobb & Associates, INC was engaged (August 2009) to review water injection operation in Mumbai High field.*

⁴⁰ *Performance contract is a tool for evaluation of performance of strategic business units, entered with the head of SBU.*

Management reply needs to be viewed in light of the fact that annual water injection plan was prepared considering the constraints based on achievable quantity and always less than the requirement as per the field development plan. In view of continuous depletion in reservoir pressure, uneven distribution of injection among different layers and resultant lower production of crude oil, keeping such static 70 per cent target by management for evaluation of field performance under this KPI has defeated its purpose. Besides, Audit noticed that from 2019-20, the parameter of reservoir health is not part of the performance contract indicating lack of monitoring of reservoir health by top management. The MoU signed by the company with the Ministry does not contain any parameter on reservoir health.

Recommendation No. 18

Company should fix the target considering benchmark of international/ industry best performance rather than achievable basis so as to evaluate true performance of its operation. Weightage of water injection may be increased in performance monitoring and benchmarking.

7.3 Impact on crude oil production

Shortfall in water injection is one of the significant reasons for less production of crude oil. The company prepares its production profile based on simulation model of its reservoirs. Audit requested management to estimate the impact on crude oil production due to deficient water injection. The company's in-house research institute, Institute of Reservoir Studies used the existing simulation model by changing the water injection quantity of the re-development scheme levels with the actual injection achieved to arrive at the crude that could not be produced due to lesser water injection. Institute of Reservoir Studies conveyed (July 2020) that in comparison with production as per feasibility report (base plus incremental), there is oil deficit of 3.695 MMT⁴¹ due to less water injection during 2014-15 to 2018-19.

Audit observed that the company reported actual operation loss at different rates at these fields during 2014-15 to 2018-19. The actual operating loss reported by the company ranged from 0.64 to 2.35 per cent (Mumbai High), 3.55 to 11.22 per cent (Heera) and 0.03 to 16 per cent (Neelam). Audit, therefore, reworked the management quoted oil deficit of 3.695 MMT by considering the actual loss reported during 2014-15 to 2018-19 which worked out to 3.79 MMT. The value of oil deficit of 3.79 MMT due to less water injection worked out to ₹11,276.79 crore (**Annexure-XIV A, B**) during 2014-15 to 2018-19. Management/ Ministry stated (February/ June 2021) that the value of oil would be ₹7,802.50 crore for ONGC after considering the statutory levies. Thus, the balance ₹3,474.29 crore is revenue loss to the Government of India.

⁴¹ This oil deficit was calculated considering an operation loss at 6 per cent.

Management stated (February 2021) that oil deficit estimated by Institute of Reservoir Studies for the period 2014-19 is not permanent but deferred production, for which firm development plans are under implementation.

Management response is not justified. Directorate General of Hydrocarbons (DGH) observed (February 2021) with regard to the reservoir performance analysis of Mumbai High and Neelam and Heera fields that once reservoir pressure is low, water injection does not get effective in terms of sweeping the oil to producer and it short-circuits to the nearby producer through low-pressure zone. Even no enhanced oil recovery process would be effective in low pressure reservoir.

Further, Ministry in its reply stated (June/ July 2021) that:

- i) Maintaining reservoir health has been a chronic problem. Historically, there has been a shortage of adequate water injection even though all the development schemes envisaged water injection as a critical input to maintain reservoir pressure and improve secondary oil recovery.
- ii) Maintaining good reservoir health and adequate reservoir pressure is *sine qua non* for achieving globally comparable recovery factor in Mumbai High and Neelam Heera fields.
- iii) EOR process will not be effective in the low-pressure reservoir. Also, once the pressure is low, water injection does not become effective in terms of sweeping the oil to producer and it short-circuits to the nearby producer through low pressure path, further reducing oil output from producer wells.
- iv) Systematic efforts at revamping the complete water injection infrastructure and boosting up reservoir pressure through adequate quantity and quality of water injection is essential. There is considerable scope for improvement, as stated earlier, and significantly raising the cumulative recovery factor hitherto achieved.
- v) Projected increase in recovery factor by 2039-40 (33 *per cent* in Mumbai High field) is low as compared with similar reservoirs worldwide. Field development and production teams need to work in cohesion keeping in mind the long-term gains by maintaining the reservoir health.

Consultant, M/s Boston Consulting Group (India) Pvt. Ltd., engaged by the company, for formulation of ONGC Energy Strategy - 2040 also observed (December 2018) that '*ONGC's recovery rate in mature fields currently stands at 25-35 per cent. In comparison, best-in-class global peers have achieved recovery rates of 45-55 per cent*'.

Management stated (June 2020/ February 2021) that production comes from base production as well as new inputs. Hence, total production provides a more realistic measure of field performance. As on 1 April 2020, in case of Mumbai High and Neelam and Heera fields, the cumulative production was 609.439 MMT against plan production of 613.105 MMT with a shortfall of 3.666 MMT.

Reply of the Management is not tenable. The company considered planned production after allowing six *per cent* loss. The average loss in case of Mumbai High during 2014-15 to 2018-19 was 1.43 *per cent*. Further, actual production reported by the company was inclusive of non-crude oil elements *viz.*, Basic Sediments & Water (BS&W)⁴², Off-gas⁴³ and condensate quantity⁴⁴ which are not part of crude oil production as per the PNG Rules. Excluding non-crude oil elements in reported production, the difference between the cumulative production and actual production till April 2020 worked out to 43.88 MMT.

DGH also agreed (July 2021) with Audit that ‘non crude oil elements’ (BS&W, Off-gas and condensate) should be excluded for the purpose of determining the production figure of ‘crude oil’ in line with Rule 3(b) of PNG Rules, 1959 as amended from time to time.

Further, Consultants (M/s. GCA, M/s. Beicip Franlab) of international repute were engaged by the company as per directives of the Ministry to independently assess remaining recoverable reserves of hydrocarbon volumes of Mumbai High, Neelam and Heera fields. As per the Consultant report covering the period 2019-2040, the estimate of the consultant was lower than the company estimate by 16.12 MMT for the period 2019-2040.

7.4 Summing up

Audit noticed inadequate water injection with less than one voidage replacement ratio since inception of water injection operations. It may be pertinent to note that the company could achieve cumulative voidage compensation of only 54.43 *per cent* in Mumbai High, 78.8 *per cent* in Heera and 42 *per cent* in Neelam fields as of March 2019. Audit also noticed uneven distribution of injection water amongst different layers, continuous drop in reservoir pressure, development of pressure sinks and production from high gas/ oil ratio wells impacting well production. With the current re-development plans on hand from

⁴² *Basic Sediment and Water (BS&W) refer to volume of non-hydrocarbon containments which is made up of dirt (sediment) and water. In ONGC offshore, partially stabilised crude oil containing BS&W is measured for reporting production of crude oil. This partially stabilised crude oil is dispatched from offshore to onshore terminal (Uran Plant) for complete stabilisation wherein BS&W from partially crude oil is removed.*

⁴³ *Off-gas is dissolved gas in partially stabilised crude oil which is separated during stabilisation process of crude oil at Uran plant and added to reported gas production.*

⁴⁴ *Condensate: Liquid hydrocarbon which is lighter than Crude Oil, having an API Gravity greater than 45 is referred as Condensate. Basically, no condensate exists in the reservoir at reservoir conditions i.e. temperature and pressure of the reservoir. During the flow of gas from the well bore to the surface, the pressure and the temperature of the well fluid undergo change i.e. reduction in both the temperature and pressure, and as a result heavier hydrocarbon components of the gas get condensed in the form of condensate.*

these mature fields, and in view of continuous decline in the profile envisaged, recovery of cumulative oil deficit of 60 MMT (43.88+16.12) is unlikely. This loss cannot be considered as deferred production as claimed by the company but a permanent loss. Further, even for exploitation of a part of this oil deficit, additional investment is required and this needs review from the point of economical oil recovery.